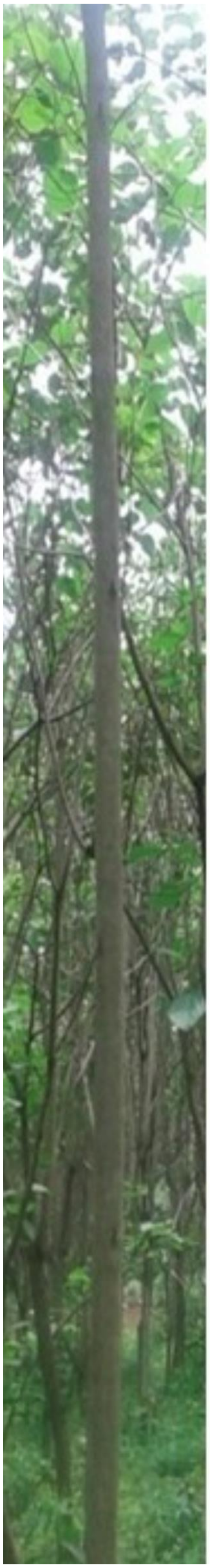

Ethiopian Environment and Forest Research Institute
የኢትዮጵያ የአካባቢና የደን ምርምር ኢንስቲትዩት

Current information and technologies on the environment and forest: Proceedings of the 3rd Annual Research Outputs Dissemination Workshop

2020
Addis Ababa

Ethiopian Environment and Forest Research Institute (EEFRI)

Current Information and Technologies on the Environment and Forest:

Proceedings of the 3rd Annual Research Outputs Dissemination Workshop

4-7 March 2019, Adama, Ethiopia

Editors:

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Front cover photo: Partial view of a *Cordia africana* tree grown at Tepi experimental site with straight, clean bole.
Back cover photo: Partial view of a natural forest at Nechsar National Park

ISBN

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PREFACE

Ethiopia faces increasing forest resource loss, environmental degradation and poor ecosystem services as the natural resource development and management is challenged by open access despite the good policies and laws put in place. More is the challenge to conserving communal or state-owned remnant natural forest as there is no ban on green felling in some regional governments or law enforcement is inadequately effective. The biggest loss is not the forest itself but the forest land, changed forever to agriculture or other land use where restoration or reforestation endeavor to productive forestry is usually not materialized.

Ethiopian Environment and Forest Research Institute undertakes development research on introduced exotic plantation tree species of high timber quality for the production forestry along with the native tree and bamboo species. The research emphasizes on informing the forest enterprises, tree farmers and the small-scale wood-based industries regarding species specific use, suitability and processing methods. Some outputs from completed research in timber and bamboo utilization are presented in this proceeding. Study results from performance of traditional agroforestry practices of different regions of the country are also presented as a baseline information to initiate and design other productive agroforestry models.

Investigations in the natural forest ecosystem on species diversity, population structure and regeneration status of woody species as well as phenology of important tree species of the Afromontane forests have also been included in this volume. Socio-economic studies, policy reviews and technology adoption challenges are put forward for readers of this volume. Hoping to produce valuable information in the years to come, would like to thank all researchers and presenters as well as editors of this proceeding.

Agena Anjulo Tanga (PhD, Agroforestry)

Deputy Director General,
Ethiopian Environment and Forest Research Institute

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The editors of the proceedings and the organizing committee

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የእንኳን ደህና መጣችሁ ንግግር

በአብዮት ብርሃኑ (ዶ/ር)
ዋና ዳይሬክተር
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ክቡር አቶ ከበደ ይማም
ክብርት ወ/ሮ ፍሬነሽ መኩሪያ
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የተከበራችሁ የአውደ ጥናቱ ተሳታፊዎች

ከሁሉ አስቀድሜ ወደ ብሄራዊ የምርምር ፕሮጀክቶች ግምገማ አውደ ጥናት እንኳን በደህና መጣችሁ እላለሁ!
የኢትዮጵያ የአካባቢና የደን ምርምር ኢንስቲትዩት በዋነኛነት የተቋቋመበት ዓላማ አካባቢ፣ ደንና አየር ንብረት ለውጥን የሚመለከቱ መረጃዎችንና ቴክኖሎጂዎችን ማስገባት፣ ማላመድ፣ አዲስ ማፍለቅ እና ለተጠቃሚዎች ማቅረብ ሲሆን፤ ይህንን ለማሳለጥ በ 7 የምርምር ዳይሬክቶሬቶችና በ 2 ማስተባበሪያዎች እንዲሁም በ 7 ማዕከላት በመደራጀት ከፍተኛ ጥረት እያደረገ ይገኛል፡፡
እንደ ኢንስቲትዩት ከተቋቋመበት ከ2007 ዓ.ም ጀምሮ ተቋሙን በልዩ ልዩ ቁሳቁስና የሰው ኃይል ለማሟላት በተደረገው ጥረት መልካም የሚባሉ ውጤቶች ተመዝግበዋል፡፡ በአሁኑ ጊዜ በአካባቢ፣ በደን ጥበቃ፣ በዘርና በእንጨት ቴክሎጂ ላይ የሚሠሩ 4 ቤተ ሙከራዎች፣ ከ 25 ያላነሱ የዛፍ ዘር ምንጭ ቦታዎች እንዲሁም በርካታ የምርምር የመስክ ሙከራዎችን በመያዝ ምርምሩን ውጤታማ ለማድረግ እየተጋ ይገኛል፡፡ በሌላ በኩል በመንግስት ገንዘብ የሚደገፉ 2 ዘመናዊ የቤተ ሙከራ ህንፃዎችና በቻይና መንግስት የሚደገፍ አንድ የኢትዮ-ቻይና ቀርከሃ ምርምር ማዕከል ግንባታ ለመጀመር ቅድመ ዝግጅት እየተደረገ ነው፡፡
በሰው ሀይል ረገድ ከ700 በላይ ሠራተኞች (250 ተመራማሪዎች) ያሉን ሲሆን፤ የተመራማሪዎችን እውቀትና ክህሎት ለማሳደግ 40 ያህል ተመራማሪዎች በረዥም ጊዜ ትምህርት ማለትም በ 2ኛና 3ኛ ዲግሪ በመማር ላይ ይገኛሉ፡፡
እንደተቋም የተመራማሪዎቻችንን እውቀትና ክህሎት ማሳደግ ብቻ ሳይሆን፣ በመስኩ የተረጋጋ ተመራማሪ እንዲኖር አስፈላጊ የሆኑ ግብዓቶችን ለማቅረብ፤ እንዲሁም እንደ ሀገር ለተመሳሳይ የምርምር ሥራና ደረጃ ተመጣጣኝ ክፍያ (ደሞዝና ጥቅማጥቅም) እንዲፈጸም ከኮሚሽን መ/ቤታችን ጋር በመተባበር ከፍተኛ ጥረት እየተደረገ ነው፡፡

ክቡራትና ክቡራን
ባለፉት በጣት የሚቆጠሩ ዓመታት በመረጃና በቴክኖሎጂ አቅርቦት እንደተቋም የማይናቁ ውጤቶች የተመዘገቡ ቢሆንም፤ ካለብን ከፍተኛ ሀገራዊ ኃላፊነትና ከሥራው ሥፋት አንጻር አሁንም በርካታ ቀሪ ሥራዎች ያሉብን መሆኑን ለመግለጽ እወዳለሁ፡፡
የአካባቢያችን መበከልና መራቆት፣ የአየር ንብረት ለውጥ እያስከተለ ያለው ጉዳት፤ እንዲሁም የብርቅዬ ብዝሀ ሕይወት መገኛ የሆኑ ደኖቻችን ላይ እየደረሰ ያለውን ጥፋት ለመግታት ከምንጊዜውም በላይ የመረጃና የቴክኖሎጂ አቅርቦት እጅግ አስፈላጊ ነው፡፡
መንግስት ይህን በአግባቡ ይገነዘባል፡፡ ለተግባራዊነቱም ካለው ውስን ሀብት የአቅሙን ያህል መዋዕለ ነዋይ መድቦ እየሠራ ይገኛል፡፡ ነገር ግን ምርምሩ ከሚጠይቀው ዘመናዊ የላብራቶሬ ቁሳቁሶችና ከፍተኛ ገንዘብ አንፃር በቂ ነው ማለት አይደለም፡፡
በምርምር ያልተደገፈ ልማት፣ በምርምር ያልተደገፈ ችግር አፈታት ዘለቄታዊ አይሆንም፡፡ በሀገራችን ያሉትን ሁሉንም ችግሮች በአንድ ጊዜ መፍታት እንደማይቻል የሚታመን ቢሆንም፤ ልዩ ትኩረት የሚሹትን በመለየት፤ ባለድርሻ አካላትንና የዘርፉ ባለሙያዎችን በማወያዬትና በመተማመን ወደ ሥራ መግባት ምርምሩ በአስተማማኝ መሠረት ላይ እንዲቆም ወሳኝ ሂደት ነው፡፡
የዚህ አውደ ጥናት ዓላማም ከዚህ የተለየ አይደለም፡፡ ከዚህ በፊት ወደ ሙከራ የገቡና የተጠናቀቁ እንዲሁም አዲስ የተቀረጹ ፕሮጀክቶች በሥፋትና በጥልቀት ይገመገማሉ፡፡ በዚህም ያገኘናቸውን ውጤቶችና ያጋጠሙን ችግሮች፣ የፕሮጀክቶች አዋጭነትና ፋይዳ ላይ የጋራ መግባባት እንደሚፈጠር ሙሉ እምነት አለኝ፡፡

ይህን አውደጥናት ለማዘጋጀት የደከሙትን ሁሉ፣ በአውደ ጥናቱ ለመካፈል ጊዜያችሁን ሰውታችሁ የተገኛችሁትን በሙሉ፣ እንዲሁም ይህን አውደ ጥናት በገንዘብና በቁሳቁስ የደገፉትን አካላት ከልብ እያመሰገንኩ፤ አውደ ጥናቱን በንግግር እንዲከፍቱልን የአካባቢ፣ የደንና የአየር ንብረት ለውጥ ኮሚሽን ኮሚሽነር **ክቡር ፕሮፌሰር ፈቃዱ በየነን** በአክብሮት ወደ መድረክ እጋብዛለሁ፡፡
ከልብ አመሰግናለሁ!

የመክፈቻ ንግግር

በክቡር ፕሮፌሰር ፍቃዱ በየነ
የአካባቢ፣ የደንና የአዬር ንብረት ለውጥ ኮሚሽን ኮሚሽነር

ክቡር አቶ ከበደ ይማም
ክብርት ወ/ሮ ፍሬነሽ መኩሪያ፤
የአካባቢ፣ የደንና የአዬር ንብረት ለውጥ ኮሚሽን ም/ኮሚሽነር
የተከበራችሁ የህዝብ ተወካዮች ምክር ቤት አባላት
የተከበራችሁ የተቋማት ኃላፊዎች፤ የዩኒቨርሲቲ ምሁራንና ተመራማሪዎች፣ ተጋባዥ እንግዶች፤

ክቡራትና ክቡራን
በድጋሜ እንኳን በሠላም መጣችሁ!
ሀገራችን ኢትዮጵያ የብዙ ፀጋዎች ባለቤት መሆኗ ይታወቃል፡፡ ከነዚህ ፀጋዎች ከሚጠቀሱት መካከል አንዱና ዋነኛው የብዝሀ ሕይወት ሀብቷ ነው፡፡ ኢትዮጵያ በብዝሀ ሕይወት ሀብት ስብጥር ከአፍሪካ ቀደምት ሀገራት መካከል አንዷ ናት፡፡ በውሃ ሀብትም የአፍሪካ የውሃ ማማ በመባል እንደምትታወቅ እንገነዘባለን፡፡ በመልካ ምድሯም የተዋበች፣ ከፍተኛ የአዬር ንብረት ተለያይነት የታደለች ሀገር ናት፡፡

በሌላ በኩል ሀገራችን ከላይ የተጠቀሱትን ፈርጀ ሰፊ የተፈጥሮ ሀብቷን በሚገባ በማልማትና በመጠቀም ረገድ በርካታ ችግሮች እንዳሉባት ይታወቃል፡፡ ምንም እንኳን ባለፉት ሁለት አሥርት ዓመታት ከፍተኛ የሆነ የኢኮኖሚ ዕድገት የተመዘገበ ቢሆንም በተለይ በዘላቂ የተፈጥሮ ሀብት ልማትና ጥበቃ ረገድ አሁንም ያልተሻገርናቸው ችግሮች አሉ፡፡ በቅርቡ በዓለም የምግብ ድርጅት ጋር በመተባበር ያደረግነው ሀገራዊ የደን ሀብት ቆጠራ እንደሚያሳየው ዛሬም በሀገራችን ከፍተኛ የደን ሀብት ውድመት እየተከሰተ መሆኑን ለመገንዘብ ችለናል፡፡

የደን ሀብት ውድመት የሚያስከትላቸው ችግሮች በርካታ ናቸው፡፡ ከነዚህም በደን ውስጥ ያሉ ሰፊ ማህበረ ኢኮኖሚያዊና ሥነ ምህዳራዊ ጠቀሜታ ያላቸው ዕፅዋቶች ይመናመናሉ፣ አሊያም እስከወዲያኛው ይጠፋሉ፡፡ የደኖች መመናመን ከፍተኛ የሆነ የሥነ-ምህዳር መናጋት ሊያስከትል ይችላል፣ እያስከተለም ነው፡፡ አሁን አሁን በሀገራችን በተለያዩ አካባቢዎች የበረሃማነት መስፋፋት፣ የመሬት መንሸራተት፣ የውሃ አካላት መቀነስ እና ከእነዚህ ጋር ተያይዞ የሚከሰት የተፈጥሮ ሀብት እጥረት እና ግጭቶችን ማየትና መስማት እየተለመደ መጥቷል፡፡ በቅርብ ጊዜ ጥናቶች እንደሚያሳዩት በርካታ ሐይቆቻችን፣ ወንዞችና በተለይ የኃይል ማመንጫና የመስኖ ግድቦቻችን በከፍተኛ ደለል እየተሞሉ እንደሆነ ነው፡፡ የመሃከለኛው የስምጥ ሸለቆ አካባቢ በከፍተኛ ፍጥነት ደኑ በመጨፍጨፉና መሬቱም ወደ ሌላ የመሬት አጠቃቀም በመቀየሩ ብርቅዬ ሐይቆቻችንም ለከፍተኛ አደጋ ተጋልጠዋል፡፡ ብዙዎች በስፋትም በጥልቀትም እየቀነሱ ከመሆናቸውም ባሻገር በብዙ ዓይነት ኬሚካሎች እየተበከሉ ነው፡፡ የመሬት ኩላሊት በመባል የሚታወቁት ውሃ አዘል (wet lands) አካባቢዎች በፍጥነት ወደ ሌላ የመሬት አጠቃቀም እየተቀየሩ ነው፡፡

በሀገራችን ከምን ጊዜም በላይ ከተፈጥሮ ሀብት አጠቃቀም ጋር የተያያዙ ግጭቶች እና ሰብዓዊ ቀውሶች እየተከሰቱ ይገኛሉ፡፡ በተለይ በቆላማው የሀገራችን ክፍሎች አርብቶ አደሮቻችን በውሃና በግጦሽ እጥረት ምክንያት እየተቸገሩ እና ቀደም ሲል በስፋት የነበረው መቻቻልም ከጊዜ ወደ ጊዜ እየቀነሰ እየመጣ መሆኑን የሚያሳዩ በርካታ እውነታዎች እየተስተዋሉ ነው፡፡
ከላይ ከተጠቀሱት ከተፈጥሮ ሀብት ዘላቂ ልማትና አጠቃቀም ጋር ከተያያዙት ተግዳሮቶች በተጨማሪ ሀገራችን ለከፋ የአየር ንብረት ለውጥ እና ተያያዥ ጉዳቶች እየተጋለጠች ነው፡፡ ድርቅ ከዛሬ 30 እና 40 ዓመታት በፊት በረጅም ጊዜ አንዴ የሚከሰት መሆኑ ብቻ ሳይሆን በተወሰኑ አካባቢዎች ብቻ የሚታይ ችግር ነበር፡፡ ከቅርብ ጊዜ ወደዚህ ግን ምልልሱም ሆነ የሚሸፍነው አካባቢ እና የሚያደርሰው ጉዳት ከፍተኛ ሆኗል፡፡

በተለይ ከደን ሃብት መመናመን ጋር ተያየዞ በሃገራችን በርካታ አካባቢዎች የአፈር መሸርሸር ፣እና የምርትና ምርታማነት መቀነስ እየተከሰተ ከመሆኑም በላይ የቆላማ የአየር ንብረት ጠባይ መስፋፋትም ሃገራችን እየገጠሙ ካሉ ችግሮች ዋነኛው እየሆነ ይገኛል፡፡ የአየር መበከል እያስከተለ ያለው የጤና ጉዳት ከምናስበው በላይ እየገዘፈ ይገኛል፡፡

ክቡራትና ክቡራን
እነዚህንና ሌሎች ችግሮችን በመቅረፍ ይልቁንም ሃገራችን ኢትዮጵያ ያላትን የተፈጥሮ ፀጋ በዘላቂነት እያለማች እንድትጠቀም ለማድረግ መንግስት በተለይ ለአየር ንብረት ለውጥ የማይበገር አረንጓዴ ኢኮኖሚ ስትራቴጂ ቀይሶ እና ከሁለተኛው የዕድገትና ተራንስፎርሜሽን ዕቅድ ጋር አቀናጅቶ በመተግበር ላይ ይገኛል፡፡ በተለይ የደን ሃብታችን ልማትና አጠቃቀም በነዚህ ሃገራዊ ሰነዶች

ትኩረት ያገኘ ሲሆን ለምሳሌ ከአራቱ የአረንጓዴ ልማት ስትራቴጂ ምሰሶዎች (Pillars) አንዱ ነው፡፡ ሀገራችን በ2030 ከ22 ሚሊዮን ሄክታር በላይ ደን በማልማት የአየር ንብረት ለውጥ ተፅዕኖን ለመቋቋም ከመቻል ባሻገር፤ ዘርፉ ለአገር ኢኮኖሚ ግንባታ ላይ ሁነኛ አስተዋፅኦ እንደሚያበረክት ይጠበቃል፡፡ ኢትዮጵያ ሥነ ምህዳሮች እንዲጠበቁ፣ ንፁህም አየር እንዲኖረን እና በዚህም ዘላቂ የኢኮኖሚ ልማት በማረጋገጥ በ2015 መካከለኛ ገቢ ካላቸው ሃገራት ተርታ ለመሰለፍ በመስራት ላይ ትገኛለች፡፡

ከላይ የተጠቀሱትን መጠነ ሰፊ ዕቅዶች ለማረጋገጥ የምርምር እና ትምህርት ሚና ወሳኝ ነው፡፡ ዘላቂ የተፈጥሮ ሃብት ልማት እና አጠቃቀም የሚረጋገጠው በፈጣን ቴክኖሎጂ አቅርቦት ነው፡፡ ይህን የቴክኖሎጂ፣ የዕውቀት የመረጃ ፍሰትን ለማሳለጥ መንግስት የኢትዮጵያ የአካባቢ እና የደን ምርምር ኢንስቲትዩትን አቋቁሟል፡፡ ተቋሙ በአካባቢ በደን እና በአየር ንብረት ለውጥ ዙሪያ ምርምር በማካሄድ ዕውቀትን፣ ቴክኖሎጂና መረጃን በማውጣት ለተጠቃሚዎች በማድረስ ላይ ይገኛል፡፡ ይሁንና ሃገራችን እየገጠማት ካለው ውስብስብ ችግሮች አንፃር የቴክኖሎጂና መረጃ አቅርቦቱ ከዚህ በፈጠነ ሁኔታ መሠራት እንዳለበት እንረዳለን፡፡ በመሆኑም ለዘላቂ የደን የአካባቢ ልማት ጥበቃና አጠቃቀም እንዲሁም ለአየር ንብረት ለውጥ ያለንን ተጋላጭነት ለመቀነስ እና ዘላቂ እና ፈጣን ልማትን ለማረጋገጥ ከሚመለከታቸው ባለድርሻ አካላት ጋር ጥብቅ ቁርኝት በመፍጠር እንዲሰራ እያሳሰብኩ ኮሚሽን መ/ቤቱም በአካባቢ በደን እና በአየር ንብረት ለውጥ ዙሪያ የሚደረግ ምርምር አቅም ለመገንባት የተቻለውን ሁሉ እንደሚያደርግ በዚሁ አጋጣሚ ለመግለጽ እወዳለሁ፡፡

የተከበራችሁ የአውደ ጥናቱ ተሳታፊዎች

ምርምር ችግር ፈቺ ሊሆን የገባል፡፡ ለዚህ ደግሞ ቅንጅታዊ አሰራር ያስፈልጋል፡፡ ይህን ስናደርግ ዛሬ ሃገራችን ኢትዮጵያ ወደ ውጭ መላክ ሲኖርባት፤ በዓመት ከ200,000 ዶላር በላይ እያወጣች የምታስገባውን የደን ውጤት መተካት እንችላለን፡፡ በየአመቱ በቢሊዮን ቶን የሚለካ አፈር ከተፋሰሶች እየታጠበ ወደ ወንዞች፣ ሃይቆችና ግድቦቻችን እንዳይገባ ማድረግ እንችላለን፡፡ ይህን ስናደርግ ነው የአካባቢ እና የደን ዘርፍ በሀገር ኢኮኖሚ ግንባታ ውስጥ ቁልፍ ሚና መጫወት የሚችለው፡፡

በተለይ ገና ብዙ መስራት በሚጠበቅብን የአካባቢና የአየር ንብረት ለውጥ ዙሪያ ምርምሩን ማጠናከር እና አቅም መገንባት ዋና ስራችን ሊሆን የገባል፡፡ በዚሁ አጋጣሚ ኮሚሽን መስሪያ ቤታችን ምርምሩን በቅርበት የምንደግፍና በምርምር የተገኙ ውጤቶችን ወደ መሬት ለማውረድ ርብርብ የምናደርግ መሆኑን እያሳወቅሁ፤ የዘንድሮው አመታዊ የምርምር ግምገማ የተሳካ እንዲሆን እየተመኘሁ አውደ ጥናቱ በይፋ የተከፈተ መሆኑን አበስራለሁ፡፡

አመሰግናለሁ፡፡

Section 1: Plantation and Agroforestry Research

Agroforestry Practices and their Role to Livelihood in Selected Districts of Cheha Woreda, Ethiopia.

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Abstract

This paper characterizes the agroforestry practices in Cheha woreda, Gurage Zone, Ethiopia based on the existing system components and evaluates socio economic role using data collected through structured questionnaire, focus group discussion and field observation. Households to be interviewed were selected through proportional sampling procedures from sixPeasant associations (Kebeles) out of 39 that were identified to be intensive practitioners of homesteads. Enset (*Ensete ventricosum*), Coffee (*Coffea arabica*) and Khat (*Catha edulis*) based homestead agroforestry and crop raising were found out to be the dominant land uses in the study area and the major sources of livelihood and income. Land holding size did not reveal marked differences across kebeles that rangedfrom 0.6 ha to 0.8 ha with an average of 0.5 ha. Significantly larger areas are allocated forEnset, coffee and khat based homestead agroforestry practices as compared to the rest of the identified land uses across all Kebeles. 12 different tree/shrub species are mainly planted in homesteads of the study area. *Eucalyptus viminalis* woodloots are integeral parts of homesteads mainly contributing to household energy demand and income generation. Incomes were found to be prominently generated from sell of Khat and *Eucalyptus*. Among the compared kebeles Emdebera gained maximum income of 6,500 Birr annually and 7,000.00 Birr in the duration of 4-6 years in the studied PAs.Water shortage, coffee tree leaf and stem drying, Enset stem and root decay and wild animals' raid are among mostserious problems that are currently constraining the practice of homestead agroforestry in the surveyed kebeles.Farmers preferably engage on homesteads than agriculture since homesteads have the potential to address household consumption demands adding to the dietary advantage of getting fresh produce and provide cash income when the need arises. It is recommended to encourage farmers engagement in integration of improved fruit tree varieties to gain increased production and enhance structural diversification of homesteads.

Keywords: Agroforestry, homesteads, species, woodlot

Introduction

The land use system in Ethiopia is associated with the decrease in the size of holding both for arable and grazing lands. Thus, there is continued trend toward the conversion of forested and marginal lands to agricultural lands, resulting in massive environmental degradation and a serious threat to sustainable agriculture and forestry. The decreasing in the size of land holding is related to population explosion. Agroforestry offers a potential solution to the problem of declining rural agricultural production in the tropics. Cultivating trees, agricultural crops and pastures and/or animals in intimate combination with one another spatially or temporally is an ancient practice that farmers have used throughout the world (Nair, 1989; 1993). There are several types of traditional systems that exist in different parts of Ethiopia and there are introduced agroforestry technologies started by several institutions at a national level across different land use systems (Abebe Yadesa et al 2001). The aim and rationale of agroforestry lies in optimizing production based on the interactions between the components and their physical environment. This will lead to higher sum and a more diversified and /or sustainable production than from a monoculture of agriculture or forestry alone.

Agroforestry provides a wider range of products, more secure subsistence or more cash income from wood products to enable the farmer to buy food. Nair (1993) indicated that the combination of several types of products which are both subsistence and income generating, helps farmers to meet their basic needs and minimizes the risk of the production system’s total failure. In tree home gardens, the production is for home consumption, but any marketable surplus can provide a safe guard against future crop failures and security for interval between the harvests (e.g. rice in Java and Sri Lanka, coffee and maize in Tanzania, coconut and rice in South Western India) Nair (2000).

It is a prerequisite to have knowledge about the potentials of existing agroforestry practices prior to attempting to introduce modificationsthat are alleged to facilitate complementarities in the existing agroforestry practices. This would call for the need for characterizing existing agroforestry practices in terms of system components and planting niches, evaluating their role to generate livelihood alternatives in rural communities and assess people's attitude towards management of agroforestry practices. Thus, this study intends to characterize the existing agroforestry practicesin the study area while evaluating the contribution of these practices to rural livelihood and assessing perception of farmers towards management and problems of agroforestry practices.

Materials and methods

Description of the study area.

GuragheZone is one of the zones found in the EthiopianSouthern Nations, Nationalities and Peoples Region (SNNPR). It is located in the western part of central Ethiopia; it is bordered on the south by Hadiya; on the West, North and East by Oromia Region; Yem on Southwest and on the Southeast by Silte Zone.

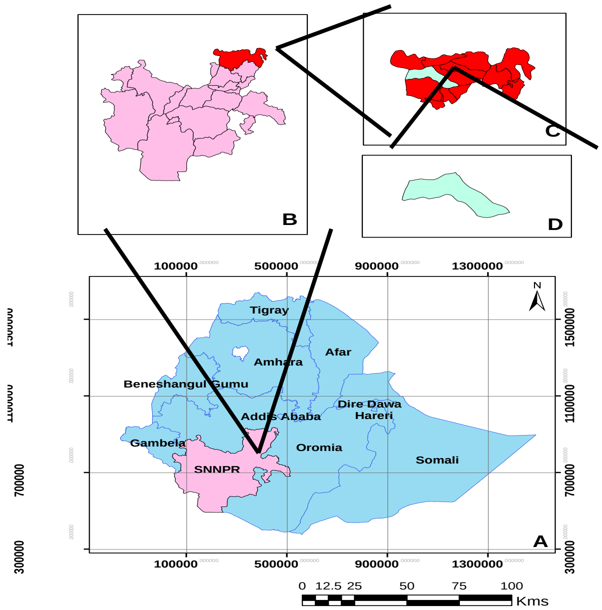

Figure 1. Map of SNNPR in Ethiopia (A), Gurage zone in SNNPR (B), Cheha woreda in Gurage zone (C), Map of Cheha woreda- the study area (D)

Its land area is estimated as 593,200 hectares. The zone is divided in to 13 woredas and 2 town administrations. The total population of the zone is estimated to be1,279,646 having distribution of 622,078 male and 657,568 females (Table 1). Most of the population 1,159,824 lives in rural areas leading an agricultural life (CSA,2007). The nature of topography in the zone exhibits three categories. These are the mountainous high land (represented by the Guraghe Mountain chain, dividing the zone east to west, having an elevation of 3600 m), the plateau flat lands and the low stretching area (the western fringe of the rift valley and the Wabe-Gibe valley having an elevation of 1000 m).

Table 1 Population of Cheha woreda

Sex	Population			
	Urban	Rural	Total	% of Total
Male	4655	82387	87042	49
Female	4845	86363	91208	51
Total	9500	168750	178250	100

Source: Cheha woreda agriculture and natural resource office

The zone is divided in to three agro ecological zones namely ‘Dega’ or highland climate (31.6%), mid highland climate or ‘Woina-dega’ (65.3%) and lowland or ‘kolla’ climate (3.1%). Most of the areas lie in the mid highland division. The distribution of rainfall and temperature mainly follows this pattern. The annual average rainfall ranges from 200 MM/annum - 1,400 MM/annum. The highest and lowest temperature record is 32^0c and 7 ^{0}c respectively.

Location and climate

The study was conducted in Cheha Woreda, located in Gurage Zone of Southern Nations, Nationalities and Peoples Regional State (SNNPRS), Ethiopia (Figure 1). The capital of the Woreda, Imdbir, is located at 188 km distance south of Addis Ababa on the way to Welkite town, the capital of the Zone. Imdibir means "mother forest" and is the combination of two words in the Gurage language, "Im" means mother and "dibir" means forest. This name clearly indicates that the area was once covered by forests (Mojoa et.al, 2015). The geographical location of the study area extends from 8° 00' 18.9" to 8° 15' 28.53" N and 37° 35' 46.48" to 38° 03' 59.59" E. Cheha woreda covers an area of 44,072 ha and its altitude ranges from 1200 m a.s.l. in the lowlands to 2600 m a.s.l. in the highlands. The annual rainfall of the area ranges from 800 to 1200 mm. Woredas bordering Cheha are Enemor Ener Woreda in the south, Oromia region in the west, Ezha Woreda in the East, Gumer and Geta in the Southeast, and Wabe River, which separates it from Abeshege, and Kebena in the North.The woreda constitutes 40 kebeles (the lowest administrative unit) of which 39 are rural and 1 is rural town.

According to the Ministry of Agriculture (MoA) (1998), the agro-ecology of Cheha is classified into three agro-ecological zones. These agro-ecological zones include Dega (Highlands, 2,300 - 3,200 m.a.s.l), Weina Dega (Midlands, 1,500 - 2,300 ma.s.l) and Kolla (Lowlands, 500 - 1,500 m.a.s.l) (EIAR, 2011). The Weina Dega covers the largest part, whichaccounts for about 94 % of the total while both Dega andKolla cover 6%. The information obtained from the Cheha Woreda Agriculture and Rural Development Office indicates that the area receives unimodal rainfall. 'Kiremt', the main rainy season is from June to September with the peak in July and August. The short rainy season with erratic nature i.e. 'Belg' extends from March to May.

Sampling procedure and sample size determination

The questionnaire survey was conducted in Cheha woreda of Gurage zone located in SNNPR. This study adopted purposive sampling procedure where samples of n private households are selected by using the formula developed by (Kothari, 2004). The woreda has 39 PAs (Peasant associations)-kebeles which were used as our base for assigning households to be interviewed. Out of the 39 kebeles we identified (purposively selected) with the support of woreda experts six kebeles that are representatives of highlands and lowlands; these kebeles also represented model sitesfor intensivepracticingof agroforestry activities in the woreda. A total of 2882 households were listed out in the selected kebeles (Table 2).

Table 2 Number of household and population size by Kebele

No	Name of PA(Kebele)	Households (HHs)	Male headed	Female headed
1	Emdebera	412	315	97
2	Wedro	353	258	95
3	Ewan	660	564	96
4	Gasore	708	585	123
5	Buchach	432	336	96
6	worden	317	261	56
	Total	2882	2317	563

The number of sample size per PA (households to be interviewed = n) was calculated proportionally based on household for each PA using (Kothari, 2004).

$$n = \frac{z^2 \times p \times q \times N}{d^2(N-1) + z^2 \times p \times q}$$

n= 112, where Z=1.96, p&q= 0.5 each, N=2882,d=0.09

Where:

n=Sample size

N=Size of population

Z=Coefficient of normalization

q=Probability of failure

d=Margin error

p=Probability of success

For allocating sample size at PA level the proportional allocation formula is used:

$$ni = \frac{Ni \times n}{N}$$

Where:

ni=The sample size proportion to be determined

Ni=The population proportion in the stratum

n=The sample size

N=The total population

Using proportionate sampling the number of households to be interviewed in each PA is depicted in Table 3.

Table 3 Number of households and sample size in each PA (kebele)

No	Name of PA	No. of households (HHs)	No households interviewed(ni)
1	Emdebera	412	16
2	Wedro	353	14
3	Ewan	660	26
4	Gasore	708	28
5	Buchach	432	17
6	Worden	317	13
Total			114

Each PA was GPS coded and information based on the contents of structured questionnaire was collected (Figure 2). Focus group discussion (FGD) was also conducted to characterize the existing agroforestry systems and their products from farmers' perspectives. The village heads and local farmer representative group consisting of 10 farmers were present in the FGD. Secondary data sources on the contribution and role of agroforestry practices were also being accessed. Data collected using questionnaires surveys were subjected to SPSS statistical software for analysis.

Agroclimatic setting of the study area

From the analysis of the altitudinal distribution of sampled household locations the studied PAs in the woreda (Figure 3) can be broadly classified as highlands (Buchach, Emdebera and Wedro) and lowlands (Worden, Ewan and Gasore).

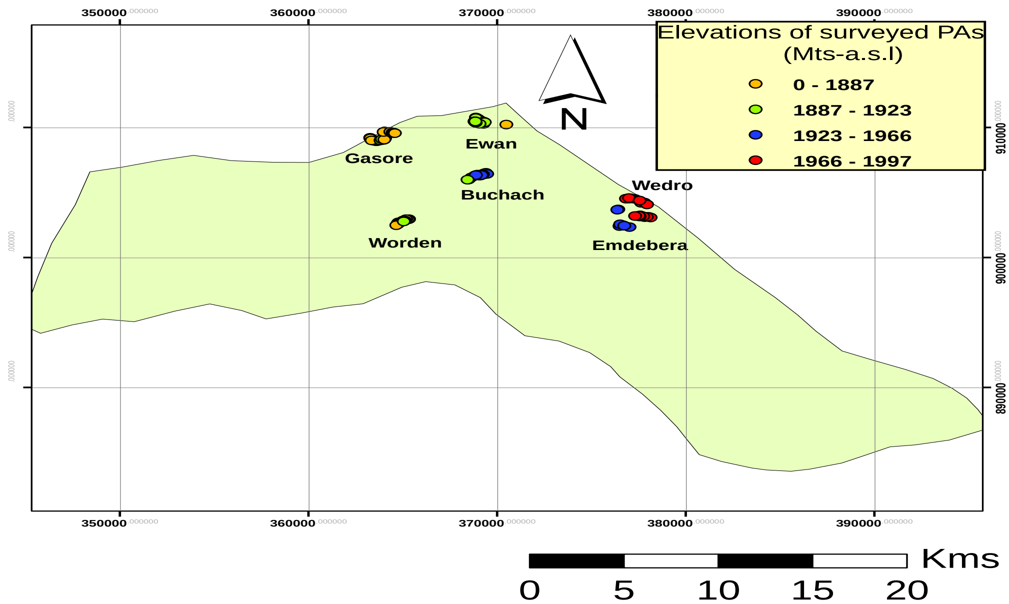

Figure 3 Elevations of household locations in the study area. Axes are locations in UTM coordinates

Results and discussion

Trends of vegetation cover:

Most respondents from the interviewed PAs replied that vegetation cover is improving from time to time. This is mainly attributed to their planting of *Eucalyptus viminalis* on woodlot plots that are mainly located at a separate yard at the back of their fruit and Enset based homegarden. The other reason stated for increasing trend of vegetation cover was their recent integration of fruit trees like *Mangifera indica* -Mango and *Persea americana* -Avocado in their land use system. Accordingly, out of 28 farmers interviewed for their opinion on trends of vegetation cover at Gasore about 25 respondents (89%) responded that it is increasing. Emdebera, Wedero, Ewan, Buchach and Worden had 50%, 85%, 88%, 82% and 76% respondents respectively that replied as increasing on trends of vegetation cover in the area (Figure 4).

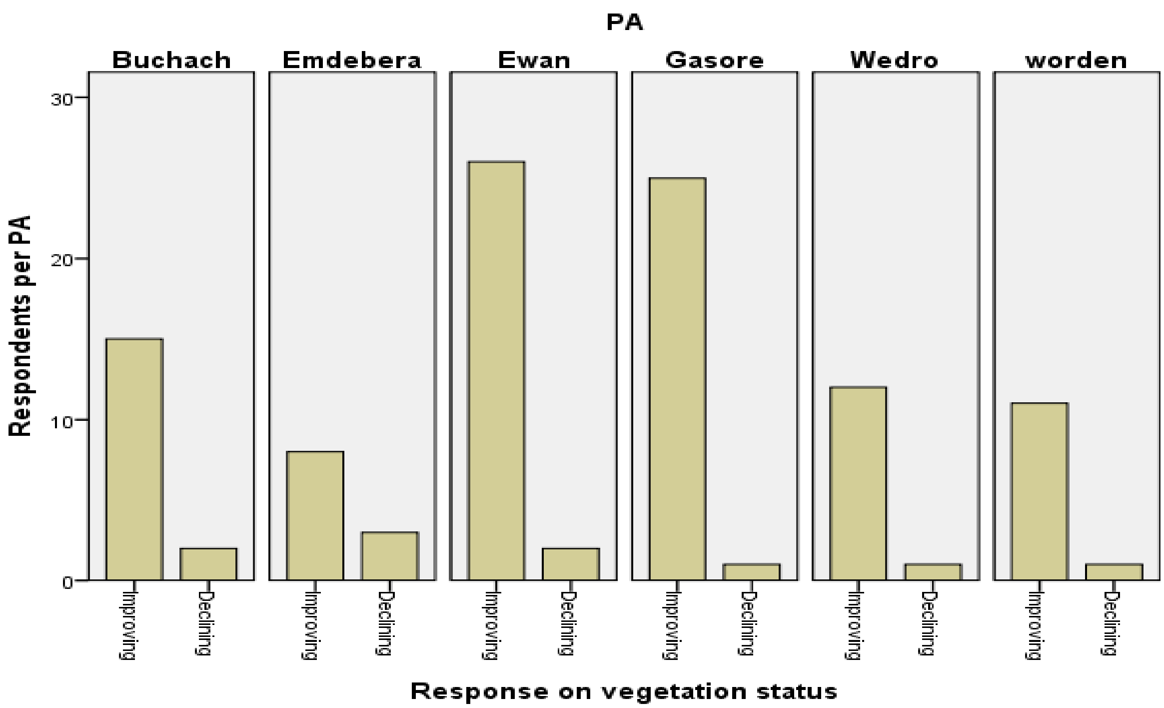

Figure 4 Comparison of responses on trends of vegetation cover across PAs (Kebeles)

Land holding and characterization of land uses:

The survey results of this study indicated that Enset, Coffee and khat based home garden agroforestry in and cropas shown in Figure 5 are the dominant land uses in the area and the major sources of livelihood and income.

Figure 5 Enset, Khat and fruit tree-based homesteads at different maturities in the study area

Land holding size did not reveal marked differences across the majority of thePAs(kebeles) except for Worden.Buchach, Emdebera, Gasore and Wedero had land holdings that ranged from 0.6 ha to 0.8 ha having no significant differences. Larger land holdings that ranged from 1- 1.2 ha were found at Worden while Ewan had comparatively the least land holding size that averaged about 0.5 ha (Figure 6). Excluding the area left for settlement the most dominant land uses identified in the study area include homestead agroforestry, agriculture and grazing lands. Significantly larger areas are allocated for Enset, coffee and Kaht based home garden agroforestry practices as compared to agriculture and grazing lands across all PAs (Kebeles) (Figure 7). Area coverage forhomegarden agroforestry practices was significantly higher (0.5ha on average) at Buchach at alpha 0.05 while the least coverage for the same practice was at Gasore and Ewan (0.2 ha on average).

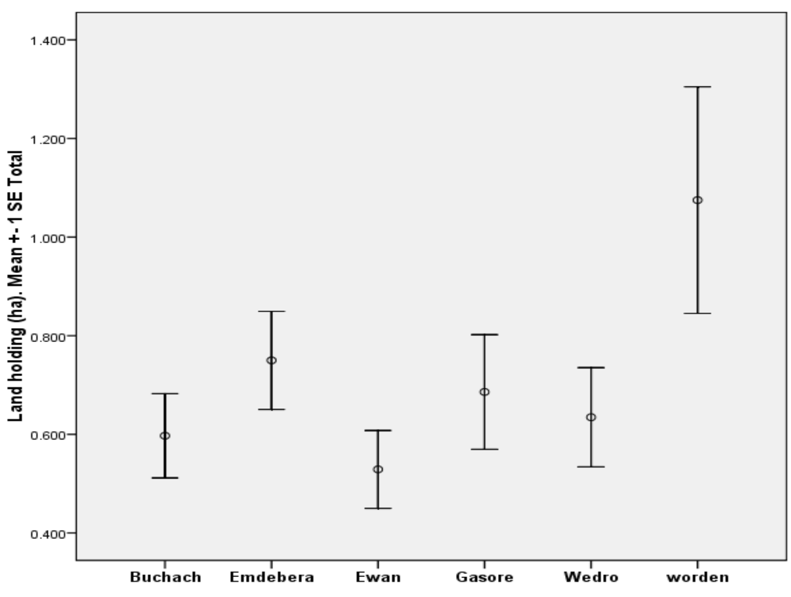

Figure 6 Average land holdings of the studied PAs (Kebeles)

Figure 7 Characterization of land uses at different PAs of Cheha woreda

Area for grazing land was larger at Worden while Buchach had the least allotment for grazing land from among the compared PAs. Cropland was found out to be the least of all the compared landuses at the studied PAs with the exception of Gasore where crop land is closely comparable with grazing land coverage and agroforestry and at Buchach where it is greater than grazing land (Figure 7).

Tree Planting Purposes:

In the study area trees are planted for various purposes. The survey results indicated that farmers plant trees and shrubsmainly for household consumption of products for food and feed, source of construction material, cash income, shade and for soil and water conservation. Of all the various usesmentioned household consumption, cash income and construction in their decreasing order were found out to be the most predominant purposes mentioned for planting of trees by respondents in the studied kebeles (Figure 8).

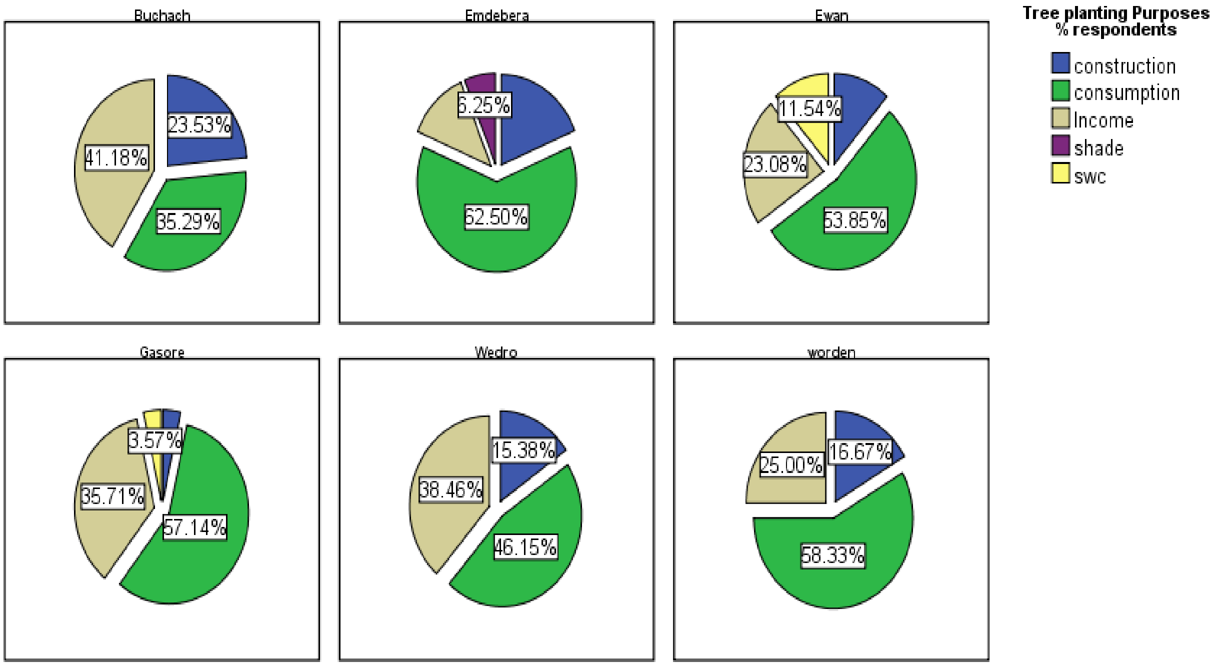

Figure 8 Characterization of tree planting purposes

It was foundout from respondants reply that about 12 different tree/shrub species are mainly planted in homegarden systems in the study area. Different tree species were found out to be planted to address the identified purposes of planting. *Eucalyptus viminalis*, *Podocarpus falcatus* and *Cordia africana* are tree species prefered for planting as sources of construction material in all the serveyed PAs.*Eucalyptus viminalis* woodloots are situated at the rear end of homesteads (Figure 9). Woodlots mainly contribute to hoshold energy demand and income generation.It must be recognized that timber, fuel wood and fodder, all of which are products that may often be of particularly high importance for local livelihoods (Thompson et al. 2010).

Figure 9 Woodlots on a separate parcel at the rear of homesteads

Catha edulis, *Enset ventricosum*, *Coffea arabica*,*Persea americana* and C*itrus reticulata* are predomenantly planted for household consuption purposes. Homestead systems play a significant role in improving food security for the resource poor rural households as discussed by Asaduzzaman et al. (2011). In terms of dietary diversification agroforestry has given more varieties of food than other forms of agriculture (Alemu 2016). Tree species planted for income generation include *Persea americana*, *Catha edulis*, *Enset ventricosum* and *Coffea arabica*. It is found out that Enset which is an integeral component of homegardens in the study area is planted more for consumption than for marketing in all the PAs studied (Figure 10).

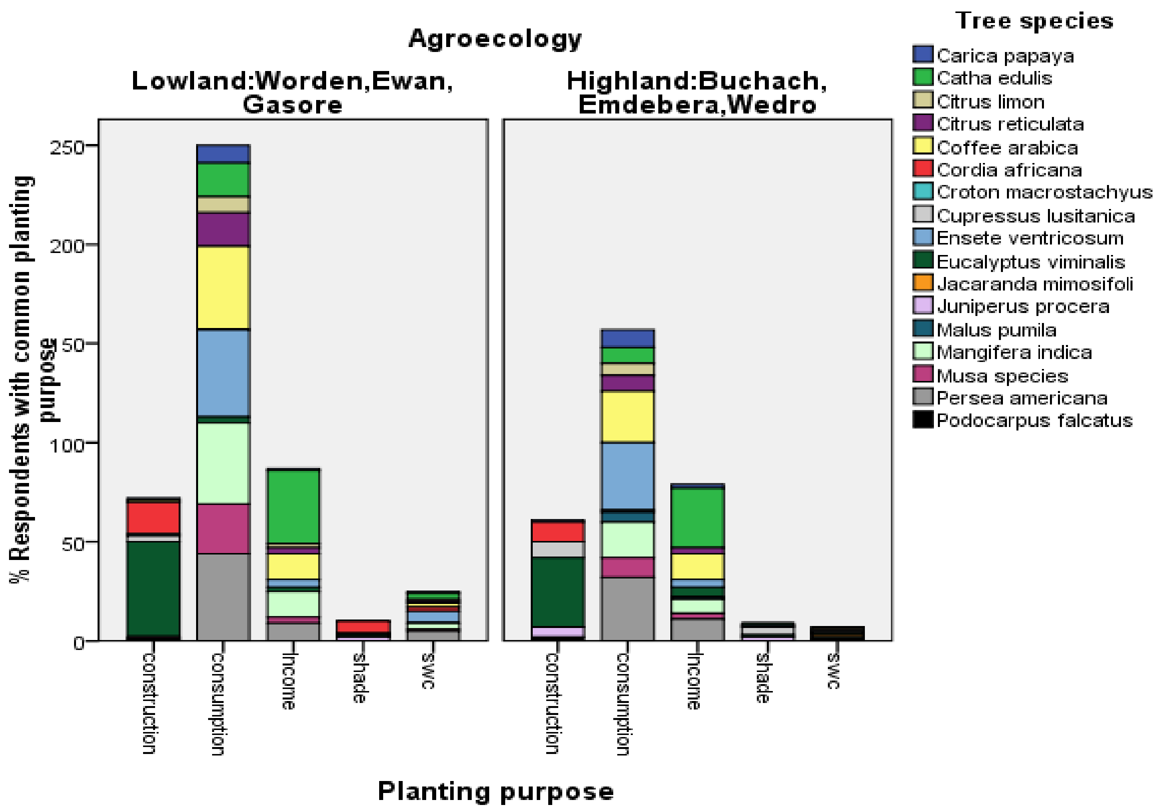

Figure 10 Tree species preferences and the associated planting purposes

Responses with respect to SWC and shade as tree planting purposes are very insignificant in most of the PAs with the exception of Ewan and Gasore where respondents mentioned that they keep tree/shrub species like Enset, Khat and persea as means for soil and water conservation apart from their primary uses. Parkland agroforestry is totally non existing in the studied PAs (Figure 7). Homestead components that are used for consumption were found more diversified at Gasore followed by Ewan than the remaing PAs.

Perception about agroforestry

The majority of the respondents recognized the environmental role of agroforestry to increase soil fertility and its contribution to farm income and household food security. Serious threats that are constraining agrofoestry are also stated by the respondents.

Perception about environmental role of agroforestry

The level of perception on the role of homestead practices to conserve soil and water was assessed during the survey. It is drawn from respondents' responses that they have positive perception about the environmental role of homestead practices. In this regard respondents either agreed or strongly agreed that homestead practices positively contribute to soil and water conservation. Respondents at Gasore where the structural components of homesteads are the most diversified were found to have more awareness on the conservation role of homesteads (Figure 11). Respondents also realized positive structural component interactions at homesteads.

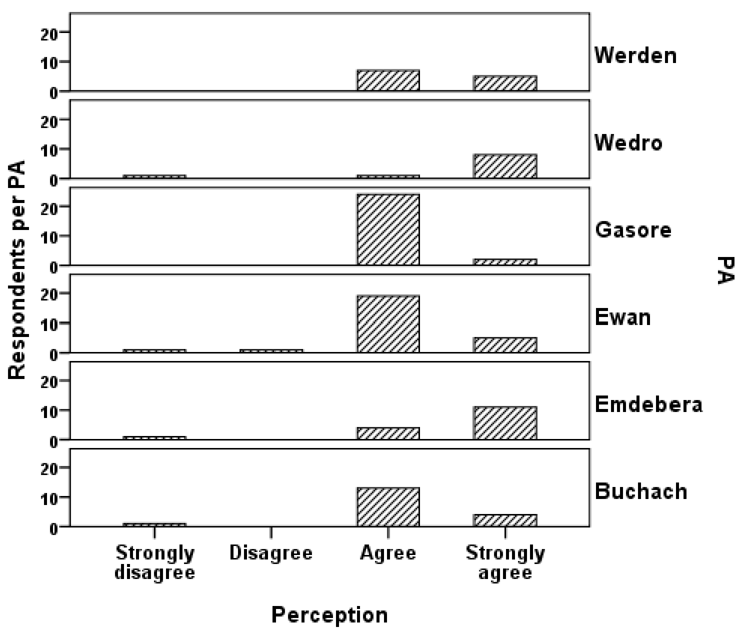

Figure 11 Responses on conservation role of homestead practices

Contribution of agroforestry to household income

The survey results revealed that homestead agroforestry positively contributes tohousehold income. Incomes were found to be prominently generated from sell of Khat and *Eucalyptus*. Practitioners of agroforestry were found to gain maximumincomeseither annually or in the duration of 4-6 years in the studied PAs. From the comparison of incomes across PAs Emdebera was found to gain the highest incomes both on annual basis (6,000 Birr on average) and in 4-6 years (7,000 Birr on average) time durations. By location also this PA is proximal to the main road which gives ease of access to market for homestead products. Khat contributed more to the income generated annually while *Eucalyptus* had the highest share for the income generated during 4-6 years and this is because 4-6 years is the rotation age of *Eucalyptus* for production of mature bole for construction material.Since it is fast growing and coppices more *Eucalyptus* is used frequently for firewood selling and construction purpose when planted as woodlots (Madalcho and Tefera 2016). As incomes are clustering more around 4-6 years this could indicate that in most of the studied PAs comparatively higher incomes are generated from agroforestry practices in longer durations than annually (Figure 12).

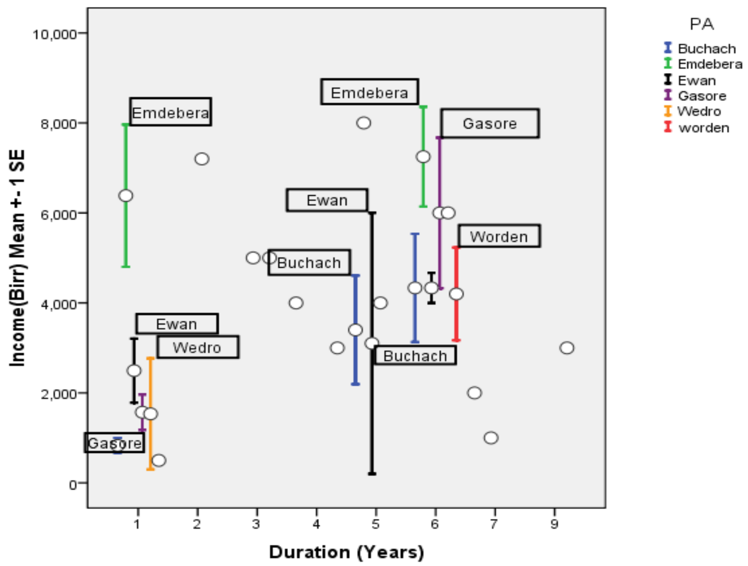

Figure 12 Household income generated from homestead agroforestry

It was found out from the survey results that agroforestry highly contributes to compensation of food security problems in times of crop failure.Interviewed farmers related from their history about the role that the part of Enset root that is locally known as "Amecho" played as a life saver during the extended drought the people faced in 1983G.C. Enset is regarded as a food security crop in this densely populated area because of its high productivity per unit area compared to cereals and because it serves as livestock feed during the dry season (Mojoa et. al, 2015; Elias, 2003). They also emphasized that their *Eucalyptus* based woodlot homestead practices play a significant role in saving the considerable time spent on fuel wood collection and hence reduces the burden imposed up on rural women to satisfy household energy demand.

Challenges against Practicing Homesteads

Despite the valuable contributions that homestead agroforestry renders to the community the practice was found out to be highly constrained by different challenges. The survey results indicated that water shortage, coffee leaf/stem drying, Enset stem/root decay and encroachment by wild animals were the most serious problems that are hampering the practice of homestead agroforestry in the surveyed PAs (Figure 13). Enset stem/root decay problems were more intense in the highlands (Buchach, Emdebera, Wedro) than in the lowlands (Worden, Ewan, Gasore) while wild animals raid was more severe in the lowlands than the highlands. Water shortage and coffee leaf/stem drying were equally severe both in the highlands and lowlands.

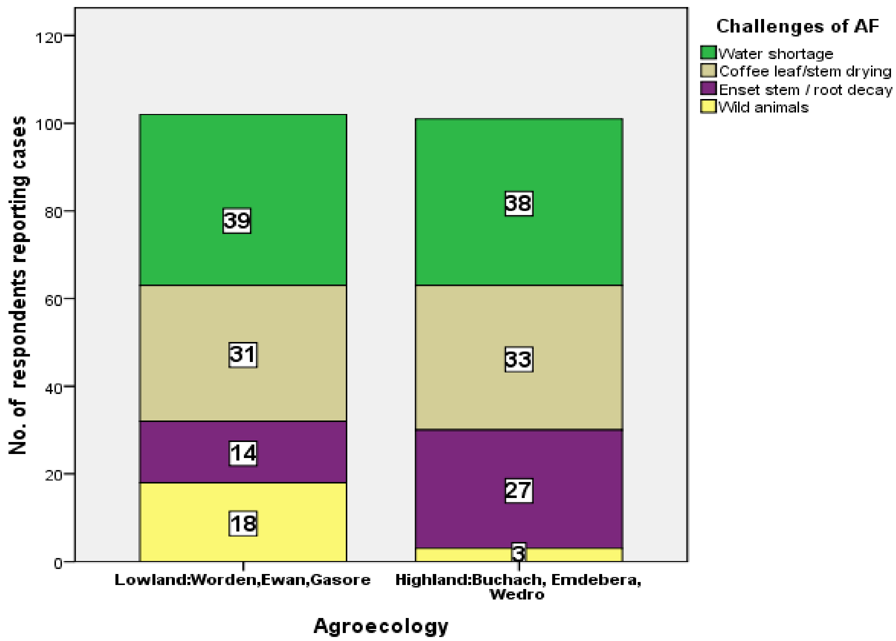

Figure 13 Categorization of factors constraining homestead practices


Figure 14 Decaying of Enset stem and root

The observed Coffee and Enset diseases requirefurther detailed studies to be clearly isolated. From the comparison of responses on the collective effectof reported challenges against homestead practices the severity was found out to be more intense at Ewan as compared to the rest of the PAs (Figure 13). In contrary the challenges were found out to be significantly lower at Wedro which indicates that homestead practices are undertaken in relatively conducive environment. The most frequently reported wild animals that attack fruit trees in the homesteads include monkeys, porcupines, warthogs and apes. The numbers of major crop raiders, particularly monkeys, porcupines, and apes are reported to be increasing. Porcupines, mole rats and wild pigs are the major pests of Enset in the study area (Mojoa et.al, 2015). As homestead components that mainly comprise fruit trees were found more diversified at Gasore followed by Ewan than the remaing PAs the threas by wild animals were also prevalent in these PAs (Figure 14).

Conclusion and Recommendation

The study has indicated that the potential of homestead agroforestry is tremendous in the surveyed PAs. Diversified products of both consumption and economic value are generated from homestead agroforestry in the study area. The existence of diversified structural components in homestead practices that include woody perennialslike *Eucalyptus*, tree crops like Coffee and fruit trees and non-woody perennials like Enset have a significant contribution to household consumption and income generation. Enset and Khat based homesteads were found indigenous age-old practices while fruit trees are introduced agroforestry technologies to the study area that contributed more to the current increased production and structuraldiversification of homesteads. Homestead components ofKhat, Coffee and Enset are organized in nicely structured assemblage of their own parcel and receive careful management. *E. viminalis* based woodlot practices are given their own separate parcel at the rear of homesteads and mainly address household energy demand and generate income through sell of construction materials.

Based on the findings of the study farmers preferably engage on homesteads than agriculture since homesteads have the potential to address household consumption demands adding to the dietary advantage of getting fresh produce and provide cash income when the need arises. Therefore, it is highly recommended to encourage farmers to engage in integration of cash crops of improved varieties at homesteads. Respondents were also found out to be cognizant of the conservation role of agroforestry. The population of fruit trees mainly of Mango and Avocado at homesteads is showing a gradual increase and these fruits are getting wider acceptance by the community. Thus, the old Enset and Khat based practices are getting diversified leading to modification of plant structure at some of thehomesteads. Incidences like insect /disease attacks on Enset and Coffee trees are currently becoming serious threats to theold homestead practices and these need immediate identification of problems and provision of preventive solutions to sustain the practice.

Reference

Abebe Yadessa, Diriba Bekere, Worku Burayu, Tamirat Arficho and Dechasa Jiru (2001). Agroforestry based maze production: Another option to sustain maize. Proceedings of the Second National Maize Workshop of Ethiopia, 12-16 November 2001 Addis Ababa, Ethiopia

Alemu, M.M. (2016). Indigenous Agroforestry Practices in Southern Ethiopia: The Case of Lante, Arba Minch. Open Access Library Journal, 3: e3278. http://dx.doi.org/10.4236/oalib.1103278

Asaduzzaman M, Naseem A, Singla R (2011). Benefit cost assessment of different homestead vegetable gardening on improving household food and nutrition security in Rural Bangladish. 2011 Annual meeting July 24-26,2011, Pittsburgh, Pennsylvania. Agricultural and Applied Economics Association, Pittsburgh, Pennsylvania.

CSA,2007). Central Statistical Agency of Ethiopia.

Dagne Mojoa, Jessica Rothschuh and Mehari Alebachew (2015). Farmers' perceptions about the impacts of human wildlife conflict on rural livelihoods and natural resource management efforts in Cheha Woreda of Guraghe Zone. Ethiopia.Int. J. Agric. Econ. Extension Vol. 3 (1), pp. 083-090.

EIAR (Ethiopian Institute of Agricultural Research).2011. Crops and Agro ecological zones of Ethiopia. EIAR, Addis Ababa.

Elias E (2003). Case Studies on Genetic Diversity, Coffee and Soil Erosion in Ethiopia. Paper prepared for the Roles of Agriculture. International Conference 20-22 October, 2003 – Rome, Italy.

Madalcho AB, Tefera MT (2016) Management of Traditional Agroforestry Practices in Gununo Watershed in Wolaita Zone, Ethiopia. Forest Res 5: 163.doi:10.4172/2168-9776.1000163

Nair P.K. Ramachandran (1993). An Introduction to Agroforestry. Kluwer Academic Publishers, The Netherlands.

Nair P.K. Ramachandran (2000). Overstory #64 - Homegarden. Agroforestry trees of life, trees for life.

Thompson I, Mackey B, McNulty S, Mosseler A (2010). A synthesis on the biodiversity-resilience relationships in forest ecosystems. The Role of Forest Biodiversity in the Sustainable Use of Ecosystem Goods and Services in Agro-Forestry, Fisheries, and Forestry. Forestry and Forest Products Research Institute, Ibaraki, Japan, 9-19

Contribution of Selected Agroforestry Practice for Food Security: A case in Homegardens of Arbaminch Zuriya and Wenago Districts of SNNPRS, Ethiopia

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Abstract

This study was conducted with objective of identifying dominant agroforestry practices and their contribution to the livelihood in two agro ecological zones of South Nations Nationalities and Peoples Regional State (SNNPRS). Using stratified random sampling method Wenagoworeda (district) of Gedeo Zone and Arbaminch Zuriya woreda of Gamo Zone were selected and a total of 220 households were randomly selected for a structured questionnaire survey. The two dominant agroforestry practices identified by this studywere *Ensete ventricosum-Coffee* based homegarden in Wenago and *Banana-Mango* fruit-based home garden in Arbaminch Zuriya. The results revealed that contribution of agroforestry practices for the livelihood of the local farmers was crucial. The annual income generated from home garden agroforestry practices ranged between 1,000 and 100,000 Birr. During food shortage periods, agroforestry practices support the livelihood of the farmers in providing year-round food supply. Avocado, Mango and Banana were the most frequent fruit trees observed in the study area. *Cordia africana* and *Croton macrostachyus* were the top 2 most utilized multipurpose trees identified by direct matrix ranking of 30 respondents. Thorough consideration and technical supports should be given to homegardens by governmental and other development sector actors in since these practices are the back bones of communities' livelihood. Some support mechanism may include support in quality disease tolerant and high fruit yield fruit trees seedlings and capacity building in nurseries and *in-situ* training for farmers in disease control and management of fruit trees and seedlings.

***Keywords*:** Livelihood, Traditional Agroforestry, Home garden, Socio-economics

Introduction

There are around 500 million smallholder farmers in the world, and they produce up to 80% of the food consumed in Africa and Asia. They are net buyers of food and very vulnerable to food price increases and spikes. Even though they play a critical role in addressing the challenges of food security, poverty and climate change, they are among the poorest and most marginalized in the world that are struggling for their livelihood (ASFG, 2013). The livelihood of farmers in Africa, especially in Ethiopia greatly depends on their farms. They try to manage their farms to produce diverse products using Agroforestry. According to world Agroforestry, Agroforestry is the interaction of agriculture and trees, including the agricultural use of trees. This comprises trees on farms and in agricultural landscapes, farming in forests and along forest margins and tree-crop production, including cocoa, coffee, rubber and oil palm.Interactions between trees and other components of agriculture may be important at a range of scales: in fields, where trees and crops are grown together, on farms, where trees may provide fodder for livestock, fuel, food, shelter or income from products including timber, and landscapes, where agricultural and forest land uses combine in determining the provision of ecosystem services (Accessed online, 2020).

However, the species diversity and component composition in agroforestry (AF) systems and practices are influenced by ecological, socio-economic and cultural factors (Wiersum, 1982; Michon *et al*, 1983; Fernandes and Nair, 1986; Mergen, 1987; Soemarwoto, 1987; Tesfaye, 2005). Physical environment such as altitude and climate are important ecological factors that influence species diversity (Soemarwoto and Conway, 1991). The traditional tree management techniques, woody species mix, both vertical and horizontal placements of the system components, economic and ecological benefits perceived by farmers could vary considerably with each other between and within the agro-ecological zones and land use systems. Both vertical and horizontal arrangements have resulted from a long history of farmer trials and check-ups rather than being supported by scientific and empirical evidence. Individual farmers pursue their own way of species selection and arrangements which lead to tremendous variation in the number, size, and placement of specific component arrangements. Moreover, the structural and functional attributes of components vary between and within agro-ecologies in traditional AF systems and practices in the country. Thus, there is a need to tap on the existing knowledge to efficiently utilize scarce resources for better economic and ecological benefits.

In this context, Ethiopian farmers have the tradition of incorporating/maintaining various tree species in their farming systems although they are not well evaluated or documented. The need to rely on the existing traditional knowledge and agro-ecology is also emphasized by ICRAF (1997) to clearly establish the overall economic and ecological benefits of a given Traditional Agroforestry Practice (TAFP) and the contribution of individual component to the overall wellbeing of the system. The main purpose of this research is therefore, to understand the contribution of TAFP for food security and their socio-economic importance at *Arbaminch Zuriya*and *Wenago* districts of Southern Nations Nationalities and Peoples Regional State (SNNPRS), Ethiopia.

Specific Objectives

- To characterize the existing traditional TAFPin the study area

- To assess and describe the contribution of TAFP for livelihood of farmers in the study area

Materials and Methods

Description of the study area

This study was conducted in *Arbaminch Zuriya* ($06^o13'$to $06^o25'$N and $38^o12'$ to $38^o24'$E) and Wenago ($05^o40'$to $06^o03'$N and $39^o05'$to $39^o28'$E) woredas (districts) which are parts of Gamo-Gofa and Sidama administrative zones, respectively, in South Nations Nationalities and Peoples Regional State (SNNPRS), Ethiopia (Figure 1).

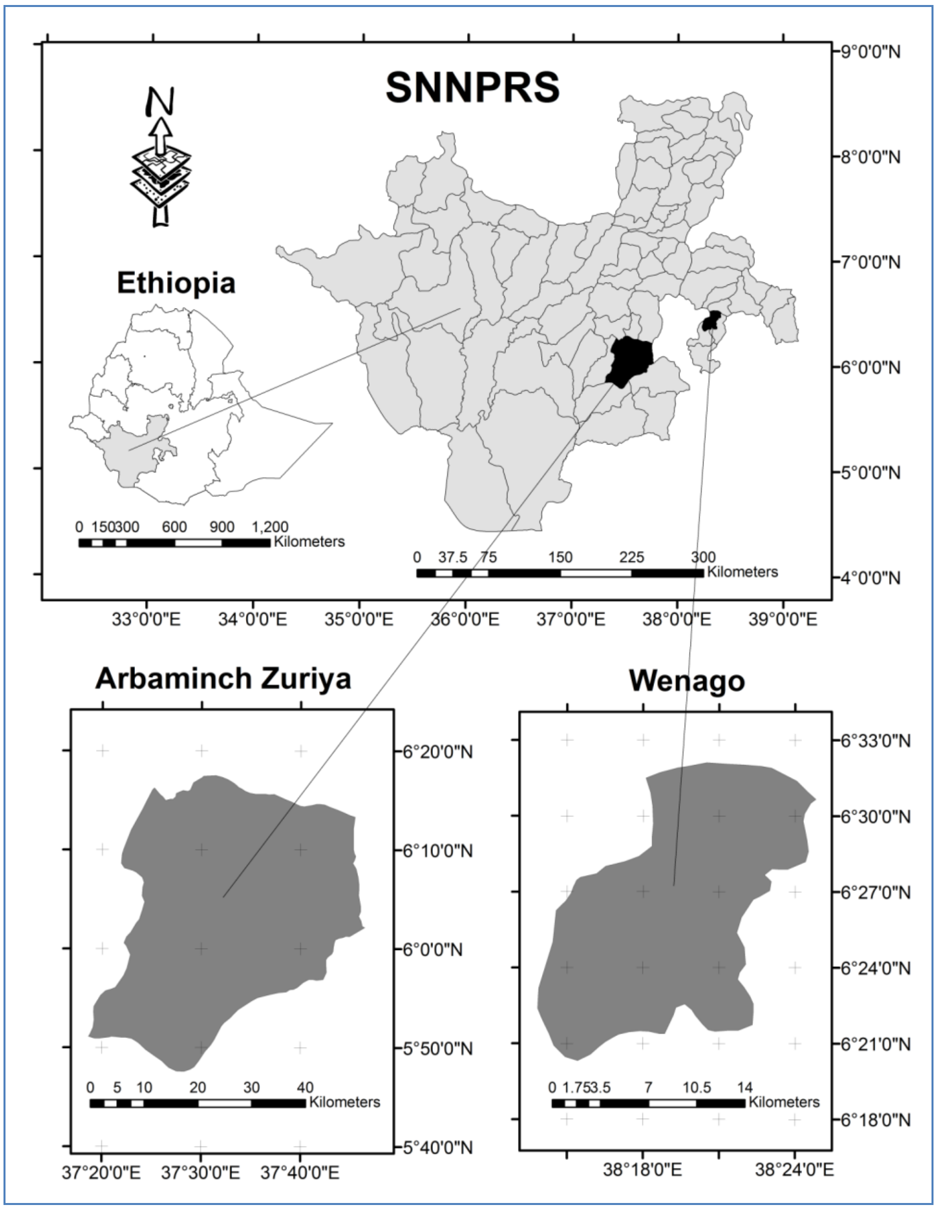


Figure 1 Map of the study area

Generally, Arbaminch Zuriya district is classified in to two Livelihood zone, these are *Chamo-Abaya* irrigated Banana livelihood zone, a lowland zone, characterized by irrigated banana production, and maize and root crop livelihood zone, the food crops are maize *Ensete ventricosum*, sweet potatoes, taro, *Teff*, and yams. Its land use pattern is Cultivated land 32567ha, Grazing land 2713ha, Forest & Bush 10058ha, Cultivable land 11421ha, Uncultivable land 50668ha, and Others 56403ha(Defaru and Tuma, 2013). The average minimum and maximum temperature of the district ranges between 17.3^{0}C and 30.6^{0}C. Rainfall pattern is bimodal, erratic and unreliable, with the mean annual precipitation ranging between750 mm and 1300 mm. '*Belg*' (long rainy season) and '*Meher*' (short rainy season) are the two rainfall seasons. The main rains are from April to May, while the small rains are from September to October.

Wenago is part of the *Gedeo* Zone and bordered on the Southwest by *Yirgachefe*district, on the Northwest by the *Oromia Region*, on the Northeast by Dilla Zuriya district, and on the Southeast by Bulie district. Wenago district include Wenago town. Based on the 2007 Census conducted by the CSA, this district has a total population of 116,921, of whom 58,150 are men and 58,771 women; 8,471 or 7.25% of its population are urban dwellers. Wenago district is located 386 Km from *Addis Ababa*and its altitude ranges between 1560 and 1920m.a.s.l. According toTilahun*et al*. (2009) the agricultural sector is the dominant means of livelihood for most of the districts. Out of the total of 24,790ha of land, 22,871ha are known to have potential for agriculture. Annual crops cover 5.03 percent; perennial crops 84.77 percent, uncultivable land 0.65 percent and others are 3.52 percent. It has three main agro-climatic zones with the topography ranging from wide flat valley bottoms to steep mountain slopes. The rainfall distribution of the district is bimodal. The main rainy season is from June to September ('*Kiremt*' or *Mahar*') and the short rainy season is from February to April ('*Belg*'). The average annual rainfall is 107.72 mm and, the mean annual average temperature of the Woreda is 20^{0}C.

Sampling procedure and sample size determination

A stratified random sampling technique was applied following Alexiades (1996) and Taherdoost (2016) method. Using purposive sampling strategy, representative districts and their corresponding kebeles (the smallest administrative unit in the government) were identifiedby discussing and consulting with regional and district level environment protection and forest development experts. As a result, Arbaminch Zuriya and Wenago districts were selected to represent lowland and midland areas, respectively. Cheno Chelba and Lante kebeles (lowest administrative unit in Ethiopia) were selected tostand for Arbaminch Zuriya and Dodoro and Jemjemo were chosen to characterize *Wenago*. The total numbers of households in *Arbaminch Zuriya* and

Wenago districtswere 506 and 521, respectively. From the selected kebeles 220 representative households were randomly selected using Watson (2001) formula:

$$n = \frac{\frac{P(1-P)}{\frac{A^2}{Z^2} + \frac{P(1-P)}{N}}}{R}$$

Where: -
n = Sample size required [set by Watson (2001)].
N = Total population (506HHs for *Arbaminch Zuriya* and 521HHs for *Wenago* districts.
P = Estimated variance in population, as a decimal: (0.1) for 90%-10%.
A = Precision desired expressed as decimal: (0.05) for 5%.
Z = Based on confidence level: (1.96) for a 95% confidence level.
R = Response rate: (0.99) for 99% response.

Data collectionand analysis

Data were collected from both primary and secondary sources. A reconnaissance survey was conducted on the existing TAFP with an intention of identifying the major Agroforestry practices. Structured questionnaire (Annex 1) was addressed to 220 household heads (respondents) and information on the contribution of TAFP for food security and overall wellbeing of the community was assessed. In addition, socio-economic contribution of TAFP in the study area and the income generated from these systems were assessed and quantified using the structured questionnaire.

Focus group discussions with 12 different groups consisting of elders, women, youngsters and studentsand key informant interviewswith 30 different key informants were conducted to extract information about the trend of vegetation change and categorize trees and shrubs of TAFP based on their major use categories and their economic and ecological benefits. The preference of the local people for tree species, knowledge on forest and woodland resources management in general and on fruit and fodder tree species was assessed by key informant interview. Furthermore, the contribution of TAFP in general and fruit and fodder tree species to the livelihood of the community were assessed through questionnaire and the focus group discussions. The selection of key informants from the community was performed using snowball method (Goodman, 1961; Naderifar *et al*, 2017) in which informants who are mentioned by many farmers were selected. During focus group discussion groups of elders, women, youths and forestry experts from the crossponding districts were incorporated. Direct matrix ranking tools were used to sort out 4 multipurpose trees by considering six attributes (Soil fertility, Fodder, Construction, Soil and water conservation, shade and medicine) at a time. Thirty respondents of Wenago district, with relatively higher number of tree richness were asked to assign value (5 = best, 4 = very good, 3 = good, 2 = fair, 1 = poor and 0 = not used) to attributes and the results were summed up to create a matrix that represents the district. The diversity of trees and shrubs was assessed by inspecting each Agroforestry farm. Secondary information was collected from reports, maps, censuses, thesis and other publications to have an overall picture of the practices across the study areas. Finally, the collected information (both qualitative and quantitative data) was encoded and analyzed by SPSS V.20.0 (2012) for various parametric and non-parametric tests.

Results

Demographic characteristics of the study area

The majority (72.7%) of the households interviewed were male headed. Age of the respondents varied between 20 and 90 with an average of 47.5. Most of our respondents (90.5%) were married and had a minimum of two and a maximum of 18 family members with an average of seven household members. Considering educational status 112 (50.9%) of the respondents were hardly able to read and write, 71 (32.3%) had primary education, 22 (10%) were involved in secondary education and only 15 (6.8%) joined higher education. The mean land holding of the respondents in the study area was 1.28ha (Table 1).

Vegetation status in the study area

Most of the respondents (63.6%) perceive the vegetation in their locality as decreasing from time to time (Figure 2). For example, 90% of *Arbaminch Zuriya* respondents reported their landscape lost its vegetation in the past 30 years. This could be best attributed to the change in climatic condition and the practice of continuous and unsustainable utilization of forest products. By taking the efforts of rehabilitation programs and expansion of private plantation forests into consideration 57 respondents (25.91%) indicated increase in vegetation in the study area. The rest 23 respondents remain neutral (reported no change in vegetation cover) (Appendix 1).

Traditional Agroforestry Practices (TAFP) in the study area

Arbaminch Zuriya district is well known for itsfruit products (Banana, Avocado and Mango) while Wenago district is famous by its *Coffee* product respectively. In Wenago district Coffee-Tree-Enset based TAFPisan identifying feature whereas *Banana-Mango* Fruit based TAFP dominate Arbaminch Zuriya district. All of the respondents involved in this study are engaged in TAFP and they allocate most of their farmland for these farming systems (Figure 3A). For instance, in Wenago district land holders assign more than 90% of their farm for TAFP. The principal TAFP identified in both districts was home garden, dominating 81.36% (179) of the farming system in the study area (Figure 3B). The land allocated for home gardens in *Dodoro* kebele showed significant difference ($p< 0.0001$) as compared with all other three kebeles (Appendix 4).

Table 1 Demographic characteristics of the study area

S.N	Variables	Range of values	Mean and/or (%) results			
			Arbaminch Zuriya		Wenago	
			Cheno Chelba	Lante	Dodoro	Jemjemo
1	Gender of the respondents	Male (M) Female (F)	M= 34 (15.5%) F= 18 (8.2%)	M= 36 (16.4%) F= 22 (10.0%)	M= 44 (20.0%) F= 16 (7.3%)	M= 46 (20.9%) F= 4 (1.8%)
2	Age of the respondent	20 – 90	47.44	51.48	44.48	46.62
3	Marital status of the respondents	Single (S) Married (M) Divorced (D) Widowed (W)	S= 0 (0%) M= 48 (21.8%) D= 2 (0.9%) W= 2 (0.9%)	S=1 (0.5%) M= 48 (21.8%) D= 1 (0.5%) W= 8 (3.6%)	S= 1 (0.5%) M= 53 (24.1%) D= 4 (1.8%) W= 2 (0.9%)	S= 0 (0%) M= 50 (22.7%) D= 0 (0%) W= 0 (0%)
4	Family size of the respondents	2 to 18	6.60	6.74	7.43	7.40
5	Educational status of the respondents	Illiterate (I) Primary (P) Secondary (S) Higher (H)	I=22 (10.0%) P=17 (7.7%) S= 7 (3.2%) H= 6 (2.7%)	I= 29 (13.2%) P= 16 (7.3%) S= 7 (3.2%) H= 6 (2.7%)	I= 32 (14.5%) P= 20 (9.1%) S= 5 (2.3%) H= 3 (1.4%)	I= 29 (13.1%) P= 18 (8.2%) S= 3 (1.4%) H= 0 (0%)
6*	Land holding of the respondents	0.15 – 10 (ha)	0.94 ha	0.98 ha	2.09 ha	1.11ha

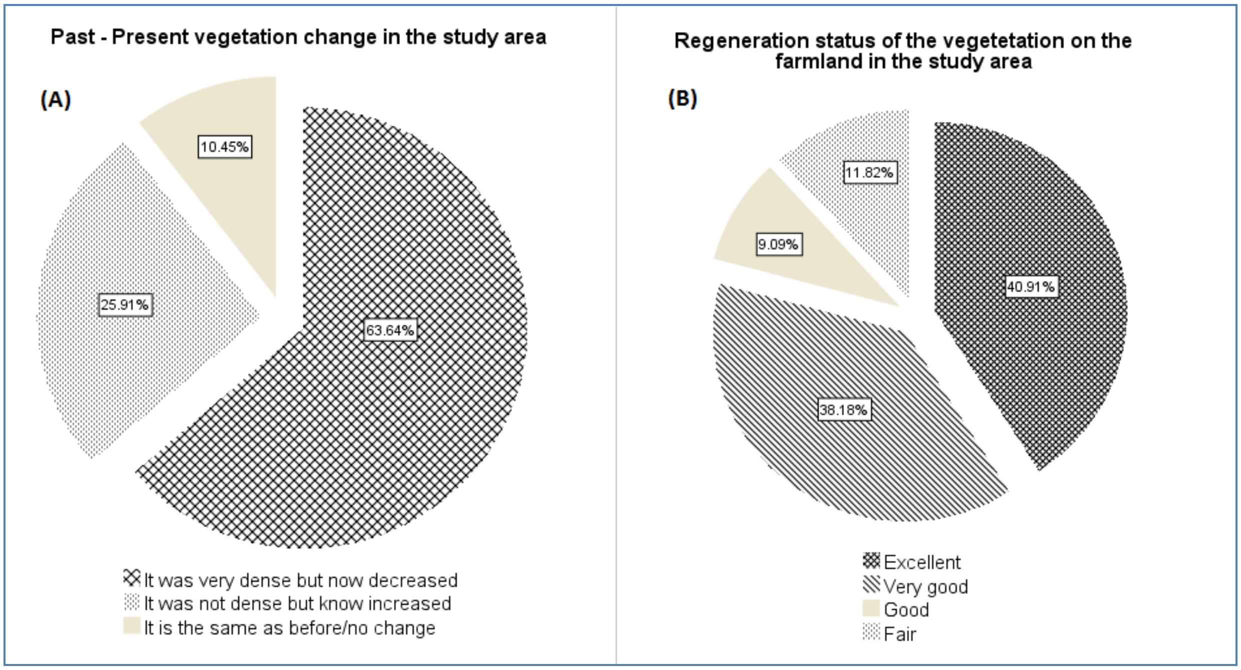


Figure 2 Change and regeneration status of vegetation in the study area

Farm richness of TAFP in the study area

Focusing on trees and shrubs, this study identified a total of 38 different multi-purpose trees and shrubs which support the direct or indirect physical and economic access of the households to enough and nutritious food both in quality and quantity.

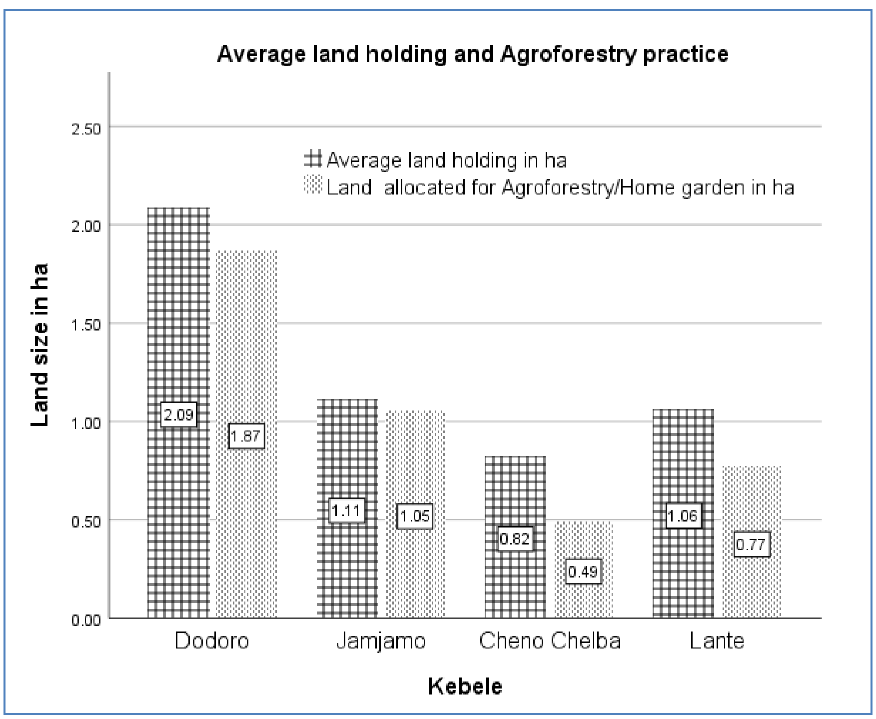


Figure 3A Land holding and Agroforestry

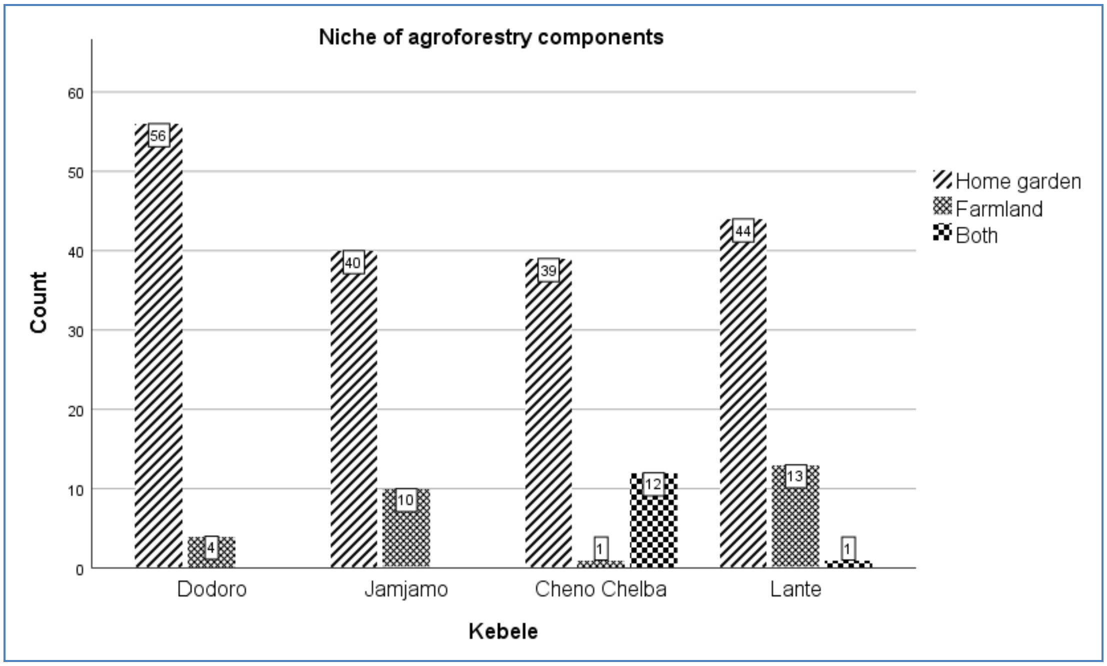


Figure 3B Niche of Agroforestry components

Major products obtained from home gardens include fruits (dominantly in *Arbaminch* Zuriya district) and timber, *Enset and Coffee*, chiefly in *Wenago*district (Figure 4). In addition, vegetables, tubers and different annual crops are also grown and managed to support the subsistence of the household. Majority of the respondents (121) managed to integrate trees and crops in their farms. Full integration of all three components (trees, crops and livestock) reported in the remaining 99 AF farms. There werea total of 10 fruit trees and 28 different multipurpose trees and shrubs species in the homegardens and farmlands of the study area (Appendix 2).

All the respondents from Wenago district indicated that the interaction between trees and crops in their homegardens and/or farmlands is either positive or neutral. Only a single respondent reported negative interaction. In Arbaminch Zuriya district 61 respondents indicated that trees negatively affect the performance or productivity of annual crops (Figure 5A). In the case of tree-livestock interaction, majority of the respondents in both districts reported similar interaction cases that trees and livestock in their corresponding areas has mutual benefit each other (Figure 5B).

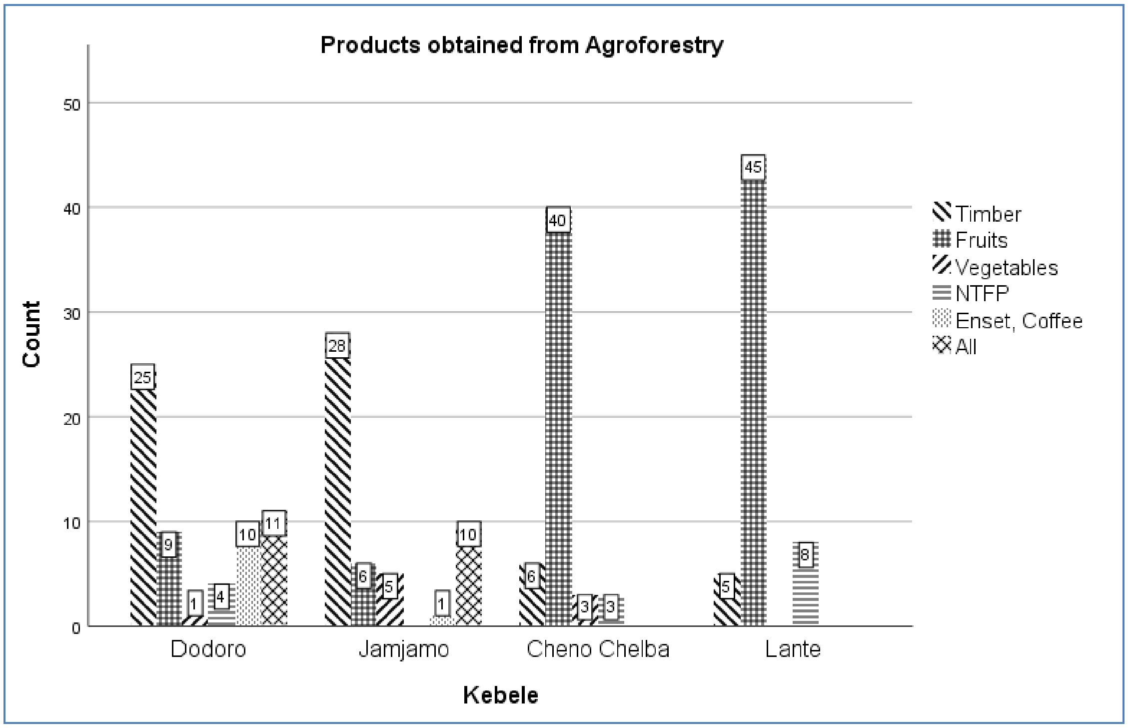


Figure 4 Major Agroforestry products use categories in the study area

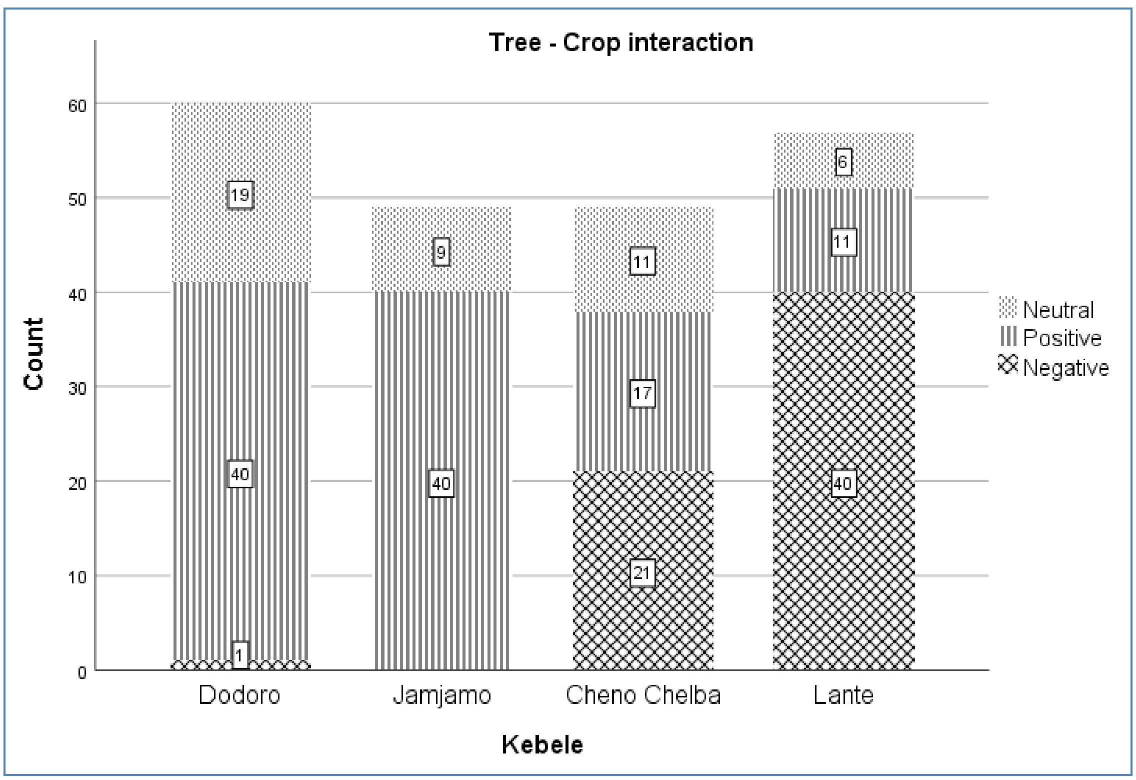


Figure 5A Tree – Crop interaction in agroforestry systems

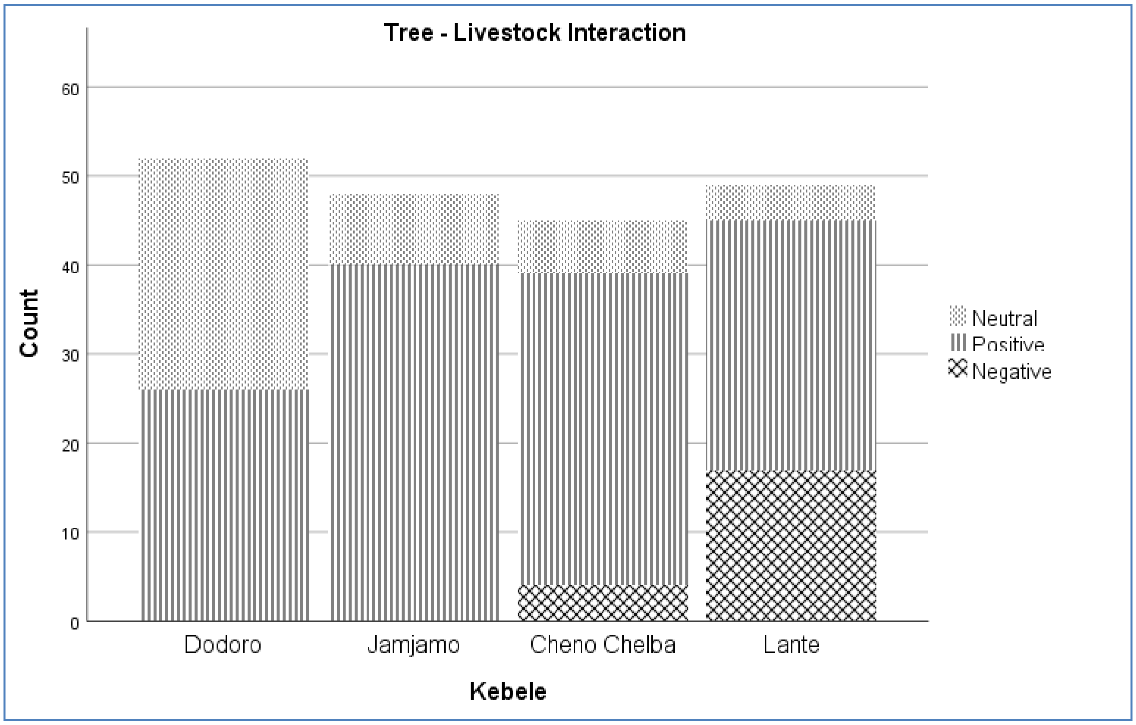


Figure 5B Tree – Livestock interaction in agroforestry systems

Caring intensity of homegardens in the study area showed variations among two districts. In Wenago district 62% of respondents noted they always give due attention and care their AF farms (Homegardens). But majority of the respondents (60%) from Arbaminch Zuriya district give occasional concern to their homegardens (Figure 6).

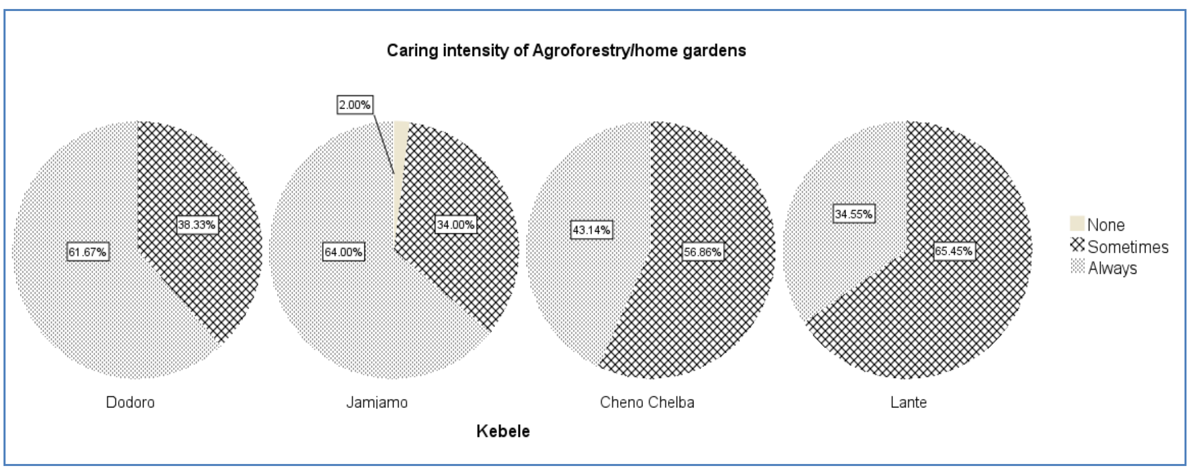


Figure 6 Caring frequency of Agroforestry farms in the study area

The contribution of TAFP for food security and socio-economic support

Agroforestry practices support livelihoods of the local communities in the study area in numbers of ways. This study revealed that TAFP in the study area benefit households in supplying valuable cash crops and generating cash income for the household. The income generated from TAFP ranged between 1000 and 100,000 Birr (Birr is Ethiopian currency with current value 1USD ≈ 32 Birr) on annual basis. Majority of the respondents (81.2%) in the study area reported that they generate a maximum of 10,000 Birr or less from their corresponding farm products. Few individuals (6 from Wenago and 23 from Arbaminch Zuriya) stated that they generate 10,000 to 40,000 Birr from AF products. This study identified 7 individuals with annual income range between 50,000 and 100,000 Birr. Respondents (92.3%) notified the income generated from TAFPs helped them in funding school fee of their children, financing different social ceremonies like wedding, grief, social savings like: *Edir*and *Ekub* (an indigenous informal financial institution in Ethiopia) and subsidize other miscellaneous social expenditures.

In maintaining food security, creating economic access to sufficient, safe and nutritious food to meet dietary needs of individuals has a great importance. In this regard homegardens in the study area play vital role in providing valuable cash crops for the household (farmers). In *Wenago* district Coffee and Avocado are the principal cash generating home garden products at the same time as Banana and Mango are for Arbaminch Zuriya district (Figure 7).

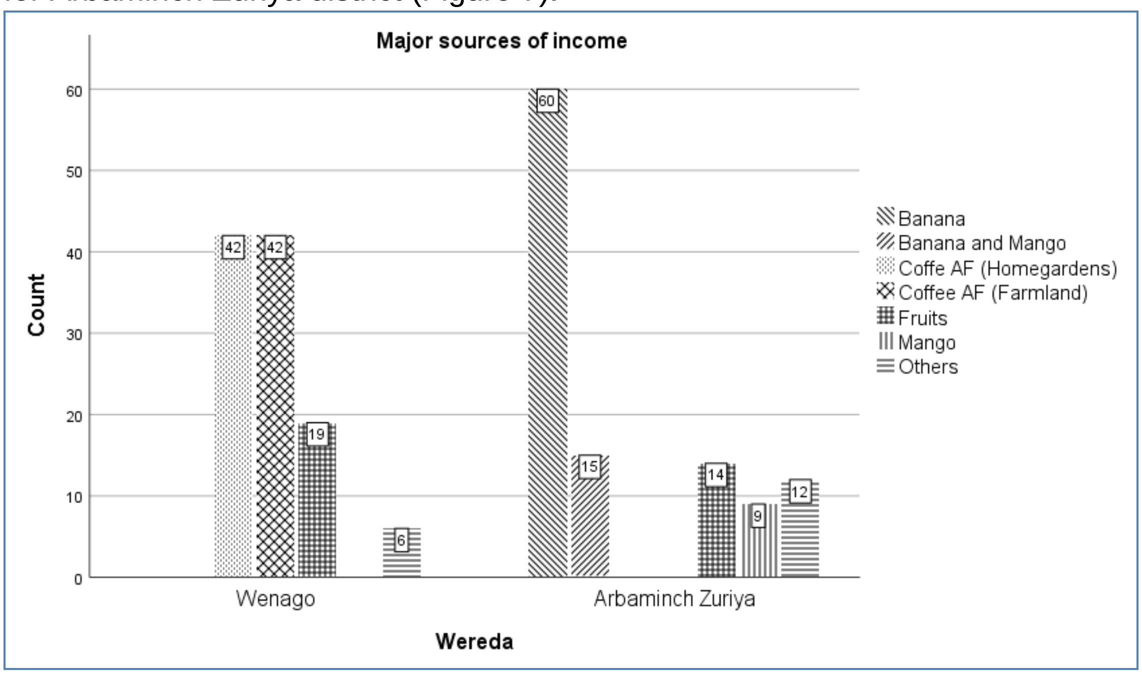


Figure 7 Sources of cash income in the study area

Regardless of income generation and food supply, TAFPsin the study area provide numbers of other socio-economic and ecologicalbenefits. Majority of the respondents in this study agree with positive influences of TAFP for the community and the environment they are subjected (Table 2). They agree onpositive impact of TAFP on; soil fertility improvement, soil and water conservation, reduction of the chance of complete crop failure, supply of firewood and fodder, maximization of overall farm income, and creating suitable and comfortable surrounding for living (micro-climate modification).

Table 2 Response given for interactions effects of Agroforestry systems

Query	Response	Kebele			
		Dodoro	**Jamjamo**	**ChenoChelba**	**Lante**
		Count	Count	Count	Count
Agroforestry practices increased soil fertility	Strongly disagree	1	0	0	0
	Disagree	1	0	3	1
	Neutral	2	1	7	7
	Agree	15	15	28	31
	Strongly agree	39	33	14	19
Agroforestry practices increased farm income	Strongly disagree	0	0	0	0
	Disagree	0	0	1	2
	Neutral	3	2	8	1
	Agree	23	21	28	32
	Strongly agree	34	27	15	23
Agroforestry practices conserved soil and water	Strongly disagree	1	0	0	0
	Disagree	0	0	0	0
	Neutral	1	4	5	4
	Agree	16	27	32	34
	Strongly agree	42	19	15	20
Agroforestry practices reduced chances of complete crop failure	Strongly disagree	7	0	0	0
	Disagree	4	4	1	0
	Neutral	3	2	8	8
	Agree	19	24	31	35
	Strongly agree	26	20	12	15
Agroforestry practices saved time on collecting fodder and fuel wood from the forest	Strongly disagree	1	0	0	1
	Disagree	0	0	6	11
	Neutral	6	7	10	2
	Agree	17	18	23	25
	Strongly agree	36	25	13	19
Agroforestry practices took a long time to get income	Strongly disagree	2	0	6	3
	Disagree	6	8	21	19
	Neutral	3	10	14	12
	Agree	31	22	10	23
	Strongly agree	18	10	1	1
Agroforestry practices maintained/improved surrounding condition	Strongly disagree	2	0	0	0
	Disagree	0	0	0	0
	Neutral	3	1	1	0
	Agree	25	33	31	27
	Strongly agree	30	16	18	30

The presence of food shortage in a locality can be considered as an indicator for food insecurity. Even though Agroforestry products play significant role in supporting farmers' subsistence, respondents noted the presence of temporal food shortage in the study area. For instance, 57.01% of respondents from Arbaminch Zuriya district indicated that they face food shortage between December and May. The result from Wenago district showed 35.78% of the respondents reported the presence of food shortage in their locality and added May to September as critical food shortage months of the year. During this food shortage period farmers of Arbaminch Zuriya district prefer to sell home garden products to subsidize their livelihood while in Wenago district farmers choose to use home garden products for indoor consumption rather than supplying to market.

Agroforestry practices in the study area play considerable role in realizing food security either by creating direct access to food (fruits, vegetables and annual crops) or by generating cash income for the household through different highly valuable cash crops (Coffee and Catha edulis). Avocado, Banana and Mango chiefly represent fruit trees in the study area and take the major share in existence or presence (Figure 8).

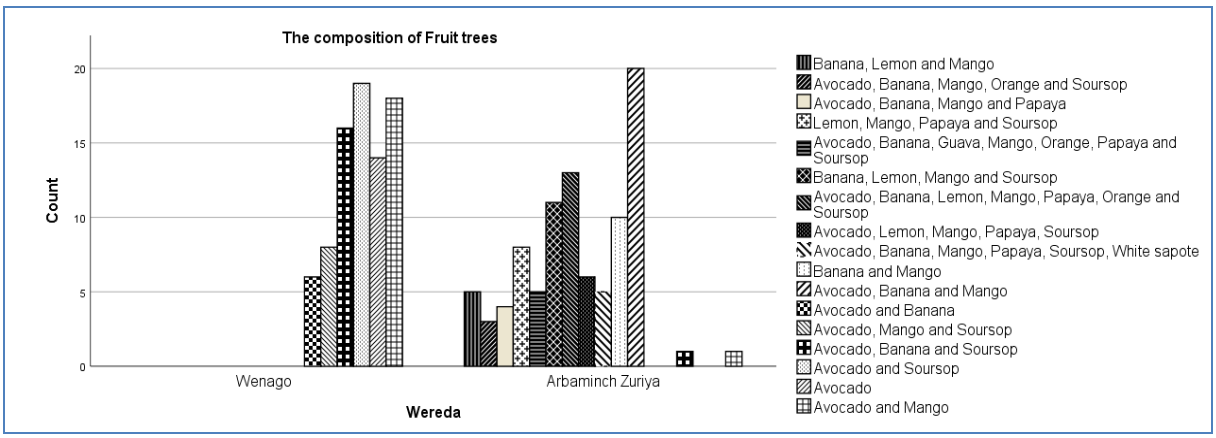


Figure 8 Most frequent fruit trees and their integration in the study area

Moringa stenopetala and *Cordia africana* are predominantly used for construction, fodder, shade, soil fertility and soil and water conservation purposes in *Arbaminch Zuriya* district (Appendix 3). In *Wenago* district *C. africana*is principally utilized for construction purpose. *Millettia ferrugenia*, *Croton macrostachyus* and *Albizia gummifera* are chiefly planted for shade, medicinal and soil and water conservation purposes, respectively. The direct matrix ranking results of top 4multipurpose tree species in *Wenago* district revealed that *C. africana* is the most preferred multipurpose tree followed by *C. macrostachyus*, *M. ferrugenia*and *A. gummifera* (Table 3).

Factors confronting the success of TAFP in the study area

In contrast to significant contribution of TAFP for livelihood of the farmers, the practice was reported to be challenged by different factors. For instance, absence of technical support and guidance from government bodies (experts and development agents) and other concerned bodies, water shortage and wild animals attack were reported as the most challenging factors in both districts. Other location specific problems like Enset and Coffee disease in the case of Wenago and Mango disease in the case of Arbaminch Zuriya districts were also reported (Figure 9).

Table 3 The result of 30 respondents direct matrix ranking for top 4 multipurpose tree species in *Wenago* district

Attributes or use categories	Multipurpose trees			
	Cordia africana	*Croton macrostachyus*	*Millettia ferruginea*	*Albizia gummifera*
Soil fertility	64	31	94	47
Fodder	79	50	-	78
Soil and water conservation	45	82	56	64
Shade	86	42	105	38
Construction material	121	44	55	46
Medicinal	62	93	-	-
Total	**457**	**342**	**310**	**273**
Rank	**1st**	**2nd**	**3rd**	**4th**

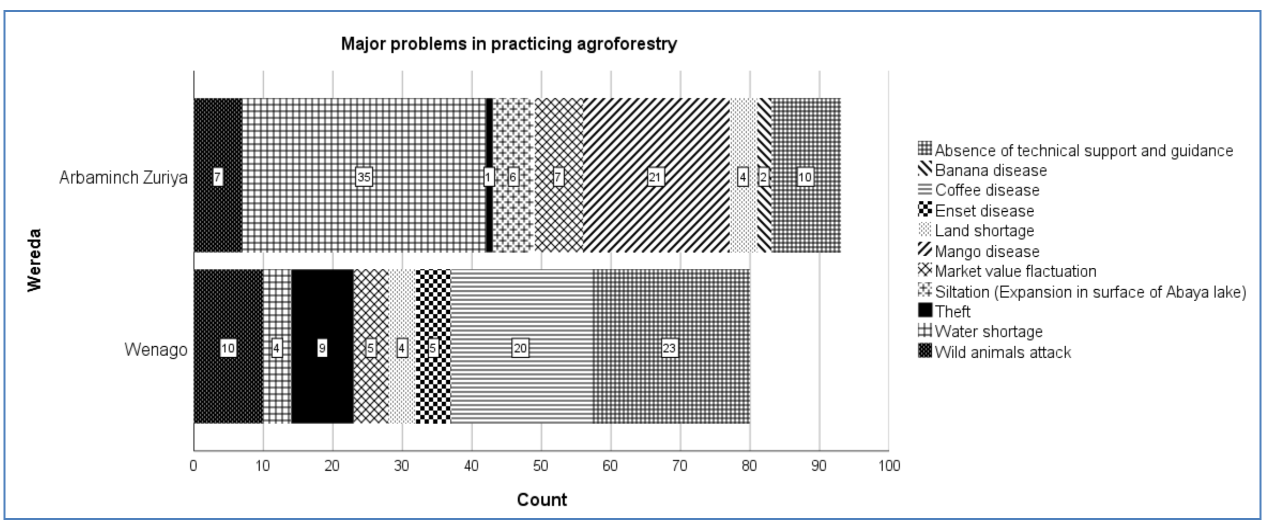


Figure 9 Challenges encountered in exercising TAFP

Discussion

In Africa, homegardens are prominent features where subsistence farming systems dominate. In countries such as Burkinafaso, Ethiopia, Ghana, Kenya, Malawi, Nigeria, Senegal and Tanzania homegardens can be recognized as well known agroforestry systems (Nair, 1993; Backes, 2001; Tesfaye, 2005; Kumar and Nair, 2006; Ernest and Alfred, 2012). Homegardens are identifying features in most parts of Ethiopia (Zemede and Zerihun, 1997; Tadesse, 2002; Badege and Abdu, 2003). This study also produced similar result with previous studies that homegardens are the dominant TAFP in the region and are the sources of food, fodder, construction materials, spices and medicinal plants (Tesfaye, 2005; Feleke, 2011; Gezahegn, 2011).

The subsistence of farmers in this study greatly dependson their farm products and majority of farm products were obtained from Homegardens. Homegardens give farmers the opportunity to harvest diversified and fresh products year-round and at least some in a production year rather than complete failure (loss). The land allocated for Homegardens in *Dodoro* kebele showed significant difference as compared with others (Appendix 4). This result could be best attributed to the geographic location and agroecology of the kebeles. Similar finding was reported by Soemarwoto and Conway (1991).

The components in these systems are managed to provide mutual benefit to each other so that their overall productivity can be diversified and increased. The difference obtained in mean numbers of richness of trees and shrubs could be due to the geographic locationand climatic condition of Homegardens locations and can be best interpreted as Homegardens in lowland areas are less diverse as compared with homegardens in midland areas.

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). This study agrees with most other scientific works that the diversity of products managed in Homegardens give farmers an opportunity to withstand critical food shortage seasons of a year and help farmers to generate immediate cash. The contribution of Homegardens for food security and the livelihood of farmers were considerable. In this regard similar results were reported by Robert (2015) and Uzokwe*et al*. (2016) testifying the role of Homegardens in family food security and traditional food plant resources.

The contribution of homegardens to the livelihood of the farmers and their socio-economic importancefor the community was vital in supplying raw materials, creating direct access to food, maintaining the productivity of their farming systems and creating favorable outdoor conditions for different religious and cultural or traditional ceremonies. To overcome the challenges mentioned respondents suggested (emphasized on) technical support from concerned governmental and non-governmental bodies.

Conclusion and Recommendations

Traditional Agroforestry Practices (TAFPs) arecharacteristic features in the study areas where all the families' subsistence depends on. Home gardens (ecologically sound and sustainable farming systems) are typical TAFP where all the integration and management of trees with crops and live stocks present. Local households reported that home gardens contribute an average of 60% of daily food intake costs, which is 80% of the average household daily wage. More significantly, Home garden contribution rises nearly to 75% among those in the lower-income bracket. It is not surprising therefore that home gardens maintained by the farmers in the study area are dominated by fruit trees and highly valuable cash crops. Different fruit trees and crops with highly valuable cash crops and annual food crops are integrated in such a way that the resultant interaction between these components could result in better productivity. Other use attributes like shade, soil fertility, fodder and medicinal values are also attained from Home gardens of the study area. Products from Home gardens help farmers to harvest diversified farm items which in turn help them to meet the food demand of each household and/or to generate income. Other socio-economic benefits like the supply of fodder, source of wooden construction raw materials and the supply of fruits are notably identifying characteristics in the study areas. On the other hand, limitations like absence of technical support, diseases on Coffee, fruit trees and Enseta nd water shortage were identified. Based on the findings from this study it is strongly recommended that thorough consideration and technical supports should be given to home gardens by governmental and other development sector actors in since these practices are the back bones of communities' livelihood. Some support mechanism may include support in quality disease tolerant and high fruit yield fruit trees seedlings and capacity building in nurseries and in-situ training for farmers in disease control and management of fruit trees and seedlings.

Acknowledgements

The research was supported by the Ethiopian Environment and Forest Research Institute. Authorsare grateful to all staff of Arbaminch Zuriya and Wenago district agricultural office members who contributed in the study sites identification and data collection. Last, but not least, our special thanks go to key informants and household heads in study site for their kind respect, support and willingness to inspect their Home gardens while collecting data.

References

Alexiades M. 1996. Collecting ethnobotanical data. In: Selected Guideline for Ethnobotanical Research: A field manual. Alexiades, M. N and Sheldon, J. W. eds, The New York Botanical garden, Bronex, Pp. 53-94 NY, USA.

African Smallholder Farmers Group (ASFG). 2013. Supporting smallholder farmers in Africa: A frame work for an enabling environment: a policy brief. http://www.ruralfinanceandinvestment.org/sites/default/files/ASFG-Framework-Report.pdf

AzeneBekeleTesemma. 2007. Useful trees and shrubs of Ethiopia: identification, propagation and management in 17 agroecological zones. Nairobi: RELMA in ICRAF Project, 552p.

Backes M. M. 2001. The role of indigenous trees for the conservation of biocultural diversity in traditional Agroforestry land use systems: The Bungoma case study. Agroforestry Systems, 52: 119–132.

Badege Bishaw and Abdu Adelkadir. 2003. Agroforestry and Community Forestry for Rehabilitation of Degraded Watersheds on the Ethiopian Highlands. International Symposium on Contemporary Development Issues in Ethiopia, July 11-12, Pp 22. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2007. Summary and statistical report of the 2007 population and housing census: population size by age and sex. Addis Ababa. 113 pp.

Defaru Debebe and Tuma Ayele. 2013. Land Use Patterns and its Implication for Climate Change: The Case of GamoGofa, Southern Ethiopia. *International Journal of Scientific Research and Reviews* (*IJSRR*).2(3): 155 – 173.

Ernest B. and N. Alfred. 2012. Home gardening: the surviving food security strategy in the Nandom traditional area, upper west region Ghana. *Journal of Sustainable Development in Africa*, Vol 14, No.1, pp 13.

Feleke Woldeyes. 2011. Home gardens and species of Basketo and Keffa (Southwest Ethiopia): Plant diversity, product valorization and implications to biodiversity conservation. PhD thesis, Addis Abeba University. Pp 242.

Fernandes, E.C.M. and P.K.R. Nair. 1986. An Evaluation of the Structure and Function of Tropical Home gardens. *Agricultural Systems*, 21:279-310.

Gezahegn Kassa Temesgen. 2011. Tree species diversity and determinants of tree growing in agroforestry practices of Yem special district, southern Ethiopia. M.Sc thesis. Hawassa University. Pp 99.

Goodman L.A. 1961. Snowball sampling: Annals of Mathematical Statistics, 32(1):148-170.

IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Kumar B.M. and P.K.R. Nair 2006. Tropical home gardens: A time-tested example of sustainable agroforestry. Springer Science, Dordrecht. Netherland. Pp 383.

Mergen F. 1987. Research opportunities to improve the production of home gardens. *Agroforestry Systems*,5: 57 – 67.https://doi.org/10.1007/BF00046413
Michon G., J. Bompard, P. Hecketseilerand C. Ducatillion. 1983. Tropical forest architectural analysis as applied to agroforests in the humid tropics : The example of traditional village agroforests in West Java. *Agroforestry Systems*. 1:117-129.
Nair P.K.R. 1993. An introduction to agroforestry. Dordrecht, Netherlands, Kluwer Academic Publishers. Netherlands. Pp 489.
Naderifar, Mahin&Goli, Hamideh&Ghaljaei, Fereshteh. 2017. Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. Strides in Development of Medical Education.In Press. 10.5812/sdme.67670.
Robert L. Freedman. 2015. Traditional Food Plant Resources: The Role of Home Gardens in Food Security.Retrieved on 17 August 2018 from: http://www.hunger undernutrition.org/blog/2015/12/traditional-food-plant-resources-the-role-of-home-gardens-in-food-security.html
Soemarwoto O. 1987. Home gardens: a traditional agroforestry system with a promising future. In: Steppler H.A. and Nair P.K.R. (eds), Agroforestry: A decade of development, pp 157 – 170. ICRAF, Nairobi.
Soemarwoto, O., and G. R. Conway. 1991. The Javanese home garden. Journal for Farming Systems Research-Extension 2 (3): 95-118.
Tadesse Kippie Kanshie. 2002. Five Thousand Years of Sustainability. A Case study on Gedeo Land Use (Southern Ethiopia). Treemail publishers. Pp 296.
Taherdoost, Hamed. (2016). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research.International Journal of Academic Research in Management. 5. 18-27. 10.2139/ssrn.3205035.
Tesfaye Abebe. 2005. Diversity in home garden agroforestry systems of Southern Ethiopia. Ph. D thesis. Wageningen University. Pp 153.
TilahunTeklehaymanot, FissehaMesfin and SebsebeDemissew. 2009. An ethnobotanical study of medicinal plants in Wonago Woreda, SNNPR, Ethiopia. *Journal of Ethnobiology and Ethnomedicine*. 5:28
Uzokwe U.N, Giweze E.A and Ofuoku A.U. 2016. Contribution of home gardening to family food security in delta north agricultural zone, delta state, Nigeria. International Journal of Agricultural Extension and Rural Development Studies, 3 (2): 26-33.
Watson Jeff. 2001. How to Determine a Sample Size: Tipsheet #60, University Park, PA: Penn State Cooperative Extension. Retrieved September 13, 2016 from: http://www.extension.psu.edu/evaluation/pdf/TS60.pdf
World Agroforestry. 2020. What is Agroforestry? http://www.worldagroforestry.org/about/agroforestry. (Accessed online, 26 January 2020).
Wiersum K.F. 1982. Tree gardening and taungyaon Java: Examples of agroforestry techniques in the humid tropics. Agroforestry Systems 1:53-70.
World Food Summit. 1996. Declaration on World Food Security. Rome.
Zemede Asfaw and Zerihun Woldu. 1997. Crop association of home gardens in Walayta and Gurage in Southern Ethiopia. SINET: Ethiop. J. Sci., 20 (1):73-90.

Appendices

Appendix 1 Vegetation change and regeneration status in the study area

Inquiry (N= 220)	Responses	Wenago		Arbaminch Zuriya		Total
		Dodoro	Jemjemo	ChenoChelba	Lante	
How the vegetation of the area was originally looks like?	Decreased	16 (7.27%)	25 (11.36%)	43 (19.55%)	56 (25.45%)	140 (63.64%)
	Increased	34 (15.45%)	13 (5.91%)	8 (3.64%)	2 (0.91%)	57 (25.91%)
	Not changed	10 (4.54%)	12 (5.45%)	1 (0.45%)	0 (0%)	23 (10.45%)
What is the regeneration status of the vegetation on your farm land?	Excellent	31 (14.09%)	20 (9.09%)	19 (8.64%)	20 (9.09%)	90 (40.91%)
	Very good	26 (11.82%)	24 (10.91%)	19 (8.64%)	15 (6.82%)	84 (38.18%)
	Good	2 (0.91%)	5 (2.27%)	2 (0.91%)	11 (5.00%)	20 (9.09%)
	Fair	1 (0.45%)	1 (0.45%)	12 (5.45%)	12 (5.45%)	26 (11.82%)

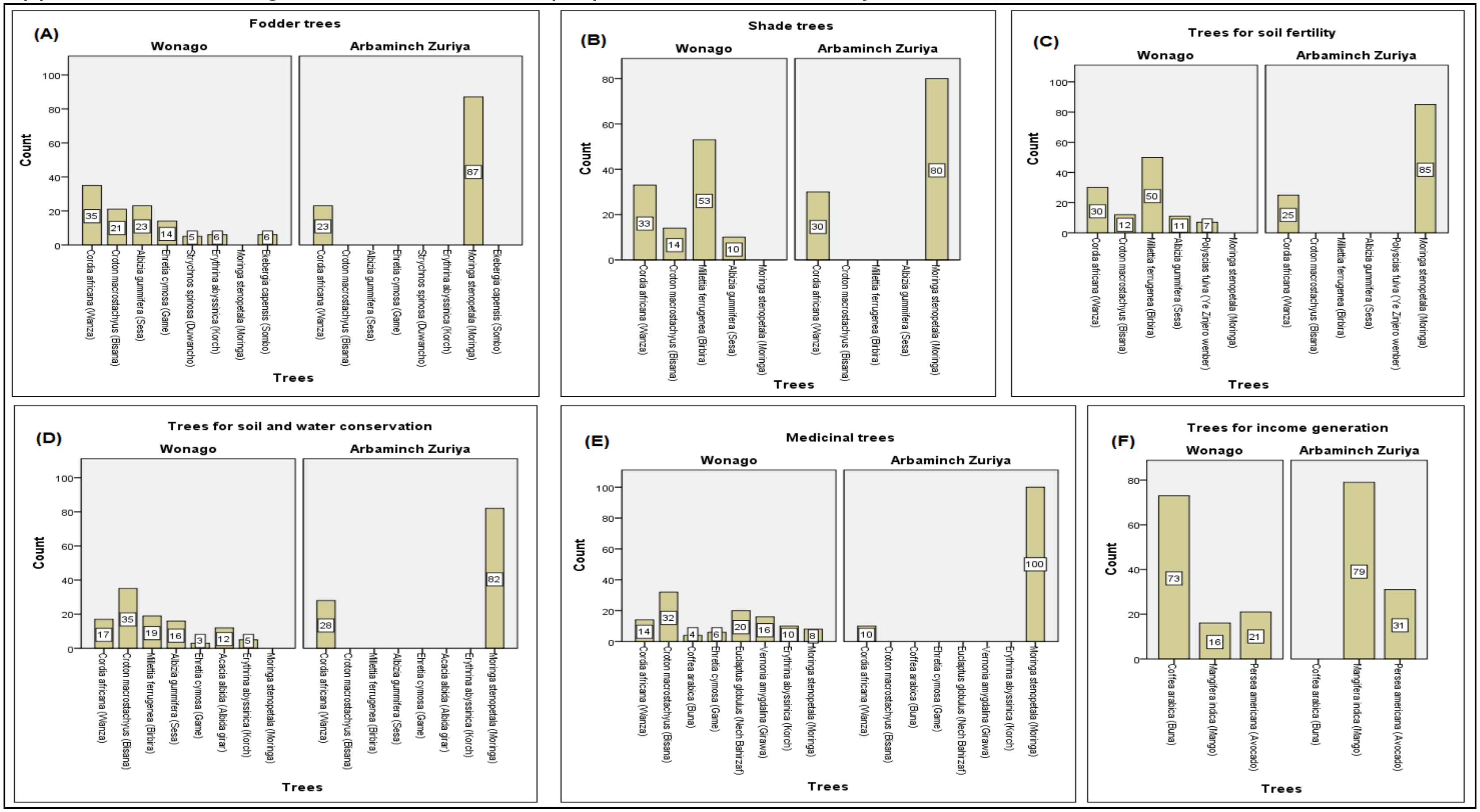
Appendix 2 List of trees and shrubs found in homegardens of the study area

S.N	Scientificname	Vernacular (Local) name	Family	Habit	Uses
1	*Acacia abyssinica* Hochst. ex Benth.	Bazra-grar (A)	Fabaceae	Tree	fd, fr and sh
2	*Acacia (Faidherbia) albida* (Delile) A.Chev.	Albida- girar (A)	Fabaceae	Tree	fd, sh, SWC
3	*Albizia gummifera* (J.F. Gmel.) C.A.Sm.	Sesa (A)	Fabaceae	Tree	sh, fw
4	*Annona reticulata* L.	Gishta (A)	Annonaceae	Tree	ft
5	*Carica papaya* L.	Papaya (A)	Caricaceae	Tree	ft
6	*Casimiroa edulis*La Llave	Kazmir (A)	Rutaceae	Tree	ft
7	*Catha edulis* (Vahl) Forssk. ex Endl.	Khat (A)	Celastraceae	Shrub	st
8	*Celtis africana* Burm. F	Kewot (A)	Cannabaceae	Tree	fr and sh
9	*Citrus aurantifolia* (Christm.) Swingle	Lomi (A)	Rutaceae	Shrub	ft and m
10	*Citrus sinensis*L.Osb.	Burtukan (A)	Rutaceae	Shrub	ft
11	*Coffeaarabica*L.	Buna (A)	Rubiaceae	Shrub	st

12	*Cordia africana* Lam.	Wanza (A)	Boraginaceae	Tree	fd, sh,fr, and tm
13	*Croton macrostachyus* Hochst. ex Del.	Bisana (A)	Euphorbiaceae	Tree	sh, fd, m and fr
14	*Ehretia cymosa* (Thonn.)	Game (S)	Boraginaceae	Tree	fd, fr
15	*Ekebergia capensis* (Sparrm.)	Sombo (S)	Meliaceae	Tree	sh, fr, fd,tm
16	*Enset ventricosum* (Welw.) Cheesman.	Enset (A)	Musaceae	Herb	fo and fd
17	*Erythrinaabyssinica* Lam. ex DC	Korch (A)	Fabaceae		fr, m, bf, sh,tm
18	*Eucalyptus globulus* Labill.	Nech-bahirzaf (A)	Myrtaceae	Tree	tm and m
19	*Ficus sur* Forrsk.	Shola (A)	Moraceae	Tree	sh
20	*Gossypium barbadense* L.	Tit (A)	Malvaceae	Shrub	fb and fr
21	*Grevillea robusta*R.Br.	Gravila (A)	Proteaceae	Tree	lf, tm and fr
22	*Juniperusprocera*Hochst. ex Del.	Tid (A)	Cupressceae	Tree	tm,fr
23	*Justicia schimperiana* (Hochst. ex Nees) T. Anderson	Sensel (A)	Acanthaceae	Shrub	lf and m
24	*Mangifer aindica*L.	Mango (A)	Anacardiaceae	Tree	ft
25	*Millettia ferrugenea*	Birbira (A)	Fabaceae	Tree	sh,sf
26	*Mimusops kummel*	Shiye/Anuno (S)	Sapotaceae	Tree	fr,tm,ft
27	*Moringa stenopetala*	Moringa (A)	Moringaceae	Tree	fo, sh,sf
28	*Musa paradisiaca L.*	Muz(A)	Musaceae	Tree	ft
29	*PerseaamericanaMill.*	Abokado (A)	Lauraceae	Tree	ft
30	*Podocarpus falcatus (Thunb.) Mirb.*	Zigba (A)	Podocarpaceae	Tree	fr and tm
31	*Polyscias fulva*	Ye Zinjerowonber (A)	Araliaceae	Tree	sd, fr, sf
32	*Pouteriaadolfi-friedercii*	Kerero (A)	Sapotaceae	Tree	tm
33	*Prunus africana*	TikurInchet (A)	Rosaceae	Tree	fr, Oth
34	*Prunus persica (L.) Batsch*	Kok (A)	Rosaceae	Tree	ft
35	*Psidium guajava L.*	Zeytuna (A)	Myrtaceae	Tree	ft
36	*Ricinus communis L.*	Qobbo, Gulo (A)	Euphorbiaceae	Shrub	sh, fr and oth
37	*Strychinos spinosa*	Duwancho (S)	Loganiaceae	Shrub	m,sh,tm
38	*Vernonia amygdalinaDel.*	Girawa (A)	Asteraceae	Shrub	m, sh and fr

Note:(A) and (S) represent vernacular names in Amharic and Sidama, respectively. Abbreviations in uses of species are: fo = food, fd = fodder, fr = firewood, ft = fruit tree, fb= fiber plant, fl= flavoring, m = medicinal, sf= soil fertility, sh = shade, lf = Livefence, st = stimulant, sp = spice, tm = timber, bf = bee forage and Oth = Other utilizations.

Appendix 3 Use categories of different multipurpose trees in the study area



Appendix 4 Multiple comparisons of mean values of land allocated for home gardens in the study area.

Kebeles	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Dodoro	60	1.8708***	1.83163	.23646	1.3977	2.3440	.25	10.00
Jamjamo	49	1.0531**	.84683	.12098	.8098	1.2963	.10	4.50
ChenoChelba	52	.4933*	.36246	.05026	.3924	.5942	.05	1.75
Lante	58	.7698	.61836	.08119	.6072	.9324	.05	4.00
Total	219	1.0692	1.21510	.08211	.9073	1.2310	.05	10.00

Note: Differences between land allocations of the respondents in four *kebeles* were analyzed using one-way ANOVA (F-test) followed by LSD test. Means in land holding of the respondents followed by ***, ** and * indicate significant differences at $p < 0.0001$, $p < 0.001$ and $p < 0.05$ respectively

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Contribution of Agroforestry Practices for Food Security in Selected District of Oromia, South Western, Ethiopia

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Abstract

Integration of tree species within the farmland of farmers is varied and unrecorded from place to place. A study aiming at understanding the contribution of agroforestry practices for food security was conducted in Gomma district, Jimma zone, Ethiopia. The study was conducted on 150 respondents randomly selected from the district. Data was collected by using questionnaire, focus group and key informant interview and direct observation of the different agroforestry practices (AFPs) on the ground. Data were analyzed by using SPSS version 22. The study showed that 100 % of the respondents were engaged in AFP and 98% of them obtained cash income from their AFP mainly on annual basis. More than half percent of the respondents confirmed the positive contribution of AFP on crop and pasture production. Almost all respondents agreed that AFP has significant contribution in soil and water conservation. About three fourth of the respondents replied that AFP reduced more time required for collecting fodder and fuel wood. Species site much shall be studied further.

***Keywords*:** Agro ecology, Farmland, Home garden, Livelihood, woody perennials

Introduction

In most parts of Ethiopia, many farmers maintain or plant trees as part of their agricultural landscapes. In south west Ethiopia, traditional agroforestry practice is mainly prolonged and well performed which has the capacity of conserving livelihood of the community and sustaining environmental integrity (Assefa, 2010; Senbeta *et al*., 2013). Agroforestry is a collective name for land use systems where woody perennials are intentionally maintained or planted in agricultural/pasture lands. It provides food and wood to the local community, sustain watershed functions, retains carbon in the plants, and supports the conservation of biological diversity (McNeely and Scherr, 2003; Schroth *et al*., 2004).

However, the species diversity and component composition in agroforestry systems and practices are influenced by ecological, socio-economic and cultural factors (Mergen, 1987; Arnold and Dewees, 1995). Physical environment such as altitude and climate are also important ecological factors that influence species diversity (Soemarwoto and Conway, 1991). This indicate that the traditional tree management techniques, woody species mix, both vertical and horizontal placements of the system components, economic and ecological benefits obtained by farmers could vary considerably with each other, between and within the agro-ecological zones, and land use systems of the country. Both vertical and horizontal arrangements have resulted from a long history of farmer trial and error rather than being supported by scientific and empirical evidences (Gold and Garrett, 2009).

Increasing the same food production does not secure food and nutrition security (Pieters *et al*., 2013). Discovering many local productions of food is recommended as an alternative to achieve FNS (Food and nutrition security) in agrarian countries. On the other hand, producing food locally is influenced by fast population growth and market channel. For example, the demand for locally available cash crop, to cover the production costs of marketable products, creates strong competition among end users (Kuhn *et al*., 2015; Virchow *et al*., 2016). Moreover, the universal demand for commercial agricultural products influences the type of crops produced by small-scale farming households on limited lands (Keyzer *et al*., 2005; Kuhn *et al*., 2015). This competition causes a decline in the amount of food and expands destruction and downgrading of lands due to overexploitation, which contributes to the food insecurity and poverty (Salam *et al.,* 2000).

Individual farmers pursue their own way of species selection and arrangements which lead to tremendous variation in the number, size, and placement of specific component arrangements (Isaac *et al*., 2007). Moreover, the structural and functional attributes of components vary between and within agro-ecologies in traditional agroforestry systems and practices in the country. Thus, there is a need to tap on the existing knowledge to efficiently utilize scarce resources for better economic and ecological benefits. In this context, Ethiopian farmers have a long history in incorporating various tree species in their farming systems although their traditional knowledge is not well evaluated or documented (Parrotta and Agnoletti, 2012). Furthermore, little systematic in-depth study has been undertaken to characterize and fully understand the existing structural and functional attributes of component and mixtures and their synergistic interactions.

Little attention has been given to describe and analyze the existing traditional agroforestry practices and their related understanding to improve or alleviate the chronic land farming problems of the country (Omarsherif and Daniel, 2017). The requirement to rely on the existing traditional knowledge and agro-ecology is also emphasized by ICRAF (1986) to clearly establish the overall economic and ecological benefits of a given traditional agroforestry practice and the contribution of individual component to the overall wellbeing of the system. Therefore, the main purpose of this research was to understand the contribution of agroforestry practices for food security and the role of agroforestry in climate resilient green economy across the different agro ecologies of Gomma district, Jimma zone, Ethiopia.

Material and Methods

Description of the study area

The study was conducted in the different agro ecologies in Gomma district of Jimma administrative zone, Oromia Regional State. Jimma zone was selected purposively because of the wide extent of agroforestry practices in the zone. Then Gomma Woreda (district) has been selected due to its agro ecological variations and the existence of traditional agroforestry practices. Jimma zone is located in the south western Ethiopia with a total area of 15,568.58 square kilometer (CSA, 2007). Gomma woreda is located in Jimma zone with altitudinal range between 1380- 2870 m. a. s. l. According to the survey of CSA (2007) the total population of the woreda is 213,023 of whom 108,637 were men and 104,386 were women. Land use types of the study area shows 60.7% is arable or cultivable, 52.7% under annual crop, 8.1% is pasture, 4.6% is forest and 20% is swampy. Coffee, Avocado and spices are the most important cash crops of the woreda. The dominant coffee shade trees are *Albizia gummiferia* and *Millitia ferrugina.*

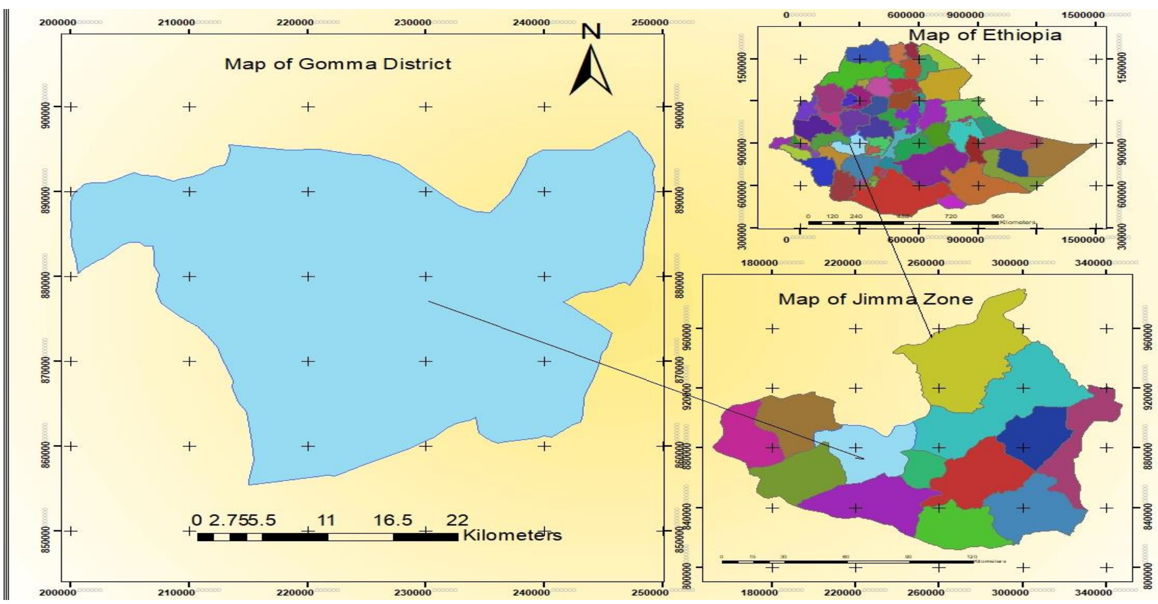

Figure 1 The map of Ethiopia showing the zone of the country and the map of Gomma woreda (Source: CSA, 2016. Coordinate system: WGS-UTM-37-North).

In the woreda, the most dominant AFPs are the traditional home garden and coffee-based agroforestry practices (AFPs). They have been practiced for a long period of time. According to reports from the agricultural office there is only a very rudimentary knowledge on how to properly manage and improve the contribution of AFPs to societal needs. The role of AFPs to food security, construction and climate change adaptation and mitigation has not been identified. Therefore, this study was conducted to fill the knowledge gaps and thereby create awareness about AFPs in the society.

Methods of Data Collection and Analysis

Survey Methodology

Secondary information was collected from reports, maps, censuses, thesis and other publications to have an overview of the agroforestry practices across the different agro-ecologies. Then specific sites for the study were identified in collaboration with a multidisciplinary research team and Woreda's development agents. Total number of households in each "kebele" was obtained from the respective woreda and "kebele" offices. After knowing the total number of households in each kebele 5% of the households have been selected randomly to administer the questionnaire. A total of 150 respondents were selected: 42 households from Oma funtule, 67 household from Ganji ilbu and 41 household from Choche. The annual rainfall, Temperature and altitude of the study site were ranges from 850-1015mm, 21-28^{o}c and 1459-2217 m.a.s.l respectively.

Informal surveys were conducted to gather qualitative information about traditional agroforestry practices and other related activities. Checklists were developed for the informal survey. A reconnaissance survey was conducted to identify the existing agroforestry practices and their role in the area as a source of livelihood for the local farmers. Additional information was collected formally by asking some farmers on management, side effects and constraints of the existing AFP on associated crops and pastures/animals. Focus group discussion and key informant interview were also used as a means of data collection tools. Household interview was done to extract information about the role of selected AFP to enhance food security from different AFS across agro ecologies (e.g. Nutrition diversification, income, costs, etc.).

The structured questionnaire was tested before implementation for its consistency, logical flow and length. Enumerators that have completed secondary school studies and understand and speak the local language were recruited. Training was given for the enumerators about the content of the questionnaires, where, when and how to conduct the interview with farmers. Furthermore, semi structured interview and group discussions were conducted to determine the presence of agroforestry components and to identify trees and shrubs species that found at the farmlands. Moreover, knowledge on forest and woodland resources management in general and on fruit and fodder tree species was assessed through the same method. In addition, tree planting practice was assessed. Furthermore, the contribution of forest and woodland resource in general and fruit and fodder tree species in particular to the livelihood of the community was assessed through the questionnaire and group discussions. Both qualitative and quantitative data was collected and analyzed.

Data Collection

Background information of the respondents, type of species planted in the home garden and farm land, purpose of plantation, major AF components, uses of AF for the household income, types of management, major problem and solutions undertaken, type of fruit tree species, area and percentage of land occupied by AFP, contribution of AFP for food security, perception and knowledge of the farmers on the contribution of AFP for economic, social and ecological purposes data were collected.

Data Analysis

Finally, the collected data were coded and entered to spread sheets and analyzed by using SPSS software version 22 for various parametric variables.

Results and Discussion

Respondent information

About 47% of respondents ranged between 41-50 years old, while 11% of the respondents were 71-80 years old. Only 8% of the respondents aged ranges between 20-30 years (Figure 2). Regarding to marital status most of respondents (125) were married (Figure 3).

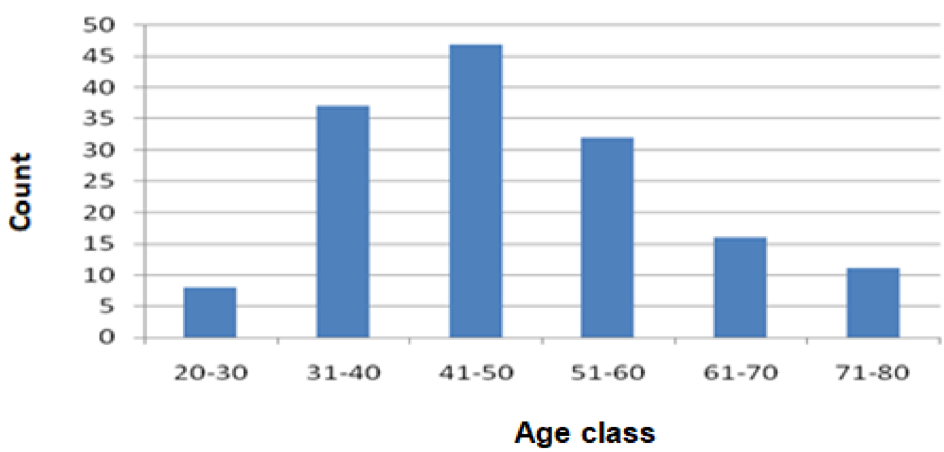

Figure 2 Respondents age group

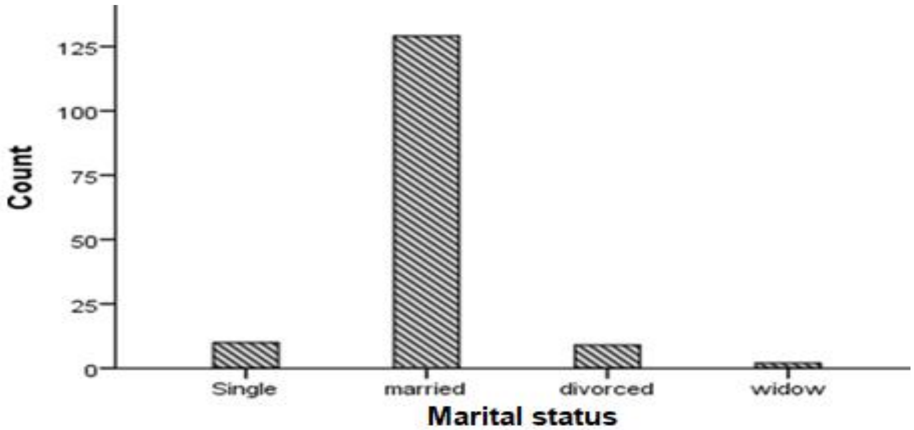

Figure 3 Marital status of the respondents

About educational status most of the respondents can read and write (Figure 4). About 30 respondents had family size of 6; 25 respondents had 5 family size and only 2 respondents had higher numbers of family size which is 11 and 12 (Figure 5).

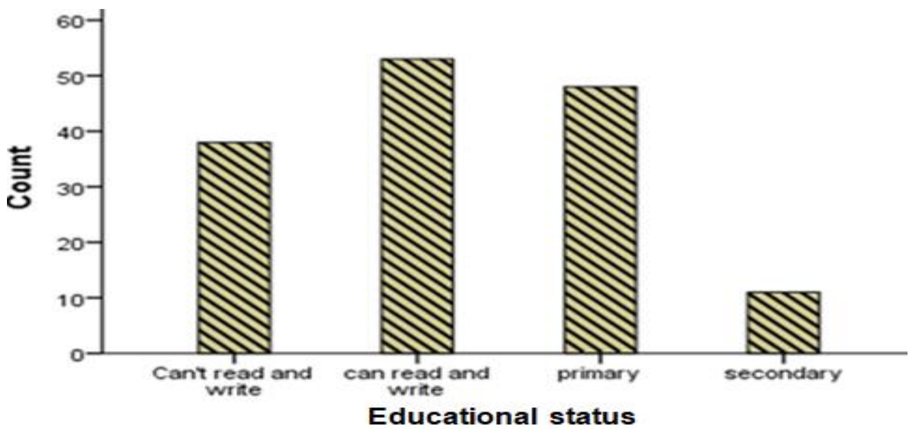

Figure 4 Educational background of the respondent

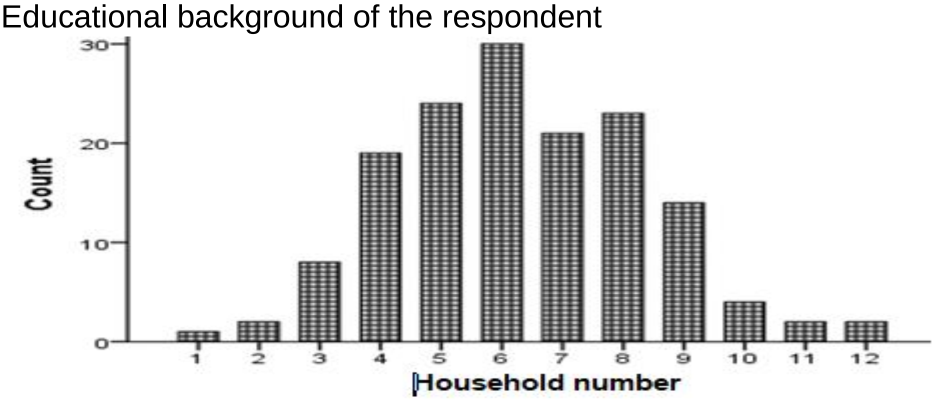

Figure 5: Respondents household numbers

Land use and land cover in the study area

Vegetation types found in the study area were presented in Table 1. The results showed that most of the areas are covered by food crops as well as trees and coffee. As the study showed, the regeneration status of the above mention vegetation was high (44.7 percent at the site). This is true for both naturally and artificially planted forests. This might relate with the presence of good management, low level of disturbance and increasing plantation in that area.

Table 1 Types of vegetation coverage

Vegetation types	Frequency	Percent
Both cultivated and uncultivated	10	6.7
Cultivated	77	51.3.3
Cultivated and farm land	21	14
Farm forest	14	9.3
Mixed forest	9	6
Not cultivated and bare lands	7	4.7
Plantation forest	11	7.3
Natural forest	1	0.7
Total	150	100.0

Farm size in the study area

As shown in the Table 2, there is a great disparity in farm size among the different households. Accordingly, about 37.3 % of the respondents had 0 to 0.5-hectare farmlands while only 3.3% of the respondents had larger size of farm lands (of about 2.04 to 2.54 hectares). This shows that there is scarcity of lands and even with this scarcity more than 80% of the land is covered by agroforestry practices though, it reduces farmland trees and crops species. Endale *et al* (2017) also reported that land-holding sizes influence the species on farm lands and affect agricultural practice negatively in semi-arid of East Shewa of Ethiopia.

Table 2 Household land size

Area in hectare	Frequency	Percent
0- 0.5	56	37.3
0.51- 1.01	38	25.4
1.02- 1.52	31	20.7
1.53- 2.03	20	13.3
2.04- 2.54	5	3.3
Total	150	100.0

Types of agroforestry practices and home garden trees/shrubs species

We found different types of agroforestry components in the study area. The dominant (71.3%) agroforestry components in area were tree, crop and pasture, and the second dominant (28.7%) was tree and crop. Most of farmers in the study area were practiced tree, crop and pasture agroforestry farming system. Based on the result, famers rank *Artocarpus heterophyllus* (Jackfruit) and *Coffea arabica* as least and most avalable tree/shrub in their home garden respectively (Table 3).

Table 3 Trees/shrubs species planted in the home garden of individual household

Species Name	Ranks
Albizia gummifera	7
Azadirachta indica	18
Catha edulis	2
Citrus sinensis	17
Coffea arabica	1
Cordia africana	8
Croton macrostachyus	9
Ensete ventricosum	5
Eucalyptus grandis	6
Grevillea robusta	11
Artocarpus heterophyllus	20
Mangifera indica	4
Malus domestica	10
Musa acuminate	14
Junipers procera	13
Persea americana	3
Psidium guajava	12
Saccharum officinarum	15
Sesbania sesban	19
Vernonia amygdalina	16

People's perception to Agroforestry practice

Results show that all the respondents were engaged in agroforestry practices. The dominant (71.3%) agroforestry components in area were tree, crop and pasture, and the second dominant (28.7%) was tree and crop. Most of farmers in the study area were practiced tree, crop and pasture agroforestry farming system.

The contribution of AFP to livelihood of local communities

The main purpose of agroforestry products is to fulfill the food needs of the families (Table 4).

Table 4 The major purpose of agroforestry practices

Uses of agroforestry	Frequency	Percent
Consumption	107	71.3
Income, construction	2	1.3
Income, consumption	2	1.3
Income, consumption, construction	39	26
Total	150	100

About 110 households gave priority to the value of products while 32 households and 8 households gave priority based on preference and existence products, respectively (Figure 6). In the case of economic activity, most households get income from agroforestry (Figure 7).

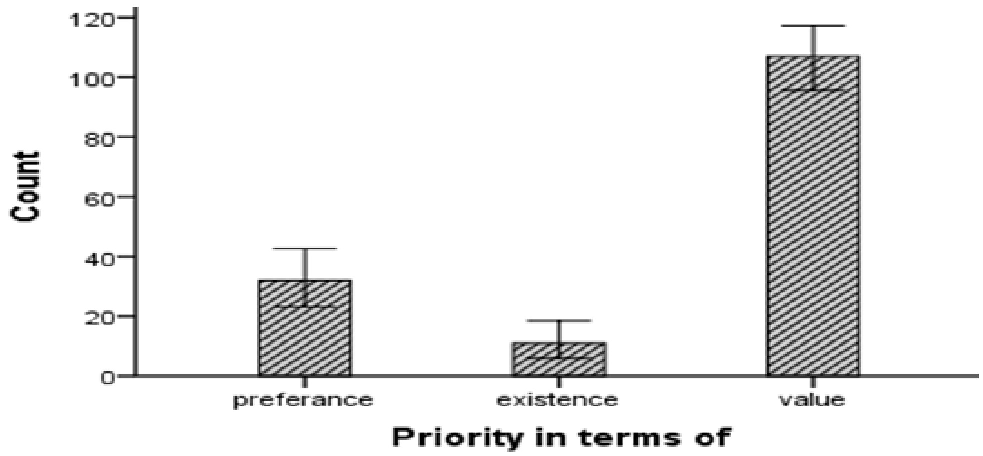

Figure 6 Respondents number and priority of products

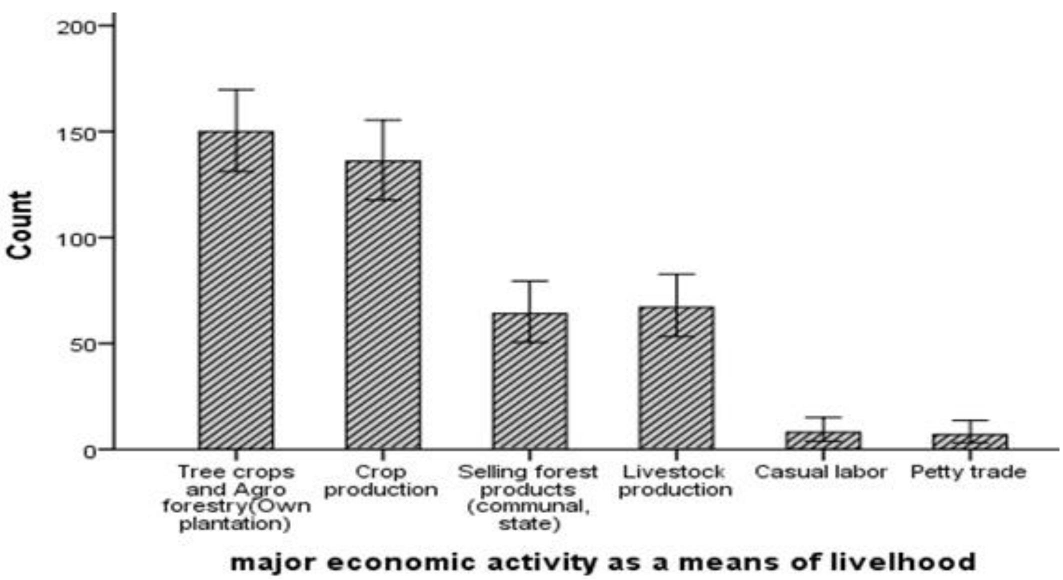

Figure 7 Respondents number and the economic activity as means of livelihood

Management practices implemented by the local community

About 34.7% of respondents practiced both weeding and hoeing and 30% of the respondents practiced weeding and pruning. The other management practices are listed in Table 5. The intensity and type of management practice were different in different types of AFPs. About 86.6% of the respondents said that the main regeneration mechanism for multiplication of trees and shrubs in the area was through artificial means. The rest 11.4% and 2% respondents said that regeneration of trees and shrubs of the area was conducted through both natural and artificial mechanisms respectively.

Table 5 Management practices by local community on AFPs

Management practice	Frequency	Percent
Pollarding	2	1.3
Hoeing	5	3.3
Pruning	3	2
Pruning and hoeing	9	6
Weeding and hoeing	52	34.7
Weeding and pruning	45	30
Weeding	16	10.7
Weeding and pollarding	18	12
Total	150	100.0

Uses of Agroforestry for soil fertility

About 40% of the respondents said that agroforestry practice was managed primarily for soil fertility improvement while 10% said that AFPs has low benefit for soil fertility. While 50% of the respondents said that AFP moderately improves soil fertility. This difference in opinion may have resulted in mismatching of trees and lands. Some researchers, for instance Felix *et al* (2012) reported that home garden agroforestry practices improve soil fertility and increases crop yields. Similarly, the higher soil fertility from animal dung also supports the performance of tree species as well as annual crops yields around homesteads.

Multipurpose species and their structural arrangement

We found four vegetation strata in the study area. These included 40% of the species in the first strata, 38.7% in the second strata, 20% in the third strata and 1.3% in the fourth strata. *Coffea arabica, Albizia gummifera, Cordia africana, Catha edulis, Croton macrostachyus* and *Eucalyptus grandis* were the most trees/shrubs species that found on farmlands (Table 6).

The fruit trees like *Persea americana, Mangifera indica, Musa species, Catha edulis, Citrus sinensis, Ensete ventricosum* and *Psidium guajava* were the most species that found in the study area (Table 7). The common edible parts of the fruit trees found in the area were the fruits or seed, leaf, root and steam.

Cash Income from agroforestry

About 147 respondents said that they obtained cash income from agroforestry and only 3 respondents said they didn’t get cash income from AFP.

The role of AFPs in combating food shortage in the study area

We found that there was a shortage of food in a few months at the study area. It was happened in the dry season where the fruit and other crops are not available. Ninety-seven from 150 respondents were encountered food shortage during the dry season. The households were taken different solution to overcome the time of food shortage (Table 8).

Table 6 Species name that found at farmlands

Name of farm species	Frequency	Ranks
Acacia abyssinica	1	12
Ficus vasta	1	12
Albizia gummifera	19	2
Azadrichta indica	1	12
Catha edulis	15	5
Coffee arabica	27	1
Cordia africana	18	3
Croton macrostachyus	17	4
Ensete ventricosum	1	12
Eucalyptus grandis	14	6
Grevillea robusta	3	10
Juniperus procera	4	9
Cupressus lusitanica	2	11
Bersama abyssinica	1	12
Moringa stenopetala	1	12
Mangifera indica	8	7
Millettia ferruginea	3	10
Persea Americana	6	8
Podocarpus falcatus	2	11
Erythrina brucei	1	12
Sesbania sesban	1	12
Vernonia amygdalina	2	11
Total	150	

Table 7 Fruit trees and shrubs

Fruit Trees	Frequency	Percent	Ranks
Catha edulis	18	12	4
Citrus sinensis	17	11.3	5
Ensete ventricosum	16	10.7	6
Artocarpus heterophyllus	1	0.7	9
Malus domestica	3	2	8
Mangifera indica	23	15.3	2
Musa acuminata	21	14	3
Persea americana	38	25.3	1
Psidium guajava	13	8.7	7
Total	150	100	

Contribution of AFP to livelihood

About 58% of the respondents said that the combination of Tree + Crop + Pasture was the most important for their livelihood. 40.7% of the respondents stated that the combination of Tree +Crop was important to their livelihood and only 1.3% respondents were said that the combination of trees and pasture has the most important for the livelihood.

Table 8 List of activities carried out to overcome the food shortage

Things to overcome food shortage	Ranks
Increase management of agroforestry	1
Working effectively and efficiently AFP	2
Planting other vegetable	3
Using river water	4
Developing saving habit	5
Using mixed farming	6
Causal labor	7
Hardworking and saving	8
Saving and buying crops	9
Using available resources	10

Effect of AFPs on crops and pasture

About 44.7% of the respondents stated that AFPs affect crops positively whereas 33.3% of the respondents said that AFPs affect crops negatively. However, small numbers of respondents (8%) stated that AFPs does not have any effect on crops and 14% of the respondents said that AFPs have both effect on crop production. About 52.7% of the respondents said that AFPs affect pasture positively and 22.7% of them said that AFP affects pasture negatively with only 11.3% of the respondents saying that AFP had no effect on pasture (Table 9).

Effect of AFPs on soil and water conservation, maintaining soil fertility and Environmental condition

Most of the respondents (52.7%) agreed that agroforestry practice improves soil fertility as well as sustains environmental conditions, while only 1.3% of the respondents strongly disagreed on the use of agroforestry practice for soil fertility enhancement. The reason is that these small numbers of farmers have never used multipurpose trees. Therefore, it is very important to screen the tree species which have positive effects on soil. A study by Torralba *et al.,* (2016) concluded that agroforestry can improve biodiversity and ecosystem services comparative to conventional agriculture and forestry in Europe and it could be an advantageous land use system.

Table 9 Effect of AFP on crops and pasture

Responses	Crops		Pasture	
	Frequency	Percent	Frequency	Percent
No effect	12	8	17	11.3
Positively	67	44.7	79	52.7
Negatively	50	33.3	34	22.7
Both	21	14	14	9.3
No response	0	0	6	4
Total	150	100	150	100

Most respondents also agreed and strongly agreed that AFP had significant contribution in soil and water conservation. About 14% of the respondents were neutral on the use of AFP in conserving soil and water. A few numbers of the respondents disagreed or strongly disagreed on the role of AFP in soil and water conservation (Figure 8).

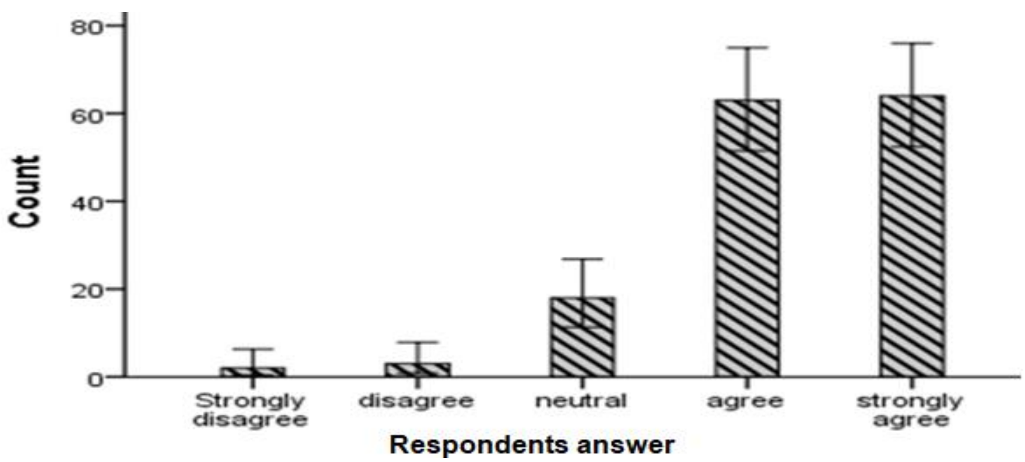

Figure 8 Respondents answer on AFP in conserving soil and water

About 78% of the respondents said that AFP has positive effect on some environmental condition and improved the surrounding condition (Table 10). About 7.3% of the respondents didn't respond. This indicates that they have no information on the role of AFP on the environmental condition.

Role of AFP in income and in saving time needed for collecting fodder and fuel wood from the forest

Most of the respondents (78) strongly agreed that AFP increased farm income and 58 of the respondents agreed AFP increased farm income. The remaining few respondents strongly disagreed and were neutral with the idea that AFP increased farm income (Figure 9).

Table 10 Importance of agroforestry practices to the environment

Responses	Frequency	Percent
No importance	1	.7
Important	117	78.0
Little important	13	8.7
Both	8	5.3
No response	11	7.3
Total	150	100.0

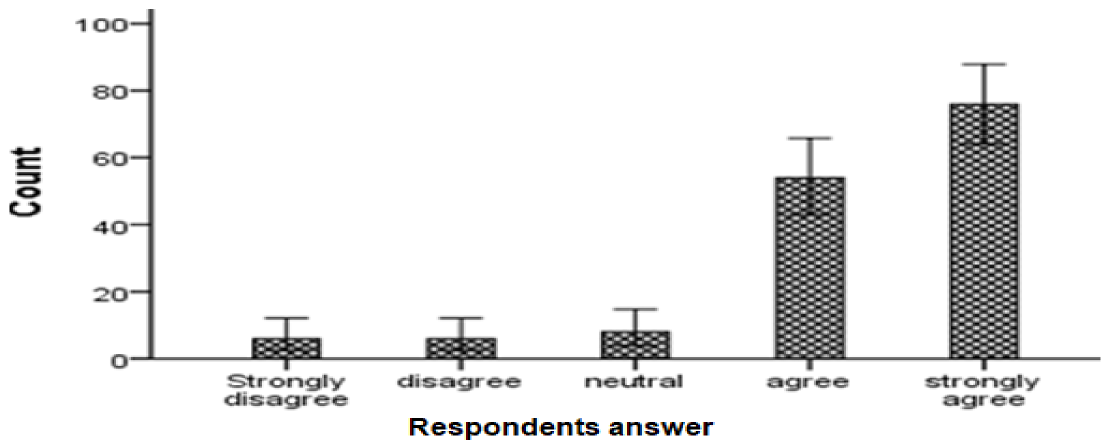

Figure 9: Respondents answer on AFP in increasing farm income

Half of the respondents agreed AFP had role in saving time to collect fodder and fuel wood. About 75 of the respondents replied that AFP reduced the time required for collecting fodder and fuel wood (Figure 10). This helps especially women because women are more responsible in collecting fodder and fuel wood. Only three respondents strongly disagreed that AFP reduced time required for collecting fodder and fuel wood. Those respondents stated that AFP takes a long time to give services and products. So, it is very important to select multipurpose tree species and fast-growing trees when we practice agroforestry. According to the study of Agidie *et al.,* (2013) some fodder trees are uses for both fuel wood and serves as live fences. Those trees are lopped from time to time for fodder, fruits and pods of standing tree species are consumed.

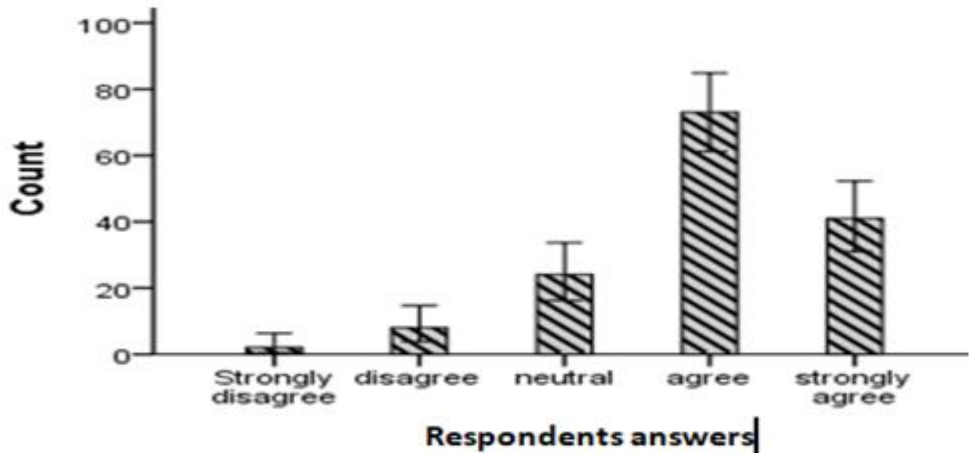

Figure 10 Respondents answer on AFP save time of collecting fodder and fuel wood

Multipurpose tree species seedling production

About 76.7% of the respondents stated that seedlings of multipurpose trees and shrubs were raised on their own nursery. The raised seedlings were mostly used by themselves and a few of them were selled to other farmers at local markets. Some of the respondents (23.3%) didn't have facilities for raising seedlings.

Major problems faced farmers during practicing agroforestry

The major problems faced by farmers in practicing agroforestry were land shortage and market problems (Table11). A study by Agidie *et al* (2013) showed that the scarcity of arable land, open free grazing, limited supply of seedlings for indigenous trees species and termite damage were the major constraints for agroforestry expansion.

Table 11 The major problems faced in practicing agroforestry

Major Problems	Ranks
Lack of time for management	9
Lack of finance	11
Land shortage	1
Management problems	5
No market access	7
Market variability	2
Monkey eat the fruit	10
Over taxation	4
Plant disease	3
Rainfall shortage during transplanting	8
problems of getting quality seed	6

What solution mechanisms can you suggest?

The solution mechanisms were perceived to solve the problems faced during practicing agroforestry presenting in (Table 12).

Table 12 The solution mechanism taken during the problems occurring in AFPs

Solutions	Ranks
Using hole water	1st
Water conservation	2nd
Wise use of time	3rd
Giving awareness	4th
Working together	5th
Solving market problems	6th

Conclusion

Based on the above finding we generally concluded that Agroforestry practices improve soil fertility and enhances food security. In addition to this agroforestry can reduce time of fuel wood collection for women and improves the livelihood of the farmers. Land shortage and absence of proper market channel were identified as the major problems in doing AFP in the site.

Recommendation

It is very important to select multipurpose tree species to increase the benefit of farmers from agroforestry practices. Further study is required to select the right tree species at right place for improved management of agroforestry practices. Awareness creation and knowledge gap filling is required to improve traditional agroforestry practices. In the area the people are not familiar with regarding to the management of agroforestry, so technical support is needed on how to apply different managerial enhancement on agroforestry practices and their products.

Acknowledgements

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References

Agidie A., Ayele B., Wassie A., Hadgu K. M., Aynekulu E. and Mowo J., (2013). Agroforestry Practices and Farmers' Perception in Koga Watershed, Upper Blue Nile Basin, Ethiopia Agriculture and Forestry, Vol. 59. Issue 3: 75-89, Podgorica.

Assefa A.D., (2010). Local institutions and their Influence on Forest Resource Management in Southwest of Ethiopia: The Case of Yayu Forest. A master thesis. School of Graduate Studies.

Central Statistics Authority, (2007). The Population and Housing. Census of Ethiopia; Addis Ababa, Ethiopia.

Dewees and Arnold, (1995). The other relates to economic considerations that influence farmer decisions about management of trees and tree crops. Because some of the products that people produce and sell from trees and forests are wood products.

Endale Y., Derero A., Argaw M. and Muthuri C., (2017). Farmland tree species diversity and spatial distribution pattern in semi-arid East Shewa, Ethiopia, Forests, Trees and Livelihoods, 26:3, 199-214.

Felix K., Ngetich, Chris A., Shisanya, Jayne M., Monicah Mucheru-Muna and Daniel M., (2012). The Potential of Organic and Inorganic Nutrient Sources in Sub Saharan African Crop Farming Systems, Soil Fertility Improvement and Integrated Nutrient Management - A Global Perspective, Dr. Joann Whalen (Ed.), ISBN: 978-953-307-945-5.

Gold M.A. and Garrett H.E., (2009). Agroforestry nomenclature, concepts, and practices. North American agroforestry: an integrated science and practice, pp.45-56.

ICRAF, (1986). World Agroforestry Centre; Trees play a crucial role in almost all terrestrial ecosystems and provide a range of products and services to rural and urban people.

Isaac M.E., Erickson B.H., Quashie-Sam S.J. and Timmer V.R., (2007). Transfer of knowledge on agroforestry management practices: the structure of farmer advice networks. Ecology and society, 12(2).

Keyzer M.A., Merbis M.D., Pavel I.F. and Van- Wesenbeeck C.F.A., (2005). Diet shifts towards meat and the effects on cereal use: can we feed the animals in 2030? Ecological Economics, 55(2), pp.187-202.

Kuhn A., Endeshaw K.A. and Heckelei T., (2015). Trends and Drivers of Crop Biomass Demand: Sub-Saharan Africa vs. the Rest of the World. Discussion Paper-Food and Resource Economics, Institute for Food and Resource Economics, University of Bonn.

McNeely J.A. and Scherr S.J., (2003). Eco-agriculture: Strategies to Feed the World and Save Wild Biodiversity. Island Press, Washington.

Mergen F., (1987). Research, Structure and Floristic of home gardens in Northeastern Brazil.

Omarsherif M. J and Daniel C. C., (2017). Potential of Agroforestry for Food and Nutrition Security of Small-scale Farming Households. A case study from Yayu, South western Ethiopia.

Parrotta J.A. and Agnoletti M., (2012). Traditional forest-related knowledge and climate change. In Traditional Forest-Related Knowledge (pp. 491-533). Springer, Dordrecht.

Pieters H., Guariso A. and Vandeplas A., (2013). Conceptual framework for the analysis of the determinants of food and nutrition security. Food Secure Working paper no. 13. LEI Wageningen UR.

Salam M.A., Noguchi T. and Koike M., (2000). Understanding why farmers plant trees in the homestead agroforestry in Bangladesh. Agroforestry systems, 50(1), pp.77-93.

Schroth G., Fonseca G.A.B., Harvey C.A., Gascon C., Vasconcelos H.L. and Izac A.M.N., (2004). Agroforestry and Biodiversity Conservation in Tropical Landscapes. Island Press, Washington.

Senbeta F., Gole T.W., Denich M. and Kelbessa E., (2013). Diversity of useful plants in the coffee forests of Ethiopia. Ethno botany Research and Applications, 11, pp.049-069.

Soemarwoto, O., and G. R. Conway. 1991. The Javanese home garden. Journal for Farming Systems Research-Extension 2 (3): 95-118.

Torralba M., Fagerholm N., Bergess P.J., Moreno G. and Plieninger T., (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis Volume 230, pp151-161.

Virchow D., Beuchelt T.D., Kuhn A. and Denich M., (2016). Biomass-Based Value Webs: A Novel Perspective for Emerging Bio economies in Sub-Saharan Africa. Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development (pp. 225-238).

Comparative Analysis of Carbon Stocks in Home Garden and Adjacent Coffee-Based Agroforestry Systems at Mana Woreda, Southwestern Ethiopia

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Abstract

Agroforestry practices can offer high potential of carbon (C) sequestration in developing countries. However, the roles of tropical agroforestry to mitigate climate change has only recently been recognized. Therefore, this study was conducted to demonstrate empirically the carbon stocks of home garden and adjacent coffee-based agroforestry system (CAFS) practiced at Mana woreda, southwestern Ethiopia. The two agroforestry systems were the predominant management practices in the study area. A total of 60 nested plots (20m×20m) were established in the two agroforestry systems for inventory of woody species. Three 1m×1m subplots were established in the main plots to collect litter and soil samples. A total of 240 soil samples, 120 for analysis of soil organic carbon fraction (% C), and 120 for bulk density determination were collected. The total C stock was estimated by summing C stock in the biomass and soil (0-60 cm depth). Results showed that, the total biomass C stocks (above and belowground) significantly differed between home garden (27.4 Mg C ha^{-1}) and adjacent CAFS (63.1 Mg C ha^{-1}). Trees accounted for 67% and 85% of the total biomass C stocks in the home garden and CAFS, respectively. Litter constituted 3% of the total aboveground biomass C stock in the home garden and 6% in the CAFS. The total C stocks (in biomass plus soil, 0-60 cm depth) were significantly higher in the CAFS (195 Mg C ha^{-1}) compared to home garden (158 Mg C ha^{-1}). The soil organic carbon (SOC) accounted for 82% for home garden and 68% for CAFS's total carbon stock. Our study revealed that, the studied agroforestry systems would fit to emission reduction and enhancement of carbon sinks besides to supporting local livelihoods in the study region.

Keywords: Biomass, Carbon Stocks, Coffee agroforestry, Ethiopia, Home garden

Introduction

Agroforestry systems have been promoted as a strategy for carbon sequestration under afforestation and reforestation programs of the Clean Development Mechanisms of the Kyoto Protocol (Watson and Eyzaguirre 2002; Smith et al 2007).

Of all land uses analyzed in the fourth assessment report on climate change by IPCC, it was also predicted that by 2040 agroforestry would offer the highest potential of carbon (C) sequestration in developing countries. However, the roles of tropical agroforestry in C sequestration and in helping to mitigate climate change has been recognized only recently. There is also variation in carbon sequestration potential of various agroforestry among various practices, climatic regimes and management.
In Ethiopia, agroforestry system is an old-aged practice (Brandt et al. 1997; Edmond et al. 2000). Currently, agroforestry systems are widespread in different agro-ecologies and farming systems in the country and known to provide food, feed and income for smallholder farmers and pastoral/agro-pastoral communities (Poschen 1986; Kanshie 2002; Negash and Starr 2015).

In the southwestern region of Ethiopia, where this study was conducted, HGAF and CAFS are the most dominant practices (Worku 2013). HGAF is a practice around a homestead where several plant species are maintained by members of the households and its products are intended primarily for subsistence consumptions (Abebe 2000). Such agroforestry systems offer potential opportunity for carbon storage due to their forest-like structure and composition (Bajigo et al. 2015). Most importantly, coffee is cultivated under shade of different indigenous tree species (Teketay and Tegineh 1991; Muleta et al. 2008). Shade trees in CAFS are used for improving growth, productivity and quality of coffee (Bote and Struik 2011). Additionally, the diverse trees integrated as coffee shade have an important potential for sequestering and storing carbon in the biomass, soil and harvested products (Dossa et al. 2008).

While several studies have been conducted on the carbon stocks of different agroforestry systems in Ethiopia (Seta and Demissew 2014; Bajigo et al. 2015; Negash and Starr 2015), there is no study on the HGAF and CAFS practiced at Mana woreda of southwestern Ethiopia. The overall objective of this study was, therefore, to analyze the carbon accumulation potential in the biomass and soil of HGAF and adjacent CAFS at the study area. The study hypothesized that; the variation in homegarden and coffee-based agroforestry systems affects the biomass and soil organic carbon (SOC) stocks because the two agroforestry systems were dominated by different types of biomass components such as coffee, woody and non-woody plants. It was further hypothesized that; soil organic carbon stock was greater than the biomass carbon stocks due to the high inputs of tree litterfall and use of mulches.

Materials and Methods

Description of the Study Area

The study was conducted at Mana Woreda, which is located at 368 km southwest of Capital city Addis Ababa and 20 km west of Jimma town of southwestern Ethiopia

(Figure 1). Geographically, it is situated between 7°37’55” N and 7°54’0” N latitude and 36°37’15” E and 36°53’31” E longitude. The study area is dominated by HGAF and CAFS farming systems (Figure 2a & b). The area has bimodal rainfall distribution with a maximum rainfall between July and September and moderate rainfall between March and May. The mean annual rainfall and monthly temperature ranges from 1200 mm-1800 mm and 13.0 °C-24.8 °C, respectively. The dominant soil type of the study area is Nitisols (Bote and Struik 2011). The dominant soil textural class of the study area is clay with pH values ranged between 4.71 and 6.44. The Munsell soil color chart indicated that the soil color ranges from dark reddish brown (5 YR3/3, Moist) to reddish brown (5 YR4/4, Moist).

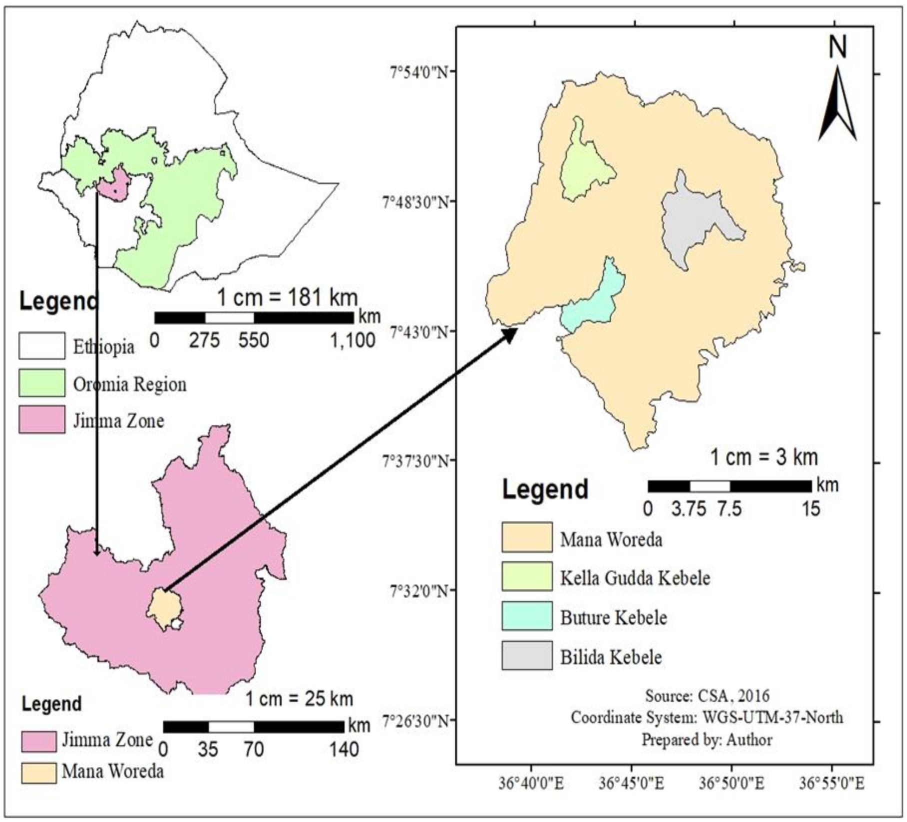

Figure 1 The nested map of Ethiopia showing the map of study region (Oromia), the zonal map of the study woreda and specific studied kebeles within the woreda

Home garden in the study area is composed of trees, shrubs, herbs, climbers and food crops that form different vertical strata. *Coffea arabica L*. (Coffee), *Catha edulis* Forskal (Khat), *Ensete ventricosum (*Welw.*) Cheesman* (enset), *Persea americana Mill* and *Musa spp*. (banana) are the dominant cash and food crops, which are grown in association with trees such as *Cordia africana* Lam. Home garden is often separated from CAFS and other farming systems using live fences composed of trees and shrubs. CAFS in the study area contains coffee and shade trees of different species. It was formed through clearing underneath shrubs and bushes and retaining shade trees over time to create more space for coffee trees. The most preferred shade trees include *Albizia gummifera (*J.F. Gmel*.)* C.A. Sm*, Acacia abyssinica, Croton macrostachyus* Del*. and C. africana.*

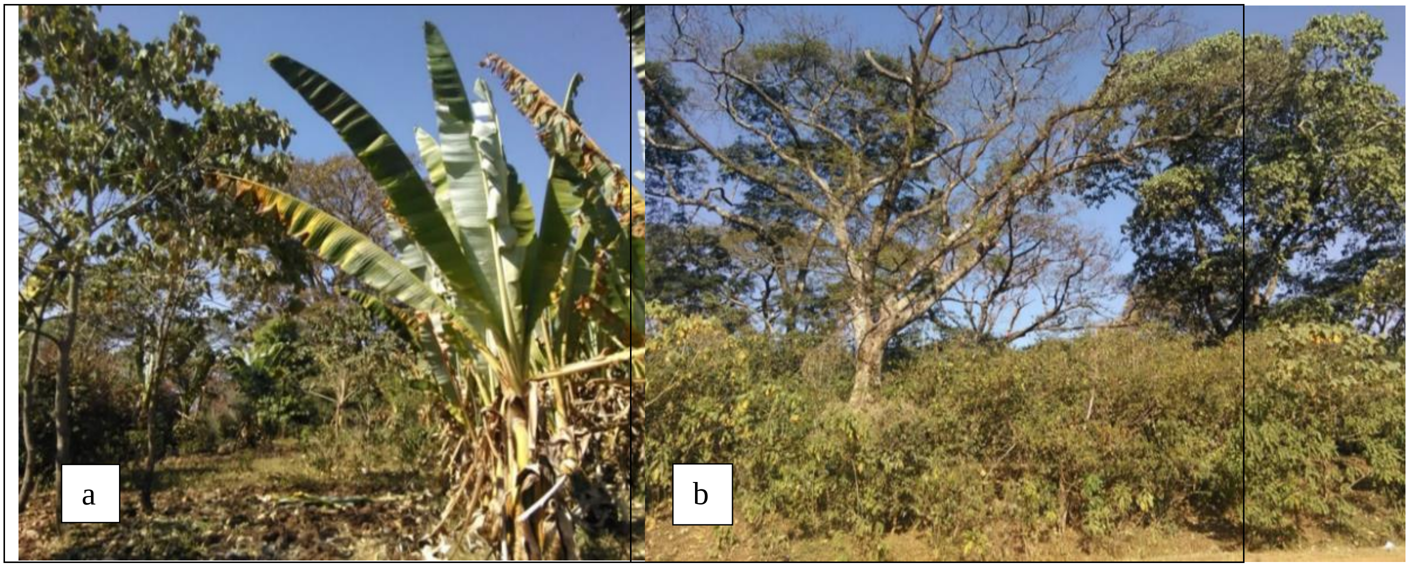

Figure 2 Photos of homegarden agroforestry (a) and Coffee based agroforestry system (b) in Mana woreda, southwestern Ethiopia

Study site and farm selection

Three Kebeles, namely Kella Gudda, Bilida and Buture, practicing HGAF and CAFS were purposively selected. These Kebeles were selected on the basis of the presence of both HGAF and CAFS as common practices of smallholder farmers' livelihood and similarity in terms of agro-ecologies such as dominant soil type (i.e. Nitisol), rainfall and temperature except their difference in land management practices. For fair representation of the site, two villages from each Kebele were randomly selected. Since the studied agroforestry systems were practiced by smallholder farmers, farm households representing each system were randomly sampled. Household sampling was done by categorizing them in to different wealth status (rich, poor, medium). Ranking of the households was carried out to control carbon stocks variation between agroforestry systems resulting from wealth difference. The ranking was done according to the classification made by key informants (Den Biggelaar and Hart 1996). Three key informants (two males and one female) per village with the higher scores were selected from the list in each village. A total of 60 farms, comprising 30 for each studied agroforestry system, were selected for field level data collection. A nested plot of 20 m x 20 m with three 1 m × 1 m sub-plots were established in each farm to carry out woody species inventory and soil sampling respectively (Figure 3). In a few cases, the plot covered the whole farm of the households. To locate the plot on the farm, first, the farm was visually divided into equal parts. Then, a number was assigned to each part and finally, a plot for data collection was randomly selected.

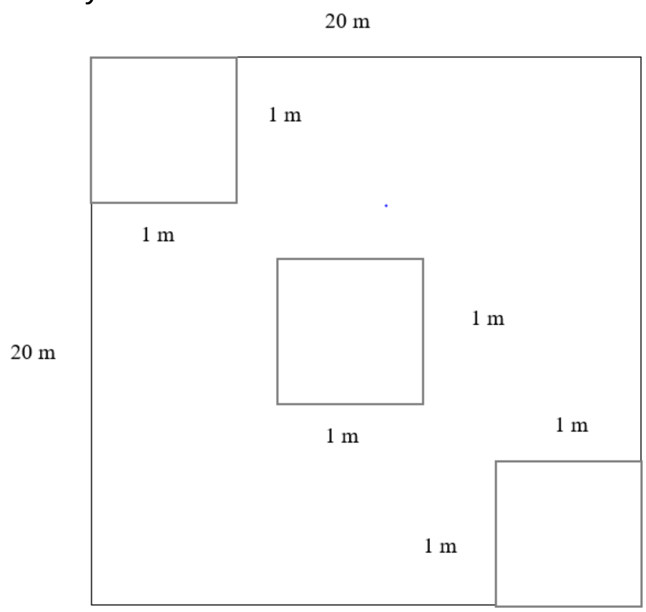

Figure 3 Plot size and design for both homegarden and coffee-based agroforestry system

Field measurements

All trees and shrubs with DBH ≥ 2.5cm and height ≥1.5 m within the sample plot were measured and recorded since the allometric equations used to estimate the biomass carbon stock of this study area had developed for a trees and shrubs greater than/or equal to 2.5cm DBH and 1.5 m. Inventory of trees and shrubs of the studied two agroforestry practices are shown in Table 1. In the case of multi-stemmed plants, each stem was measured, and the equivalent diameter of the plant was calculated as the square root of the sum of diameters of all stems per plant ($d_e = \sqrt{\sum_{i=1}^{n} di^2}$) (Snowdon et al. 2002).

Biomass of woody species were estimated using already existing allometric equations (Table 2). Allometric equation developed by Kuyah et al. (2012) was used for estimating the aboveground biomass of woody species. This equation was selected, because it was developed for trees in agricultural landscapes in western Kenya having similar climate and soils as those in the current study area. Moreover, this equation used the most important biomass predictor variables such as diameter at breast height and wood density.

Woody density was obtained from the document of Ethiopia's Forest Reference level submission to the United Nation Framework Convention on Climate Change (UNFCCC) (EFRLS 2016). Aboveground biomass of other components such as coffee, enset, khat and banana were also estimated using available equations. While belowground biomass was estimated based on root to shoot ratios except enset. The C content of 48% for woody species, 49 % for coffee, 47 % for enset, and 48% for banana was used (Table 2).

Litter sampled include dead leaves, branches, twigs, flowers, and dead wood with a diameter of less than 10 cm. litter samples were collected from the three randomly selected sub-plots in themain sample plot. The collected fresh litter was weighed right on the site using string balance. Then, the subsamples were evenly mixed, and 100-gram litter sample was taken and transported to Wondo Genet College of Forestry and Natural Resources soil laboratory, and oven dried at 65ºC for 24 hours to determine dry to fresh weight ratio. To determine the C content of litter, the samples were weighted, grinded using mortar and pestle, and sieved with 2 mm mash. The loss on ignition (LOI) method was used to estimate percentage of organic matter in the litter. The amount of C in the litter was determined by multiplying litter organic matter by 0.50 (Pearson et al. 2007).

Table 1 Stand characteristics (mean ±SD) of homegarden (HGAF) and adjacent coffee-based agroforestry systems (CAFS) in southwestern Ethiopia (n=30 for each)

	HGAF					CAFS	
Stand characteristic	Tree	Coffee	Banana	*Khat*	*Enset*	Trees	Coffee
d_{10}, cm	_	_	_	6.5±2.9	35.8±12.	_	_
d_{40}, cm	_	5.06±2.1	_	_	_	_	5.05±2.6
d, cm	10.53±6	_	10.51±4	_	_	17.86±9.2	_
h, m	7.15±4.3	3.24±1.0	4.78±1.7	4±1.7	5.27±1.9	12.45±6.1	3.98±0.8
BA, m^2 ha^{-1}	5.54±0.1	1.48±0.1	1.04±0.1	0.88±0.1	32.3±0.1	12.86±0.1	5.87±0.03
Stems ha^{-1}	307.5±225	566±512	315±232	505±391	356±188	204±168	2247±954

d_{10} refers diameter at 10 cm height, d_{40} diameter at 40 cm height, *d* diameter at breast height, *h* height (dominant height in the case of *enset, khat* and banana), Ba basal area

Table 2 Allometric equations used to estimate the biomass carbon stocks of homegarden and adjacent coffee-based agroforestry systems in Mana Woreda, southwestern Ethiopia

Species	Equation	R^2	D, cm	% C	Source
Woody species	$AGB = 0.225 \times d^{2.341} \times \rho^{0.73}$	0.98	≥2.5	48	(Kuyah et al. 2012a)
	$BGB = 0.490 \times AGB^{0.923}$	0.95	>10	48	(Kuyah et al. 2012b)
	$BGB = 0.28 \times AGB$	-	≤ 10	48	(Kuyah et al. 2012b)
Coffee *(Coffea arabica)*	$AGB = 0.147 \times d_{40}^2$	0.80	≥3.8	49	(Negash et al. 2013a)
	$BGB = 0.28 \times AGB$	-	≥3.8	49	(Kuyah et al. 2012b)
Enset *(Ensete vetricosum)*	$\ln AGB = -6.57 + 2.316 \ln(d_{10}) + 0.124 \ln(dh)$	0.91	≥20	47	(Negash et al. 2013b)
	$BGB = 7 \times 10^{-6} \times d_{10}^{4.082}$	0.68	≥20	47	(Negash et al. 2013b)
Banana (*Musa* spp.)	$AGB = -6.415 + 2.940 \ln d$	0.82	>10	48	(Kamusingiz al. 2017)
	$BGB = 0.24 \times AGB$	-	>10	48	(Negash et al. 2013b)
Khat *(Catha edulis)*	$AGB = 0.4796 \times d_{10}^{1.5818} \times dh^{0.1089}$	0.97	≥2.5	48	(Dessalegn 2016)
	$BGB = 0.28 \times AGB$	-	≥2.5	48	(Kuyah et al. 2012b)

AGB refers aboveground biomass, kg/plant, *BGB* belowground biomass, kg/plant, d_{40} diameter at 40 cm height (cm), *d* diameter at breast height (cm), d_{10} diameter at 10 cm height (cm), ρ wood density, g cm^{-3}, *dh* dominant height (m), *ln* is natural logarithm

Soil samples were collected from the three sub-plots used for litter sampling. Two sets of soil samples were taken, one set for the determination of organic C fraction (%C), texture and pH, and one set for the determination of soil bulk density. A total of 120 soil samples (layers of 0-30 and 30-60 cm) were collected for % C analysis using soil auger. In addition, similar size of undisturbed soil samples was collected separately for the determination of soil bulk density. Soil analyses were undertaken at Wondo Genet College of Forestry and Natural Resources soil laboratory. The soil samples for bulk density were oven-dried at 105°C for 48 hours and weighed (Pearson et al. 2007). Bulk density was determined by the core method (Blake and Hartge 1986). The soil samples for %C were air dried and analyzed using Walkley and Black method (Schnitzer 1982).

SOC stocks (Mg C ha^{-1}) was calculated as a product of C fraction (%) * bulk density (g/cm^3) * layer thickness (cm)) (Norris 2014). Total ecosystem C stock was calculated by summing up biomass C stocks (above-and-below) and SOC stocks.

Data Analysis

Data was checked for normality using Kolmogorov-Smirnov test prior to further statistical analysis. The differences in mean C stocks between the two agroforestry systems were tested by one-way ANOVA. Two-way ANOVA was also performed to test the differences of SOC in relation to Agroforestry practice and soil depth. The data were analyzed using Statistical Package for Social Science (SPSS version 20).

Results

Biomass carbon stocks in HGAF and CAFS

The basal area of trees in CAFS (12.86 m^2ha^{-1}) was 2.3 times higher than HGAF (5.54 m^2ha^{-1}). *C. arabica* (2247 stems ha^{-1}) was the most dominant species in the CAFS. *C. arabica* (566 stems ha^{-1}), *C. edulis* (505 stems ha^{-1}) and *E. ventricosum* (356 stems ha^{-1}) were the three dominant species in the HGAF.

Aboveground biomass C stock (trees, coffee, enset, banana, khat, litter) was significantly higher ($p < 0.001$) in the CAFS than in the HGAF (Table 3). The mean aboveground biomass C stock of CAFS was approximately 2.33 times higher than HGAF. Trees' aboveground biomass C stock in CAFS was 3 times higher than home garden, and their contribution was 66% for home garden and 83% for CAFS. Coffee accounted for 6% and 11% of total aboveground biomass C stock in the HGAF and in the CAFS, respectively. Litter contributed in average 2 Mg C ha^{-1} across the two studied practices, 3% for HGAF and 6% for CAFSof the aboveground biomass C stocks.

Belowground biomass C stock was significantly higher ($p< 0.001$) in the CAFS than in the HGAF (Table 3). The mean belowground biomass C stocks in the HGAF and in the CAFS were 6.0 Mg C ha^{-1} and 13 Mg C ha^{-1}, respectively. The contribution of trees to the total belowground biomass C stocks was 70% for the HGAF and 89% for the CAFS. Coffee accounted for 6% of the total belowground biomass C stock in the HGAF and 12% in the CAFS.

The total biomass C stocks in CAFS was 57% higher than HGAF. Trees contributed 85 and 67% of the total C stocks in CAFS and HGAF, respectively (Table 3). Cash generating coffee shared 11% in CAFS whereas coffee and Khat altogether accounted for 20% (respectively 6% and 14%) of the total biomass C stocks in HGAF. The contribution of food crop (enset plus banana) estimated to 11% C stock in HGAF. Litter contributed < 5% of the biomass C stocks in both studied agroforestry practices.

SOC stocks in HGAF and CAFS

Within each HGAF and CAFS, SOC stock was significantly higher ($p<0.001$) in the top layer (0-30cm) than in the lower layer (30-60 cm) (Table 4). The top layer accounted for 56% of the total SOC in the HGAF and 57% of the total SOC in adjacent CAFS. It was hypothesized that, total soil organic carbon stocks (0-60 cm depth) could be significantly different between agroforestry systems; However, the total SOC stocks for the soil depth of 0-60 cm for the two systems were comparable. General linear analysis showed that SOC stock significantly differed along depths for the two studied systems but not the interaction of agroforestry system and soil depth (Table 5).

Table 3 Mean (± SD, Mg ha^{-1}) above and belowground biomass carbon stocks of the two studied agroforestry system in Mana woreda, southwestern Ethiopia (n=30 for each)

Biomass component	Agroforestry	Litter	Trees	Coffee	Enset	Banana	Khat	Total
AGBC	HGAF	0.7±0.4[a]	14.2±11.8[a]	1.3±1.3[a]	1.4±0.9	0.75±0.6	3.1±3.04	21.5±12.9[a]
	CAFS	3.1±0.3[b]	41.7±24.1[b]	5.3±1.7[b]	-	-	-	50.1±24.6[b]
BGBC	HGAF	-	4.2±3.5[a]	0.4±0.4[a]	0.4±0.3	0.2±0.2	0.8±0.86	5.9±3.82[a]
	CAFS	-	11.5±6.71[b]	1.5±0.5[b]	-	-	-	13±6.90[b]
TBC	HGAF	0.7±0.4[a]	18.4±15[a]	1.7±1.7[a]	1.8±0.5	1.1±0.8	3.8±3.9	27.4±16.9[a]
	CAFS	3.1±0.4[b]	53.7±30[b]	6.8±2.2[b]	-	-	-	63.1±31.5[b]

Different letters show significant (p<0.05) different between agroforestry systems, and similar letters not significance differences, AGBC shows aboveground biomass carbon, BGBC belowground biomass carbon, TBC total biomass carbon; HGAF home garden agroforestry, CAFS Coffee based agroforestry system.

Table 4 Mean (±SD, Mg ha^{-1}) of soil organic carbon (SOC) in the two studied agroforestry system in Mena woreda, southwestern Ethiopia (n=30 for each)

Depth, cm	HGAF	CAFS
0 – 30 cm	73.70 ± 16.29^{b}	75.15 ± 10.32^{b}
30 – 60 cm	56.67 ± 16.25^{a}	56.71 ±9.68^{a}
Total (0 – 60 cm)	130.37 ±27.78^{c}	131.86 ±13.88^{c}

Different letters show significant (*p*<0.05) different between agroforestry systems, and similar letters not significance differences, AGBC shows aboveground biomass carbon, BGBC belowground biomass carbon, TBC total biomass carbon; HGAF home garden agroforestry, CAFS Coffee based agroforestry system

Table 5 Results of general linear model to SOC stocks in relation to Agroforestry systems and soil depths

Sources of variance	F value	*p-value*
Agroforestry systems	0.092	0.762
Soil depth (SD)	51.72	<0.001
Agroforestry systems x SD	0.083	0.774

Total Carbon Stocks (TCS) of Agroforestry systems

The total carbon stocks were significantly different between the two studied agroforestry practices (F=22.55, p < 0.001). The estimated mean total carbon stock for home garden was 158 Mg C ha^{-1} and 195 Mg C ha^{-1} for the CAFS (Figure 3). Of which, the SOC accounted for 83% and 68% for home garden and CAFS, respectively. The relative contribution of biomass C to the total C stock in CAFS was significant (F=33.65, p<0.001), valuing approximately 2 times higher than that of home garden. While SOC contributed in home garden approximately 1.2 times higher than CAFS.

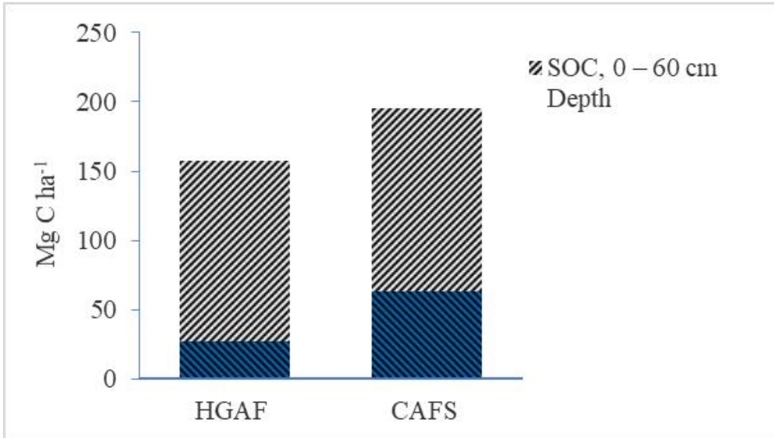

Figure 3 Total ecosystem carbon stocks (biomass plus SOC) of the studied homegarden agroforestry (a) and Coffee based agroforestry system (b) in Mana woreda, southwestern Ethiopia

Discussion

Biomass Carbon Stocks

Most of the biomass carbon in both the HGAF and CAFS was stored in trees. However, tree biomass carbon was 26 % lower in the HGAF compared with the CAFS. The low C stock contribution of trees to the total biomass C stock in home garden was attributed to the presence of predominantly low diameter trees (< 10 cm). Additionally, the CAFS accumulated large aboveground biomass in the litter compared with home garden. The higher litter biomass carbon contribution in CAFS might be due to the falling of small branches and leaves during the tree and coffee-shrubs pruning, which is a common management practice in the study area. Furthermore, CAFS was dominated by native species, which are relatively large and deciduous. Similarly, Munishamappa et al (2012) reported that, the amount of litter and associated C stocks is higher in stand composed of native woody species than exotic ones.

Case studies show variation among sites and agroforestry practices in terms of their total biomass C stock. For instance, the biomass carbon stocks in the HGAF of the current study area is substantially higher than the biomass carbon stocks (8.3 Mg C ha^{-1}) of the HGAF in Gununo Watershed, southern Ethiopia (Bajigo et al. 2015. Similarly, the mean biomass carbon stocks (63.1 Mg C ha^{-1}) of CAFS in this study was higher than the biomass carbon stocks (58.3 Mg C ha^{-1}) of coffee based agroforestry system of Gera, Jimma Zone, South-West Ethiopia (Mohammed and Bekele 2014). The difference in biomass carbon stocks might be derived from differences in measured diameter for coffee plants, adopted allometric equation, soil condition, and climate.

For instance in coffee based agroforestry system studied by Mohammed and Bekele (2014), the diameter for coffee shrub was measured at 15 cm above ground while in this study, the stump Height diameter (40 cm above ground) was used for coffee plant biomass calculation. Similarly, in the case of coffee based agroforestry system studied by Mohammed and Bekele (2014) both the aboveground biomass of trees and coffee plants was determined by Brown et al (1989) allometric equation and Segura et al (2006) allometric equation respectively. But, for this study, the generic equation developed by Kuyah et al (2012a) and the one that was locally developed by Negash et al (2013a) were used for calculation of above ground biomass in tree species and coffee plants respectively.

The biomass carbon stocks of the HGAF of the current study area was approximately 2.3 − 5.4 times lower than what is reported for indigenous agroforestry systems of the south-eastern Rift Valley escarpment, Ethiopia (Negash and Starr 2015). This difference might be due to the difference in the density of trees and structural parameter (DBH and height) in the Rift Valley agroforestry systems. According to Negash and Starr (2015), the stands in agroforestry systems in the south-eastern Rift Valley were characterized by high density of trees (fruit and non-fruit trees) of bigger sizes whereas in the present study area, non woody plants and woody plants with smaller diameter took a major proportion of the HGAF.

The findings in the current case study were also compared to studies outside Ethiopia. Accordingly, the average biomass carbon stocks of HGAF at the current study area was lower than the biomass carbon stocks (46.8 Mg C ha^{-1}) of 13 years HGAF in Lampung, Indonesia (Roshetko et al. 2002) and 69.15 Mg C ha^{-1} of HGAF in Rangpur District, Bangladesh (Jaman et al. 2016). However, the mean above ground biomass of the HGAF was higher than the mean above ground biomass (13 Mg C ha^{-1}) of the HGAF in a dry zone area of Moneragala district, Sri Lanka (Mattsson et al. 2015) and 9-years old Sumatran agroforests (14 Mg C ha^{-1}(Roshetko et al. 2002). The variability among the HGAF in this respect might be because of differences in garden composition, site characteristics, management practices, land holding sizes of HGAF, ancillary factors (e.g. soil condition, climate, system age, land-use history), and adopted allometric model for biomass estimation (Montagnini and Nair 2004).

Our biomass C stock in CAFS was also compared with similar system practiced at other parts of the tropics. For example, the mean biomass carbon stocks of organic polyculture coffee (OPC), non-organic polyculture coffee (NOPC) and organic Inga species (OIS) in Chiapas, Mexico ranged between 53.2 Mg C ha^{-1} and 63.5 Mg C ha^{-1} (Soto-Pinto and Aguirre-Dávila 2014) which is comparable with the current study. In contrast, a study of Falcata-coffee multistory system and mixed multistory system in Bukidnon, Philippines found a mean aboveground carbon stock of 7.6 Mg C ha^{-1} and 37.2 Mg C ha^{-1}, respectively (Labata et al. 2012) which is lower than what is found in the current study. Similarly, Hager (2012) found that, coffee farms in the Rio Grande watershed; Costa Rica stored an average biomass carbon stock of 29.6 Mg C ha^{-1} which is also lower than the biomass carbon stocks of CAFS in this study.

SOC Stocks

The SOC stock in the present study was significantly ($p< 0.001$) varied by soil depths but not by agroforestry practice and interaction of depth and agroforestry. Across both agroforestry systems, SOC stock was significantly higher in the upper layer than in the lower layer. This finding agrees with the findings of Yimer et al. (2015) that showed decreasing SOC concentration with increasing soil layer.

The overall mean (0-60 cm depth) of SOC was higher in soil under CAFS than HGAF. The higher SOC content in the CAFS might be attributed due to the lower organic carbon turnover rate because of minimum soil disturbance in the system as compared and more litterfall inputs from trees and coffee plants. For instance, litter accounted 4.4 times higher C inputs in CAFS than home garden. While in home garden, common intensive management practices like cleaning, weeding, burning and relocation of biomass might influence accumulation of litter C.

The total soil organic carbon stocks at soil depth (0- 60 cm) for the two agroforestry systems in this study (130.37−131.86 Mg C ha^{-1}) were within the range of soil organic carbon stocks up to 1 m depth reported for the agroforestry systems globally (30 - 300 Mg C ha^{-1} (Nair et al. 2010) and in Ethiopia (49.41 - 256.3 Mg C ha^{-1}) (Gebeyehu et al. 2017). The upper layer (0-30 cm depth) SOC of both agroforestry systems at this study area is higher than the mean (65.2 C Mg ha^{-1}) of Nitisol soil (the dominant soil type of this study area) in Ethiopia (Gebeyehu et al. 2017). The result of SOC in 0-30 cm depth in HGAF was higher than the 0-30 cm depth SOC (61.6 Mg C ha^{-1}) recorded in home garden of Gununo watershed agroforestry practices (Bajigo et al. 2015), and 0-30 cm depth SOC (60.8 Mg C ha^{-1}) of Indonesia home garden systems (Roshetko et al. 2002).

The total SOC stocks (75.15 Mg C ha^{-1}) of upper layer (0-30 cm depth) in CAFS in this study is lower than the same layer of total SOC stocks (92.48 Mg C ha^{-1}) of coffee based agroforestry systems of Gera, Jimma Zone, South-West Ethiopia (Mohammed and Bekele 2014). The differences in SOC might have resulted from differences in factors such as rate of mineralization by soil micro-organisms (Balesdent et al. 1990; Reicosky et al. 1997), elevation and climate (Soto-Pinto et al. 2010), soil type (Lal 2004), silvicultural management (e.g. planting density, pruning, thinning), kind/type of plant material added with its rate of decomposition and land-use history (Nair et al. 2009)0. The 0–60 cm SOC stocks (131.9 Mg C ha^{-1}) of CAFS in this study was also noticeably lower than the fruit-coffee system (179 Mg C ha^{-1}) of the indigenous agroforestry systems in the south-eastern Rift Valley escarpment, Ethiopia (Negash and Starr 2015). The differences in this regard might be due to the high proportion of tree and shrubs in the fruit-coffee system than CAFS of this study.

Total carbon stocks of agroforestry systems

Similar to previously reported carbon stocks of agroforestry systems (Dossa et al. 2008; Soto-Pinto et al. 2010; Schmitt-Harsh et al. 2012; Negash and Starr 2015), in the current HGAF and CAFS agroforestry systems, more carbon was stored in the soil. The total carbon stocks of the two agroforestry systems (157.74 - 195.40 Mg C ha^{-1}) of this study was within the range reported for agroforestry systems globally (12−228 Mg C ha^{-1}) (Albrecht and Kandji 2003). The total carbon stocks of this study is noticeably higher than the total carbon stocks of organic coffee polyculture (134.49 Mg C ha^{-1}) and comparable to Inga species shade coffee systems (154.28 Mg C ha^{-1}) and non-organic coffee polyculture (194.69 Mg C ha^{-1}), in Chiapas, Mexico (Soto-Pinto and Aguirre-Dávila 2014). Additionally, the total carbon stocks of the two agroforestry system reported in this study is substantially higher than the total carbon stocks of shade-grown coffee systems in Indonesia (82 Mg C ha^{-1}) (van Noordwijk 2002) and in Togo (82 Mg C ha^{-1}) (Dossa et al. 2008).

Conclusions

The study affirms both home garden and coffee-based agroforestry practices serve to reduce emission and enhance sinks on agricultural landscape besides supporting local livelihoods. The potential to C storage depends on the biomass components and management practices. Trees play substantial roles for enhancing biomass C stocks in agroforestry. Perennial cash crops (coffee and Khat) and food crops (enset and banana) also contribute meaningful amount of carbon stocks in the two studied agroforestry practices. Hence, neglecting perennial cash and food crops in agroforestry would underestimate valuing the potential contribution of agroforestry to climate change mitigation. Moreover, soil is a vital component in preserving significant amount of carbon in the system. This will also enhance soil fertility, productivity and food security. Thus, valuing the carbon storage potential of agroforestry help to promote the ecosystem services of the system, and boost up its acceptance in sustainable natural resource management strategy in the tropics.

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References

Abebe T (2000) Indigenous Management and Utilization of Tree Resource in Sidama: In Mother Earth FTTP Newsletter.Human and Environment Lem.

Albrecht A, Kandji ST (2003) Carbon sequestration in tropical agroforestry systems. Agric Ecosyst Environ 99:15–27. doi: 10.1016/S0167-8809(03)00138-5

Alebachew M (2012) Traditional Agroforestry practices, opportunities, threats and research needs in the highlands of Oromia, Central Ethiopia. Int Res J Agric Sci Soil Sci 2:2251–44.

Bajigo A, Tadesse M, Moges Y, Anjulo A (2015) Estimation of Carbon Stored in Agroforestry Practices in Gununo Watershed, Wolayitta Zone, Ethiopia. J Ecosyst Ecography. doi: 10.4172/2157-7625.1000157

Balesdent J, Mariotti A, Boisgontier D (1990) Effect of tillage on soil organic carbon mineralization estimated from 13C abundance in maize fields. J Soil Sci 41:587–596. doi: 10.1111/j.1365-2389.1990.tb00228.x

Blake GR, Hartge KH (1986) Particle Density. In: Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods. Soil Science Society of America, American Society of Agronomy, pp 377–382

Bote AD, Struik PC (2011) Effects of shade on growth, production and quality of coffee (Coffea arabica) in Ethiopia. J Hortic For 3:336–341.

Brandt SA, Spring A, Hiebsch C, et al (1997) Tree Against Hunger,enset-Based Agricultural Systems in Ethiopia. Am Assoc Adv Sci Washingt p 56.

Brown S, Gillespie AJR, Lugo AE (1989) Biomass Estimation Methods for Tropical Forests with Applications to Forest Inventory Data. For Sci 35:881–902.

den Biggelaar C, Hart N(1996) Farmer experimentation and innovation: A case study of knowledge generation processes in agroforestry systems in Rwanda. Community For Case Study Ser 123.

Denu D, Platts PJ, Kelbessa E, et al (2016) The role of traditional coffee management in forest conservation and carbon storage in the Jimma Highlands, Ethiopia. For Trees Livelihoods 25:226–238. doi: 10.1080/14728028.2016.1192004

Dessalegn G (2016) Comparative Analysis of Biomass and Soil Carbon Stocks in Multistory Agroforestry Systems and Khat (*Catha edulis*) Farming.MSc thesis, Hawassa University, Wondogenet college of forestry and natural resources.

Dossa EL, Fernandes ECM, Reid WS, Ezui K (2008) Above- and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. Agrofor Syst 72:103–115. doi: 10.1007/s10457-007-9075-4

Edmond N, Yakam-Simen F, Tadesse K, Romeij P (2000) Gedeo Zone Mapping Project Phase 2 Final Report. Treemail, Heelsum, The Netherlands, Privateers N.V. and the Agricultural Bureau for Gedeo Zone. http://www.treemail. nl/download. Cited 20 Nov 2016.

EFRLS (2016) Ethiopia's Forest Reference Level Submission to the UNFCCC.Addis Ababa, Ethiopia.

Gebeyehu G, Soromessa T, Teketay D (2017) Organic Carbon Stocks, Dynamics and Restoration in Relation to Soils of Agroecosystems in Ethiopia: A Review. Int J Environ 6:1. doi: 10.3126/ije.v6i1.16864

Hoekstra D, Torquebiau E, Bishaw B (1990) Agroforestry: potentials and research needs for the Ethiopian highlands.

ICRAF (2000) Paths to prosperity through agroforestry. ICRAF's corporate strategy, 2001–2010. Nairobi: International Centre for Research in Agroforestry.

Jaman MS, Hossain MF, Islam S, et al (2016) Quantification of Carbon Stock and Tree Diversity of Homegardens in Rangpur District , Bangladesh. 6:169–180. doi: 10.5923/j.ijaf.20160605.01

Kamusingize D, Majaliwa JM, Komutunga E, et al (2017) Allometric relationships and carbon content for biomass-carbon estimation of East African Highland Bananas (Musa spp.). Kibuzi, Nakitembe, Enyeru and Nakinyika. 12:1217–1225. doi: 10.5897/AJAR2016.11960

Kanshie T (2002) Five thousand years of sustainablity? A case study on Gedeo land use (Southern Ethiopia).Dissertation, Wageningen Agricultural University Wageningen.

Kuyah S, Dietz J, Muthuri C, et al (2012a) Allometric equations for estimating biomass in agricultural landscapes: I. Aboveground biomass. Agric Ecosyst Environ 158:216–224. doi: 10.1016/j.agee.2012.05.011

Kuyah S, Dietz J, Muthuri C, et al (2012b) Allometric equations for estimating biomass in agricultural landscapes: II. Belowground biomass. Agric Ecosyst Environ 158:225–234. doi: 10.1016/j.agee.2012.05.010

Labata MM, Aranico EC, Tabaranza ACE, et al (2012) Carbon stock assessment of three selected agroforestry systems in Bukidnon , Philippines. Adv Environ Sci 4:5–11.

Lal R (2004) Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science (80-) 304:1623–1627. doi: 10.1126/science.1097396

Mattsson E, Ostwald M, Nissanka SP, Pushpakumara DKNG (2015) Quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka. Agrofor Syst 89:435–445. doi: 10.1007/s10457-014-9780-8

Mohammed A, Bekele L (2014) Changes in Carbon Stocks and Sequestration Potential under Native Forest and Adjacent Land use Systems at Gera, South- Western Ethiopia Changes in Carbon Stocks and Sequestration Potential under Native Forest and Adjacent Land use Systems at Gera, Southwest Ethiopia. Glob J Sci Front Res 14:2249–4626.

Montagnini F, Nair PKR (2004) Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agrofor Syst 61:281–295.

Muleta D, Assefa F, Nemomissa S, Granhall U (2008) Distribution of arbuscular mycorrhizal fungi spores in soils of smallholder agroforestry and monocultural coffee systems in southwestern Ethiopia. Biol Fertil Soils 44:653–659. doi: 10.1007/s00374-007-0261-3

Munishamappa M, Austin D, Muddumadappa N (2012) Carbon Sequestration in Litter and Soils of Cofee Based Agroforestry Systems in Central Western Ghats Pf Kodagu District of Karnataka. Environ. Ecol. 30:985–987.

Nair PKR, Nair VD, Kumar BM, Haile SG (2009) Soil carbon sequestration in tropical agroforestry systems: a feasibility appraisal. Environ Sci Policy 12:1099–1111. doi: 10.1016/j.envsci.2009.01.010

Negash M (2007) Trees Management and Livelihoods in Gedeo's Agroforests, Ethiopia. For Trees Livelihoods 17:157–168. doi: 10.1080/14728028.2007.9752591

Negash M, Starr M (2015) Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia. Plant Soil 393:95–107. doi: 10.1007/s11104-015-2469-6

Negash M, Starr M, Kanninen M (2013b) Allometric equations for biomass estimation of Enset (Ensete ventricosum) grown in indigenous agroforestry systems in the Rift Valley escarpment of southern-eastern Ethiopia. Agrofor Syst 87:571–581. doi: 10.1007/s10457-012-9577-6

Negash M, Starr M, Kanninen M, Berhe L (2013a) Allometric equations for estimating aboveground biomass of Coffea arabica L. grown in the Rift Valley escarpment of Ethiopia. Agrofor Syst 87:953–966. doi: 10.1007/s10457-013-9611-3

Norris T (2014) Detection of differences in soil carbon and nitrogen stocks between paired dairy and drystock pastures.Dissertation, Waikato University, Waikato.

Pearson T, Walker S, Brown S (2005) Sourcebook for Land use, Land-use change and forestry Projects.Winrock International and the BioCarbon Fund of the World Bank.

Pearson TRH, Brown SL, Birdsey RA (2007) Measurement Guidelines for the Sequestration of Forest Carbon.U.S. Department of Agriculture, Forest Service, Northern Research Station.

Poschen P (1986) An evaluation of the *Acacia albida*-based agroforestry practices in the Hararghe highlands of Eastern Ethiopia. Agrofor Syst 4:129–143. doi: 10.1007/BF00141545

Reicosky DC, Dugas WA, Torbert HA (1997) Tillage-induced soil carbon dioxide loss from different cropping systems. Soil Tillage Res 41:105–118. doi: 10.1016/S0167-1987(96)01080-X

Roshetko JM, Delaney M, Hairiah K, et al (2002) Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage? Am J Altern Agric 17:138–148. doi: 10.1079/AJAA200116

Schmitt-Harsh M, Evans TP, Castellanos E, Randolph JC (2012) Carbon stocks in coffee agroforests and mixed dry tropical forests in the western highlands of Guatemala. Agrofor Syst 86:141–157. doi: 10.1007/s10457-012-9549-x

Schnitzer M (1982) Organic Matter Characterization.Chemical and Microbiological Properties-Agronomy Monograph no. 9 (2nd Edition)

Segura M, Kanninen M, Suárez D (2006) Allometric models for estimating aboveground biomass of shade trees and coffee bushes grown together. Agrofor Syst 68:143–150. doi: 10.1007/s10457-006-9005-x

Seta T, Demissew S (2014) Diversity and Standing Carbon Stocks of Native Agroforestry Trees in Wenago District, Ethiopia. J Emerg Trends Eng Appl Sci 5:125–137.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes B (2007) Agriculture. In 'Climate change: mitigation.Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 497–540.

Snowdon P, Raison J, Keith H, et al (2002) Report No. 31-Protocol for sampling tree and stand biomass. Natl Carbon Account Syst Tech Rep No 31 Canberra, Aust Greenh Off 66.

Soto-Pinto L, Aguirre-Dávila CM (2014) Carbon Stocks in Organic Coffee Systems in Chiapas, Mexico. J Agric Sci 7:117. doi: 10.5539/jas.v7n1p117

Soto-Pinto L, Anzueto M, Mendoza J, et al (2010) Carbon sequestration through agroforestry in indigenous communities of Chiapas, Mexico. Agrofor Syst 78:39–51. doi: 10.1007/s10457-009-9247-5

Teketay D, Tegineh A (1991) Traditional tree crop based agroforestry in coffee producing areas of Harerge, Eastern Ethiopia. Agrofor Syst 16:257–267. doi: 10.1007/BF00119322

van Noordwijk M (2002) Scaling trade-offs between crop productivity, carbon stocks and biodiversity in shifting cultivation landscape mosaics: the fallow model. Ecol Modell 149:113–126. doi: 10.1016/S0304-3800(01)00518-X.

Watson JW, Eyzaguirre PB eds. (2002) Home Gardens and in Situ Conservation of Plant Genetic Resources in Farming Systems. International Home Gardens Workshop, 17-19 July 2001Witzenhausen, Federal Republic of Germany.

Worku M (2013) Potentials and Limitations of Plantation Crop Combination Agroforestry Practice in Southwest Ethiopia. J Appl Sci Technol 4:21–34.

Yami M, Mekuria W, Hauser M (2013) The effectiveness of village bylaws in sustainable management of community-managed exclosures in Northern Ethiopia. Sustain Sci 8:73–86. doi: 10.1007/s11625-012-01762

Yimer F, Alemu G, Abdelkadir A (2015) Soil property variations in relation to exclosure and open grazing land use types in the Central Rift Valley area of Ethiopia. Environ Syst Res 4:17. doi: 10.1186/s40068-015-0041-2

Carbon Stock and Woody Species Diversity Patterns in Church Forests Along Church Age Gradient in Addis Ababa, Ethiopia

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Abstract

Most of the Ethiopian Orthodox Churches comprise natural and planted forests and trees on their premises. A study was conducted to investigate carbon stock and woody species diversity patterns along the church age gradient in Addis Ababa city. We hypothesized that the carbon stock would relate to the church age gradient. Thus, the study was conducted in forests belonging to churches that were selected in a stratified random sampling from four age categories with the year of establishments ranging from 1897 to 1993. Counting of all the woody species and DBH and height measurement of all individuals with DBH of 5 cm and above was carried out. Carbon stock and different diversity indices were computed, and the relationships between church age and tree parameters were evaluated. Results showed that the forests were characteristically small (0.6 ± 0.57 ha), and the tree species with the highest total carbon stock were *Juniperus procera, Eucalyptus globulus* and *E. camaldulensis.* The mean amount of carbon stock contained in each church forest was 156 ± 92 t ha^{-1}. A total of 50 indigenous and 40 exotic woody species were identified. A statistically significant difference ($p < 0.05$) among the four Strata was revealed for the carbon stock of native trees. Correlation analysis also revealed a significant positive relationship between church age and native trees' carbon stock. We conclude that the church forests have a very important role in carbon sequestration and biodiversity conservation, and thus scaling up the long-term maintenance and management of such small-sized forests in urban green spaces is vital.

Keywords: biodiversity conservation, climate change mitigation, diversity indices, urban forest

Lumber Seasoning Technologies and Prospective Uses of Tree Species *Acacia caffra* (Thunb.) Willd. at Pawe, Benishangul-Gumuz Regional State

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Abstract

Inappropriate drying (seasoning), moisture content (MC) in wood and density of wood are amongst the main factors that can highly influence quality, suitability, usability, stability, serviceability and overall performance of wood and wood-based products. The seasoning and density characteristics of the *Acacia caffra* (Thunb.) Willd. lumber was studied to evaluate lumber seasoning technologies that can give result in high lumber quality and appropriate utilization. Sample trees were harvested, and log specimen collected from Pawe. Lumber seasoning experiments were carried out using air and kiln seasoning methods. Moisture content of the lumber was determined using microwave/ oven seasoning method. Results revealed that mean initial and final MC for both air and kiln seasoning stacks was 60.04% and13.28%, respectively. For sawn boards of 3 cm thickness, air seasoning time to reach to about 12% MC took 46 days, while kiln seasoning took 12 days implying that the kiln seasoning rate was ~ 3.8 times faster than air seasoning. The species was classified as very rapid air and kiln seasoning timber species. Mean shrinkage (%) values of the tangential, radial and volumetric shrinkage when seasoning the lumber from 60.04% to ~ 13.28% MC were 4.22%, 3.87% and 6.37%, respectively and longitudinal shrinkage was nil. Defects such as cup, bow and twist, crook, end split, wane, collapse, honeycomb, dead knot, and heart rot were observed with different extent on air and kiln seasoned boards. Mean density of the lumber at green condition and when seasoned to 12% MC was 1056 and 815 Kg/m^3, respectively. Seasoned density of *A. caffra* lumber was classified as very heavy density. It has been comparable with many indigenous and exotic timber species in density, seasoning rate and shrinkage characteristics. The lumber of *A. caffra* recommended decorative furniture.

Keywords: Density, lumber, moisture content, quality, seasoning, shrinkage, kiln, utilization.

Introduction

Demand and supply of forest products in Ethiopia for industries, construction and energy sectors for the year 2020 was projected as 132.5 million m^3 and ~ 28.7 million m^3, respectively (Shiferaw Alem, 2016). Due to the limited information on their different wood characteristics and utilization technologies, only few species are currently utilized in wood industries. Utilization of limited tree species for every intended occurred due to low recovery rate of the saw mills and further processing industries, lack of technical experience and information wood characteristics, the rapid development of construction (industrial, commercial and residential buildings) and increasing demand for furniture in the country, have resulted inappropriate utilization and degradation (both in quality as well as quantity) of the existing forests and selected tree species.

The quality, suitability, service life and overall performance of wood and wood-based products in service are among the major factors that strongly determine moisture content (MC), inappropriate seasoning (here after, seasoning) and defects, variations in density, mechanical, shrinkage characteristics (tangential, radial, and volumetric), rates of seasoning, defects (natural seasoning), types of processing and utilization technologies (Simpson 1991; Denig *et al.*, 2000; FPL 2010). Quality and suitability testing research and promotion has been paramount importance on economically potential timber species such as *A. caffra* may be available only at Pawe (Abat Belese area) is not yet known by the development institutions, product processing and construction sectors, manufactures and end users in the lumber market of the country.

Research was conducted with the general objective of generating technical information (seasoning and density characteristics) and selecting appropriate utilization technologies for *A. caffra* lumber tree species grown at Pawe, Benshaingul-Gumuz Regional State. The specific objectives were to: (i) evaluate appropriate seasoning technologies for the lumber species, (ii) determine the appearance, moisture content seasoning characteristics and handling techniques for seasoned lumber, (iii) determine density of the lumber species at different MC levels, (iv) assess biodeterioration attack during and after seasoning, and (v) indicate potential uses of the lumber species.

Materials and methods

The species

Acacia caffra (Thunb.) Willd is a shrub or small tree up to 14 m tall; bole often twisted, up to 60 cm in diameter (Lemmens, 2006). It is found mostly in northern and eastern parts South Africa and Swaziland, but occurs also in Botswana, Mozambique and

Zimbabwe. A planted population is also found in India (Lemmens, 2006). The species generally occurs in open woodland, wooded grassland and on dry rocky hills, often along watercourses, up to 1500 m altitude. *A. caffra* coppices well.

Description of site

The wood specimen was collected from Pawe, which is located about570 km from Addis Ababa on the way to the Renaissance dam (Figure 1). The site has an altitude of 1100 m, latitude 11°19′N and longitude 36° 24′. It has tepid to cool sub-moist agroecology. The site has 1000-1500 mm mean annual rainfall and mean annual minimum and maximum temperature of 25°C and 30°C (Anonymous, 2001; Behailu Kebede et al., 2011).

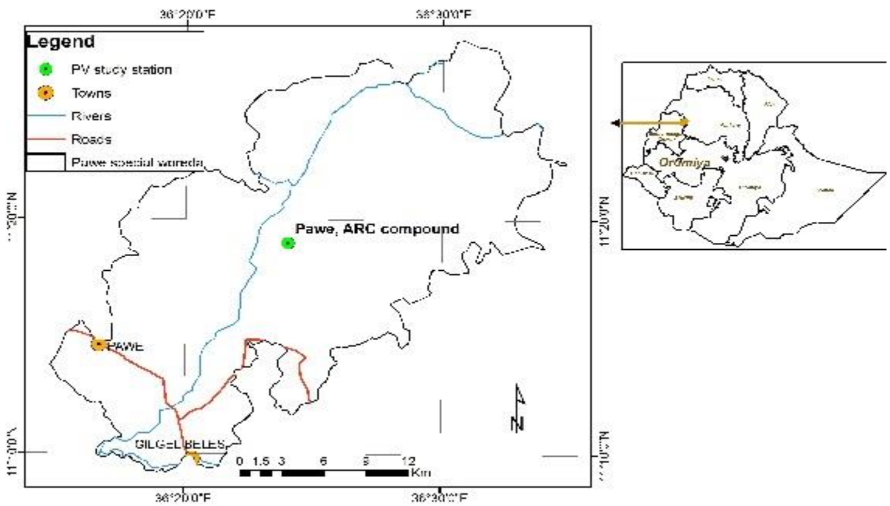

Figure 1 Location of wood specimen collection site in Pawe District, western Ethiopia (Adapted from Behailu Kebede *et al.,* 2011).

The specimen collection

In April 2017, sample trees of *A. caffra* were harvested at the age of 33 from Pawe. The sample trees had a mean height of 15.5 m and a mean breast height diameter (dbh) of 34.23 cm and an estimated total volume of about10 m^3 (Figure 2). The sample trees had relatively good morphological quality, straight and cylindrical stem that was free from visible defects. Lumber seasoning samples were selected and prepared proportionally from each tree and log at 1 m interval along height of the sample trees and marked with identification codes using an indelible waterproof permanent ink.

Sample trees were felled, cross- cut into a series of 2.5 m long logs up to top merchantable diameter of 12 cm. Sample logs while green (> 30% MC) were transported to ex-Wood Technology Research Center (WTRC) now Forest products and Innovation Research and Training Center (FOIRTC), Addis Ababa for the preparation and testing of samples (Figure 3). Logs were flat sawn to 3 cm thickness boards at FOIRTC using mobile circular sawmill.

Figure 2. *A. caffra* trees during sample selection at Pawe.

Boards were converted to samples with appropriate dimensions, quantity and quality for each wood characteristic (Moisture content, seasoning rate, seasoning defects, shrinkage and density) test. Laboratory experiments on different wood characteristics were conducted following the ISO standards/ protocols (ISO 3129, 1975; ISO 3130, 1975; ISO 3131, 1975); Denig *et al*., 2000; FPL, 2010; Moya *et al.*, 2013.

Figure 3 *A. caffra* logs at WTRC sawmill area.

Ten defect free sawn boards with dimensions of 250 cm in length, 3 cm thickness and width equal to log diameter were selected and prepared for each air and kiln seasoning experiments. The samples were used to conduct the seasoning experiments and determination of the different characteristics. The middle part of the sample boards having 1 m length were used as control sample boards both for air and kiln seasoning experiments. The initial MC of each sample was determined using small sections/ samples cut from both ends of sample boards having 1.2 cm length and 3 cm thickness. Twenty specimens free from visible defects, clearly visible tangential and radial surfaces having 2 cm width, 2 cm thickness and 3 cm length at green state were prepared to determine shrinkage characteristics (ISO/DIS 4469, 1975) and density. The shrinkage samples and the measurements (weights and dimensions) were also used to determine the density values of the species at different MC using mathematical formulas.

Lumber stacking for seasoning

Sawn boards from sawmill area were transported to the air seasoning yard and kiln seasoning chamber areas. Boards were stacked horizontally in vertical alignments separated by well-seasoned, squared, uniform sized and standard stickers at 3 cm spacing between successive boards. The heartwood and radial boards, which have less moisture content, were placed in the middle, while the sapwood and tangential boards having high moisture content were placed along the sides, top and bottom of the stacks. The ends of boards were made equal on one direction (Figure 4). The control sample boards were properly distributed and positioned in the pockets of the different layers (bottom, middle and top) of each stack to represent the different zones/layers in the stack (Moya et al., 2013).

Figure 4 Air (a) stack and kiln seasoning stack (b) (Kiln seasoning stack before entering the kiln chamber)

Stickers/strips with a dimension of 2.5 cm width, 2.5 cm thickness and 180 cm length were placed at equal distance of 75 cm across each layer of lumber and aligned board on board from bottom of the stack to the top (Reeb and Brown, 2007). The stickers were used to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process. The short strip stickers (2.5x2.5x20 cm) were superimposed on the long stickers stated above to easily access, measure weight of the control sample boards and determine moisture content of each stack progress. Top loading using heavy stones weighing about 50 kg/m^2 was applied on top of the air and kiln seasoning stacks at a spacing of 75 cm to minimize warping of the boards (Simpson, 1991; Denig *et al*., 2000; FPL, 2010; Moya *et al*., 2013).

Boards for air seasoning were stacked under shed without direct exposure to moisture, rainfall or sunshine (Simpson, 1991; Denig *et al*., 2000; FPL, 2010). Boards for air seasoning were stacked on firm level foundation/ yard having 45 cm clearance above the ground, 1.80 width and 4 m length. The boards were aligned in a north-south direction where the ends were not exposed to the direction of the wind. The north-south direction alignment of boards was done to facilitate good air circulation and reduce the direct influence of temperature, wind and relative humidity. Boards for kiln seasoning were stacked out of the kiln on the transfer carriage having dimensions of 1.6 m width, 0.30 m height and 2.7 m length and then placed in the kiln-seasoning chamber by sliding the stack on the rail.

Applied seasoning technologies

Air, microwave and artificial kiln seasoning methods were used for testing and determination of the different seasoning and density characteristics of the lumber species.

Initial moisture content determination

Samples were prepared while green, weighted and dimensions were taken immediately to determine initial moisture content of the stack. Well ventilated oven with the temperature controlled at 105°C was used for seasoning the test pieces. The oven trays were having open grids to allow free air circulation around the test pieces. Re-weighing of sections/samples at 4 hours interval was done. Samples were weighed hot, immediately after removal from the oven to minimize moisture absorption and desorption (Desch, 1986; Simpson, 1991; Denig *et al*., 2000; FPL, 2010; Moya *et al*., 2013).The process was continued until the difference between two successive weights of each specimen became constant (0-0.2 g) and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010). Afterwards, the moisture content of air and kiln seasoning stacks were determined.

Air seasoning

After initial MC determination, the control sample boards were weighed and placed into the stack, re-weighed at week interval until the average final moisture content of the stack reached moisture content about 12%, which is the equilibrium moisture content for in- and out-door purposes and standard for comparison within and between timber species.

Kiln seasoning

The artificial kiln seasoning chamber/machine used in this study was insulated with brick wall having about 2.5 m^3 lumber loading capacity per kiln seasoning operation. The air velocity, temperature and humidity of the kiln was adjusted for the species. The kiln has psychrometers (dry bulb and wet bulb thermometers) positioned indoor and outdoor of the kiln seasoning chamber/case. The kiln has been equipped with fans to force air circulation, through the chamber and air outlet at the top. The kiln operates at a temperature range of 40-70ºC (Tack, 1969). In this study, kiln seasoning schedule Ethiopia 3 that was adapted from Sweden for hardwood species was used.

During kiln seasoning test samples were weighed, moisture content calculated, psycrometrs regulated, steaming done, and the direction of the fan changed at 8 hours interval (three times in 24 hours) to allow uniform air circulation, control the seasoning process and quality of the lumber seasoned. The process was continuous until the required final 12% MC reached (FPL, 2010; Moya *et al*., 2013). The kiln seasoning schedule applied was similar for the one applied for *Eucalyptus pilularis*, *Eucalyptus viminalis*, *Tichilia dregeana* and *Casuarina equisetifolia* (Getachew Desalegn and Gemechu Kaba, 2015; Getachew Desalegn *et al*., 2016; Getachew Desalegn *et al*., 2017).

Data Collection

The major data collected were dimensions and weight of each sample board which were helped to determine themoisture content, rate of seasoning of boards, shrinkage and swelling characteristics, seasoning defects as well as density.

Lumber characteristics determined

Moisture content

Moisture content was determined in accordance with ISO 3130 (1975) procedures. All test specimens were weighed to obtain the green weight and then oven dried at a temperature of 105 ± 2°C to constant weight to obtain the dry weight (FPL, 2010; Moya et al., 2013). The same method of the air seasoning was applied for the determination of MC for kiln seasoning stack.

$$MC\ (\%) = [(\text{Green weight} - \text{Oven dry weight}) / \text{Oven dry weight}] * 100$$

Lumber seasoning rate

Air and kiln seasoning rates of the lumber species were estimated from the MC samples of the species using the formula adapted from Moya et al. (2013). Classification of air and kiln seasoning rates was done based on the adapted standards from Longwood (1961) and Farmer (1987), respectively.

Shrinkage characteristics

Twenty samples of the lumber species with a dimension of 2x2x3 cm (ISO/DIS 4469, 1975) were seasoned in the microwave (oven seasoning chamber) to a constant dimension at a temperature of 105°C. Initial dimensions and weights of all the shrinkage samples were measured and put in the oven. Measurements of weights were continuous until the difference between the two successive weights of each specimen was constant (0-0.2 g). Then, the final weights and dimensions were taken as oven dry weights and dimensions, respectively. Shrinkage of each specimen at tangential, radial, longitudinal directions and volumetric were determined from green (≥ 60.04%) condition to 13.28% MC and from green to 0% MC. The different formulas were adapted from ISO/DIS 4469 (1975); ISO/DIS 4858 (1975); FPL (2010). Shrinkage values from green to oven dry were classified based on Chudnoff (1984).

Seasoning defects

Seasoning defects of the lumber were measured, and seasoned boards were properly piled in the air seasoning yard, board on board, without stickers between boards. Boards were handled and conditioned well without direct access of moisture and sunshine to avoid/minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack.

Handling of seasoned lumber

Follow-up of seasoned boards was done for more than a year (April 2107-May 2018) and observations were recorded against seasoning defects and biodeterioration attack.

Density test

The sampling procedures and measurements applied during shrinkage experiments were used to determine the density values of the species using mathematical formulas at different MC and sample conditions (green, oven dry and seasoned to 12% MC). Basic density was determined based on green volume and oven dry weight (ISO/DIS 3131, 1975). The dry density values were converted to standard 12% equilibrium MC by applying the formulas adapted from (Denig *et al*., 2000; Reeb and Brown, 2007; FPL, 2010; Moya *et al*., 2013). Density value of the species at 12% MC was classified based on the adapted standard classification from Farmer (1987).

Results and discussion

Lumber Appearance

The lumber of *A. caffra* (Figure 5) showed that the sapwood was creamy white while the heartwood was dark brown.

Figure 5 Appearance of *A. caffra* lumber.

Moisture content

Before air and kiln seasoning commenced, the mean initial MC of the lumber of moisture content of the species was 60.04%, while the final mean MC for air and kiln seasoning stacks was 13.31% and 13.24%, respectively (Table 1). After seasoning, the species attained 13.28% MC. The MC of seasoned lumber is equilibrum moisture content (EMC), which is useful to consider during storage, maufacturing of products and shipping of sawn lumber. The mean initial MC for air seasoning was 70.54%, while for kiln seasoning was 49.54%. The initial MC along height of the lumber during air seasoning varied slightly. The bottom part had 65.11% MC; middle part had 55.79% MC, while top part had 59.21%. The final mean MC for air seasoning was 13.31%, while for kiln seasoning was 13.24%. Trend of MC along height of the tree varies irregularly.

Air and kiln seasoning rate of A. caffra lumbers

The time it took reach to about 13% MC was 46 days for air seasoning, while kiln seasoning took only 12 days (Table 1). Kiln seasoning rate was 1.11%/day. The kiln seasoning was four times faster than the air seasoning. In terms of final lumber quality, no significant difference was found between the air and the kiln seasoning technologies. The species was classified as very rapid in air and kiln seasoning. The kiln seasoning significantly shortens the seasoning time required to season the lumber to 12% MC.

Shrinkage characteristics

The mean shrinkage percentage values of *A. caffra* lumber when dried from green (60.04%) to 13.28% MC were 4.22%, 2.32 % and 6.37% in tangential, radial and volumetric, respectively. When lumber of *A. caffra* was seasoned from green to 0% MC the tangential, radial and volumetric shrinkage characteristics were 6.33, 3.53 and 9.64%, respectively (Table 1).

The longitudinal shrinkage values of seasoned wood at 12% MC varies from 0.1%-0.3%; Radial shrinkage: 2.1-7.9%; Tangential shrinkage: 4.7-12.7%. Tangential shrinkage is generally 1.5 to 2 times greater than radial shrinkage. The shrinkage values of the species are well in the expected range for lumber species.

Seasoning defects

Several defects were recorded during both the air and the kiln seasoning. The dead knot which natural defect was being the dominant type (Table 2).

Table 1 Lumber seasoning and density characteristics (Kg/m^3) of *A. caffra at different MC(*%)

on along height of the tree	Moisture content (%)				Shrinkage characteristics (%) 0% MC				Shrinkage characteristics (%) 12% MC				Density (Kg/m^3)			
	Initial MCof Air seasoning stack	Final Air seasoning MC	Initial MC of Kiln seasoning stack	Final MC of Kiln seasoning	Tangential	Radial	Longitudinal	Volumetric	Tangential	Radial	Longitudinal	Volumetric	Test(at Green condition)	Basic Density	Oven dry	12 % MC
Bottom	71.31	11.78	58.92	14.03	6.36	3.16	0	9.32	3.82	1.89	0	5.59	974	1073	648	830
Middle	65.56	15.1	46.03	12.18	8.41	4.9	0	12.91	5.05	2.94	0	7.74	1084	1246	679	793
Top	74.74	13.05	43.69	13.51	6.33	3.54	0	9.64	3.8	2.12	0	5.79	1110	1229	651	822
Grand mean	70.54	13.31	49.54	13.24	7.03	3.87	0	10.62	4.22	2.32	0	6.37	1056	1183	659	815

Table 2 Seasoning defects extent in air and kiln seasoning stacks.

Seasoning method Defects	Warp				Checks		Split		Knots Diameter (mm)	Number of knots	Other seasoning defects occurred			
	Cup (mm)	Bow (mm)	Twist (mm)	Crook	Surface check (mm)	End check	End split diameter	End split length (cm)						
Mean (Air seasoning defects)	1.60	3.61	0.00	2.60	0.00	0.00	1.37	18.33	51.47	5.58	Wane	collapse	Surface split	honey comb
Mean (Kiln seasoning defects)	1.22	5.08	0.27	0.45	0.00	0.00	3.12	10.59	48.93	6.82	Wane	collapse	Surface split	honey comb

Average kiln seasoning rate for *A. caffra* lumber was 1.11%/day while for lumber species *Cupressus lusitanica*, *Gmelina arborea*, *Tectona grandis* ranges 0.20-1.27%/hour (Moya *et al.*, 2013). Maximum rate of moisture loss (%)/day for some hardwoods ranges 1-2%, while for other species ranges 2% (Oak) to13.8% (Soft maple) (Reeb and Brown, 2007).

Handling of seasoned lumber

Seasoned boards were properly piled on foundation, board on board (under shed), without stickers and top loading. Boards were handled well without direct access of rain and sunshine and inspected for more than a year (April 2107 - May 2018). Within this time no further seasoning defects, neither infestation nor biodegradation attack were observed.

Density characteristics

Mean density of *A. caffra* lumber species at green (initial), basic, oven dry conditions and when seasoned to 12% MC were 1056, 1183, 659 and 815 Kg/m^3, respectively (Table 3). Based on thedensity value (815 kg/m^3 at 12% MC), the species can be classified under very heavy density (800 – 1000 Kg/m^3) lumber species. The wood of *A. caffra* lumber was found to have a hard and heavy wood in South Africa with an air-dry density of 900-1200 kg/m^3, and sapwood being slightly heavier than heartwood (Lemmens, 2006).

Comparison of A. caffra lumber with commercial timbers available and studied in Ethiopia Comparison of A. caffra lumber was made with commercial timbers available in Ethiopia using rate of seasoning and density values at 12% MC. Comparable lumber species with A. caffra in rate of seasoning by kiln technology (6 days) were *Cordia africana* (6 days), *Albizia gummifera* (5 days), *Eucalyptus camaldulensis* (5 days), *Eucalyptus viminalis* (4 days) and (Getachew Desalegn *et al*., 2012). The best comparable species with *A. caffra* in density at at 12% MC were *Cletis africana* (760 Kg/m^3), *Diospyros abyssinica* (790 Kg/m^3), *Eucalyptus globulus* (780 Kg/m^3), *Eucalyptus nitens* (760 Kg/m^3), *Syzygium guineense* (740 Kg/m^3), *Warburgia ugandensis* (770 Kg/m^3) (Getachew Desalegn *et al*., 2012).

End uses of *Acacia caffra* lumber and prospects

A. caffra has Potential applications/uses for decorative furniture. *A. caffra* tree species has potential as a fast-growing and attractive ornamental which is drought and frost resistant (Lemmens, 2006) and can be used for decorative furniture.

Conclusions and wayforward

Acacia caffra has lumber and several non-timber forest products and services. The species has comparable wood with many indigenous and home-grown exotic lumbers of Ethiopia in terms of density, seasoning rate and shrinkage characteristics. Several seasoning defects were observed that need care during seasoning. Trees and logs must be properly harvested, sawn, boards stacked properly and seasoned to less than 20% MC. Lumber shall be seasoned using kiln seasoning technology to minimize seasoning time, maintain wood quality and suitability for different applications.

The air seasoning technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises. It needs air seasoning shed with good foundation and air circulation without direct access of moisture and rainfall. The kiln seasoning technology is expensive that could be affordable and recommended to medium and large-scale forest products processing industries, construction sectors and marketing enterprises.

Air seasoning under shed, with proper stacking and top loading recommended. Seasoned lumber of the study species must be properly stacked board on-board without stickers and handled without direct access of moisture and bio-deteriorating agents.

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References

Anonymous 2001. Forestry research strategy. Forestry Research Sector. Ethiopian Agricultural Research Organization. Addis Ababa, Ethiopia.

Anonymous 2018. *Acacia caffra* data sheet. [Online 12 October 2018], sheet.http://ecocrop.fao.org/ecocrop/srv/en/dataSheet?id=11819

Behailu Kebede, Yigremachew Seyoum, Getachew Desalegn, Melaku Abegaz and Demelash Alem (2011). Performance of traditional wood protection measures in controlling termite and fungal attack in Pawe wereda, research report no. 92. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia.

Chudnoff, M. 1984. Tropical timbers of the world. Forest Products Laboratory. Forest Service. US Department of Agriculture. Agriculture handbook, no. 607, Madison, Wis. USA. 451pp.

Denig, J., E.M., Wengert, W.T. Simpson. 2000. Drying of hardwood lumber. Forest Products Laboratory. Forest Service. United States. Department of Agriculture (USDA). General Technical Report. PL-GTR-118. 138pp.

Farmer R.H. 1987. Handbook of hardwoods. Department of the Environment. Building Research

FPL (Forest Products Laboratory). 2010. Wood handbook-wood as an engineering material. Forest Service. Gen. Tech. Rep FPL-GTR-113. Madison, WI: US, Department of Agriculture, 463 pp.

Getachew Desalegn and Gemechu Kaba. 2017. Imperative physical characteristics and potential uses of *Eucalyptus pilularis*, *Eucalyptus viminalis* and*Tichilia dregeana* lumber tree species. In፡ Forest and Environment: Technologies and Information, Mehari Alebachew, Getachew Desalegn, Wubalem Tadesse, Agena Anjulo and Fassil Kebede (eds) (June 2017). Proceedings of the 1st Technology dissemination workshop, 26-27 November 2015. Tokuma Hotel, Adama, Ethiopia.

Getachew Desalegn, AntenehTesfaye, Gemechu Kaba and Saifu Amanuel. 2016. Seasoning and density characteristics and potential uses of *Gmelina arborea* lumber tree species grown at BongaDebre, Ethiopia. Wood Technology Research Center, Forest Resources and Utilization Research Directorate, Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia.

Getachew Desalegn, Gemechu Kaba, AntenehTesfaye, Saifu Amanuel, Tsegaye Wubshet, Tesfanesh Ababu (2018). Lumber Seasoning Technologies and Prospective Uses of Casuarina equisetifolia L. Tree Species Grown at Bishoftu, Oromiya Regional State. 1-6Wood Technology Research Center, Forest Resources and Utilization Research Directorate, Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia.

Getachew Desalegn, Melaku Abegaz, Demel Teketay and Alemu Gezahgne. 2012. Commercial timer species in Ethiopia: Characteristics and Uses - A Handbook for forest industries, construction and energy sectors, foresters and other stakeholders. Addis Ababa University Press, Addis Ababa.

ISO (International Organization for standardization) 3129. 1975. Wood-sampling methods general requirements for physical and mechanical experiments. ISO International standard no.3129. 1st edition, Switzerland, 4p.

ISO 3130.1975. Wood-Determination of moisture content for physical and mechanical experiments. ISO International standard no. 3130. Switzerland. 3 pp.

ISO 3131.1975. Wood-Determination of density for physical and mechanical experiments. ISO International standard no.3131. Switzerland. 2 pp.

ISO/DIS 4469 (International Organization for standardization/Draft International Standard). 1975. Wood-Test methods-determination of radial and tangential shrinkage. ISO/DIS Standard no. 4469. Explanatory report. Switzerland. 3 pp.

ISO/DIS 4858 .1975. Wood- Test methods-determination of volumetric shrinkage. ISO/DIS standard no. 4858. Explanatory report. Switzerland. 4 pp.

Lemmens, R.H.M.J., 2006. *Acacia caffra* (Thunb.) Willd. In: Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). Prota 7(1): Timbers/Bois d'œuvre 1. [CD-Rom]. PROTA, Wageningen, Netherlands.

Longwood F.R. 1961. Puerto Rican Woods: Their machining, seasoning and related characteristics. Agriculture Handbook No. 205. USDA Forest Service. US Government Printing Office, Washington, USA.

Moya R., Urueña E., Salas C., Muñoz F. and Espinoza O. 2013. Kiln drying behavior of lumber from ten fast-growth plantation species in Costa Rica. Wood Material Science and Engineering, 8:1, 37-45.

Reeb J.E. and Brown T.D. 2007. Air-and shed-drying lumber. Oregon State University. Extension Service.

Shiferaw Alem. 2016. Status and trends of the processed wood products trade in Ethiopia. Department of Forest Botany, Dendrology and Geo-biocenology, Mendel University in Brno, Brno, Czech Republic. Journal of Sustainable Forestry, 2016, VOL. 35, NO. 4, 251–260.

Simpson, W.T, ed. 1991. Dry kiln operator's manual. Forest service. Gen. Tech. Rep FPL-GTR-113. Madison, Wisconsion: US, Department of Agriculture. Agricultural handbook. AH No.188. 274pp.

Webb, D.B. Wood. P.J., Smith, J.P., Henman, G.S. 1984. A guide to species selection for tropical and sub-tropical plantation. Unit of tropical silviculture. Commonwealth Forestry Institute. University of Oxford. Tropical forestry papers No. 15. 2nd edition, Revised, 84-256 pp.

Lumber Seasoning Technologies of *Casuarina equisetifolia* L. Tree Species Grown at Bishoftu, Oromiya Regional State

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Abstract

Moisture content (MC) in wood, inappropriate drying (seasoning) and density are among the major factors that can strongly influence quality, suitability, usability, stability, serviceability and performance of wood and wood-based products. *Casuarina equisetifolia* lumber was investigated to determine seasoning and density characteristics of the lumber and to evaluate best lumber seasoning technologies in terms of lumber quality and appropriate utilization. Sample logs were harvested from Debere Zeit Agricultural Research Center estate. Lumber seasoning tests were conducted using air and kiln seasoning techniques. he mean initial final MC for both air and kiln seasoning stacks was of *C. equisetifolia* 48.41%, while the final MC was 12.53%. Air seasoning time for sawn boards of 3 cm thickness took 24 days to reach to about 12% MC, while kiln seasoning took 6 days. Kiln seasoning rate of the lumber species was 4 times faster than air seasoning. The species was classified as very rapid air and kiln seasoning timber species. When seasoning the lumber from 48.41% to ~ 12.5% MC, mean shrinkage (%) values of the tangential, radial and volumetric shrinkage were 8.6%, 3.43% and 11.5%, respectively and longitudinal shrinkage was nil (0%). Defects such as cup, bow, twist, crook, end split, wane, collapse, honeycomb, dead knot, and heart rot were observed with different extent on air and kiln seasoned boards. Mean density of the lumber species at green condition and when seasoned to 12% MC was 1040 and 760 Kg/m3, respectively. Seasoned density of *C. equisetifolia* lumber was classified as heavy density. The species is comparable with many indigenous and exotic timber species in density, seasoning rate and shrinkage characteristics. Further lumber seasoning research is recommended to be conducted on logs collected from well managed stands of *C. equisetifolia*.

Keywords: Density, lumber, seasoning, kiln, utilization.

Introduction

The demand and supply of forest products for industries, construction and energy for the year 2020 was projected as 132.5 million m^3 and about 28.7 million m^3, respectively (CSA, 2012; Habtemariam Kassa and Zeleke Ewnetu, 2014; Shiferaw Alem, 2016). This indicated that demand of forest products sectors in Ethiopia is 4.6

times higher than the supply. Even though many timber species are available in Ethiopia only few species were utilized in wood industries owing to the limited information on wood characteristics and utilization technologies of different tree species. Utilization of limited tree species for every intended purpose coupled with the low recovery rate of the saw mills and further processing industries, inappropriate utilization due to lack of technical experience and information on properties (here after, characteristics), the rapid development of construction (industrial, commercial and residential buildings) and increasing demand for furniture in the country, have resulted in the degradation (both in quality as well as quantity) of the existing forests and selected tree species.

Among the major factors that strongly determine the quality, suitability, service life and performance of wood and wood-based products in service are moisture content (MC), drying (here after, seasoning) and defects, variations in density, mechanical, shrinkage characteristics (tangential, radial, and volumetric), rates of seasoning, defects (natural seasoning), types of processing and utilization technologies (Kininmonth and Williams, 1980; Hodaley 1989; Simpson 1991; Denig *et al.*, 2000; FPL 2010). Quality and suitability testing research and promotion on economically potential timber species such as *C. equisetifolia* that is not yet known by the development institutions, product processing and construction sectors, manufactures and end users in the lumber market of the country has been paramount importance.

The wood Product uses of *C. equisetifolia* include heavy and light construction, shingles and wall paneling, exterior fittings, house posts, building poles, piles, rafters, electric poles, tool handles, oars, wagon wheels and mine props, carved material, boat building, railway sleepers, fence posts. In summary it has versatile uses in lumber, fiber, medicinal, pharmaceutical, tannin or dyestuff and in textiles industries (Webb *et al.,* 1984; Orwa *et al.*, 2009; Anonymous, 2017b).

An investigation was conducted with general objective of generating technical information (seasoning and density characteristics) and selecting appropriate utilization technologies grown at Bishoftu Oromiya Regional State. Specific objectives were to: (i) appraise appropriate seasoning technologies for the lumber species, (ii) determine appearance, moisture content, seasoning characteristics (seasoning rate, shrinkage characteristics, seasoning defects, handling techniques for seasoned lumber), (iii) determine density of the lumber species at different MC levels, (iv) assess biodeterioration attack during and after seasoning, and (v) indicate potential uses of the lumber species.

Materials and methods

The species

C. equisefolia L. [Family: Casuarinaceae] is an evergreen, dioecious or monoecious tree with straight and cylindrical trunk, usually branchless up to 10 m, 6-60 m tall, 40-50 cm in diameter and with a finely branched light crown (Webb *et al.,* 1984; Orwa *et al*, 2009; Anonymous, 2016). *C. equisetifolia* was officially described by Linnaeus in 1759 as *C. equisefolia*. The specific name *equisetifolia* is derived from the Latin *equisetum*, meaning "horse hair" referring to the resemblance of the drooping branchlets to horse tail (Anonymous, 2016; Anonymous, 2017a). *C. equisetifolia* ecologically may be the only woody species growing over a ground cover of dune grasses and salt-tolerant broadleaved herbs; it can also be part of a richer association of trees and shrubs collectively termed the Indo-Pacific strand flora (Orwa *et al*, 2009). It is an actinorhizal plant able to fix atmospheric nitrogen, and harbours a symbiosis with a *Frankia* actinomycete (Anonymous, 2016).

The genus *Casuarina*, native and most plentiful in Australia, but are also found in Africa, India, Indo-china, the Philippines, and parts of the Polynesian Islands. Quite plentiful in southern Florida and cultivated mostly in sandy areas near the sea and inland in Nigeria (Anonymous, 2017b). Natural distribution: latitudes: 31.5-12°s and 18-22°n. Altitudinal range: 0-1,400 m; mean annual temperature: 10-35°C and mean annual rainfall 750-2,500 mm (Webb *et al.,* 1984; Orwa *et al.*, 2009). Native distribution: Australia, Bangladesh, Brunei, Cambodia, Fiji, Indonesia, Malaysia, New Zealand, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Tonga, Vanuatu, Vietnam (Orwa *et al.*, 2009) and wide exotic distribution.

Specimen collection site

Bishoftu is located 47. km from Addis Ababa on the way to Adama high way. It site has an altitude of 1900 m, latitude 8′44″ and longitude 38′85″. It has tepid to cool sub-moist agroecology. The site has 1100 mm mean annual rainfall and mean annual maximum and minimum temperature of 28.3°C and 8.9°C (Anonymous, 2001).

Sample trees selection, harvesting, conversion and test samples preparation

In March 2016, sample trees of *C. equisetifolia* were harvested from Bishoftu Agricultural Research Center compound. The sample trees have 19.3 cm mean breast height diameter (dbh) and total volume of 7.4 m^3. Trees/wood samples harvested were not representative of merchantable log size (Figure 1). Sample trees were harvested from not well managed stand (planted in wide spacing and trees were not pruned to reduce knots). The trees were old and with many knots (defects). Several serious seasoning defects were observed and recorded. This could be attributed to big branches/knots that resulted from bad stand management. The sample trees didn't have good morphological quality, straight and cylindrical stem and free from visible defects.

Sample trees were felled, cross- cut into a series of 2.5 m long logs up to top merchantable diameter of 12 cm. Sample logs were transported to Wood Technology Research Center (WTRC) while green (> 30% MC) for the preparation and testing of samples. Logs were sawn using flat (through-and-through) type of sawing method into 3 cm thickness boards using mobile circular sawmill.

Figure1 *Casuarinaequisetifolia* during sample trees selection and harvesting at Bishoftu (1 a & 1b) ARC.

Boards were converted to samples with appropriate dimensions, quantity and quality for each wood characteristic (Moisture content, seasoning rate, seasoning defects, shrinkage and density) test. Lumber seasoning samples were selected and prepared proportionally from each tree and log at 1 m interval along height of the sample trees and marked with identification codes using an indelible waterproof permanent ink. Wood characteristics and laboratory tests were conducted following the ISO standards/ protocols (ISO 3129, 1975; ISO 3130, 1975; ISO 3131, 1975); Burley and Wood, 1977; Lavers, 1983; Simpson, 1991; Denig *et al*., 2000; FPL, 2010; Moya *et al.*,2013.

Ten defect free sawn boards with dimensions of 250 cm in length, 3 cm thickness and width equal to log diameter were selected and prepared for each air and kiln seasoning tests. The samples were used to conduct the seasoning tests and determination of the different characteristics. The middle part of the sample boards having 1 m length were used as control sample boards both for air and kiln seasoning tests. The initial MC of each sample was determined using small sections/samples cut from both ends of sample boards having 1.2 cm length and 3 cm thickness. Twenty specimens free from visible defects, clearly visible tangential and radial surfaces that have 2 cm width, 2 cm thickness and 3 cm length at green state were prepared to determine shrinkage characteristics (ISO/DIS 4469, 1975) and density. The shrinkage samples and the measurements (weights and dimensions) were also used to determine the density values of the species at different MC using mathematical formulas.

Stacking sawn boards for seasoning

Sawn boards were stacked horizontally in vertical alignments separated by well-seasoned, squared, uniform sized and standard stickers at 3 cm spacing between successive boards. The heartwood and radial boards, which have less moisture content, were placed in the middle, while the sapwood and tangential boards having high MC were placed along the sides, top and bottom of the stacks. The ends of boards were made equal in both directions. The control sample boards were properly distributed and positioned in the pockets of the different layers (bottom, middle and top) of each stack to represent the different zones/layers in the stack (Moya, *et al.*, 2013).

Stickers with a dimension of 2.5 cm width, 2.5 cm thickness and 180 cm length were placed at equal distance of 75 cm across each layer of lumber and aliened board on board from bottom of the stack to the top (Reeb and Brown, 2007). The stickers were used to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process. The short strips/stickers (2.5x2.5x20 cm) were superimposed on the long stickers stated above to easily access, measure weight of the control sample boards and moisture content of each stack progress. Top loading using eavy stones weighing about 50 Kg/m^2 were applied on top of the air and kiln seasoning stacks at a spacing of 75 cm to minimize warping of the boards (Simpson, 1991; Denig *et al.*, 2000; FPL, 2010; Moya *et al.*, 2013).

Boards for air seasoning were stacked under shed without direct exposure to moisture, rainfall or sunshine (Simpson, 1991; Denig *et al.*, 2000; FPL, 2010). Boards for air seasoning were stacked on firm level foundation/ yard having 45 cm clearance above the ground, 1.80 width and 4 m length. The boards were aligned in a north-south direction where the ends were not exposed to the direction of the wind. The north-south direction alignment of boards was done to facilitate good air circulation and reduce the direct influence of temperature, wind and relative humidity. Boards for kiln seasoning were stacked out of the kiln on the transfer carriage having dimensions of 1.6 m width, 0.30 m height and 2.7 m length and then placed in the kiln-seasoning chamber by sliding the stack on the rail.

Seasoning technologies applied

Air, microwave and artificial kiln seasoning methods were used for testing and determination of the different seasoning and density characteristics of the lumber species *C. equisetifolia.*

Microwave seasoning and initial moisture content determination

Samples were prepared green, weighted and dimensions were taken immediately to determine initial moisture content of the stack. Well ventilated oven with the temperature controlled at 105°C was used for seasoning the test pieces. The oven trays were open grids to allow free air circulation around the test pieces. Re-weighing of sections/samples at 4 hours interval was carried out and they were weighed hot, immediately after removal from the oven to minimize moisture absorption and desorption (Desch, 1986; Simpson, 1991; Denig *et al*., 2000; FPL, 2010; Moya *et al.*, 2013).The process was continued until the difference between two successive weights of each specimen became constant (0-0.2 g) and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010). The MC of air and kiln seasoning stacks determined using formulas.

Air seasoning

After initial MC determination, the control sample boards were weighed and placed into the stack, re-weighed at week interval until the average final MC of the stack reached MC of about 12%, which is the equilibrium MC for in- and out-door purposes and standard for comparison within and between timber species.

Kiln seasoning

The artificial kiln seasoning machine used in this study was well insulated with brick wall and as about 2.5 m^3 lumber loading capacity. The air velocity, temperature and humidity of the kiln were adjusted for the species. It has psychrometers (dry bulb and wet bulb thermometers) positioned indoor and outdoor of the kiln seasoning chamber/case. The kiln has been equipped with fans to force air circulation, through the chamber and air outlet. The kiln operates at a temperature range of 40-70ºC (Tack, 1969). In this study, kiln seasoning schedule Ethiopia 3 that was adapted from Sweden for hardwood species was used. The kiln seasoning schedule applied was similar for the one applied for *Eucalyptus pilularis, Eucalyptus viminalis, Tichilia dregeana* and *Casuarina equisetifolia* (Getachew Desalegn and Gemechu Kaba, 2015; Getachew Desalegn *et al.,* 2016; Getachew Desalegn *et al.,* 2017).

During kiln seasoning test samples were weighed, MC calculated, psycrometrs regulated, steaming done, and the direction of the fan changed at 8 hours interval (three times in 24 hours) to allow uniform air circulation, control the seasoning process and quality of the lumber seasoned. The process was continuous until the required final 12% MC reached (Haygreen and Bowyer, 1996; FPL, 2010; Moya *et al.*, 2013).

Data Collection

The major data collected were dimensions and weight of each sample which were used to determine the moisture content, rate of seasoning of boards, shrinkage and swelling characteristics, seasoning defects as well as density.

Major lumber characteristics tested and determined

Moisture content

Moisture content was determined in accordance with ISO 3130 (1975) procedures. All test specimens were weighed to obtain the green weight and then oven dried at a temperature of 105± 2°C to constant weight to obtain the dry weight (Haygreen and Bowyer, 1996; Reeb, 1997; Denig *et al.*, 2000; MTC, 2002; FPL, 2010; Moya *et al.*, 2013). The same method was applied for the determination of MC of the air and kiln seasoning stacks.

MC (%) = [(Green weight-Oven dry weight)/ Oven dry weight]*100 (Reeb and Brown, 2007).

Rate of seasoning

Air and kiln seasoning rates of the species were estimated from the MC samples of the species using the formula adapted from Moya *et al.* (2013). Classification of air and kiln seasoning rates was done based on the adapted standards from Longwood (1961) and Farmer (1987), respectively.

Shrinkage and swelling characteristics

Twenty samples of the lumber species with a dimension of 2x2x3 cm (ISO/DIS 4469, 1975) were seasoned in the oven seasoning chamber to a constant dimension at a temperature of 105°C. Initial dimensions and weights of all the shrinkage samples were measured and put in the oven dryer. Measurements of weights were continuous until the difference between the two successive weights of each specimen was constant (0-0.2 g). Then, the final weights and dimensions were taken as oven dry weights and dimensions, respectively. Shrinkage of each specimen at tangential, radial, longitudinal directions and volumetric were determined from green (48%) condition to 12% MC and from green to 0% MC. The different formulas were adapted from ISO/DIS 4469 (1975); ISO/DIS 4858 (1975); Chudnoff (1984); Simpson (1991); Reeb (1997); Denig *et al.* (2000); FPL (2010). Shrinkage values from green to oven dry were classified based on Chudnoff (1984).

Seasoning defects and handling of seasoned lumber

Seasoning defects of the lumber were measured (Figure 2) and seasoned boards were properly piled in the air seasoning yard, board on board, without stickers between boards. Boards were handled and conditioned well without direct access of moisture and sunshine to avoid/minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack.

Figure 2 Discussion during seasoning defects measuring.

Follow-up of seasoned boards was done for more than a year (March 2106-April 2017) and observations were recorded against seasoning defects and biodeterioration attack.

Density test

The sampling (2x2x3cm) procedures and measurements applied during shrinkage tests were used to determine the density values of the species using mathematical formulas at different MC and sample conditions (green, oven dry and seasoned to 12% MC). Basic density was determined based on green volume and oven dry weight (ISO/DIS 3131, 1975). The dry density values were converted to standard 12% equilibrium MC by applying the formulas adapted from Haygreen and Bowyer (1996); Denig *et al.* (2000); MTC (2002). Density value of the species at 12% MC was classified based on the adapted standard classification from Farmer (1987).

Results and discussion

Lumber appearance

Appearance, one of the physical characteristics of the lumber *C. equisetifolia* (Fig.3) showed a white to yellowish white, with pinkish.

Figure 3 Surface appearance of *C. equisetifolia* boards

Moisture content

Before air and kiln seasoning commenced, the mean initial MC of the lumber of moisture content of the species was 48.41%, while the final mean MC for air and kiln seasoning stacks was 13.9% and 11.97%, respectively (Table 1 and Figure 4). After seasoning, the species attained 12.53% MC. The mean 12.53% MC means that 0.13 times (12.5%) the weight of the wood substance has been occupied by moisture/water, while 0.87 times (87.47-%) was only wood substance. The MC of seasoned lumber is equilibrium moisture content (EMC) very useful during storage, manufacturing of products and shipping of sawn lumber.

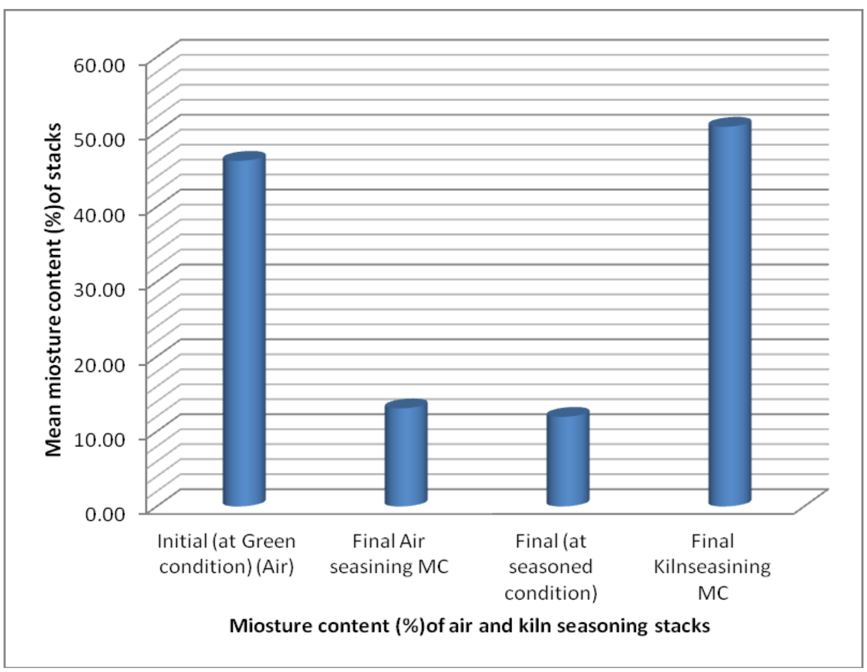

Figure 4 Initial and final MC of *C. equisetifolia* lumber stacks using air and kiln seasoning technologies.

The mean initial MC for air seasoning was 46.11%, while for kiln seasoning was 50.7%. Initial MC along height of the lumber during air seasoning varies slightly. *C. equisetifolia* bottom part had 49.48% MC; middle part had 49.13% MC, while top part had relatively the least MC (46.61%). The final mean MC for air seasoning was 13.09%, while for kiln seasoning was 11.97%. Trend of MC along height of the tree varies irregularly.

Air and kiln seasoning rate of C. equisetifolia

The time required for air seasoning of *C. equisetifolia* sawn boards that have 3 cm thickness to reach to about 12% MC was 24 days, while kiln seasoning took only 6 days (Table 1). Air seasoning rate was 0.54%/day, while kiln seasoning rate was 2.94%/day. In terms of final lumber quality, no much difference was found between air and kiln seasoning technologies. The kiln seasoning was four times faster than air seasoning. The species was classified as very rapid in air and kiln seasoning. The kiln seasoning significantly shorten the seasoning time required to season the lumber to 12% MC. Oak (*Quercus* spp.) lumber having 10 cm thickness had a maximum moisture loss rate of 2-4%/day, while maple (*Acer* spp.) lose 8-10%/day (Reeb and Brown, 2007).

Table 1 Lumber seasoning and density characteristics (Kg/m^3) of *C. equisetifolia* at different MC (%).

Position along height	Moisture content (%)				Shrinkage characteristics (%) 0% MC							Density (Kg/m3)			
	Initial MC of Air seasoning stack	Final MC of Air seasoning	Initial MC of Kiln seasoning stack	Final MC of Kiln seasoning	Tangential	Radial	Longitudinal	Volumetric	Radial	Longitudinal	Volumetric	Test (at Green condition)	Basic Density	Oven dry	12 % MC
Bottom	49	13	50	13	17	6	0	22	4	0	13	1070	640	820	810
Middle	49	16	50	11	14	5	0	18	3	0	11	1030	660	810	800
Top	40	10	53	13	12	6	0	17	3	0	10	1010	580	700	680
Grand mean	46	13	51	12	14	6	0	19	3	0	12	1040	620	770	760
SD	5	3	2	1	2	1	0	3	0	0	2	31	67	42	72

Shrinkage characteristics

The mean shrinkage percentage values of *C. equisetifolia* lumber seasoned from green (48.41%) MC to 12.5% MC was 8.6%, 3.4 % and 11.5 % in tangential, radial and volumetric, respectively. When lumber of *C. equisetifolia* was seasoned from green to 0% MC the tangential, radial and volumetric shrinkage characteristics were

14.3, 5.7 and 19.2%, respectively (Table 1 and Figure 5). The longitudinal shrinkage values of seasoned wood at 12% MC varies from 0.1%-0.3%; Radial shrinkage: 2.1-7.9%; Tangential shrinkage: 4.7-12.7%. Tangential shrinkage is generally 1.5 to 2 times greater than radial shrinkage in line with the results obtained in this study.

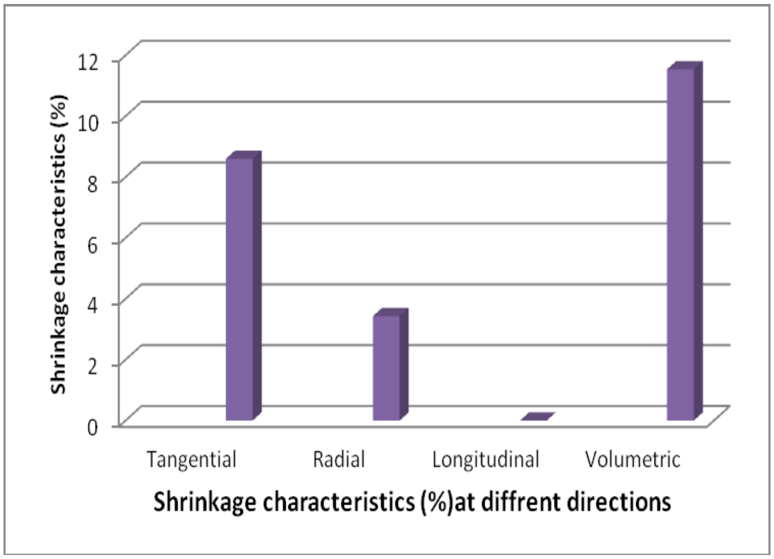

Figure 5 Shrinkage characteristics (%) when *C. equisetifolia* lumber seasoned from green to 12% MC.

Seasoning defects

In air seasoning, seasoning defects cup, bow, twist, crook, end split, wane, collapse as well as dead knot and heart rot defects were observed and recorded with different extent (Table 2). In Kiln seasoning, seasoning defects cup, bow, twist, crook, end split, wane, collapse, Honeycomb as well as dead knot and heart rot were observed and recorded with different extent (Table 2).

Table 2 Seasoning defects extent in air and kiln seasoning stacks.

	Common seasoning defects occurred										Other seasoning defects occurred	
	Warp				Checks		Splits		Knots			
Seasoning method	Cup (mm)	Bow (mm)	Twist (mm)	Crook	Surface check (mm)	End check	End split diameter	End split length(cm)	Knots Diameter(mm)	Number of knots		
Air	7	5	11	4	*	*	4	24	70	6	Collapse	Wane
Kiln	8	6	10	3	*	*	4	38	67	6	Collapse	Wane

*- observed

The defects could be attributed to knots that resulted from bad stand management. The wood of *C. equisetifolia* tends to warp and crack on seasoning (Midgley and Sylvester, 2008).

Average kiln seasoning rate for *Cupressus lusitanica*, *Gmelina arborea*, *Tectona grandis* ranges 0.20 - 1.27%/hour (Moya *et al.*, 2013). Maximum rate of moisture loss (%)/day for some hardwoods ranges 1 - 2%, while for other species such as ranges 2% (Oak) - 13.8% (Soft maple) (Reeb and Brown, 2007).

Seasoned lumber storing and handling

Seasoned boards were properly piled on foundation, board on board (under shed), without stickers and top loading. Boards were handled well without direct access of rain and sunshine and inspected for more than a year (March 2106 - April 2017). Within this time no further seasoning defects, neither infestation nor biodegradation attack were observed.

Density characteristics

Mean density of *C. equisetifolia* lumber species at green (initial), basic and oven dry conditions and when dried to 12% MC were 1040, 770, 620 and 760 kg/m3, respectively (Table 1). The density value 760 kg/m3 at 12% MC can be classified under light density (kg/m3) lumber species. From similar studies, the wood of *C. equisetifolia* lumber is hard and heavy with an air-dry density of 900-1200 kg/m3, sapwood being slightly heavier than heartwood. Green logs have moisture content of 40-60% (Webb *et al*., 1984; Midgley and Sylvester, 2008; Anonymous, 2017b).

Comparable lumber species in density values at 12% MC (760 kg/m3) with an accuracy of about 10% and belonging to the same light density classification (650-800 Kg/m3) were *Cletis africana*, *Diospyros abyssinica*, *Eucalyptus globulus*, *Eucalyptus nitens*, *Syzygium guineense*, *Warburgia ugandensis* (Getachew Desalegn *et al*., 2012). Density value of the study species at 12% MC were also in comparison with similar studies of (Webb *et al*.,1984; Midgley and Sylvester, 2008; Anonymous, 2017b).

The best comparable species with *C. equisetifolia* in density at at 12% MC were *Cletis africana* (760 Kg/m3), *Diospyros abyssinica* (790 Kg/m3), *Eucalyptus globulus* (780 Kg/m3), *Eucalyptus nitens* (760 Kg/m3), *Syzygium guineense* (740 Kg/m3), *Warburgia ugandensis* (770 Kg/m3) (Getachew Desalegn *et al*., 2012).

Conclusions and recommendations

C. equisetifolia has multipurpose lumber and non-timber forest products and services. The species was comparable with many indigenous and home-grown exotic lumbers of Ethiopia in terms of density, seasoning rate and shrinkage characteristics. Several serious seasoning defects were observed that need care during seasoning. Trees and logs must be properly harvested, sawn, boards stacked properly and seasoned to less than 20% MC. Boards shall be seasoned using kiln seasoning technology to minimize seasoning time, maintain wood quality and suitability for different applications.

Air seasoning under shed, with proper stacking and top loading recommended. Seasoned lumber of the study species must be properly stacked and handled without direct access of moisture and biodeteriorating agents. Lumber has to be rationally utilized at specified MC and density for intended construction and furniture purposes. Further lumber seasoning research recommended from well managed stands of C. equisetifolia available in Ethiopia.

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References

Agriculture Handbook No. 205. USDA Forest Service. US Government Printing Office, Washington, USA.

Anonymous 2001. Forestry research strategy. Forestry Research Sector. Ethiopian Agricultural Research Organization. Addis Ababa, Ethiopia.

Anonymous 2017a. Casuarina equisetifolia (casuarina). [Online 03November 2017], https://www. cabi.org/ isc/ datasheet/16718.
Anonymous 2017b. Casuarina equisetifolia. Wood Database and Searchable Library. [Online 03 November 2017], https://www. woodworkerssource.com/online _show_wood. php? wood=Casuarina%20equisetifolia
Anonymous.2016. Casuarina equisetifolia [Online 07 April 2016], https://en. wikipedia. org/wiki/Casuarina_equisetifolia.
Burley, J. and Wood, P.J. (eds.).1977. A Manual on the Species and Provenance Research with Particular Reference to the Tropics. Tropical forestry paper No. 10A. Department of Common wealth Forestry Institute. University of Oxford. UK.
Chudnoff, M. 1984. Tropical timbers of the world. Forest Products Laboratory. Forest Service. US Department of Agriculture. Agriculture handbook, no. 607, Madison, Wis. USA. 451pp.
CSA 2012. Retail Price at Addis Ababa Terminal Market, Addis Abeba.
Denig, J., E.M., Wengert, W.T. Simpson. 2000. Drying of hardwood lumber. Forest Products Laboratory.
Desch, H.F. 1986. Timber, its structure, characteristics and utilization. 6th edition. HMSO, London.
Farmer R.H. 1987. Handbook of hardwoods. Department of the Environment. Building Research
Forest Service. United States. Department of Agriculture (USDA). General Technical Report. PL- GTR-118. 138pp.
FPL (Forest Products Laboratory). 2010. Wood handbook-wood as an engineering material. Forest Service. Gen. Tech. Rep FPL-GTR-113. Madison, WI: US, Department of Agriculture, 463 pp.
Getachew Desalegn and Gemechu Kaba. 2017. Imperative physical characteristics and potential uses of Eucalyptus pilularis, Eucalyptus viminalis andTichilia dregeana lumber tree species. In፡ Forest and Environment: Technologies and Information, Mehari Alebachew, Getachew Desalegn, Wubalem Tadesse, Agena Anjulo and Fassil Kebede (eds) (June 2017). Proceedings of the 1st Technology dissemination workshop, 26-27 November 2015. Tokuma Hotel, Adama, Ethiopia.
Getachew Desalegn, AntenehTesfaye, Gemechu Kaba and Saifu Amanuel. 2016. Seasoning and density characteristics and potential uses of Gmelina arborea lumber tree species grown at BongaDebre, Ethiopia. Wood Technology Research Center, Forest Resources and Utilization Research Directorate, Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia.
Getachew Desalegn, Melaku Abegaz, Demel Teketay and Alemu Gezahgne. 2012. Commercial timer species in Ethiopia: Characteristics and Uses - A Handbook for forest industries, construction and energy sectors, foresters and other stakeholders. Addis Ababa University Press, Addis Ababa.
Habtemariam Kassa and Zeleke Ewnetu. 2014. The importance of forestry in Ethiopia and the need for investing in the sector to meet national goals and international commitments (Un-published report).
Haygreen J.G., and Bowyer J.L.1996. Forest products and wood science. An introduction. 3rd edition. USA, 484p.
Hodaley, R.B. 1989. Understanding wood. Sixth edition. The Taunotn Press INC. USA. 256 pp.

ISO (International Organization for standardization) 3129. 1975. Wood-sampling methods general requirements for physical and mechanical tests. ISO International standard no.3129. 1st edition, Switzerland, 4p.
ISO 3130.1975. Wood-Determination of moisture content for physical and mechanical tests. ISO International standard no. 3130. Switzerland. 3 pp.
ISO 3131.1975. Wood-Determination of density for physical and mechanical tests. ISO International standard no.3131. Switzerland. 2 pp.
ISO/DIS 4469 (International Organization for standardization/Draft International Standard). 1975. Wood- Test methods-determination of radial and tangential shrinkage. ISO/DIS Standard no. 4469. Explanatory report. Switzerland. 3 pp.
ISO/DIS 4858 .1975. Wood- Test methods-determination of volumetric shrinkage. ISO/DIS standard no. 4858. Explanatory report. Switzerland. 4 pp.
Kininmonth J.A. and Williams D.H, 1980. Measuring the moisture content of wood. New Zealand Forest Service, Wellington, New Zealand.
Lavers G.M. 1983. The strength characteristics of timber. Forest Products Research. Bulletin no. 50. 3rd edition. London. 60p.
Longwood F.R. 1961. Puerto Rican Woods: Their machining, seasoning and related characteristics.
Madison, Wisconsion: US, Department of Agriculture. Agricultural handbook. AH No.188. 274pp.
Midgley S.J. and Sylvester R. 2008. Casuarina equisetifolia. [Online 03 November 2017], http://uses.plantnet-project.org/en/Casuarina_equisetifolia_(PROSEA).
Moya R., Urueña E., Salas C., Muñoz F. and Espinoza O. 2013. Kiln drying behavior of lumber from ten fast-growth plantation species in Costa Rica. Wood Material Science and Engineering, 8:1, 37-45.
MTC (Malaysian Timber Council). 2002. Timber drying .http://www.mtc.com./mypublication/ library/drying /contents.html . Date accessed 30/10/2002.
Orwa C, A Mutua, Kindt R, Jamnadass R, S Anthony. 2009 Agroforestree Database: a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/ sites/ treedbs/treedatabases.asp).
Reeb J.E. 1997. Seasoning wood. Cooperative Extension Service. University of Kentucky. College of Agriculture.
Reeb J.E. and Brown T.D. 2007. Air-and shed-drying lumber. Oregon State University. Extension Service.
Shiferaw Alem. 2016. Status and trends of the processed wood products trade in Ethiopia. Department of Forest Botany, Dendrology and Geo-biocenology, Mendel University in Brno, Brno, Czech Republic. Journal of Sustainable Forestry, 2016, VOL. 35, NO. 4, 251–260.
Simpson, W.T, ed. 1991. Dry kiln operator's manual. Forest service. Gen. Tech. Rep FPL-GTR-113.
Tack, C.H. 1969. Uganda timbers. Ministry of agriculture and forestry, Forest department. Printed by the government printer, Entebbe, Uganda, 138 pp.
Webb, D.B. Wood. P.J., Smith, J.P., Henman, G.S. 1984. A guide to species selection for tropical and sub-tropical plantation. Unit of tropical silviculture. Commonwealth Forestry Institute. University of Oxford. Tropical forestry papers No. 15. 2nd edition, Revised, 84-256 pp.

Zhang S.Y. 2003.Wood quality attributes and their impacts on wood utilization. Forintek Canada crop. Quebec, Canada.

Chemical Properties of *Yushania alpina* Grown in the Central Highland of Ethiopia

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Abstract

This paper studied the chemical composition of cultivated 3, 4- and 5-year-old highland bamboo (*Yushania alpina*) which were classified into three position (top, medium and bottom) to determine the main compositions especially cellulose, lignin, extractive and ash content. From all culms representative samples were converted to the required size of wood chips to prepared sample for chemical testing. Then the specimens prepared from bottom, middle and top portions for the three ages were used to determine the chemical properties in accordance to American Society for Testing and Materials (ASTM) standards except for cellulose test determined according to Kurschner and Hoffer method. All parameters in the experiment were expressed by percent based on dry basis. From this research, we have found small but significant increases in mean cellulose content from the base to the top of the culm at all three ages. The lignin content in *Y. alpina* species of bamboo is in the ranged of 23.04 to 30.03%. The mean values of the chemical constituents in 3, 4 and 5- year-old culms were 51.83, 54.94 and 49.78% for cellulose content, 28.28, 24.99 and 24.53% for lignin content, 7.8, 10.09, and 9.54% for alcohol-toluene extractive, respectively. In general, the comprehensive knowledge of the chemical components in the bamboo species will facilitate the use of the materials in the forestry industrial sector and help to enhance their utilization in the chemical and bio-chemical related industry.

Keywords: Highland bamboo, age, position, cellulose, lignin, extractives, ash contents.

The Influences of Age, Height and Growing Site on the Chemical Compositions of *Yushania alpina* Grown in Central and Northwest Ethiopia

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Abstract

This work focuses on chemical properties such as cellulose, lignin, extractive and ash content of highland bamboo (*Yushania alpina).* Samples used for characterizing chemical properties were collected from bamboo of three different ages (three, four and five), and culm positions (top, middle, and bottom) grown at three different growing sites (and) of central (Tikurinchini and Shenen*)* and northwest (Injibara*)* Ethiopia. All chemical analysis was conducted according to the American Society for Testing and Materials (ASTAM) standards except cellulose content which was characterized by Kurschner and Hoffer method. The results were analyzed by SAS Statistical Software. Except for ash content, the study showed that the chemical properties of *Y. alpina was* significantly (*P<0.001*) affected by growing site, age and culm position. Mean values of ashcontent significantly (*P<0.001*) varied by culm position versus growing site. The top culm position of age three had maximum cellulose content (64%) whileminimum lignin content (23.04%) was observed for age four from Injibara growing site. Extractive yield highly significant occurred in the bottom culm position of age three (12.28%) from *Shenen* growing site. The least ash content was recorded for the middle culm position (1.48%), which yielded 38.84% lower than the maximum (2.11%). The results revealed that cellulose content, lignin content and extractive yield are significantly varied by growing site, age, and culm position. Ash content also statistically similar characters on age and culm position.

Keyword: Cellulose, Extractive yield, Lignin, *Yushania alpine*

Introduction

Bamboo is the familiar name for a member of a taxonomic group of perennial grass with a large woody stem or culm belonging to the family Poaceae, subfamily Bambusoideae (Ohrnberger, 1999; Gurmessa *et al*., 2016). In recent years, bamboo has attracted more attention with the greatest potential as an alternative to timber due to its easy propagation, fast growth, and high yield (Li *et al*., 2007; Zhan *et al*., 2015). It provides important raw material forpulp and paper production industries, construction as well as for other versatile uses and services. Bamboo properties differ with age, location, species and external factors (Abd Latif, 1993; Zhan *et al*., 2015).

Ethiopia has two indigenous bamboo species, namely, highland bamboo (*Yushania alpina)* and lowland bamboo (*Oxytenanthera abyssinica)*, covering over one million hectares of land with a wide distribution and is the largest in Africa. Out of which the *Y. alpine* is estimated to comprise over about 20% or 300,000 ha out of which 19,000 ha planted by farmers (Desalegn and Tadesse, 2014; Tolessa *et al*., 2017). However, its utilization is fundamentally undeveloped due to a lack of awareness about its multiple uses and lack of scientific knowledge about their production and main properties.

The choice of bamboo species for various applications is not only associated with physical and mechanical properties but also to the chemical composition. The chemical composition in relation to age and culmpositions as well as growing site are important factors that influence the processing and utilization of bamboo culms and has a big influence on the physical and mechanical properties (Liese, 1985; Zhan *et al*., 2015). The chemical composition of bamboos also has an influence on deciding what kinds of bamboos with which kind of material in combination is suitable for the utilization. Nevertheless, due to a lack of knowledge about the chemical properties of *Y. alpina,* its potential for industrial utilization in the country is not yet well-understood. Moreover, age-dependent changes in chemical composition are less well characterized. Hence, this study is conducted to determine the influences of age, height and growing site on the chemical compositions of *Y. alpine* culms that will finally be used to improve its utilization.

Materials and Methods

Study Area and sample collection

Bamboo culms for this study were collected from the potential growing sites such as Injibara (northwest), Shenen and Tikurinchini (central) districts in the country. The age of culms was determined based on visual inspection (i.e. internode cover and color, sheaths in culms, and surface lichen growth) by local experienced field personnel familiar with the history of the clump. Ten representative *Y. alpina* culmsfor each age group, namely, three, four and five years old were harvested from the above-mentioned sites. For sample preparation, internodes were consecutively numbered from bottom to top for each culm which was then cut into three sections, i.e. bottom, middle and top, each with an equal number of internode sections.Then coded as B for the bottom, M for middle and T for top and chipped and dried in an oven at 40°C for three days for all the three age groups and sites. The dried sample was ground into a powder with Willey mill to pass through a No. 40 mesh (425 μm) sieve but retained on a No. 60 mesh (250μm) sieve. The resulting material was placed in a polyethylene bag labeled accordingly for further chemical analysis. A total of 27 treatment combinations were used for the study. The design for the experiment was a completely randomized design with three replications. The main chemical compositions which were studied are extractive, ash, cellulose and lignin content.

Characterization of chemical properties of *Y. alpina*

Except for cellulose content, all tests were conducted followingthe standards of the American Society for Testing and Materials (ASTM). There was a minor modification for testing extractive content test in this case instead of benzene solutions, toluene solution was used. The method followed for each chemical property analysis ispresented below.

Cellulose determination (Kurschner and Hoffer method)

One-gram milled culm sample was placed into a 250ml round bottom flask. It was refluxed with three successive portions of a mixture of concentrated nitric acid (20 percent volume by volume) in ethyl alcohol. The reflux process was conducted on average for one hour each. At the end of the extraction process, the flask containing the extractive nitric acid solution was transferred into a known weight of gauche crucible to proceed to the filtration process by using vacuum suction. The extractive materials were washed several times by distilled water. Then the acid mixture extractives were dried in an oven at 105^{0}C for an average of 1hour, cooled in desiccators, and weighed until a constant weight was obtained.

$$Cellulose\ (\%) = \frac{\mathrm{W2}}{\mathrm{W1}} 100$$

Where: -

W1 = the amount of extract free samples taken for analysis

W2 = the residual mass of cellulose

Klason Lignin of bamboo culms (ASTMD 1106-56 Method)

One gram of oven-dried extractive-free culm powder was placed in 100 ml beakers. 15 ml of cold sulfuric acid (72%) was added slowly in each beaker while stirring and mixed well. The reaction proceeded for two hours with frequent stirring. Then after, the specimens were transferred, into 1,000 ml flasks by washing them with 560 ml of distilled waterand diluting the concentration of the sulfuric acid to three percent. The flasks were placed on hot plates for four hours. The flasks were then removed from the hot plates and the insoluble materials were allowed to settle. The contents of the flasks were filtered by vacuum suction into G-3 glass crucibles of known weight. The residues were washed with distilled water and then oven-dried at 105±2^{o}C. Crucibles were then cooled in desiccators and weighed until a constant weight was obtained. The following formula was used to obtain the Klason lignin content of culm samples:

$$\mathrm{Lignin\%} = \frac{(\mathrm{w2} - \mathrm{w1})\mathrm{x}\ 100}{\mathrm{O.D.weightofsample}}$$

Where: -

W2 = stands for weight of crucible + sample.
W1 = stands for weigh of empty crucible.
O.D = oven-dry test specimen

Alcohol-Benzene Extractive Solubility (ASTMD 1107-56 Method)

Two grams (O.D.) culm samples were placed into filter paper extraction thimbles. The thimbles were placed in a soxhlet extraction tubes. The boiling flasks contained a 2:1 solution of benzene and distilled alcohol respectively were placed on heating mantles. The extraction was conducted for eight hours at a rate of approximately six siphoning per hour. After the extraction process is completed, the thimbles were removed from soxhlet tubes and dried at 105 ± 2^{0}C for overnight. The materials were removed from the thimbles and weighed. The following formula was used to obtain the alcohol-benzene solubility content of bamboo:

$$Extractive\ (\%) = ((W2 - W1)/W1)100$$

Where: -
W2 = Stands for O.D. weight of the sample before extraction.
W1 = Stands for O.D. weight of the sample after extraction.

Ash content (ASTMD 1102-84 Method)

The ash content is an approximate measure of the mineral salts and other inorganic matter in plant fiber. The ash in bamboo culms is the inorganic residue after combustion at a temperature of 575 ± 25^{o}c. An empty crucible was ignited and covered in the muffle at 600^{o}C for 3hours, cooled in desiccators containing silica gel up to room temperature and weighed to the nearest 0.1 mg. About 2 gm of the sample was taken with crucible and kept in a muffle furnace at 600 ± 50^{0}C for 4 hours. Removal of all the carbon particles was ascertained by blocking air from the formation of black char particles. The crucible was cooled in desiccators with silica gel to room temperature and weighed. The process of heating and cooling was repeated until the difference in two successive weightings is less than 1 mg. The lowest weight was recorded as follows:

$$Ash\ content\ (\%) = (W1/W2)100$$

Where W_1 = weight of ash, g
W_2 = weight of test specimen, g moisture-free

Data analysis

Effects of height (position), age and growing site on chemical compositions were assessed by analysis of variance using SAS software version 9.0 and SAS Studio The classical general linear model with two-way ANOVA was used to fit the data. Mean separation was carried out using LSD at (*P<0.001*).

Results

Variation in Chemical Properties of *Y. alpina* culms: -Cellulose content, lignin content and extractive yield of *Y. alpina* culms were significantly (*P<0.001*) affected by growing site, culmage and culm position (Table 1). While the ash content of culms taken at three positions and the different growing sites also showed a highly significant difference at P = 0.001 (Table 2). The interaction effect between growing sites, age and culm position showed highly significant variation cellulose and lignin contents and extractive yield. Although, ash content as well as highly significantly (*P<0.001*) difference for bamboo culm position versus bamboo growing site.The chemical composition of the culms of *Y. alpina* found in this study is inline with what is found by Xiaobo Li. (2004) that showed significant variations among bamboo ages of 1, 3 and 5 and top, middle and bottom culm positions.

Table 1 Analysis of variance of chemical composition at different age, position and location for *Y. alpina* grown in Central and Northwest Ethiopia

Source of Variation	DF	Cellulose	Klason Lignin	Extractive Solubility
Loc	2	534***	64***	27.95***
Age	2	63***	67***	10.15***
Pos	2	36***	11***	8.77***
Loc*Age*Pos	8	61***	5.53***	4.73***
Error	54	54	53	54
R^2		0.94	0.89	0.83
CV		3.21	3.56	11.89

***= Significant at *P*< 0.001; **= Significant at *P*< 0.01; *= Significant at *P*< 0.05; ns= Non-significant at *P*< 0.05, EOC_0 = Essential oil content at harvest, EOC_w = Essential oil content at wilting day

Table 2 Analysis of variance of ashcontent on different growing site and culm position of*Y. alpina* grown in Central and Northwest Ethiopia

Source of Variation	DF	Mean Square
		Ash
Location	2	0.35***
Position	2	2.05***
Location*Position	4	3.35***
CV	4.75	
R^2	0.99	

***= Significant at *P*< 0.001; **= Significant at *P*< 0.01; *= Significant at *P*< 0.05; ns= Non-significant at *P*< 0.05,

Interaction effect of culm age, position and growing site on chemical composition of *Y. alpina*,

Cellulose content

As presented in Table 1, the interaction effect between the comparison factors (age, culm position and growing site) on cellulose content of *Y. alpine* varied significantly. Li *et a*l., (2010) which is stated that there is variation in the chemical composition bamboo depending on their age. In this study maximum, cellulose content was found on culm age of three years (64%) in top position followed by culms of age five (58.5%) in the middle culm position at the Injibara site. The next higher value of cellulose content occurred in meddle and bottom culm position on bamboo tree age 4 with statistically at par according to the values 52.5% and 54%, respectively. The smallest cellulose content was obtained on bamboo tree age 3 (43.69%) in the top Bamboo culm position which grown at the Tikurinchini site and followed statistically similar values was observed middle (43.95%) and bottom (43.64%) bamboo culm position at Shenen and Injibara growing sites, respectively. Different authors have confirmed that by the previously studied cellulose content was varied for different bamboo species; they include bamboo *Kumamoto* (Japan) and Moso bamboo (*Phyllostachys pubescens* Mazel) with the value of 47% and 45%, respectively (Scurlock J.*et al*., 2000 and Yamashita Y. *et al*., 2010). The least and the most amount of cellulose content in this study are much closed and an adequate observed; comparing with the discussion part mentioned above.

Klason Lignin content

The interaction effect of between growing site, Bamboo age and Bamboo culm position on Klason lignin content of Yushania *alpina* in the study has shown highly significant and statistically similar lignin content were recorded in bottom and meddle with the value of 31.56%, and 31.55%, respectively on Bamboo tree age 3 at *Shenen* growing site. The next higher value of lignin content takes place in the top bamboo culm positionat *Shenen* growing site and followed statistically uniform in bottom culm positionat *Injibara* growing site together on Bamboo tree age 3 with the value of 30.59% and 30.03%, respectively. The least lignin content was a witness on Bamboo age 4 (23.04%) in the top and followed on Bamboo age 5 (23.16 %) in middle culm position together at *Injibara* for *Yushania alpina* (Table 3). When computing Klasonlign in separately in each growing site on bamboo age 3 across the bottom to top culm position observed statistically similar and higher yielded recorded than on age (4 and 5) at *Shenen*. Klason lignin for bamboo age 4 and 5 culm appeared to show relatively small difference across the study sites, which is almost similar observation made by (X.B.Li., *et al*., 2007), which was found no significant difference Klason lignin between bamboo ages (1, 3 and 5) and bamboo culm position.

Extraction yield

The interaction effect (Bamboo tree age, Bamboo culm positionversus growing site) on extractive yield of *Yushania alpina*is highly significant occurred in bottom bamboo culm position on Bamboo tree age 3 (12.28%) at the *Shenen* growing site and followed *Injibara* and *Shenen* growing sites with the respective value of 11.37% on Bamboo tree age 4. The least extractive yield was foundin top (5.79%) bamboo culm positions at grown *Tikurinchini* and followed statistical uniform values have observed in the same culm position on Bamboo tree age 3 (6.48%), which grew at *Shenen* (Table 3). This result comparing with the previous reported by Tolessa, *et al.,* (2017), which is much higher than in *Oxytenanthera abyssinica* (5.6%). X.B.Li., *et al*., (2007), in their studies reported that alcohol-toluene extractivecontent increased from the base to the top ofthe stem in the three- and five-year-old bamboosand showed a continuous increase with age. Nevertheless, the present studies revealed that the extractive yield decreases from the bottom to the top culm position in the three, four and five-year-old bamboo at each growing site. However, average extractives yield increased significantly with age both growing site and five age bamboo having the highest average content (9.54%) at Injibara. These variation might be permissible because the nature of wax material attached to inner, middle and outer layers in the cellular structure of the plant depending on culm position and bamboo age maturity and also the particle size of the extracted material influences on the accessibility of the required components (tannins,gums, sugars, starches and coloring matter) present in bamboo andindicated easy access and penetration of chemicals to the cell wall materials.

Ash content

As shown in Table 4, the ash content was highly significantly affected by the bamboo culm position versus the growing site in the studies. Maximum and minimum ash content was found on top (3.77%) and bottom (0.94 %) Bamboo culm position both collected at *Shenen.* In this study, the overall mean value of ash content revealed a significantly higher value for top Bamboo culm position (2.42%), which is in conformity with other findings mad by Xiaobo Li., 2004. the ash content in the top portion of the culm was found maximum across the age (1,3 and 5) with the value of 1.95%, 1.41%, and 1.35%, respectively. The least ash content was recorded for the middle Bamboo culm position (1.48%), which yielded 38.84% lower than the maximum (2.42%) (Table 4).

Table 3 Interaction effect between culmage, position and growing site on cellulose, lignin and extraction content of *Y. alpina*

Bamboo age	Bamboo culm position	Tikurinchini			Shenen			Injibara		
		Cellulose	Lignin	Extractive	Cellulose	Lignin	Extractive	Cellulose	Lignin	Extractive
3	Bottom	45.34^{hijk}	28.03^{fghij}	9.95^{bcd}	45.99^{ghijk}	31.56^{a}	12.28^{a}	51.83^{cd}	30.03^{abcd}	$7g^{hij}$
	middle	47.14^{efgh}	27.7^{ghijk}	6.64^{ij}	48.59^{ef}	31.55^{ab}	9.21^{cde}	54.33^{c}	24.89^{no}	8.56^{defg}
	Top	43.69^{k}	29.56^{cdef}	4.71^{k}	45.42^{hijk}	30.59^{abc}	6.48^{ij}	64^{a}	29.92^{bcde}	7.83^{efghi}
4	Bottom	45.12^{hijk}	28.31^{fghij}	8.08^{efghi}	44.47^{ijk}	27.34^{hijk}	11.37^{ab}	54^{c}	26.49^{iklmn}	11.37^{ab}
	middle	46.63^{fghi}	26.30^{klmn}	7.45^{fghij}	46.4^{fghij}	26.55^{jklm}	8.89^{ed}	52.5^{c}	25.45^{mno}	9.75^{bcd}
	Top	$49.53d^{e}$	27.3^{hijkl}	6.88^{hij}	45.51^{hijk}	27.11^{ijkl}	7.05^{fghij}	58.33^{b}	23.04^{p}	9.17^{ed}
5	Bottom	45.34^{hijk}	28.03^{fghij}	9.95^{bcd}	47.51^{efgh}	28.93^{efgh}	8.65^{def}	43.64^{k}	24.5^{op}	10.83^{abc}
	middle	44.38^{ijk}	28.31^{efghi}	9.22^{cde}	43.95^{jk}	29.26^{cdefg}	8.43^{defgh}	58.5^{b}	23.16^{p}	9.11^{ed}
	Top	46.27^{fghij}	28.58^{efghi}	5.79^{jk}	45.83^{ghijk}	27.21^{ijkl}	7.63^{efghi}	47.17^{efgh}	25.92^{imno}	8.67^{def}

Table 4 Interaction effect of culm position and location on ash content of *Y. alpina*

Bamboo culm position	Ash content (%)			
	Tikurinchini	*Shenen*	*Injibara*	Mean
Bottom	2.72[b]	1.21[h]	2.41[c]	2.11[b]
Middle	1.84[e]	0.94[i]	1.67[f]	1.48c
Top	2.09[d]	3.77[a]	1.40g	2.42[a]
Mean	2.22[a]	1.97[b]	1.83[bc]	

Conclusions

In this study, we have observed that cellulose, lignin and extractive contents of *Y. alpina* culms significantly varied by growing site, age, and culm position. Ash content also demonstrated similar trend on bamboo age and culm position. The *Shenen* growing site showed 43.94% at middle culm position for culm age five and significantly higher cellulose content than Tikurinchini and Injibara study sites. While lignin (31.56%) and extractive (12.28%) content also significantly higher percentage yield was found at *Shenen* than the two study sites. The least ash (0.94%) content was found inthe middle culm position and the bamboo plants grown at *Shenen*. The overall mean of culm position across the three growing sites indicated that highly significant ash (2.42%) content was found on top culm position. Our studies give as a good image of the chemical composition profile and support the idea that *Yushania alpine* bamboo plants have potential use for chemical and biochemical industrial applicationsin the country.

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Reference

Abd L.M., 1993. Effects of age and height of three bamboo species on their machining properties. *Journal of Tropical Forest Science* 5(4), 528-535.

Tolessa A., Woledeyes B..; Feleke S., 2017. Chemical composition of lowland bamboo (*Oxytenantheraabyssinica*) grown around Asossa Town, Ethiopia. *World Scientific News, 74,* 141-151*.*

Desalegn G., and Tadesse W., 2014.Resource Communication. Resource potential of bamboo, challenges and future directions towards sustainable management and utilization in Ethiopia.*Forest Systems* 23(2): 294-299.

Gurmessa F., Gemechu T., Soromessa T., Kelbessa E., 2016.Allometric Equations to Estimate the Biomass of *Oxytenanthera Abyssinica* (A. Rich.) Munro. (Ethiopian Lowland Bamboo) in Dicho Forest, Oromia Region, Western Ethiopia.*International Journal of Research Studies in Biosciences (IJRSB) 4(12), PP 34-48.*

Li L.J., Wang Y.P., Wang G., Cheng H.T., Han X.J., 2010. Evaluation of properties of natural bamboo fiber for application in summer textiles. Journal of Fiber Bioengineering and Informatics.*3 (2), 94-99*

Scurlock J., Dayton D., Hames B.,2000. An overlooked biomass resource? Biomass and Bioenergy. *19 (4), 229-244*.

X B.Li., shup T.F., Hse G.Y., and Eberhard T.L., 2007. Chemical changes with maturation of the bamboo species *phy-llostachkspubescens.*

Xiaobo Li., 2004.Physical, chemical, and mechanical properties of bamboo and its utilization potential for fiberboard manufacturing. *Louisiana State University and Agricultural and Mechanical College*, xli4@lsu.edu.

Yamashita Y., Shono M., Sasaki C., Nakamura Y., 2010. Alkaline peroxide pretreatment for efficient enzymatic saccharification of bamboo. Carbohydrate Polymers. *79 (4) : 914-920.*

Production and Characterization of Charcoal Briquette from *Oxytenanthera abyssinica, Yushania alpina, Acacia mellifera,* and *Prosopis juliflora*

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Abstract

Production of sustainable and renewable energy source from locally available biomass feedstocks provides great opportunities to achieve sustainable growth and development in economic, social and environmental aspects for all nations across the globe. This study focused on production and characterization of charcoal briquettes from forest biomasses such as, *Oxytenanthera abyssinica, Yushania alpina, Acacia mellifera, and Prosopis juliflora,* which were collected from different regions of Ethiopia (Amhara, Oromia and Somali). The experiment was conducted to determine moisture content (MC), volatile matter (VM), ash content (AC), calorific value (CV), fixed carbon (FC) and sulfur content (SC). The results were analyzed by using Statistical Analysis System (SAS) software. The analysis indicated that the effect of parameters considered in the experiment (i.e. Temperature, Binder ratio, Number of press and pressure) on the four species type and sample types were significant at level of probability, $P = 0.0001$. The maximum amount of MC was recorded for *P. juliflora* samples (i.e. Sawdust, Charcoal and Briquette) with respective values of 7.95%, 6.70 % and 6.88 %. The minimum amount of moisture was recorded on *Y. alpina* Sawdust with value of 5 % and *A. mellifera* Charcoal with value of 5.29 %. Moreover, the least amount of VM (17.31 %) was found in biomass briquettes produced by *Y. alpina* species and have better fuel quality in comparison with the other species. The maximum CV was recorded on Densified Biomass Briquette (DBB) obtained from *Y. alpina* and *P. juliflora* with the values of 7106.8 cal/gm and 6755.6 cal/gm, respectively. The study suggested that charcoal briquette produced from selected species exhibits good fuel characteristics (i.e. higher CV, less MC, and high level of FC, and low SC) in compliance with the internationally accepted standard. Therefore, the obtained research output in the study encourages proper utilization of the biomass feedstocks for consumers and ensure healthier environment via the supply of renewable sources of energy.

***Keywords*:** Briquette, *Oxytenanthera abyssinica, Yushania alpina, Acacia mellifera,* and *Prosopis juliflora*

Introduction

Energy is vitally necessary to harness the life of human being and makes significant contributions for economic, social and environmental aspects of human development. The potential sources of this energy can be classified into two major categories, namely renewable and non-renewable energy sources. The sustainable and renewable energy sources are considered as a better option and preferable to the non-renewable sources because the non-renewable energy sources such as gasoline, coal, kerosene, diesel, etc. have no capability to be replenished and would be exhausted (Kuti, 2007). Furthermore, the environmental impacts as a result of emissions of greenhouse gases (GHG), CO_2, SOx, and NOx, etc. during combustion and utilization of the non-renewable energy resources is a driving force towards the use of alternative, renewable and sustainable energy sources for domestic cooking, space heating, heat and power generation and heating of rural and urban households' particularly in developing countries. Among the renewable sources of energy, forest biomass feedstocks such as *Oxytenanthera abyssinica, Yuahania alpina, Acacia mellifera, and Prosopis juliflora* have become one of the most promising choices as cooking fuels due to their adequate availability and would have substantial roles in bioenergy (i.e. densified bio-briquettes) production processes (Vongsaysana, 2009). However, the utilization of these biomass resources in their natural or raw form as fuel is difficult because of their very low bulk density, low calorific value (CV) and the excessive amounts of smoke they generate during combustion, difficult to handle, store and transport.

Application of effective and efficient briquetting technology is one of the ways of ameliorating calorific value (CV), the bulk density and handling techniques for such forest biomasses (Wilaipon, 2007). This requires appropriate densification of the subjected biomass resources to produce the densified bio-briquettes (DBB) with better handling characteristics and meliorated volumetric calorific value (Oladeji, 2010). The production and processing of bio-briquettes from forest biomass resources illustrate the potential of proper technology for waste wood and fuelwood utilization (Styles, *et al*., 2008). Moreover, briquettes have several advantages over fuelwood in terms of convenience in use, cleanliness, greater heat intensity, and qualified fuel characteristics, uniformity in size and requirement of relatively smaller space for storage and transportation (Wamukonya and Jenkins, 1995; Yaman, *et al*., 2000; Stefan and Hans, 2014). During the utilization of charcoal briquette, there would be low emissions of the oxides of the combustible elements, for instances, the emission of CO_2 from the combustion of biomass feedstocks is equivalent to the amount of CO_2 absorbed during its growing cycle by means of photosynthesis; hence, the net CO_2 emission into the environment is approximately zero by mass (Hall and Scrase, 1998; Weither, et al., 2000; Han, 2004). The aim of the present study was production and characterization of charcoal briquette from *O. abyssinica,* *Y. alpina, A. mellifera and P. juliflora* and to evaluate its corresponding fuel properties of such as physical properties, proximate analysis, and ultimate analysis, calorific value (CV).

Materials and methods

Description of Study Area

The study was conducted in *Pawe*, *Injibara and Borena* areas of Ethiopia. The study sites were selected based upon adequate resource availability and considered as potential representative sites for the selected species across the regions of Ethiopia. The detail descriptions of study sites were expressed in Table 1 below.

Table 1 Description of the Study Sites

Study Site	Regional State	Altitude in masl.	Annual Rainfall in (mm)	Mean Annual Temperature in (^{0}C)	Literature source
Pawe	*Amhara region*	1050	1200-1585	16-32	[12]
Injibara	*Amhara region*	2540-3000	1813	16.25	[13-14]
Borena	*Oromia*	1350-1800	588	19	[15]
Metehara	*Oromia*	980	567	25.8	[15]

Sample Collection and Preparation

Sample of *P. juliflora* stem with 3-4 cm in diameter was collected from the Oromia region in February 2013. Sample of *A. mellifera* was collected from Borena zone in 2015, and samples of bamboo species (*O. abyssinica* and *Y. alpina*) were collected from Pawe and Injibara areas in 2016. Then, the collected samples of specified species were chopped into suitable size, and then dried for further milling, washed in tap water to remove impurity from outer part of the stem and dried in oven dryer at a temperature of 65^{0}c for 48 hr. Then, the oven-dried samples were milled using hammer mill into 2-3 mm in size, and further milled into mesh sizes of 0.25 mm and 1.4 mm using the disk mill.

Carbonization of Samples of the Specified Species' Strip Wood

The carburization of the strip wood (i.e. the disk mill with mesh sizes of 0.25 mm and 1.4 mm) was carried out in the furnace at a temperature of 500^{0}c for 60 and 90 minutes, respectively. Then, the charcoal was removed immediately from the furnace and cooled under tap water. The cooled charcoal was spread over the floor and thereby dried in a naturally ventilated room with relative humidity (RH) of 86-89% at an ambient temperature of 25^{0}c - 30^{0}c for three days. The dried charcoal was cut into small strips manually by using a sledgehammer to reduce sample sizes into the appropriate mesh for making briquette.

Processing of Charcoal for Making Briquette

The prepared powder samples were taken a turn by turn and proportionally mixed with the binder to make briquette. *Acacia seyal* gum Arabic was used as a binding agent for making briquette during the experimentation. The binder concentration of 5% was prepared and manually mixed with the prepared charcoal powder with solid to volume ratio in the range of 0.65 - 0.87 g/ml. The mold was then filled up to the edge of the mold tube and it was pressed by the Peterson Press. During the operation the pressure of machine (i.e. the Peterson Press) was reached the maximum when the lever was at its lowest position; and then, dropped off before starting the next cycle. During the process, distilled water was squeezed out from the holes around the mold. The small-time gap was maintained between two pressure cycles to facilitate the squeezing of water out from the briquette. Finally, 20 - 25% (wt.) moisture content of the densified biomass briquette (DBB) was obtained. A natural drying process method was used in the experiment until the moisture content of the DBB lies within the range of 12 - 15% [16].

Proximate Analysis of the Sawdust and Charcoal Briquettes Produced from Different Species

Determination of Moisture Content

Percentage of the moisture content (PMC) was determined using standard method of American Society for Testing Materials (ASTM D 4442-07) on basis of dry biomass was found by weighing samples of obtained briquette (W_1) and oven drying it at 105 ^{o}C and intermediate weight of sample was recorded in every 60 minutes until the constant weight was obtained (W_2). Then, the difference in weight (W_1 - W_2) was calculated to determine the sample's percentage moisture content using the following equation: -

$$PMC = \frac{W1 - W2}{W1} \times 100$$

Where,

W_1 = Initial weight of the sample before drying
W_2 = Final weight of the sample after drying
PMC = Percentage Moisture Content

Determination of Volatile Matter

The percentage of volatile matter (PVM) content was determined using the standard method CEN/TS 15148. Two grams of the sample was pulverized and oven-dried at 105 ^{o}C until its weight was constant. Then, the sample was heated at 550 ^{o}C for 10 min and weighed after cooling in desiccators. The PVM was calculated using the following equation:

$$PVM = \frac{W1 - W2}{W1} \times 100$$

Where PVM = Percentage of Volatile Matter
W_1 = Initial weight of the sample
W_2 = Final weight of the sample after cooling

Determination of Ash Content

The percentage of ash content (PAC) was determined using the CEN/TS14775 standard method. The percentage of ash content (PAC) was also determined by heating 2g of the pulverized sample in the furnace at a temperature of 550 ^oC for 4hrs and weighed after cooling in a desiccator to obtain the weight of the ash. The PAC was determined using the following equation:

$$PAC = \frac{W2}{W1} \times 100$$

Where,
W_1 = Initial weight of the dry sample
W_2 = Final weight of ash obtained after cooling sample
PAC = percentage of Ash content

Determination of Fixed Carbon

The percentage of fixed carbon (PFC) was calculated by subtracting the sum of percentage volatile matter (PVM) and percentage ash content (PAC) and percentage moisture content from 100 % as shown in the following equation:

$$\text{Fixed Carbon} = 100\,\% - (PAC + PMC + PVM)$$

Determination of Caloric value

The calorific value of briquette determines the amount of heat energy present in the material. The calorific value was determined in line with the moisture content, ash content, and volatile matter on the briquettes. The calorific value (kJ/kg) of the samples under test was calculated from the temperature rise of the briquettes when burnt and its heat capacity. A calorimeter apparatus was used to determine the calorific value of the produced briquettes.

Determination of Sulfur Content

The sulfur content was determined by Eschka method using ASTM-D 3177 standard. One gram of sample was put into a porcelain crucible and mixed with 3.00 g of Eschka mixture. The mixture was then covered with 1.00 g of Eschka mixture. The crucibles were then put in a muffle furnace and heated gradually to 800 °C for 60 minutes.

Data Analysis

A total of the four tree species (*O. abyssinica, Y. alpina, A. mellifera and P. juliflora*) treatments with three replications and 6 measurement parameters were designed in the experiment. Statistical analysis of data was carried out using SAS Software, Version 9 and Microsoft Excel (2010) computer software. Means that exhibited significant differences were compared using the Least Significant Difference (LSD) at ($P < 0.001$) level.

Results and discussion

Variation in Proximate and Ultimate analysis on the Selected Species

The proximate analysis such as moisture content, volatile matter, fixed carbon and ash content of the four species where highly significant at probability, $P = 0.0001$, and affected by sample type and species type (Table 2); Whereas, the ultimate analysis (caloric value and sulfur content) among the selected species were also significant at level of probability, $p = 0.0001$, and affected by sample type and species type (Table 2). Moreover, the interaction effect among the selected species has shown a highly significant value on the proximate and ultimate analysis (Table 2).

Table 2 Analysis of Variance (ANOVA) for evaluation of test parameters on species of *Yushania alpina, Oxytenanthera abyssinica, Prosopis juliflora,* and *Acacia mellifera* ***= significant at $p < 0.0001$; **= significant at $p < 0.01$; significant at $p < 0.05$; and

Source of variation	*DF*	Mean square					
		MC	VM	FC	Ash	CV	SC
Species Type	3	4.25***	20.16***	108***	126***	505782***	0.08***
Sample Type	2	4.48***	10276***	8374***	85**	21785563***	0.12***
Species Type * Sample Type	6	3.79***	53.91***	104***	158***	674239***	0.02***
Cv		7.58	3.93	2.95	8.56	2.81	31.09
R^2		0.90	0.99	0.99	0.99	0.99	0.91

non- significant at $p < 0.05$

DF – Degree of freedom, MC – Moisture content, VM – Volatile matter, FC – Fixed carbon, CV – Calorific value, SC– Sulfur content, Cv - Coefficient of variance and R – Regression factor

The Interaction Effects of Sample type and Species type on Proximate Analysis of the Selected Species

Moisture Content

The interaction effect of the moisture content between the species types and sample type has shown significant value at *p = 0.001,* with the corresponding average moisture content of sawdust (6.82%), charcoal (5.60 %) and briquette (6.09 %), respectively. Regarding the species of *A. mellifera* and *P. juliflora*, it has been shown that statistically similar and significantly higher values of moisture contents were recorded as 8.55% for sawdust of *A. mellifera* and 7.95% for sawdust of *P. juliflora* (Table 3). Moreover, relatively higher values of moisture contents were also obtained from samples of *P. juliflora* charcoal (6.70%) and its corresponding sample briquettes with the value of 6.63%. On the other hand, statistically similar and minimum values of moisture contents were obtained from *Y. alpina* sawdust with value of 5% and from sample of *A. mellifera* charcoal (4.62%) (Table 3).

Volatile Matter

The interaction effect of volatile matter between the selected species types and sample types has shown that it is significant at the level of probability, *p= 0.001*. The value of volatile matter content for the selected species varies in pre-carburization and post-carburization processes of biomasses. With this regard, it has been illustrated that maximum values of volatile matter content were obtained in the sawdust of *O. abyssinica* (71.95%), *Y. alpina* (74.52%), *A. mellifera* (72.11%) and *P. juliflora* (63.05%) with the corresponding mean value of volatile matter content of 70.41% in pre-carbonization process. In this study, the recorded values of volatile matter content in the sawdust of the selected species followed the reports of 70.1% volatile matter content in the sawdust of tree species (Adenkunle, *et al*., 2015). On the other hand, the minimum and statistically similar values of volatile matter content were recorded in post-carburization processes (i.e. in charcoal with mean value of 19.91% and in densified biomass briquettes with mean value of 20.17%) (Table 3).

When the volatile matter (VM) contents of biomasses compared transversally, it was demonstrated that for each sample type, significantly the least values of VM were observed on DBB of *Y. alpina* (17.70%), *O. abyssinica* (19.18%) and *P. juliflora* (20.56%) (Table 3). The presence of low volatile matter in the resulting DBB enhances its combustion tendency in which a heterogeneous smokeless and flameless burning process takes place within the porous fuel or burning on the surface (De Souza and Sandberg, 2004). Moreover, the DBB sample with the minimum volatile matter content is anticipated to have the maximum energy value or calorific value (Imeh, *et al*., 2017). Therefore, the presence of the least volatile matter content in the densified biomass briquette produced from sawdust of *Y. alpina* species enables the briquette to have better fuel characteristics or fuel quality in comparison with the rest biomass briquettes of the selected species in the study.

Ash Content

The interaction effect of ash content among the selected species type and sample types is significant at the level of probability, *P = 0.01*. In order to compare the amount of ash content transversally among the sample types in pre-carburization and post-carburization processes, it has been indicated that the minimum mean value of ash content (6.55%) was obtained in pre-carburization (i.e. in sawdust sample of the selected species) than in post-carburization processes (i.e. in charcoal and densified biomass briquette products with mean values of ash content 11.88% and 9.16%, respectively). Moreover, the minimum percentage of ash content was recorded for DBB produced from *P. juliflora*, *A. mellifera* and *Y. alpina* with their respective values of 3.56%, 6.56%, and 5.18%; whereas, the maximum value of ash content (21.34%) was recorded in DBB produced from sawdust of *O. abyssinica* (Table 3).

The decrease in the amount of ash content in the biomass increases the quality of fuel (Shafizadeh, 1981; Kumar, *et al*., 2010). Hence, it has been shown that the DBB produced from sawdust of species: *P. juliflora*, *A. mellifera,* and *Y. alpina* relatively exhibits better fuel characteristics or fuel quality than the DBB produced from the sawdust of *O. abyssinica*. This study also indicated that the average value of ash content in Densified Biomass Briquette and carbonized sawdust for all selected species were in the range of 9.16 - 11.88 % (Table 3). The obtained values were much better than the reported values of average ash content by Aries et al (2017), which were in the range of 14.6 - 31% for Feasibility of Biomass Briquette Production from Municipal Waste.

Fixed Carbon

Fixed carbon is the major quality measuring parameter that determines the energy behaviors in the production of densified biomass briquettes. It has been shown that the interaction effects of fixed carbon between sample types and species types are of significant value at level of probability, *P = 0.0001*. In the study, maximum value of fixed carbon was recorded on DBB made from species of *Y. alpina* (71.17 %) and *P. juliflora* (70.22 %). The minimum percentage of fixed carbon was observed in DBB made by *A. mellifera* and *O. abyssinica* with respective values of 56.60 % and 53.01 % (Table 3).

Table 3 Interaction effects between species type and sample type on proximate analysis of *Oxytenanthera abyssinica, Yushania alpina, Acacia mellifera,* and *Prosopis juliflora*

Sample Type	Moisture Content (%)			Volatile Mater (%)			Fixed Carbon (%)			Ash Content (%)		
	Sawdust	Charcoal	Briquette	Sawdust	Charcoal	Briquette	Sawdust	Charcoal	Briquette	Sawdust	Charcoal	Briquette
Oxytenanthera abyssinica	5.79d^{e}	5.2ef^{g}	5.71^{def}	71.95^{b}	14.29^{h}	19.18^{fg}	19.07^{f}	62.31^{c}	53.01^{e}	3.53^{h}	18.43^{b}	21.34^{a}
Yushania Alpina	5f^{g}	5.89^{cde}	6.42^{bcd}	74.52^{a}	20.43^{ef}	17.7^{g}	18.6^{f}	64.23^{bc}	71.17^{a}	1.97^{g}	9.45^{e}	5.18^{g}
Acacia Mellifera	8.55^{a}	4.62^{g}	5.67^{def}	72.11^{ab}	21.82^{de}	20.72^{def}	17.51^{f}	58.37^{d}	56.6^{d}	4.05^{gh}	14.47^{d}	6.56^{f}
Prosopis Juliflora	7.95^{a}	6.7^{b}	6.63^{bc}	63.05^{c}	23.09^{d}	20.56^{ef}	12.28^{g}	65.04^{b}	70.22^{a}	16.66^{c}	5.16^{g}	3.56^{h}
Mean	6.82^{a}	5.60^{b}	6.11^{ab}	70.41^{a}	19.91^{b}	20.17^{b}	6.55^{b}	11.88^{a}	9.16^{a}			

Means followed by the same letters under the same column are statistically non-significant at the level of probability, $P = 0.05$.

Calorific Value (Heating Value)

The calorific value is the principal quality index for fuels (Demirbas and Sahin, 1998). The calorific value of densified biomass briquettes relies on the moisture content, ash content and fixed carbon content (Tabares, *et al*., 2000) in relation with other factors such as species types, raw materials' pretreatment, types of binding agent, particle's size, solid to liquid ratio and the nature of briquetting machine. Hence, the mixing of pretreated biomass species with appropriate ratio of binding agents is helpful to produce the DBB with better fuel characteristics (Ajit, *et al*., 2017).

The interaction effect among the selected species types and sample types with respect to the calorific values of DBB has shown significant value at the level of probability, $P = 0.001$. In the study it has been found that the DBB produced from species of *Y. alpina* and *P. juliflora* with respective calorific values of 7167 cal/gm and 6979 cal/gm exhibits good fuel characteristics in comparison with DBB produced from species of *A. mellifera* (6791 cal/gm) and *O. abyssinica* (6140 cal/gm) (Table 4). Moreover, the observed calorific values of DBB showed an improvement in fuel quality when relatively compared with the reported value of 4641.14 cal/gm in previous work (Perera, *et al*., 2004).

Table 4 Interaction effects between species type and sample type on ultimate analysis of *Oxytenanthera abyssinica, Yushania alpina, Acacia mellifera* and *Prosopis juliflora*

Sample Type	Calorific Value (cal/gm)			Sulfur Content (%)		
	Sawdust	Charcoal	Briquette	Sawdust	Charcoal	Briquette
Oxytenanthera abyssinica	4390^{g}	6485^{d}	6140^{e}	0.24^{b}	0.37^{a}	0.09^{cd}
Yushania alpina	4737^{f}	6558^{cd}	7167^{a}	0.17^{bc}	0.39^{a}	0.06^{cd}
Acacia mellifera	4587^{fg}	6071^{e}	6791^{bc}	0.22^{b}	0.23^{b}	0.04^{d}
Prosopis juliflora	3393^{h}	6225^{cd}	6979^{ab}	0.02^{d}	0.02^{d}	0.02^{d}
Mean	4277^{c}	6335^{b}	6769^{a}	0.16^{b}	0.25^{a}	0.05^{c}

Means followed by the same letters under the same column are statistically non-significant at the level of probability, $P = 0.05$.

Sulfur Content

The sulfur content in the produced DBB contributes to the emission of compounds of SO_x into the atmosphere during the utilization of the fuel. The interaction effect among species type and sample type on the amount of sulfur content has shown significant value at level of probability, $P = 0.001$. The overall mean value of DBB produced from all species was recorded to be 0.05 %. This value was relatively lower than the value of sulfur content in charcoal (0.16 %) and sawdust (0.25 %) (Table 4). In addition, statistically similar values of sulfur content were found in DBB (i.e. 0.09%

from *O. abyssinica*, 0.06% from *Y. alpina*, 0.04% from *A. mellifera* and 0.02% from *P. juliflora*) ranging from the mean value of 0.02 – 0.05 % by dry matter weight. The obtained values of sulfur content in the experiment were lower when compared to fuels of other biomass briquettes such as mixed paper, bituminous coal and refuse-derived fuel (Demirbas and Sahin, 1998; Vassilev, *et al*., 2010; Stolarski, *et al*., 2013) and it followed the DIN 51731 standards of < 0.3% and < 0.08%, respectively.

Conclusion and recommendations

The increase in the number of human population and depletion of non-renewable energy resources have necessitated the exploration of sustainable, renewable and environmentally friendly energy sources. Another driving forces behind this research were the need to address the environmental consequences and health hazards associated with the utilization of solid fuels such as fuelwood and coal as well as to develop an effective means of recycling and managing forest products and by-products of the wood processing industries.

The most relevant findings in the present study were the production of environmentally friendly solid biofuel (i.e. charcoal briquettes) from sawdust of *O. abyssinica, Y. alpina, A. mellifera* and *P. juliflora;* and characterization (i.e. proximate and ultimate analysis) of the corresponding products accordingly. The experiment was conducted to determine moisture content, volatile matter, ash content, calorific value, fixed carbon, and sulfur content. The results were analyzed by using Statistical Analysis System (SAS) software. The analysis showed that the effect of parameters considered in the experiment (i.e. moisture content, volatile matter, fixed carbon, calorific value and sulfur content) on the four species types and sample types were significant at level of probability, $p = 0.0001$; whereas, the ash content was significant at $P = 0.001$.

The domestic use of charcoal briquettes in low-income families provides great opportunities as an alternative, renewable and sustainable energy source that could be further developed and implemented at large scale. It is also helpful and contributes to the economic revaluation of the forest biomass and wood wastes from wood processing industries while insuring mitigation of greenhouse gas emissions.

The produced DBB from the selected species has also positive outcome as it exhibits higher calorific value, less moisture content, high levels of fixed carbon and low sulfur content in the range within the international acceptable limit. The energy content of charcoal briquette is considered enough for domestic use in low-income sectors. Therefore, it is recommended that sawdust from wood processing industries should be utilized properly; and the use of charcoal briquettes produced from sawdust of *O. abyssinica, Y. alpina, A. mellifera* and *P. juliflora* will also be helpful for the fuel cost savings, higher performance in domestic cooking, and the ease of use and health care issues.

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References

Adenkunle J.O., Ibrahim J. S. and Kucha E.I., 2015, Proximate and Ultimate Analyses of Biocoal Briquettes of Nigerian's Ogboyaga and Okaba Sub-bituminous Coal. British Journal of Applied Science & Technology 7(1): 114-123.

Ajit Kaur., Madhuka Roy and Krishnendu Kundu, 2017, Densification of Biomass by Briquetting: A Review. *Int J Recent Sci Res*. 8(10), 20561-20568. DOI: http://dx.doi.org/10.24327/ijrsr.2017.0810.0916.

Anonymous, 1988, National Atlas of Ethiopia. Ethiopian Mapping Authority. Addis Ababa.

Aries Roda D. Romallosa and Eckhard Kraft, 2017, Feasibility of Biomass Briquette Production from Municipal Waste Streams by Integrating the Informal Sector in the Philippines. *Resources*.

Dagnew Y. and Fikremariam H., 2017, Assessment of Physico-chemical properties of gum-arabic of commerce from *Acacia senegal* found in different localities of Ethiopia.

De Souza, F. and Sandberg, D., 2004, Mathematical model of a smoldering log. Combustion and Flame, 139:227-238.

Demirbas, A. &Sahin, A., 1998, Briquetting waste paper and wheat straw mixtures. Fuel Processing Technology, 55(2), 175-183.

Hall D. O. and Scrase J.I., 1998, Will Biomass be the environmentally friendly fuel of the future? *Biomass and Bioener*gy 15:357-367.

Han L.V., 2004, *Co-firing of rice husk for electricity generation in Malaysia*. B.Eng; Dissertation, Faculty of Engineering and Surveying, University of Southern Queensland.

Imeh E. Onukak, Ibrahim A. Mohammed-Dabo, Alewo O. Ameh, Stanley I.R. Okoduwaand Opeoluwa O. Fasanya, 2017, Production and Characterization of Biomass Briquettes from Tannery Solid Waste. *Recycling, 2: 17; doi: 10.3390/recycling2040017.*

Kumar R., Pandey K.K., Chandrashekar N., Mohan S, 2010, Effect of tree-age on calorific value and other fuel properties of Eucalyptus hybrid. J. For. Res., 21, 514-516.

Kuti O. A., 2007, Impact of charred palm kernel shell on the calorific value of composite sawdust briquette. *Journal of Engineering and Applied Sciences,* 2: 62-65.

Oladeji J. T., 2010, Fuel Characterization of Briquettes Produced from Corncob and Rice Husk Resides. Pacific Journal of Science and Technology. 11 (1):101-106.

Perera K. K. C. K.; Rathnasiri P. G., Senarath S. A. S., Sugathapala A. G. T., Bhattacharya S. C., Abdul Salam P.,2005, “Assessment of sustainable energy potential of non-plantation biomass resources in Sri Lanka”, Bio mass and Bio energy, Vol. 29, Issue 3, 199-213.

Shafizadeh, F., 1981, Basic principles of direct combustion. In Biomass Conversion Process for Energy and Fuels; Sofer, S.S., Zabrosky, O.R., Eds.; Plenum Press: New York, NY, USA; 103 - 112.

Stefan H. and Hans F., 2014, Emission of biomass combustion plants.

Stolarski, M.J., Szczukowski, S., Tworkowski, J., Krzyzaniak, M., Gulczynski, P., &Mleczek, M., 2013, Comparison of quality and production cost of briquettes made from agricultural and forest origin biomass. Renewable Energy, 57:20-26.

Styles D., Thorne F. and Jones M. B., 2008, Energy crops in Ireland: an economic comparison of willow and miscanthus production with conventional farming systems. Biomass Bioenergy, 32, 407- 421.

Tabarés J.L.M., Ortiz L., Granada E., Viar F.P., 2000, “Feasibility study of energy use for densificated lignocellulosic material (briquettes)”, Fuel, Vol. 79, Issue 10, 1229 -1237.

Vassilev, S.V., Baxter, D., Anderson, L.K., & Vassileva, C.G., 2010, An overview of the chemical composition of biomass. Fuel, 89 : 913-933.

Vongsaysana, 2009, Comparison of the physical-chemical properties of briquette charcoal and wood Charcoal *Environment and natural resources journal*, 7:12-24.

Wamukonya, L. and Jenkins, B., 1995, Durability and relaxation of sawdust and wheat straw briquettes as possible fuels for Kenya. Biomass and Bioenergy 8(3): 175-179.

Weither J., Saenger M., Hartge E. U., Ogada T., and Siagi Z., 2000. Combustion of agricultural residues. *Progress in Energy and Combustion Science* 26:1-27.

Wilaipon P., 2007, “Physical Characteristics of Maize Cob Briquettes under Moderate DiePressure”. American Journal of Applied Science, 4:995-998.

Yaman, S., Sahan M., Haykiri-acma, H., Sesen, K. and Kucukbayrak, S., 2000, Production of fuel briquettes from olive refuse and paper mill waste. Fuel Processing Technology 68: 23-31.

Comparative Growth Performance of Fast-growing Tree Species for Woodfuel Production in Selected Highland Area of Ethiopia

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Abstract

Biomass fuel is the most important source of energy in Ethiopian highlands where the fuelwood demand is high. The objective of the study was to evaluate the performance of 11 tree species for fuelwood production in Diksis Woreda, Oromiya Region of Ethiopia. Randomized Complete Block Design with three replications was employed for the purpose. Survival count, root collar diameter growth, height and Diameter at breast height (DBH) were measured annually until six year since the time of planting. A one-way ANOVA was performed, and treatments separation were made by using LSD Fisher Tests ($P \leq 0.05$). *Eucalyptus saligna* showed maximum survival (98%), followed by *E. grandis* (89%), *E. camaldulensis* (87%), *E. globulus* (86%) and *Acacia decurrens* (83%); while the lowest survival rate was recorded for *Schinus molle* (37%). Most of the Eucalyptus species showed good growing performances both in height and in DBH. The highest average DBH growth (6±1.75 cm) registered for *Eucalyptus saligna* and the age-height graphs on the other hand indicated that *Eucalyptus viminalis* is the fastest growing in height (8 ± 2.13 m) followed by *E. globulus* (7.5±1.7 m) and *E. saligna* (7.2±2.31 m), respectively. The wood volume estimation six year after planting also showed significant differences among the six most selected species and *E. globulus* showed the highest significant overall mean stem volume (10±3.73 m^3), with the exceptional of *E. saligna* (8.64± 0.34 m^3) and *E. viminalis* (7 ± 1.33 m^3). Thus, these three species recommended for fuelwood plantations in the area. However, an ecological based study on the species effects in other potential highlands recommended before using for large-scale fuelwood plantations.

Keywords: Biomass, DBH, Height, Survival, Oromiya, Wood volume,

Effects of Culm Position and Age on Chemical Properties of *Yushania alpina* Grown at Dire-Inchini in North Part of Ethiopia

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Abstract

This paper studied the effect of chemical compositions on the indigenous species of *Yushania alpina* (highland bamboo), which is grown at Dire-Ichini in the north part of Ethiopia. The experiment has been done to determine extractive yield, cellulose content, lignin content and ash content. Chemical characterization was carried out according to the standard outlined in ASTM except Kurschner -Hoffer method for cellulose determination. The results were analyzed by using SAS Statistical Software. From the study it has been shown that the main effect of culm position on cellulose content and the interaction effect between age and position on cellulose and lignin content were not significant ($p<0.05$). The main effects of extractive yield and ash content with respect to bamboo age and culm position was highly significant ($p<0.0001$). The least lignin content was obtained at the middle culm position for age four species with value of 27.44%. The maximum yield of extractive contents was found in bottom culm position for age five species with value of 9.95% and minimum extractive content was obtained in top culm position for age three species with the value of 4.71%. The percentage composition of cellulose was found in a range of 43.69% - 49.53% and statistically there was no difference across the culm position. The least ash content was recorded for age four culms species (1.29%) with yield of 54.09% lower than the maximum. In view of the results, it was observed that Bamboo tree age, Bamboo culm position and interaction of the two factors have clear impact on all the chemical compositions.

Key words: Cellulose, Extractives, Lignin, *Yushania alpina*

Introduction

Bamboo is a woody perennial belonging to the family of grasses, *Gramineae* (*Poaceae*) with distinctive qualities. It is a self-sustaining, self-regenerating, fast growing species and renewable non-timber natural resource (Bystriakova, *et al.,* 2004).It has gained a considerable attention as a sustainable and renewable fast growing energy resource with short growth cycles of four to seven years (Kigomo, 2007). The raise in population number with increasing economic development and energy needs has resulted to depletion of other forest resources has led to exploration of bamboo forests for commercial exploitation (Muchir, *et al.*, 2013).

Bamboo is well known as a multipurpose plant with a number of applications ranging from: pulp and paper, furniture, construction materials, fence, handicraft, edible shoots and animal fodder (CIBART, 2004; Kassahun, 2004). It has been given much attention by governments across the world for its proper utilization and it would not be exhausted, abundant and environmentally friendly (Asif, *et al*., 2007).

Ethiopia has two indigenous bamboo species namely *Yushania alpina* and *Oxythenanthera abyssinica* which covers an area of 31,003 and 1,070,198 hectares, respectively (Kassahun, *et al*, 2000). *Y. alpina* is growing at steeper and higher altitude while *O. abyssinica* is growing at lowland parts of the country. *Y. alpina* offers an alternative source of energy because of its fertile regeneration and fast growth, besides its wide distribution in the study area and previous research work on this bamboo have mainly focused on mechanical, physical and nutritional properties of the species and less on energy potential such that it has been neglected by the bioenergy industry as a potential energy alternative (Engler, *et al.,* 2012). *Y. alpina,* is predominantly found in north-western, south-western, and central parts of the country. Bamboos are usually well known by high level biomass production per small land area, fastest growth rate, and bamboos are environmentally friendly (Senyanzobe, *et al.,* 2013). Seeding and flowering are the essential means for reproduction and new generations (Bystriakova, *et al.,* 2004) and on the other hand, the indigenous method of Ethiopian farmers in propagating bamboo is the offset method - the use of the portion of culms and the rhizomes (Ahlawat, *et al.,* 2002). Moreover, bamboo is the most effective in controlling soil erosion mechanism, stabilizing drainage channels, conserving moisture and reinforcing embankments (Zhou, *et al.*, 2005) due to its accumulation of leafy mulch and extensive rhizome-root system. The aim of present study was comparison of Culm Position and Age on chemical properties of *Y. alpina* grown at Dire-Inchini in Western part of Ethiopia.

Material and Methods

Study Area

The *Y. alpina* culm samples for this study were collected from Dire-Inchini 72 km distance from Addis Ababa in the northern part of Ethiopia which have a respective altitude and longitude of $8^{0}59^{'}N37^{0}51^{'}E$, respectively and an elevation of 2101 meters.

Sample Harvesting and Drying

Bamboo culms were collected from the area of Dire-Inchini district in April 2016. The age of culms was estimated based on visual inspection (i.e. color, sheaths in culms and surface lichen growth) by experienced field personnel familiar with the history of the culm Twelve representative bamboo culms for each age group, namely, three, four, and five years old were harvested. Details for the sampling method were previously reported by (Li, 2004): Internodes were consecutively numbered from bottom to top for each culm which was then divided into three sections, i.e. bottom, middle and top, each with an equal number of internodes sections. The selected internodes from each selection and age group were cut into small strips with a razor blade. The strips were dried in an oven drier at 40^0C for 8hrs and then, grounded in a Wiley mill equipped with a No. 20 mesh screen. The grounded material was placed in a shaker and particles that passed through a No.40 mesh sieve (425-µm) yet retained on a No. 60 mesh sieve (250- µm). The resulting material was placed in a polyethylene bag according to the experimental setting for further chemical analysis in the study. A total of 27 treatment combinations were used for the study, comprising three levels of position (bottom, middle and top) and three levels of bamboo culm ages (three, four and five years). During the study the design used for the experiment was completely randomized design (CRD) with three replications (Gomez and Gomez, 1995).

Characterization of Chemical properties on Bamboo species

All tests were conducted under the standards of American Society for Testing and Materials (ASTM) except for Cellulose content of *Y. alpine* where Kurschner and Hoffer method was applied. There was a minor modification for extractive content test. Instead of benzene solutions, toluene solution was used. The exact standard that was followed for each chemical property analysis and presented as per specified in Table 1.

Table 1 Standards followed for chemical analysis

Property	Standard
Cellulose	Kurschner and Hoffer method
Klason lignin	ASTMD 1106-56
Alcohol-toluene solubility	ASTMD 1107-56
Ash Content	ASTMD 1102-84

Statistical Analysis

Effects of culm position and age on chemical properties were done with SAS software version 9.0 and SAS Studio (which is free university license and very good for assumption checking). The classical general linear model with two-way ANOVA fits the data very well as shown on the results. Mean separation tests/analyses were carried out using LSD at ($P < 0.001$).

Results and Discussion

Variation in Culm Position and Age on Chemical Properties of Y. alpina

Except the interaction effect of bamboo ages versus culm position on lignin content and the main effect of culm position on cellulose content were highly significantly ($p <$

0.001) difference for extractive yield and ash content on main effects of bamboo age and culm position and their interaction between bamboo age and culm position while, cellulose and lignin content were significantly (p < 0.001) different for main effect of bamboo age (Table 2).

Table 2 Analysis of Variance (ANOVA) for chemical properties of *Y. alpina* grown at Dire-Incheni

Source of variation	*DF*	Mean square			
		Extractive	cellulose	*Lignin*	Ash
Age	2	11.60***	7.05**	5.53**	0.7***
Position	2	15.27***	0.45ns	3.07*	1.84***
Age*position	4	2.38***	17.12***	1.23ns	0.46***
Error	18				
CV		3.70	2.18	3.07	5.81
R^2		0.98	0.82	0.62	0.96

***= Significant at $p < 0.001$; ** Significant at $p < 0.01$; *= Significant at $p < 0.05$; ns= Non- significant at $p <$ 0.05

The Main Effects of Culm Position and Age on Lignin Content of Y. alpina

The main effects of age and culm position on Klason lignin content of *Y. alpina* in the study had shown highly significant and statistically similar lignin content were recorded at top and bottom culm positions with the value of 28.49% and 28.41%, respectively. While, for age three and five the lignin content values were 28.77% and 28.31%, respectively (Table 3). The least lignin content was found at middle culm position and bamboo age 4 with the similar value of 27.44% for *Y. alpina* (Table 3). This was larger by 19.08% to earlier results reported by (Amsalu, *et al.,* 2017) and very close to (Ireana, 2010) reported that the lignin content in bamboo (*B. blumeana*) with the value of 28.86%.

Table 3 Main effect of age and position on Lignin of *Y. alpina* grown at Dire-Incheni

Treatment		Mean Separation
		Lignin
Age	3	28.77^a
	4	27.44^b
	5	28.31^a
position	T	28.49^a
	M	27.44^b
	B	28.41^a

Interaction Effect of Culm Position and Age on Extractive, Cellulose and Ash Content of *Y. alpina*

Extractive Yield

The interaction effect of factors (Bamboo age and Bamboo culm position) on extractive yield showed significant difference ($p < 0.001$) in higher yielding of extractive contents with statistical similar were found in culm positions at middle and bottom under bamboo age five with values of 9.22% and 9.95%, respectively. Statistically the least extractive content was observed on bamboo with age 3 and 5, each at the top culm position with respective values of 4.71% and 5.79% (Table 4). Overall mean value of extractive content revealed significantly higher value for age five culms (8.32%). This value was in argument with earlier results reported by (Razak, *et al*., 2013) and was within the range of 8% to 9.23%. The least extractive content was recorded for age three culms (6.06%) with yield 27.16% lower than the maximum (Table 4) and higher when compared with previous studies. Softwoods constitute 3% and the hardwoods 5% extractives (Thomas, 1977).

Cellulose Content

As shown in Table 4, the interaction effect between bamboo ages and bamboo culm position on cellulose content of *Y. alpina* was highly significant. When bamboo ages were observed separately in each culm position, significantly higher cellulose content was found on Bamboo of age four (49.53%) at top culm position, which was followed by bamboo of age 3 (48.24%) at bottom culm position. Statistically the least cellulose content was observed on bamboo of ages 3 and 5 at culm position top and middle with values of 43.69% and 44.34%, respectively. Overall mean value of cellulose content revealed significantly higher and statistically at par values for age 3 (46.36%) and age 4 (47.09%) bamboos. The least cellulose content was recorded for age 5 bamboo with yield 3.75% lower than the maximum (Table 4). The cellulose composition found in this study was ranged between 43.69% to 49.53%, which is in conformity with other report by (Razak, *et al.,* 2013) with the value in the range 37.09% to 51.58%. This is similar to observation made by (X.BLi., *et al*., 2007), which was found in the range 43.69% to 49.53%.

Ash Content

Overall mean of interaction between Bamboo age and culm positions showed a significantly higher ash content for bamboo of age 5. The minimum overall average ash content recorded was for bamboo of age 3 and bamboo age 4. When compared between bamboo ages at both bamboo culm position, the ash content in the interaction effect was observed significantly higher and statistically similar for age 4 and age 5 at bottom culm position with the recorded value of 2.81%and 2.71%, respectively (Table 4). The least ash content was recorded for age 4 (1.29%), which yielded 54.09% lower than the maximum (Table 4). This is like earlier results reported by Razak, *et al* (2013) and is within the range between 1.28% to 1.89%.

Table 4 Interaction effects between age and culm position on chemical properties of *Y. alpina* grown at Dire-Inchini.

Age	Extractive				cellulose				Ash			
	Top	Medium	Bottom	mean	Top	Medium	Bottom	mean	Top	Medium	Bottom	Mean
3	4.71^{g}	6.65^{e}	6.83d^{e}	6.06^{c}	43.69^{e}	47.14^{bc}	48.24^{ab}	46.36^{a}	2.48^{b}	1.78^{d}	2.63^{ab}	2.3^{b}
4	6.88^{de}	7.25^{d}	8.08^{c}	7.4^{b}	49.53^{a}	46.63^{bcd}	45.11^{de}	47.09^{a}	1.62^{d}	1.29^{e}	2.81^{a}	1.91^{c}
5	5.79^{f}	9.22^{b}	9.95^{a}	8.32^{a}	46.27^{cd}	44.38^{e}	45.34^{de}	45.33^{a}	2.18^{c}	2.45^{b}	2.71^{a}	2.45^{a}
Mean	5.8^{c}	7.7^{b}	8.29^{a}		46.5^{a}	46.05^{a}	46.23^{a}		2.09^{b}	1.84^{c}	2.7^{a}	

***= Significant at $p < 0.001$; ** Significant at $p < 0.01$; *= Significant at $p < 0.05$; ns= Non-significant at p < 0.05.

Conclusion

From this research, we have found no significant difference Cellulose content from the base to the top of the culm at overall mean of all three ages. Alcohol-toluene extractive content increased from the top to the bottom of the stem in the increase with age bamboos. Maximum ash content was observed at bottom culm position relatively from at top and medium culm position crosses in each bamboo age. Minimum Lignin content was observed on middle culm position and bamboo age 4 considering the main effects.

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References

Abd.Latif, M., Tarmeze W.A.W., and Fauzidah A.,1990. Anatomical features and mechanical properties of three Malaysian bamboos. *J. Tropical Forest Sci*. 2(3): 227- 234.

Ahlawat S., Haridasan, P., and Hegde S.N., 2002. Field manual for propagation of bamboo in North-east India. Bulletin No. 4.

Asif, M., and Muneer, T., 2007. Energy Supply, Its Demand and Security Issues for Developed and Emerging Economies. Renewable and Sustainable Energy Reviews, 11, 1388-1413.

Bystriakova, V., Kapos., and Igor L., 2004. *Bamboo Biodiversity*: Africa, Madagascar and the Americas. UNEP-CMC/INBAR. UNEP World Conservation Monitoring Centre, Cambridge, UK. International Network for Bamboo and Rattan. Beijing, China 2004, 90 pp.

CIBART., 2004. Let's strengthen the bamboo movement. Center for Indian Bamboo Resource and Technology. CIBART 2004.

Engler B., Schoenherr S., Zhong Z.. and Becker G., 2012. Suitability of Bamboo as an Energy Resource: Analysis of Bamboo Combustion Values Dependent on the Culm's Age. International Journal of Forest Engineering, 23, 114-121.

Feleke S., 2013. "Site factor on nutritional content of *Arundinaria alpina* and *Oxytenanthera abyssinica* bamboo shoots in Ethiopia", *Journal of Horticulture and forestry*, 5 (9): 115-121.

Gomez and Gomez., 1995. Dual Lamguage Enrichement (DLE) model was originally developed in 1995 and first implemented in 1995 in the pharr- san juan- Alamb.

Ireana Y., 2010. Characteristics of Bamboo, Fenaf and Rice Straw Fibers.M. Sc Thesis, USM.

Kassahun., 2000. The Indigenous Bamboo Forests of Ethiopia: an overview. *Ambio* 29: 518-521.

Kigomo B.N., 2007 Guidelines for Growing Bamboo. KEFRI Guideline Series: No. 4.

Lakkad S.C., and. Patel J.M., 1981. Mechanical properties of bamboo, a natural composite. *Fiber Sci. and Tech*. 14(3): 319-322.

Muchiri M.N., and Muga M.O., 2013A Preliminary Yield Model for Natural *Yushania Alpina* Bamboo in Kenya. Journal of Natural Sciences Research, 3, 77-84.

Senyanzobe R., Jennifer G., Mukanyamwasa F., Nizeyimana G., Mukagakwaya R.,. Wizangoga., and. Dieu J.D., 2013. Growth of Bambusa vulgaris and Araundinaria alpina under different nursery Site conditions at the higher institute of agriculture and animal husbandry, Northern Rwanda. *Journal of Biodiversity and Environmental science* (2013), 3, 9-14.

Zhou M., Fu Y., Xie J.Z., and Z. C. Li Z.C., 2005. Ecological functions of bamboo forest: Research and application, *J. For. Res.* (2005), 16(2), 143-147.

Effects of Harvesting Techniques and Intensities on Productivity of *Oxytenanthera abyssinica* (A. Rich.) Munro. in Pawe District, Beshangul-Gumz region, Ethiopia

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Abstract

The aim of this study was to assess the effects of harvesting techniques and intensities on sustainable utilization ingenious *Oxytenanthera abyssinica* and to select the best harvesting technique and intensity which enables continuous resource use. It was conducted during 2013-2018 on *O abyssinica* plantation forest in the compound of Pawe Agricultural Research Centre. Clump size was considered as a blocking variable within similar soil and management conditions. Thus, clumps of similar number and growth were used for sampling from each block. Most similar clumps were used for sampling. Different cutting intensities (25, 50, 75, 100 and 0% harvesting of old culms) under X-shape and Horse-shoe shape harvesting techniques were implemented. Prior to applying the treatments, all dead culms were extracted out and the site was fenced to avoid any encroachment. Number of culms per clump and mean culm diameter via age class were recorded. Cutting of mature culms was applied in the dry season to prevent attack on the rhizome. Afterwards, sprouted, recruited and dead culms, and mean culm diameter at breast height were recorded. The data were analysed using Two-way-ANOVA. The results depict there were no interaction between harvesting techniques and harvesting intensities on culm sprouting, culm recruitments and shoots aborting and was not significantly different in all treatments. Both harvesting techniques and intensities had a significant effect on mean culm diameter 95% confidence interval. X-shape harvesting technique yielded thicker bamboo culm than horse-shoe harvesting technique. Harvesting of 75% and 100% old culms with x-shape harvesting technique yielded higher mean culm diameter compared to harvesting of old culms under horse-shoe harvesting technique and it was significantly different. In addition, culm sprouting, recruitment and aborting were varied over seasons and the variations were significant at 95% confidence interval. Following different harvesting techniques and intensities, *O abyssinica* forest population structure varied with harvesting techniques and intensities. Culm production was decreased overtime in all treatments. Therefore, harvesting more than 75% of mature culms is recommended to manage the resource on sustainable approach even if significant difference was not observed between harvesting techniques and intensities.

Introduction

Bamboo has a long history as a building material in many parts of the world. It is light and strong species (INBAR, 2003). In addition, this species is suitable for biomass-based energy (Ha-truong and Thi, 2015) and food production (Nongdam and Tikendra, 2014). Recently, the world has given attention to this species because it is fast- growing and renewable resource (Gupta and Kumar, 2008). Therefore, this species has to be managed sustainably to get continuous benefits from this resource. Improper harvesting of culms deprived the productivity of bamboo forest. For instance, harvesting young culms reduced production of new culms in the following years (Suwannapinun, 1990). However, Silvicultural practices such as harvesting of mature culms enhance productivity of bamboo stand (Mulatu and Fetene 2013). Selective thinning of old culms combined with soil loosening increases culm yield and reduced culm mortality (Mulatu and Fetene, 2013, Midmore, 2017). Similarly, appropriate harvesting technique increases the growth of bamboo (number of shoots, culm diameter and height) (Kleinhenz and Midmore, 2001). Generally, thinning of dead, damaged and defective culms increases the productivity bamboo forest by providing space for the growth of new shoots (Alipon *et al.,* 2014).

The number of harvested culms significantly influences the sustainability of bamboo forest. Studies have shown that clear felling of bamboo forest kills/ damages bamboo forest stand (Suwannapinunt, 1988). Only mature culms have to be harvested in order to reduce the effect of harvesting on culms that would be produced in the following years. On the other hand, unharvesting of bamboo culms lead to bamboo forest degradation (Midmore, 2017, Mulatu and Fetene, 2013). Thereby, selective harvesting of mature culms is recommended. The number of mature culms to be harvested varies with species and annual average of shoots produced by the clump (Sulthoni, 1996). For instance, in Malaysia *Gigantochloa scortechinii* plantations are managed sustainably by felling 40% of mature culms for timber production (Mohamed, 1996). Moreover, Colombia uses 25% selective harvesting of mature culms each year (Poppens *et al.* 2013).

Ethiopia has two native species, which contributes the largest coverage of African bamboo forest, with around 1.47 million ha (INBAR 2018) and it constitutes 67% of the total area of bamboo in the continent (Embaye, 2000). *O. abyssinica* accounts 85 % of Ethiopian bamboo coverage (Embaye, 2000). This species grows in a clumpy form and new culm shoots sprout at the periphery of the clump (Sulthoni, 1996). The nature of this species makes harvesting of mature culms very difficult because mature bamboo culms found at the centre of clump. Lack of knowledge on the extraction of old/mature culms leads to resource degradation. According Sulthoni (1996), sympodial bamboo species culm harvesting should be done selectively from the middle of clump. Therefore, this study introduced different harvesting techniques and intensities; i.e. horse-shoe and x-shape harvesting technique with various harvesting intensities to cut mature culms without damaging the clump.

To ensure sustainable production culms in *O. abyssinica* forest stand, the best silvicultural management method is in need. Information on sustainable management of this species is scanty. Understanding the response of *O. abyssinica* to different harvesting techniques and intensities would help to test and select sound management method. Therefore, this research focused to develop the best harvesting technique and intensity that will help to boost productivity. The study was designed to answer the following questions: 1. Does harvesting techniques and intensities have effect on bamboo culm recruitment? 2. Is bamboo culm production and recruitment varied with harvesting techniques and intensities over seasons (years)? 3. In which harvesting technique and intensity can bamboo managed sustainably? 4. Is the culm diameter affected by cutting techniques and intensities? 5. Does culm harvesting intensity and techniques has impact on *O. abyssinica* population structure?

Materials and Methods

Study Site

The experiment was conducted within Pawe Agricultural Research Centre (PARC), Metekel, Ethiopia (11°18′ N latitude, 36°24′ E longitude), from 2013 to 2018. The average minimum and maximum temperatures were 17.7°C and 37.6°C, respectively. The area receives a mean annual rainfall of 1600 mm. The altitude of the area ranges between 1000 to 1200 metres above sea level. The soils are broadly categorized as Vertisols, which account for 40 to 45% of the area; Nitisols that account for 25 to 30%, and intermediate soils of a blackish brown colour, which account for 25 to 30% as cited by Seyoum et al (2012).

Sampling and Experimental Design

Plantation bamboo forest, which was established on June 2008 and, planted 2m x 2m spacing were used to implement the experiment. Four clumps, which are close to each other, were considered as one plot. Factorial experiment with two main factors; i.e. X-shape and Horse-shoe shape harvestings techniques and sub-factors with five levels i.e. harvesting of old culms with 25%, 50%, 75%, 100% and control (no cutting) to investigate their effect on bamboo culm recruitment and new culm size (Table 1).

Generally, nine plots, each with four clumps, were used in a block and it was replicated three times. Thus, 108 clumps were used for the whole experiment (two harvesting techniques X five harvesting intensities X four clumps per plot X three replications). Before commencing the experiment, all dead bamboo culms were extracted out and the experimental area was fenced. Then, weeding was performed in every summer (rainy) season from July to August.

Initially, the number of culms per clump was counted through age class (< 1 year, 1-3 year and > 3 years old). In addition, mean culm diameter and height via age class and height of clumps was measured. Treatments were applied in the dry season (February to March) that is the recommended harvesting season for its low damage on regenerating new shoots and low starch content of the mother culm (Othman *et al*., 1996). Afterwards, sprouted, recruited and dead culms were counted in each of plots from august to September, every year, until the end of experiment period (January 2018) following treatment application. In addition, mean culm diameter at breast height was measured for recruited culms.

Data Analysis

Descriptive statistics were used to summarize and rearrange the data for further analysis. The experiment was factorial design and then two-way-ANOVA in R software was used to analyse the data. Assumptions such as normality and homogeneity of variances were checked prior to running two-way-ANOVA. When the main effects or interaction effects were statistically significant, post-hoc test were conducted to determine which groups differ significantly from other groups. The graphs and tables were presented to explain the results.

Table 1 Treatments applied on the experiment

Main factors	Treatments	Description
X-shape harvesting technique	25%	Harvesting 25% of culms older than three years old in the clump
	50%	Harvesting 50% of culms older than three years old in the clump
	75%	Harvesting 75% of culms older than three years old in the clump
	100%	Harvesting 100% of culms older than three years old in the clump
Horse shoe shape technique	25%	Harvesting 25% of culms older than three years old in the clump
	50%	Harvesting 50% of culms older than three years old in the clump
	75%	Harvesting 75% of culms older than three years old in the clump
	100%	Harvesting 100% of culms older than three years old in the clump
Control	No cutting	No Harvesting in the clumps

Note: Old culm refers bamboo culms which are older than three years old.

Results

Effects of Harvesting Techniques and Intensities on Culm Sprouting Potential of *O. abyssinica* Plantation Forest

The highest culm sprouting was observed with fifty and hundred percent harvesting of mature culms under horse shoe harvesting techniques and fifty- and seventy-five percent harvesting of mature culms in X-shape harvesting technique. Generally, harvesting of mature culms yielded too many culms when it compared with control (no cutting of mature culms) (Table 2).

Table 2 Mean of culm sprouting, recruitment, and culm aborting under different harvesting technique and intensities

Harvesting intensities	Harvesting techniques					
	Horse-shoe harvesting			X-shape harvesting		
	Sprouting	Recruitment	Aborting	Sprouting	Recruitment	Aborting
Harvesting 25% of mature culms	15,2±4,2	8,7±0,7	6,5±0,8	15,3±1,1	9,2±0,8	6,1±0,7
Harvesting 50% of mature culms	16,6±6,1	11,0±1.4	6,6±0,4	18,1±1,6	11,2±0,9	6,8±0,5
Harvesting 75% of mature culms	15,6±4,7	9,7±1,2	5,9±0,5	17,0±1,8	11,0±1,3	6,0±0,6
Harvesting 100% of mature culms	16,5±4,9	10,7±0,9	5,9±0,8	16,0±1,8	9,8±1,2	6,2±0,7
No harvesting	14,8±1,2	9,4±0.7	5,4±0,7	14,8±1,2	9,4±0.7	5,4±0,7

The result revealed that, there was no interaction between harvesting techniques and harvesting intensities on bamboo culm sprouting. Though the difference in culm sprouting was observed between harvesting techniques and intensities, it was not significantly different between at 95% confidence interval (Table 3).

Table 3 Summary of ANOVA table on the effect of harvesting technique and intensities on, bamboo culm sprouting, recruitment and mortality

Variables	Comparisons	Sum sq	Mean sq	F-value	P-value
Culm sprouting	Harvesting intensities	535	134	0.419	0.794
	Harvesting techniques	174	174	0.546	0.462
	Harvesting intensities: Harvesting techniques	399	133	0.417	0.741
Bamboo culm recruitment	Harvesting intensity	857	214	0.971	0.425
	Harvesting technique	278	278	1.260	0.263
	Harvesting intensity: Harvesting technique	335	112	0.506	0.679
Culm mortality	Harvesting intensity	102	25.4	0.443	0.777
	Harvesting technique	7	6.9	0.121	0.729
	Harvesting intensity: Harvesting technique	9	133	3.0	0.984

Note: Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Effects of Harvesting Techniques and Intensities on Culm Mortality

Bamboo culm mortalities varied through cutting techniques and intensities, but it doesn't significantly differ between harvesting techniques and intensities (Table 3). Higher shoot mortality was observed in twenty-five and fifty percent harvesting of mature culms with both harvesting techniques (Table 2).

Effects of Harvesting Techniques and Intensities on Bamboo Culm Recruitment

Like bamboo culm sprouting and mortality, culm recruitments were not significantly different between harvesting techniques as well as harvesting intensities (Table 3). However, higher culm recruitment was observed under fifty and seventy-five percent harvesting of mature culms with X-shape harvesting technique (Table 2).

Effects of harvesting Techniques and Intensities on Culm Diameter

Table 4A has shown the culm harvesting on clumps has effect on the diameter of newly produced bamboo culms. Culms produced under both harvesting techniques are smaller DBH compared to culms produced in unharvested plot.

Table 4A Mean culm diameter at breast height (DBH) via treatments

Treatments	Harvesting techniques	
	Horse shoe	X-shape
Harvesting 25% of mature culms (mm)	40.44	55.61
Harvesting 50% of mature culms (mm)	58.44	52.61
Harvesting 75% of mature culms (mm)	41.11	59.72
Harvesting 100% of mature culms (mm)	52.11	62.50
Control (no cutting) (mm)	72.50	

Table 4B ANOVA table on the impact of harvesting technique and intensities on culm diameter

Response: culm diameter	Sum Sq	Mean Sq	F value	Pr(>F)
Harvesting intensity	8220	2055	3.185	0.0152 *
Harvesting technique	3306	3306	5.125	0.0250 *
Harvesting intensity: Harvesting technique	3159	1053	1.632	0.1844
Residuals	95481			
Signif. codes: 0 '***'	0.001 '**'	0.01 '*'	0.05 '	' ' 1

This study revealed that cutting technique as well as cutting intensity has significant effects on culm diameter (Table 4B). Cutting 25% and 75% old culms under horse shoe harvesting were significantly different in mean bamboo culm diameter from harvesting of 25% old culms with x-shape harvesting technique (Appendix 1).

Culm Sprouting, Recruitment and Mortality Varied Over Years

This study has shown that bamboo culm sprouting, recruitment and aborting varied with season to season and the variations were significant over years (Table 5). Even if sprouting, recruitment and aborting were varied over seasons of the experiment period, the trend shows dwindling in all aspects but in some season's massive bamboo culms sprouting were observed. For instance, in 2013 massive bamboo culm sprouting were observed.

Table 5 Variation of culm sprouting, recruitment and aborting over experimental period under different harvesting techniques and treatments

Parameters	Sum Sq	F value	Pr(>F)
Bamboo culm sprouting	6512.0	21.5244	1.429e-05 ***
Bamboo culm recruitment	8986	11.411	0.0009169 ***
Aborted bamboo culms	1185.4	22.378	9.641e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 ' ' ' 1

Impact of Different Harvesting Techniques and Intensities on O. abyssinica Population Structure

Prior to commencing the experiment, all culms were recorded according to their age; <1, 1-3, and > 3 years in all plots and exhibited inverted J shape (Figure 1).

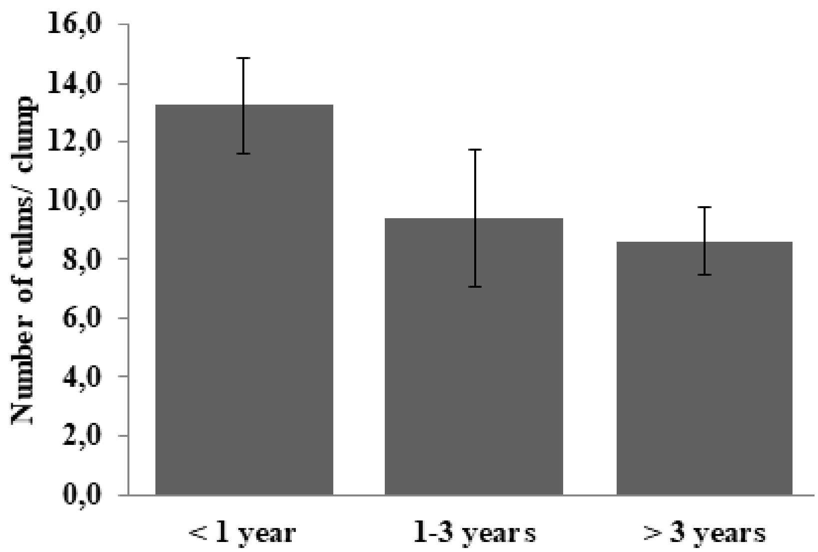
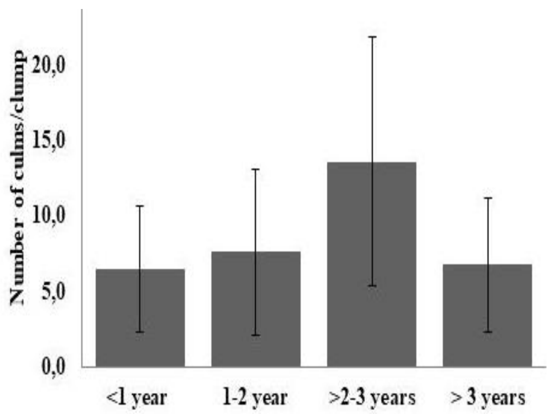
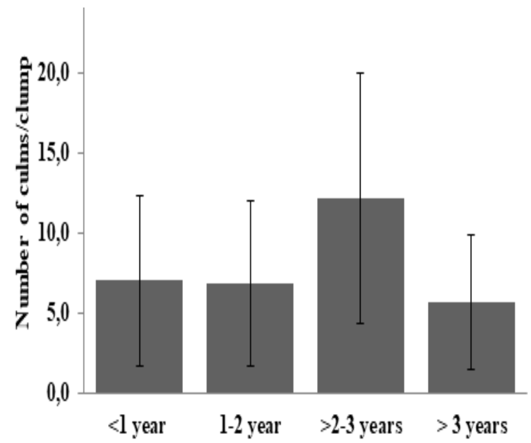


Figure 1 Mean number of *O. abyssinica* culms per stump via age class at the age of 5 years

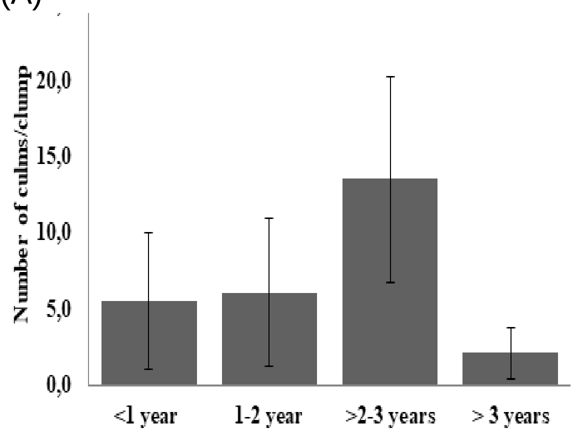
However, following the application of different cutting techniques and intensities for five consecutive years, the *O. abyssinica* population structure varies with harvesting techniques and intensities. All harvesting techniques and intensities show bell shaped structure except 100% harvesting old culms under Horse shoe and X-shape harvesting technique (Figure 2 and 3). On the other hand, hundred percent harvesting of old culms with Horse shoe and X-shape harvesting techniques showed J-shape structure.



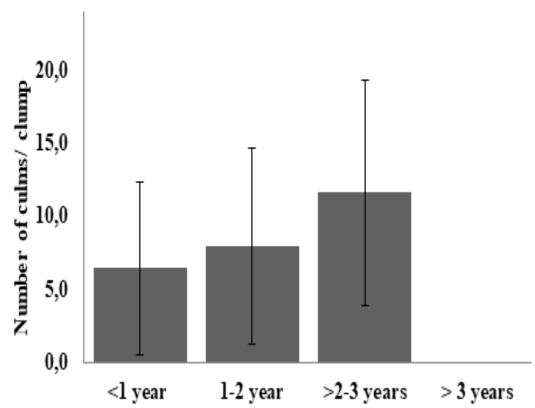
(A)



(B)

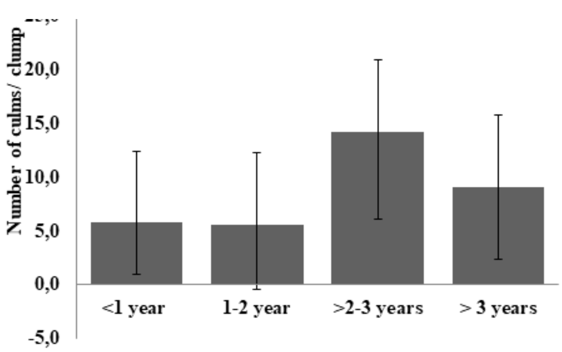


(C)

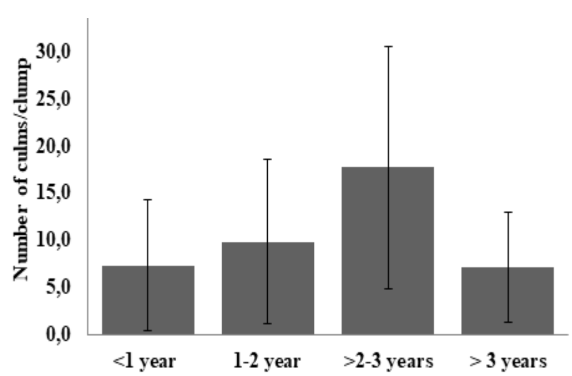


(D)

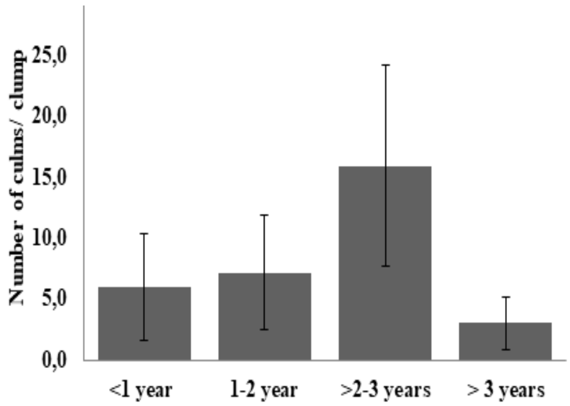
Figure 2 effect of (A) 25%, (B) 50%, (C) 75% and (D) 100% harvesting old culms with Horse shoe harvesting technique



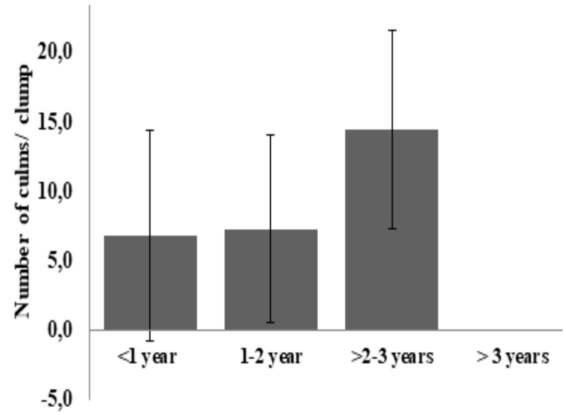
(E)



(F)



(G)



(H)

Figure 3 effects of (E) 25%, (F) 50%, (G) 75% and (H) 100% cutting old culms with X-shape harvesting technique

Protected (unharvested) *O. abyssinica* forest also showed close to bell shaped structure (Figure 4).

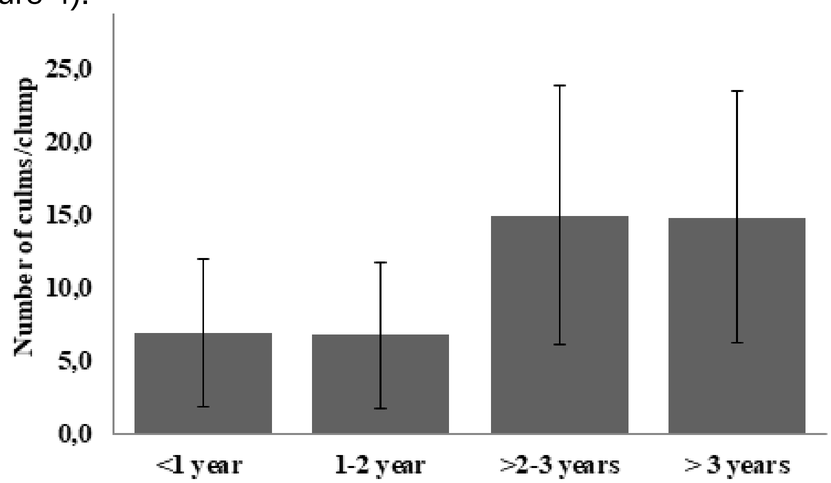


Figure 4 Population structure of *O. abyssinica* in controlled (no harvesting of culms) plots via age class in plots

Discussion

Effects of Harvesting Techniques and Intensities on Sprouting, Culm Recruitment, and Mortality of lowland bamboo

Culm Sprouting

Selective harvesting of mature culms under different harvesting techniques and intensities didn't have significant difference in new culm sprouting. However, different literatures have shown that culm production was influenced through harvesting intensities. For instance, Darabant et al. (2016) observed lower intensity selective harvesting looks sustainable until the third year of successive harvesting, while clear cut and higher intensity Horse shoe cut yielded more shoots and culms. On the contrary, Nath et al. (2006) found that in India the new culm production of *B. cacharensis*, *B. vulgaris*, and *B. balcooa* were higher under selective felling. Though selective harvesting of mature *O. abyssinica* culms enables continuous production of young shoots (UNIDO 2009), harvesting intensities and techniques have not effect on new culm production.

Culm Recruitment and Mortality

Horse shoe harvesting technique yielded higher number of culm sprouting and recruitment when compared with x-shape harvesting technique (see Figure 1). Clear cutting is believed to decrease the vitality of bamboo stands and recuperation of the stand takes considerable amount of time (Poppens *et al.,* 2013). However, this study reveals there was no significant difference in culm recruitment and mortality under different harvesting techniques and intensities. Culm recruitment and mortality of *O. abyssinica* were significantly different over years. This may be linked to environmental parameters including raining season.

Effects of Harvesting Techniques and Intensities on Culm Diameter

This study has shown that culm diameter was influenced with harvesting technique and intensities. X shape harvesting technique yielded better culm diameter when compared with horse shoe harvesting technique (Table 4). This might be due to the availability of more space that obtained because of cutting of old culms. Similarly, the density of bamboo has effect on the diameter of culms, i.e., the dense stand produced smaller diameter culms compared to sparse stand (Poppens *et al.*, 2013). Studies indicated that harvesting old culms improved the diameter of newly produced culms. For instance, Nath (2006) observed the greater culm diameter of *B. cacharensis*, *B. vulgaris*, and *B. balcooa* were produced under selective felling (Nath et al. 2006).

Population Structure of O. abyssinica Under Different Harvesting Regimes

Initially, *O. abyssinica* forest stand were depicted inverted J-shape, which means the forest is sustainable. Following the introduction of different harvesting techniques and intensities for five consecutive years, *O. abyssinica* forest was depicted bell shape and J-shape including unharvested stand. This study found that there was no difference between harvested and unharvested stand in structure of bamboo culms via age class. Similarly, Vázquez-lópez et al. (2004) observed there was no significant difference in structure between harvested and unharvested stands. It is known that harvesting regimes determines the culm population structure of a clump (Nath *et al*, 2006). Embaye *et al*. (2005) also reported that in Masha Forest, *Y. alpina* stand age-structure heavily skewed towards older culms that resulted in low productivity of the bamboo stands. Therefore, harvesting of mature culm is needed to ensure sustainability of bamboo forest. However, as cited Nath et al. (2006) age class structure of 3:3:3:1 for 1- to 4-year- old bamboo culms is recommended for sympodial bamboo species for optimum culm production. The age structure of *O. abyssinica* is not similar with the recommended age structures for lowland bamboo. This may be due to consecutive harvesting of mature culms over five years. Darabant *et al.,* (2016) described annual harvest mature culms over several years also jeopardizes clump productivity.

Conclusion and Recommendation

Culm production decreased overtime in all harvesting techniques and treatments including the control (unharvested plot). Therefore, there is a need for developing better management strategies for optimum yield without continuously impairing the potential of the bamboo resource productivity. Culm productions were influenced by different harvesting techniques and intensities, but the effect was not significant. Harvesting intensity determine the culm population structure of a clump. Higher culm diameter can result from clear felling of mature (old) culms with X-shape cutting technique each year. Therefore, this study recommends that if the ultimate goal is culm production, it would be important to harvest bamboo stand with X-shape harvesting technique by harvesting of seventy-five percent of mature culms because factories need thickest bamboo culms for constructing various end products.

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References

Alipon, Marina a, Elvina O, Salome R, Victor, Tesfaye H (2014). “Plantation Management and Bamboo Resource Ecconomics in China.” *Ciencia Y Technologia* 7 (1). Elsevier B.V.:1–12. https://doi.org/10.1017/CBO9781107415324.004.

Darabant, A, Prem R, Christina S, and Tshewang D (2016). “Designing and Evaluating Bamboo Harvesting Methods for Local Needs: Integrating Local Ecological Knowledge and Science.” *Environmental Management* 58 (2):312–22. https://doi.org/10.1007/s00267-016-0702-6.

Embaye K, Weiha M, Ledinc S, and Christerssona L (2005). Biomass and Nutrient Distribution in a Highland Bamboo Forest in Southwest Ethiopia : Implications for

Management Biomass and Nutrient Distribution in a Highland Bamboo Forest," no. August 2014. https://doi.org/10.1016/j.foreco.2004.07.074.

Embaye, K (2000). The Indigenous Bamboo Forests of Ethiopia: An Overview." *Source: AMBIO: A Journal of the Human Environment Published By: Royal Swedish Academy of Sciences Ambio* 29 (8):518–21. https://doi.org/10.1579/0044-7447-29.8.518.

Gupta A and Kumar A (2008). Potential of Bamboo in Sustainable Development." *Asia Pacific Business Review* IV (4):100–107.

Ha-truong M, and Thi L (2015). "Overview of Bamboo Biomass for Energy Production." UNIVERSITY OF SCIENCES AND TECHNOLOGIES OF HANOI, VIETNAM.

INBAR (2003). Proceedings of Bamboo Housing Workshop." *International Network for Bamboo and Rattan (INBAR) & Bamboo and Rattan Development Program (BARADEP)*.

INBAR (2018). Remote sensing-based regional bamboo assessment report of Ethiopia, Kenya and Uganda

Kleinhenz V and Midmore D (2001). Aspects of Bamboo Agronomy." *Advances in Agronomy* 74:99–145. https://doi.org/10.1016/S0065-2113(01)74032-1.

Mohamed A (1996). In *Effects of Fertilizing Intensity on Natural Stands of and Harvesting Gigantochloa Scortechinii: II.V. Ramanuja Rao , Cherla B. Sastry, I.V. Ramanuja Rao and Elizabeth Widjaja in International Proceeding of Bamboo, People and Environment the V the Internat*.

Mulatu Y, and Masresha F (2013). The Effect of Silvicultural Management on Regeneration , Growth and Yield of Arundinaria Alpina (Highland Bamboo) at Choke Mountain , East Gojam , Northwest Ethiopia" 27:11–27.

Nath, A, Gitasree D, and Ashesh D (2006). Population Structure and Culm Production of Bamboos under Traditional Harvest Regimes in Assam, Northeast India." *Journal of Bamboo and Rattan* 5 (1–2):79–88.

Nongdam P and Leimapokpam T (2014) "The Nutritional Facts of Bamboo Shoots and Their Usage as Important Traditional Foods of Northeast India" 2014.

Othman A, Noor R, Quingyi L, Koyama H, Uchimura E, Liese W, and Weiner G (1996). Bamboo, People and the Environment." In *Shooting Period of Sympodial Ba Mboo Species: An Important Indicator to Manage Culm Harvesting: Proceedings of the Vth International Bamboo Worskop and the IV International Bamboo Congress*, 1:156.

Poppens R, van Dam P, and Elbersen H (2013). Bamboo: Analyzing the Potential of Bamboo Feedstock for the Biobased Economy," no. January:32. http://library.wur.nl/WebQuery/wurpubs/fulltext/381054.

Sertse D, Tesfaye D, Kassahun B, Mehari A, Negash E, and Sintayehu E (2011). Mass Flowering and Death of Bamboo : A Potential Threat to Biodiversity and Livelihoods in Ethiopia." *Journal of Biodiversity and Environmental Sciences (JBES)* 1 (5):16–25. https://doi.org/ISSN: 2220-6663.

Seyoum Y, Demelash A, Fikadu G, and Behailu K (2012). Nursery Growth and Biomass of the Seedlings of Nine Tree Species Planted Under Different Potting Media in Northwest Ethiopia." *Ethiop. J. Biol. Sci* 11 (2):105–16.

Sulthoni A (1996). Shooting Period of Sympodial Bamboo Species; An Important Indicator to Manage Culm Harvesting., In: Rao, Ramanunja & Wi- djaja, 315 E., (Editors) Bamboo, People, The Environment; Proceedings of the V International Bamboo

Workshop and the IV International Bamboo Congress, Ubud, Bali, Indonesia. 1995. Volume 1 Propagation and Management. INBAR Technical Report No. 8.

Suwannapinun W (1990). In *Horse-Shoe Harvesting Trials in Natural Gigantochloa Hasskarliana Stands. In .V. Ramanuja Rao, R. Gnanaharan, Cherla B. Sastry (ED), Proceedings of the International Bamboo Workshop Held in Cochin, India from 14-18 November 1988. Kerala Forest Research In*, 83–86.

Suwannapinunt W 1988. Horse-Shoe Harvesting Trials in Natural Gigantochloa Hasskarliana Stands." In *In I.V. Ramanuja Rao, R. Gnanaharan, Cherla B. Sastry (Ed) Bamboos Current Research. Proceedings of the International Bamboo Workshop*, 199–205.

UNIDO (2009). Bamboo cultivation manual : Guidelines for cultivating ethipian lowland bamboo.

Vázquez-lópez J, José M, Heike V, and Edmundo G (2004). Effects of Harvesting on the Structure of a Neotropical Woody Bamboo (Otatea : Guaduinae) Populations.

Perception of Farmers Towards Farm Level Rubber Tree Planting: A case study from Guraferda, South–western Ethiopia

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Abstract

In Ethiopia *Heavea brasiliensis* tree plantation has been mainly conducted by the state. Now a day, attempts are being made to extend the practice towards farm level by the rural communities. Then, the future plan may largely depend on addressing farmer's perception as well as the identification of factors that encourage or discourage rubber tree planting on their farms. Insight about the above issues will be helpful as well in designing effective out–growers scheme for rubber tree plantations by the farmers, thereby contributing to the betterment of the livelihood in the country. Thus, the general objective was to identify the factors that underlie farmer's decisions to be engaged in rubber tree plantation and to understand farmers' perception towards the forest use and conservations in the study area. We used informal discussion and semi–structured questionnaire survey. The results indicated that all the respondents were farmers, self–employed in farming. They grow cash crops, food crops, rearing animals and daily labor were their livelihood activities and sources of income. The concept of conservation and forest development is supported by the majority of the respondents and about 40% are dependent on the forests for income generation. Majority of the respondents (68%) expressed their willingness to plant rubber tree on their farm. However, land availability, market for the products, gestation period of the investment, lack of technical knowhow and nearness to resource such as seedlings are discouraging factors for the engagement of rubber plantations by farmers in the study area. Therefore, taking all these as opportunities helped us to devise and recommend strategies such as rubber tree agroforestry, which probably intensify the farming system and results willingness to plant rubber trees by farmers in the study area, if the market access for rubber products facilitated by the government.

Keywords: Agroforestry, *Heavea brasiliensis*, income source, livelihoods, Out–growers

Section 3: Forest Protection Research

Apate monachus Fabricius (Coleoptera) Infestation in Ethiopia

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Abstract

In recent times, the saplings and trees of *Arundinaria alpine*, *Coffea* sp., *Grevelia robusta*, *M. azedarach* were reportedly damaged by unknown wood borer in Pawe District, Kalu and Chencha Districts of Ethiopia. The objective of the study was to investigate the causative agent of this damaging borer. *Apate monachus* was found in forming circular tunnel in these species. In Pawe district, the pest selectively infested some species over others. This study is the first record on the infestation of *M. azedarach, Grevelia robusta*, and *Arundinaria alpine* species in Ethiopia. In future, the geographical distribution and other hosts of the pest need to be addressed at the country level.

Keywords: *Apate monachus*, *Arundinaria alpine*, *Coffea* sp., *Grevelia robusta*, *M. azedarach*, Ethiopia

Introduction

Apate monachus Fabricius is a polyphagous bostrichid beetle that belongs to Family Bostrichidae. The infestation of host tree by the adult and larvae of *A. monachus* results in the formation of tunnels that retards growth, prone trees to wind damage and even kills the host plant under heavy infestation (Nardi and Mifsud 2015, Wylie and Speight 2012, Hill 2008, Timyan 1996; Wagner, *et al*. 1991). It also deteriorates timber quality. *A. monachus* attacks more than 80 plant species around the world (Bonsignore 2012, El-Shafie 2012). In Ethiopia, there is limited information available on the host range of *A. monachus* other than coffee tree infestation (Waller, *et al*. 2007). Therefore, the objective of this study was to determine the presence of *Apate monachus* in other economically and ecologically important trees in Ethiopia.

Materials and method

On the bases of tree growers report and field observation, a survey was conducted between 2015 and 2017 in Pawe, Kalu, and Chencha Districts of Benishangul Gumuz, Amhara, State and Southern Nations and Nationalities and Peoples (SNNP) Regional States, respectively. The stem, branches and twigs of *Melia azedarach* (in Pawe), *Coffea* sp and *Grevelia robusta* (in Kalu), and *Arundinaria alpine* (also known as *Yushania alpine*) (in SNNP) were examined for infestation by *A. monachus*. Finally, infested stems of *M. azedarach* and insect specimens that were collected from dissected stems of *G. robusta* and *A. alpine* were transported to Central Ethiopia Environment and Forestry Research Center (CEE-FRC) Forest Protection laboratory at Addis Ababa. In the laboratory, segment of infested stems of *M. azadarach* saplings were dissected to look for the presence insect, and the remaining samples were cut into 5 cm segment put in glass bottles to observe for emergence of developing adult.

Results

There were two types of insects collected opening the 7 mm diameter holes of *M. azedarach*: *Apate monachus* (Figure 1a) and *Carpophilus* species (Nitidulidae-Capophilinae) (Figure 1d). *A. monachus* has 11 to 16 mm length. It has black elytra. The forehead of adult *A. monachus* was covered by yellow and long bristles that formed brush-like structure (Figure 1a-c). Only adult *A. monachus* was collected during field collection. It is usually designated and named by its color as black stem borer.

The infestation of *A. monachus* occurred in both the stems and branches of saplings, coppices and matured trees. Species such as *G. robusta* released exudates during infestation periods (Figure 1e). This infestation resulted in the production and accumulation of large volume of sawdust at the bases of living trees (Figure 1f), harvested trees and in laboratory collection bottles. Ooze of resin and sawdust accumulation was more evident during the dry and hot seasons of the districts, i.e. January to May. Infestation was rare during rainy season. Thus, warm climatic conditions might favor the reproduction and dissemination of the pest.

Apate monachus infested *Melia azedarach* (in Pawe), *Coffea* sp. and *G. robusta* in Kalu, and *Arundinaria alpine* (in SNNP) District. There was limited infestation of *Carica papaya,* Citrus sp., *Pinus* sp., *Coffea* sp., *Eucalyptus camaldulensis*, *Oxytenanthera abyssinica* (lowland bamboo), *Bambusa bambos, Dendrocalamus asper*, *Annona senegalensis* and *Azandrica indica* saplings that were grown mixed with *M. azedarach* in Pawe District. In contrast, all *M. azedarach* saplings were infestation in the District. The infestation of one but not the other might indicate preference of host trees. Overall, *A. monachus* resulted in poor growth, reduced productivity and gradual death of saplings and matured trees.

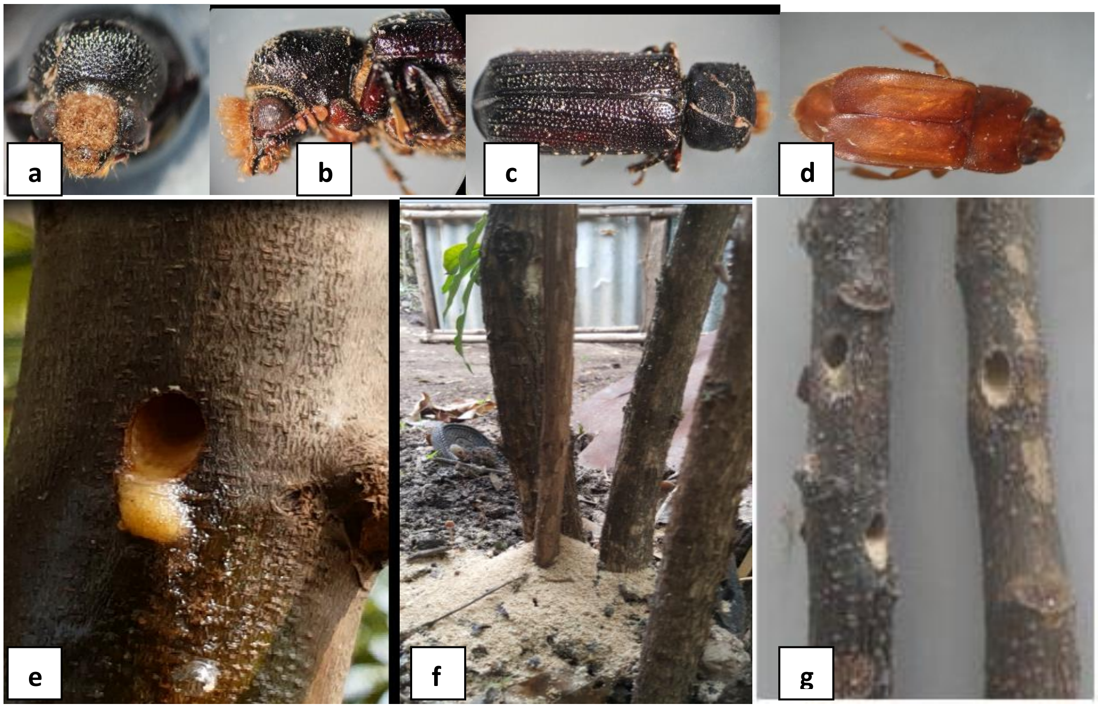

Figure 1. (a-c) *Apate monachus*, (d) *Carpophilus* sp., (e and f) Damaged stems of *G. robusta*, (g) *Melia azedarach*

Discussion

Apate monachus form circular tunnels in stems and branches of infested hosts. It enhances the risk of wind-throw and inducing trunk malformation or resin pockets within the stem wood (Jactel, *et al*., 2002). Because of which, several tree growers in the surveyed areas removed infested trees and discouraged to plant those infested tree species. Although *Apate monachus* was previously reported in coffee trees of East African countries (Waller et al. 2007) that include Ethiopia, our survey has indicated the infestation of *Melia azedarach* (in Pawe), *Coffea* sp and *G. robusta* (in Kalu), and *A. alpine* (in SNNP) for the first time. The presence of the pest in districts that is distantly situated districts, and several species indicates the wider dissemination of *A. monachus* in Ethiopia. On the other hand, the *Carpophilus* species is known as detritivore that are associated with dead wood or old trees (Grove 2010).

Apate monachus is native throughout Africa, distributed in Caribbean, Brazil, Aisa, Europe (France, Great Britain, Germany, Georgia, Italy, The Netherlands, Portugal, Spain, Sweden and Switzerland) and Africa (Wagner, *et al*. 1991). Currently, the pest was reported in several tropical and some temperate forests (Ciesia 2011) in Africa (Eritrea, Ethiopia, Kenya, Tanzania and Uganda in coffee trees, and in Madagascar in unspecified host), in Sardinia, Corsica, Spain, Syria, Israel, W. Indies and tropical's, and America (Hill 2008; Waller et al. 2007). It is known to infest more than 80 plant species including *Acacia* spp.; *Azadirachta indica*; *Coffea arabica*; *Coffea robusta*; *Eucalyptus polycarpa*; *Khaya* spp.; *Melia composita*; *Pithecellobium dulce*; *Psidium guajava*; *Terminalia ivorensis*; *Theobroma cacao*; *Triplochiton scleroxylon* (Bonsignore 2012, El-Shafie 2012).

The infestation of *A. monachus* is frequently disseminated by the transfer of infested plant materials. The preventive and curative interventions of this pest include thorough inspection of beetle penetration holes among young seedlings prepared for transplantation, inserting a flexible metal wire such as bicycle spoke into the tunnels to kill adult insects, the use of cotton plug soaked in insecticide and inserted into penetration holes, painting up and down the insect entrance holes by Neonicotinoids insecticides, and the use of registered natural enemies such as Bethylidae (Hymenoptera) and Clyptodoryctes (Braconidae). Under all conditions, infested trees of all forms (dead, decaying wood and moribund trees) which serve as reproductive site of stem borer insect should be removed and destroyed as soon as possible (Braham and Gahbiche, 2016; Schaffer, *et al*. 2013; Bonsignore, 2012; Ciesia, 2011; Hill 2008; Waller *et al*. 2007).

Limitation of the study and Recommendation

Since this survey was conducted in limited districts of the country, future studies need to address more districts and define the geographical distribution and other hosts of the pest.

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Reference

Bekele-Tesemma A (2007) Useful trees and shrubs for Ethiopia: identification, propagation and management for 17 Agroclimatic zones, RELMA in ICRAF Project, Nairobi, 552 pp

Bonsignore CP (2012) *Apate monachus* (Fabricius, 1775), a Bostrichid Pest of Pomegranate and Carob Trees in Nurseries-Short communication. Plant Protec. Sci. 48: 94-97. www.agriculturejournals.cz/publicFiles/70880.pdf

Bonsignore, C.P. 2012. Apate monachus (Fabricius, 1775), a Bostrichid Pest of Pomegranate and Carob trees in Nurseries. Plant Protect. Sci. 48 (2): 94-97

Braham, M. and Gahbiche, H. (2016). Occurrence of Apate monachus Fabricius 1775 (Coleoptera: Bostrichidae), a black borer attacking pomegranate trees in the Center-East region of Tunisia. International Journal of Entomology and Nematology 2(1): 27-41

Ciesia W M (2011) Forest Entomology: A Global Prospective, Blackwell Publishing Ltd, 416pp.

El-Shafie HAF (2012) Reviewe: List of arthropod pests and their natural enemies identified worldwide on date palm, *Phoenix dactylifera* L. Agric. Biol. J. N. Am. 3: 516-524. http://www.scihub.org/ABJNA/PDF/2012/12/ABJNA-3-12-516-524.pdf

Grove SJ (2010) Tasmanian Forest Insect Collection web-site and database (Hobart: Forestry Tasmania). www.Tfic.net.au/speciesPages/CarpophilusTFICsp04.html (accessed 19 April 2015).

Hill DS (2008) Pests of crops in warmer climates and their control. Springer Science. UK, 704pp.

Jactel, H., Goulard, M., Menassieu, P. and Goujon, G. 2002. Habitat diversity in forest plantations reduces infestations of the pine stem borer *Dioryctria sylvestrella Journal of Applied Ecology* 39(4):618-628

Nardi G, Mifsud D (2015) The Bostrichidae of the Maltese Islands (Coleoptera). ZooKeys 481: 69-108.doi:10.3897/zookeys.481.8294

Omondi W, Maua JO, Gachathi FN (editors) (2004) Tree seed handbook of Kenya, Nairobi, 284pp.

Schaffer BA, Volstenholme BN, Wiley AW (editors) (2013) The Avocado: Botany, production and Uses, CABI, 576pp.

Styles BT, White F (1989) Meliaceae. Pittosporaceae to Araliaceae. Flora of Ethiopia. (eds. Inga Hedberg and Sue Edwards). Volume 3. Addis Ababa and Asmara, Ethiopia, Uppsala, Sweden

Timyan J (1996) Bwa yo: Important trees of Haiti. South-East consortium for International Development, Washington, D.C. http://hdl.handle.net/2027/mdp.39015040685151

Wagner MR, Atuahene SKN, Cobbinah JR (1991) Forest entomology in West Tropical Africa: forest insects of Ghana. Dordrecht, Boston and London: Kluwer Academic Publishers, 210 pp

Waller JM, Bigger M, Hillocks RA (2007) Coffee pests, diseases and their management. CPP. CABI International, Oxfordshire OX10 8DE, UK. www.cabi.org

Wylie FR, Speight MR (2012) Insect pests in tropical forestry. CABI, 376pp, http://dx.doi.org/10.1079/9781845936365.0000

Contribution of Traditional Agroforestry Practices to Livelihood Diversification in the Face of Climate Change in Tigray, Northern Ethiopia

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Abstract

Most of the respondents confirmed that climate change has been risking ecosystems and livelihoods. The study evaluated the role of traditional agroforestry practices in diversifying livelihoods in the face of climate change in Tigray, Ethiopia. Three Kebeles representing different agroecologies were selected based on the experience in agroforestry practices and a total of 197 households were selected for interview. A questionnaire developed based on the prototype of PEN was used for data collection. Analysis was carried out using chi-square test, correlation and descriptive statistics. Even though, there is difference across agroecologies, agrosilopastoral were the dominant traditional agroforestry systems in all agroecologies. About 94% of the respondents have confirmed the presence of climate change, evidenced by low precipitation, increased temperature and extreme climate events. The main coping strategy in the face of climate change is found to be livestock sell (36.5%) followed by support from government and non-governmental organizations (24.4%). Trees on farm contributed 40% of respondents' livelihood cash income. Besides, during droughts the main source of feed for cattle, sheep and goat is mainly from trees on farm land. This is because grasses and forage from crop residues can't be harvested much in drought times. Farmers with increased number of trees on their farm land have an increased crop production ($r = 0.31$) and enhanced income level ($r = 0.48$) that showed an increase in adaptive capacity of households.

Key words: agroforestry practices, climate change, drought, adaptive capacity and livelihoods

Introduction

Climate change is unambiguous and is affecting ecosystems evidenced by various climate indicators (IPCC, 2007a). The IPCC (2014) states that climate change has been already risking some ecosystems, livelihoods, cultures and infrastructures, and unfortunately, the negative impacts of climate change is expected to raise in the developing countries, undermining their efforts to minimize poverty, enhance food security and sustainability. Climate change affects smallholder farmers since they are vulnerable to environmental and climatic problems (Lasco et al, 2014). Climate change highly affects the agriculture sector. Subsistence agriculture is the most vulnerable due to the absence of adequate resources for adaptation to smallholder farmers. The impact becomes intense on smallholder farmers due to the inter-annual variability of rainfall and temperature (Verchot et al, 2007). To minimize or avoid the negative impacts, efforts are necessary, especially in developing countries (FAO, 2007) and there is high confidence that adaptation mechanisms are in place to be implemented (IPPC, 2007a). Combining adaptation with mitigation has been recognized as a necessity in developing countries, particularly in the agriculture, forestry and other land uses (Montagnini and Nair, 2004). Increased attention is being given to agroforestry to increase the resilience of smallholder farmers to climate risks (Lasco et al, 2014).

Agroforestry is an old land use system developed by subsistent farmers in tropics (Zomer et al, 2009, Leakey, 1996 and Beets, 1989) and livelihood option promoted by different actors (Zomer et al, 2009). Assessments show that several thousands of village communities in Asia, Latin America and Africa and in other parts of the world rely on Agroforestry systems for their income, employment, market opportunities, and overall livelihood improvement (Basu, 2013).

Agroforestry can be a good strategy for climate change adaptation by diversifying farmers' production systems and enhancing sustainability due to their ability to maintain production during wetter and drier years (Verchot et al, 2007). It may increase farm profitability through improvement and diversification of output per unit area of tree/crop/livestock, through protection against damaging effects of wind or water flow, and through new products added to the financial diversity and flexibility of the farming enterprise, while also substantially contribute to climate change mitigation (Montagnini and Nair, 2004). It helps farmers to diversify their income and reduce farms risks coming from different challenges such as drought. For instance, teak agroforestry systems provide 40% of household income in Indonesia (Roshetko et al., 2013) and millions of African farmers have been using agroforestry as means of escaping out in the time of climate problems (Mbow, et al, 2013).

Agroforestry practices have an immense role in environmental amelioration, food security, climate change mitigation and adaptation. Agroforestry systems could enhance carbon sequestration, minimize environmental degradation, diversify and sustain production for increased economic benefits for land users at all levels (Torres et al., 2014). Microclimatic improvement through agroforestry changes crop performance as trees can regulate climatic extremes that affect crop growth (Montagnini and Nair, 2004). In particular, the shading effects of agroforestry trees can buffer temperature and atmospheric saturation deficit, and thereby, reducing exposure to supra-optimal temperatures, under which physiological and developmental processes and yield become increasingly vulnerable. Scattered trees in agroforestry farms can enhance the understory growth by reducing incident solar radiation, air and soil temperature, while improving water status, gas exchange and water use efficiency (Mbow, 2013).

Despite its role in increasing the resilience of tropical farming systems (Verchot et al, 2007and Jamnadass et al, 2013), our understanding of the contribution of agroforestry to climate change adaptation and mitigation is not well developed. The role of agroforestry in regulating climate problems is not well-studied (Verchot et al, 2007). Scientists claimed that research is needed regarding the integration of ecological knowledge and socio-economic constraints to scaling up agroforestry and to enable promote tree-based farming (Carsan et al, 2014, Coe et al, 2013). This could enhance yields of tree foods and improve the synergy of food production in smallholders' agroforestry systems (Jamnadass et al , 2013). As vulnerability of smallholder farmers and pastoral and agro-pastoral communities and their production systems to climate change is growing over time, it is important to investigate the traditional agroforestry systems that diversify livelihoods and thereby, enhance adaptation to and mitigation of climate change (Hassan et al, 2015).

Ethiopia is one of the countries having agroforestry practices (Teketay and Tegineh, 1991). Nevertheless, adequate research and extension is limited in agroforestry in the country (Hassan et al, 2015). It is important to answer the question how significant the benefits of practicing agroforestry systems for adaptation are? Therefore, this study was intended to examine the contribution of traditional agroforestry systems and practices which diversify livelihoods in the face of climate change problems in various agroecologies in Tigray, Ethiopia.

Materials and Methods

Study site

The selected study sites, Endamekhoni, Kilteawlaelo and Tanqua Aberegele are located in the southern, central and eastern parts of Tigray Regional State (12^0-15^0 N and 36° 30' - 40° 30' E), respectively. The three districts represent highland, midland and lowland agroecologies respectively.

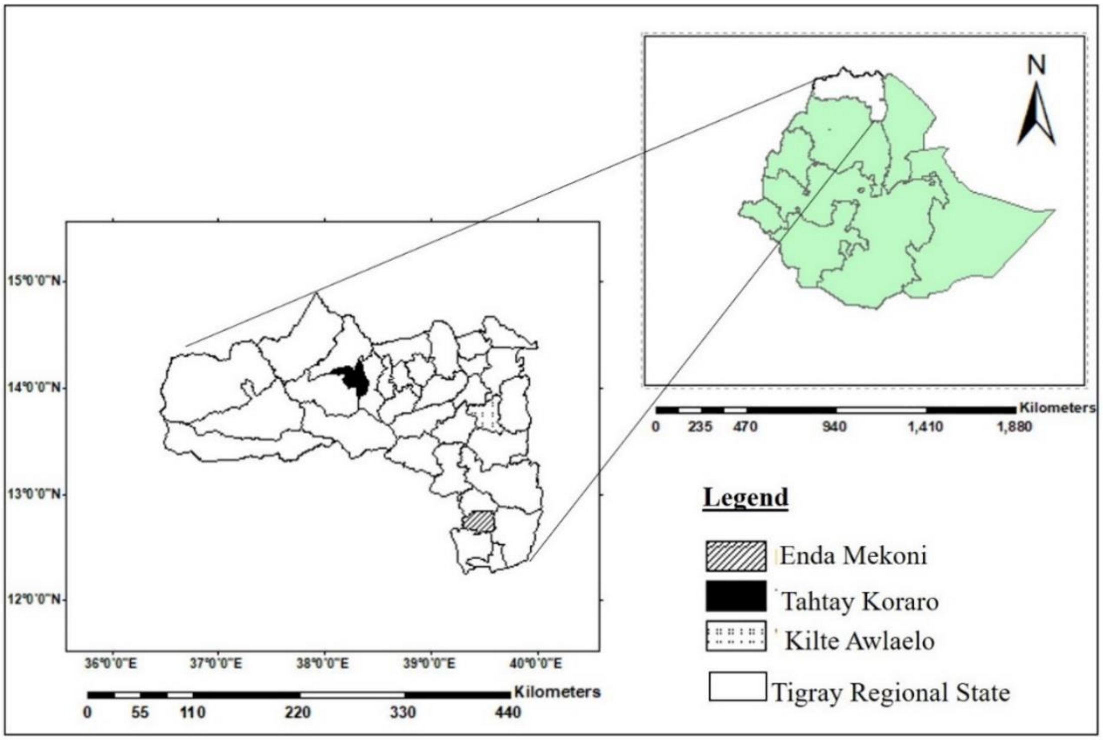

Figure 1 Map of the study area

The study sites received bimodal (Endamekoni and Kilteawlaelo) and unimodal (Tanqua Abergel) type of rainfall with average mean of 754 mm per year. It has mean minimum monthly temperature varying from 10 to 14 ˚C and mean maximum temperature ranges between 23 to 30 ˚C. The dominant soil type are Leptisol and Cambisol (FAO, 1988). *Ziziphus spina-christ*, *Faidherbia albida* and *Eucalyptus species* are the most dominant species in Tanqua Abergele (low land), Kilteawlaelo (midland) and Endamekhoni (highland).

Data collection and Analysis

First, a reconnaissance survey was conducted in potential agroforestry sites across different agroecologies. Based on the reconnaissance survey, one site was selected from each agroecology to be studied. Mekhan, Abrehaweatsbeha and Shekhatekli kebelese were selected representing highland, midland and lowland areas respectively.

A questionnaire was developed based on the prototype of the PEN (Poverty Environment Network) of the CIFOR (Bakkegaard, 2013). Sixty-eight sample households were selected from each kebele for interview. But, the only 68 questionnaires from Shkhaekli, 64 from Abrehaweatsbeha and 65 from Mekhan were validated.

Data regarding household characteristics, climate change adaptation strategies, livelihood strategies and income from agroforestry systems and its relative contribution to other livelihood strategies and its role in household's asset maintenance and building were collected through the questionnaire survey. After appropriate data were collected, analysis was done using SPSS. Descriptive method and statistical techniques like chi-square test, correlation, frequency and percentage were used to analyze the data gathered.

Result and Discussion

Socioeconomic characteristics of respondents

Sixty-nine percent of respondents were males and the remaining were females. The mean average of age of respondents was 49±13 in the highland, 48±13 in the midland and 47±14 in the lowland agroecologies. The average family size was 6±2 across all agro-ecologies. Most of the respondents were illiterate (48.2%) and elementary level (and 41.6%), Most of the sample households (63%) were in medium level wealth status (Table 1).

Table1: Socioeconomic characteristics of respondents (N =197)

Characteristics		Frequency	Percent
Gender	Male	136	69
	Female	61	31
Educational status	Elementary	84	42.6
	Illiterate	95	48.2
	Secondary	15	7.6
	Diploma	3	1.5
Wealth status	Poor	57	28.9
	Medium	124	62.9
	Rich	16	8.1

Note: Rich people owning land and 2 pair of oxen, medium owning land and pair of oxen and poor owning no pair oxen

Topologies of traditional agroforestry

The study reveals that most of the people practice agro-silvo-pastoral system (71.6%) followed by agro-silviculture (25.4%) and Silvo-pastoral (1.6%) type of agroforestry system (Figure 1). Under each agroforestry system there are different types of agroforestry practices. The agroforestry practices are varied with agroecology. In the lowland (Tanqua Abergele district), almost all the households practiced parkland type of agroforestry. In the midland (Kilte-Awlaelo district) parkland agroforestry (90%), woodlot (7 %) and home garden (3 %) were practiced. Whereas in the highland (Endamehoni district), 48% of the respondents were found practicing woodlot followed by home garden (31%) and boundary panting (20%). Overall, most of the residents adopted parkland (61.2%) agroforestry.

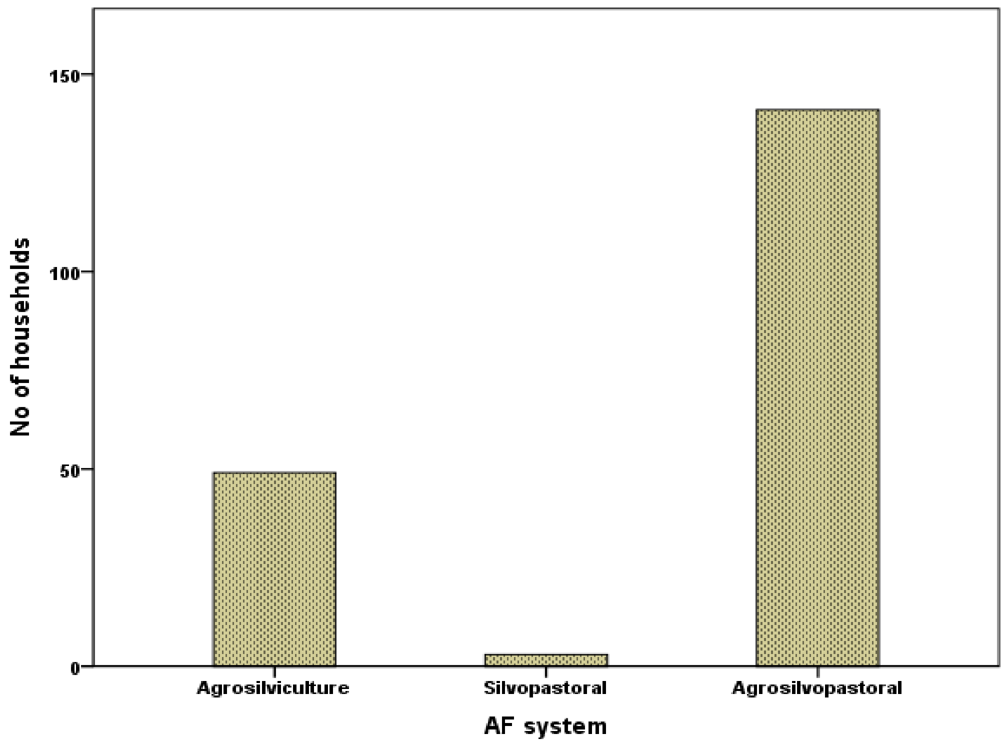

Figure 2 Types of agroforestry systems in the study areas

In the lowland agroecology of the study area, the type of crops integrated mostly with *Ziziphus spina-christi* trees were *Zea mays* (Maize), *Sorghum bicolour* (sorghum), *Eragrostis teff* (teff), *Linum usitatissimum* (Linseed) and *Eleusine coracana* (finger millet). In the midland, the dominant trees of *Faidherbia albida* were integrated with crops of *Triticumae stivum* (wheat), *Eragrostis teff* (teff), *Zea mays* (Maize) and *Eleusine coracana* (finger millet). In the highland the dominant tree species was *Eucalyptus globules* (Table 2). In southern Ethiopia, agroforesry practices comprise multipurpose trees like moringa, enset, mango, papaya, lemon, orange, avocado and banana along with vegetables and livestock (Alemu, 2016).

Benefits of traditional agroforestry system

Results show on farm trees provide subsistence benefits for timbers (29.4%), fodder (24.4%), firewood (14.4%) and for other uses (Figure 2). Respondents stated that agroforestry practices have an immense role in enhancing food security in addition to fodder, poles, farm equipment and fuel wood provisions (Badege and Abdu, 2003). At the household level, TAF system provides livelihood support to the households by contributing various services such as improve land productivity and provide food, timber, fuel wood, and fodder directly to the households. Besides, by sequestering carbon from the atmosphere, agroforestry is also providing services at the global level (Torres et al., 2014).

Table 2 Components of TAF system in three Agroecologies of Tigray regional state

District	Main tree /shrub species	Main crops	Main livestock
Highland	*Eucalyptus globulus, E. camaldulensis, Olea europaea subsp. africana, Sesbania sesban, Acacia abyssinica, Cupressus lusitanica*	*Hordeum vulgare* (Barley),*Triticum aestivum* (wheat) and *Zea mays* (Maize)	Cattle & Oxen and sheep
Midland	*Faidherbia albida, Eucalyptus camaldulensis, Acacia etbaica, Acacia saligna, Maytenus senegalensis*	*Triticumaestivum* (wheat),*Eragrostis teff* (teff), *Zea mays* (Maize), Eleusine coracana (finger millet)	Cattle & Oxen, Donkey, Bee and Sheep
Lowland	*Ziziphus spina-christi, Combretum mole, Albezia amara, Acacia etbaica, Acacia seyal, Cordia Africana*	*Zea mays* (Maize), *Sorghum bicolour* (sorghum),*Eragrostis teff* (teff), *Linum usitatissimum* (Linseed) and *Eleusine coracana* (finger millet)	Got, Cattle & Oxen, Donkey, Bee and Sheep

Crop production in the absence of trees on farm was decreased as evaluated by the respondents. Only some respondents claimed that crop productions in the absence or presence of trees on farm have limited change (Figure 3). This indicates that farmers are enjoying an enhancement of crop production through the trees they manage on their farm land.

Agroforestry increases farm profitability through improvement and diversification of output per unit area of tree/crop/livestock, through protection against damaging effects of wind or water flow, and through new products added to the financial diversity and flexibility of the farming enterprise, while also substantially contribute to climate change mitigation (Verchot et al, 2007, and Montagnini and Nair, 2004).

Agroforestry practices for Livelihood diversification

This study showed that, tree-based farming systems have significant role in diversifying livelihood of farm households. The Pearson correlation showed that there is a positive relationship ($p < 0.01$) of number of tress with household income ($r = 0.482$) and crop production ($r = 0.308$) (Table 3). This shows that agroforestry plays role in better adaptive capacity building of farm households to climate change. Others studies (Quandt*et al*, 2017) also showed that agroforestry help to build financial and human capital by which people with better financial and human capital are better prepared to drought and floods.

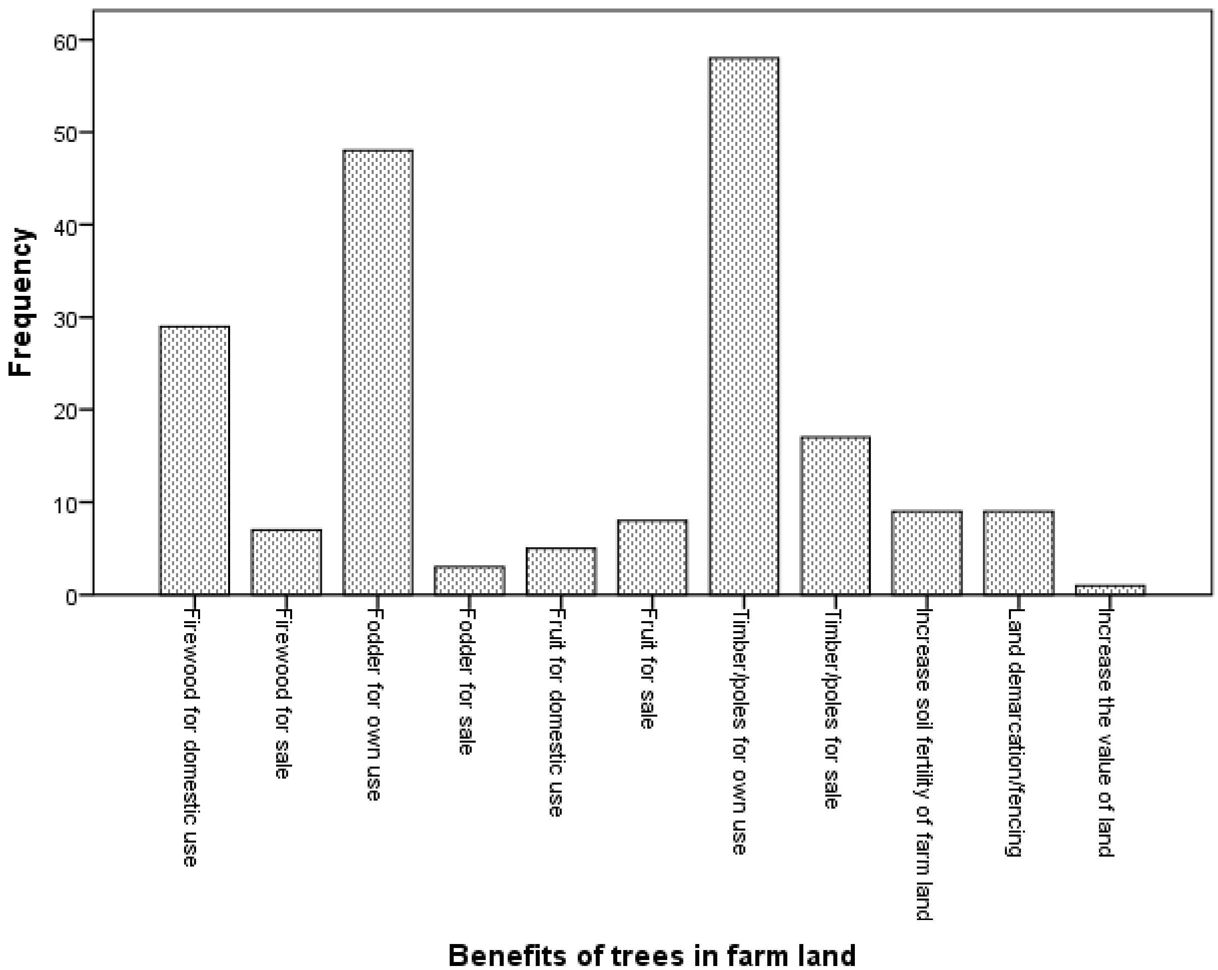

Figure 3 The uses of agroforestry to households' livelihood

Table 3 The relationship of income and crop production Vs tree stands in farm land

Variables		Total tree stands in farm land
Household income	Pearson Correlation	0.482
	Sig. (2-tailed)	0.000
	N	174
Crop production	Pearson Correlation	0.308
	Sig. (2-tailed)	0.000
	N	160

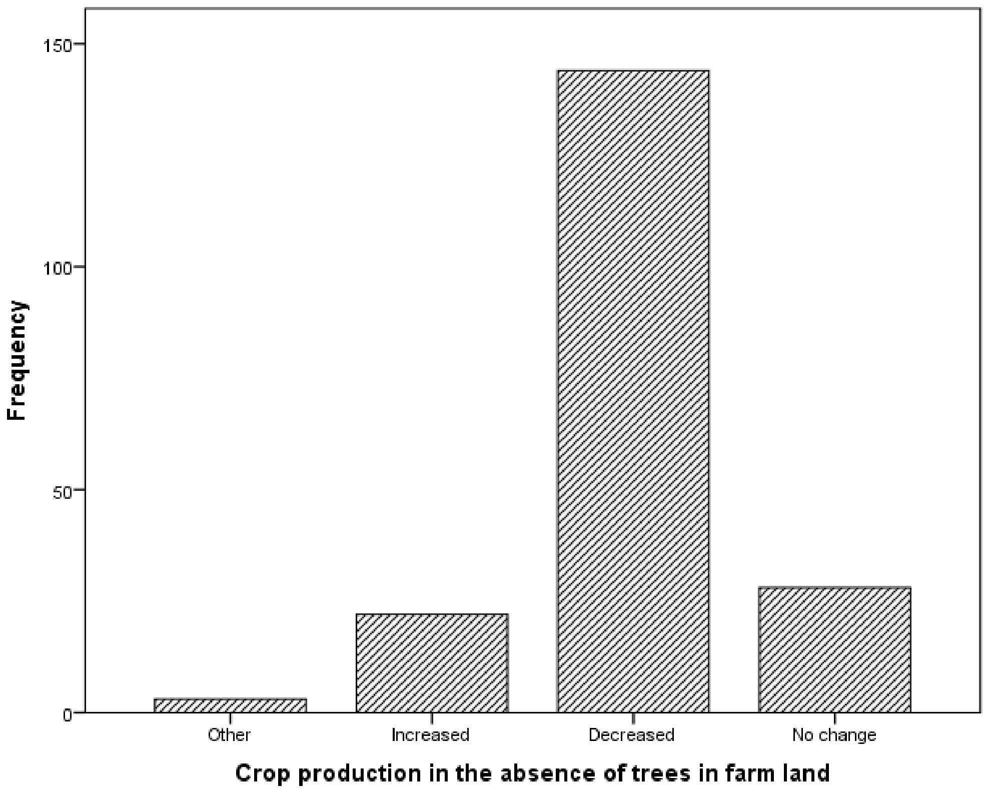

Figure 4 Farmers response on crop production in the absence of trees on farm land

Overall, the study showed that agroforestry contributed about 40% of the subsistence products (timber, fruit, fuel wood, etc). The contributions of traditional agroforestry to livelihood production of the households were about 52%, 37% and 70%, respectively, in highland, lowland and midland agroecologies. In general, timber and fuel wood were the most important wood product obtained from agroforestry practices (Figure 4). However, in the midland, the prime need of tree on farm was provision for fodder (65%) to feed their livestock, so that livestock will sustain their productivity and strive in time of drought.

The traditional agroforestry products were important for diversifying household income. Considerable amount of income has been earned from agroforestry products. But, the income generated from TAF product significantly ($p < 0.05$) varied among each agroecologies (Table 4).

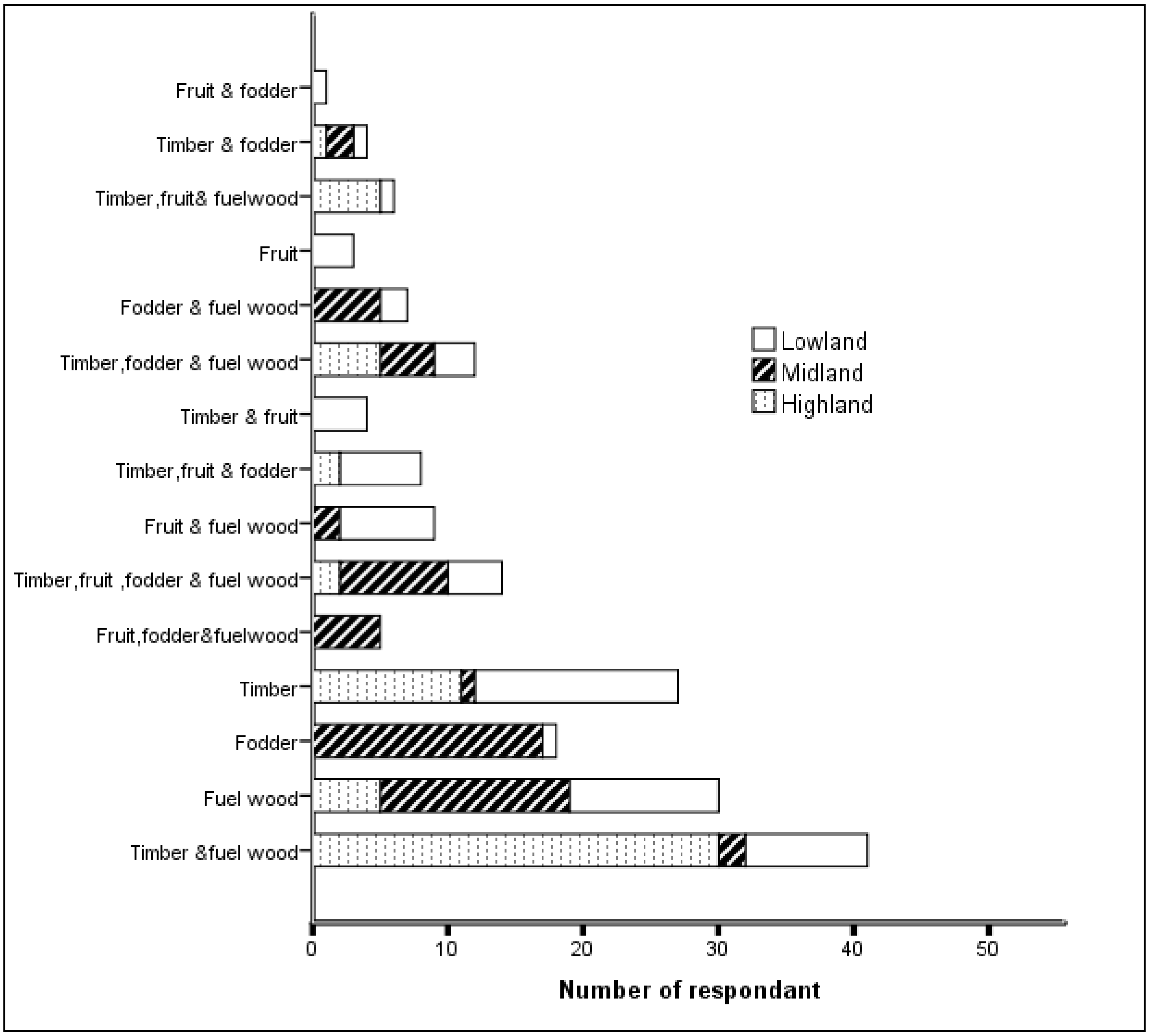

Figure 5 Important products of agroforestry for subsistence in different agroecologies of Tigray

The study showed that the annual share of tree stands compared to the main household asset is ranked third next to cattle and crop production (Table 5). The highlanders have highest asset accumulation of trees on farms and the midlanders are the lowest. This show, trees on farm asset differ among households, indicating there is variation in adopting the practice, there by obtaining the subsequent benefits This indicates tree-based farming system have significant role in diversifying livelihood. Similar study conducted in north western Ethiopia, indicated farmers practicing home garden agroforestry improve their livelihood strategy better than non-practitioners (Linger, 2014). Many households in Southern Ethiopia also supported their livelihood through agroforestry to attain food security. Households with increased tree-based land use system were found better in terms of food security in the area (Kebebew and Urgesa, 2011).

Table 4 Income generating from AF product of Tigray regional state

Product	Agroecology	N	Mean	SD
Crops	Highland	64	10645.94	7888.86
	Lowland	68	9961.03	7946.14
	Mid land	64	6314.53	4561.98
	p-value		0.003	
Fruit	Highland	64	1.17	9.38
	Lowland	68	481.25	389.91
	Mid land	64	809.70	1791.11
	p-value		0.000	
Timber	Highland	64	2789.38	4797.55
	Lowland	68	1522.88	2668.44
	Mid land	64	333.83	970.27
	p-value		0.002	
Fuelwood	Highland	64	1339.66	3236.40
	Lowland	68	521.91	976.41
	Mid land	64	136.17	252.32
	p-value		0.001	
Fodder	Highland	64	42.97	313.56
	Lowland	68	1203.31	2448.29
	Mid land	64	940.63	1790.93
	p-value		0.003	

Table 5 Main household livelihood assets in the study areas

Agroecology		Crop production (Birr)	Money saved (Birr)	Sheep and goat (Birr)	Tree stands (Birr)	Cattle asset (Birr)
Highland	Mean	17214.29	2437.38	516.1538	15986.63	11936.92
	SD	13811.401	7843.985	764.39864	23636.206	10983.646
Lowland	Mean	9506.62	969.12	9954.4776	4098.70	14653.23
	SD	10319.717	2492.571	11610.53183	3997.609	8541.412
Midland	Mean	5146.88	735.94	2752.3438	3074.84	17003.13
	SD	3467.077	2104.219	4266.02887	4841.089	13829.965

Agroforestry and livelihood diversification in the face of climate change

Most of the respondents (94%) agreed that climate change is happening. The results from the open-ended questions indicated that climate is being changed, evidenced by low precipitation, rainfall shortage, short rainfall duration, irregular rainfall, increased temperature (different from the past times) and extreme climate events (mostly drought). As evidenced by the respondents (72%) drought is the most frequent climate hazard threatening the community (Table 6). Studies also confirm the presence of climate change (IPCC, 2007) and its impact on ecosystems, livelihoods, cultures and infrastructures (IPCC, 2014).

Table 6 People's perception to the presence of climate change

Perception if climate is changed (N= 197)		
	Frequency	Percent
Yes	185	94
No	4	2
Not sure	8	4

Respondents confirmed that climate change problems have been threatening livelihoods of the local people by decreasing production system of the farmers. Other researchers also found that climate change affects agriculture sector by which small holder farmers are and will be the most affected (IPCC, 2014, Lasco et al, 2014 and Verchot et al, 2007). The IPCC underscored that there is high confidence that smallholder farmers in developing countries will suffer more because of climate change impacts (Lasco, et al, 2011).

When livelihoods are affected by climate change problems, they come up with strategies to adapt to the problem. The primary adaptation strategy of farm households in the face of climate change is livestock sell (37%), second adaptation strategy was selected livestock sell (28%) followed by aid support (20%) and third was tree products from farm land (21%) (Table 7). But, the study showed that preference of adaptation options differs among farmers (Table 8). Apart from these, respondents confirmed that in drought times their main source of income is livestock by which source of feed for their cattle, sheep and goat is mainly from trees in farm land. This is because grasses and forage from crop residues can't be harvested much in drought times. This was similar with other findings (Quandt*et al*, 2017). Quandt et al (2017) stated that when hunger of livestock occurs due to drought, farmers in Kenya used agroforestry to feed nutritious fodder and thereby enhance their livelihood resilience.

Scholars found that tree based agricultural practices produce staples and commercial tree products, thereby diversify production systems and improve livelihoods (Carsan et al, 2014). In Africa, trees have been contributing for food security, environmental and social benefits in the face of climate change. It has been providing a way for millions of Africans when their livelihoods are threatened by climate change and land degradation (Mbow et al, 2014).

Thus, agroforestry diversifies income of farmers thereby reduce farms risks coming from different climate change challenges (Roshetko et al., 2013). It played significant role in enabling to cope up with disaster by improving the resilience of the community in times of drought (Alemu, 2016).

Table 7 Livelihood strategies in drought times

	The 1st livelihood strategy		The 2nd livelihood strategy		The 3rd livelihood strategy	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Livestock sell	72	36.5	56	28.4	18	9.1
Saving	20	10.2	17	8.6	15	7.6
Tree product	12	6.1	27	13.7	41	20.8
Insurance	7	3.6	15	7.6	21	10.7
Migration	4	2.0	4	2.0	3	1.5
Remittance	2	1.0			3	1.5
Gov and NGO support	48	24.4	39	19.8	25	12.7
support from relatives	1	0.5	3	1.5	8	4.1
Extra labour	13	6.6	11	5.6	15	7.6
Others	7	3.6	2	1.0	5	2.5
Missing	11	5.6	23	11.7	43	21.8
	197	100.0	197	100.0	197	100.0

Table 8 Preference of adaptation option

	The 1st adaptation option	The 2nd adaptation option	The 3rd adaptation option
Chi-Square	261.312	138.931	81.584
df	9	8	9
Asymp. Sig.	0.000	0.000	0.000

In an increasing risk of climate change, agroforestry systems as a strategy enhance the resilience of smallholder farmers (Lasco et al, 2014). Directly or indirectly, agroforestry builds livelihood resilience to floods and drought. For instance, farmers in Kenya have been escaping from drought using mango, papaya and banana products. This indicates agroforestry is promising option for livelihood resilience in drought times (Quandt et al, 2017). In north western Ethiopia farmers practicing home garden agroforestry improve their livelihood strategy better than non-practitioners, thereby enhance their adaptive capacity to climate change and/or climate related stress/drought (Linger, 2014). Besides, the number of tree stands on farm land showed a positive correlation with crop production and also with income of households (Table 4). This justifies an increase in adaptive capacity of households. Similarly, tree-based land use system has positive relationship with food security in southern Ethiopia (Kebebew and Urgesa, 2011).

Conclusion and Recommendation

Climate change is threatening communities by disturbing their livelihood negatively. In time of such difficulties, farmers come up with adaptation strategies such as agroforestry practices. In drought times, farmers' main source of income is livestock by which the source of feed for their cattle, sheep and goat is mainly from trees on farm land. This is because grasses and forage from crop residues can't be harvested much in drought times. The study indicates that agroforestry significantly diversifies livelihood strategy of farmers in the face of climate change directly (as source of income) and indirectly (as source of feed). In addition to that, the study revealed that agroforestry provides various benefits by improving farm productivity and optimizing livelihood options of farmers. Tree products obtained from farm land are found to be the third most important livelihood product, indicating that agroforestry practice is one of the most relevant livelihood strategies for many households.

Researchers argue that agroforestry practices should be included in agriculture and forestry agendas in initiatives of climate change globally. Therefore, responsible bodies should put their effort to upscale agroforestry practices. Including agroforestry systems/practices in policy issues will have high impact in up calling the country's effort to climate resilient economy. Further study is required on innovative agroforestry practices which can improve the livelihood of smallholder farmers. There is a need to focus on research, training and extension for better adoption of best agroforestry practices so that adaptive capacity of smallholder farmers could be enhanced.

References

Alemu, M. (2016). 'Indigenous Agroforestry Practices in Southern Ethiopia: The Case of Lante, ArbaMinch', *Open Access Library.Journal*, 3:e3278. http://dx.doi.org/10.4236/oalib.1103278

Badege, B. and Abdu, A. (2003). Agroforestry and Community Forestry for Rehabilitation of Degraded Watersheds on the Ethiopian Highlands', *International Conference on African Development Archives,* Paper 78 http://scholarworks.wmich.edu/africancenter_icad_archive/78

Bakkegaard, R. K. (2013). CIFOR Poverty Environment Network (PEN) Survey Analysis: Consultancy report.

Carsan, S., Stroebel, A., Dawson, I., Kindt, R., Mbow, C., Mowo, J. and Jamnadass, R. (2014) 'Can agroforestry option values improve the functioning of drivers of agricultural intensification in Africa?', *Current Opinion in Environmental Sustainability* 2014, 6:35–40

Coe, R., Sinclair, F. and Barrios, E. (2013), 'Scaling up agroforestry requires research 'in' rather than 'for' development', *Current Opinion in Environmental Sustainability* 2014, 6:73–77.

FAO (1988) ‘Unesco Soil Map of the World, Revised Legend, with corrections and updates’, *World soil resources Report*, 60, p. 140.

FAO (2007), *Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities*, InterdepartmentalWorking Group on Climate Change, Food and Agriculture Organization (FAO) of the United Nations, Rome.

Hassan, M., Hadgu, K., Birhane, E., Muthuri, C., Mwangi, A., Sinclair, F. and Mowo, J. (2013), *Agroforestry in Ethiopia: using trees on farms to boost crop productivity and strengthen food security,* World agroforestry center, policy brief.

IPCC (2007), *Climate Change: Synthesis Report*. Cambridge University Press, Cambridge.

IPCC (2014), Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Jamnadass, R., Place, F., Torquebiau, E., Malézieux, E., Iiyama, M., Sileshi, GW., Kehlenbeck, K., Masters, E., McMullin, S., Weber, JC. And Dawson, IK. (2013),*Agroforestry, food and nutritional security,* ICRAF Working Paper No. 170. Nairobi, World Agroforestry Centre. DOI:http://dx.doi.org/10.5716/WP13054.PDF

Kebebew, Z. and Urgessa, K. (2011), ‘Agroforestry Perspective in Land Use Pattern and Farmers Coping Strategy: Experience from Southwestern Ethiopia’, *World Journal of Agricultural Sciences* 7 (1): 73-77, 2011 ISSN 1817-3047.

Lasco, RD.,Habito, CMD.,Delfino, RJP., and Rogelio, FBP.(2011), *Climate Change Adaptation for Smallholder Farmers in Southeast Asia,* World Agroforestry Centre (ICRAF) ISBN 978-971-93153-9-1

Lasco,RD., Delfino, RJP., Catacutan, DC., Simelton, ES.and Wilson, DM. (2014), ‘Climate risk adaptation by smallholder farmers: the roles of trees and agroforestry’, *Current Opinion in Environmental Sustainability* 2014, 6:83–88

Linger, E. (2014), ‘Agro-ecosystem and socio-economic role of home garden agroforestry in Jabithenan District, North-Western Ethiopia: implication for climate change adaptation’, *SpringerPlus*, 2014 3:154.

Mbow, C., Noordwijk, MV., Luedeling, E., Neufeldt, H., Minang, PA. and Kowero, G. (2013). ‘Agroforestry solutions to address food security and climate change challenges in Africa’, *Current Opinion in Environmental Sustainability* 2014, 6:61–67.

Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M. (2014), ‘Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa’,*Current Opinion in Environmental Sustainability*2014, 6:8–14.

Montagnini, F. and Nair, PKR. (2004),‘Carbon sequestration: An underexploited environmental benefits of agroforestry systems’,*Agroforestry Systems* 61: 281–295, 2004, Yale University, School of Forestry and Environmental Studies.

Quandt, AH.,Neufeldt, and McCabe (2017),‘The role of agroforestry in building livelihood resilience to floods and drought in semiarid Kenya’, *Ecology and Society* 22(3):10. https://doi.org/10.5751/ES-09461-220310

Roshetko, JM., Rohadi, D., Perdana, A., Sabastian, G., Nuryartono, N., Pramono, AA., Widyani, N., Manalu, P., Fauzi, MA., Sumardamto, P. andKusumowardhani, N.

(2013),'Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation', *Forests, Trees and Livelihoods*, 22:4, 241-256, DOI: 10.1080/14728028.2013.855150

Teketay, D. and Tegineh, A. (1991),'Traditional tree crop based agroforestry in coffee producingareas of Harerge, Eastern Ethiopia', *Agroforestry Systems*16:257--267, 1991. KluwerAcademic Publishers, Netherlands.

Verchot, LV., Noordwijk, MV., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, KV. And Palm, C. (2007), 'Climate change: linking adaptation and mitigationthrough agroforestry', *Mitig Adapt Strat Glob Change* (2007) 12:901–918DOI 10.1007/s11027-007-9105-6

Zomer,RJ.,Trabucco, A., Coe, R. and Place, F. (2009). *Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agroforestry*, ICRAF Working Paper no. 89. World Agroforestry Centre, Nairobi, Kenya.

Selecting Productive and Climate Resilient Traditional Agroforestry Systems in Tigray Region, Northern Ethiopia

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Abstract

Agroforestry addresses both food security of small-scale farmers and creates synergies amongclimate change adaptation and mitigations. Despitethere is still limitation on which traditional agroforestry system (TAF) is resilient to changing climate, which system better works where, for whom and under which conditions. Thus, the present study is aimed on evaluating the TAF practices on the face of climate resilience in three agro–ecologies logical part of Tigray Region, Ethiopia. Onedistricts from each agroecologywere purposively selected. Then, systematic random sampling was employed to collect social and biophysical data from total of 197 households (HHs). Socioeconomic data were collected using semi-structured questionnaires while woody species inventory (dbh and total height) was done on each HHs randomly established different plot size. Agro–sivopastoral was the dominant TAF systems of all agroecologies. Park land AF practices were dominant in the midland and lowland whereas, rotational woodlot in Highland. In overall agroforestry contributes about 39.5% of the livelihood products. A total of 59 species, belonging to 48 genera and 32 families were recorded. Shannon diversity index (H') of highland agroecology was higher in-home garden AF while in the midland and lowland the higher H' were recorded in parkland agroforestry. The mean total biomass carbon stocks of the TAF system were 21.4 tC $ha^{-1.}$ In the highland and midland, the biomass carbon stock was significant ($p< 0.05$) between each TAF practices. Thus, Combined ranking of our study showed that TAF practices such as parkland followed by home garden agroforestryhas mutual benefits on providing food security to small-scale farmers and improve the climate change adaptation and mitigations strategies

Introduction

Nowadays climate change is a challenge for ourworld in general and developing countries in particular (Verchot *et al.*, 2007; Mbow, Smith*et al.*, 2014; Ali and Erenstein, 2017). This affects directly and indirectly to the agricultural production and provision of ecosystem goods and services. Moreover, there is an evidence that climate change affects tremendously Sub-Saharan Africa(SSA) (Gebrehiwot and Veen, 2013; Mbow *et al.*, 2014; Bishaw et al., 2013; Kuyah *et al.*, 2016).

Ethiopia is among the most vulnerable countries to climate change (Conway and Schipper, 2011; Gebrehiwot and Veen, 2013). As a result, majority of the community remain chronically food insecure.The northern part of the country (stud region) is also identified as vulnerable area to climate change (Hadgu *et al.*, 2015). As a result, the community need special attention.

Agroforestry practice increases the carbon stock potential andenhance agricultural productivity (Unruh*et al*, 1993; Mbow*et al.*, 2014). In many Africa countries including Ethiopia, there is an urgent need to further develop and introduce Agroforestrytechnologies to avert climate change (Mbow, *et al.*, 2014). Nevertheless, in Ethiopia, integration of trees and shrubs into the agricultural systems practiced thousand years ago (Negash and Starr, 2015). Though indigenous knowledge and experience of the local community should be documented.

Currently the government of Ethiopia promoted agroforestry to improve local livelihood by income diversification; reduce GHG emissions and enhance forest and soil carbon stocks (MEFCC, 2015). Despite the significant contribution of agroforestry systems in climate adaptation and mitigation (Bishaw et al., 2013; Lasco et al., 2014; Montagnini & Nair, 2004; Nguyen et al., 2013; Verchot et al., 2007), it doesn't mean that all agroforestry systems are effective and apply everywhere. Mbow et al. (2014) argue that, there is still limitation of knowledge in understanding, Which system is better works in which agroecological Zones? and How can small holder farmers be benefited from farm-based carbon? Thus, the present study is aimed on evaluate the most climate resilience traditional agroforestry practices in the different agroecological part of Tigray region, Ethiopia.

Material and methods

Study site

The study was conducted in three districts (Klite Awlalo, Tanqua Abergele and Endamehoni) of Tigray regional, Northen Ethiopia. The study sites geographically bounded 12^0-15^0 N latitude and 36° 30' - 40° 30' E longitude of the Northern, Ethiopia (Figure 1).

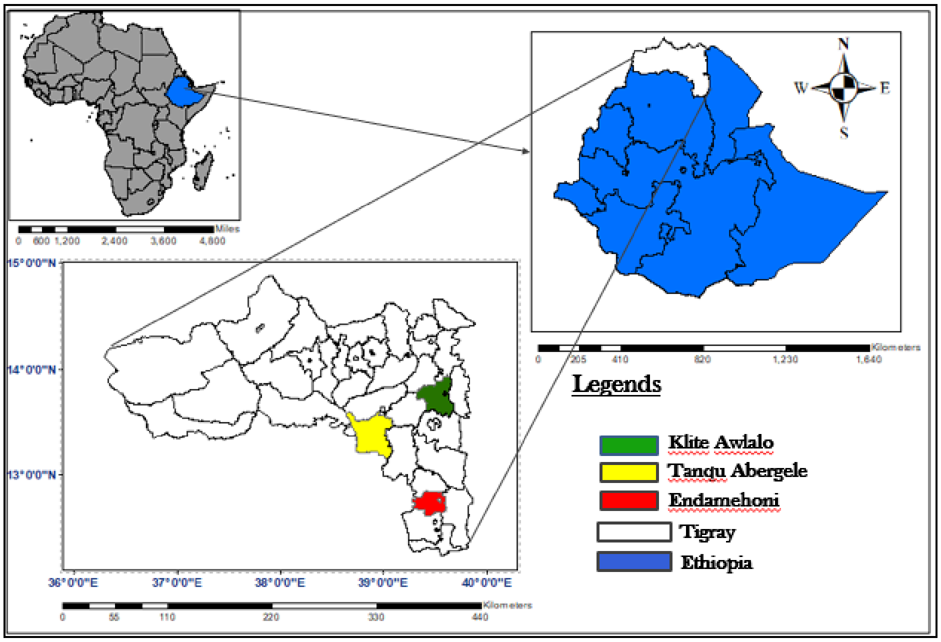

Figure 1 Location of the study area in the different agro - ecology of Tigray Region, Ethiopia.

The mean annual rainfall of the study districts (From year 2000-2014) ranged from 580 to 968 mm year^{-1}. Whereas, the monthly temperature was ranged from 10 to 30 ^{O}C. (Figure 2).

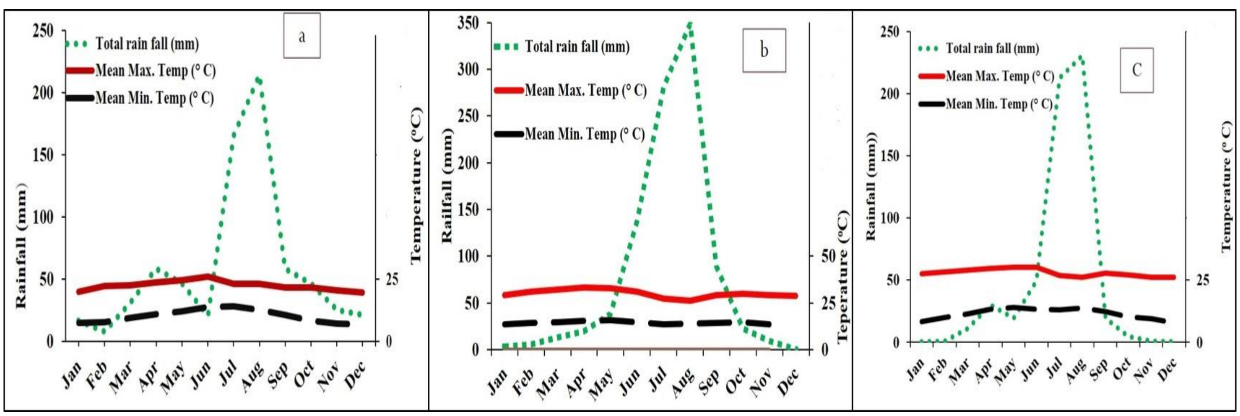

Figure 2 Climate diagram of the study Maychew (a), TanquaAbergele (b) and KlilteAwlalo (c) districts

The dominant soil type of the study districts are Leptosol and Cambisol, while the dominant woody species were *Ziziphus spina-christ* in the lowland, *Faidherbia albida*in midland and *Eucalyptus species* in the highlands. (FAO, 1988). Whereas the dominant agricultural crops are *Eragrosti steff* (teff), *Zea mays* (Maize), *Triticum aestivum* (wheat), *Sorghum bicolour* (sorghum)and *Hordeum vulgare* (Barley).

Sampling design, data collection and analysis

A preliminary survey has been done to identify the existed agroforestry types. Endamehoni, Tanqua Abergele and KliteAwlalo districts were purposively selected from Tigray region, represents variation in agroecological of the region which is from highland, lowland and midland respectively. A multistage sampling technique was employed to collect the data. Systematic random sampling was used to select a total of 197 households. From each HHs Socioeconomic and inventory data have been taken. The plot size was established randomly for inventory data with 20*20 m (Abiot, and Gonfa, 2015) plot size for home garden agroforestry, 50*100 m for park land agroforestry, 10*10 m for wood lot agroforestry (Bajigo& Tadesse, 2015) and 10*50 for boundary plantations. The sample households were determined based on the procedures of (Akinnifesinu*et al*., 2011) (Equation 1).

$$n = \frac{z^2 . N . \sigma^2}{(N-1)\, e^2 + z^2 . \sigma^2} \quad \text{.......... Equation (1)}$$

Where *N* = size of population; n= size of sample; *e* = acceptable error (the precision); σ = standard deviation of population; z= standard variate at a given confidence level.

For the sake of uniformity, the following values will be used for calculation,
$e = 0.5$ $\sigma = 3$ $z = 1.96$ (95% confidence level)

Semi-structured questionnaires were used to collect socio - economic data.To estimate the above ground biomass (AGB) carbon stock diameter at breast height (dbh) was measured directly from each plot. For multi-stemmed woody species such as *Ziziphus spina-christ*, each stem will be measured separately and the equivalent diameter of the plant was calculated as the square root of the sum of diameters of all stems per plant (Snowdon *et al.*, 2002).

Then AGB and BGB was estimated using the general allometric equations of Kuyah et al. (2012a) & Kuyah et al (2012b) respectively, developed for agroforestry species of Kenya. Tree/shrub biomass was converted to C by multiplying the above ground biomass by 0.5 (MacDicken, 1997). SOC stocks (Mg ha^{-1}) were determined following the procedure of Pearson et al. (2007). The Ecosystem carbon stocks were calculated with the summation of biomass and soil C stocks.

$$AGB = 0.091\ X\ dbh^{2.472} \quad ; R^2 = 0.977,\ n = 72\ (1)$$

Where, ABG is the aboveground biomass (kg dry mass per tree) and dbh is diameter at a breast height (cm)

$$BGB = 0.490\ x\ AGB^{0.923} \quad ; R^2 = 0.\ 95;\ n = 72\ (2)$$

Where, BGB is belowground biomass (kg dry matter/ tree) and AGB is aboveground biomass (kg dry matter per tree)

Tree biomass was converted into C by multiplying the above ground biomass by 0.5(MacDicken, 1997).

Statistical analysis

A normality and equality of variance was done to check the data prior to analysis using non-parametric test. The variations in socio - economic and biophysical data were analyzed using descriptive statistics and Chi square test. Mean separation was conducted using ANOVA at (α = 0.05). Spearman correlations test was conducted to see the relation between numbers of trees on farm andcrop yield.

Results

Socioeconomic characteristics of Households

167 respondents, about 69% male and 31% female, were selected (Table 1). 50% of the respondents were read and write. The total average land holding size of each respondent was 0.76 ha. The primary preferred product of the targeted area wascrop production (91%), followed by livestock production (70%) and agroforestry (67%).

Table 1 Household (HH) characteristics of the three districts of Tigray region, Ethiopia

Variable	Highland	Midland	Lowland
No of respondent (by sex)	Total = 65 (M=43); (F=22)	Total = 64 (M=36); (F=28)	Total =68 (M=57); (F=11)
Average family size (±SD)	6±2	6±2	6±2
Average age of the respondent	49±13	48±13	47±14
Mean land holding size (ha ±SD)	0.76 ±0.49	0.89 ±0.78	1.62±0.76

Characterization of the traditional agroforestry systems

Three (Agro - silvicultural, Silvopastoral & Agrosilvopastoral) TAF systems were identified, which dominated by agrosilvopastor followed by agrosilviculture and Silvopastor (Figure 3).

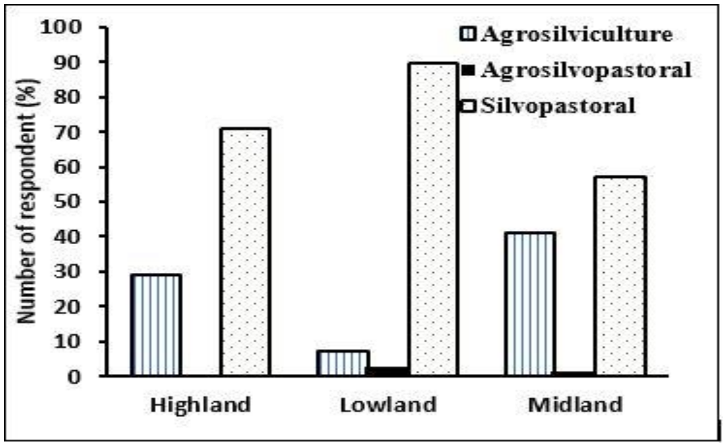

Figure 3 Types of traditional agroforestry system in three agroecologies of Tigray Region, Ethiopia

In the highland (Maychew district) the dominant TAF practice was woodlot (59%) followed by home garden (38%) and then boundary plantation (3%). In the midland 90% of the TAF practices was dominated by park land agroforestry followed by woodlot (7%). The TAF component (Tree, crop and livestock) were significantly ($p < 0.05$) differed between the agroecologies (Table 2).

Table 2 Households' means types of AF components with different TAF systems at three agroecologies of Tigray region, Ethiopia

Agro - ecology	TAFststem	TAF components		
		Tree	Crop	Livestock
Highland	Agrosilvocultural	3	2	
	Agrosilvopastoral	4	3	2
	p-value	ns	Ns	
Midland	Agrosilvocultural	2^{a}	4^{a}	2^{a}
	Agrosilvopastoral	3^{a}	4^{a}	3^{a}
	Silvopastoral	1^{a}		2^{a}
	p-value	ns	ns	ns
Lowland	Agrosilvocultural	4^{a}	3^{a}	3^{a}
	Agrosilvopastoral	5^{b}	4^{a}	4^{a}
	Silvopastoral	3^{a}		4^{a}
	p- value	0.019	ns	ns

Note: this study was limited for all woody species with dbh ≥ 2.5cm

In the lowland agricultural crops (*Zea mays* (Maize), *Sorghum bicolour* (sorghum), *Eragrostis teff* (teff), *Linum usitatissimum* (Linseed) and *Eleusine coracana* (finger millet) were integrated with Ziziphus spina-christi trees with Got, Cattle & Oxen, Donkey, Bee and Sheep. In the midland *Faidherbia albida* was integrated with

Triticum aestivum (wheat), *Eragrostis teff* (teff), *Zea mays* (Maize), *Eleusine coracana* (finger millet).

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A total of 59 species, belonging to 48 genera and 32 families were recorded. Of these 22 species, belongs to 19 genera in the highland (Endamehoni). In the midland (KlteAwlalo) about 19 species belongs to 14 genera were recorded where as in the lowland a total of 37 species belongs to 30 genera were recorded. The most abundant tree species were *Eucalyptus globules, Faidherbia albida* and *Ziziphus spina-christi*.

Table 1 Total woody species richness, Shannon diversity index(H') and evenness in the TAF practices of three agro ecologies of Tigray Region, Ethiopia

Agroecology	TAF practices	Richness	H'	Evenness
Highland	Boundary planting	11	1.31	0.34
	Home garden	21	2.34	0.50
	Wood lot	8	0.54	0.22
Midland	Home garden	3	0.87	0.80
	Park land	19	1.55	0.25
Lowland	Park land	37	1.57	0.13

Table 4 Mean (±) woody species density, dbh and height of agroforestry practices in different agroecologies of Tigray Region, Ethiopia

Agroecology	TAF practices	Stem number (ha $^{-1}$)	DBH (cm)	Height (m)	BA (m $^{-2}$ ha^{-1})
Highland	Boundary planting	132 (115) ^{a}	11.7(6.9)	10.8(4.5) ^{b}	1.8(2.1)^{a}
	Home garden	181(155) ^{a}	11.5(15.4)	8.4(3.9) ^{a}	2.6(1.9)^{a}
	Woodlot	1870(728) ^{b}	11.4(8.6)	11.6(3.7) ^{c}	29.6(70)^{b}
	p- value	< 0.001	ns	<0.001	< 0.001
Midland	Home garden	263(18) ^{a}	18.0(15.4) ^{a}	5.3(1.7) ^{a}	11.3(7.8) ^{b}
	Park land	16(11) ^{a}	28.7 (24.3) ^{b}	5.9(2.6) ^{a}	1.8(2.0) ^{b}
	Woodlot	3725(2209) ^{b}	10.0(7.3) ^{a}	10.9(4.0)^{b}	44.3(24.6) ^{c}
	p- value	<0.001	<0.001	<0.001	<0.001
Lowland	Park land	49.6(25.2)	15.2(9.9)	5.9(1.9)	1.3(1.1)

Within the same agroecology the variation of TAF practices in woody species density, dbh and height were significant (p <0.05) (Table 4).

Kruskal Wallis Test ANOVA was conducted to evaluate mean differences between groups and followed by Mann-Whitney U test for multiple comparisons. Similar letter shows not significant difference and different letters indicate significance differences between groups at p <0.05; ns not significant.

The carbon stock was significantly differed among agroecologies ($p < 0.05$) (Figure 4). Woodlot agroforestry practice contributes about 83 and 73% of the total biomass carbon sock of highland and midland agroecologies while 100% was contributed by the park land agroforestry practices in lowlands.

Overall in this study agroforestry contributed about 39.5% of the livelihood products .i.e. the contribution of traditional agroforestry was 52 %, 37 % and 70% respectively in the highlands, lowlands and midland agro–ecologies for the sampled households. In general, agroforestry trees provided timber and firewood (Figure 5). However, in the midland the prime need of tree was for fodder (65%).

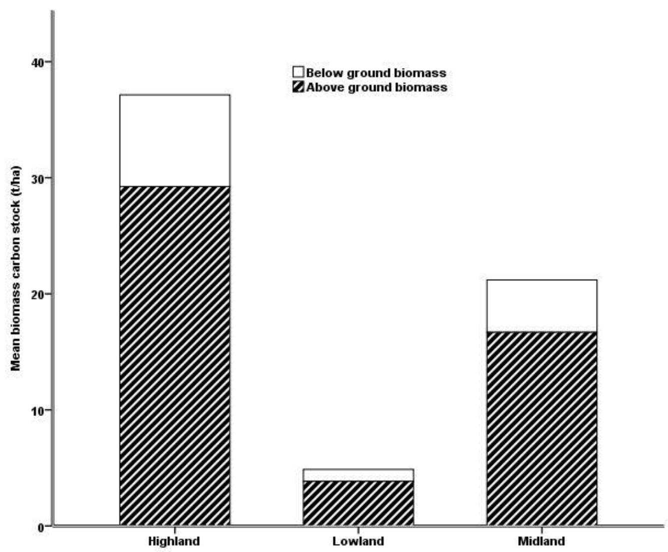

Figure 4 Total biomass (AGB & BGB) Carbon stock of the traditional agroforestry practices with in three agroecologies of Tigray Region, Ethiopia

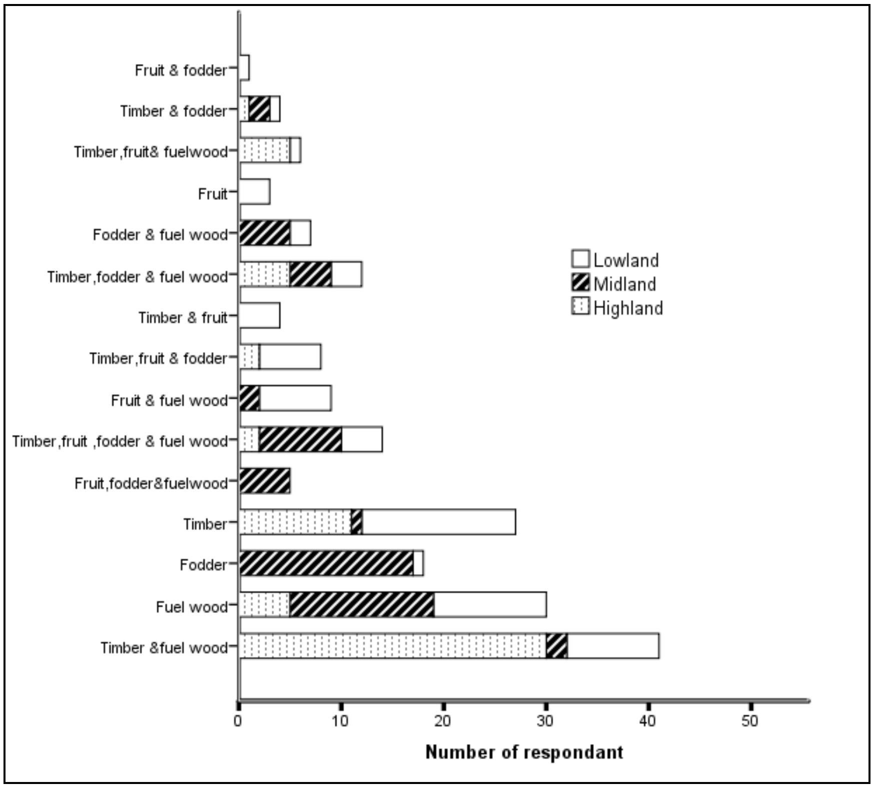

Figure 5 Important products of agroforestry for livelihood under the changed climate in different agroecologies of Tigray Region, Ethiopia.

In this study 73% of the respondent was agreed that tree planting on farmland increased crop productivity. However, there was significant variation among the association of local communities on tree planting (X^2 (4) > = 39.9. $p < 0.05$). In the lowlands 100 % of the local communities perceived that tree - planting on the farm land improved crop productivity.

Climate change perception and adaptation strategies of the community

94 % respondents (Highland= 30%, Midland= 37% & Lowland = 33%) perceived the presence of climate change (Figure 6). About 60%, 85% and 69% of the local communities respectively in the highland, lowland and midland wereperceived that the climate change was faced as drought hazard (Table 4).

Respondents claimed that crops (i.e. *Zea mays* (Maize) & *Sorghum bicolour* (sorghum)), livestock (large ruminant i.e. cattle) and fruit trees (i.e. *Psidium guajava*) were highly susceptible to climate variabilities. In contrast from livestock goat and cattle, from crops *Eragrostis teff* (teff) and from trees all acacia species where resistant to climate variabilities

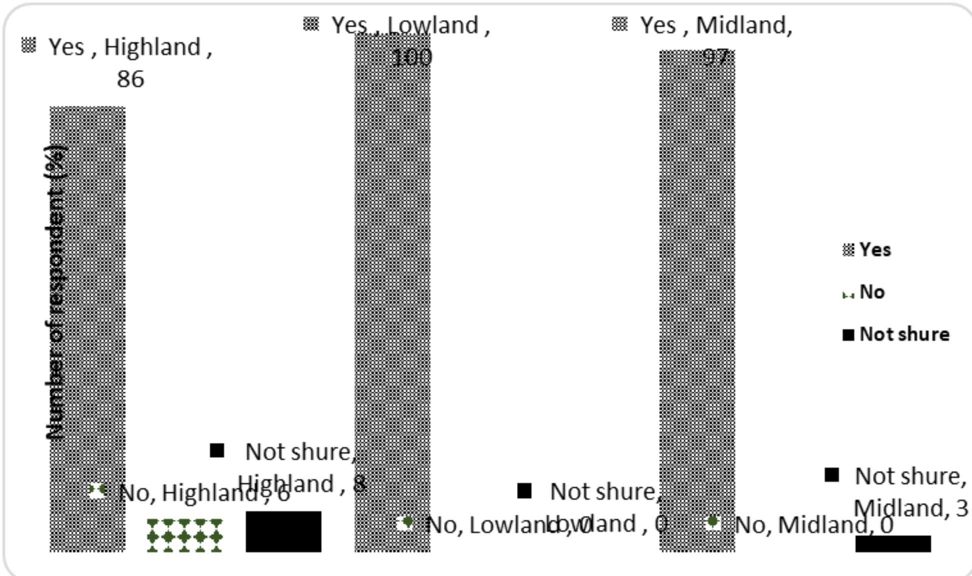

Figure 6 Farmers perception on climate change in Tigray Region, Ethiopia

The major adaption strategies adopted by communities for climate change was selling their livestock followed by support from government (Figure7).

Table 5 Climate hazards observed in three agroecologies of Tigray Region, Ethiopia

Climate hazards	Number of respondents			Total
	Highland	Lowland	Midland	
Drought	39	58	44	128
Heat wave	0	0	1	1
Erratic rainfall	11	1	4	14
Drought & flood	2	4	11	16
Drought, Flood, Heat and wind wave	4	0	0	1
Drought & heat wave	1	2	3	6
Drought, Flood, Heat wave	1	2	0	3
Drought, Flood & wind wave	0	1	1	2
Total	58	68	64	190

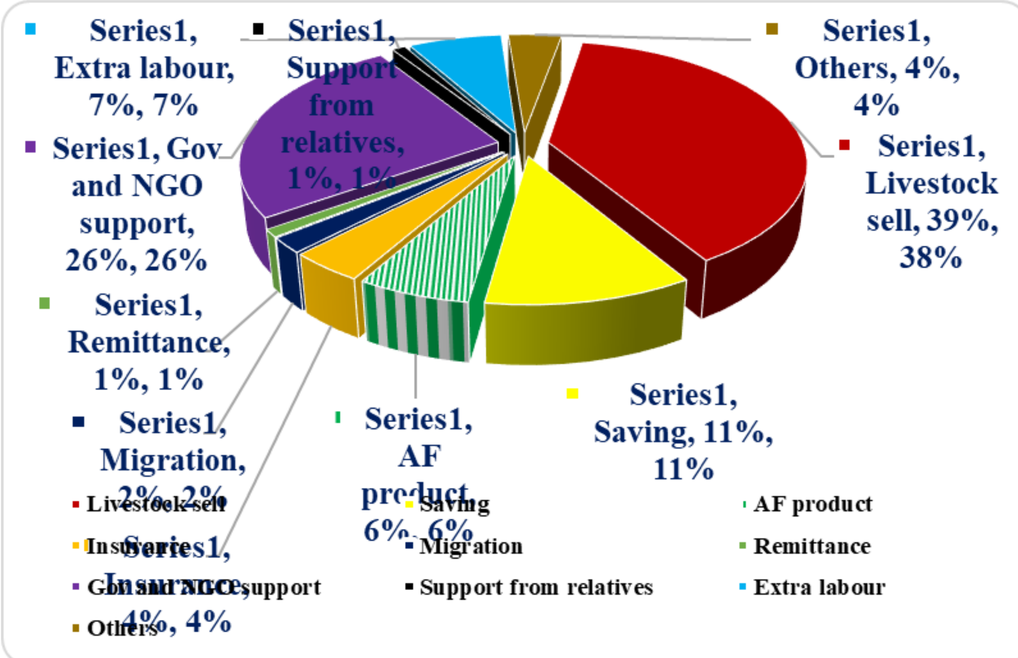

Figure 7 Climate change adaptation strategies of farmers in Tigray Region., Ethiopia

Discussion

Characterization of the traditional agroforestry systems

The dominant agroforestry practices of the study area were Parkland, home - garden, woodlot and boundary planting. The variation in agroforestry practices of the study site was due to variation in land holding size, climatic condition and agroforestry practices. Farmers in the highland of Tigray established fast growth Eucalyptus trees aswoodlot, boundary planting and home garden. This were also in line with other reports in the highlands of Ethiopian, Tanzania and India(Bekele, 2007; Duguma, 2013; Madalcho and Tefera., 2016). Whereas, the dominant parkland agroforestry practices in the semiarid dry lowland and mid land of the study were in line with findings of (Rosell, R.A., Gasparoni, J.C. and Galantini, 2001; Hadgu *et al.*, 2011; Noulekoun *et al.*, 2017) and elsewhere in Sub Saharan Africa of Shahl and Sudan (Boffa, 1999), Niayes, Senegal (Marone *et al.*, 2017). In the midlands, farmers deliberately retained *Faidherbia albida* due to its multipurpose use. The traditional knowledge of our study was in line with other studies conducted in semiarid region of Ethiopia (Gebrehiwot, 2004; Bekele, 2007; Hadgu *et al.*, 2009, 2011; Birhane *et al.*, 2016; Noulekoun *et al.*, 2017). Similarly, *Zizyphus spina-christi* dominant in the farmland of semiarid dry lowland of Tanqua Abergele district due to favorable niche and uses

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Fifty nine species richnesswas recorded in the study TAF systems which is in line with Gedeo AF by (Negash *et al*, 2012),but lower than the study conducted in South Central Highlands of Ethiopia (Tolera *et al.*, 2008).

In the highland higher species diversity of home garden agroforestry was due to large number of species richness as well as boundary and woodlots plantation. This was in line with study conducted in the highland part of Ethiopia Bajigo &Tadesse (2015). The species evenness was higher in-home garden than parkland agroforestry due to higher number of species richness and abundancy. This result was in line with reports of (Tolera *et al.*, 2008).

The mean total biomass carbon stock of the study was within other findings in tropical African (12-228 t ha^{-1}) (Dixon *et al.*, 1994; Albrecht and Kandji, 2003), West Africa Sahe (0.7-54 t ha^{-1}) (Takimoto, Nair and Nair, 2008) and in Sri Lanka (Mattsson *et al.*, 2015) but higher than Kenya and Sri Lanka (Glenday, 2008; Mattsson *et al.*, 2015). Beside to the role of TAF system to increasing CO_2 sequestration and biodiversity conservation. This also in line with the TAF systems of Ethiopia and Elsewhere (Quinion *et al.*, 2010; Bishaw *et al.*, 2013; Luedeling *et al.*, 2014; Mbow, Smith, *et al.*, 2014; Fouladbash and Currie, 2015; Kassie, 2017).

Alike with study conducted in TAF system of Ethiopia, trees in agroforestry practices were for providing timber/pole and for fuel wood (Negash, 2007; Duguma, 2013). This was also true for in the tropical forest margins (Robiglio*etal*., 2011). The positive attitude towards of retaining /planting trees on farmland was line with study conducted in the sub Saharan Africa including Ethiopia (Akinnifesi*et al.*, 2011; Hadgu *et al.*, 2011; Meijer *et al.*, 2015; Kassie, 2017).

Climate change perception and adaptation strategies of the community

The findings of the presence of climate change In the study site was in line with the same studies conducted in Ethiopia (Deressa *et al*., 2011; Gebrehiwot and Veen, 2013; Tambo and Abdoulaye, 2013; Habtemariam *et al.*, 2016; Ayal and Filho, 2017) and elsewhere in Sub-Saharan Africa (Silvestri *et al.*, 2012; Bryan *et al.*, 2013; Codjoe, Owusu and Burkett, 2014; Sanogo *et al.*, 2017). However, the level of perception of the study farmers were higher than other studies conducted in Ethiopia and else - where (Deressa *et al.*, 2009; Gebrehiwot and Veen, 2013; Tambo and Abdoulaye, 2013; Habtemariam *et al.*, 2016). The climate hazards observed in the study sites was also in line with to other parts of Ethiopian and Kenya (Silvestri *et al.*, 2012; Simane *et al.*, 2016). Moreover the major adaptation strategies of the study region was also in line with the experiences of other countries found in semiarid region such as Kenya communities Silvestri *et al.,* (2012).

Conclusion and recommendations

The finding of this study revealed that the different TAF practices found in the three agroecologies of Tigray Region are potential to improve food security and livelihoods diversification of small-scale farmers, biodiversity conservation and carbon sink to climate change mitigation.

agrosilovopastoral were the main TAF system used by the small-scale farmers in all agroecological zones. Farmers from different agro-ecological zones had preferences for different AF practices and different tree species. The dominant AF practices in the midland and highland agroecologies were park land agroforestry dominated by *Faidherbia albida* and *Zizyphus spina-christi, respectively*. Whereas in the highland rotational woodlot AF with dominated Eucalyptus species were practiced. The higher carbon stock was obtained from the rotational woodlot while higher species diversity and livelihood diversification was obtained on the home garden and parkland agroforestry practices.

AF helps to avert climate change of the farmers by providing sustainable food security, improve adaptation capacity and minimize impacts. agroforestry can contribute directly to the target of reducing emission from deforestation and forest degradation plus ($REDD^+$) or indirectly as a menace of success by reducing leakage. However, all agroforestry practices don't mean are perfectly solution of climate resilience strategies. The following should be addressed

- In the highlands multipurpose and fast-growing tree species Eucalyptus should be promoted.
- The governments and NGOs working on agroforestry should deal promote silvicultural practices to increase productivity and yield of the planted trees
- A research should be conducted to generate information about the tree – crop interaction effect
- Awareness creation should be made from climate change mitigation and adaptation measures

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References

Akinnifesi, F.K., Ajayi, O.C., Sileshi, G., Chirwa, P.W. and Chianu, J. (2011) 'Fertiliser Trees for Sustainable Food Security in theMaize-Based Production Systems of East and Southern Africa', in In Sustainable Agriculture. Springer Netherlands, pp. 129–146.

Albrecht, A. and Kandji, S. T. (2003) 'Carbon sequestration in tropical agroforestry systems', Agriculture, Ecosystems and Environment, 99(1–3), pp. 15–27. doi: 10.1016/S0167-8809(03)00138-5.

Ali, A. and Erenstein, O. (2017) 'Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan', Climate Risk Management. The Authors, 16, pp. 183–194. doi: 10.1016/j.crm.2016.12.001.

Ayal, D. Y. and Leal Filho, W. (2017) 'Farmers' perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia', Journal of Arid Environments. Elsevier Ltd, 140, pp. 20–28. doi: 10.1016/j.jaridenv.2017.01.007.

Bajigo, A., Tadesse, M. and Res, F. (2015) 'Forest Research Woody Species Diversity of Traditional Agroforestry Practices in Gununo Watershed in Wolayitta Zone , Ethiopia', Forest Research, 4(4). doi: 10.4172/2168-9776.10001.

Bekele-Tesemma, A. (2007) Profitable Agroforestry Innovations for Eastern Africa: Experience from 10 Agroclimatic Zones of Ethiopia, India, Kenya, Tanzania, and Uganda. Regional Land Management Unit: Regional Land Management Unit.

Birhane, E. et al. (2016) 'Integrating Faidherbia albida trees into a sorghum field reduces striga infestation and improves mycorrhiza spore density and colonization', Agroforestry Systems. Springer Netherlands, pp. 1–11. doi: 10.1007/s10457-016-0027-8.

Bishaw, B. et al. (2013) Farmers ' strategies for Adapting to Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya Farmers ' Strategies for Adapting to and Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya. Edited by and A. D. Caryn M. Davis, Bryan Bernart. Forestry Communications Group, Oregon State University, Corvallis, Oregon.

Boffa, J. M. (1999) Agroforestry parklands in sub-Saharan AfricaLes parcs agroforestiers en Afrique subsaharienne (No. FAO CG-34). FAO, Roma (Italia).

Bryan, E. et al. (2013) 'Adapting agriculture to climate change in Kenya: Household strategies and determinants', Journal of Environmental Management. Elsevier Ltd, 114, pp. 26–35. doi: 10.1016/j.jenvman.2012.10.036.

Codjoe, S. N. A., Owusu, G. and Burkett, V. (2014) 'Perception, experience, and indigenous knowledge of climate change and variability: The case of Accra, a sub-Saharan African city', Regional Environmental Change, 14(1), pp. 369–383. doi: 10.1007/s10113-013-0500-0.

Conway, D. and Schipper, E. L. F. (2011) 'Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia', Global Environmental Change. Elsevier Ltd, 21(1), pp. 227–237. doi: 10.1016/j.gloenvcha.2010.07.013.

Deressa, T. T. et al. (2009) 'Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia', Global Environmental Change, 19(2), pp. 248–255. doi: 10.1016/j.gloenvcha.2009.01.002.

DERESSA, T. T., HASSAN, R. M. and RINGLER, C. (2011) 'Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia', The Journal of Agricultural Science, 149(01), pp. 23–31. doi: 10.1017/S0021859610000687.

Dixon, R. K. et al. (1994) 'Carbon pools and flux of global forest ecosystems', Science, 263(20), pp. 185–190. doi: 10.1126/science.263.5144.185.

Duguma, L. A. (2013) ‘Financial analysis of agroforestry land uses and its implications for smallholder farmers livelihood improvement in Ethiopia’, Agroforestry Systems, 87(1), pp. 217–231. doi: 10.1007/s10457-012-9537-1.
FAO (1988) ‘Unesco Soil Map of the World, Revised Legend, with corrections and updates’, World soil resources Report, 60, p. 140.
Fouladbash, L. and Currie, W. S. (2015) ‘Agroforestry in Liberia: household practices, perceptions and livelihood benefits’, Agroforestry Systems, 89(2), pp. 247–266. doi: 10.1007/s10457-014-9763-9.
Gebrehiwot, T. and Van Der Veen, A. (2013) ‘Farm level adaptation to climate change: The case of farmer’s in the ethiopian highlands’, Environmental Management, 52(1), pp. 29–44. doi: 10.1007/s00267-013-0039-3.
Glenday, J. (2008) ‘Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya’, Environmental Monitoring and Assessment, 142(1–3), pp. 85–95. doi: 10.1007/s10661-007-9910-0.
Habtemariam, L. T. et al. (2016) ‘Factors Influencing Smallholder Farmers’ Climate Change Perceptions: A Study from Farmers in Ethiopia’, Environmental Management. Springer US, 58(2), pp. 343–358. doi: 10.1007/s00267-016-0708-0.
Hadgu, G. et al. (2015) ‘Farmers ’ climate change adaptation options and their determinants in Tigray Region, Northern Ethiopia’, African Journal of Agricultural Research, 10(9), pp. 956–964. doi: 10.5897/AJAR2014.9146.
Hadgu, K. et al. (2009) ‘Assessing the effect of Faidherbia albida based land use systems on barley yield at field and regional scale in the highlands of Tigray, Northern Ethiopia’, Food Security, 1(3), pp. 337–350. doi: 10.1007/s12571-009-0030-2.
Hadgu, K. M. et al. (2011) ‘Current extent of Evergreen Agriculture and Prospects for Improving Food Security and Environmental Resilience in Ethiopia’, International Journal of Agricultural Sciences, 1(December), pp. 251–262.
Kassie, G. W. (2017) ‘Agroforestry and farm income diversification: synergy or trade-off? The case of Ethiopia’, Environmental Systems Research. Springer Berlin Heidelberg, 6(1), p. 8. doi: 10.1186/s40068-017-0085-6.
Kuyah, S., Dietz, J., Muthuri, C., Jamnadass, R., Mwangi, P., et al. (2012) ‘Agriculture , Ecosystems and Environment Allometric equations for estimating biomass in agricultural landscapes : I . Aboveground biomass’, ‘Agriculture, Ecosystems and Environment’, 158, pp. 216–224. doi: 10.1016/j.agee.2012.05.011.
Kuyah, S., Dietz, J., Muthuri, C., Jamnadass, R. and Mwangi, P. (2012) ‘Agriculture , Ecosystems and Environment Allometric equations for estimating biomass in agricultural landscapes :II. Belowground biomass’, Agriculture, ecosystems & environment, 158, pp. 225–234.
Kuyah, S. et al. (2016) ‘Trees in agricultural landscapes enhance provision of ecosystem services in Sub-Saharan Africa’, International Journal of Biodiversity Science, Ecosystem Services and Management, 12(4), pp. 255–273. doi: 10.1080/21513732.2016.1214178.
Lasco, R. D. et al. (2014) ‘Agroforestry systems: Helping smallholders adapt to climate risks while mitigating climate change’, Wiley Interdisciplinary Reviews: Climate Change, 5(6), pp. 825–833. doi: 10.1002/wcc.301.
Luedeling, E. et al. (2014) ‘Agroforestry systems in a changing climate-challenges in projecting future performance’, Current Opinion in Environmental Sustainability. Elsevier B.V., 6(1), pp. 1–7. doi: 10.1016/j.cosust.2013.07.013.
MacDicken, K. (1997) ‘A guide to monitoring carbon storage in forestry and agroforestry projects. Forest carbon Monitoring Program’, Winrock International Institute for Agricultural Development (WRI), p. 87.

Madalcho, A. B. and Tefera., M. T. (2016) 'Management of Traditional Agroforestry Practices in Gununo Watershed in Wolaita Zone, Ethiopia', Forest Research: Open Access, 05(01), pp. 1–6. doi: 10.4172/2168-9776.1000163.

Marone, D. et al. (2017) 'Carbon storage in agroforestry systems in the semi-arid zone of Niayes, Senegal', Agroforestry Systems. Springer Netherlands, 91(5), pp. 941–954. doi: 10.1007/s10457-016-9969-0.

Mattsson, E. et al. (2015) 'Quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka', Agroforestry Systems, 89(3), pp. 435–445. doi: 10.1007/s10457-014-9780-8.

Mbow, C., Smith, P., et al. (2014) 'Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in africa', Current Opinion in Environmental Sustainability. Elsevier B.V., 6(1), pp. 8–14. doi: 10.1016/j.cosust.2013.09.002.

Mbow, C., Van Noordwijk, M., et al. (2014) 'Agroforestry solutions to address food security and climate change challenges in Africa', Current Opinion in Environmental Sustainability. Elsevier B.V., 6(1), pp. 61–67. doi: 10.1016/j.cosust.2013.10.014.

MEFCC (2015) 'NAMA PROPOSAL AFFORESTATION , REFORESTATION AND AGROFORESTRY NAMA Facilitating Implementation and Readiness for Mitigation (FIRM)'.

Meijer, S. S. et al. (2015) 'The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa', International Journal of Agricultural Sustainability, 13(1), pp. 40–54. doi: 10.1080/14735903.2014.912493.

Montagnini, F. and Nair, P. K. R. (2004) 'Carbon sequestration: An underexploited environmental benefit of agroforestry systems', Agroforestry Systems, 61–62(1–3), pp. 281–295. doi: 10.1023/B:AGFO.0000029005.92691.79.

Negash, M. (2007) 'Trees management and livelihoods in gedeo's agroforests, ethiopia', Forests Trees and Livelihoods, 17(2), pp. 157–168. doi: 10.1080/14728028.2007.9752591.

Negash, M. and Starr, M. (2015) 'Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia', Plant and Soil, 393(1–2), pp. 95–107. doi: 10.1007/s11104-015-2469-6.

Negash, M., Yirdaw, E. and Luukkanen, O. (2012) 'Potential of indigenous multistrata agroforests for maintaining native floristic diversity in the south-eastern Rift Valley escarpment, Ethiopia', 85(1), pp. 9–28. doi: 10.1007/s10457-011-9408-1.

Nguyen, Q. et al. (2013) 'Multipurpose agroforestry as a climate change resiliency option for farmers: An example of local adaptation in Vietnam', Climatic Change, 117(1–2), pp. 241–257. doi: 10.1007/s10584-012-0550-1.

Noulekoun, F. et al. (2017) 'Characterization of Faidherbia albida (Del.) A. Chev. population in agroforestry parklands in the highlands of Northern Ethiopia: impact of conservation, environmental factors and human disturbances', Agroforestry Systems. Springer Netherlands, 91(1), pp. 123–135. doi: 10.1007/s10457-016-9910-6.

Pearson, T. R. H., Brown, S. L. and Birdsey, R. A. (2007) Measurement Guidelines for the Sequestration of Forest Carbon. 18th edn. Department of Agriculture, Forest Service: Forest Service, Northern Research Station. Available at: https://www.fs.usda.gov/treesearch/pubs/13292.

Quinion, A. et al. (2010) 'Do agroforestry technologies improve the livelihoods of the resource poor farmers? Evidence from Kasungu and Machinga districts of Malawi', Agroforestry Systems, 80(3), pp. 457–465. doi: 10.1007/s10457-010-9318-7.

Robiglio, V., Peter Minang, and R. A. (2011) On-farm timber production for emission reduction with sustainable benefits at the tropical forest margins.

Rosell, R.A., Gasparoni, J.C. and Galantini, J. A. (2001) ‘Soil organic matter evaluation.’, in In Assessment methods for soil carbon,. Lewis Publishers Boca Raton, pp. 311–322.

Sanogo, K. et al. (2017) ‘Farmers’ perceptions of climate change impacts on ecosystem services delivery of parklands in southern Mali’, Agroforestry Systems. Springer Netherlands, 91(2), pp. 345–361. doi: 10.1007/s10457-016-9933-z.

Silvestri, S. et al. (2012) ‘Climate change perception and adaptation of agro-pastoral communities in Kenya’, Regional Environmental Change, 12(4), pp. 791–802. doi: 10.1007/s10113-012-0293-6.

Simane, B. et al. (2016) ‘Review of climate change and health in Ethiopia: Status and gap analysis’, Ethiopian Journal of Health Development, 30(SpecialIss), pp. 28–41.

Snowdon, P. et al. (2002) ‘National carbon accounting system technical report: Protocol for Sampling Tree and Stand Biomass’, (31), p. 76.

Takimoto, A., Nair, P. K. R. and Nair, V. D. (2008) ‘Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel’, Agriculture, Ecosystems and Environment, 125(1–4), pp. 159–166. doi: 10.1016/j.agee.2007.12.010.

Tambo, J. A. and Abdoulaye, T. (2013) ‘Smallholder farmers’ perceptions of and adaptations to climate change in the Nigerian savanna’, Regional Environmental Change, 13(2), pp. 375–388. doi: 10.1007/s10113-012-0351-0.

Tolera, M. et al. (2008) ‘Woody species diversity in a changing landscape in the south-central highlands of Ethiopia’, Agriculture, Ecosystems and Environment, 128(1–2), pp. 52–58. doi: 10.1016/j.agee.2008.05.001.

Unruh, J. D., Houghton, R. A. and Lefebvre, P. A. (1993) ‘Carbon storage in agroforestry: an estimate for sub-Saharan Africa’, Climate Research, 3, pp. 39–52. doi: 10.3354/cr003039.

Verchot, L. V. et al. (2007) ‘Climate change: Linking adaptation and mitigation through agroforestry’, Mitigation and Adaptation Strategies for Global Change, 12(5), pp. 901–918. doi: 10.1007/s11027-007-9105-6.

Traditional Weather Forecast for Climate Change Adaptation: Case Study from the Ethiopian Central Rift Valley

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Abstract

Climatic elements like rainfall and temperature are of great importance in determining agricultural production. Predicting these elements either traditionally or scientifically is pivotal for agricultural and natural resource management by farmers. Traditional knowledge may prove useful for understanding the potential for certain adaptation strategies that are cost-effective, participatory and sustainable. The indigenous observations and interpretations of meteorological phenomena have guided seasonal and inter-annual activities of local communities for millennia. Farmers' crop management strategies are shaped by predictive climate information, particularly rainfall related forecasts. Household survey was conducted in Adami Tulu Jido kombolcha district from three kebeles on 92 randomly selected households. The results showed that risks because of climate change and variability related extremes and other environmental degradations were the most critical challenges that intensify social-ecological vulnerability at the study areas. In this regards, indigenous knowledge has played important role in managing those risks in the day-to-day agricultural activities of farmers even in absence of formal weather information. Communities use various indicators such as animal behaviour, wind circulation, cloud cover and movement, water bodies, plant characteristics, etc. To this end, choice on future adaptation strategies should acknowledge existing and age-old traditional knowledge system of a given communities as the lessons learnt from this research results showed exclusion of these system has facilitated social-ecological vulnerability of rural communities.

Keywords: Indigenous Knowledge, Weather forecast, Adaptation, Perdition

Introduction

Climate change is the greatest developmental challenge of the 21st century (IPCC, 2007). Its impacts are far-reaching and, to varying degrees, potentially very damaging to all nations, sectors and communities. Climate change undermines the gains accrued from development investments and largely hits the poorest and most vulnerable sections of the society. Especially in semi-arid and arid areas of developing countries its potential impact could reverse the economic contribution of vulnerable sectors to the national development and put additional pressure on fragile resources (Desalegn *et al.,* 2015).

Climatic elements like rainfall and temperature are of great importance in determining agricultural production. Rainfall is one of the most important elements since most communal areas depend on rain-fed subsistence agriculture for their livelihood. Other elements, like temperature and humidity influence the availability of moisture to crops through their influence on the rates of evaporation (Makwara, 2013).

The terms indigenous, traditional and/or local knowledge make reference to knowledge and know-how that is accumulated over generations and guides human societies in their innumerable interactions with their surrounding environment; are used interchangeably. Common names include, but are not limited to: indigenous knowledge, traditional knowledge, traditional ecological knowledge, local knowledge, farmers' knowledge, ethno-science, folk knowledge and indigenous science or ethno-science (Mafongoya and Ajayi, 2017).

The recognition of IK was reaffirmed at the 32nd Session of the IPCC in 2010, where it was stated that, "Indigenous and traditional knowledge may prove useful for understanding the potential for certain adaptation strategies that are cost-effective, participatory and sustainable" (IPCC, 2010). The indigenous observations and interpretations of meteorological phenomena have guided seasonal and inter-annual activities of local communities for millennia. This knowledge contributes to climate science by offering observations and interpretation at a much smaller spatial scale with considerable temporal depth, and by highlighting aspects that may not be considered by climate scientists.

UNFCCC (2011) recognizes the importance of indigenous knowledge (IK) conservation as key to the benefits of an ecosystems-based approach to climate adaptation. The expanding volume of scientific and grey literature around IK, primarily documents the system as community-based observations of climate change impacts, whose traditional practices and mechanisms may provide a robust basis for effective responses to climate change.

The global research policy agenda is only just starting to investigate the role of IK in adaptation, as evidenced by the introduction of a section on IK for the first time in the IPCC fifth assessment report (IPCC, 2015). The practices and tools proposed for the incorporation of IK into adaptation are often the same tools that seek to build community development or participation into decision-making. Such practices and tools are embedded in participatory development work. The review of practices and tools to implement the use of IK in climate adaptation, assess IK mobilization within each of the following steps of adaptation: observation of climate change and its impacts; assessment of impacts of vulnerability and adaptation to climate change;

adaptation response, planning, implementation and monitoring and evaluation (Mafongoya and Ajayi, 2017).

The enhancement of indigenous capacity is vital for the empowerment of local communities and their effective participation in the development process (Boko *et al.,* 2007). How smallholder farmers respond to climate change and variability depends on the information they obtain and use to decipher appropriate coping and adaptation strategies (Gukurume, 2014). Climate information (including observations, research, predictions and projections) has a central role to play in both adaptation and mitigation of climate change (Zillman, 2009). In sub-Saharan Africa (SSA), however, there is limited access to climate information and relatively low capacity to meaningfully utilize scientific climate information. Farmers, therefore, tend to rely on indigenous knowledge and information from local social networks to make decisions and manage technology related risks and climate variability (Nyong et al., 2007).

More recent studies have shown that resilience building for smallholder farmers in Africa is a process that starts with the ability to anticipate change and accordingly adjust farming practices and set the base for sound food security, particularly in the context of climate variability and change (Kolawole *et al.*, 2014). Farmers tend to use a combination of meteorological information and indigenous knowledge in their seasonal forecasting, as they primarily rely on indigenous knowledge but are also open to receiving scientific forecasts (Mapfumo *et al*., 2015; Roudier *et al*., 2014).

Studies highlighted that farmers' crop management strategies (planting time, weeding, fertilizing, application of pesticides) are shaped by predictive climate information, particularly rainfall related forecasts (Moeletsi *et al*., 2013; Roudier *et al.,* 2014). There is an increasing realization that agro-climatological information (from formal and informal sources as in Figure 1), particularly that which provides details on climate extremes and recommendations for actions to be taken, is crucial to improve on agricultural production and responsible use of agricultural resources and managing agricultural risk imposed by climate extremes (Moeletsi *et al*., 2013).

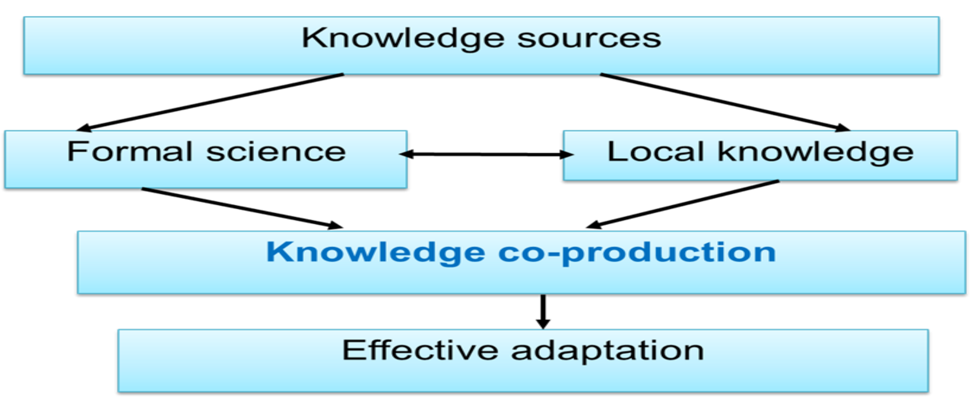

Figure 1: Indigenous and scientific knowledge co-production for effective adaptation

Climate information is vital in building resilience, disaster preparedness, and livelihood improvement, governance of resources and assets as well as to predict future uncertainty (Figure 2). The ability to anticipate changes at seasonal and shorter time scale and how to adjust the farming practice accordingly is a key element in creating resilience of indigenous farmers to the vagaries of weather conditions thus serving as the basis for improving food security (Kalowe *et al.*, 2014).This is particularly important in the context of climate variability and change which now constitute a serious threat to agricultural productivity and food security in sub- Saharan Africa.

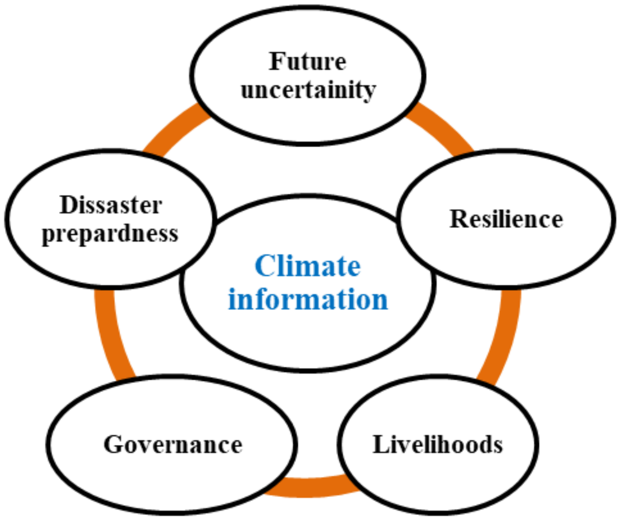

Figure 2 Framework of vulnerability and resilience based on access and usage of climatic information (Gukurume, 2014)

The uptake and use of climate information service (CIS) in Africa is influenced by many factors including the lack of reliable historical observations, coarse scale of future climate projections, weak coordinated CIS delivery, among others. On the side of the users, the main obstacles for poor uptake and utilization of CIS include limited awareness about the existence of specific climate information, poor data accessibility, and lack of capacity to use climate information in decision making process (UNECA, 2010). There are still challenges in the provision of precise downscaled location-specific, reliable, timely, and user-friendly weather and climate information that are required to provide fit-for-purpose climate information services that effectively address vulnerability in communities, as well as capitalizing on emerging opportunities due to climate change.

Before the advent of modern scientific methods, rural communities must have realized that some animals, birds, insects and plants had the capacity to detect and respond to changes in atmospheric conditions. They also mastered the positions of stars, the sun and associated shadows and the moon, the wind strength and direction and the cloud position and movement and the lightning patterns (Makwara, 2013). In the same token it has been added that, equally, the sight and sound of a lot of croaking frogs is indicative of an imminent wet spell. Despite the loss of 24,000 people, wild animals seemed to have escaped the Indian Ocean tsunami, adding weight to the notion that they possess a “sixth” sense for predicting seasonal quality and impending disasters (Planet ark, 2004).

While the indigenous communities are almost dependent on indigenous rainfall prediction information, there are potential constraints or threats to the forecast. The constraints were criticism from religious people, lack of trust by young generation that inclined to modernization/, the degradation of indicators due to environmental degradation and climate change and due to absence of documentation. According to Desalegn *et al*., (2015), it is among the Christians that indigenous weather forecasting is most rejected as the worship of idols. For Christians, indigenous experts (or they would prefer to call them witchdoctors) are guided by evil spirit that can neither tell nor change the future which is determined and known only by God. The other threats to the continuation of IK practices largely emanate from the fact that this knowledge system is stored in people’s minds and orally transferred. Other factors contributing to the loss in IK are related to population migration and displacement, technology and modernization (Mapara, 2009). As the world warms, traditional weather indicators may become less and less valuable. Individual species will adapt to local climatic impacts in idiosyncratic and unpredictable ways (Mafongoya and Ajay, 2017). Animals may change their behavior or their range, while plants may begin flowering at different times. These changes will make traditional knowledge less reliable

Indigenous knowledge is local which is rooted to a particular place and a set of experiences and is generated by people living in those places (Ellen and Harris 1996). The result of such factors is that transferring IK from one place to another runs the risk of dislocating it. IK is orally transmitted or transmitted through intrinsic dramatization. Therefore, writing it down changes some of its fundamental properties, but also makes it more portable and permanent. IK is a consequence of practical engagement in everyday life, and is constantly refined by experience, trial and error. This experience is a product of many generations of intelligent reasoning and its failure has undesirable consequences for the lives of its practitioners. Its success is very often a good measure of a combination of factors. It is tested in the rigorous laboratory of survival. IK is imperial rather than theoretical knowledge.

Repetition is an essential characteristic of tradition, even when new knowledge is added. Repetition aids retention and reinforces ideas. IK is constantly changing, being produced as well as reproduced, discovered and lost, though it is often portrayed as being static. IK is characteristically much further ahead than other forms of knowledge. Therefore, it is called the people’s science. However, its distribution is still segregated and socially clustered. It is usually asymmetrically distributed within a population by gender and age and is preserved through the memories of individuals.

IK may be focused on individuals and may achieve a degree of coherence in rituals and other symbolic occurrences; however, its distribution is always fragmented. It does not exist in totality at anyone point or within any one individual. IK is characteristically solicited within oral cultural traditions and therefore, separation of the technical from the non-technical and the rational from the non-rational, is problematic. Modern scientific knowledge is centralized and associated with the machinery of state, and those who are its bearers believe in its superiority. In contrast, IK is scattered and associated with low prestige rural life and even those who are its bearers may believe it to be inferior to scientific knowledge. IK is more deeply rooted in its environment (Agrawal, 1995).

Western science is seen to be open, systematic, objective and very much dependent on a detached centre of rationality and intelligence. IK is seen to be closed, parochial, unintellectual, primitive and emotional (Ellen and Harris, 2000). Consequently, western knowledge systems are part of the whole notion of modernity, whilst IKS are perceived as part of a residual, traditional and backward way of life. However, IKS have become central to sustainable development. This is because of the way in which IK has evidently allowed people to live in harmony with nature for generations. The privileging of IKS in development is welcomed because it also presents a shift away from the preoccupation with centralized, technically oriented solutions, which have failed to alter the life prospects for many peasants and smallholder farmers worldwide (Agrawal, 1955).

Just like scientific forecasts, indigenous forecasts rely on observation and interpretation of specific phenomena. The indicators farmers mostly rely on include fruit production and tree phenology, animal behavior, wind and atmospheric phenomena, and spiritual manifestations in the form of divinations, visions and dreams. The conclusions of indigenous observations are based on multiple environmental and social factors that they consider in an integrated manner e.g. rainfall patterns, wind speed, wind direction and the variability of temperature .In contrast, scientists may use a range of parameters e.g. temperature, wind speed or rainfall, but base their conclusions on the extrapolation of data from a narrow data set (Gearheard *et al*., 2010).

Traditional knowledge use indicators such as use of wind direction and speed, rainbow occurrence, moon and star position, water and sky colors, cloud types and so on. These are compatible with the indicators used in formal science to predict precipitation. Given the existing voids in a comprehensive analysis of climate impacts in Zimbabwe, Chanza (2014) argues that IK is capable of filling knowledge gaps and validating current understandings about climate change, particularly at local levels.

This view resonates with that of Nakashima *et al.,* (2012), who claim that the climate observations of indigenous communities generate knowledge that contributes to climate science by offering detailed interpretations and explanations at a much finer spatial scale. Evidently, climate impact assessments carried out in consultation with indigenous observers of climatic changes are useful for both refining current understandings of climate change and giving clear indications of the magnitude of impact on local affected populations. This consideration is crucial in framing appropriate responses for climate adaptation and management of climatic risks and disasters. The application of this knowledge is highly valued in Muzarabani and can contribute towards enhancing the community's adaptive capacity, especially against a background of limitations in official climate assessments and the poor dissemination of seasonal forecast information (Patt and Gwata, 2002).

Reports from Africa in this volume show convergence of IK system forecasts with scientific forecasts, climate change and seasonal predictions. However, parameters observed by scientists are different in meaning to those observed by traditional sources (Mapfumo *et al*., 2015). Western science is seen to be open, systematic, objective and very much dependent on a detached center of rationality and intelligence. However, IKS have become central to sustainable development. This is because of the way in which IK has evidently allowed people to live in harmony with nature for generations. The privileging of IKS in development is welcomed because it also presents a shift away from the preoccupation with centralized, technically oriented solutions, which have failed to alter the life prospects for the majority of peasants and smallholder farmers worldwide (Agrawal, 1955).

The purpose of this study was to evaluate the compatibility of indigenous climate change adaptation and mitigation with that of scientific prediction by way of identifying and analyzing local indicators used in IK forecasting over the study area and evaluate the compatibility with scientific forecast.

Materials and Methods

Description of the Study Area

Adami Tulu Jido kombolcha district is located in central rift valley (CRV) at altitude of 1500-2300 m a.s.l. It is 150 km from Addis Ababa. It extends from 38°25'E and 38° 55'E to 7°35'N and 8°05'N. The population density of the district is 139 persons/ km^2. Twenty-seven percent of the district is cultivated with crops, 22% is used for pasture, 10% forest and woodlands, 16% is swampy and the remaining 25% is unproductive or degraded (CSA, 2005).

According to traditional agro-climatic zonation, its climate falls under semi-arid and classified as 'Dry Weyna Dega' (Abera *et al.,* 2016). The annual rainfall varies from

600-800 mm and it is characterized by bimodal rainfall. There exists very short and unreliable rain during the months of April-May, while most of the rain occurs during the months of June-August and sometimes up to September. The annual rainfall varies from 600-800 mm. The pattern of rainfall is usually erratic with fluctuations in the start and end of the season, in addition to the total absence of rainfall at sometimes (Tesfaye, 2008).

Data collection and analysis

The study was conducted by household survey, individual interview and literature reviews. Data on background information of respondents, potential constraints of indigenous rainfall prediction, source of weather information was collected by household survey. Scientific interpretation of each indigenous rainfall prediction indicators was analyzed using scientific literatures and similar studies. Compatibility of the indigenous indicators was collected by individual interview.

Three sample kebeles were systematically selected from the district for household survey. Sample size was determined by Kothari (2004) sample size determination. Accordingly, 19, 41 and 32 sample households were randomly selected from each of Haroresa Kalbo, Abine Germama and Galo Hirape kebeles, respectively. Three key stakeholders having role in climate information were selected: National Meteorology Agency (NMA), Disaster Risk Management and Food Security Sector (DRMFSS) and Ethiopian Institute of Agricultural Research (EIAR). Interviews served as means to gather data through probing the feelings and attitudes of the respondents/ meteorological experts on the compatibility of indigenous rainfall forecasting into conventional rainfall forecasting. The collected household survey data was analyzed using Statistical Package for Social Science (SPSS) and the scientific interpretation of indigenous rainfall forecasting, compatibility with scientific rainfall forecasting was summarized in narrative.

Result and discussions

Households characteristics

Nearly, 98% of the respondents have land of their own (holding right) and 78% of the respondents rear livestock. The major crops cultivated were maize, teff and barley, and rarely chicken pea and wheat. The result shows that 85% of the respondents use indigenous rainfall prediction for their agricultural activities decision making. Most of the farmers (79%) have no or up to elementary level of education-35% illiterate and 44% elementary level.

Indigenous weather predictions

While farmers are almost dependent on indigenous rainfall prediction information, there are potential constraints or threats to the forecast. The constraints listed by the respondents were criticism from religious people, lack of trust of young generation, the loss of some indicators (e.g. bees) due to environmental degradation and climate change, and due to absence of documentation. The study showed that communities rely on different indigenous rainfall prediction mechanisms that include meteorological (wind, cloud, tornado and lightning), astronomical (moon, sun and star), animal behavior (frog and cattle) and other environmental and social indicators (Table1).

Table 1 Local indicators used in forecasting rainfall in the study area

Phenomenon	Indication	Responses	Related with scientific indicators
Red sky at sunrise	Rain is expected	Start to cultivate land	Yes
Temperature of the day become hotter	It is going to rain soon	Go to home sooner	Yes
'Harbu' tree started to flushing leaves	Coming of rainfall in a few days	Start to cultivate land	Yes
Colour of lake become black	It will be good season	Plan to do more agricultural activities	Need study
Rain started on women 'Ayana' day	It will be good season		
Rain started on horse 'Ayana' day	It will rain erratically	Plan to store grain to next season and use some available irrigations	Need study
Rain started on elephant 'Ayana' day	Heavy rain is expected	Plan to prepare for flood diversion and control	Need study
Rain started on the day of 'Ayana korma'	Drought is expected	Prepare grass for livestock and store grain for next season, harvest water	Need study
Children unusually cry for food	The coming season will be bad	Pray God to liberation	Need study
Bulls capering in the field Hyenas screaming in low tone Roaming of red ants around home	Rain to come soon	Land preparation when it is during may or crop harvesting when it is during November	Need study
Bee migration to lowland	Better rainfall at lowland	Hung beehives and prepare farm land	Need study
Change in the direction of cloud movements from normal	Expectation of the absence of rainfall (i.e. drought)	Store fodder for livestock and grain for humans for the coming drought year	Yes

Similarity between informal and formal rainfall prediction indicators

Different scientific studies have been conducted on the scientific explanation of indigenous rainfall prediction indicators. Makwara (2013) emphasized that there is similarity between indigenous and contemporary weather indicators. The cumulo-nimbus cloud is associated with a heavy storm with lightning and thunder (Barry and Chorley, 1998). Increasing hot temperatures indicate a good rainy season (Isaac et al., 2009), whilst violent winds during the dry season may predict a bad rainy season. The direction of winds is also associated with particular rainfall patterns (Mafongoya and Ajayi, 2017). Red sky in the morning is considered to indicate rain, while red sky in the evening is considered to indicate that there would be no rain. Shadow of the rainbow near the source of water is considered to indicate clear weather (Piyoosh and Bhavna, 2015). Under different weather conditions, the color of the sea changes with the time, the viewing angle and the height. The sea appears blue under a clear sky because the blue light from the sky is reflected by the water surface. Therefore the dark color of lake may be the reflection of cloudy sky.

Astronomy- Mafongoya and Ajayi (2017) briefed that there is a strong relationship between astronomy and rainfall. The visible phases of the moon are associated with rainfall, drought or a dry spell. The full moon is expected to indicate dry weather. Star constellations and the time of their appearance indicate rainfall patterns and hence, when farmers should plant their crops. Changes in the appearances of stars and the moon provide a framework of sequences for expected rain events and mark key points in relation to cropping calendars.

The position and the size of the moon are important predictor of weather. Simply stated, changes in the moon's movement can trigger changes in our weather (King, 2005). This could be explained in terms of the four interfacing tides caused by lunar gravitation. In the same token, if the moon influences sea tides, then it would control the distribution of water. The effect then spreads onto the atmosphere and weather through the distribution of clouds. From a local perspective, the crescent and full moon phases are perceived as linked to the movements of the rain-bearing winds in the area (Makwara, 2013). Crescent moon facing upwards indicates upholding water and when facing downwards is releasing water in the next 3 days (Mafongoya and Ajayi, 2017). A study in different parts of Africa by Mafongoya and Ajayi (2017) indicated that star pattern and movement from west to east at night under clear skies means rain will fall in 3 days. Wind swirls or frequent appearance, appearance of many nimbus clouds, appearance of red clouds in the morning are signs of good rains.

Temperatures and winds- During the year and within seasons, farmers expect natural phenomena such as temperature, winds, clouds and rain to conform to certain patterns that they define as the norm (Roncoli *et al*., 2009). The beginning of the cold season and its end follow certain rainfall patterns. Increasing hot temperatures indicate a good rainy season (Isaac *et al*., 2009), whilst violent winds during the dry season may predict a bad rainy season. The direction of winds is likewise associated with rainfall patterns in indigenous prediction (Table 3). Frequent appearance of wind swirls is a sign of good rains. Body feels increased or excessive heat during the night and day; a feeling of body pain (headache, flu, backaches) are indicators for rain in 1-3 days (Mafongoya and Ajayi, 2017).

Animal behavior- The behavior of animals such as livestock, birds, insects and amphibians are used by farmers to predict the onset of the rainy season (Mafongoya and Ajayi, 2017). The songs and movements of different birds to signal the onset of rains has been reported in Mali, Nigeria, Swaziland, Tanzania and Zimbabwe, among other countries in SSA. Frogs in swampy areas croaking at night is indicator for onset of rains.

Veterinary scientists hold views that partially contradict and partially agree with indigenous explanations of the body languages and behavior of cattle (Desalegn *et al*, 2015). On one hand, they seem to support indigenous views, when for instance, they noted that animals could naturally perceive and respond to the incoming weather condition, which is regarded as a central feature of survival strategy. In fact, some veterinarians have the opinion that animals can perceive future natural phenomenon more sharply than modern technology sources. Thus, from a veterinary point of view, sensing future developments and making physiological and behavioral changes is a central element of instinct animals' survival. For instance, cattle can prepare themselves for future harsh conditions by reducing their appetite for food and mating. Other veterinarians attribute animal behavior and body conditions, traditionally regarded as indicators of future drought, to disease and environmental stress.

Interviewed experts stated that both formal science and indigenous knowledge are using atmospheric phenomenon, have seasonal demarcation and consider local conditions in some extent. According to the experts, however, formal science depends on concrete evidence while indigenous knowledge is based on assumption.

Barriers between formal and informal predictions

Interviewed experts explained that the shortcomings of scientific forecast are the use of various global, continental, regional and local level climatic inputs with considerable level of uncertainty. In addition, there is limitation on timely provision of forecast information to grassroots community. The forecasts mostly use meteorological terminologies that are not easily understandable for people outside meteorological background. Barriers for access of scientific forecast for end users are lack of internet access, lack of smart phone, lack of weather forecast at district and kebele levels.

The experts explained concerning the limitations or reliabilities of indigenous rainfall indicators. There are more than ten cloud species, but only limited cloud types produce rainfall. Winds originate from water bodies or land areas. So, wind direction also changes seasonally. Rainbow occurs before the rain showing the rain is going to come and after the rain showing the rain is going to stop. Wind pattern and types of clouds have intimate connection with scientific forecast. However, religious and social indicators are nor relevant to scientific forecast. Formal science and indigenous knowledge are compatible if they use similar weather variables. They can also complement each other particularly when both use atmospheric indicators. But fusion is might be difficult as scientific forecast is about the systems having different components. Indeed, to integrate with traditional forecast, we should consider all the components which are used in the traditional forecasting.

Conclusions and recommendation

The study shows that rainfall prediction indicators that are meteorological like wind direction, clouds and temperature are the same in both indigenous and scientific rainfall prediction systems. The findings showed that some indicators such as wind direction, clouds and temperature are the same in both formal and informal knowledge systems. This study also shows that there are short comings as well as strengths in both indigenous and scientific rainfall forecasting. Local forecasts focus on rainfall characteristics relevant to farmers for seasonal prediction in managing climate risk such as time of onset, duration and distribution. Farmers' forecasts concentrate on number, type and timing of rainfall rather than total quantity, which is key in scientific forecasting. Farmer forecasts address local rather than regional scale crop-climate interactions; and farmers recognize that rainfall patterns have different impacts on each crop depending on when and how they occur.

Farmers develop adaptation measures based on their own observations and interpretation of climate variability and change. Their observations and weather forecasting systems in future may become less meaningful, affecting their decisions. This is due to more rapid and complex global change. In addition, it doesn't show clear demarcation between good and bad season, sufficient and insufficient amount of rainfall etc. Therefore, facilitating access to scientific knowledge and technologies such as early warning systems may help decrease indigenous peoples' vulnerability to climate change impacts.

Given the significant gaps in scientific knowledge, ethno-meteorological knowledge plays a key role in farmers' ability to devise climate variability and update adaptation measures. There is evidence that show farmers have a natural inclination towards reliance on indigenous forecasts as opposed to scientific forecasts, because they value their own experiences above scientific data. Faced with this unfortunate possibility, it is sensible to call for the marriage of local knowledge and modern science as applying them in isolation might eliminate the complementarities that should help make the farmers succeed in the farming business. Hence, integration of scientific knowledge with local knowledge might allow some inferences in this regard. Farmer forecasts address local rather than regional scale crop-climate interactions; and farmers recognize that rainfall patterns have different impacts on each crop depending on when and how they occur. Therefore, combining the knowledge of local resource-dependent people with evidence provided by formal climatology analysis holds the potential to reduce uncertainty and increase the relevance of future assessments of vulnerability and climate change adaptation.

Although indigenous knowledge is important in climate prediction and natural resource management, there remain some challenges to it. These include the youth is unable to accept this knowledge; consideration as evil spirit in religious perspective; perceived incompatibility formal science; absence of documentation (oral transformation); considered as backward and hindrance to modernization; and confidentiality to tell the information by the owner.

References

Abera, T., Zerihun, M., and Melaku, B.2016. Local People Perception on the Role of Area Exclosure in the Central Rift Valley of Ethiopia: A Case Study at Adami Tulu Jido Kombolcha District.International Journal of Scientific and Research Publications 6(10),583-594.

Agrawal, A. 1995. ‘Dismantling the divide between indigenous and scientific knowledge.’ Development and Change 26: 413–439.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., OsmanElasha, B., Tab O, R and Yanda, P.2007. Africa Climate Change 2007: Impacts, Adaptation and Vulnerability Contribution of Working Group 2to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.L., Canziani, O.F., Paluticof, J.P., vanderLinden, P.J, and Hanson,C. E.(Eds.), Cambridge University Press,Cambridge,U.K. 433-467

Central Statistical Authority (C.S.A), 2005. A survey of Ethiopian Agricultural Inventory., Addis Ababa.

Chanza, N. 2014. Indigenous knowledge and climate change: Insights from Muzarabani, Zimbabwe. Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Desalegn, A., Desta, S. and Robinson, L. 2015. Institutional assessment for climate change adaptation, Didahara, Borena, southern Ethiopia. ILRI Project Report. Nairobi, Kenya, International Livestock Research Institute (ILRI).

Ellen, R. and Harris, H. 1996. Concepts of Indigenous Environmental Knowledge in Scientific and Development Studies Literature - A Critical *Assessment*. Draft Paper Presented at East-West Environmental Linkages Network workshop 3, University of Kent, Canterbury, UK.

Ellen, R. and Harris, H. 2000. 'Introduction.' In. Ellen, R., Parkes, P. and Bicker A. (eds.), Indigenous Environmental Knowledge and its Transformations. Harwood Academic Publishers, Amsterdam, the Netherlands.
Gearheard, S., Pocernich, M., Stewart, R., Sanguya, J. and Huntington, H.P. 2009. 'Linking Inuit knowledge and meteorological station observations to understand changing wind patterns at Clyde River, Nunavut'. Climatic Change, 100:26–294.
Gukurume, S. 2014. Climate change, variability and sustainable agriculture in Zimbabwe's rural communities. Russian Journal of Agricultural and Socio-Economic Sciences, 2(14), 89-100.
Intergovernmental Panel on Climate Change (IPCC). 2010. Review of the IPCC Processes and procedures, report by theInter Academy Council (IPCC-XXXII/Doc. 7). Amsterdam, The Netherlands.
IPCC.2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the 4th Assessment Report of the IPCC, Cambridge, Cambridge University Press.
Isaac, M.E., Dawoe, E. and Sieciechowicz, K. 2009. 'Assessing local knowledge use in agroforestry management with cognitive maps.' Environmental Management 43 (6): 1321–1329.
Kolawole, O. D., Wolski, P., Ngwenya, B., & Mmopelwa, G. 2014. Ethno-meteorology and scientific weather forecasting: Small farmers and scientists' perspectives on climate variability in the Okavango Delta, Botswana. *Climate Risk Management, 4-5*, 43-58. http://dx.doi.org/10.1016/j.crm.2014.08.002
Kothari, C.R. 2004. Research Methodology: Methods and Techniques. New Age International Publishers, India .418p
Mafongoya, P.L. and Ajayi, O.C. (eds.), 2017, Indigenous Knowledge Systems and Climate Change Management in Africa, CTA, Wageningen, The Netherlands, 316pp.
Makwara, E., C. 2013. Indigenous Knowledge Systems and Modern Weather Forecasting: Exploring the Linkages. Curriculum Studies Department, Great Zimbabwe University. Journal of Agriculture and Sustainability. Volume 2, Number 1, 98-141.
Mapara, J. 2009. 'Indigenous knowledge systems in Zimbabwe: Juxtaposing postcolonial theory.' *Journal of Pan African Studies* 3 (1): 139–155.
Mapfumo, P., Mtambanengwe, F., & Chikowo, R. 2015. Building on indigenous knowledge to strengthen the capacity of smallholder farming communities to adapt to climate change and variability in southern Africa.*Climate and Development*. http://dx.doi.org/10.1080/17565529.2014.998604
Moeletsi, M. E., Mellaart, E. A. R., Mpandeli, N. S., & Hamandawana, H. 2013. The Use of Rainfall Forecasts as a Decision Guide for Small-scale Farming in Limpopo Province, South Africa. Journal of Agricultural Education and Extension, 19(2), 133-145. http://dx.doi.org/10.1080/1389224X.2012.734253
Nakashima, D., Galloway, M., Thulstrup, H., Ramos, C. and Rubis, J. 2012. Weathering Uncertainty: TraditionalKnowledge for Climate Change *Assessment and Adaptation*. The United Nations Educational, Scientific and Cultural Organization and United Nations University, Paris andDarwin.
Nyong, A., Adesina, F., & Elasha, O. B. 2007. The value of indigenous knowledge in climate change mitigationand adaptation strategies in the African Sahel. *Mitigation and*

Adaptation Strategies in Global Change, 12,787-797. http://dx.doi.org/10.1007/s11027-007-9099-0

Patt, A. and Gwata, C. 2002. 'Effective seasonal climate forecast applications: Examining constraints for subsistence farmers in Zimbabwe'. Global Environmental Change, 12:185–195.(Mafongoya *et al*., this volume).edit

Roncoli, C., Jost, C., Kirshen, P., Sanon, M., Ingram, K.T., Woodin, M and Hoogenboom, G. 2009. 'From accessing to assessing forecasts: an end-to-end study of participatoryclimate forecast dissemination in Burkina Faso (West Africa). Climatic Change 92: 433-460.

Roudier P., Muller B., D'Aquino P., Roncoli C., Soumaré M.A., Batté L., Sultan B. 2014. The role of climate forecasts in smallholder agriculture: Lessons from participatory research in two communities in Senegal.*Climate Risk Management*, 2 : p. 42-55.

Tesfaye S.2008. Socio-ecological Functioning and Economic Performance of Rain-fed farming Systems in Adami Tulu Jido Kombolcha District, Ethiopia: Agroecology Masters Program Norwegian University of Life Sciences.UMB, Ås

UNECA (United Nations Economic Commission for Africa).2017. WISER Policy and Enabling Environment Climate Information Services Day Enhancing Uptake and Use of CIS in Development Planning in Africa. Concept note. Addis Ababa, Ethiopia

United Nations Framework Convention on Climate (UNFCCC). 2011. *Ecosystem-Based Approaches to Adaptation: Compilation of Information*. Note by the Secretariat. Available at: http://unfccc.int/resource/docs/2011/sbsta/eng/inf08.pdf [Date accessed: 23.11.2016].

Zillman, J. 2009. *Adaptation to a variable and changing climate: Challenges and opportunities for NMHSs*.Scientific Lecture, World Meteorological Organisation, EC-LXI, Geneva, June 11, 2009.

Drought Analysis Using Reconnaissance Drought Index (RDI): In the case of Awash River Basin, Ethiopia

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Abstract

Drought is a natural disaster associated with scarcity of water due to reduction in the amount of precipitation over an extended period, usually a season, a year or more in length which leads to food, fodder and water shortages along with destruction of vital ecological system. This study was designed to analyze and characterize drought in Awash River Basin of Ethiopia based on meteorological data in the period of 1981-2015. Metrological data of 18 stations were taken from Ethiopian national meteorology agency. Reconnaissance Drought Index (RDI) was used to determine the temporal and spatial analyses of meteorological drought whereas Mann-Kendall test was used to analyze the drought trend. Spatial extents of drought maps are generated using Arc GIS by summarizing the percentage of occurrence of droughts in areas within the study basin. The result shows that, extreme drought events were occur six times in the past 35 years all over the basin with the highest RDI12 value registered in Dubti station in 1984. About to areal extent, lower Awash basin and some parts of middle Awash was affected by extreme drought in 1984 while in 2015 the extremity and severity of drought is very high in upper part of Awash River basin. In general, the extreme drought was occurred within six years intervals in the past 35 years in the basin while the highest meteorological drought was occurred in 2015 which 100 % of the total areas of the basin covered by extreme, severe, moderate and mild drought. Using the Mann-Kendall test Most of the stations showed an increasing trend of drought severity during autumn, winter and spring seasons only one station showed a decreasing trend of severity during Autumn & Summer seasons. These results could be associated with the consequences of climate change as it is postulated that droughts would become more common in the future.

Keywords: Drought, Awash basin, RDI, Spatial extent, Temporal extent

Introduction

Drought is nothing but a natural disaster which prevails due to scarcity of water or moisture (Abdullah et al., 2018). Droughts can be considered as multidimensional hazardous phenomena characterized by their severity, duration and areal extent (Tsakiris et al., 2013). Ethiopia is affected by recurrent drought events and suffers a severe drought in different years. The causes are either natural or manmade or both. Scientific investigations have revealed that the primary cause is the fluctuation of the general atmospheric circulation. Because of such fluctuations the rain-producing components for Ethiopia have been weakened or dislocated during drought years. Human interferences such as deforestation, overgrazing and over cultivation enhance the severity and prolongation of drought recurrences (Tesfaye, 1988).

Droughts in Ethiopia had drastic impacts on agricultural output with total crop failure and massive livestock deaths being recorded in many parts of the country. For instance, the 1984 drought in Wollo province led to a 61% and 94% decline in the yield of two important crops, teff and sorghum, respectively (Desalegn et al., 2006/2009). According the survey conducted in 2006 on Upper Awash Basin, reported that drought occurs every two years in the area. Understanding the characteristics of drought is crucial for establishing an effective and comprehensive monitoring and early warning system. In the Awash River Basin, only few farmers are organized under farmers-managed smallholder irrigation and a large portion of rural poor are engaged in rain fed agriculture on marginal lands. Therefore, identification of the drought-prone areas in the basin is the basis to planning for improving socioeconomic conditions of the farmers living in the basin.

According to Dracup et al. (1980), droughts are related to precipitation (meteorological), stream flow (hydrological), soil moisture (agricultural) or any combination of the three. A similar classification can be found in Wilhite and Glantz (1985), where four categories are identified: meteorological drought, agricultural drought, hydrological drought, and socio-economic drought. The first three groups could be defined as environmental indicators, the last group as a water resources indicator. The causes of droughts could be attributed to natural phenomena but studies in certain places have indicated that water sources which are under the impact of human (e.g. rivers and groundwater) are two times more vulnerable than sources with less human interference, (e.g. snow cover and precipitation) (Shaban, 2009). Meteorological drought which we will see in detail in this document is based based on the degree of dryness (in comparison to some normalǁ or average amount) and the duration of the dry period of an area. This paper is devoted to the identification and assessment of meteorological drought in Awash river Basin. Meteorological drought is simple deficit of rainfall from the normal (Ravi, 2013).

Materials and Methods

Description of the study area

The Awash River Basin is the most important river basin in Ethiopia and covers a total land area of 110,000 km^2 and serves as home to 10.5 million inhabitants. The geographic location of the Awash River Basin is between 7°53'N and 12°N latitudes and 37°57’E and 43°25’E of longitudes (Taddese. et al., 2006). The largest part of the Awash River Basin is located in the arid lowlands of the Afar Region in the northeastern part of Ethiopia (Figure 1). The total length of the main course is about 1200 km and it is the principal stream of an endorheic drainage basin covering parts of the Oromia, Somali, Amhara, and Afar region (Koriche, 2012). The Awash River Basin is the most important basin in Ethiopia and covers a total land area of 110,000 km^2 and serves as home to 10.5 million inhabitants (Sonder and Peden, 2008). The river rises on the high plateau near Ginchi town, in the west side of the capital city of Ethiopia, Addis Ababa, and flows along the Rift Valley into the Afar Triangle and terminates in the salty Lake Abbe on the border with Djibouti.

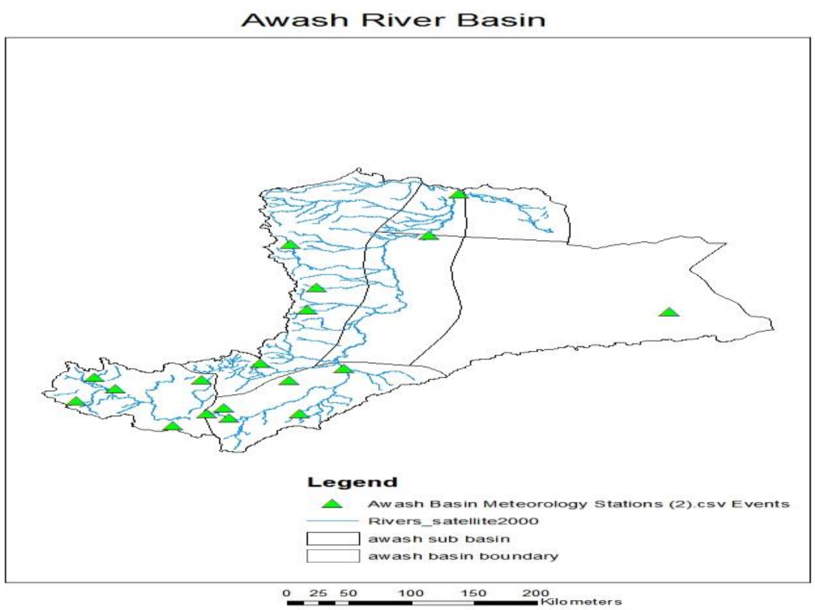

Figure 1 Study area Awash River Basin

Methodology

Monthly precipitation data of 18 meteorological stations were taken from National Meteorological Agency for a maximum period of 35 years from 1981 to 2015. The reconnaissance Drought Index (RDI) was used in this study for identification of drought conditions in Awash river Basin because this method uses both precipitation and evapotranspiration data which is more representative of the deficient water balance conditions than an index based only on precipitation. Evapotranspiration and standardizes RDI are calculated using a newly developed DrinC software package. The Mann-Kendall test is used for determining trend analysis and ArcGis for Interpolation.

The Reconnaissance Drought Index (RDI) can be characterized as a general meteorological index for drought assessment (Tsakiris et al., 2005). The RDI can be expressed with three forms: the initial value αk, the normalized RDI (RDIn) and the standardized RDI (RDIst). In this paper we will focus on RDIst. The Standardized RDI (RDIst) is computed following a similar procedure to the one that is used for the calculation of the SPI: The expression for the Standardized RDI is:

$$RDI_{st(k)}^{(i)} = \frac{y_k^{(i)} - \overline{y_k}}{\overline{\sigma}_{yk}}$$

In which yi is the ln ($\alpha_0(i)$), yk is its arithmetic mean and $\overline{\alpha}yk$ is its standard deviation. The Reconnaissance Drought Index (RDI) was developed to approach the water deficit in a more accurate way, as a sort of balance between input and output in a water system. It is based both on cumulative precipitation (P) and potential evapotranspiration (PET), which are one measured (P) and one calculated (PET) determinant. Positive values of RDIst indicate wet periods, while negative values indicate dry periods compared with the normal conditions of the area.

Table 1 Classification of drought conditions according to the RDI

RDI Values	Classification
−0.5 to −1.0	Mild
−1.0 to −1.5	Moderate
−1.5 to −2.0	Severe
< −2.0	Extreme

.

Mann-Kendall Test:

The Mann-Kendall statistic S is given as

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}\left(x_j - x_i\right)$$

The application of trend test is done to a time series xi that is ranked from i = 1, 2 …n-1 and xj, which is ranked from j = i+1, 2 ….n. Each of the data points xi is taken as a reference point which is compared with the rest of the data point’s xj so that

$$\text{Sgn}\left(x_j - x_i\right) = \begin{cases} +1, \left(x_j - x_i\right) \\ 0, \left(x_j - x_i\right) \\ -1, \left(x_j - x_i\right) \end{cases}$$

It has been documented that when n ≥ 8, the statistic S is approximately normally distributed with the mean. E(S) = 0

The variance statistic is given as

$$\text{Var(S)} = \frac{n(n-1)(2n+5) - \sum_{i+1}^{m} ti(i)(i-1)(2i=5)}{18}$$

Where ti as considered the number of ties up to sample i. The test statistics Zc is computed as

$$Zc = \begin{cases} \frac{s-1}{\sqrt{\text{var}(s)}}, s > 0 \\ 0, s = 0 \\ \frac{s-1}{\sqrt{\text{var}(s)}}, s < 0 \end{cases}$$

Z_c Here follows a standard normal distribution. A positive (negative) value of Zc signifies an upward (downward) trend. The significance level, or a Type I error, α, is the probability of rejecting the null hypothesis, when it is true. A significance level α is also utilized for testing either an upward or downward monotonic trend. If Z_c appears greater than Zα/2 where α depicts the significance level, then the trend is considered as significant. Significance levels are normally set quite low at values of 0.01, 0.05 or 0.10. The smaller the valve of α, the more is the confidence there is that the null hypothesis is false when it has been identified as such. From the relationship among power, slope of trend, and sample size for the given significance level of 0.05 and coefficient of variation CV = 0.5, the power of the test is an increasing function of both the absolute slope and the sample size. In other words, as the sample size increases, the power of the test increases leading to an increased ability to discern the existence of trend. (Yue S. et al., 2002). In this study significance level (α) of 0.05 i.e. confidence level (1-α) of 95% as per Mann-Kendall is used for drought trend analysis over the Upper Krishna basin in Maharashtra.

Sen's Slope Estimator Test:

The magnitude of the trend is predicted by the Sen's estimator (Sen, 1968). Here, the slope (Ti) of all data pairs is computed as

$$\text{Ti}=\frac{x_j - x_k}{j-k}$$

Where: x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of Ti is represented as Sen's estimator of slope which is given as:

$$\text{Qi}=\begin{cases} \frac{\text{TN}+1}{2} \\ \frac{1}{2}\left(\frac{\text{TN}}{2}+\frac{\text{TN}+2}{2}\right) \end{cases}$$

Sen's estimator is computed as

Qmed=T (N+1)/2 if N appears odd, and it is considered as

Qmed= [TN/2+T (N+2)/2]/2 if N appears even.

At the end, Qmed is computed by a two-sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Qi indicates an upward or increasing trend and a negative value of Qi gives a downward or decreasing trend in the time series.

Results and Discussions

Drought characterization

Drought characterization mainly focuses on the analysis of the historical drought conditions of an area. A 12 month RDI values were estimated during the period 1981 - 2015 to provide an overview of drought occurrences. The result of RDIst12 shows that there were 146 (23.2%) drought events occurred in the basin and the rest 76.8% were normal conditions (Figure 2).

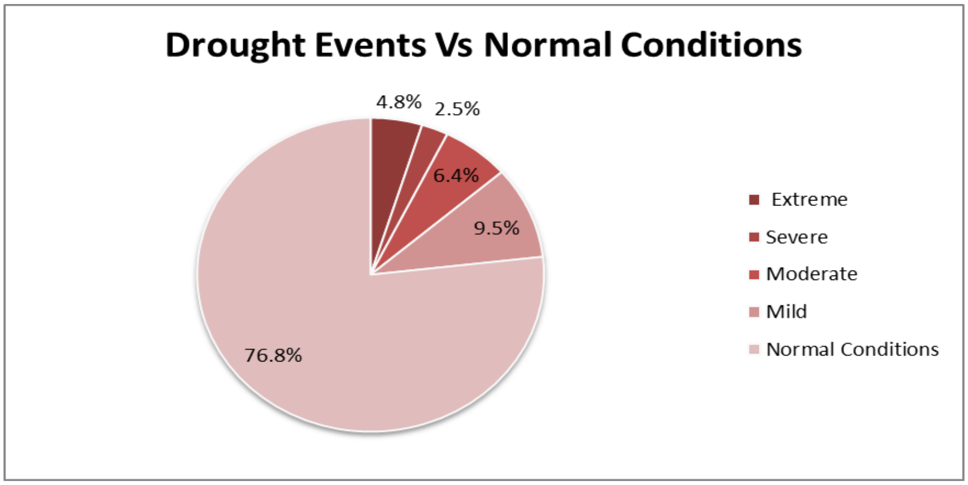

Figure 2 Normal vs drought events of Awash Basin

Drought Frequecy

From 1981 to 2015, 146 times drought events occurred within 18 stations in the basin and from these 20.5 % was extreme, 11% was severe and 27.4% was moderate droughts occurred (Figure 3). Most drought events recorded in station Ataye (Middle Awash) 11 times and extreme drought events recorded in station Abomsa (Upper Awash) 4 times within these 35 years.

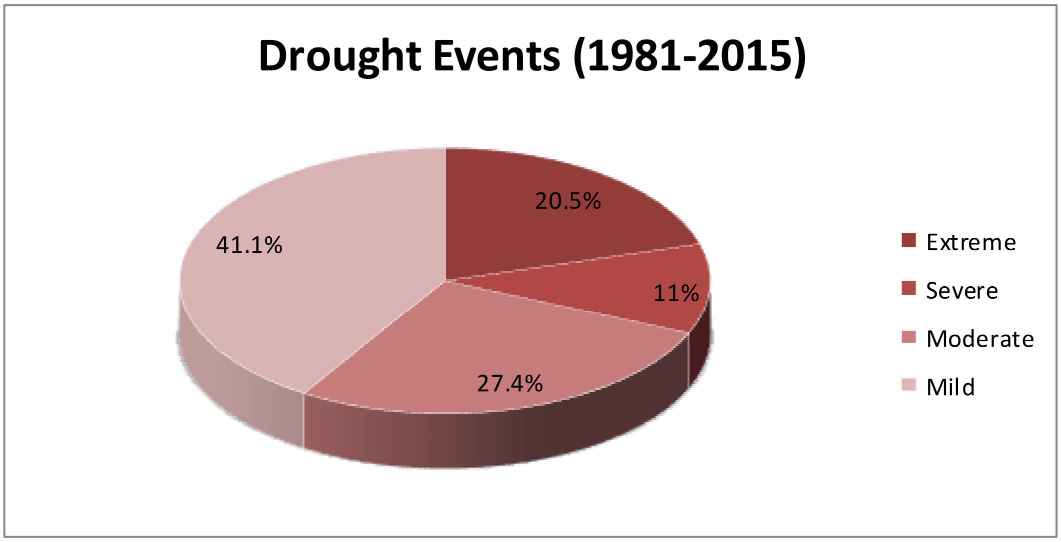

Figure 3 Frequency of droughts events

Duration and Intensity

The results of RDI showed the duration ranges between 1- 4 months. The longest drought recorded in 6 stations and it's about 4 months duration in 1999-2000, 2002-03, 2014-15 and 2015-16. The maximum number of dray months recorded in station Kimoye (Middle Awash) in 2015-16 and reached 6 months. Results from RDI12 calculation shows that, severe drought was recorded in all stations of the basin and the highest severity and extremely dry condition was recorded in Dubti meteorological station with index value of -3.64 (Lower Awash) during 1985.

Drought Periods

The RDI12 results showed that extreme drought occurred in 1984-85, 1985-86, 1997-98, 2002-03, 20014-15, and 2015-16 in the Awash River basin (Figure 4-6).

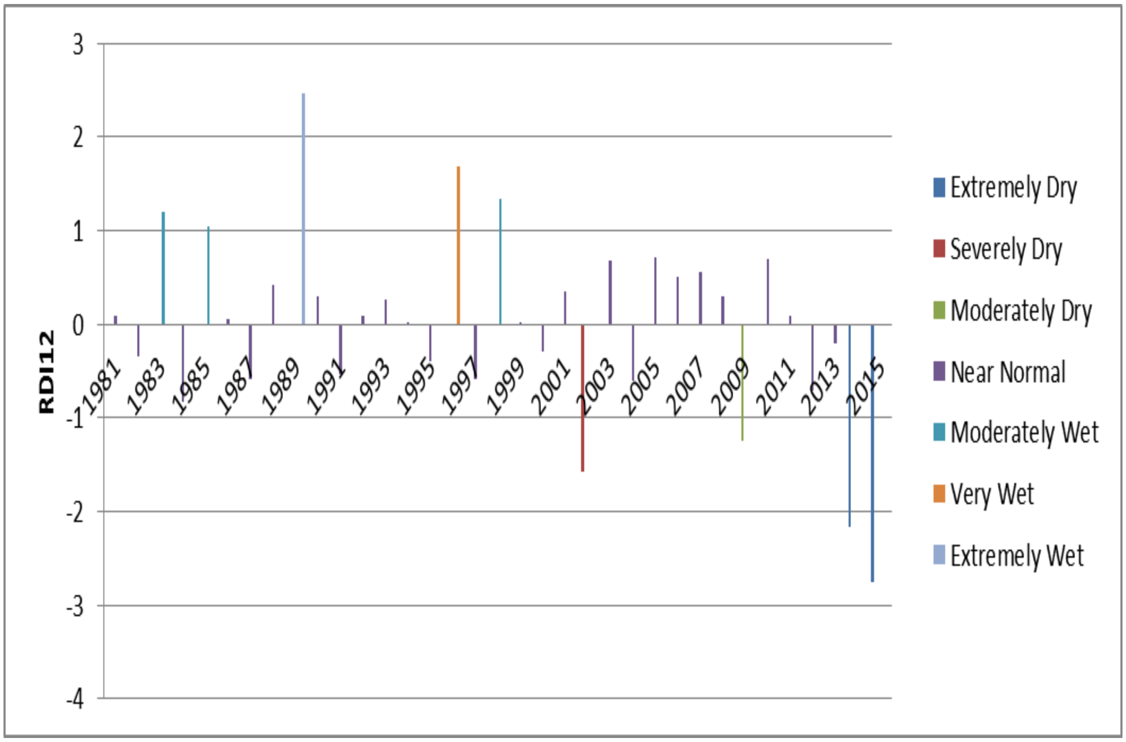

Figure 4 RDI12 of Chefedonsa in upper Awash Basin

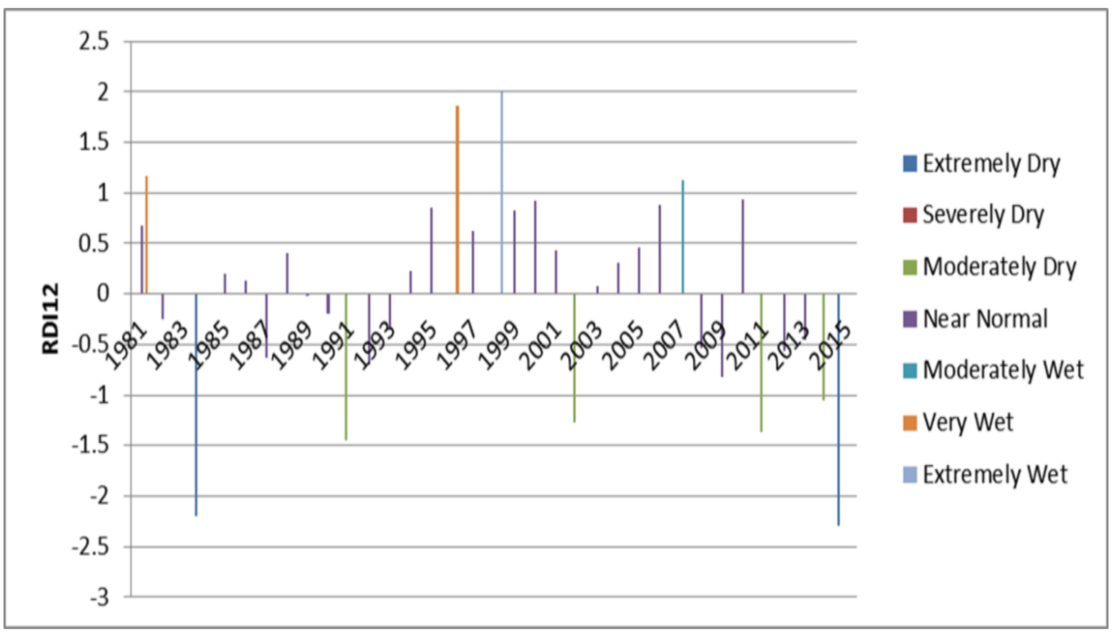

Figure 5 RDI12 of Ataye in Middle Awash Basin

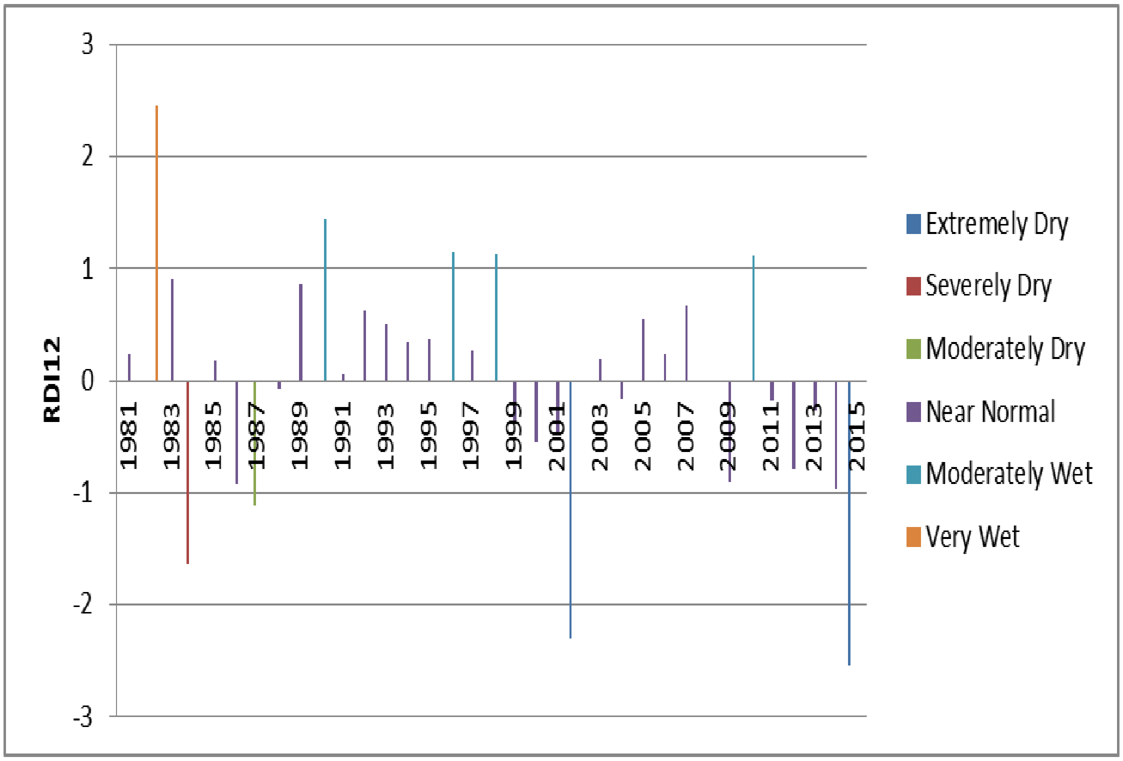

Figure 6 RDI12 of Awash Arba in Lower Awash Basin

Areal Extent of Drought

In the literatures (e.g. Webb et al. 1992, Degefu 1987, Segele and Lamb 2005) the 1984 drought of Ethiopia was very sever and extreme because in the spring season, the interaction between tropical lows and middle latitude low pressure systems was hindered by pressure anomalies over the Sahara and the Arabian Peninsula. The ERA-Interim wind field at 700 and 850 hPa suggests that the transport of air and moisture from the equatorial Indian Ocean toward Ethiopia in April was reduced, and the vertical velocity at 500 hPa indicates reduced convection / increased subsidence over the Horn of Africa (Shanko and Camberlin, 1998). Due to these, all part of Ethiopia was affected at the seasonal level while there were severe in the northeastern half of the country. In line with this Degefu (1987) indicates that, Northeastern Rift Valley, the Northeastern Highlands, the Central Highlands, and Central part of Ethiopia were among the driest areas for 3 consecutive years.

A finding from the meteorological data shows that, in 1984 about 99% of the total area of the basin was affected by drought and 62.4% of the area was covered by extreme drought. The highest meteorological drought was occurred in 2015 which 100 % of the total areas of the basin covered by drought and 73.4% was extreme and the highest meteorological drought was occurred in 2015 which 100 % of the total areas of the basin covered by drought and 73.4% was extreme. In 1984 the extreme drought was in lower Awash Basin but in 2015 the extreme was in upper, middle and some parts of lower (Figure 7).

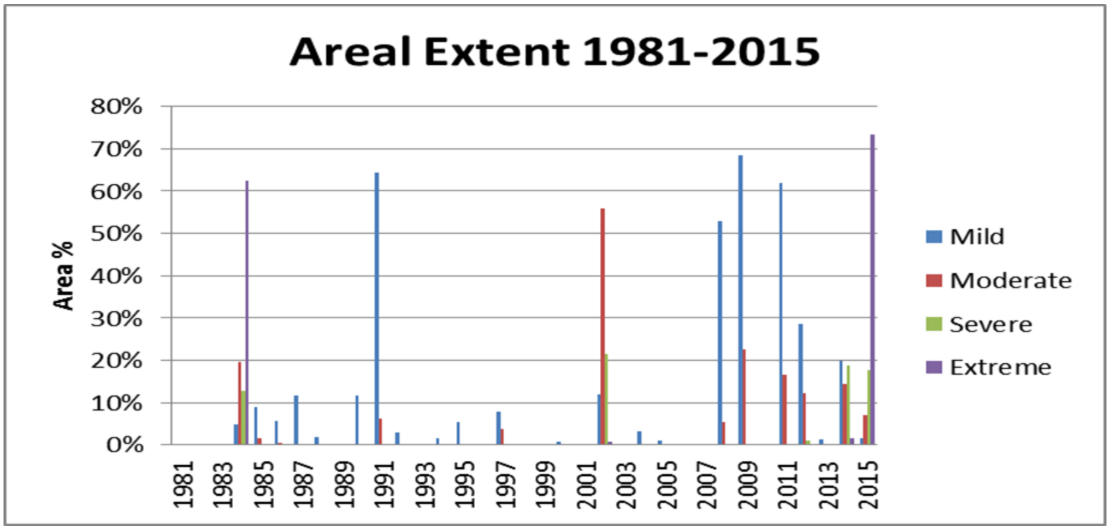

Figure 7 Areal Extent of drought in Awash Basin

In 1984 extreme drought occurred in lower awash basin and some parts of middle awash was affected by extreme drought and mild moderate and severe droughts occurred in upper and some part of middle awash basin (Figure 8). while in 2015 the extremity and severity of drought is very high in upper part of Awash and moderate level drought is occurred in lower part of the basin (Figure 9). While extreme droughts occurred in the upper and middle part of Awash basin, severe and moderate droughts occurred in the lower part of Awash basin

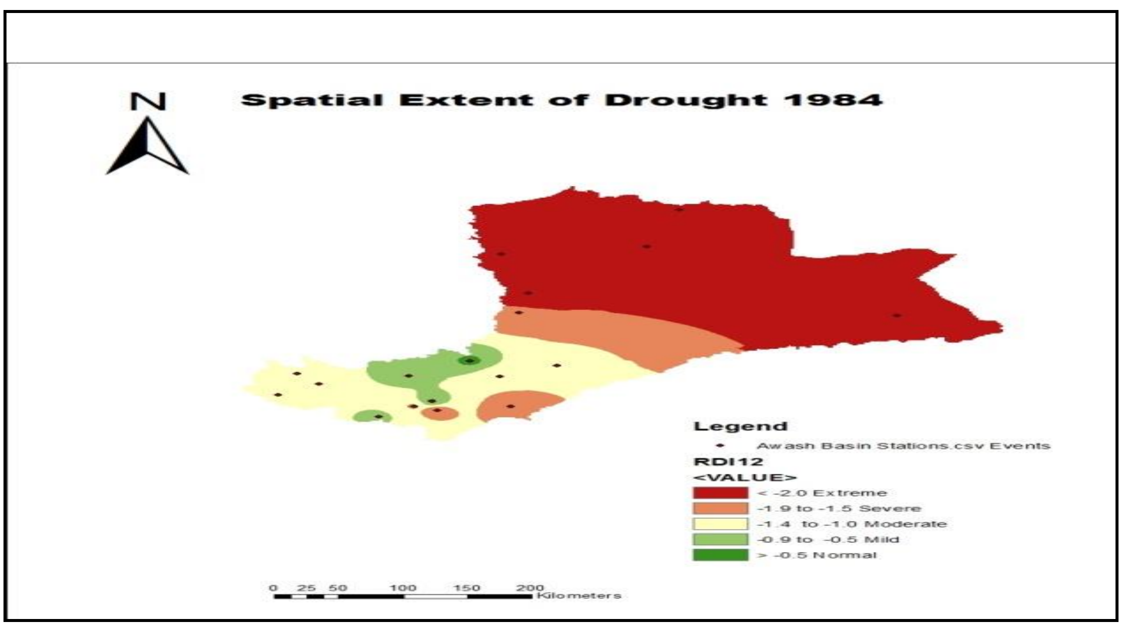

Figure 8 Spatial Extent of drought the year 1984

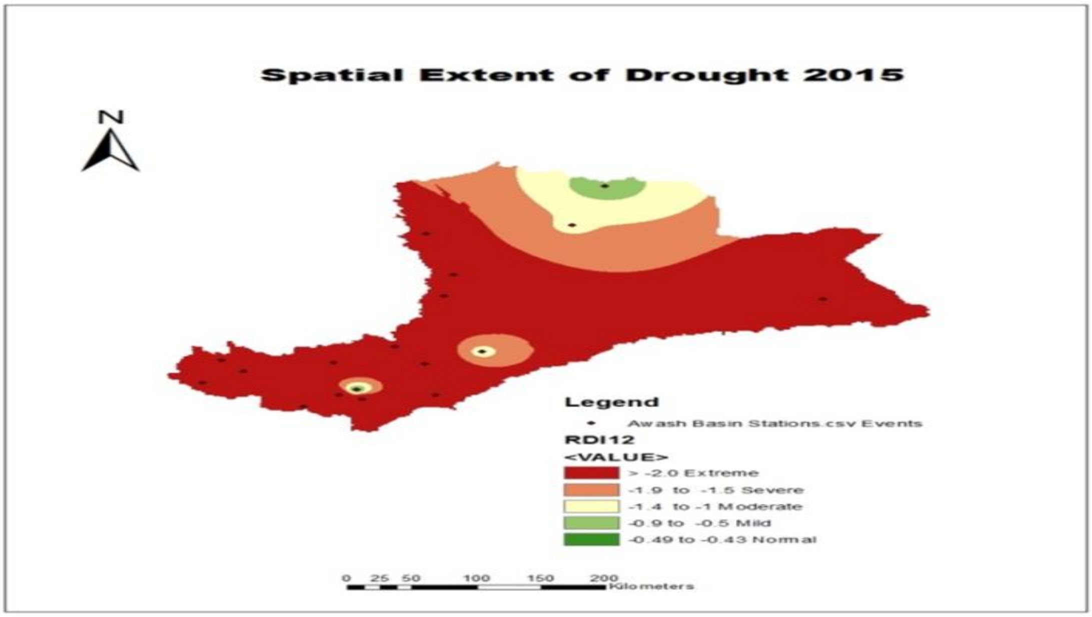

Figure 9 Spatial Extent of drought the year 2015

According to Singh et al. 2016, there was a large-scale ocean-atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east-central Equatorial Pacific in March 2015. In Ethiopia, this events leads to drier conditions mainly in northwestern regions, especially affecting the rainy season that occurs from June through September. Overall, 2015 was a very dry year in large parts of Ethiopia, as represented by rainfall anomalies from the Climate Hazards Group Infrared Precipitation with Stations (Funk et al., 2015c) data. Over 90% of the basin area was affected by moderate and severe level drought in the year of 2015-2016 and 78% of the area was affected by extreme drought events (Figure 3). As compare to 1984/85 drought period the basin was highly encountered by extreme drought in 2015. According to UN (2015) report and Sjoukje et.al. (2017), it was the worst drought in decades and the impact was aggravated in northern and central part of Ethiopia, which leads hundreds of thousands of farmer’s crop production to be failed and loss of their livestock’s.

Trend

Using the Mann-Kendall test Most of the stations showed an increasing trend of drought severity during autumn, winter and spring seasons only one station showed a decreasing trend of severity during Autumn & Summer seasons.

Conclusion and Recommendation

The analysis of drought using RDI from rainfall data and evapotranspiration is useful to determine the spatial distribution and characteristics of drought. RDI12 showed recurrent drought events occurred within 35 years from 1981-2015 and its intensity includes mild, moderate, severe and extreme. Extreme drought occurred in the years 1984-85, 1985-86, 1997-98, 2002-03, 20014-15, and 2015-16 and the maximum RDI12 value (extreme drought) occurs in station Dubti in the year 1984. In 1984 about 99% of the total area of the basin was affected by drought and 62.4% of the area was covered by extreme drought. The highest meteorological drought was occurred in 2015 which 100 % of the total areas of the basin covered by drought and 73.4% was extreme and the highest meteorological drought was occurred in 2015 which 100 % of the total areas of the basin covered by drought and 73.4% was extreme. In 1984 the extreme drought was in lower Awash Basin but in 2015 the extreme was in upper, middle and some parts of lower.

In general, recurrent droughts occurred in upper, middle and lower Awash Basin due to below average precipitation. Severity is increasing in upper and middle Awash basin and the spatial coverage of drought & intensity is increasing in the basin in different years. There is also an areal shift of extreme drought from lower basin to upper and middle part of the basin. The worst drought is 2015 by its intensity, duration and areal extent.

Recommendations

Developing efficient and properly functioning drought early warning systems specific to the extremely drought prone area and short- and long-term adaptation plan, water harvesting technologies, integration of drought-risk management approaches into long-term development measures and involving investors around the river in different adaptation practice and intervention for drought are highly recommended to minimize the risk.

References

Abdullah A., Niaz FR, Abdullah A., Abdul Q, Ismail H, Arafat IN and Shahjahan K. 2018. Meteorological Drought in Bangladesh.

Degefu, W. 1987. Some aspects of meteorological drought in Ethiopia. In Drought and hunger in Africa. Denying famine a future. M. H. Glantz. Cambridge, Press Syndicate of the University of Cambridge.

Desalegn E, Babel MS, Gupta AD, 2009. Drought Analysis in the Awash River Basin, Ethiopia.

Desalegn E, Babel MS, Gupta AD, Seleshi BA, Merrey D 2006. Farmers’ perception about water management under drought conditions in the Awash River Basin, Ethiopia. Int J Water Resour Dev 22(4):589–602

Funk et al. 2015c: The climate hazards infrared precipitation with stations—A new environmental record for monitoring extremes. Sci. Data, 2, 150066, https://doi.org/10.1038/sdata.2015.66.

Mahajan DR, Dodamani BM , 2015. Trend Analysis of Drought Events Over Upper Krishna Basin in Maharashtra.

Malakiya AD, Suryanarayana TMV, 2015.Assessment of Drought Using Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI): A Case Study of Amreli District.

Muhammad A, Seung J, Hyung S, Seung W, Jae. E, 2018. Spatial and Temporal Trend Analysis of Precipitation and Drought in South Korea

Nazahiyah S, Niranjali. J, Muhammed. B., 2012. Trend analysis of drought using Standardized Precipitation Index (SPI) in Victoria, Australia.

Ravi S, Manekar VL, Christian RA, Mistry NJ 2013. Estimation of Reconnaissance Drought Index (RDI) for Bhavnagar District, Gujarat, India.

Segele, ZT and Lamb PJ 2005. Characterization and variability of Kiremt rainy season over Ethiopia. Meteorology and Atmospheric Physics 89(1): 153–180.

Shaban, A., 2009. Indicators and aspects of hydrological draught in Lebanon. Water Resour Manag 23:1875–1891

Shanko, D, Camberlin P 1998. The effects of the Southwest Indian Ocean tropical cyclones on Ethiopian drought. International Journal of Climatology 18(12): 1373–1388.

Singh, R., and Coauthors, 2016. Reality of resilience: Perspectives of the 2015–16 droughts in Ethiopia. BRACED Resilience Intel, No. 6, http://www.braced.org/resources/i/ ?id518256c98-2a10-4586-9317-17a68b45c1a7.

Tesfaye H 1988. Causes and Characteristics of Drought in Ethiopia.

Tigkas D, 2008. Drought Characterization and Monitoring in Regions of Greece

Tigkas D, H. Vangelis, G. Tsakiris, 2013.The RDI as a composite climatic index.

Tigkas D, Vangelis H, Tsakiris G, 2014. DrinC: software for drought analysis based on drought indices.

Tsakiris, G, Vangelis, H., 2005. Establishing a Drought Index Incorporating Evapotranspiration, ‖ European Water (9/10), pp 3-11.

UN 2015. 'Ethiopia: UN warns of deepening food insecurity, allocates emergency funds to tackle severe drought'. United Nations News Centre www.un.org/apps/news/story.asp?NewsID=52569#.WQr5X4nyui5).

Webb, P, Braun JV, et al. 1992. Famine in Ethiopia : Policy implications of coping failure at national and household levels. Research Reports. G. Desai. Washington, D.C., International Food Policy Research Institute. 92 pp.

Wilhite DA, Glantz MH 1985. Understanding the drought phenomenon: the role of definitions. Water Int 10(3):111–120

Vulnerability Analysis to Climate Variability and Change: Smallholder Farmers Adjacent to Humbo Afforestation and Restoration CDM Project, Ethiopia

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Abstract

In Ethiopia, Humbo carbon sequestration afforestation and restoration clean development mechanism (A/R CDM) project has managed to restore degraded forest (2728 ha) through strategic replanting and protection and thereby managed to generate revenues from carbon sale. However, the study fulfil research gap in terms of the impact of the intervention on the resilience of households against climate variability. Hence, the study was conducted at Humbo district households adjacent to A/R CDM project area to measure the household livelihood vulnerability to climate variability. Both quantitative and qualitative approaches were employed for the study. The livelihood vulnerability index framed with LVI-IPCC framework was applied through cross-sectional household survey conducted on 139 households that were randomly selected from three representative kebeles. The results indicated that major income sources for the households were categorized into livestock production (29.1%), crop (42.9%), off-farm (17%) and non-farm (42.6%) such as petty trade, and labour. The overall LVI-IPCC showed that 16% of households were highly vulnerable to climate extremes while 54% and 30% of households were categorized as less and moderately vulnerable, respectively. Substantial variation across the kebeles was observed in components, sub-components and three dimensions (adaptive capacity, sensitivity and exposure) of vulnerability. The LVI-IPCC estimated that households in the Abela Longena kebele were highly vulnerable (0.000) to climate variability and change compared to Habicha Bade (-0.035) and Bosa Wanche (-0.046). Therefore, integrating rural development schemes aimed at increasing adaptive capacity and designing site-specific intervention strategies to reduce vulnerability of the communities to climate variability and change is recommended to the range of climate extremes that they experience.

Keywords: CDM; Climate variability; Exposure; Livelihood strategies; Vulnerability index

Introduction

In Ethiopia, forest resources play a significant role in the country's economy, particularly in the livelihood of rural people, as important sources of energy, food, employment, medicine, fodder and income [1, 2, 3]. Apart from depending on forests and woodlands for domestic energy, studies [1, 4] undertaken in various parts of the country indicated that rural households engage in commercial supply of wood, charcoal, and other timber and non-timber forest products to urban areas to generate cash income thereby to support their livelihood. Besides the significant role forests play as livelihood assets to rural people, currently their importance is further emphasized due to their key role in controlling and maintaining the stability, functioning, and sustainability of global ecosystems [5, 6] in the face of frighteningly changing global climate. Forests serve as the world’s most important terrestrial storehouses of carbon. However, in order to serve this function, the mature forests should be left intact [5].

Most of the developed countries’ governments have now committed to increased funding for carbon sequestration and protection of forest biodiversity in order to reduce emissions of greenhouse gases [6]. Particularly, under Clean Development Mechanism (CDM) of Kyoto protocol on Green House Gas emission, investing in land and forest resources of developing countries has received the attention of industrialized countries. Having twin objectives of reducing greenhouse gasses and promoting sustainable development in host countries, the CDM projects are being implemented in non-industrialized countries since 2005 [5, 7]. In line with this, in 2006, carbon sequestration Afforestation and Reforestation (A/R CDM) project has started its implementation in Humbo district of Southern Ethiopia [8, 9]. Initiated by World Vision Australia and World Vision Ethiopia, the initiative introduced a farmer-managed natural regeneration technique to restore the degraded natural forest and thereby to generate carbon credits. Consequently, the forestland that had long been an open access resource has become enclosed and protected [3]. Since the time of its introduction, the project managed to restore 2,728 hectare of degraded forest and thereby contributed to the reduction of greenhouse gases from the atmosphere [9, 10].

Despite the widespread debate over the potential of CDM projects to achieve their sustainable development goals, as CDM pipeline shows, the number of A/R CDM project is rapidly increasing. The available scanty study on potential benefit of A/R CDM projects in Africa [11] indicates that, in short run, the projects are less likely to benefit local communities and may even harm them by restricting access to natural resources and competing for scarce groundwater. In Ethiopia, the available published study [9] indicated that Humbo carbon sequestration A/R CDM project has managed to restore degraded forest through strategic replanting and protection and thereby managed to generate revenues from carbon sale. However, it did not touch the impact of the intervention on the livelihoods of households.

In a midterm evaluation report of the Humbo carbon sequestration A/R CDM project, World Vision Australia reported protection and enhancement of biodiversity, reduced water and wind erosion, increased water supply, and returning of wild animals as major outcomes of the project [12]. The report claims the establishment of local cooperatives, securing of user rights to cooperatives, and financial inflows from the sale of carbon stocks as social and economic benefits of the regeneration and protection of the degraded forest. However, the midterm evaluation report did not disclose how the surrounding communities cope with the loss of forest products caused by the sudden restrictions imposed by the project. It neither did assess the impacts of the benefits claimed to be associated with the project on the livelihood assets of the households nor on communities participating in it. The study by Aynalem [3] comprehensively revealed various factors influencing local people's access to the forest products and their bargaining power over the carbon revenue. However, the costs incurred, or the benefits enjoyed by a given community in turn significantly influences the way that community views and manages the natural resource under consideration. Therefore, this study was conducted to measure household livelihood vulnerability to climate extremes.

Methods

Study site description

This study was conducted in Humbo Tabala district of southern Ethiopia which is located 397km southwest of the capital city Addis Ababa [13]. The Humbo town, capital of the district geographically located in approximate coordinates of 6°46'48.47'' to 6°41'04.28''N latitude and 37°48'35.44'' to 37°55'14.51''E longitude (Figure 1). Agro ecologically, 11% of the district falls under highland ('Dega'), 27% falls under mid-highland ('Woina-Dega') and the remaining 61% falls under lowland ('Kolla'). Mean annual temperature of the district is 22ºC and mean annual rainfall is 1123mm with altitudinal range of 1100 to 2335m.a.s.l [13]. The vegetation can be classified as the dry woodland forest type. It had been covered by dense broad-leaved vegetation types and montane forests before they were cleared around fifty years ago. Besides, Fabaceae and Combretaceae and Oleaceae were found to be the most species rich families in the area [14].

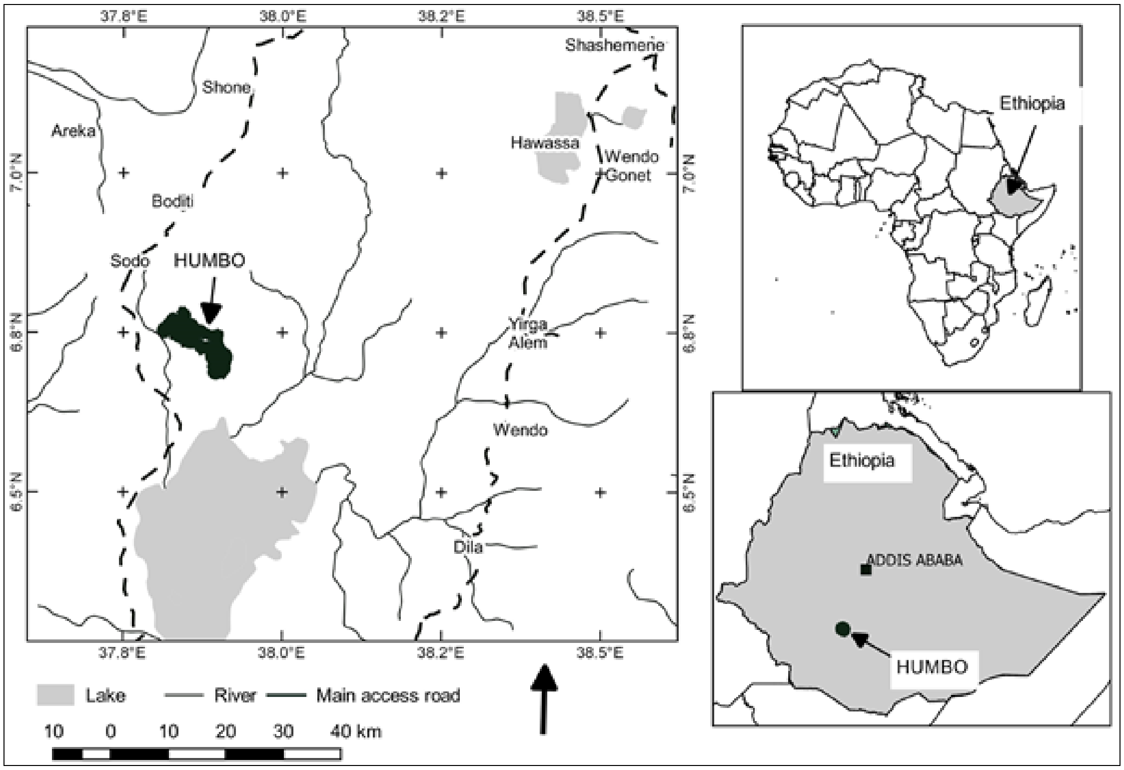

Figure 1 Map of Humbo district in southern Ethiopia [15].

Research design and sampling

This research has employed both quantitative and qualitative approaches obtained by household survey, key informant interview, focus group discussion, and review of secondary sources. This study was also employed a cross-sectional research design to get in-depth insight of the issues under consideration including quantitative and qualitative approaches of data collection [16, 13]. The sampling frame for survey included those households that are legally organized as forest development cooperatives to manage the forest of interest. A two stage sampling procedures was employed to select the sample households in the study area [15]. In the first stage, three representative cooperatives, out of seven, were purposively selected based on their accessibility and representativeness: Abela Longena, Hobicha Bada and Bosa Wanche. In the second stage, proportional sampling technique was applied to draw samples from the population. Thus, 10% of the households from each cooperative were included in the sample *i.e*. 51, 46 and 42 household heads were selected, respectively, from each cooperative using systematic random sampling technique.

Livelihood vulnerability analysis

The livelihood vulnerability index (LVI) was utilized based on modified version of [17] Hahn et al. (2009). The LVI developed contains nine major components and the sub-components comprised thirty-eight indicators (Table 1). The computation of each indicator value followed the process of standardization adopted from the computation of the life expectancy index of the Human Development Index [17] as in Equation 1:

$$Index\ S_b = \frac{S_b - S_{min}}{S_{max} - S_{min}} \quad (1)$$

In the index, S_b is the original subcomponent of the block b, S_{min} and S_{max} are the minimum, and maximum values for each subcomponent determined using data from the three blocks (*i.e.* three kebeles) of the district. After each was standardized, the subcomponent was averaged using Equation 2 to calculate the value of each major component:

$$M_b = \frac{\sum IndexS_{bi}}{n} \quad (2)$$

Where: M_b equals one of the major components for the block b, index S_b represents the subcomponents, indexed by *i*, that makes up each major component and *n* is the number of subcomponents in each component. Once values for each of the eight major components for a block were calculated, it was averaged using Equation 3 to obtain the LVI at block level:

$$LVI_b = \frac{\sum W_{Mi} M_b}{\sum W_{Mi}} \quad (3)$$

Where: LVI_b is the livelihood vulnerability index for the block *b*, and the weightage of the eight major components, W_{Mi} determined by the number of subcomponents that make up each major component, contribute equally to the overall LVI [5, 17]. In this study, the LVI is scaled from zero (least vulnerable) to one (most vulnerable).

On the other hand, the LVI-IPCC approaches utilize household level primary data to measure the subcomponents. The major contributing factors of LVI-IPCC are exposure, sensitivity, and adaptive capacity to measure the influence of the climate change and variability on the households' vulnerability and resilience. All three major components were combined [17] as in Equation 4.

$$CF_b = \frac{\sum W_{Mi} M_{bi}}{\sum M_{bi}} \quad (4)$$

Where: CF_b is an IPCC-defined contributing factor (exposure, sensitivity or adaptive capacity) for the block *b*, M_{bi} is the major components for the block *b*, indexed by *i*, M_{bi} is the weightage of each major component, and *n* is the number of major components in each contributing factor.

Table 1 Major and sub-components comprising the LVI developed for the study area

LVI-IPCC	Major components	Descriptions of sub-components	Hypothesized function
Adaptive capacity	Demographic profile	Household dependency level	The higher the dependence ratio, the higher the vulnerability
		Age of Household head	The higher the age, the higher the vulnerability
		Sex of Household head (Male/Female)	
		Education level Household head	The more the information, the more the adaptive capacity
		Percentage of literates in the Households	
		Household size (Persons/HH)	The larger households tend to have more economically inactive dependents which in turn increases vulnerability
	Livelihood strategies	Total household income (Amount of Birr/HH)	The more the wealthy status, more the adaptive capacity
		Income from crop (Amount of Birr/HH)	
		Income from livestock (Amount of Birr/HH)	
		Number of livestock (TLU/HH)	
		Off-farm income (Amount of Birr/HH)	
		Land size (Ha/HH)	
		Number of crops (diversity) in the system	The more diversification of crop species, the more the adaptive capacity
	Social network and Infrastructure	Membership in farmers' association (Yes/No)	The more in membership in social network, the more the adaptive capacity
		Membership in "*Ikub*"/"*Idir*" (Yes/No)	
		Access to schools (Walking distance in km)	The more access to infrastructure, the more the adaptive capacity
		Access to nearby market (Walking distance in km)	
		Percentage of HHs using saving and credit	
		Percentage of HHs accessing electricity	
		Percentage of HHs using telephone	
		Social safety-net program (Yes/No)	
	Technologies	Percentage of HHs applying fertilizer	The more access to technology, the more the adaptive capacity
		Percentage of HHs using improved seed	
		Percentage of HHs who have radio/TV set	

Table 1. Continued

LVI-IPCC	Major components	Descriptions of sub-components	Hypothesized function
Sensitivity	Health	Access to health care (in km)	The more access to infrastructure, the less the sensitivity
		Privet toilet facility (Yes/No)	
	Water resources	Access to clean drinking (in km)	The more access to infrastructure (the shorter this time), the less the sensitivity
		Availability of consistent water supply (Yes/No)	
	Ecosystem	Distance from forest to household (in km)	The more access to forest resources, the less the sensitivity
		Number of forest products utilized before A/R project	
		Improved access to firewood (Yes/No)	
		Improved access to fodder (Yes/No)	
		Assistances in tree planting in farms (Yes/No)	The higher practice of planting tress the less the sensitivity
Exposure	Natural disasters	Average number of natural disasters in the past two decades	More reflects higher exposure
	Climate variability	Average number of factors triggered climate change in the past two decades	More reflects higher exposure
		Average number of climate effects on livelihoods in the past two decades	Increase in climate effects on livelihoods, increase vulnerability
		No. of response measures to halt shocks of climate variability in the past two decades	More reflects and response measures to shocks, the lower exposure
		Perception on change in climate in past three decades (Yes/No)	The higher perception on climate variability, the less exposure

'HHs' stands for the 'households'. The table is customized from Hahn [17].

Once exposure, sensitivity and adaptive capacity were calculated, the three contributing factors were combined using Equation 5.

$$LVI\ IPCC_{db} = (E_b - AC_b) * S_b \tag{5}$$

Where LVI-IPCC$_{db}$ is the LVI for the district *d* and block *b* expressed using the IPCC vulnerability framework, *E* is the calculated exposure score for the block, AC is the calculated adaptive capacity score for the block, and *S* is the calculated sensitivity score for the block [17]. Then, the LVI-IPCC is scaled from -1 (least vulnerable) to 1 (most vulnerable).

Results and Discussion

Demographic and socio-economic characteristics of households

The results showed that most of the sampled households (92.6%) were male-headed, while the rest were female-headed. This indicates that male-headed households highly dominated the female-headed households in the surveyed area. The age distribution showed that the age of respondents ranged from 25-86. More than half (52.5%) of the respondents falling in the age category of less than 18 years, 19.9% in the age range of 19-29 years, 17.3% in the age range of 30-40 years and the remaining 10.2% were 41 and above. This shows that there is large age gap among the respondent household heads. However, on average respondents are in the productive age group. On the other hand, mean family size of the surveyed households was 7.2 with minimum and maximum of 2 and 16, respectively. The results showed that household heads have better penetration of formal education system. More than 35.8%, 38.8% and 11.9% of household heads in the studied community have access to attend the primary, secondary and tertiary level of education, respectively. The rest (13.4%) of interviewed household heads were not attended formal education.

The mean land holding size of the household was 0.89 hectare of land. This indicates that there is a severe shortage of agricultural land in the area even though most of the respondents reported that their main livelihood activity is farming. On the other hand, the results indicated that major livelihood strategies include sole crop farming (21.5%); mixed agriculture (34.1%); crop, livestock and fuel (23.7%); labour (6.7%) and the others (12.5%) in the studied community. The farmers grew diversity of cereal and perennial crops on their farmlands mainly maize, sorghum, *teff*, horicon beans, pigeon pea, coffee, inset and other root crops. Cattle, goat, sheep, and donkey were the major livestock species in the study areas. The results indicated that the mean livestock holding of the households was about 1.93 TLU[1].

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[1] *TLU is Tropical Livestock Unit as defined in [18].*

However, due to severe soil erosion, fragmented land size, and erratic rainfall, crop production has been negatively affected [8; 19; 3]. Livestock (e.g. cattle, sheep, goat, poultry, and donkey) has also important place next to crop production in the economy of the inhabitants of the district. Furthermore, other economic activities like handcraft industry, trade and others also play important role in the livelihood of the inhabitants of the district [19;13].

Pattern of household vulnerability

Adaptive capacity

Demographic characteristics: The index analysis indicated that demographic profile component scored 0.301, 0.375 and 0.341 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). The results indicated that Hobicha Bade was more vulnerable and has less adaptive capacity to prevailing climate impact compared to the rest two sites. This could be due to higher household dependency ratio, increased family size, and relatively poor education level of household heads that triggered the community being vulnerable to climate variability in the area. For instance, 28.9% individuals in the households in the Hobicha Bade community were dependent on family resources to run the day to day life styles. According to Dechassa [20], large family sizes have negative impacts on the households in the Didessa basin. This is because the available livelihoods opportunities to family members are very much limited and only one or two of a household member usually engage in productive livelihood activities that can support the family plus members of the households whose ages are less than 14 and greater than 65 age categories are also not active participants. Similar study confirmed that in west Arsi zone of Ethiopia that children, women and large sized families are affected mostly by the climate change events [21].

Livelihood strategies: The vulnerability index analysis indicated that livelihood strategies component scored 0.658, 0.693 and 0.651 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). This shows that households in Hobicha Bade was more vulnerable to climate change mainly due to lower income level from crop and livestock production and off-farm activities, and shortage of farming land that was highly contributed for the low adaptive capacity of the communities to climate extremes. In general, this implies that increasing total income of the households by enhancing the revenue generated from crop production through planting improved crop varieties, increasing livestock productivity through practice of good performing breeds, and alternative means regarding off-farm activities is crucial improving livelihood strategy of the households and in turn, better adaptive capacity against climate variability.

Social network and infrastructure: The vulnerability index analysis indicated that social network and infrastructure component scored 0.266, 0.286 and 0.178 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). The results show that households in Hobicha Bade community were relatively more vulnerable to prevailing climate impacts mainly due to insufficient electricity coverage, limitations related with saving and credit services, and poor access to safety net program in the study area. For instance, the results indicated that 71.1% and 67.4% of the sampled households in Hobicha Bade community were lack electricity coverage and access to saving and credit service in their area, respectively. Borrowing and lending money indicate the financial assistance households receive in cash and kind from their social network and households that borrow money more than they lend are more vulnerable [17].

In other hands, more than 61.9% of the sampled households have no access support from the safety net program in study area. In contrast, the result indicated significant portion of the community have better access to basic infrastructure such as primary school (99.2%), market information (99.2%), and all-weather roads (87.8%) in the study area. This implies the household vulnerability level was determined by balanced investment in terms of infrastructure development across the study area and emphasis should be given. Moreover, formal education tends to improve the ability of smallholder farmers to better comprehend issues affecting them and therefore look for possible solutions at the appropriate places. On the other hand, illiteracy limits smallholder farmer's access to information especially from written sources, thereby increasingly their susceptibility to climatic stresses [22]. Other studies indicate that farm households with an access to formal education greatly contribute to climate change adaptation and reduce vulnerability. Extension services have the potential to influence farmers' decision to change their farming practices in response to climate change [23, 24].

Technologies: Regarding the technologies, the vulnerability index analysis indicated that the component scored 0.333, 0.391 and 0.261 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). The result considered use of agricultural fertilizers, supply and use of improved seed varieties, and having of radio/TV set showed that households in Hobicha Bade community were relatively vulnerable and low adaptive capacity to climate change impacts compared to the others. For instance, 78.3% of the households in the Hobicha Bade community have no access to either radio/TV set as means of information. Key informant interview and focus group discussion also revealed majorities of households in the study area have no radio/TV set mainly due to lack of awareness and problems related with electricity. In contrast, results indicated that 90% and 87.5% of the sampled households use organic fertilizer and improved seed varieties in their farm lands in general.

Sensitivity

Health: The vulnerability index analysis indicated that health component scored 0.184, 0.089 and 0.172 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). This shows that households in Bosa Wanche community were highly sensitive and in turn, more vulnerable to climate change mainly due to insufficient access to healthcare centre relatively compared to other communities. The results indicated that 62.6% of the sampled households in the Bosa Wanche community do not have better access to health care centre. In contrast, majorities of sampled households (99.2%) have private toilet in the study area.

Water resources: The vulnerability index analysis indicated that water resource component scored 0.230, 0.098 and 0.091 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). This shows that households in Bosa Wanche were highly sensitive and in turn, more vulnerable to climate change impacts mainly due to insufficient availability of sustainable water supply (including streams and rivers) and clean drinking water in the area. Although the area have relatively better water resources, the results indicated that 24% and 20% of households in Bosa Wanche community do not access clean drinking water and lacks sustainable water supply, respectively. In other hands, key informants and information from focus group discussion revealed that water sources were increased due to restoration of the forest area and investment carried out through carbon sequestration A/R CDM project. Even though the even distribution of the drinking water sources built by the carbon sequestration A/R CDM project should be managed, the actions made to improve the access to clean drinking waters across the community was encouraging that needs to be continued in collaboration with local government administration according to interviewed key informants. On the other hand, utilization of a natural water source is likely to lead to an increase in a household's vulnerability to water borne diseases and water scarcity due to inadequate rainfall. Furthermore, water is usually sourced by women and young girls hence distant water sources increases the time burden of household chores and affects time for care in the case of women, and school attendance in the case of the girl child [22, 20].

Ecosystem: The vulnerability index analysis indicated that ecosystem component scored 0.675, 0.691 and 0.567 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). This shows that households in Hobicha Bade community were sensitive and in turn, more vulnerable to climate change impacts compared to others. This is mainly due to restriction on forests resource such as firewood for household consumption and fodder for the livestock populations. The results indicated that majorities (86%) of respondents perceived complete restriction on firewood and fodder collection from the forest as introduction of the A/R project. In contrast, 43.7% of the sampled households in study area confirmed that carbon sequestration A/R CDM projects provided assistance to plant trees on their farm lands. According to interviewed key informants, the restriction on forest resources triggered the communities to establish own woodlots and encouraged to plant trees in the farm lands so that it improved the microclimate compared to last two decades. Natural capital and vulnerability to climate change are tightly linked [25]. The greater the level of dependence of a household and the greater sensitivity of natural resources, such as farming, forestry, the higher their vulnerability to climate change and vulnerability level varies depending on the contribution of natural resources to their livelihoods [20].

Exposure

Natural disaster: The vulnerability index analysis indicated that natural disaster component scored 0.155, 0.234 and 0.304 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). This shows that households in Abela Longena community were more vulnerable and exposed to climate change impacts compared to the rest two mainly due to increasing encounter of natural disasters such as drought, and flooding. The results also indicated that 76.1% of sampled households perceived the climate related natural disasters were increased in alarming rate in past three decades in the area. In addition, key informants also indicated that natural disasters like prolonged drought resulted decline in agricultural productivity and exposing the community to climate extremes so that planting trees with sustainable watershed management should be prioritized. Similar studies identified such indicators as the measurement of exposure [26, 27].

Climate variability: The vulnerability index analysis indicated that climate variability component scored 0.346, 0.403 and 0.411 for the Bosa Wanche, Hobicha Bade and Abela Longena, respectively (Table 2). This shows that households in Abela Longena community were more vulnerable and exposed to climate change impacts mainly due to increased number of factors contributed to climate change, insufficient response mechanisms to halt the shocks, and increased climate effect on the livelihoods in the communities. In contrast, 99.3% of the households have perceived significant changes on climatic parameters such as temperature and precipitation in the area in past three decades. This implies that increasing the response mechanism of households in the communities to climate shocks should be given emphasis to minimize the level of exposure to climate variability. In general, the vulnerability diagram of the major components of the LVI shown in Figure 2.

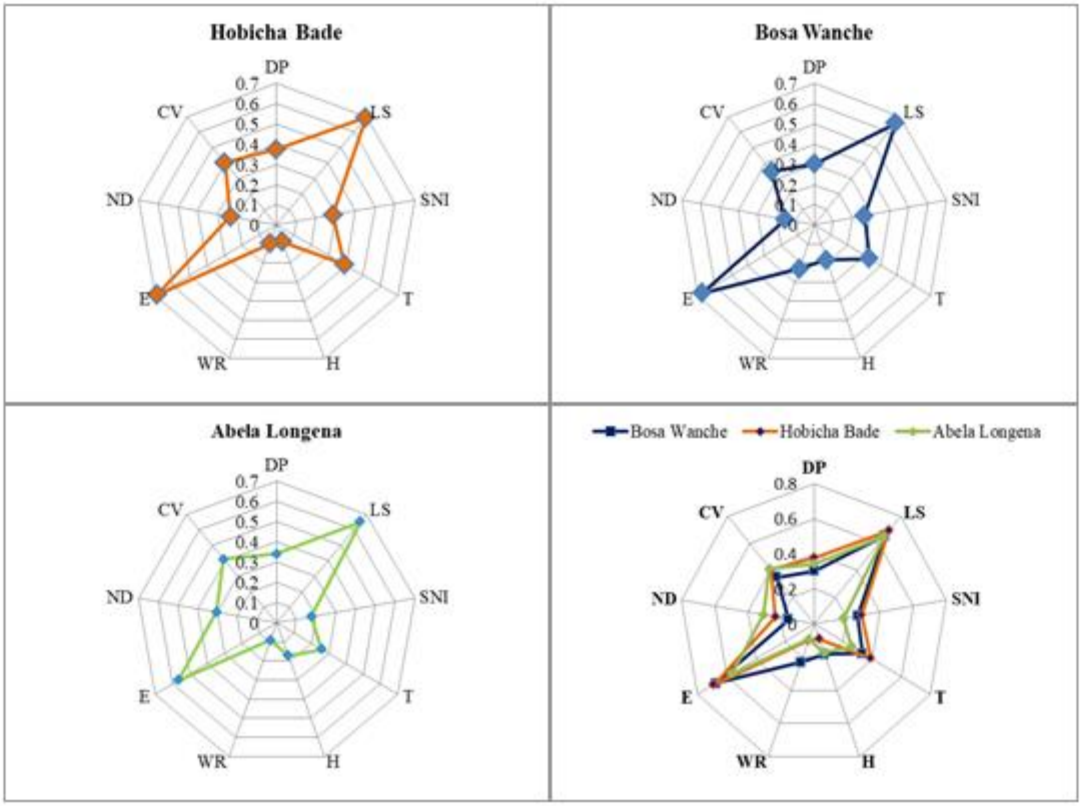

Figure 2 Vulnerability spider diagram of major components of LVI

Overall vulnerability scores Where: DP, demographic profile; LS, livelihood strategies; SNI, social network and infrastructure; T, technology; H, health; WR, water resources; E, ecosystem; ND, natural disaster; CV, climate variability. The scale represents 0 for least vulnerable and 0.8 for most vulnerable.

Based on final weighted average score, the household vulnerability index ranged from -0.373 to 0.402. The overall LVI-IPCC scores indicate that households in Bosa Wanche are comparatively less vulnerable to climate extremes compared to others because of better adaptive capacity (0.390) and less exposure (0.263). In other terms (Table 2), the calculation of LVI-IPCC showed that the households in Abela Longena kebele are more vulnerable to climate change compared to Habicha Bade (-0.035) and Bosa Wanche (-0.046).

The calculation of overall LVI-IPCC indicated that 16.1% of the households in the communities were highly vulnerable to climate change and variability that need urgent intervention. On other hands, 54% and 29.9% of the households in the communities were categorized as less and moderately vulnerable to climate extremes, respectively. In this regard, 25.5% of the households in Abela longena were highly vulnerable to climate change and variability that need urgent intervention. The rest, 29.4% and 45.1% of the households were less and moderately vulnerable to climate extremes. On other side, the results indicated that 10.9% of the households in Hobicha Bada were highly vulnerable to climate extremes. In this regard, 65.2% and 23.9% of the sampled households were categorized into less and moderate level of vulnerability to climate variability. Unlike other communities, only 4% of households in Bosa Wanche were highly vulnerable in addition to 72.5% and 17.5% of the sampled households were less and moderately vulnerable to climate change respectively.

Table 2 Indexed major components LVI-IPCC for the sampled kebeles

Contributing factors	Major components	No of sub-components	Sampled kebeles (LVI)			Overall sample
			Bosa Wanche	Hobicha Bade	Abela Longena	
Adaptive capacity	Demographic profile	6	0.301	0.375	0.341	0.341
	Livelihood strategies	9	0.658	0.693	0.651	0.667
	Technologies	3	0.333	0.391	0.261	0.326
	Social networks and Infrastructure	7	0.266	0.286	0.178	0.240
	Mean score		0.390	0.436	0.358	0.394
Sensitivity	Health	2	0.184	0.089	0.172	0.147
	Water resources	2	0.230	0.098	0.091	0.135
	Ecosystem	5	0.675	0.691	0.567	0.640
	Mean score		0.363	0.293	0.288	0.311
Exposure	Natural disasters	1	0.155	0.234	0.304	0.239
	Climate variability	4	0.346	0.403	0.411	0.390
	Mean score		0.263	0.318	0.358	0.317
LVI-IPCC			-0.046	-0.035	0.000	-0.024

Regarding the impact of contributing factors, on average the adaptive capacity component has contributed 38.5% followed by exposure 31% and sensitivity 30.5% to overall household vulnerability index. The analysis indicated that adaptive capacity score contributed 41.7% to household vulnerability index in Habicha Bade community resulted household with lowest adaptive capacity and in turn, higher vulnerable to climate extremes compared to Bosa Wanche and Abela Longena. On other hands, sensitivity score contributed 35.7% to household vulnerability index in Bosa Wanche community resulted household with most sensitive and vulnerable to climate extremes compared to Hobicha Bade and Abela Longena. The findings also indicated that exposure score contributed 35.7% to household vulnerability index in Abela Longena community resulting household highest exposure to climate extremes compared to Bosa Wanche and Hobicha Bade (Figure 3).

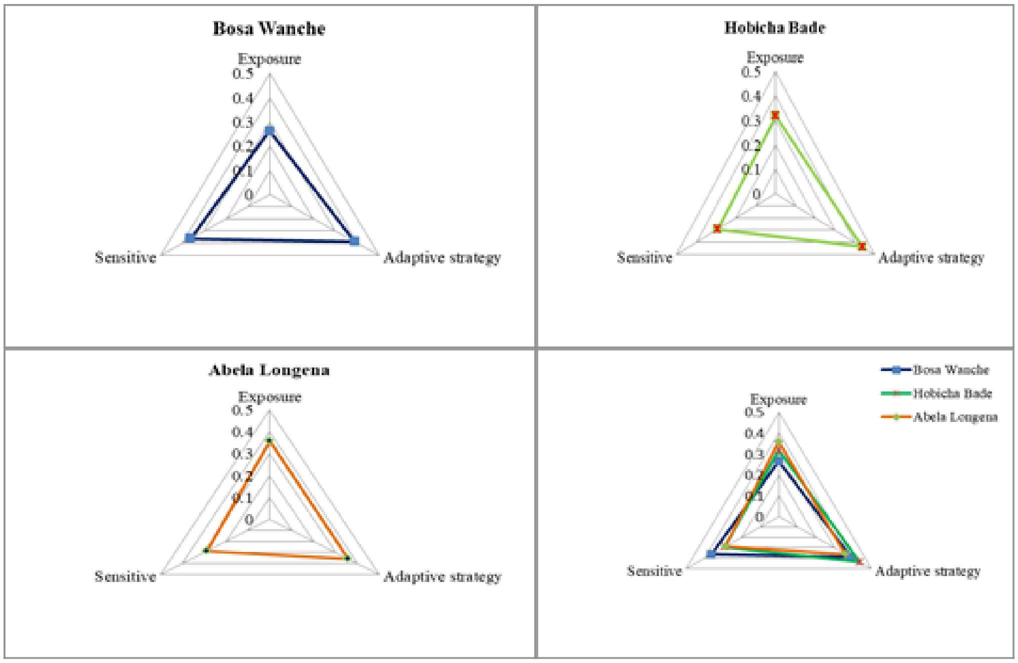

Figure 3 Vulnerability triangle diagram of contributing factors of LVI-IPCC

Conclusion

The researcher presented the LVI and LVI-IPCC as alternative methods for assessing vulnerability of farmers to climate variability and change. The sub-components used to construct the LVI in this study were based on the current conditions of our study sites, available data from household survey and focus group discussions. Hence, the LVI-IPCC indicated that 16% of the households in the communities were highly vulnerable to climate change and variability. On other hands, 54% and 29.9% of the households in the communities were categorized as less and moderately vulnerable to climate extremes, respectively. The results also showed that the households in Abela Longena site are more vulnerable to climate change compared to Habicha Bade and Bosa Wanche. The improvement in the condition of ecosystem, health and water helps to reduce sensitivity whereas strengthening demographic profile, social network and infrastructure, technologies and diversification of livelihood activities enhance adaptive capacity of the communities. The findings of this study provide insight to devise coping strategies for indigenous communities and incorporate them in the climate change policies. Overall, it is hoped that the LVI will provide a useful tool for development planners to evaluate livelihood vulnerability to climate change impacts in the communities in which they work and to develop programs to strengthen the most vulnerable sectors. Therefore, integrating rural development schemes aimed at increasing adaptive capacity to climate variability and change is recommended to the range of climate extremes that they experience.

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References

[1] Alemayehu Mulatu, “Contribution of Forest Products Extraction to Livelihood Support and Forest Conservation in Masha and Andracha Woredas in Southwestern Ethiopia,” MSc. thesis, Addis Ababa University, 2010.

[2] T.A. Yemiru, B.M. Roos, Campbell, and F. Bohlin, “Forest incomes and poverty alleviation under participatory forest management in the Bale Highlands, Southern Ethiopia,” *International Forestry Review,* 12(1): 66-77, 2010.

[3] Aynalem Getachew, “When the Forest was ours: Ownership and Partnership in a CDM Forestry Project in South-western Ethiopia,” MSc. thesis, University of Oslo, Norway. http://urn.nb.no/URN:NBN:no-32769, 2012.

[4] Kasahun Kelifa, “Assessment of Forest Based Livelihoods of Majenger Community and Trends in Forest Resource Utilization: The Case of Godere District, Gambella Regional State,” MSc. thesis, Addis Ababa University, 2008.

[5] Streck, Charlotte, Robert O’sullivan, Toby J Smith, and Richard Tarasofsky, “Climate Change and Forests: Emerging Policy and Market Opportunities,” Washington, D.C. Brooking Institution Press, 2008.

[6] World Bank, “Forests Sourcebook: Practical Guidance for Sustaining Forests in Development Cooperation,” Washington, D.C: The International Bank for Reconstruction and Development. doi: 10.1596/978-0-8213-7163-3, 2008.

[7] UNFCCC, “The Kyoto Protocol Mechanisms: International Emissions Trading, Clean Development Mechanism and Joint implementation,” Bonn, Germany: United Nations Framework Convention on Climate Change, 2010.

[8] World Vision, “Ethiopia Humbo/Sodo Community Based Forest management Project (H/SCBFMP),” Activity Accomplishment Report. South Branch Office, Humbo ADP, 2006.

[9] R. D. Brown, D. Paul, R. Tony, Hailu Tefera, and Assefa Tofu, “Poverty Alleviation and Environmental Restoration Using the Clean Development Mechanism: A Case Study from Humbo, Ethiopia,” *Environmental Management* 48(2): 322–33, 2010.

[10] S. Shames, E. Wollenberg, L.E. Buck, P. Kristjanson, M. Masiga and B. Biryahaho, “Institutional innovations in African smallholder carbon projects,” CCAFS Report no. 8. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org, 2012

[11] Jindal, Rohit, Brent Swallow, and John Kerr, "Forestry-based carbon sequestration projects in Africa: Potential benefits and challenges," *Natural Resources Forum,* 32: 116–130. doi: 10.1111/j.1477-8947.2008.00176.x, 2008.
[12] C. Kabore, "Community Managed Natural Regeneration Forest Project in Humbo Area Development Program," Mid-term Evaluation Report, World Vision Australia, 2010.
[13] Padmanaban Murugan, and Fekadu Israel, "Impact of Forest Carbon Sequestration Initiative on Community Assets: The Case of Assisted Natural Regeneration Project in Humbo, Southwestern Ethiopia," African Studies Quarterly. http://www.africa.ufl.edu/asq/v17/v17i1a2.pdf, 2017.
[14] K. Markos, and S. Simon, "Floristic Composition, Vegetation Structure, and Regeneration Status of Woody Plant Species of Oda Forest of Humbo Carbon Project, Wolaita, Ethiopia," *Journal of Botany*. doi: 10.1155/2015/963816, 2015.
[15] E.N. Negewo, Z. Ewnetu, and Y. Tesfaye, "Economic Valuation of Forest Conserved by Local Community for Carbon Sequestration: The Case of Humbo Community Assisted Natural Regeneration Afforestation/Reforestation (A/R) Carbon Sequestration Project; SNNPRS, Ethiopia," *Low Carbon Economy,* 7, 88-105. doi: 10.4236/lce.2016.72009, 2016.
[16] A. Bryman, "Social Research Methods," Second edition. Oxford, UK. Oxford University Press, 2004.
[17] M.B. Hahn, A.M. Riederer, and S.O. Foster, "The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change: a case study in Mozambique," *Global Environmental Change,* 19:74–88, 2009.
[18] H. Storck, Bezabih Emana, Berhanu Adnew, A. Borowiccki, and Shimelis W/Hawariat, "Farming Systems and Resource Economics in the Tropics: Farming System and Farm management practices of small holders in the Hararghe Highland," Vol. II, Wissenschaftsverlag Vauk, Kiel, Germany, 1991.
[19] Bisrat Lemma, "A History of Humbo Wereda, 1941-1991," MSc. thesis, Addis Ababa University, 2011.
[20] C. Dechassa, Belay Simane, Bamlaku Alamirew, and Hossien Azadi, "Agro-ecological based small-holder farmer's livelihoods vulnerability to climate variability and change in Didesa sub Basin of Blue Nile River, Ethiopia," *Academia Journal of Agricultural Research,* 4(5): 230-240. doi: 10.15413/ajar.2016.0150, 2016.
[21] F. Abate, "Climate change impact on livelihood, vulnerability and coping mechanisms: A Case Study of West Arsi Zone, Ethiopia", 2009.
[22] K.M. John, M.E. Prince, M.A. Ramatu, and O. Yaw, "Application of Livelihood Vulnerability Index in Assessing Vulnerability to Climate Change and Variability in Northern Ghana," *Journal of Environment and Earth Science,* 3(2):157-170, 2013.
[23] C. Nhemachena, and R. Hassan, "Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa," IFPRI Discussion Paper No. 00714. International Food Policy Research Institute. Washington DC, 2007.
[24] D. Maddison, "The perception of and adaptation to climate change in Africa," CEEPA. Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria, 2007.
[25] G. Bankoff, G. Frerks, and D. Hilhorst, "Mapping vulnerability: disasters, development and people," Earth scan, London, 2004.

[26] H. Fussel, "How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: a comprehensive indicator-based assessment," *Global Environmental Change,* 20: 597–611, 2010.
[27] T. Gutu, E. Bezabih, and K. Mengistu, "Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia," *Journal of Agricultural Science*, 3(6): 871-888, 2012.

Woody Species Composition, Regeneration Status and Biomass Production in Arba Gugu Forest

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Abstract

Arba Gugu forest is one of the remnants of logged dry Afromontane forests in the central highlands of Ethiopia. Despite the availability of some studies, up to date information on the woody species composition, diversity and regeneration status and carbon stock of trees are lacking. Hence, a survey and systematic random sampling technique were employed in the study of the forest. Moreover, 51 temporary sample plots with a total area of 2000 m^2 (100m * 20m) were established for data collection. A total of 37 woody species belonging to 25 families were recorded in the study area. The density of seedlings, saplings and matured trees were 1174, 101 and 84 stems ha^{-1}, respectively. The total basal area of trees with DBH ≥ 2 cm was 21.3m^2 ha^{-1}. The overall Shannon-Wiener diversity and evenness values of woody species were 2.58 and 0.70, respectively. Out of the 32 tree species, only five species exhibited good regeneration. On the other hand, eight tree species had no regeneration. Eighteen tree species had fair regeneration status and one tree species exhibited poor regeneration status. The total biomass (aboveground and belowground) ranged between 12.53 and 1671.25 Mg ha^{-1} with a mean biomass value of 355.4 Mg ha^{-1}. The total carbon stock (aboveground and belowground) ranged between 6.3 Mg C ha^{-1} and 835.6 Mg C ha^{-1} with a mean value of 177.7 Mg C ha^{-1}. This value is equivalent to 639.6 Mg CO_2 e ha^{-1}. Observations on the regeneration of the forest indicated that there are woody species that require urgent conservation measures. The absence of regeneration for most of the tree species (9 tree species that have poor and no regeneration status) need serious attention and should get conservation priority among practitioners and policymakers to ensure the sustainable management and utilization. Overall, the forest stored an enormous amount of biomass and carbon, thus providing evidence of their great potential for carbon sequestration. However, due attention and measures should be taken to address the observed poor regeneration status of tree species, free grazing practice as well as enhance the awareness of the local communities.

Keywords: Dry Afromontane forest, diversity, carbon stock, climate change, Ethiopia

Introduction

The global forest cover is estimated at over 4 billion hectares, which comprises 31 % of total land area (FRA, 2010). These forests contribute around 50 % of the global greenhouse gas mitigation (IPCC 2013). Forests also help rural food security through contributions to dietary needs during seasons of scarcity and add variety to diets, providing essential vitamins, minerals, proteins, and calories (Byron and Arnold, 1999). Furthermore, they provide fuelwood for an estimated 2.4 billion rural people in less developed countries and the main material for the houses of at least 1.3 billion people worldwide (FAO, 2014). According to a recent study by FAO (2018), many people in developing countries depend on forests as a source of income, livelihoods, and well-being.

Ethiopia has a total land area of 1.12 million hectares of which about 15.5% are covered by forests including plantations, woodlands and high forests (Bekele et al., 2014). These forests have played very important roles in the national economy. According to MEFCC (2015), the contribution of the forest to the national economy was estimated at 8 % through import substitution, NTFP, and employment opportunity. Furthermore, these forests supply the largest proportions of wood used in the furniture industry, the construction sector and household energy consumption (Lemenih and Kassa, 2014).

In Ethiopia, forests exhibited a variety of structures and composition resulting from the diverse biophysical and social conditions (Teketay et al., 2010). Dry evergreen montane forests are among the forest types widely dispersed throughout the country and it concentrated in central, southeastern, eastern, northern and southern highlands (Friis et al., 2010). The dry evergreen montane forests of Ethiopia have been reported as a threatened ecosystem category that is under the concern of degradation and deforestation. Reports indicated that deforestation rate amounts to 92,000 $ha^{-1}yr^{-1}$, while, new plantation area change is about 18,000 ha^{-1} yr^{-1} (Moges et al., 2010). In general, agricultural expansion (both subsistence and commercial), fuelwood consumption, illegal logging, and forest fire are the main drivers of deforestation in Ethiopia and in dry Afromontane forest ecosystem (Bekele et al., 2015).

Arba Gugu forest is one of the forests that had been designated as a National Forest Priority Area (NFPA) in the country (EFAP, 1994). According to a recent study, the rate of deforestation is 1.4 % Yr^{-1} (Nesibu, 2015). In addition, the forest is among the logged and disturbed forests by fire and cattle grazing. It is obvious that these causes of disturbances bring changes in the woody species composition and forest structures. Despite this fact, no systematic study was conducted to assess the vegetation status of the Arbagugu forest. This has become a serious problem for the sustainable management and utilization of forest resources. Therefore, this study was aimed to determine the woody species composition, diversity, and regeneration status of tree species as well as to quantify the biomass and carbon stock in the forest. This information will help to complement the ongoing efforts to develop decision support tools that guide the sustainable management and utilization of dry Afromontane forests in Ethiopia.

Material and Methods

Description of the study site

Arba Gugu forest is located between 5˚14' - 5˚39' E and 8˚15' - 8˚16' N (Figure 1). It is located about 230 Km towards the southeast direction from Addis Ababa. The altitude ranges between 2200 m and 2775 m. According to Friis et al. (2010), the study area belongs to the Dry Evergreen Afromontane forest. The mean annual rainfall is about 1424 mm with the highest rainfall extending between July and September, and a less pronounced wet season between March and May. The mean annual temperature is 14.7 °C. The dominant soil type of landscape is Nitosol and Cambisol (Nigussie, 2014).

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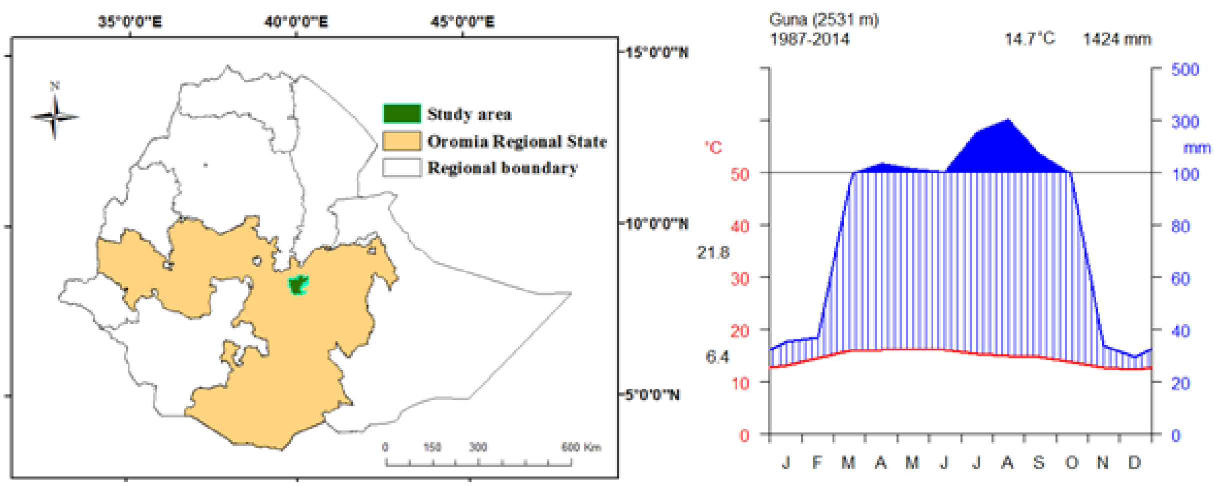

Figure 1 Map of the study area and climate diagram showing mean annual temperature and mean annual rainfall for the years 1987 to 2014. Data were obtained from the National Meteorology Agency of Ethiopia.

Data collection

We conducted a reconnaissance survey in Arba Gugu dry Afromontane forest. A systematic random sampling technique was employed to collect vegetation data. Fifty-three sample plots (20 x 200 m) were established along the transect lines. The first transect was aligned parallel to the edge of the forest (20 m) and others were laid out systematically at 500 m intervals. The first plot was located randomly, and the subsequent plots were established at 300 m interval along the transect lines. In each sample plot, the diameter at breast height (diameter at 1.3 m) and the total height of all tree species and saplings were measured using a diameter tape and Vertex III digital height measurement device. Seedlings were counted in the subplots (20 x 20 m) established at the center of each main plot. The local names of all woody species were recorded and identified to the species level in the field following the Flora of Ethiopia and Eritrea (Edwards et al., 1995, Edwards et al., 2000, Hedberg and Edwards, 1989, Hedberg et al., 2003, Hedberg et al., 2004, Tadesse, 2004). For those species difficult to identify in the field, their specimens were collected, pressed and identified at the National Herbarium, Addis Ababa University. The spatial location (latitude and longitude), slope and elevation of each main plot were measured using Suunto Clinometer and Garmin GPS-72 receiver.

Data Analysis

Woody species composition and diversity

Individual woody species were categorized into trees (DBH ≥ 5 cm), saplings (height ≥ 1.3 m and DBH 2.5 - 5 cm) and seedlings (height 0.30 - 1.3 m and DBH ≤ 2.5 cm) following Lamprecht classification (Lamprecht, 1989). Woody species with DBH ≥ 2 cm were considered to describe the structure and diversity of the forest. For structure, the density (stem. ha^{-1}), basal area (m^2. ha^{-1}), frequency (number of subplots with species present), and Importance Value Index (IVI) was calculated for each species. IVI is the sum of relative density (RD), relative basal area (RBA) and relative frequency (RF) (Kent and Coker, 1992). RD (%) is the density of each species as a percentage of the total density of all species together, RBA (%) is the total basal area of a species as percentage of the total basal area of all species and RF (%) is the number of subplots with the species present as percentage of the sum of the frequencies of all species together. For describing diversity, species richness, Shannon-Wiener diversity index (Equation 1) and Shannon's measure of Evenness (Equation 2) index were quantified following Magurran (2004).

$$H' = -\sum_{i=1}^{s} (p_i * \ln p_i) \quad \text{(Equation 1)}$$

Where; H' = Shannon - Wiener Diversity index,
pi = proportion of individuals found in the i^{th} species and evenness were calculated using the following formula:

$$J' = \frac{H'}{H'_{max}} \quad \text{(Equation 2)}$$

Where; H' is Shannon-Wiener Diversity index and H'max is the natural logarithm of the total number of woody species identified in the study area.

Regeneration status

The density of seedlings, saplings and mature trees was calculated for all identified woody species. The regeneration status of each woody species was determined by comparing the density of seedlings, saplings, and matured trees following the procedure in Khan et al. (1987). Good regeneration if seedlings > saplings > mature trees; fair regeneration, if seedlings > or ≤ saplings ≤ mature trees; poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be or = mature trees). If a species is present only as a mature tree, we considered it as not regenerating.

Aboveground biomass

The aboveground biomass of trees was calculated using the general allometric equation developed by Chave et al. (2014) for tropical dry forests by using all woody species with DBH ≥ 5 cm in the study area (Equation 3). The equation shows the relationships between wood specific gravity, biomass, height, and DBH.

$$AGB = 0.0673 * (\rho * H * DBH^2)^{0.976}$$ ....(Equation 3)

Where AGB = aboveground biomass (in kg), DBH = Diameter at breast height (cm), H = height (m), and ρ = basic wood density (g cm^{-3}). The wood density data information was obtained from the global wood density database (Zanne et al., 2009), ICRAF wood density database (www.worldagroforestry.org) and Ethiopian Environment and Forest Research Institute Wood Technology Research Centre (Desalegne 2012). In addition, we obtained the wood density for *Allophyllus abyssinicus, Olea europaea subsp. Cuspidiata, Olinia rochetiana, Rhus glutinosa* and *Scolopia theifolia* from Tesfaye et al., (2019).

Belowground biomass

The general equation developed by MacDicken (1997) was used to estimate the belowground biomass of trees (Equation 4).

$$BGB = AGB \times 0.2$$ .... (Equation 4)

Where BGB is below ground biomass, AGB is aboveground biomass, 0.2 is the conversion factor. Then, the aboveground tree biomass was converted into Carbon by multiplying the estimated value by 0.47 (IPCC, 2006) and the Belowground biomass by 0.24 (Gibbs et al., 2007; Ponce-Hernandez, 2004).

$$AGC = AGB \times 0.47 \text{ ………………………. (Equation 5)}$$
$$BGC = ACD * 0.24 \text{ ………………………… (Equation 6)}$$

Total Carbon Stock

The carbon stock density was calculated by summing up the two carbon pools (above ground and below ground) in the forest following the procedures in Pearson et al. (2005) and Sundquist et al. (2010). Consequently, the carbon density was calculated using (Equation 7).

$$C\ stock = AGC + BGC \text{ ……………………………………..……... (Equation 7)}$$

Where, C stock = total carbon stock in all pools (Mg ha^{-1}), AGC = carbon in above-ground tree biomass (Mg C ha^{-1}) and BGC= carbon in below-ground tree biomass (Mg C ha^{-1}). The total carbon stock was converted into tons of CO_2 equivalent by multiplying the value by 3.67 (Pearson et al., 2007).

Results

Woody species composition and diversity

A total of 37 woody species belonging to 25 families were recorded in the Arba Gugu forest (Appendix 1). The most species-rich families were Euphorbiaceae *(*represented by three species), Araliaceae, Celastraceae*,* Flacourtiaceae, Meliaceae, Rosaceae, Rubiaceae, and Sapindaceae (each contains two species). The remaining sixteen families were represented by one tree species only. The overall Shannon-Wiener diversity and evenness values of woody species were 2.58 and 0.70, respectively.

Density and Basal area

The density of seedlings, saplings and matured trees were 1174, 101 and 84 stems ha^{-1}, respectively. The highest density of mature tree species was recorded for *Podocarpus falcatus*, followed by *Juniperus procera*, *Schefflera volkensii*, *Croton macrostachyus,* and *Maesa lanceolata*, which together accounted for 73 % of the total matured tree density (Appendix I). The total basal area of tree species with DBH ≥ 2 cm was 21.3 m^2 ha^{-1}. *Podocarpus falcatus* was the dominant tree species in the forest comprising 44.5 % of the total basal area followed by *J. procera* (41.3 %), *S. abyssinica* (3 %), *S. volkensii* (1.5 %) and *Prunus africana* (1.3 %).

Regeneration status

The tree species showed a considerable variation in regeneration status (Table 1). Out of the 32 tree species, only five tree species (16 %) including *Lepidotrichilia volkensii, Calpurnia aurea, Canthium oligocarpum, Doviyalis verrucosa,* and *Scolopia theifolia* exhibited good regeneration.

Table 1. List of woody species and their regeneration status

No	Scientific name	Family	Se	Sa	Mt	Se:Sa	Sa:Mt	RS
1	*Lepidotrichilia volkensii* (Gurke) Leroy	Meliaceae	21	4	1.0	5.1	4.00	GR
2	*Canthium oligocarpum* Hiern	Rubiaceae	6	5	0.0	1.2	0.00	GR
3	*Doviyalis verrucosa* (Hochst.) Warb.	Flacourtiaceae	24	3	0.0	7.8	-	GR
4	*Calpurnia aurea* (Ait.) Benth	Fabaceae	13	1	0.0	13.2	-	GR
5	*Maesa lanceolata* Forssk.	Myrsinaceae	26	4	3.0	6.6	1.33	GR
6	*Maytenes senegalensis (Lam.) Exell*	Celastraceae	379	5	1.0	75.9	5.00	GR
7	*Allophylus abyssinicus* (Hochest.) Radlkofer.	Sapindaceae	60	3	1.0	20.1	3.00	GR
8	*Celtis africana* Burm.f.	Ulmaceae	47	2	1.0	23.5	2.00	GR
10	Galinera saxifrage (Hochst.) Bridson	Rubiaceae	90	1	0.0	89.7	-	GR
9	*Prunus africana* Kalkm.	Rosaceae	21	4	0.9	5.1	4.44	GR
11	*Maytenus undata* (Thunb.) Blackelock	Celastraceae	91	20	1.2	4.6	16.5	GR
12	*Scolopia theifolia* Gilg	Flacourtiaceae	43	2	2.0	21.3	1.00	FR
13	*Podocarpus falcatus (Thunb.) Mirb.*	Podocarpaceae	37	36	46.2	1.0	0.78	FR
14	*Juniperus procera Hochst.*	Cupressaceae	7	1	10.0	7.4	0.10	FR
15	*Croton macrostachyus* Del.	Euphorbiaceae	9	1	4.0	8.8	0.25	FR
16	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	60	1	2.0	60.3	0.50	FR
17	*Olea europaea*. subsp. Cuspidata	Oleaceae	16	1	1.0	16.2	1.00	FR
18	*Ekebergia capensis* Sparrm.	Meliaceae	4	-	1.0	-	0.00	FR
19	*Olinia rochetiana* A.Juss.	Oliniaceae	13	-	0.5	-	0.00	FR
20	Hirqamu	**	74	-	0.0	-	0.00	FR
21	*Zanha golungensis* Hiern	Sapindaceae	-	1	0.7	-	1.48	FR
22	*Psydrax schimperiana* (A. Rich.) Bridson	Rubiaceae	1	1	0.4	1.5	2.66	FR
23	Pavetta abyssinica Fresen.	Rubiaceae	126	-	0.0	-	-	FR
24	*Pittosporum viridiflorum* Sims	Pittosporaceae	1	-	0.2	-	0	FR
25	*Osyris quadripartita* Decen.	Santalaceae	3	-	0.4	-	0	FR
26	*Brucea antidysenterica* J.F. Mill.	Simaroubaceae	-	1	0.0	-	-	PR
27	*Bersama abyssinica* Fresen.	Melianthaceae	-	3	0.6	-	5.0	PR
28	*Vernonia auriculifera* Hiern	Asteraceae	-	1	0.5	-	2.22	PR
29	*Nuxia congesta* K.Br. ex Fresen.	Loganiaceae	-	-	0.5	-	0	NR
30	*Schefflera abyssinica* Harms.	Araliaceae	-	-	0.8	-	0	NR
31	*Rhus glutinosa* A.Rich.	Anacardiaceae	-	-	0.4	-	0	NR
32	*Clutia abyssinica* Jaub. & Spach.	Euphorbiaceae	-	-	1	-	0	NR
33	*Euphorbia amplophylla Pax*	Euphorbiacea	-	-	1	-	0	NR
34	*Ficus sur Forssk.*	Moraceae	-	-	1	-	0	NR
35	*Hagenea abyssinica* I.F.Gmel.	Rosaceae	-	-	1	-	0	NR

Where Se = Seedlings/ha, Sa = Saplings/ha, Mt = Mature trees/ha, Se: Sa = Seedling to Sapling ratio, Sa: Mt = sapling to mature tree ratio, RS = Regeneration Status, GR= Good regeneration, FR = Fair regeneration, PR = Poor regeneration and NR= No regeneration. ** = unidentified species

On the other hand, eight tree species (25%) including *Clutia abyssinica*, *Euphorbia amplophylla*, *Ficus sur*, *Hagenea abyssinica*, *Nuxia congesta*, *Osyris quadripartita, Rhus glutinosa* and *Schefflera abyssinica* had no regeneration. Fifteen tree species (56 %) such as *Podocarpus falcatus, Juniperus procera, Maesa lanceolata, Maytenus senegalensis, Allophylus abyssinicus, Croton macrostachyus, Cassipourea malosana, Celtis africana, Olea europaea subsp. Cuspidata, Prunus africana, Ekebergia capensis, Olinia rochetiana, Zanha golungensis, Psydrax schimperiana,* and *Pittosporum viridiflorum* had fair regeneration status and one tree species (3 %) exhibited poor regeneration status. We did not record new tree species from the study area (Table 1).

Biomass and Carbon stock

The total biomass ranged between 12.53 and 1671.25 Mg ha^{-1} with a mean value of 355.4 Mg ha^{-1} in the Arba Gugu forest. About 81 % of the total biomass was contained in aboveground vegetation; whereas 19 % was contained in below ground. The total carbon stock (aboveground and belowground) ranged between 6.3 Mg C ha^{-1} and 835.6 Mg C ha^{-1} with a mean value of 177.7 Mg C ha^{-1}. This value is equivalent to 639.6 Mg CO_2 e ha^{-1}. Among the tree species, *Juniperus procera*, *Podocarpus falcatus*, *Prunus africana*, *Schefflera abyssinica*, and *Olea africana subsp. Cuspidata* contributed 95.7 % of the total aboveground biomass and carbon stock.

Discussion

Woody species composition and diversity

The woody species richness (37 species) recorded in this study is lower than the findings from Wof-Washa forest (Fisaha et al., 2013), Yegof forest (Woldearegay et al., 2018), Jibat forest (Bekele, 1993), Denkoro forest (Ayalew, 2003) and Menagesha Amba Mariam forest (Tilahun et al., 2011). However, it is relatively similar to the findings from the Chilimo forest (Siraj, 2019), Gedo forest (Kebede et al., 2014), Awi zone forest (Gebeyehu et al., 2019b) and Yerer mountain forest (Yahya et al., 2019). The Shannon-Wiener diversity is also lower than the findings from Wof-Washa forest (Yirga et al., 2019), Chilimo forest (Woldemariam et al., 2000), Tara Gedam and Abebaye forests (Zegeye et al., 2011) and Adelle forest (Yineger et al., 2008) and Zengena forest (Tadele et al., 2014). However, Shannon-Wiener's diversity value is higher than the findings from Yegof forest (Woldearegay et al., 2018) and Yerer Mountain forest (Yahya et al., 2019). The observed variation in diversity and species richness might be due to differences in anthropogenic disturbances (free grazing, illegal logging, and forest fire) and climatic and edaphic factors. It was observed that the Arba Gugu forest is highly affected by human activities i.e. free grazing, fire, farm expansion, settlement, and illegal logging as compared to other Dry Afromontane forests in Ethiopia.

Density and Basal area

Mean densities of trees in the present study are higher than the findings from Wof-Washa forest (Yirga et al., 2019), Denkoro forest (Ayalew, 2003), Awi zone forest (Gebeyehu et al., 2019b) and Chilimo forest (Siraj, 2019). Similarly, the basal area (21.3 m^2 ha^{-1}) was also lower than the findings from the Mana Angetu forest (Lulekal et al., 2008), Denkoro forest (Ayalew, 2003) and Gedeo forest (Kebede et al., 2014). The variation in density and the basal area may be due to the dominance of small-sized trees/shrubs and lower number of larger sized trees (DBH ≥ 55 cm) in the Arba Gugu forest.

Regeneration status

The mean densities of seedlings and saplings were lower than the findings from other similar dry Afromontane forests in Ethiopia (Kebede et al., 2014, Girma and Mosandl, 2012). This variation is probably due to the differences in the anthropogenic disturbance. Several authors confirmed the effect of anthropogenic disturbances i.e. fire and grazing on seedling survival and growth (Wassie et al., 2009, Giday et al., 2018, Kikoti et al., 2015). The local communities around the forest use the forest as their communal grazing land during the dry period of the year. Grazing involves removing whole plants or parts of the vegetative or reproductive structures as well as trampling of the soil surface by the animals resulting in seedling mortality and soil compaction that limits recruitment and seedling establishment (Teketay, 2005). The free grazing practice in most of the dry forests of Ethiopia had been reported to affect the survival and growth of tree seedlings (Wassie et al., 2009).

The dominant trees of dry Afromontane forests such as *Podocarpus falcatus*, *Juniperus procera*, *Olea europaea subsp. Cuspidata* exhibited a fair regeneration status. The least abundant shrub species *Lepidotrichilia volkensii*, *Canthium oligocarpum*, *Dovyalis verrucosa*, *Calpurnia aurea* and *Maesa lanceolata* exhibited good regeneration status (Table 1). The lack of regeneration of trees such as *Polyscias fulva*, *Schefflera abyssinica, Erythrina brucei, Apodytes dimidiata* has been reported from various dry Afromontane forests in Ethiopia (Tadele et al., 2014, Teketay, 2005, Tesfaye et al., 2010). The lack of regeneration may be partially attributed to the absence of a conducive environment for seed germination, the harvesting of mother trees and free grazing and browsing by livestock (Tadele et al., 2014, Woldearegay et al., 2018). This will affect the viable seed production potential of the trees, seedling establishment and survival and threatens their existence in the forest.

Above-ground biomass and carbon stock variation

The mean biomass and carbon stock estimate of the present study was lower than the findings from Chilimo dry Afromontane forest (Siraj, 2019), Awi zone forest (Gebeyehu et al., 2019a) and Ziquala monastery forest (Girma et al., 2014). This variation may be due to the variation in the models used to estimate the carbon stock, woody species composition and the number of larger diameter trees, which constituted a significant amount of biomass. Brown and Lugo (1990) Concluded that the total amount of accumulated biomass in forest ecosystems might differ with variation in biophysical characteristics, microclimate, and level of anthropogenic disturbances. The number of stumps in the Arba Gugu forest indicates the extent of exploitation in the forest. Most of the stumps in the forest are very large in size, which indicates the removal of large diameter trees from the forest in the past, which in turn resulted in lower biomass today.

Conclusions and recommendations

Arba Gugu forest is one of the degraded dry Afromontane forest fragments to a certain degree in central Ethiopia. The forest had a very low species richness and woody species diversity. Furthermore, some tree species lack regeneration and the forest stored lower carbon stock compared with other dry Afromontane forests. This study provides a piece of basic information for the ongoing national-level forest landscape restoration (FRL) programs in Ethiopia. Due attention and measures should be taken to address the observed poor regeneration status of tree species, free grazing practice as well as enhance the awareness of the local communities.

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References

Ayalew, A. 2003. A Floristic Composition And Structural Analysis Of Denkoro Forest, South Wello. *Master's Thesis, Addis Ababa University*.

Bekele, M., Tesfaye, Y., Mohammed, Z., Zewdie, S., Tebikew, Y., Brockhaus, M. & Kassa, H. 2015. *The Context Of REDD+ In Ethiopia: Drivers, Agents And Institutions*, CIFOR.

Bekele, T. 1993. *Vegetation Ecology Of Remnant Afromontane Forests On The Central Plateau Of Shewa, Ethiopia*, Sv. Växtgeografiska Sällsk.

Brown, S. & Lugo, A. E. 1990. Tropical Secondary Forests. *Journal Of Tropical Ecology,* 6, 1-32.

Byron, N. & Arnold, M. 1999. What Futures For The People Of The Tropical Forests? *World Development,* 27, 789-805.

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., Duque, A., Eid, T., Fearnside, P. M. & Goodman, R. C. 2014. Improved Allometric Models To Estimate The Aboveground Biomass Of Tropical Trees. *Global Change Biology,* 20, 3177-3190.

Edwards, S., Tadesse, M., Demissew, S. & Hedberg, I. 2000. Flora Of Ethiopia And Eritrea, Volume 2, Part 1: Magnoliaceae To Flacourtiaceae. *Addis Ababa, Ethiopia And Uppsala, Sweden: The National Herbarium, Addis Ababa University*.

Edwards, S., Tadesse, M. & Hedberg, I. 1995. Flora Of Ethiopia And Eritrea, Volume 2, Part 2: Canellaceae To Euphorbiaceae. *Uppsala: The National Herbarium, Addis Ababa, Ethiopia, And Department Of Systematic Botany*.

Efap, E. F. A. P. 1994. The Challenge For Development.

Fisaha, G., Hundera, K. & Dalle, G. 2013. Woody Plants' Diversity, Structural Analysis And Regeneration Status Of Wof Washa Natural Forest, North-East Ethiopia. *African Journal Of Ecology,* 51, 599-608.

Friis, I., Demissew, S. & Van Breugel, P. 2010. *Atlas Of The Potential Vegetation Of Ethiopia*, Det Kongelige Danske Videnskabernes Selskab.

Gebeyehu, G., Soromessa, T., Bekele, T. & Teketay, D. 2019a. Carbon Stocks And Factors Affecting Their Storage In Dry Afromontane Forests Of Awi Zone, Northwestern Ethiopia. *Journal Of Ecology And Environment,* 43, 7.

Gebeyehu, G., Soromessa, T., Bekele, T. & Teketay, D. 2019b. Species Composition, Stand Structure And Regeneration Status Of Tree Species In Dry Afromontane Forests Of Awi Zone, Northwestern Ethiopia. *Ecosystem Health And Sustainability*.

Giday, K., Humnessa, B., Muys, B., Taheri, F. & Azadi, H. 2018. Effects Of Livestock Grazing On Key Vegetation Attributes Of A Remnant Forest Reserve: The Case Of Desa'a Forest In Northern Ethiopia. *Global Ecology And Conservation,* 14, E00395.

Girma, A. & Mosandl, R. 2012. Structure And Potential Regeneration Of Degraded Secondary Stands In Munessa-Shashemene Forest, Ethiopia. *Journal Of Tropical Forest Science*, 46-53.

Girma, A., Soromessa, T. & Bekele, T. 2014. Forest Carbon Stocks In Woody Plants Of Mount Zequalla Monastery And It’s Variation Along Altitudinal Gradient: Implication Of Managing Forests For Climate Change Mitigation. *Science, Technology And Arts Research Journal,* 3, 132-140.

Hedberg, I. & Edwards, S. 1989. *Flora Of Ethiopia: Pittosporaceae To Araliaceae*, National Herbarium, Biology Department, Science Faculty, Addis Ababa University.

Hedberg, I., Edwards, S. & Nemomissa, S. 2003. Flora Of Ethiopia And Eritrea, Vol. 4, Part 1. *Apiaceae To Dipsacaceae. Sweden: Addis Ababa, And Uppsala University, Uppsala*, 352.

Hedberg, I., Friis, I. & Edwards, S. 2004. Flora Of Ethiopia And Eritrea. Asteraceae. *Addis Ababa, Ethiopia, And Department Of Systematic Botany, Uppsala, Sweden: The National Herbarium*.

Kebede, B., Soromessa, T. & Kelbessa, E. 2014. Structure And Regeneration Status Of Gedo Dry Evergreen Montane Forest, West Shewa Zone Of Oromia National Regional State, Central Ethiopia. *Science, Technology And Arts Research Journal,* 3, 119-131.

Kent, M. & Coker, P. 1992. Vegetation Description And Analysis: A Practical Aproach. CRC Press, Inc., London.

Khan, M., Rai, J. & Tripathi, R. 1987. Population Structure Of Some Tree Species In Disturbed And Protected Subtropical Forests Of North-East India. *ACTA OECOL.(OECOL. APPL.).* 8, 247-255.

Kikoti, I. A., Mligo, C. & Kilemo, D. B. 2015. The Impact Of Grazing On Plant Natural Regeneration In Northern Slopes Of Mount Kilimanjaro, Tanzania. *Open Journal Of Ecology,* 5, 266.

Lemenih, M. & Kassa, H. 2014. Re-Greening Ethiopia: History, Challenges And Lessons. *Forests,* 5, 1896-1909.

Lulekal, E., Kelbessa, E., Bekele, T. & Yineger, H. 2008. Plant Species Composition And Structure Of The Mana Angetu Moist Montane Forest, South-Eastern Ethiopia. *Journal Of East African Natural History,* 97, 165-186.

Magurran, A. 2004. Measuring Biological Diversity. 2004. *Malden: Blackwell*.

Moges, Y., Eshetu, Z. & Nune, S. 2010. Manual For Assessment And Monitoring Of Carbon In Forest And Other Land Uses In Ethiopia (Draft). *Ethiopian Forest Research Center, Addis Ababa, Ethiopia*.

SIRAJ, M. 2019. Forest Carbon Stocks In Woody Plants Of Chilimo-Gaji Forest, Ethiopia: Implications Of Managing Forests For Climate Change Mitigation. *South African Journal Of Botany,* 127, 213-219.

Tadele, D., Lulekal, E., Damtie, D. & Assefa, A. 2014. Floristic Diversity And Regeneration Status Of Woody Plants In Zengena Forest, A Remnant Montane Forest Patch In Northwestern Ethiopia. *Journal Of Forestry Research,* 25, 329-336.

Tadesse, M. 2004. *Asteraceae (Compositae)*, National Herbarium Biology Department, Science Faculty.

Teketay, D. 2005. Seed And Regeneration Ecology In Dry Afromontane Forests Of Ethiopia: I. Seed Production-Population Structures. *Tropical Ecology,* 46, 29-44.

Teketay, D., Lemenih, M., Bekele, T., Yemshaw, Y., Feleke, S., Tadesse, W., Moges, Y., Hunde, T. & Nigussie, D. 2010. Forest Resources And Challenges Of Sustainable Forest Management And Conservation In Ethiopia. *Degraded Forests In Eastern Africa.* Routledge.

Tesfaye, G., Teketay, D., Fetene, M. & Beck, E. 2010. Regeneration Of Seven Indigenous Tree Species In A Dry Afromontane Forest, Southern Ethiopia. *Flora-Morphology, Distribution, Functional Ecology Of Plants,* 205, 135-143.

Tesfaye, M., Bravo-Oviedo, A., Bravo, F., Pando, V. & De Aza, C. H. 2019. Variation In Carbon Concentration And Wood Density For Five Most Commonly Grown Native Tree Species In Central Highlands Of Ethiopia: The Case Of Chilimo Dry Afromontane Forest. *Journal Of Sustainable Forestry*, 1-22.

Tilahun, A., Soromessa, T., Kelbessa, E. & Dibaba, A. 2011. Floristic Composition And Community Analysis Of Menagesha Amba Mariam Forest (Egdu Forest) In Central Shewa, Ethiopia. *Ethiopian Journal Of Biological Science,* 10, 111-136.

Wassie, A., Sterck, F. J., Teketay, D. & Bongers, F. 2009. Effects Of Livestock Exclusion On Tree Regeneration In Church Forests Of Ethiopia. *Forest Ecology And Management,* 257, 765-772.

Woldearegay, M., Woldu, Z. & Lulekal, E. 2018. Species Diversity, Population Structure And Regeneration Status Of Woody Plants In Yegof Dry Afromontane Forest, Northeastern Ethiopia. *European Journal Of Advanced Research In Biological And Life Sciences,* 6.

Yahya, N., Gebre, B. & Tesfaye, G. 2019. Species Diversity, Population Structure And Regeneration Status Of Woody Species On Yerer Mountain Forest, Central Highlands Of Ethiopia.

Yirga, F., Marie, M., Kassa, S. & Haile, M. 2019. Impact Of Altitude And Anthropogenic Disturbance On Plant Species Composition, Diversity, And Structure At The Wof-Washa Highlands Of Ethiopia. *Heliyon,* 5, E02284.

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Ilic, J., Jansen, S., Lewis, S. L., Miller, R. B., Swenson, N. G., Wiemann, M. C. & Chave, J. 2009. Global wood density database.

Appendix I: Species composition, frequency, density (number of stem ha-1), basal area (m2 ha-1) and IVI (Importance Value Index) of tree species >2 cm diameter. The asterisks (*) indicates vernacular names of unidentified woody species in Oromifa language

Rank	Scientific name	Family	Habit	Density	Freq	BA	IVI
1	*Podocarpus falcatus* (Thunb.) Mirb.	Podocarpaceae	T	42.15	0.20	9.48	31.49
2	*Juniperus procera* Hochst.	Cupressaceae	T	13.88	1.41	8.80	21.49
3	*Osyris quadripartita* Decne.	Santalaceae	S	0.30	4.53	0.01	7.63
4	*Croton macrostachys* Del.	Euphorbiaceae	T	3.02	1.41	0.22	3.85
5	*Maesa lanceolata* Forssk.	Myrsinaceae	T	3.52	0.60	0.16	2.61
6	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	S	1.91	0.91	0.04	2.30
7	*Lepidotrichilia volkensii* (Gurke) Leroy	Meliaceae	S/T	0.70	1.11	0.01	2.12
8	*Allophyllus abyssinicus* (Hochest.) Radlk.	Sapindaceae	T	1.11	0.80	0.21	2.10
9	*Celtis africana* Burm.f.	Ulmaceae	T	1.51	0.70	0.19	2.05
10	*Psydrax schimperiana* (A.Rich.) Bridson	Rubiaceae	T	0.50	1.01	0.04	1.92
11	*Maytenes senegalensis* (Lam.) Exell	Celastraceae	T	2.21	0.40	0.12	1.71
12	*Schefflera abyssinica* Harms.	Araliaceae	T	0.40	0.30	0.63	1.64
13	*Maytenus undata* (Thunb.) Blackelock	Celastraceae	T	1.61	0.50	0.05	1.53
14	*Teclea nobilis* Del.	Rutaceae	T	2.72	0.20	0.06	1.47
15	*Schefflera volkensii* (Engl.) Harms	Araliaceae	T	0.80	0.30	0.33	1.33
16	*Olinia rochetiana* A. Juss.	Oliniaceae	T	0.60	0.50	0.12	1.25
17	*Vernonia auriculifera* Hiern	Asteraceae	T	0.60	0.50	0.00	1.07
18	*Prunus africana* (Hook. f.) Kalkm.	Rosaceae	T	0.70	0.20	0.27	1.03
19	*Nuxia congesta* K.Br. ex Fresen.	Loganiaceae	T	0.60	0.40	0.06	0.99
20	*Bersama abyssinica* Fresen.	Melianthaceae	T	0.70	0.40	0.00	0.94

21	*Ekbergia capensis* Sparrm.	Meliaceae	T	0.70	0.30	0.10	0.94
22	*Rhus glutinosa* A. Rich.	Anacardiaceae	T	0.50	0.40	0.03	0.91
23	*Rytigynia neglecta* (Hiern) Robyns	Rubiaceae	S/T	0.60	0.40	0.00	0.91
24	*Calpurnia aurea* (Ait.) Benth	Fabaceae	S	0.50	0.40	0.00	0.86
25	*Olea europaea. subsp. Cuspidata*	Oleaceae	T	0.91	0.10	0.15	0.76
26	Mukedimu	***	S	0.20	0.40	0.00	0.75
27	*Doviyalis verrucosa* (Hochst.) Warb.	Flacourtiaceae	S	0.50	0.30	0.01	0.72
28	*Zanha golungensis* Hiern	Sapindaceae	T	0.80	0.10	0.03	0.52
29	*Canthium oligocarpum* Hiern	Rubiaceae	S/T	0.30	0.20	0.04	0.52
30	Akoma	*	S/T	0.30	0.20	0.01	0.46
31	*Euphorbia amplophylla* Pax	Euphorbiaceae	T	0.20	0.20	0.02	0.44
32	*Dovyalis abyssinica* (A. Rich.) Warb.	Flacourtiaceae	S/T	0.20	0.20	0.00	0.41
33	*Clutia abyssinica* Jaub. & Spach.	Euphorbiaceae	S	0.20	0.10	0.08	0.37
34	*Ficus sur Forssk*.	Moraceae	T	0.20	0.10	0.02	0.27
35	Pavetta abussinica Fresen.	Rub	S	0.20	0.10	0.00	0.25
36	*Hagenea abyssinica* I.F. Gmel.	Rosaceae	T	0.10	0.10	0.00	0.21
37	*Brucea antidysenterica* J.F. Mill.	Simaroubaceae	S/T	0.10	0.10	0.00	0.21

Socioeconomic Importance of the Woodland at Gibe Valley National Park for Local Community, Southwestern Ethiopia

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Abstract

Woodland forests are home to wealth of diverse and unique fauna and flora and provide various goods and services which are important for livelihood options. The objective of this paper was to describe and quantify the socio-economic contribution of the woodland vegetation in Gibe Valley National Park to the surrounding community. Data was collected using a structured interview, from a total of 130 households, residing in three adjacent selected districts. The data was analyzed using descriptive statistical methods. Crop production was ranked as the primary house hold livelihood option and income source for the people. Livestock constituted 75.4 % of their secondary source of income. The main grazing land for their livestock was the woodland. The major forest products derived from the woodland include fuel wood construction wood and farming utensils. The commonest wild fruit producing tree species in the study area was *Ximenia americana* followed by *Tamarindes indica*. The major forest products collected from the woodland vegetation by the respondents were fuelwood, farming utensils, construction woods, wild fruits and fodder for their grazing animals. About 47.7 % of the respondents knew the presence of gum and resin bearing species among these, only 20 % of them were collecting it for household consumption. About 62 % the respondents stated that the size of the woodland is decreasing from time to time due to several factors. Attention must be given to reduce deforestation of the woodland and enhancing its non-timber forest products through sustainable forest management is necessary.

Keywords: Woodlands, Gibe Valley National Park, Socioeconomic, Forest Product

Introduction

The definition of the word woodlands varies from one author to another authors. For instance, woodlands are defined as vegetation types covered by trees and shrubs with canopy cover more than 10 % (Chidumayo, 2010) and have growing period of only 179 days (FAO, 2000). Whereas FAO (2000), (Sahle & Yeshitela, 2018) defined woodland in arid and semiarid area as area with open stands of trees mainly dominated by *Acacia* species. The woodland vegetation are habitat and source of livelihood and it is supporting the livelihood of over 2 billion or 1/3 of the world's population (Solomon, Birhane, Tadesse, Treydte, & Meles, 2017). The wood land vegetation provides various forest products like fuel wood, constructing materials, food, honey, fodder, farming utensils, handy crafts for household consumption (baskets, mats, tanning materials), gum and resin for household consumption, national and international market and traditional medicines. Foods collected from the woodland vegetation are often significant in providing essential vitamins, minerals, carbohydrates and protein (Bahru, Asfaw, & Demissew, 2014). In addition to harvesting forest products, various ecosystem services like protecting soil erosion, ameliorating microclimate, improving and restoring soil fertility and hosting genetic diversity of flora and fauna resource are among the use of woodland vegetation.

Woodlands in Africa are comprised from proper woodland, and are included bush land, shrub land and thicket and in some cases wooded grassland. Exportable non-wood forest products from this forest type in Africa play an important role for the national and international market. For instance, shea butter production in Burkina Faso created job opportunity for 300,000 – 400,000 women (Chidumayo, 2010). Annual income from various forest products like medicines, bamboo shoots, wild foods, shea butter, oil, honey, gum arabic, curios, and weaving materials in Uganda comprised US $ 40 million (Monjane, 2009). Honey production from such forest type in Zambia and Tanzania has been made them the largest volume of honey exporter in the continent. For instance, Zambia and Tanzania earned US$491,000 from 219 tons and US$674,000 from 466 tons of honey in 2005 respectively (Chidumayo, 2010). Fuel wood collection and charcoal production constitute ninety percent of wood production in Africa (Alem, 2015) (Grieg-Gran, Bass, Booker, & Day, 2015). According to this source, 63% of population in Africa used either wood or charcoal for cooking food in households' level. It is also important source of energy for industrial sector for brick, tile and ceramics drying and tobacco curing.

Woodland vegetation in Ethiopia covers an estimated area more than 50 % of the total area of the land [9] [10]. *Combretum-Terminalia* woodland vegetation that the type of woodland where the current study was carried out is the largest vegetation type among the different tropical dry forests found in Ethiopia (Dejene, Mohamed, & Adamu, 2013). It is a type of dry woodland vegetation served as source of internationally traded non-timber forest products. According to some authors (Mulugeta & Demel, 2003), Ethiopia earned an average revenue of US $ 24,399,601.5 only from gum and resin product exported within five years (1999-2003). A ten-year (1998-2007) data showed that the country gained 34,138,670 $US which was equivalent to 307,248,000 Ethiopian Birr. The annual economic contribution of forest products from the woodland vegetation to household income in case of South Omo was estimated to be 21.4% of the total income (Fikir, Tadesse, & Gure, 2016).

The woodland vegetation in Ethiopia are mainly found in arid areas of the country. Local people living in such woodland areas are poor (probably amongst those with the country's highest incidence of poverty and poor access to basic social services such as infrastructure, education and health services, far from the administrative centers) and mainly depend their livelihood on the woodland vegetation (Kassa, 2010). But, the woodland forests are endowed with nationally and internationally marketable forest products. Even though the forest products from the woodland forests of Ethiopia are well recognized as the source of household income in many parts of the country, there is lack of information on the socio-economic contribution of the woodland forests to the local community. Such information is important for better understanding of forest sector contributions, to develop forestry strategic plans and for policy formulation purposes. The aim of the present paper was to identify the major forest products and quantify the economic contribution of the woodland vegetation in Gibe Valley National Park to the surrounding community.

Materials and Methods

Description of the study area

The study was carried out in Gurage zone in South Nation Nationality and Peoples' Region. Gibe Valley National Park is geographically located at E 037° 30'- 038° 10' and N 07° 40'-08° 20' latitude. Gibe Valley National Park is recently established Regional Park due to its high endemism and biodiversity conservation importance and home for numerous migratory and endemic bird species. It covers 360 km^2 and it dissected by deep gorges of the Gilgel Gibe and Wabe rivers. It is about 174 kilometers away from the southwestern part of Addis Ababa which is the capital city Ethiopia (Figure 1).

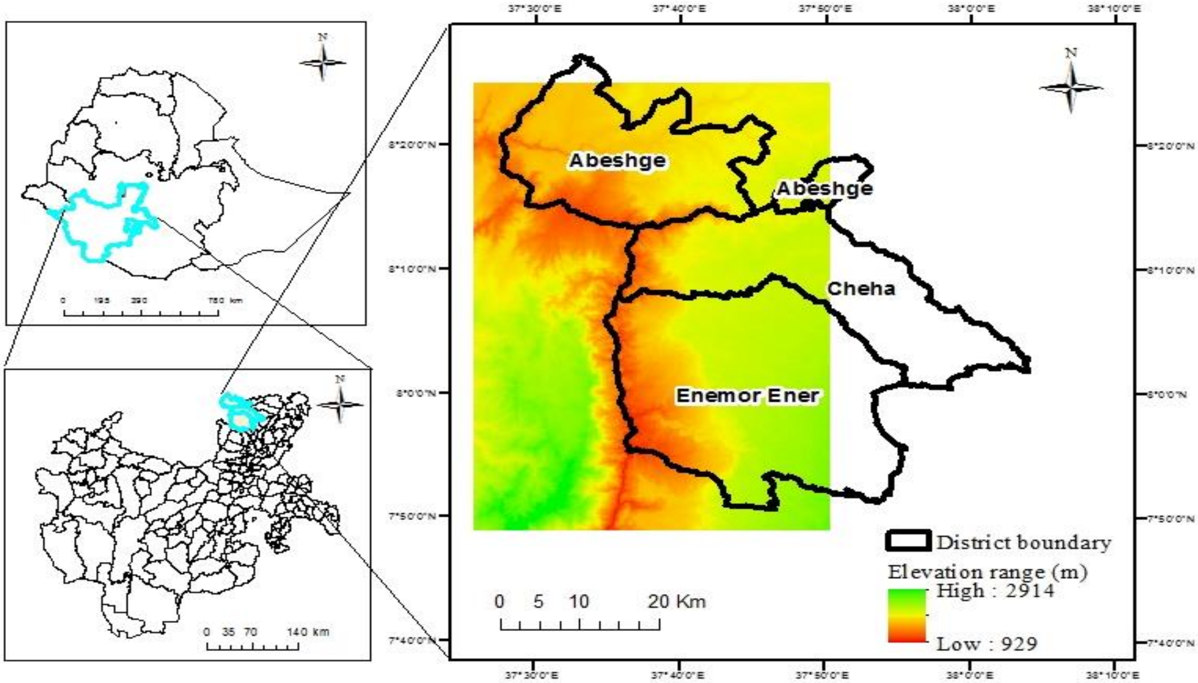

Figure 1 Map of Ethiopia, South Nation Nationality and People Region and studied location, Southwestern Ethiopia

The park is found in three administrative districts namely Abeshge, Cheha and Enemorna Ener. The park has an altitudinal range between 1050 to 1600 meter above sea level. The mean annual temperature (MAT) of the park ranges from 18.5 °C - 25 °C. And its annual rainfall is 1000 mm where the highest is in July. It is categorized as hot to warm sub-humid agro ecological zone (Ministry of Agriculture, 1998) (Figure 2).

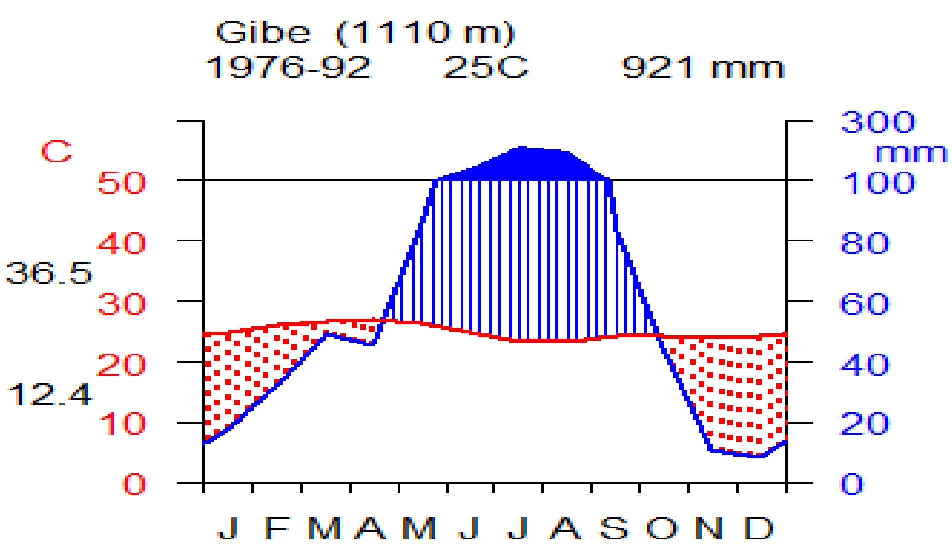

Figure 2 Climate diagram of the area. Source: (Bekele, 2017, unpublished)

Currently, the woodland is in a recovering process even though it has facing numbers of anthropogenic pressures. Because, there are community members lived in the park's compound. Clear displacement of people in the park need enough compensation for their resource. Therefore, the explicit description of the current benefits of local people gaining from the woodland would indicate future comparable incentives given to local community after total re displacement of the people found in the park compound.

Socio economy of the study area

The life style of people in Guragae zone in general and at studied districts is a sedentary way of life with agriculture. *Ensete ventricosum* (Ethiopian banana) is the main staple food crop grown in their home stead agroforestry system. Cereal crops like *Zea mays* (maize), Sorghum bicolor (sorghum), and *Eragrostis tef* (teff) are widely cultivated crops. Cash crops like *Coffea arabica* (coffee) and *Catha edulis* (chat) are also grown in the study area in the form of agroforestry complex. In addition to these crops, *Capsicum annum* (hot pepper), *Sesamum orientale* (selit) and *Guizotia abyssinica* (nug) are produced as also cash crop. Animal husbandry is widely practiced. Currently, *Eucalyptus* plantation is aggressively expanding in order to maximize the local peoples' household income, because its product is sold as cash crop in the local and national market.

Method of data collection

Pilot survey was conducted prior to the development of structured and semi structured interview to accommodate all important information during data collection process. Then socioeconomic survey was conducted to assess the socioeconomic importance of the Gibe Valley National Park woodland vegetation for the local community. Gurage Zone has a total of 13 districts. In the current study three adjacent (neighboring) districts to the woodland vegetation (Abeshge, Cheha and Enemorna Ener) were selected together with Gibe Valley National Park and experts at district environment and forest office. Accordingly, one purposive peasant association (PA) (the closest to the woodland) were selected from the two districts. These were Lukena Eba and Jatu from Cheha and Enemorna Ener districts respectively. Three representative PAs (Gibe Yibare, Hudad Arat and Serite) were chosen from Abeshge, this is because of the major part of the woodland is found in this district. Randomly 7 % of household were interviewed from each PAs. A total of 130 household heads were interviewed through structured and semi structured interviews. Key informant discussion was made at farmer, manager and expert levels. The number of households at each PAs were shown in table (Table 1).

Method of Data analysis

The collected data were encoded in an excel sheet. Descriptive statistical methods (percentages, mean, graphs) and inferential statistical methods (t-test, and ANOVA) were used to analyses the data. Pearsons correlation was also used to analyses the data.

Table 1 Number of households at each sampled PAs, Southwestern Ethiopia.

Sampled PAs	District	Total household	Sampled household
Gibe Yibare	Abeshge	221	15
Serite	Abeshge	583	40
Hudad Arat	Abeshge	335	26
Lukena Eba	Cheha	298	23
Jatu	Enemorna	345	26
Total		1782	130

Source: (Office of the Population Census Commission, 2007)

Results

Social characteristics

The social status such as sexual gender, age, family size and educational level of the respondents were analyzed. The proportion of male and female household heads were 81.5% (106) and 18.5 % (24) respectively. The age distribution of the interviewee showed that 43.8% (57) and 56.1% (73) were > 40 and between 20 and 40 years old respectively. The aged group were believed to have better understanding of the surrounding woodland. More than 78 % (98) of the respondents were live in the study area for greater than twenty years. Therefore, it was believed that nearly all of the interviewee has detail knowledge about the surrounding woodland. From the total respondents 31.5 % (41), 29.2 % (38), 20 % (26) and 2.3 % (3) were attended elementary, read and write and secondary and college level education respectively and 12.3 % (16) of the respondents were illiterate. The family size of majority of the respondents (70.77 %) were more than four, 20 % of the respondents had less or equal to four family size and the remaining 9.2 % were chosen to keep silent.

Livelihood options

The people in the study area mainly carried out mixed type of agriculture (farming and livestock production). Unlike other districts, people from Cheha district were not depend their livelihood on the woodland. There was no any respondent from Enemorna Ener district who depend his or her livelihood on government employment. Most of the local people in the study area engaged on cereal and oil crop production and livestock raring (Figure 3).

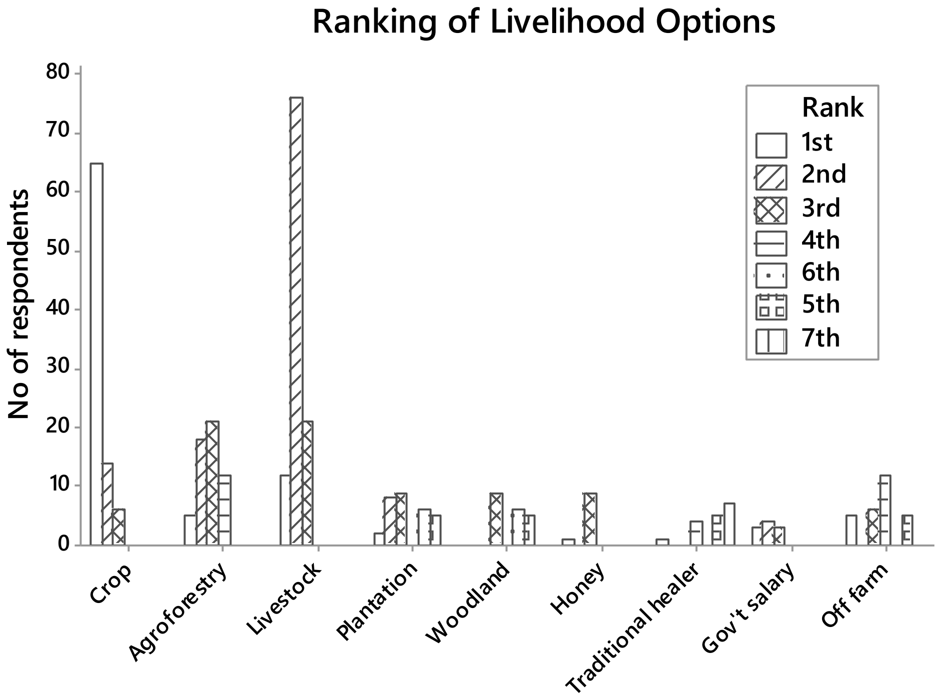

Figure 3 Livelihood options and their ranks in Gibe Valley National Park woodland, Southwestern Ethiopia

The major crops grown in the area include *Sorghum bicolor* (Sorghum), *Zea mays* (maize), *Capsicum annum* (hot pepper), *Sesamum orientale* (selit) and *Guizotia abyssinica* (nug) and others. Even though crop production was their primary sources of livelihood options and income source, majority of the people depended their livelihood options on livestock production (Figure 4).

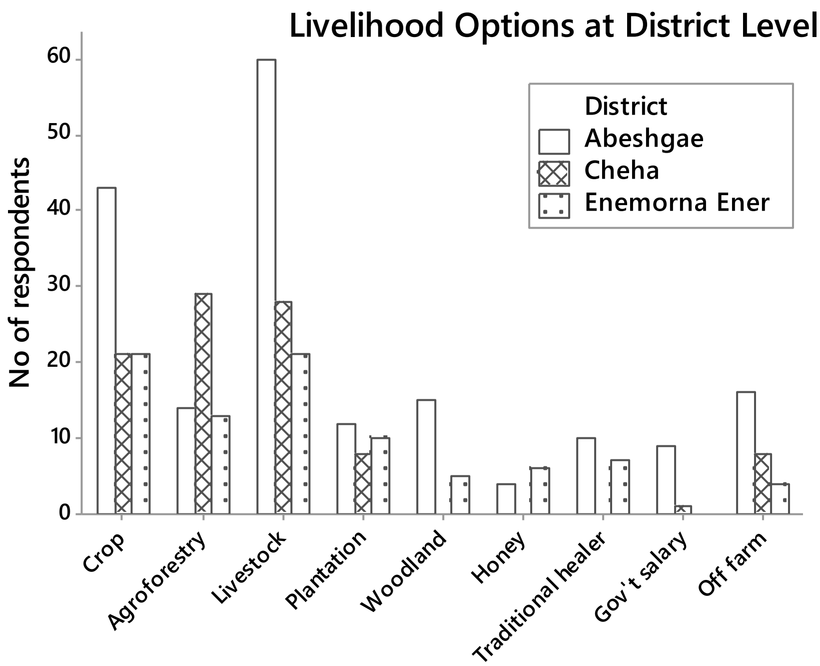

Figure 4 Livelihood options of the local people at district level in Gibe Valley National Park woodland, Southwestern Ethiopia

About 76.1 % of the respondents in the study area were raring livestock as major livelihood support. Livestock production was the second livelihood options for the local community. The main grazing land for their livestock was under the Ashenafiwoodland vegetation. This showed that how the woodland vegetation supports other livelihood options of the local people. All livelihood options illustrated above (Figure 3 and 4) have interrelations among each other. For instance, the livestock raring, honey production, crop production and traditional medicine are dependent on the existing woodland vegetation. Therefore, the economic contribution of the woodland can also be reflected on the other livelihood options of the people.

Income

The five dominant livelihood options for majority of the local people were crop production, livestock raring, agroforestry practice, plantation forestry and income from the woodland like selling of construction wood. But, government employment has been one of the livelihood options in Abeshge district. Here honey production was listed as source of house hold income for three of the districts (Figure 5).

But, it was stated that respondents from Cheha district had not been depend their livelihood by honey production. This was due to less contribution for livelihood support when compared to other major livelihood options. Because, honey production has been linearly decreased from time to time due to the entrance of bee colonies in to the hollowed concreted electric pole (according to respondents and confirmed through field observation). Direct income from the woodland was generated only from one district (Enemorna Ener). Income from honey production and traditional medicine were not generated from Cheha district. The different livelihood options, their mean annual income between the three districts and the p-value of the means were described (Table 2).

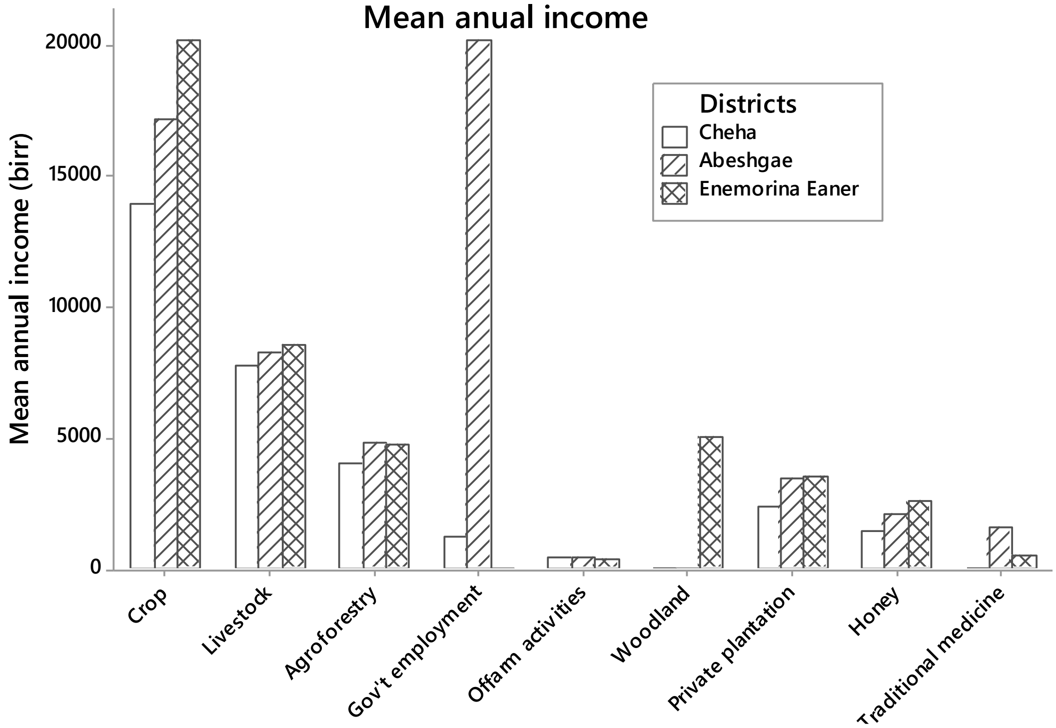

Figure 5 The annual mean income of local people at district level in Gibe Valley National Park woodland, Southwestern Ethiopia (1$US=30.1 Birr)

Forest products

More than 30 % of the respondents in the study area gather various forest products from the nearby woodland vegetation like fuel wood, charcoal, construction wood, traditional medicines, gum and resins, farming utensils, handicrafts and grazing. Among these forest products three of them namely fuel wood, construction wood and farming utensils had been taken the larger shares of the forest products that the local people gathered from the woodland vegetation (Figure 6).

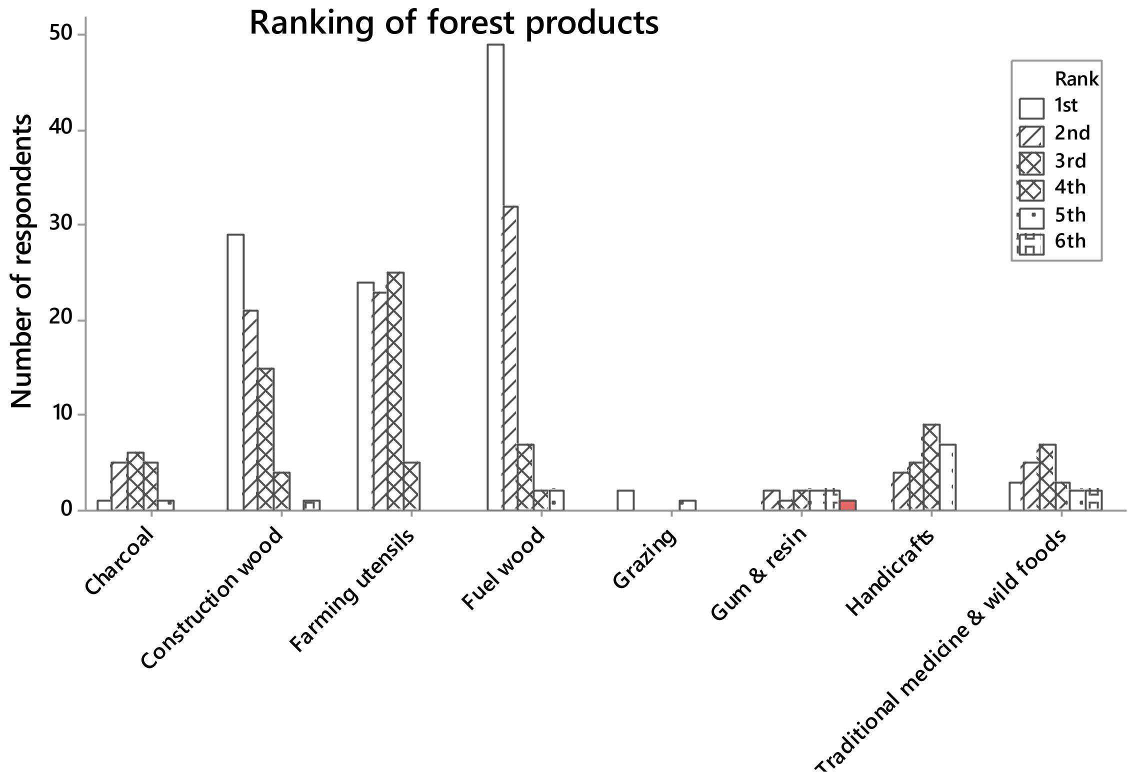

Figure 6 Major type of forest products collected and their ranking at Gibe Valley National Park woodland, Southwestern Ethiopia

Table 2 Livelihood options and mean annual income (in Birr) at Gibe Valley National Park woodland, Southwestern Ethiopia.

Livelihood	N	Mean	StDev	P-value
Agroforestry	3	5,961.00	1,773.00	
Crop production	3	23,724.00	24,844.00	
Government salary	2	16,102.00	5,801.00	
Honey	2	188.00	265.00	
Livestock	3	6,650.00	3,083.00	0.264
Off farm	3	6,113.00	4,951.00	
Tree plantation	3	3,372.00	375.00	
Traditional healer	2	834.00	472.00	
Woodland	1	5,000.00	-	

About 49.2 % of the respondents were gathering wild fruits from woodland. The gather of wild edible plants from the woodland was not significantly varied with sexual gender, age and family size but it was significantly varied with educational level (Table 3).

Table 3 Social background and their activities at Gibe Valley National Park woodland, Southwestern Ethiopia.

Asked question	Social description	Response	Mean	T-value	P-value
Do you collect wild edible plants from the woodland?	Age class (>40 and ≤40)	Yes	41.5	0.15	0.91
		No	38		
	Sex (Male and Female)	Yes	26.5	0.13	0.92
		No	30		
	Family size (≥5 and <5)	Yes	24.5	0.19	0.88
		No	29.5		
	Educational level (illiterate, writing and reading, elementary, secondary and college)	Yes	9.5		0.78
		No	11		
Are there gum and resin bearing species in woodland?	Age class (>40 and ≤40)	Yes	17.5	2.31	0.26
		No	39.5		
	Sex (Male and Female)	Yes	28.5	-0.26	0.81
		No	24.8		
	Family size (≥5 and <5)	Yes	8.5	1.1	0.47
		No	45.5		
	Educational level (illiterate, writing and reading, elementary, secondary and college)	Yes	11		0.65
		No	13		
Which type of medicine do you prefer to cure your illness?	Age class (>40 and ≤40)	Traditional	6.5	4.24	0.15
		Modern	49		
	Sex (Male and Female)	Traditional	6.5	1.39	0.39
		Modern	49		
	Family size (≥5 and <5)	Traditional	6.5	1.26	0.43
		Modern	47		
	Educational level (illiterate, writing and reading, elementary, secondary and college)	Traditional	1.6		0.01
		Modern	18.6		

Lowland woodland forests are known by their richness of gum and resins bearing species in the genus of *Sterculia* (*Sterculia setigera*) *Boswellia* (*Boswellia pyrottee*), *Commiphora* (*Commiphora africana*) and *Acacia* (*Acacia seyal*). Likewise there are gum and resin bearing species in the current study area, but only 47.7 % of the respondents had knowledge about the presence of these species and 20 % of them were gathering it for household consumption. Some of the reasons why they did not collect and sold the product in the market include inaccessibility (23 %), lack of knowledge (53.8 %). Knowing the presence of gum and resin bearing species in the woodland was not significantly varied with social characteristics.

About eighty percent of the sampled household did not gather and use traditional medicinal plants in the study area. Most of the respondents in the study area preferred modern medicine than the traditional one. Of the total sampled households, 75.4 % (98) of the sampled households preferred the modern medicine to cure their illness. The reason for preferring modern medicine by majority of the sampled households were due to appropriate dosage and better access to get it. Whereas 10 % (13) of the sampled population preferred the traditional medicine. They preferred traditional medicine for disease which would not be cured by modern medicine. And almost all (93 %) of the respondents agreed that traditional healers were not willing to share their knowledge to the other members of the community.

Some of the major wild fruit bearing species in the study area were shown in the table (Table 4). The commonest wild fruit producing tree species in the study area was *Ximenia americana* (enkoy) followed by *Tamarindes indica* (komtate).

Table 4 Major plant species providing wild fruits for the local community at Gibe Valley National Park woodland, Southwestern Ethiopia.

Species botanical name	Parts used	Local name	No of respondents
Carisa spinarum	Fruit	Agam	4
Cordia africana	Fruit	Wanza	2
Diospyros abyssinica	Fruit	Lega	1
Dioscorea bulbifera	Fruit	Boye	1
Dovyalis abyssinica	Fruit	Koshim	13
Ficus sur	Fruit	Shola	7
Rhus retinorrhoea	Fruit	Qeme	2
Rubus steudneri	Fruit	Enjori	1
Syzygium guineense	Fruit	Guareba	11
Tamarindus indica	Fruit	Komtate/Roka	15
Ximenia americana	Fruit	Enkoy	42
Ziziphus spina-christi	Fruit	Qurqura	1

The people feed the fruits for various purposes like for the intention of medicinal value, mental satisfaction (just to feel happy after consumption), for marketing, to release hunger and to fill stomach (Table 5). But, 31.5 % of the interviewee kept silent about the purpose of feeding wild fruits in the study area.

Table 5 The role wild fruits for the local community around Gibe Valley National Park woodland, Southwestern Ethiopia.

Reasons for collecting wild edible fruits	No of Interviewee	%
Mental satisfaction	40	30.8
Mental satisfaction, medicinal value, to fill stomach	20	15.4
Release hunger	12	9.2
Mental satisfaction, marketing, release hunger	5	3.8
Mental satisfaction, medicinal value	5	3.8
Medicinal value	4	3.1
Mental satisfaction and to fill stomach	2	1.5
Marketing	1	0.8
Not responded	41	31.5

Threats

It is known that deforestation, specifically in dry land woodlands of Ethiopia is a serious and devastating phenomenon. More than 62 % the interviewees replied that the size of the woodland is decreasing from time to time due to a number of factors. These include investment, fire, charcoal production, agricultural expansion, gazing and settlement (Figure 7).

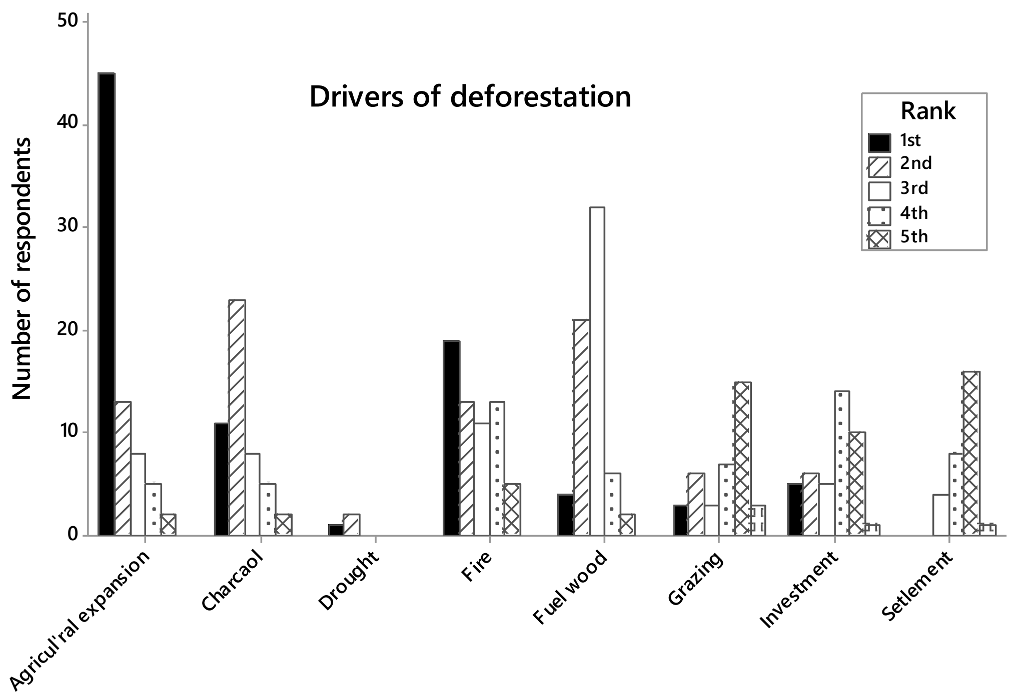

Figure 7 Major drivers of deforestation at Gibe Valley National Park woodland, Southern Ethiopia.

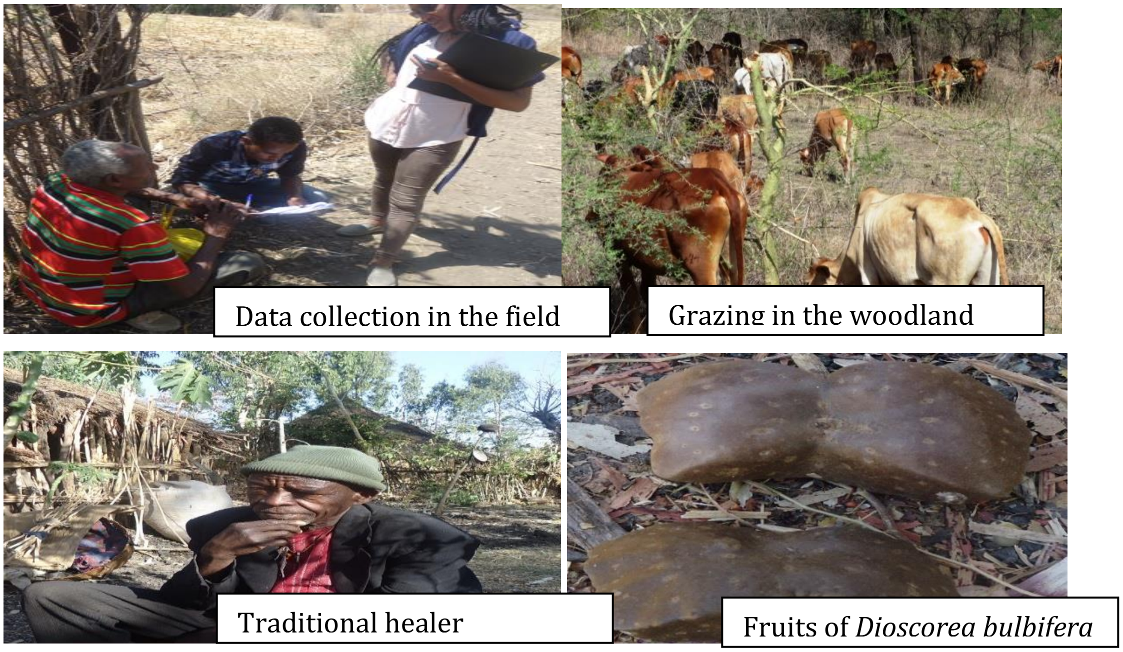

Plate 1 Socioeconomic survey around Gibe Valley National Park woodland, Southwestern Ethiopia.

Discussion

Crop production was ranked as the first livelihood option while livestock production was ranked as the second livelihood options for local people in the study area. This result was in line with the findings of some authors (Teshome, Kassa, Mohammed, & Padoch, 2015). The respondents indicated that the main grazing land for the livestock of the study area was the woodland vegetation which could indicate that it also provides grasses for their livestock. Lemenih and Kassa (2011) and (CIFOR, 2011) stated that the only source of fodder for livestock for the local community in Ethiopia especially in the dry season is the woodland. Some authors (Fikir et al., 2016) stated that the wood land forests are playing a role in livestock production in arid and semi-arid areas of the country where the wood land vegetation is widely distributed.

The livelihood options illustrated in the study area (Figure 3) above have depend on one other. For instance, livestock raring, honey production, crop production and traditional medicine were dependent on the existing woodland vegetation. Therefore, the economic contribution of the woodland could also be reflected by other livelihood options of the people. The results indicated that the people from Cheha district did not depend their livelihood on the woodland forest. This could be associated with an alternative means of livelihood which is mainly depend on agroforestry practices. In addition to agroforestry practice, inaccessibility to the woodland forest has also affected their independency on the woodland. Some authors (Wale & Dejenie, 2013) indicated that the dependency to a woodland forest as a means of livelihood depends on the availability of alternative income sources such as agroforestry.

The livelihood share of livestock production (23.6 %) for the local community of the current study was less by thirteen from the minimum range reported (EPCC, 2015), which was 37-87 %. The mean annual income of the people from crop, livestock, agroforestry, plantation forestry and woodland were 49.4 %, 23.6 %, 13.1 %, 9.0 % and 4.8 %, respectively. The contribution of non-wood forest products, for example gum and resin, wild fruits, medicinal plants and honey in the present study area was nearly five times less than similar research works carried out (Fikir et al., 2016). This difference might be associated with uncommon gathering practices of gum and resin. Some authors (Mulugeta & Demel, 2003) reported that woodland forest constituted the second source of income generation next to livestock production in case of Liben and Tigray, southern and northern Ethiopia respectively.The livelihood contribution of non-wood forest product constituted 14 % (Ogbazghi & Bein, 2006).

The major forest products provided by woodland forests for local community include honey, fuel wood, gum and resin, and crafts and construction materials, contributing 49 %, 39 %, 6 %, and 6 % of the forest income, respectively (Fikir et al., 2016). In current study, fuel wood was the most important forest product that the local community collected from the forest. Some authors (Fikir et al., 2016) reported that the most important goods collected from the woodland forest was honey. This result could indicate that the goods provided by the woodlands to the local communities varies depending on their interest.

The people feed the fruits for various purposes like for the intention of medicinal value, mental satisfaction (just to feel happy) and for marketing. About 30.8 % of the respondents consumed the gathered wild fruits for mental satisfaction. According to some authors (Assefa & Abebe, 2011a), wild edible plants consumed to supplement staple food where there is ample food production, fill the gap of seasonal food shortage and during famine. Therefore, in the current study, gathering and consuming wild fruits for mental satisfaction might be used when at the periods of surplus food production was available. Wild edible plants are also important sources of essential vitamins, minerals, carbohydrates and proteins (Agustino, Mataya, Senelwa, & Achigan-Dako, 2011).

The commonest wild fruit producing tree species in the study area was *Ximenia americana* followed by *Tamarindes indica*. The later species (*Tamarindes indica)* was reported as locally and internationally marketable wild fruit bearing tree species(Tebkew, 2015). Fruits of *Cordia africana*, *Balanites aegyptica*, *Dovyalis abyssinica* and *Ficus spp*. were commonly used plants in dry lands of Ethiopia. Fruits of

Opuntia ficus-indica and *Borassus aethiopum* were consumed and traded in the markets for cash generation in Tigray and Afar. If accounted properly, wild edible plant species contribute considerable amount of the national and local economy (EPCC, 2015).

Gum and resin bearing species in the above-mentioned genera are available in the current study area. However, only less than half of the respondents knew about the presence of the species and few (20 %) of them are gathering it only for home consumption. This was due to inaccessibility and lack of knowledge were barriers for the utilization of the gum and resin bearing species in the study area by the local community. But, according to some authors (Abtew, Pretzsch, Secco, & Mohamod, 2014) income from gum and resin production reduced poverty level by 23-48 %. But, some authors (Mekonnen et al., 2013) well stated about the potential contribution of gum and resins for local and national economy of the country.

More than half of the interviewee replied that the size of the woodland is decreasing from time to time due to several factors such as investment for crop production, fire, charcoal production, farmland expansion by small scale farmer, gazing and settlement. Many authors like Assefa & Abebe, (2011b) Tadesse, Desalegn, & Alia, (2014) and Amare, (2015) also indicated that investment crop production, fire, agricultural expansion are the major derivers of deforestation and forest degradation the wood land forests in other parts of Ethiopia. This result could indicate that attention has to be given to halt degradation of the wood land forests and developing sustainable wood land forest management plan to enhance their benefits is necessary.

Conclusion and Recommendation

The results showed that despite the average annual income from woodland forest for the local community of the study area was very less (5000 Birr) as the respondents mainly involve in crop production, the role of the woodland forest in the provision of fuel wood, farming utensils, construction woods and other non-timber forest products is immense. The major forest products derived from the woodland forest was fuel wood followed by construction wood and farming utensils. Besides of providing different goods, the woodland forest is also serving as a grazing land for their livestock, though it has impact on the seedling regeneration, which shows that, it indirectly plays a role in alternative livelihood options. People consumed wild fruits without knowing they are source of vitamins and carbohydrates. Despite such an importance of the woodland forest in the study area, the local communities responded that the forest is dwindling from time to time due to different causative factors. Lack of awareness about gathering gum and resin caused to fail the people diversify their income. Therefore, the authors recommended that halting the deforestation of the woodland forest is necessary. Moreover, it is recommended that training to the local community on how to tap, market, and utilize the gum and resin from the gum and resin bearing species is necessary since they do have a very good market values in the local as well as in international markets.

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References

Abtew, A. A., Pretzsch, J., Secco, L., & Mohamod, T. E. (2014). Contribution of small-scale gum and resin commercialization to local livelihood and rural economic development in the drylands of Eastern Africa. Forests, **5(5):** 952–977. https://doi.org/10.3390/f5050952

Agustino, S., Mataya, B., Senelwa, K., & Achigan-Dako, E. . (2011). *Non-Wood Forest Products and Services for Socio-Economic Development*.

Alem, S. (2015). International trade of different forest products in Ethiopia. African J. of Economic and Sustainable Development, **4(4):** 353–361. https://doi.org/10.1504/ajesd.2015.072703

Amare, A. (2015). Conservation Challenges of Gibe Sheleko National Park, Southwestern Ethiopia. *Natural Resources*, *06*(04), 286–289. https://doi.org/10.4236/nr.2015.64025

Assefa, A., & Abebe, T. (2011a). Assegid Assefa & Tesfaye Abebe 2011. Wild Edible Trees and Shrubs in the Semi-arid Lowlands of Southern Ethiopia. Journal of Science and Development, **1(1):** 5–19.

Assefa, A., & Abebe, T. (2011b). Wild edible trees and shrubs in the semi-arid lowlands of Southern Ethiopia. Journal of Science and Development, **1(1):** 1-10.

Bahru, T., Asfaw, Z., & Demissew, S. (2014). Wild edible plants: sustainable use and management by indigenous communities in and the buffer area of Awash National Park, Ethiopia. Ethiopian Journal of Science, **36(2):** 93–108. https://doi.org/10.4314/sinet.v36i2.103502

Bekele, F. (2017). Effects of Grazing Exclusion on Field Layer Species Composition, Biomass and Selected Soil Properties in Gibe Valley National Park, South-western Ethiopia, (May).

Chidumayo, E. N. (2010). *The Dry Forests and Woodlands of Africa Managing for Products and Services*. *Earth scan*. https://doi.org/10.4324/9781849776547

CIFOR. (2011). *Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia*. (H. Lemenih, M. and Kassa, Ed.), *Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia*. Bogor: CIFOR. https://doi.org/10.17528/cifor/003478

Dejene, T., Mohamed, O., & Adamu, H. (2013). Boswellia papyrifera Pre-dominated Wood

Lands of Ethiopia: Present Roles and Threats. *HortFlora Research Spectrum*, ***2*****(4)**: 277–285.

EPCC. (2015). Ethiopian Panel on Climate Change: First Assessment Reoport, Working Group II Biodiversisty and Ecosystems, 210 p.

FAO. (2000). Land Resource Potential and Constraints at Regional and Country Level, 122pp.

FAO. (2003). Forests , Grasslands , and Drylands-- Ethiopia, *2002*, 1–7.

Fikir, D., Tadesse, W., & Gure, A. (2016). Economic Contribution to Local Livelihoods and Households Dependency on Dry Land Forest Products in Hammer District, Southeastern Ethiopia. *International Journal of Forestry Research*, 1–11. https://doi.org/10.1155/2016/5474680

Grieg-Gran, M., Bass, S., Booker, F., & Day, M. (2015). *The role of forests in a green economy transformation in Africa*.

Kassa, M. L. and H. (2010). Socio-economic and Environmental Significance of Dry Land Resources of Ethiopia and their Development Challenges. *JAD*, **1:** 72–91.

Mekonnen, Z., Worku, A., Yohannes, T., Bahru, T., Mebratu, T., & Teketay, D. (2013). Economic contribution of gum and resin resources to household livelihoods in selected regions and the national economy of Ethiopia. *Ethnobotany Research and Applications*, **11:** 273–288.

Ministry of Agriculture. (1998). Agroegological Zones of Ethiopia.

Monjane, M. (2009). Eastern and Southern Africa Forest and Woodlands Situational Analysis, **1:** 1–47.

Mulugeta, L., & Demel, T. (2003). Frankincense and myrrh resources of Ethiopia: I distribution, production, opportunities for dryland development and research needs. SINET: Ethiopian Journal of Science, **26(1):** 63–72. https://doi.org/10.4314/sinet.v26i1.18201

Office of the Population Census Commission. (2007). The 2007 Population and Housing Census of Ethiopia: Statistical Report for Southern Nations, Nationalities and Peoples' Region.

Ogbazghi, B. W., & Bein, E. (2006). Assessment of Non-Wood Forest Products and their Role in the Livelihoods of Rural Communities in the Gash-Barka Region, Eritrea, (40).

Sahle, M., & Yeshitela, K. (2018). Dynamics of land use land cover and their drivers study for management of ecosystems in the socio-ecological landscape of Gurage Mountains, Ethiopia. *Remote Sensing Applications: Society and Environment*, *12*(September), 48–56. https://doi.org/10.1016/j.rsase.2018.09.002

Solomon, N., Birhane, E., Tadesse, T., Treydte, A. C., & Meles, K. (2017). Carbon stocks and sequestration potential of dry forests under community management in Tigray, Ethiopia. Ecological Processes, **6(1)**: 1–11. https://doi.org/10.1186/s13717-017-0088-2

Tadesse, W., Desalegn, G., & Alia, R. (2014). Natural gum and resin bearing species of Ethiopia and their potential applications. *Investigación Agraria: Sistemas y Recursos Forestales*, ***16*****(3):** 211. https://doi.org/10.5424/srf/2007163-01010

Tebkew, M. (2015). Wild and semi-wild edible plants in Chilga District , Northwestern Ethiopia : Implication for food security and climate change adaptation, ***3*****(3):** 72–82.

Teshome, B., Kassa, H., Mohammed, Z., & Padoch, C. (2015). Contribution of Dry Forest Products to Household Income and Determinants of Forest Income Levels in the Northwestern and Southern Lowlands of Ethiopia. *Natural Resources*, ***6*****(5):** 331–338. https://doi.org/10.4236/nr.2015.65030

Wale, H. A., & Dejenie, T. (2013). Dryland Ecosystems : Their Features , Constraints , Potentials and Managements. *Journal of Agricultural and Environmental Management*, ***2*(10):** 277–288.

Phenology of Selected Indigenous Tree Species at Wof Washa Dry Afromontane Forest Area, Central Highlands of Ethiopia

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Abstract

Leafing and flowing patterns of *Juniperus procera*, *Prunus africana, Olea hochstetteri, Podocarpus falcatus, Olea africana* and *Hagenia abyssinica* tree species were evaluated in Wof washa forest over four years. A total of 60 individual trees, 10 individuals per species, were selected, considering the visibility of their crowns. Continuous monitoring of the targeted tree species was conducted on their flower and fruit phonological sequences. The result indicated that *P. falcatus* and *J. procera* were found to be with foliage all year round. Flowering and fruiting of *P. falcatus* were from September to May and from September to August respectively. Flowering in *J. procera* is inconspicuous within the observation periods, while fruiting is from March to August. *Hagenia abyssinica* is flushing flowers from December to March and fruiting from January to June. *Olea africana* gives flowers from February to May and fruits April to December. The flowering period of *Olea hochstetteri* was from December to May and the fruiting period was from January to August. The flowering period *of Prunus africana* was from January to March and the fruiting was from January to July. The results obtained from this study would help the natural resources management agents and other interested stake holders to use the appropriate seed collection seasons of the study tree species considered in the study forest areas.

Keywords: Flowering, flower sheding, fruiting, seasonality, mature tree

Introduction

Phenology is the scientific study of the seasonal timing of life events (Sulistyawati et al., 2012). It focuses events in nature and cyclical biological events. These events can include flowering, leaf unfolding (budburst), seed set and dispersal, and leaf fall (Lechowicz, 2002). Among these flowering is the most important as it varies vary with geographic locations and trees (Bawa et al., 2003), which can affect the reproductive output of the plants. Also, the phonological events are influenced by climatic factors and variables thus less predictable from year to year. Thus, phonological studies are important for the conservation and management of the biological resource we have as well as for the better understanding of the ecological adaptation of plant species and community-level interactions.

Although phonological knowledge of various trees has been accumulating globally, such information from Ethiopian natural forests is critically lacking. Such information is basic to understand the biological processes and the functioning of the forest ecosystem. Thus, this type of study will help to understand various phenophases of valuable trees in the context of global climatic change scenario at local level. Moreover, developing viable local conservation strategies for the tree species in any locality depend on the ability to realize the vegetative and reproductive potential of the species which overlay on the species phenology. Also, the timing and duration of flowering and fruiting, for instance is crucial in understanding forest regeneration dynamics as seasonality affects the reproductive output and performances such as seed production, germination, survival, and seedling growth. This paper presents the phenology of Six indigenous trees from the central highland part of Ethiopia. The results obtained would help to stem appropriate period of seed collection and handling technologies that would be applicable in similar agro-ecological zones of the country.

Materials and Methods

Description of the study site

Wof-Washa Dry Afromontane Forest is located in Tarmaber, Ankober and Bassona Werana Weredas (Figure 1) of 14 Peasant Associations (Baso Dengora, Gudo Beret, Aba Mote, Keyt, Gosh Hager, Debele, Lay Gorebella, Mahel Menz, Zego, Eme-Mihret, Mescha, Zembo, Wof-Washa and Debre Meaza Kebels) , North Shewa Zone, Amhara National Region State, Central Highlands of Ethiopia with latitudes and longitudes of 9º 43' 46.3'' N to 9º 46' 26.2'' N 39º01'10.78 '' E to 39º47'15.8'' E, respectively with a total area of about 3600 ha (Tamrat Bekele, 1993).

According to the climate data (1992-2010) obtained from the National Meteorological Agency, the mean annual rainfall of Ankober Woreda is 1254 mm. The mean annual rainfall of Tarmaber is 1250 mm, falling in two wet seasons from February to March, and July to September (Magin, 2001).

The mean monthly temperature of the daily maxima at DebreSina ranges from 15.5°C to 24.2°C, and the corresponding minima from 1.2°C to 11.8 °C. The mean monthly temperature ranges from 8.4°C to 18°C (Figure 2). There are often dry winds during the day, frosts may occur at night, and snow sometimes settles on the summit of EmeMihret, Kundi and Wuti.

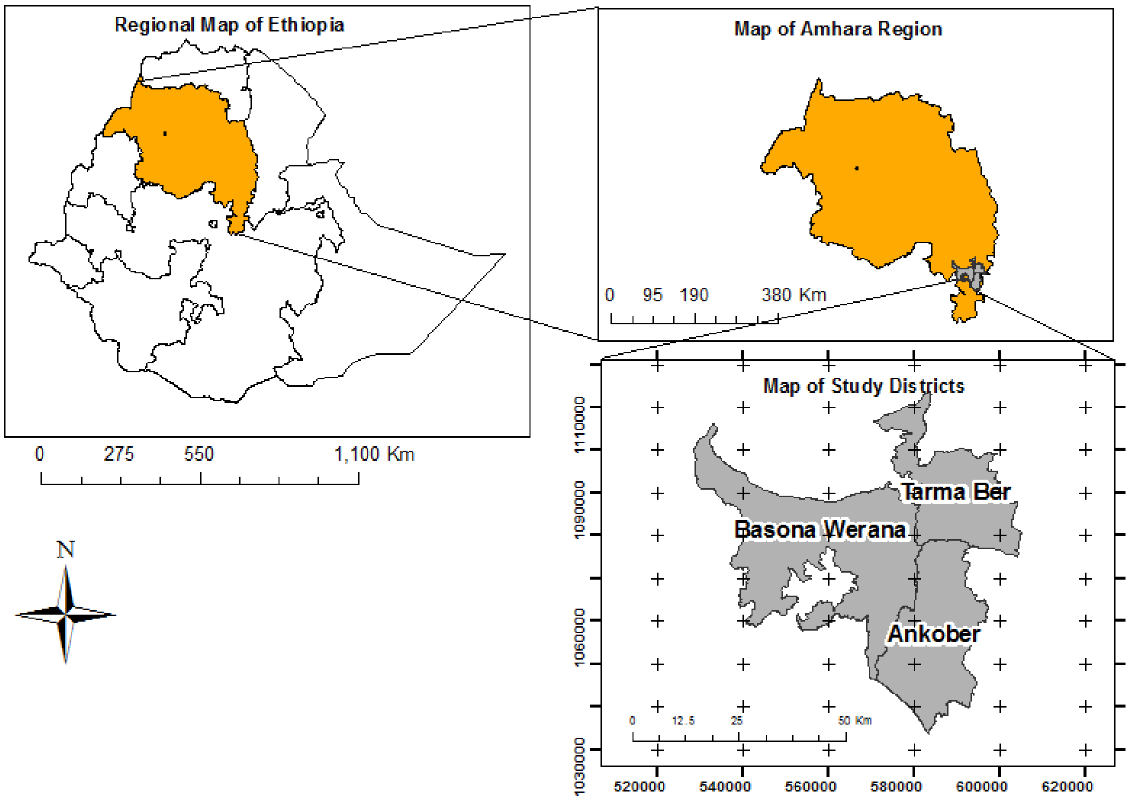

Figure 1 Map of Wof Washa Natural Forest

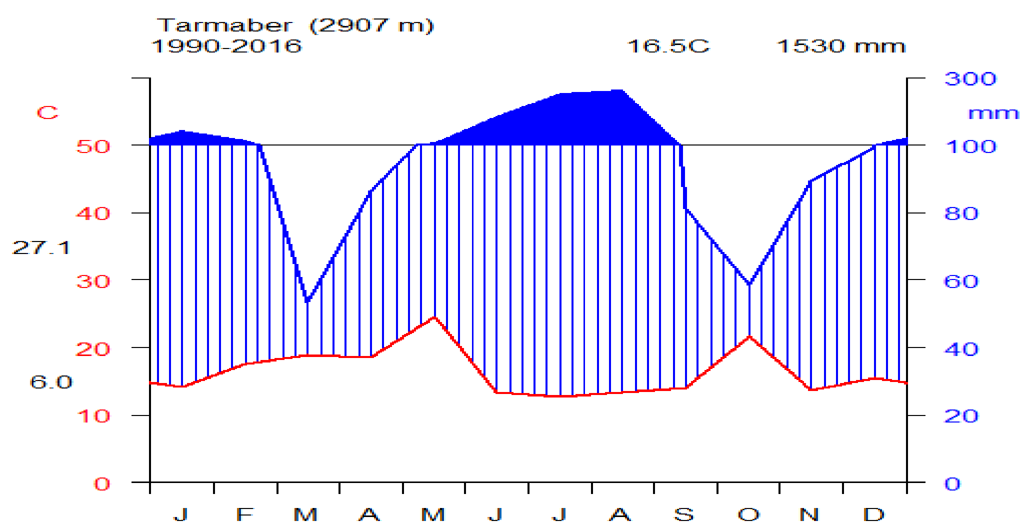

Figure 2 Climate diagrams (1990-2016), Source: NMSA

Methods

Flowering and fruiting assessments were done for the entire key, dominant and high value indigenous tree species found in the dry afromontane of Wof washa natural forest. These tree species are *Hagenia abyssinica, Juniperus procera, Olea Africana, Olea Hochstetteri, Podocarpus falcatus* and *Prunus africana*. The flowering and fruiting periods of these six reproductively matured and average individual trees with easily visible crowns of each species from representative provenances within the permanent plots were observed.

Data Collection

A continuous observation and data recording on their flowering phenology (flower initiation, peak flowering time, flower shading) and fruiting phenology (fruit initiation, fruiting development, fruit maturity and dispersal time) were recorded based on the observation made at intervals of 15 days per months for consecutive four years.

Data Analysis

The data analysis was made based on the recorded observations of the phenology (flowering and fruiting times) of six indigenous tree peciess (*Juniperus procera* Hochst*, Prunus africana* (Hook.f.) Kalkman, *Olea hochstetteri* Bak*, Podocarpus falcatus* (Thunb.) R. Br. ex Mirb, *Olea African* Mill and *Hagenia abyssinica* Bruce.), i.e. the observed data on the time of flowering and fruiting were analyzed subjected to phenological calendars of the tree species. The results obtained from the study illustrated using the following diagrams and the months of the year indicated on the X-axis and the species phenophase on the Y-axis.

Results

The flowering of *Hagenia abyssinca* opens at the beginning of December when the dry season in the years. Although regularity was not followed, the full manifestation of the flower was observed at the end of March (Figure 3). Fruit on setting and maturation for *Hagenia abyssinca* were observed from January through June. Surprisingly, there observed overlapping for flowering and fruiting, indicating there is early fruiting of trees.

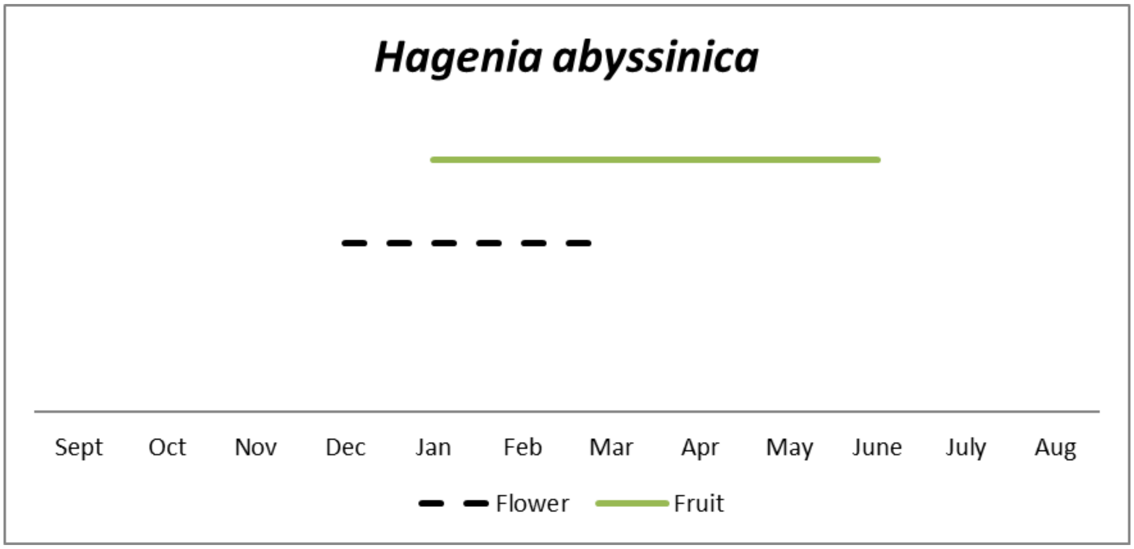

Figure 3 Flowering and fruiting of *Hagenia sbyssinica* during the study periods in Wof Washa forest. Lines in color refer to phenology during the months.

Fruiting of *Juniperus procera* opens at the beginning of March and the full manifestation and maturation is during the month of August (Figure 4). Flowering in *J. procera* was inconspicuous within the observation periods.

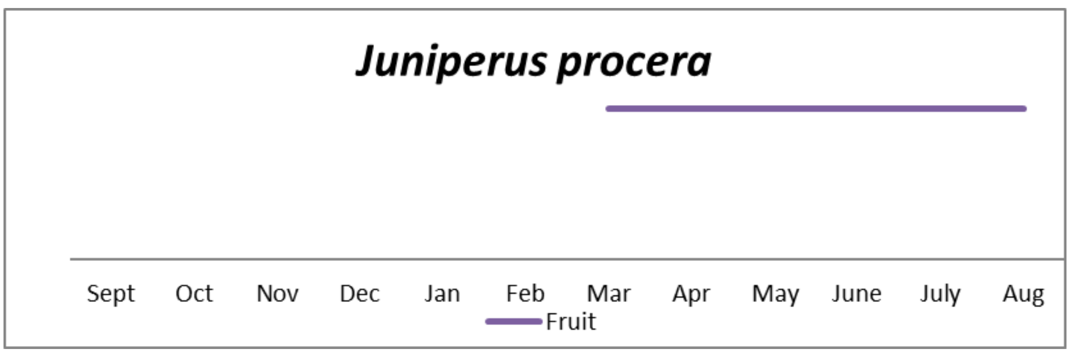

Figure 4 Fruiting of *Juniperus procera* during the study periods in Wof Washa forest. Lines in color refer to phenology during the months.

The flowering of *Olea africana* opens at the beginning of February and ends in end of May when the rainy season in the years. Long period for fruiting was observed for *O. africana,* though there are overlapping in flowering and fruiting (Figure 5). In this species, fruits start in early April and peaks through the months and end in December. The overleaping in fruiting and flowing during Aprile to May indicate there are early fruiting by some individual trees (Figure 5).

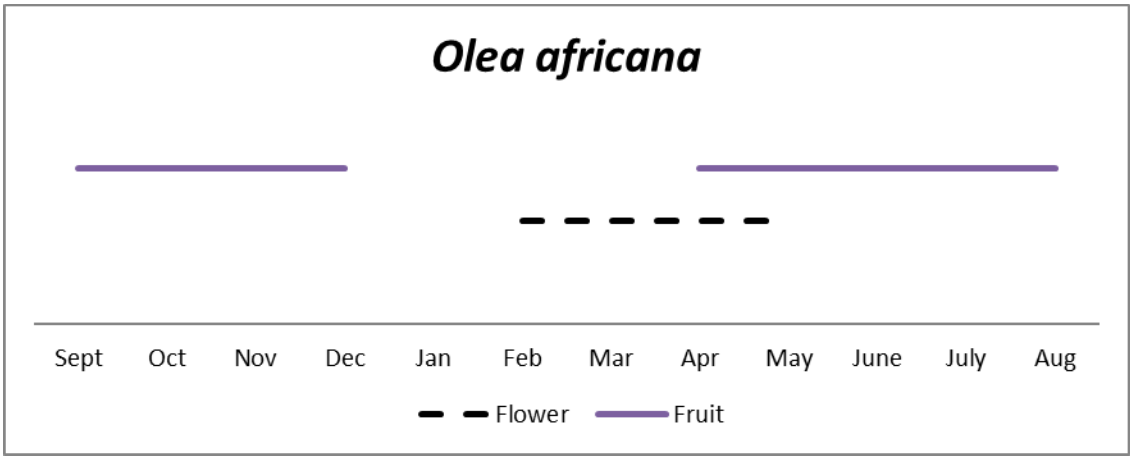

Figure 4 Flowering and fruiting of *Olea africana* during the study periods in Wof Washa forest.

Olea hochstetteri exhibited a unique feature in flowering and fruiting (Figure 5), both occurred together almost for the entire periods. Flowering opens at December and ends in May when the rainy season in the years. Fruits starts in early January and peaks through the months and end in May. Long overlapping is in between January to (Figure 5).

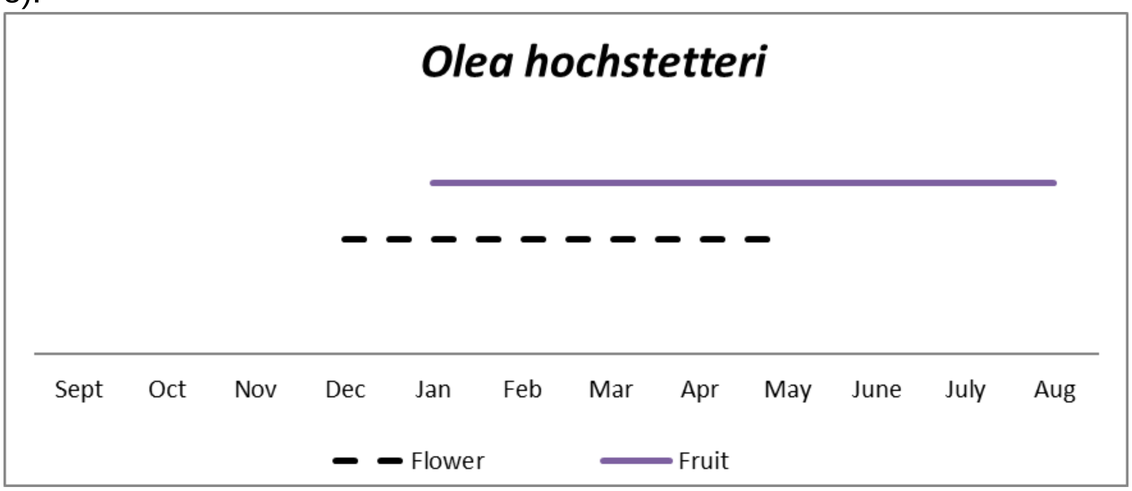

Figure 5 Flowering and fruiting of *Olea hochstetteri* during the study periods in Wof Washa forest.

Unlike the others, *Podocarpus falcatus* exhibited long overlapping in flowering and fruiting (Figure 6), occurred from September to April. Flower starts in September and ends in May when the rainy season in the years. Fruits start in May, and continue throughout the year, indicating the availability of *P. falcatus* seeds over the year (Figure 6).

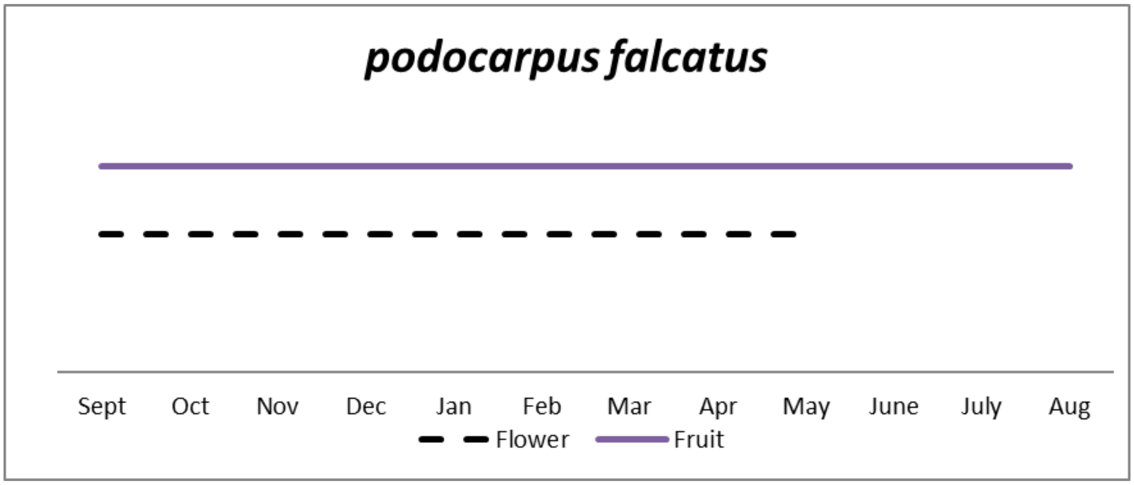

Figure 6: Flowering and fruiting of *Podocarpus falcatus* during the study periods in Wof Washa forest.

The shorter flower season was observed for *Prunus africana* (Figure 7), as compared to the other targeted tree species. Unlike other trees, flowing and fruiting start equally, in January. In *P. africana*, flowering and fruiting ends in May and July when the rainy season in the year (Figure 7).

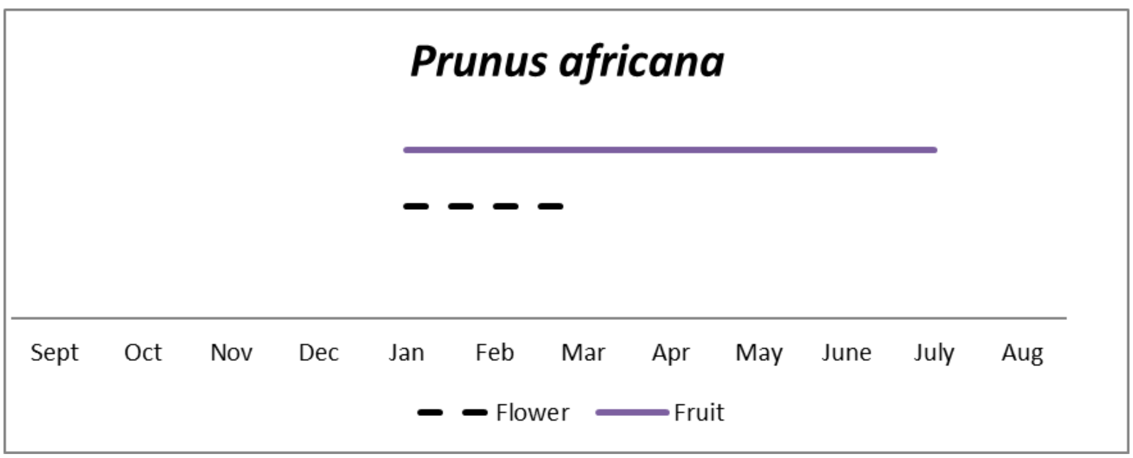

Figure 7 Flowering and fruiting of *Prunus africana* during the study periods in Wof Washa forest.

Discussion

Phenological events include flowering, leaf unfolding (budburst), seed set and dispersal and leaf fall. Phenological studies of six indigenous tree species; *Hagenia abyssinica*, *Juniperus procera*, *Olea africana*, *Olea hochstetteri*, *Podocarpus falcatus* and *Prunus africanum* were studied at Wof Washa dry Afromontane forest area, central highlands of

Ethiopa. A total of 60 mature trees (10 individuals from each tree species) were selected and marked. Phenological data of these tree species which include flowering and fruiting were taken twice a month from May 2014 to June 2017. Based on the phonological data collected, the phonological calenders of the tree species were prepared. Among the tree species under consideration the flowering of *Hagenia abyssinca* opens at the beginning of December when the dry season in the years. Although regularity was not followed, the full manifestation of the flower was observed at the end of March (Figure 3). Fruit on setting and maturation for *Hagenia abyssinca* were observed from January through June. Surprisingly, there observed overlapping for flowering and fruiting, indicating there is early fruiting of trees. Fruiting of *Juniperus procera* opens at the beginning of March and the full manifestation and maturation is during the month of August (Figure 4). Flowering in *J. procera* was inconspicuous within the observation periods. The flowering of *Olea africana* opens at the beginning of February and ends in end of May when the rainy season in the years.

Long period for fruiting was observed for *O. africana,* though there are overlapping in flowering and fruiting (Figure 5). In this species, fruits start in early April and peaks through the months and end in December. The overleaping in fruiting and flowing during Aprile to May indicate there are early fruiting by some individual trees (Figure 5). *Olea hochstetteri* exhibited a unique feature in flowering and fruiting (Figure 5), both occurred together almost for the entire periods. Flowering opens at December and ends in May when the rainy season in the years. Fruits starts in early January and peaks through the months and end in May. Long overlapping is in between January to (Figure 5). Unlike the others, *Podocarpus falcatus* exhibited long overlapping in flowering and fruiting (Figure 6), occurred from September to April. Flower starts in September and ends in May when the rainy season in the years. Fruits start in May, and continue throughout the year, indicating the availability of *P. falcatus* seeds over the year (Figure 6). The shorter flower season was observed for *Prunus africanum* (Figure 7), as compared to the other targeted tree species. Unlike other trees, flowering and fruiting start equally, in January. In *P. africana*, flowering and fruiting ends in May and July when the rainy season in the year (Figure 7). Such phonological information is important for collection of quality seeds and forest interventions to enhance natural regeneration.

Conclusion

The flowering and fruiting period seemed to have quite a different pattern. According to the observation made during the study, fruiting period seems to last longer than flowering period. For the duration of the study, it was rather difficult to observe flowering compared to fruiting. This might be due to lack of visibility of flower as compared to fruits either because of the weather, tree height or size. Therefore, data of flowering species gathered tended to be underestimated. Although the overall flowering and fruiting pattern cannot be clearly identified, the most notable phenomenon was both events reached their peaks during dry seasons. Therefore, the results obtained from this study would help the natural resources management agents and other interested stake holders to use the appropriate seed collection seasons of the study tree species considered in the study areas. The seeds of *Hagenia abyssinica*, *Juniperus procera, Olea africana*, *Olea hochstetteri* and *Podocarpus falcatus* are Orthodox seeds and the seeds of *Prunus africanum* are recalcitrant seeds. Orthodox seeds acquire desiccation tolerance during development and may be stored in the dry state for predictable periods under defined conditions. Unless debilitated by zero-tolerant storage fungi, orthodox seeds should maintain high vigor and viability at least from harvest until the next growing season (Berjak and others 1989). Recalcitrant seeds are those that undergo little or no. maturation drying and remain desiccation sensitive both during development and after they are shed. Recalcitrant seeds are not equally desiccation sensitive, in that variable degrees of dehydration are tolerated depending on the species.

Recommendation

Actors that involve in seed collection process should make use of the output of this study to collect matured and quality seeds of the study tree species specifically in Wof washa Dry Afromontane Forest. The appropriate seed collection seasons of *Podocarpus falcatus* and *Juniperus procera, Hagenia abyssinica, Olea Africana, Olea hochstetteri, and* Prunus *africana* were different along location. Appropriate silvicultural practices need to be implemented following seed dispersal to enhance natural regeneration of the study species. Tree phenology provides knowledge about the pattern of plant growth and development as well as the effect of environment and selective pressure on flowering and fruiting behavior. The foresters, tree growers, the forest seed distributors, the tree seed sellers and the forest related professionals can use the information obtained on the time of flowering, fruiting and the seed dispersal seasons of the tree species under the study.

Acknowledgment

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Reference

Bawa, K. S., H. Kang & M. Grayum. 2003. Relationships among time, frequency, and duration of flowering in tropical rain forest trees. American Journal of Botany 6: 877-887.

Berjak and Others.1989. Orthodox and Recalcitrant seeds.

Endah S., Nusa, M., Nuri N., Setiawan Devi N. C.and Pipin S. 2012. Flowering and Fruiting Phenology of Tree Species in Mount Papandayan Nature Reserve, West Java, Indonesia

Ethiopian Wildlife and History Society. 2010. A glimpse at Biodiversity Hotspots of Ethiopia: The Essential Directory of Environment and Development, Addis Ababa, Ethiopia.

Fenner, M. 1988. The phenology of Growth and Reproduction in Plants.

Friis, I. 1992. Forest and Forest Trees of Northeast Tropical Africa. Kew Bulletin Additional Series XV.

Getachew Tesfaye. 2008. Ecology of Regeneration and Phenology of Seven indigenous Tree Species in a Dry Tropical Afromontane Forest, Southern Ethiopia.

Getachew Tesfaye, Demel Teketay, Masresha Fetene and Erwin Beck. 2011. Phenology of seven Indigenous tree species in a dry Afromontane Forest, Southern Ethiopia

Karmer, K., 1997. Phenology and growth of European trees in relation to climate change. Pp 39-50

Kikim, A. and Yadava, P.S. 2001. Phenology of tree species in subtropical forests of Manipur in Eastern India

Mamo Kebede and Jarkko Isotalo. 2011. Flowering and fruiting phenology and floral visitation of four native tree species in the remnant moist Afromontane forest of Wondo Genet, south central Ethiopia.

Murali K.S. and Sakumar R., 1994. Reproductive Phenology of Tropical Dry Forest in Mudumalai, Southern India.

Singh, K.P., Kushwaha, C.P., 2005. Emerging Paradigms of Tree Phenology in Dry Tropics. Current Science 89: 964-975.

Tamrat Bekele. 1993. Vegetation Ecology of Remnant Afromontane Forests on Central Plateau of Shewa, Ethiopia. PhD Dissertation. Uppsala University, Uppsala, Sweden.

Van Schaik, C., W.J. Terborgh & J. S. Wright. 1993. The phenologiy of tropical forests: adaptive significance and consequences for primary consumers. Annual Review of Ecology and Systematics 24: 353-377.

Yadav, R. K. & A. S. Yadav. 2008. Phenology of selected woody species in a Tropical Dry Deciduous Forest in Rajasthan, India. *Tropical Ecology* 49: 25-34.

Zhang, G., Song, Q., Yang, D. 2006. Phenology of Ficus racemosa in Xishuangbanna, Southwest China. Biotropica 38: 334-341.

Species Diversity, Population Structure and Regeneration Status of Woody Species on Yerer Mountain Forest, Central Highlands of Ethiopia

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Abstract

Yerer Mountain forest is one of the few remaining dry Afromontane forests found in the central highlands of Ethiopia. Information on woody species composition, diversity and regeneration status in the forest are lacking. The study, therefore, aims to study the diversity, population structure and regeneration status of woody species in the Forest of Yerer Mountain. Data were collected using 36 main plots of size 20 m × 20 m for tree/shrub. Two 5 m × 5 m (opposite corner) and five 2 m × 2 m (four at the corner and one at the center) subplots were established in the main plot sapling and seedling, respectively. DBH, height of trees and environmental data (altitude, latitude, longitude, aspect and slope) were recorded. Thirty-one indigenous woody species that belong to 23 families were observed. The Shannon-Wiener diversity indices of woody species in the study sites were 2.0, 2.14 and 2.38 in the higher, middle and lower altitude, respectively. The density of seedling, sapling, shrubs and trees were 6383, 1022,481 and 115 ha^{-1}, respectively. Seven woody species (*Juniperus procera*, *Pittosporum abyssinicum*, *Buddleja polystachya*, *Rhus retinorrhoea*, *Croton macrostachyus*, *Prunus africana* and *Acacia bussei*) dominated the forest while *Juniperus procera* is the most dominated one (95 %). The structural analyses of the whole community of the study area shows a reverse "J" shape pattern, which indicate healthy regeneration status of woody species. However, the population structure of the dominant species exhibited unhealthy structure. The study concluded that the forest is diverse, however, dominated by small-sized tree/shrub species that is under early stage of succession after disturbance. Therefore, intervention of forest management practices to enhance its diversity and natural regeneration is needed.

Keywords: Evenness, Frequency, Important value index, Richness

Phenology of Selected Indigenous Tree Species in Gera Natural Forest, Southwest Ethiopia

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Abstract

Four indigenous tree species; *Cordia africana*, *Pouteria altisima*, *Podocarpus falcatus* and *Hagenia abyssinica* were studied for their phenology. The study was conducted in Gera Natural Forest Southwest Ethiopia. A total of 40 matured trees, 10 trees from each species, were selected and marked. Phenological data including leaf flushing, flowering and fruiting was taken between 2014 to 2017 two times in a month. The result revealed that pattern of leafing, flowering and fruiting are following the rainfall pattern of the study area. The phonological calendars of the studied trees species were prepared. *Podocarpus falcatus* and *Pouteria altisima* don't lose their foliage all year round. Flowering was not observed by *Podocarpus falcatus,* phonological calendar not prepared for this species*.* Leafing and flowering of *Hagenia abyssinica* occur from October to December and from January to February respectively. Leafing by *Pouteria altisima* is all year round and flowing is from April to May. Also fruiting for this species is between January to August. Leafing in *Cordia africana* is in between September and August; and flowering occur between January and September. *Fruiting in Cordia africana* is also from November up to December.

Keywords: Leafing, Mature, Flowering, Fruiting

Introduction

Phenology is defined as the scientific study of the seasonal timing of life procedures (Sulistyawati et al., 2012). It focuses events in nature and cyclical biological events. These events can include flowering, leaf unfolding (or budburst), seed set and dispersal, and leaf fall (Lechowicz, 2002). Among these flowering is the most important as it varies vary with geographic locations and trees (Bawa*et al*., 2003), which can affect the reproductive output of the plants. Also, the phenological events are influenced by climatic factors and variables thus less predictable from year to year. Thus, phenological studies are important for the conservation and management of the biological resource we have as as well as for the better understanding of the ecological adaptations of plant species and community-level interactions.

Although phenological knowledge of various trees has been accumulating globally, such information from Ethiopian natural forests is critically lacking. Such information is basic to understand the biological processes and the functioning of the forest ecosystem. Thus, this type of study will help to understand various phenophases of valuable trees in the context of global climatic change scenario at local level. Moreover, developing viable local conservation strategies for the tree species in any locality depend on the ability to realize the vegetative and reproductive potential of the species which overlay on the species phenology. Also, the timing and duration of flowering and fruiting, for instance, is crucial in understanding forest regeneration dynamics as seasonality affects the reproductive output and performances such as seed production, germination, survival, and seedling growth. This paper presents the phenology of four indigenous trees from the Southwest part of Ethiopia. The results obtained would help to stem appropriate periods of seed collections and handling technologies that would be applicable in similar agro-ecological zones of the country.

Materials and methods

Description of the study area

The study was conducted in Gera forest of Oromia region, South West Ethiopia (Figure 1). It is located between 7^0 $13^|$ - 8^0 $56^|$N and 35^0 $52^|$ - 37^0 $37^|$ E. The total area of the studied forest is 113,514 ha (Cheng *et al.,* 1998). This forest is rich in biodiversity and having large plantation forest area. Participatory forest management is a common practice in the studied forests and so far, a total of 81 Forest user associations were established to manage 63,828ha of forest land. The total population living in the forest area is 76, 571 individuals in 17,473 households (Cheng *et al.,* 1998).

Climate

Daily climatic data of the study area was collected from Chira meteorological station which is located $7^0.44^{\|}07^{\|}$ latitude and $36^0 14^{\|}06^{\|}$ longitude 8 km from the study area at elevation of 2095 ma.s.l. The data was obtained from West Oromia Metrological Service Center. From this climatic data mean of precipitation and temperature for seven years (2012–2018) distribution is presented in Figure 2. The area showed higher mean monthly rainfall from April to September that ranges from 157–228mm (rainy season), while from November to March it received lower mean monthly rainfall ranging from 26–98 mm (dry season). The monthly rainfall in the month of May in the years 2015 and 2016 was found to be low (<100mm) because it is a transition between dry season and beginning of rainy season. The area has also experienced a relatively higher temperature of about 21^0c – 28^0c from January to March and having a minimum temperature of 10^0c - 12^0c during the month of October to December.

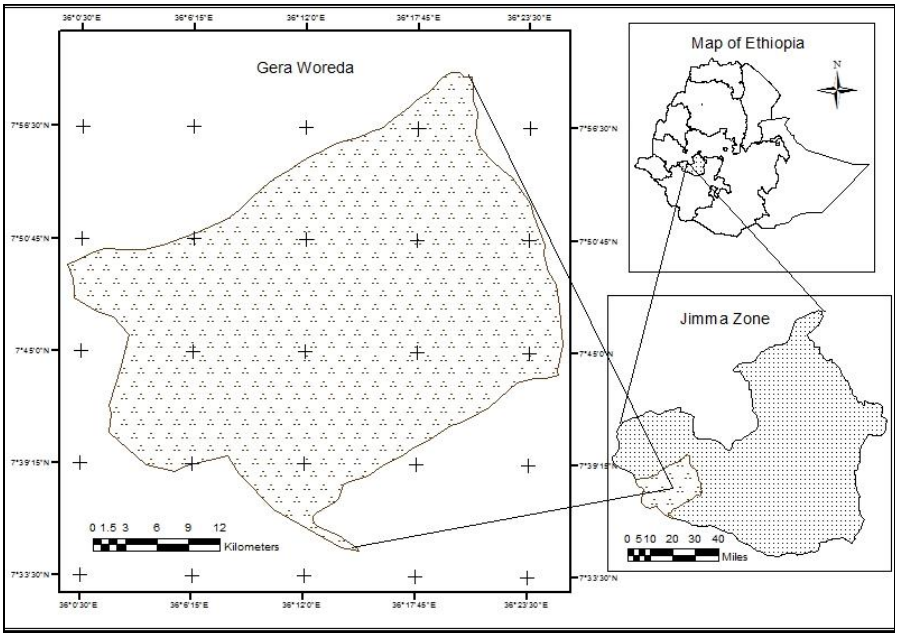

Figure 1 map showing Gera district where the study area was located

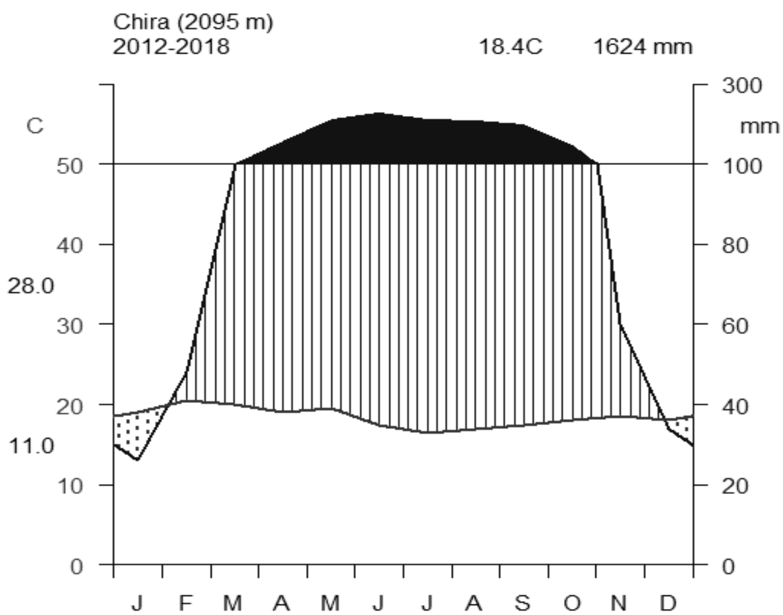

Figure 2 Climadiagram of Chira station from 2012-2018 (NMSA, 2018)

Description of the Study Species

The study focused on phenophases of four important indigenous tree species namely; *Cordia africana*, *Pouteria altisima, Podocarpus falcatus* and *Hagenia abyssinica.* These species are known to have significant ecological and economic importance and widely grown in the area.

Cordia africana is a small to medium-sized evergreen tree, up to 30 m high, heavily branched with a spreading, umbrella-shaped or rounded crown. Bole typically curved or crooked. Bark greyish-brown to dark brown, smooth in young trees, but soon becoming rough and longitudinally fissured with age (Orwa*et al.,* 2009).

Podocarpus falcatus is an evergreen tree up to 46 m in nature but quite smaller if planted, with a long clean and cylindrical trunk. Leaves vary in disposition sometimes being spirally arranged, but at others in two opposite or sub-opposite ranks (Orwa*et al.,* 2009).

Hagenia abyssinica is a slender tree up to 20 m tall, with a short trunk and thick branches; branchlets covered in silky brown hairs and ringed with leaf scars. Bark thick, brown or reddish-brown and readily peeling. No thorns or buttresses. Leaves compound, 40 cm long, in terminal tufts; leaflets pale or bright green above, with silvery hairs below, reddish and sticky when young, 3-6 pairs plus a terminal leaflet, each about 10 cm long; margin finely toothed and fringed with long hairs; leaf stalks 12 cm long, with expanded wings formed from the stipules, densely hairy on the underside. These species are widely distributed in tropical Africa and their ecology and biogeography has been discussed elsewhere cited in (Tesfaye*et al.,* 2011).

Methods

Tree phenology

Within the forest site, 10 trees of the targeted tree species were selected. The selected trees could be dominant or co-dominant in the plot, but are easily visible, crowns of each species from representative provenances, with in the permanent plots. Then, a continuous monitoring and data recording on their flowering (flower initiation, peak flowering time, flower shading) and fruiting (fruit initiation, fruiting development, fruit maturity and dispersal time) were recorded based on observation made at intervals of 15 days for three years.

Results

Sequential phenophasese

The phenophases of targeted tree species were recorded with particular consideration, and four phenophases were noticed (Table 1).

Flower and fruit phenology

The flowering of *Hagenia abyssinca* opens at the beginning of October when the dry season in the years. Although regularity was not followed, the full manifestation of the flower was observed at the end of February. Fruit on setting and maturation for *Hagenia abyssinica* were observed between January to through February parallel (Figure 3).

Table 1 Summary of observed phenophases of the targeted tree species from 2014 to 2017 in the Gera forest, South West Ethiopia.

Species	**Phenophasese**	**Month**
Cordia africana	Flower set	June- July
	Full flower	July-September
	Fruit set	September-October
	Ripe fruit	November-December
Hagenia abyssinica	Flower set	October-November
	Full flower	November-December
	Fruit set	November-December
	Ripe fruit	January-February
Pouteria altissima	Flower set	April – May
	Full flower	May-June
	Fruit set	July-August
	Ripe fruit	August - September

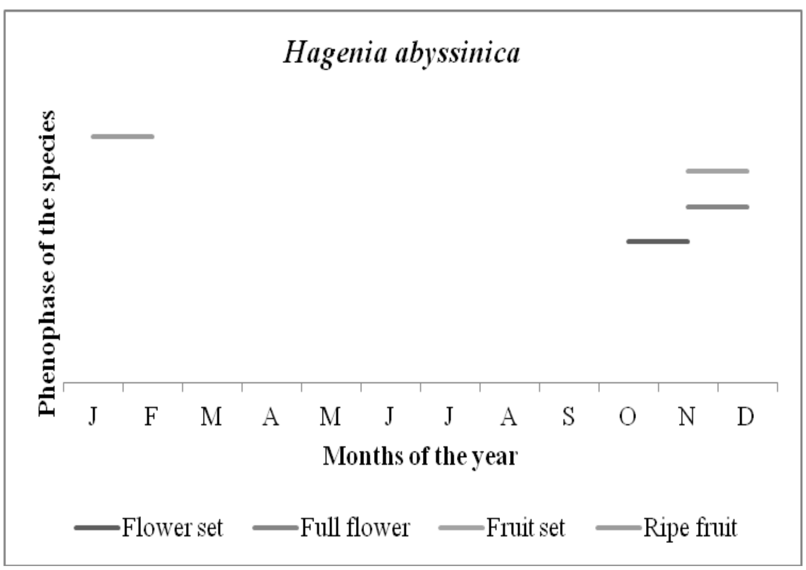

Figure 3 Flowering and fruiting of *Hagenia asbyssinica* from January to December of 2014 to 2017 in Gera forest. Lines in color refer to phenology during the months.

The long period between flowering and fruiting was observed for *Pouteria altissima*. In this species, flower flushes in early April and peaks in May. Fruiting starts in June and maturity reaches the peak in September (Figure 4).

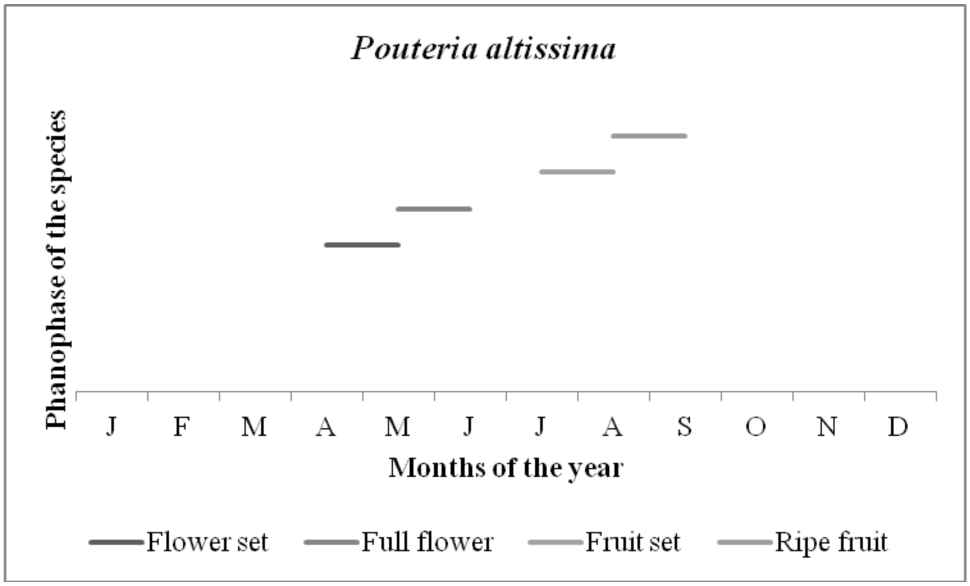

Figure 4 Flowering and fruiting of *Pouteria altissima* from January to December of 2014 to 2017 in Gera forest. Lines in color refer to phenology during the months.

Steady flowing and fruiting were also observed in *Cordia africana*. Flowering starts in June and fully flushes in September. During this time trees were transferred into fruiting. Then, at the beginning of September, fruiting started, and maturation was in December (Figure 5).

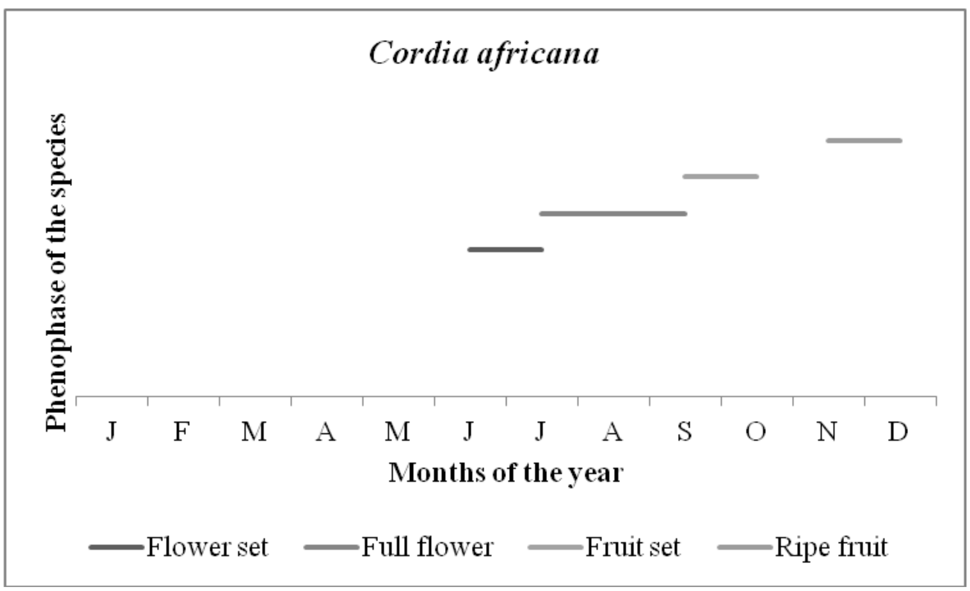

Figure 5: Flowering and fruiting of *Cordia africana* from January to December of 2014 to 2017 in Gera forest. Lines in color refer to phenology during the months.

Discussion

The leafing, flowering and fruiting periods of *Cordia africana, Podocarpus falcatus, Hagenia abyssinica* and *Pouteria altissima*were monitored from May 2014 to June 2017 in the Gera afromontane. Based on the three years phonological data collected, the phonological calendars for the tree species under the study were determined. Among the tree species under the study *Hagenia abyssinica* and *Podocarpus falcatus* were evergreen with foliage (leaves) occurring all the years round.

Hagenia abyssinica bears compound leaves, with terminal tufts; leaflets pale or bright green throughout the year. The field observed data showed that flowering took place from October to December and the fruiting period was extended from January to February. Flowers of *Hagenia abyssinica* are looking handsome multi-branched, terminal, drooping panicles up to 60cm long and 30 cm wide, polygamo-dioecious in nature. The fruits are small, dry, winged, and single seeded.

Pouteria altissima exhibit leaves during the periods of data collection. The observed data revealed that *Pouteria altissima* can give flowers from April up to May and also bears fruits from June to August. *Cordia africana* shade leaves from January to February. The tree gives flowers from July up to September and bears fruits from November up to December. In most species flowering pattern was strongly seasonal and annual. It was reported that fruiting was non-seasonal and extended over several months of a year and the peak fruiting period occurred around mid to late of the long dry season Tesfaye (2008).

Conclusion

The flowering and fruiting period seemed to have quite a different pattern. According to the observation made during the study, fruiting period seems to last longer than flowering period for instance, *Pouteria altissima* and *Cordia africana*. During the study, it was rather difficult to observe flowering compared to fruiting. This might be due to lack of visibility of flower compared with fruits, either because of the weather, tree height, or size. The data of flowering species gathered tended to be underestimated. Although the overall flowering and fruiting pattern cannot be clearly identified, the most notable phenomenon was both events reached their peaks during dry seasons. Therefore, the results obtained from this study would help the natural resources management agents and other interested stake holders to use the appropriate seed collection seasons of the four species considered in this study area.

Acknowledgment

The authors would like to thank the initiators of the project and also for those who prepared the project proposals. Special thanks go to Mr. Nigatu Ararso who started the experiment and handover the previously collected data of the phenology. Our thanks are also to Mr. Tibebu Shiferraw, Mr. Mehaammed Abdella and Mr. Raya Abajobir who assisted us in the data collection. Funding for this study was provided by the Ethiopian Environment and Forestry Research Institute.

Reference

Bawa, K. S., H. Kang and Grayum, M. (2003). Relationships among time, frequency, and duration of flowering in tropical rain forest trees. American Journal of Botany, 6: 877-887.

Cheng, S., Hiwatashi, Y., Imai, H., Naito, M. and Numat, T. (1998). Deforestation and Degradation of Natural Resources in Ethiopia: Forest Management Implications from a Case study in the Belete-Gera Forest. Journal of Forest Resources, 3:199-204.

Fenner, M. (1988). The phenology of growth and reproduction in plants.

Lechowicz M.J (2002). Phenology. The Earth system: biological and ecological dimensions of global environmental change, 2:461–465.

Orwa C, A Mutua, KindtR, Jamnadass R, S Anthony. (2009). AgroforestreeDatabase: a tree reference and selection guide version 4.0

Sulistyawati, E., N. Mashita, N. N. Setiawan, D.N, Choesin and Suryana, P. (2012). Flowering and Fruiting Phenology of Tree Species in Mount Papandayan Nature Reserve, West Java, Indonesia Tropical Life Sciences Research, 23(2): 81–95.

Tesfaye G., D. Teketay, M. Fetene and Beck.E. (2011). Phenology of seven Indigenous tree species in a dry Afromontane forest, southern Ethiopia

Tesfaye.G. (2008). Ecology of Regeneration and Phenology of Seven indigenous Tree Species in a Dry Tropical Afromontane Forest, Southern Ethiopia.

Zhang, G., Song, Q., Yang, D. (2006). Phenology of *Ficusracemosa* in Xishuangbanna, Southwest China.Biotropica, 38: 334-341.

The effect of Natural Gaps on Regeneration of Kafa Afromontane Forest, Southwest Ethiopia

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Abstract

Forest canopies are changing continually because of natural disturbance as trees grow up and die on a tree-by-tree basis. This dynamism continuously reshapes forest structure by filling the gaps with younger trees. It passes through diverse stages that include the death of canopy trees that initiate gap formation, recruitment and gap construction stages. The over all processes depend on several physical and biological factors. Thus, understanding of the gap dynamics in natural forests is principal for forest restoration, sustainable management and conservation. This study was conducted at Kafaafromontane forest, located in Gimbo and Gawata Districts of Kafa Zone at 450km west of the capital Addis Ababa. Plots with an area of four hectare (200 m x 200 m) were selected systematically inside the main forest area in each of the three sites (Yeyibto, Achewa and Saja). Inside these plots, four transacts were laid 50m apart from each other. For each forest gap encountered along these transects, the longest distance between any two-canopy and the largest distance perpendicular to the length was measured and fitted using an ellipse formula. Distances from the centre of the gap to the edges of the gaps was measured in eight compass directions, namely 0, 45, 90, 135, 180, 225, 270 and 315 and a sketch map of the gap was drawn. The result showed that the mean gap size of the study area was 223.31m^2 with standard deviation of 152.14m^2. Most of the gaps were caused by snapping (43%), followed by broken branches that account for 29% of the gap former trees. About 57% of the gaps were categorized as smaller gaps. Within these gaps seedling of 36 woody species belonging to 21 families were recorded. Among these Rubiaceae was the most dominant family, which constituted seedlings of six woody species. The population structure of the seedlings showed an inverted J-shape

Keywords: Forest gap size, natural diturnance, canopy disturbance, natural regeneration

Introduction

Forest canopies are in a dynamic state, changing continually as trees grow up and die, others replace them, and these circumstances are common by replacement of trees usually by a tree-by-tree basis because of gap formation (Runkle, 1992). Gaps in the forest canopy are important for the regeneration of forest species and represent a different microenvironment compared to the forest understory. The gaps favor seedlings of shade-intolerant species to be established and at least few may reach to the canopy layer in these gaps (Yamamoto, 2000). Natural disturbances are among the major phenomenon that result in canopy gaps formation (Dietze and Clark, 2008; Wiafe, 2014). Particularly, Afromontane forests are subject to a wide range of disturbances of variable duration, intensity, and frequency (Wiafe, 2014). The presence of gaps succeeded by natural regeneration is important in forest ecosystem restoration (Omoro and Luukkanen, 2011, Arihafa and Mack, 2012). The incidents portray the death of one or more canopy trees or fall of large branches that resulted in the formation of small openings on the canopy of forests (Yamamoto, 2000).

Gap formation depends on several physical and biological factors involving canopy closure, intensive growth of advanced regenerations and species colonization (Arriaga, 2000). It passes through diverse stages, but the most important stage is the initiation stage known as gap stage (Schnitzer & Carson, 2010). This stage contributes in altering light availability, to enhance seedling and sapling establishment among species, which otherwise blocks most light from reaching the forest interior (Numata et al., 2006). Gaps help to maintain tree diversity, density and niche partitioning (Denslow, 1980). Thus, regeneration processes are associated with gap building phase (Arriaga, 2000). The occurrence particularly interplays with recruitment, allowing the coexistence of species that otherwise could not make it (Brokaw & Busing 2000; Lima, 2005). Finally, construction stage takes place where the canopy gaps are forming virtually closed by tree vegetation (Lima, 2005).

Size distribution and frequency of gap occurrences in a forest is a function of local climate, topography, soil, bedrock and the composition and size distribution of trees (Denslow, 1980). This is the result of the shift in microclimate near and below the ground, such as light intensity, temperature and drought stress at the soil surface, as gap size. The micro-climatic features of a canopy gap might change with its size from one season to another, and even with extreme climate events. These conditions may be optimal for certain species at a certain point in time, though they can change in a mid/long term (Brown, 1993). Some plant species can only regenerate in a narrow range of light availability (Whitmore, 1990). In addition to the marked variation in the canopy opening, the reduction of basal area and the increase in gap-area found in canopy gaps that can also interfere in the process of regeneration and in the growth of tree seedlings (Sapkota and Odén, 2009).

Traditional gap theory assumes that shade-intolerant species, which have profuse seed production and rapid seedling growth, are best adapted to exploit the high light environment in gaps. The colonization of gaps by species of different categories or successional groups are influenced by eco-physiological responses of species in the area by the seed bank and by seedlings and/or remnant individuals, as well as by post-disturbance migrant species via dispersal processes (Martins et al., 2009). Moreover, it will also depend on the time the opening has occurred, the opening size, the substratum conditions, and the relationship with herbivores as well as on density dependent factors. Increasing population size reduces available resources limiting population growth. In restricting population growth, a density-dependent factor intensifies as the population size increases, affecting everyone more strongly (Hartshorn, 1980). Understanding the dynamics of gaps in tropical forests is paramount for forest restoration, sustainable management and conservation of forest remnants (Martins et al., 2002). This study aims to identify ecological patterns related to richness and the potential of natural regeneration of tree species in a natural gap represented by gaps of different sizes found in Bonga Afromontane forest, southwest Ethiopia.

Material and methods

Site description

This study was conducted in Kafa Afromontane forests, Gimbo and Gawata Districts, located at 450km west of the capital Addis Ababa (Figure 1). The area lies between 6^0 16^{ll} - $8^0 13^{ll}$N latitude and 35^0 12^{ll} - $36^0 47^{ll}$E longitude. The area is characterized by a long rainy season that extends from March through October with mean annual rainfall of 1800mm. The area has a relatively higher temperature in the months December to February with maximum temperature that ranges from 26^0C to 29^0C and the mean annual temperature of the area is 19^0c (Senbeta*et al.,* 2014).

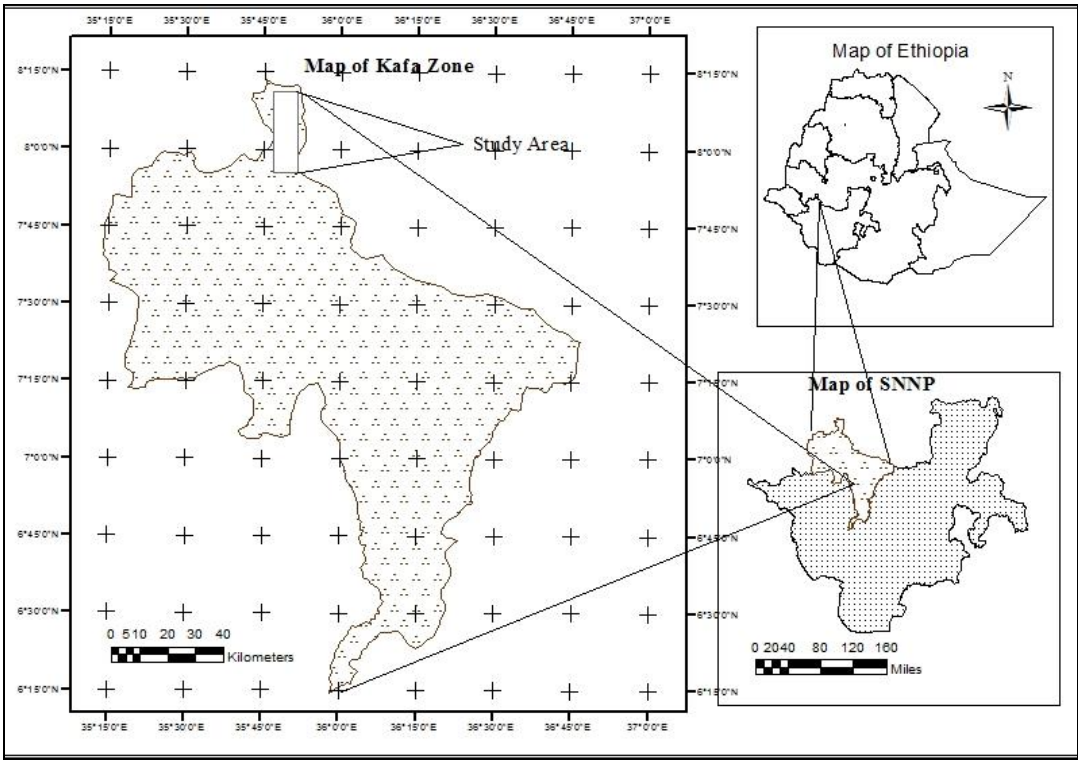

Figure 1 Map showing location of Kafa Zone where the study area is located

The study area lies within the altitudinal range of 1400 to 1650m asl. Forests of this area are characterized as moist Afromontane forest, which is situated in areas that receive rainfall for a longer period. The biggest trees of this forest community reach over 150cm in diameter (Senbeta et al., 2014). Common trees in this area include *Pouteriaadolfi-friederici, Ficus species, Syzygium guineense, Olea welwitschii* and *Trilepisium madagascariense.*

Methods

Data Collection and Analysis

For this study, a forest with an area of four-hectare (200m x 200m) plot was selected systematically inside the main forest blocks of Kafa forest; one plot at each of the three sites (Yeyibto, Achewa and Saja). Inside these plots identification of natural gaps was made along four line transacts laid 50m apart from each other. Gap detection was made during field observation when the following indicators were encountered: wood debris, broken branches, snapped off trees or dead canopy tree boles which have over 10m long and created an area of over 40m^2 following Goulamoussène *et al.* (2017). The longest distance between any two-canopy trees i.e. gap length and the largest distance perpendicular to the length (gap width) were measured for each gap encountered. Distances from the centre of the gap to the edges of the gap was measured in eight compass directions, namely 0, 45, 90, 135, 180, 225, 270 and 315 and a sketch map of the gap was drawn (Figure 2). The area of each gap was calculated by the ellipse formula following Runkle (1981), where: A -is gap area, L- is the longest width and W -is the longest perpendicular distance.

$$A = \frac{\pi LW}{4}$$

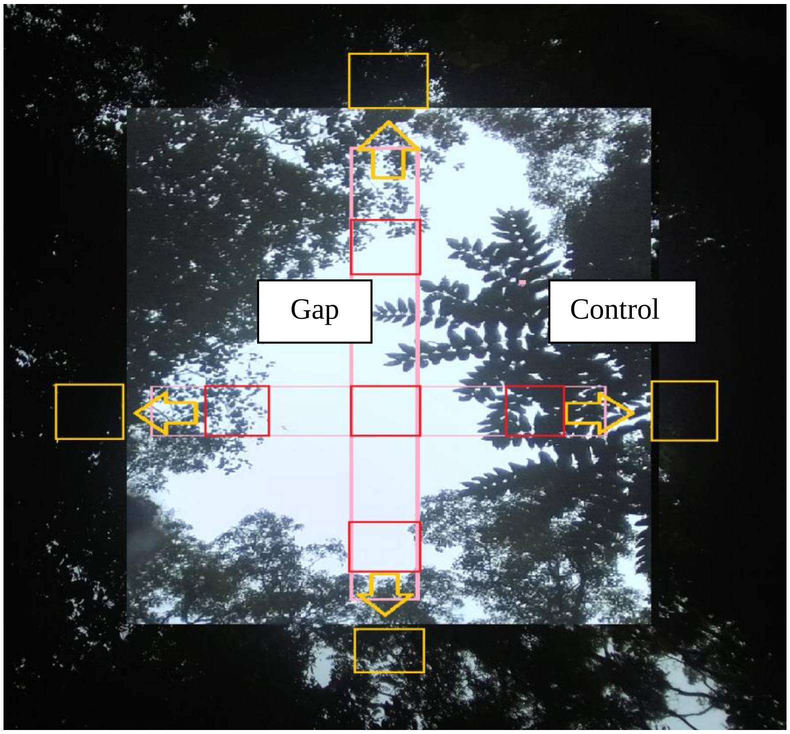

Figure 2 Gap area measurement schematic diagram in Bonga forest, south west Ethiopia

Gap makers are the trees that initially fell to create gaps (see Figure 3). These species were identified during field collection by looking the intact leaves when available and recognized remnants. Gap former trees were categorized based on the category set as standing dead, tree fall by snapping off, tree fall by uprooting, broken branch/crown and branch fall (LuiQinghong & Hytteborn, 1991). Measurements of collar diameter and heights of all woody seedlings and saplings were made in five subplots of 3 x 3m, which was set up one at the center and four-border areas of the gaps. Similarly, measurements were made in four control plots of 3m by 3m outside gaps separately. The measurement was used for comparison of seedlings located in the extended gap zone of a canopy gap ('gap' seedling) and under a closed forest canopy ('forest' seedling) following (Peter *et al.,* 1998).

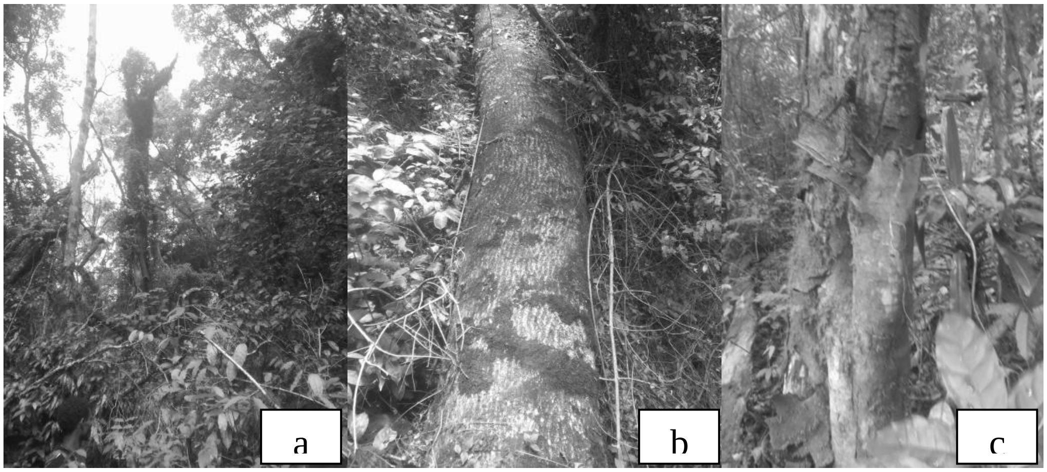

Figure 3 Some of the causes of gap formation in Kafa moist Afromontane forest (a-broken branch, b- snapping off and c-standing dead)

Calculations of dominance, frequency, and density values were conducted for each species. The correlation between species richness and canopy–gap size was analyzed using a linear correlation to investigate whether species show a response to size variation in canopy openings caused by gaps of different sizes. The similarity of species present in canopy gaps were investigated using the Cluster Analysis. Gap size was categorized as small (<200m^2), medium (200-400m^2) and large (>400m^2). Shannon-Wiener Diversity Index (H), Evenness (E) and density (number of stems per ha) in the gaps and control forests were also carried out. The turnover time of the forest was calculated by dividing the total studied area by the total area covered by gaps created during the last year. This way, an estimate of the total number of years necessary to cover the entire plot with gaps (turnover time), was obtained (Hartshorn 1978).

Results and discussion

Gap Sizes

The result showed gap sizes ranged from 75 to 555m^2 with the mean gap size of the study area being 223.31m^2 with standard deviation of 152.14m^2 (Table 1).

Table 1 Area of different gaps and their relative frequencies

Category	Area Class	Mean Area in (m^2)	Number of gaps	Percentage (%)
Small	< 200	117 ± 42	8	57.1
Medium	200-400	289 ± 61	4	28.6
Large	>400	513 ± 59	2	14.3
Mean		223 ± 152		

Most of the gaps had an area that falls below 200 m^2 (57.1%, n=8) of the gaps. While four gaps (28.6%) were grouped as in gap size class 200-400m^2. On the other hand, gap size which has an area of above 400m^2 was the least encountered (14.3%, n=2). Generally, the size distributions of the gaps skewed to the left.

Gap maker species

Gap maker species were found to be *Olea welwitschii, Ehretia abyssinica, Polyscias fulva, Prunus africana, Syzigium guineense, Schefflera abyssinica* and *Elaeodendron buchananii*. The largest proportions (36%) of gaps were created by *Olea welwitschii* (Table 2). This species is also the most dominant tree species in the forest area.

Table 2 Gap former tree species in Kafa moist Afromontane forest and number of gaps

Gap maker tree Species	Average Dbh (cm)	Average Height (m)	Number of gaps	Percentage (%)
Olea welwitschii	47.12	29.9	5	35.71
Prunus africana	55.00	28.0	2	14.29
Shefleria abyssinica	77.50	29.5	2	14.29
Syzigium gueneense	32.00	21.0	2	14.29
Ehretia abyssinica	24.00	35.0	1	7.14
Elaeodendron buchananaii	74.00	26.0	1	7.14
Polyscias fulva	24.00	35.0	1	7.14

Causes for Gap formation

The major causes of gap formation in the study area were caused due to four reasons, namely snapping off, uprooting, broken branches and standing dead. Among these snapping off accounted 43% (n=6) of the causes of gap formation (Figure 4). The study by Arihafa and Mack (2012) in a tropical rainforest of Papua New Guinea also showed that higher probability of gap formations was due to boles snapping off than uprooting of trees. Broken branches constituted 29% (n=4) and uprooting and standing dead constitutes 21% and 7%, respectively.

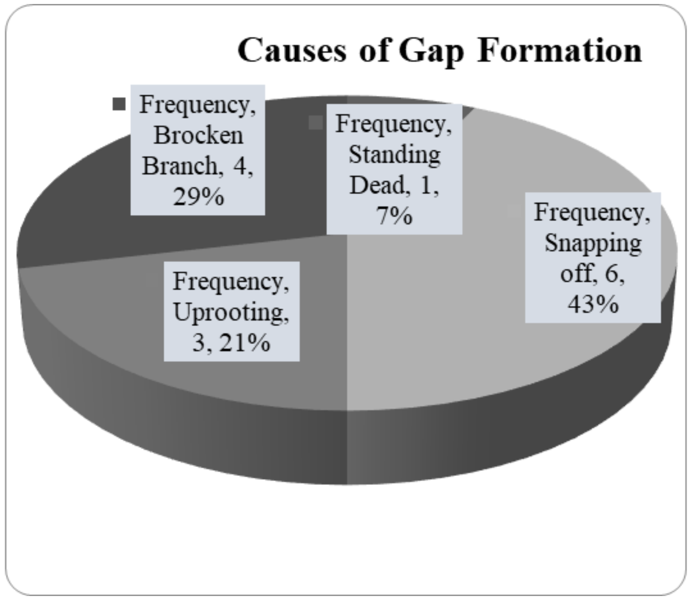

Figure 4 Causes of gap formation in Kafa afromontane forests south west Ethiopia

There were 36 species of woody seedlings belonging to 21 families recorded in 14 gaps and at three sites (Table 3). The number of tree species recorded in control plots was about 30 species. The gap area had higher density of 11,274 stems per hectare as compared to 7974 in control plots. There was also more species richness (36) in canopy gaps than (30) species in control plots. Evenness of the area was found to be 0.390 and 0.448 for gaps and control plots, respectively. Shannon diversity was 2.643 for gaps and 2.599 for control plots. Simpson index was 0.879 for gaps and 0.873 for control plots. The study indicated that there were higher species diversities in canopy gaps than the closed forest/control plots (Figure 5).

Table 3 Comparison of diversities of Kafa Afromontane forest gaps and control plots

Parameter	**Gap**	**Control**	**p-value**
Number of species	36	30	0.001
Number of seedlings	11,274	7,974	0.000
Dominance	0.121	0.127	0.034
Shannon H	2.643	2.599	0.012
Evenness e^H/S	0.390	0.448	0.001
Simpson indx	0.879	0.873	0.034

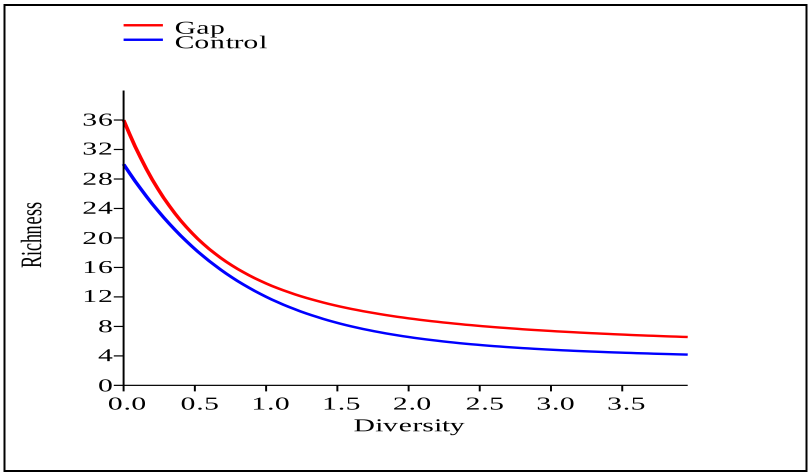

Figure 5 Diversity profiles of gaps and control plots

Table 4 Plant Families with their number species occurred in Kafa afromontane forest

S/N	Family	Species number per site			Total	% age
		Yeyibto	Achewa	Saja		
1	Rubiaceae	6	5	3	6	17.14
2	Fabaceae	2	2	3	3	8.57
3	Moraceae	2	1		3	8.57
4	Asteraceae	1	1		2	5.71
5	Celastraceae	1		1	2	5.71
6	Meliaceae	1	1	2	2	5.71
7	Oleacae	2	2	1	2	5.71
8	Sapindaceae	1	1	1	2	5.71
9	Aquifoliaceae	1			1	2.86
10	Araliaceae	1	1		1	2.86
11	Boraginaceae			1	1	2.86
12	Euphorbiceae	1	1		1	2.86
13	Icacinaceae	1	1	1	1	2.86
14	Melianthaceae	1	1		1	2.86
15	Myrsinaceae			1	1	2.86
16	Myrtaceae	1			1	2.86
17	Pittosporaceae	1	1		1	2.86
18	Rosaceae	1		1	1	2.86
19	Rutaceae	1	1	1	1	2.86
20	Sapotaceae	1	1	1	1	2.86
21	Ulmaceae		1		1	2.86
	Total	**25**	**20**	**16**	**36**	**100**

The three most abundant families encountered in the study area were Rubiaceae (6 species), Fabaceae (3) and Moraceae (3). The three dominant families Rubiaceae, Fabaceae and Moraceae contributed 40% of the total species abundance. Out of all tree families, only eight of them were represented by more than one species while the rest 13 families were represented by a single species (Table 4).

The patterns of height class distribution indicated the general trends of population dynamics and recruitment processes of a given species. The evaluation of selected tree species revealed six main patterns of population distribution. It occurred as pioneer or light-demanding species which are highly specialized and can only germinate in canopy gaps followed by non-pioneer or shade-tolerant species which are able to germinate under a closed forest canopy but may need canopy gaps at a later stage during their life cycle to reach maturity (Poorted and Arets, 2003). Species such as *Cordia africana, Vernonia auriculifera* and *Ilex mitis* were only recorded in gaps. Whereas, species like *Ekebergia capensis, Lepidotrichilia volkensi,* and *Maesa lanceolata* were specialized to control plots. Most of the species were recorded in both gaps and control plots (Table 5).

Table 5 Dominant tree seedling abundance in Kafa Afromontane forest inside gaps and control plots

Scientific name	Gap Regeneration		Control Regeneration	
	N	Relative Density (%)	N	Relative Density (%)
Chionanthus mildbraedii	3030	29.9	2377	32.8
Rothmanniau rcelliformis	1785	17.6	579	8.0
Elaeodendron buchananii	883	8.7	691	9.5
Oxynanthus speciosus	997	9.8	968	13.5
Deinbollia kilimandscharica	574	5.7	671	9.3
Allophyllus abyssinicum	509	5.0	355	4.9
Albizia gummifera	448	4.4	235	3.2
Vipris dainelli	376	3.7	421	5.8
Galiniera saxifrage	336	3.3	204	2.8
Pouteria adolfi-friederici	311	3.1	231	3.2
Lepidotrichilia volkansis	256	2.5	127	1.8
Bersama abyssinica	243	2.4	135	1.9
Prunus africana	201	2.0	77	1.1
Mellettia ferruginea	199	2.0	181	2.5
Total	**10148**	**100.0**	**7252**	**100**

The height class distribution of the seedling growth inside gaps and control plots indicated that the number of individuals in the lower height class is very high (Figure 6). The lowest numbers of individuals were found in the height class of >200cm increasing with decreasing height. The number of individuals in the gaps was higher than in the closed forests (controls). The population structure regenerating seedlings in the gaps and control plots almost followed a similar trend (Figure 7).

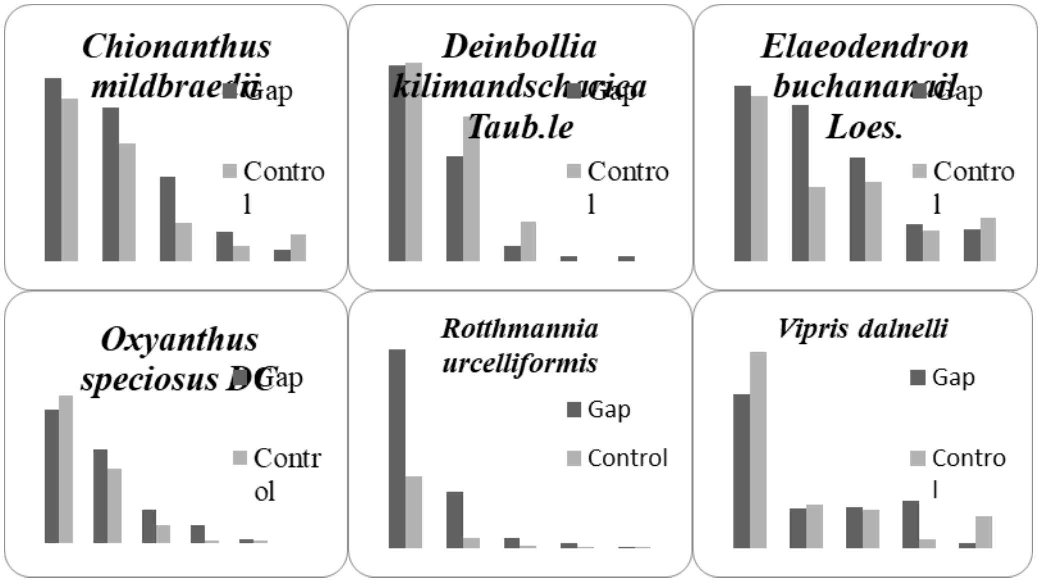

Figure 6 Height class distribution of seedlings and saplings of the six dominant species in gaps and control plots of Kafa Afromontane forest

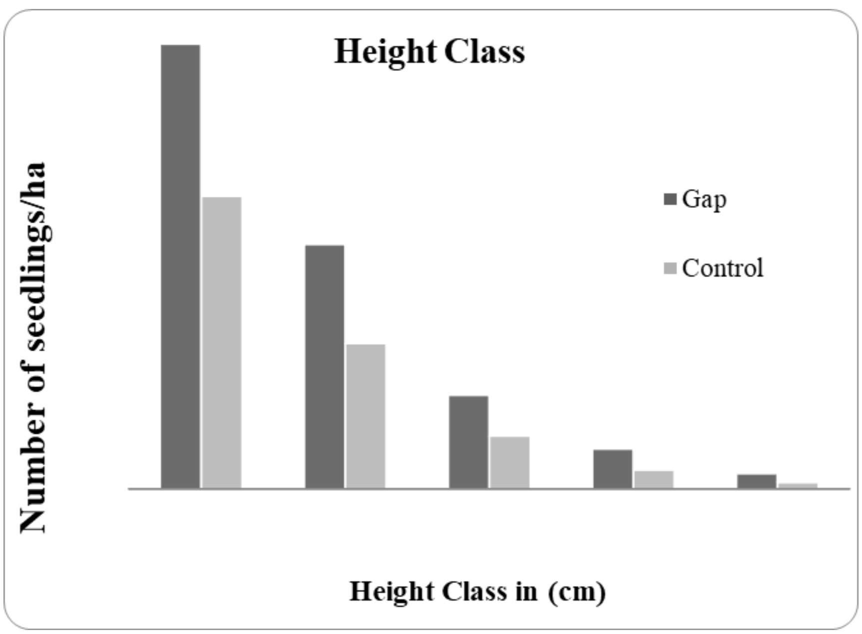

Figure 7 Height class distribution of seedlings and saplings of the communities in gaps and control plots of Kafa Afromontane forest

Conclusion

The study in gap dynamics in Kafa Afromontane forest revealed that natural gaps caused by single tree or multiple trees fall are essential for maintaining the diversity of woody species in the forest. The mode of mortality was mainly related to snapping off the canopy trees. Variations in the gap sizes were observed due to factors such as mode of death of the canopy trees. Regeneration in the forest was low in closed forest as compared to the gaps. The current study of gap dynamics could provide some information on aspects of gap regeneration in the forest where such data can be used in planning sustainable management of the forest.

Acknowledgment

The authors would like to thank the initiators of the project and also for those who prepared the project proposals. Special thanks go to Mr. Girma Meshesha who assisted us in the data collection. The Ethiopian Environment and Forestry Research Institute provided funding for this study, so the Institute deserves great thanks.

References

Arison Arihafa and Andrew L. Mack 2012. Treefall gap dynamics in a tropical rainforest in Papua New Guinea. Pacific Science, 67(1):1-26.

Arriaga L. 2000. Gap-building-phase regeneration in a tropical montane cloud forest of northeastern Mexico.Journal of Tropical Ecology. 16:535-562

Brokaw, N. & Busing, R. T. 2000. Niche versus chance and tree diversity in forest gaps, *Trends in Ecology and Evolution. 15:* 183-188.

Brown, N. 1993.The implications of climate and gap microclimate for seedling growth conditions in a bornean lowland rain forest, *Journal of Tropical Ecology.9:* 153- 168.

Deslow, J. S. 1980. Gap partitioning among tropical rainforest trees, *Biotropica. 12:* 47- 55.

Dietze, M. C., and J. S. Clark. 2008. Changing the gap dynamics paradigm: vegetative regeneration control on forest response to disturbance. Ecological Monographs, 78(3), 331–347.

Hartshorn, G.S. 1989. Application of gap theory to tropical forest management: natural regeneration on strip clear-cuts in the Peruvian Amazon. Ecology 70(3): 567- 569.

Lima, R.A.F. 2005. Estrutura e regeneração de clareirasem Florestas Pluviais Tropicais, Revista Brasileira de Botânica 28: 651-670.

Lui Qinghong and Hytteborn, H. 1991. Gap structure, disturbance and regeneration in primeval *Piceaabies*forest.*Journal of vegetation Science.***2:**391-402.

Martins, S.V., Rodrigues, R.R. 2002.Gap-phase regeneration in a semi-deciduous mesophytic forest, southeastern Brazil.*Plant Ecology.*163:51-62.

Numata, S., Yasuda, M., Okuda, T., Kachi, N. & NurSupardi, M. N. 2006. Canopy gap dynamics of two different forest stands in a Malaysian lowland rain forest. Journal of Tropical Forest Science. 18(2): 109–116.

Omoro L.M.A. and O. Luukkanen. 2011. Native Tree Species Regeneration and Diversity in the Mountain Cloud Forests of East Africa, Biodiversity Loss in a Changing Planet, PhD. Oscar Grillo (Ed.), ISBN:978-953-307-707-9, In Tech, Available from:

http://www.intechopen.com /books/biodiversity-loss-in-a-changingplanet/native-tree-species-regeneration-and-diversity-in-the-mountain-cloud-forests-of-east-africa.

Peter J. Van Der Meer, F. J. Sterck and F. Bongers 1998. Tree seedling performance in canopy gaps in a tropical rain forest at Nouragues, French Guiana. Journal of Tropical Ecology, 14: 119-137

Poorter, L. and Arets, E. 2003. Light Environment and Tree Strategies in a Bolivian Tropical Moist Forest: An Evaluation of the Light Partitioning Hypothesis. Plant Ecology. 166(2): 295-306.

Runkle, J.R. 1981.Gap Regeneration in some old-growth forests of the Eastern United States.Ecology. 62(4): 1041-1051.

Runkle, J. R. 1992. Guidelines and sample protocol for sampling forest gaps. Gen. Tech. Rep. ~NW-GTR-283. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 44 p.

Sapotka, I.P., Odén, P.C. 2009. Gap characteristics and their effects on regeneration, dominance and early growth of woody species. *Journal of Plant Ecology (2) 1:* 21- 29

Senbeta, F., Ch. Schmitt, T. Woldemariam, H. J. Boehmer and M. Denich. 2014. Plant Diversity, Vegetation Structure and Relationship between Plant Communities and Environmental Variables in the Afromontane Forests of Ethiopia. SINET: Ethiop. J. Sci., 37(2):113–130,

Whitmore, T.C. 1990. An introduction to tropical rain forests, Clarendon Press 226p.

Whittaker R. H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Wiafe, E. D. 2014. Tree Regeneration after Logging in Rain-forest Ecosystem. Research Journal of Biology, 2:18–28.

Yamamoto, S-I. 2000. Forest gap dynamics and tree regeneration, Journal of Forest Research 5: 223-229.

Section 6: Environmental Laboratory

Perception of Regulatory Bodies and Service Providers Towards Genetically Modified Organisms (GMOs) in Ethiopia: A preliminary Survey.

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In Press in African Journal of Biotechnology**.**

Abstract

This descriptive research was conducted to obtain scientific information on the perception towards GMOs of regulatory bodies and service providers by administering questionnaires to randomly selected 405 respondents drawn from 5 regional states (Amhara, Afar, Benshangul Gumuz, Somali, and Southern Nations Nationalities and Peoples) and 2 city administrations (Addis Ababa City administration and Dire Dawa City Council). The result shows that the perception towards GMOs of the majority of the regulators and service providers was negative. It was found that 50.9% of respondents, even those who have sufficient information about GMOs, thought GMOs are dangerous for the environment and the society. This study recommends the awareness towards of GMOs for public and regulatory body bodies should be increased by the government through promotion, and increase the media coverage about GM.

Keywords: GMOs; Perception; Information; Regulatory; Service providers

Section 7: Socio-Economics, Policy, Extension and Gender Research

Income Contribution and Adoption Potential of Apple Based Agroforestry on Homestead Farms in West and North Shoa Zones of Ethiopia

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Abstract

Ethiopian highlands have the suitable climatic condition and fewer disease incidences thus are preferred by the most people for habitation. The huge size of population in the highlands becomes the proximate cause of forest and land degradation. To reduce the local people high reliance on the remnant forest, the then Forestry Research Center and GTZ introduced and provided Apple tree seedlings for selected residents in the West and North Shoa Zones of Ethiopia, two decades ago. Four introduced apple varieties viz. Anna, Crispin, Dorset-golden, and Princesa have started fruit yielding to land users/ local farmers. However, despite the provision of such variety of seedlings to the farmers in the area, a study that assessed the contribution of the fruit tree against the offer institutions goals, to the household economy improvement, and the various determinant factors that limit the adoption of the technology was lacking. Therefore, this study was initiated to estimate and compare households' income from apple-based agroforestry system and identify factors that influence its adoption by smallholder farmers in both West and North Shoa Zones of Ethiopia. From three Woredas of the two zones, four potential Kebeles were purposefully chosen, and from which 600 households were randomly selected where 85 were adopters and the remaining 515 were non-adopters. To gather the necessary information both primary and secondary data were collected, and group discussions were conducted. The results showed that farmers predominantly carry out various livelihood activities such as the production of grain crops, livestock, vegetables, and apple fruit. in the agri-horticulture approach, apple trees were integrated with vegetables at homesteads by adopters. In both study areas, the aggregated adopter household mean annual gross income from vegetable + apple fruit was 24,337.22ETB $ha^{-1}yr^{-1}$and mean annual gross income of non-adopters from vegetables was 7480.53ETB $ha^{-1}yr^{-1}$. The income obtained from apple contributes 16.84 percent to the income of agri-horticultural system. The agri-horticulture system contributed three-fold higher gross revenue for adopters in addition to its nutritional value. However, adoption of apple-based agroforestry systems was significantly influenced by the different factor such as formal educational levels (+), a Market problem (-), Disease and Pest (-). To maximize the benefits from the system, interdisciplinary research needs to be conducted to reduce the problem of marketing, disease and pest. Besides, land users are advised to follow integration of apple fruit trees in their food production activities incorporating their own farm resources to minimize input costs.

Keyword: Agri-horticulture system; Apple tree adoption; Household income

Introduction

Fruit-tree-based agroforestry involves intentional, simultaneous association of annual or perennial crops with perennial fruit-producing trees on the same farm unit (Bellow et al 2008). Trees grown on farms for their non-timber forest products such as fruits, nuts, and spices constitute the basis for many vibrant and sustainable farming systems. Because of a high market value of their products and the contribution of fruits to household dietary needs, fruit-tree-based agroforestry enjoys high popularity among resource-limited producers worldwide (Bellow 2004). Farmers prefer fruit-producing species to other trees for on-farm planting (Franzel et al. 1996), and appreciate the dual contributions of food for consumption (Salam et al. 2000) and the potential for income generation (Ayuk et al. 1999). Fruit trees are considered advantageous because of the relatively high returns to labor resulting from low labor inputs (compared with annual crops); moreover, fruit tree-based systems also offer a more uniform distribution of income throughout the year than annual crop systems.

Most examples of fruit-tree-based agroforestry have developed over long periods of time in response to interactions between agro-ecological conditions, plant diversity, and farmer resources and needs. Because of this, the system performance at any given location will depend on several site-specific features. Nevertheless, the system performance also follows some general characteristics such as their potential benefits and limitations that are applicable to wider regions (Bellow et al., 2008). An understanding of such general characteristics of these systems is helpful for adaptation and extension of the system to other highland areas with similar production environments. Successful establishment of Fruit-based agroforestry system in the highland areas can increase farm household income, enrich their diets with essential minerals, vitamins and increase varieties of fruits available in the local markets. However, the relatively "free" availability of forest-based timber- and fuelwood products in some areas are disincentives for growing tree species for those purposes (Hellin et al. 1999).

Promotions of on-farm tree/shrub plantings could also greatly relieve the pressure on the remnant natural forest by providing the variety of forest products (NegussieAchalu, 2004). To minimize farmers pressure on the forest and improve the livelihood of the people the then Forestry Research Centre (FRC), in 2007 and GTZ, in 2008 introduced and provided four apple varieties namely, Anna, Crispin, Dorset-golden, and Princesa, to the dwellers of North and West Shoa Zones of Ethiopia. This study is based on the premise that farmers in land-scarce situations can directly benefit by incorporating fruit trees into an agricultural landscape with few other trees and this also relieve the peoples' pressure to the natural forest. Since, fruit trees enjoy great popularity among subsistence farmers and provide tangible benefits in short time frames (Bellow et al., 2008). Despite the provision of such variety of Apple tree seedlings to the farmers in the area, yet knowledge of critical factors that can lead to the adoption of the system as a land management alternative is not identified. Thus, the objective of the study was to assess the income contribution and various determinant factors in the adoption of Apple based Agroforestry system. We hypothesized that Fruit-tree-based agroforestry would be of interest to smallholder farmers, but that potential differences in adoption rates could be explained by various socioeconomic factors.

Materials and Methods

The study area

The study was conducted in West and North Shoa Zones of Oromia region. Dendi Woreda is one of the 19 Woredas in West Showa zone of Oromia region and consists of 48 Kebeles[2]. It is about 78 km west of Addis Ababa along the Addis Ababa-Nekemte highway. The Woreda lies within the coordinates from $8^0$43'North to $9^0$17' North Latitude and $37^0$47'East to $38^0$20'East Longitude, by relative location, the Woreda shares boundaries with other seven Woredas: Jaldu and Ilfeta Woredas in the north, Dawo and Walliso Woredas in the south, Ejere and Ilu Woredas in the east and Ambo Woreda in the west (DARDO, 2011). Among the 48 Kebeles, the study was conducted in two Kebeles of Dendi Woreda, namely Gare Area and Bejiro Kebeles'. The major fraction of Gare Arera Kebele is covered by forest (68 per cent, the Chilimo National Forest Priority Area) (Amare Haileslassie et al., 2006).

From the North Shoa Zone, Degem and Hindbu Abote Woredas were selected. Degem Woreda, lies between 9^0 47' 29" - 9^0 47' 13'' N latitude and 380 31' 09" - 380 32' 50" E longitudes about 125 Km North of Addis Ababa. The Woreda covers a total land of 67,020 ha with a widely varying altitudinal range of 1500-3450 m.a.s.l., accordingly, 30 % of the total land area lies in high land, 38 % mid high land and 32 % low land. The area receives a mean annual rainfall of 1157mm with a mean maximum temperature of 20^0C and a mean minimum temperature of 8.7^0C (DWARDO, 2009). Degem woreda has eighteen peasant associations from this the dominant Apple based agroforestry producer was Ali doro kebele. From Hiduabote Woreda Yaya Dakabora kebele had high apple fruit production. From North Shoa Zones, two Woreda's selected and two kebeles namely Yaya Dakabora and Ali doro kebele were purposively selected based on production of Apple-based Agroforestry system.

[2] *Kebele* is the smallest governmental administration unit

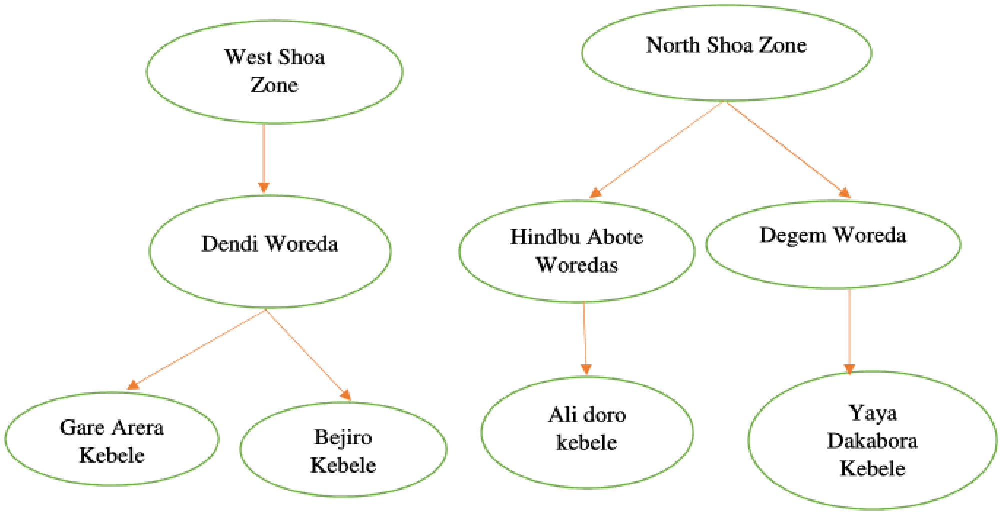

Figure 1 Selected Study areas

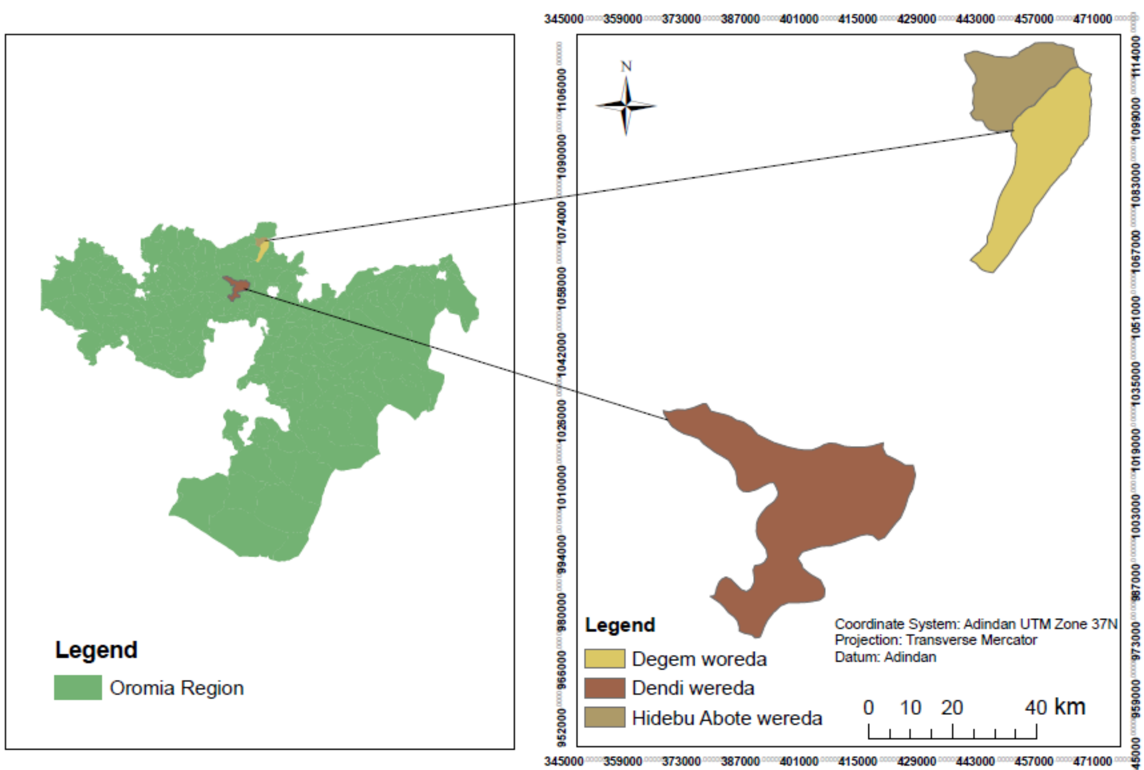

Figure 2 Map of the Study Area

Sampling

Dendi, Degem and Hindbu Abote Woredas were selected based on the productivity of apple-based agroforestry system. Before the selection of appropriate Kebeles, consultation with the expertise of the Woreda agricultural office was made to get information related to potential fruit producer Kebeles. Consequently, four Kebeles namely, Gare Area, Bejiro, Alidoro and Yaya Dakabora were purposefully selected based on high fruit production and accessibility.

Several rules-of-thumb have been suggested for determining the minimum number of subjects (households) required to conduct multiple regression analysis. For this study, a rule-of-thumb that $N \geq 50 + 8m$, where N is the minimum number of households and m is explanatory variables, was used (Green, 1991). The explanatory variables hypothesized to influence the adoption of apple-based agroforestry in this study were fourteen. Thus, a total of 600 farm households were randomly selected from the purposively selected four Kebeles. In each selected apple growing Kebeles, two groups of farmers were identified as adopters and non-adopters using adoption category as stratification criteria. From each stratum using simple random sampling technique, proportional to the population of Kebeles identified, study sample respondents were selected randomly from the list of household heads. Accordingly, from all selected Kebeles a total of 85 adopters and 515 non-adopters were randomly identified.

Source and Methods of Data Collection

Both primary and secondary data were collected to address the objectives of the study. Primary data were collected from sampled household heads by conducting the formal survey using a structured questionnaire. In addition, information collected using structured questionnaire was supplemented with group discussions (GDs). The discussion was conducted to confer specific issues related to the purpose of the study by forming small groups with a homogeneous composition. Hence, eight GDs were held with selected farmers in the specific Kebeles and the researcher thoroughly investigated the advantage that adopters achieve and the various determinant factors that limit the adoption process. Secondary data that were important for supporting the primary data have been collected from the Zone and Woreda offices.

Method of Data Analysis

To meet the objectives of the study, both descriptive and econometric analysis was employed. To answer the question of factors influencing the adoption of apple-based agroforestry system, a binary logistic regression model was used. The model used to describe the relationship between dependent variable and a set of independent variables. The dependent variable was binary or dichotomous and had only two groups: adopters and non-adopters, whereas, the explanatory variables could be continuous, categorical or dummy (Long and Freese, 2006). The logistic function was used since it represents a close approximation to the cumulative normal distribution and is easier to use than other types of model (Gujarati, 2004). Logistic regression model has been used by many agroforestry adoption studies to analyze dichotomous adoption decisions in which the dependent variable is binary: 1 if household head is the adopter, 0 otherwise (Mercer, 2004).

Variables Used in the Empirical Model and Hypothesized Effects

Dependent variables: In this study, adoption of apple-based AF system used as a dependent variable.

Independent variables: It is hypothesized that farmers' decision to adopt or reject new technologies at any time is influenced by the combination of various factors. This includes both dummy and continuous variables such as: household characteristics, socioeconomic characteristics and institutional characteristics in which farmers operate. In this study fourteen explanatory variables were considered as the determinant factors for the adoption of the system.

Table: 1. Definition of independent variables, included in the econometric model and expected sign

Variable code	Description	Unit of measurements	Expected sign
ADOPTION	Apple fruit adoption	1=adopter, 0=non-adopter	
EDU	Education level of the Household head	The level of formal education	+
LABSHO	Labor Shortage	Minimum number of available labor	-
TLAHOLD	Total Land Holding	Size of Land	+
OFFFARMIN	Off-Farm Income	Amount of money	-
CREDIT	Access to credit	1=Yes, 0=No	+
EXTEN	Access to Extension	1=Yes, 0=No	+
MARPROB	Market Problem	1=Yes, 0=No	-
DWATER	Distance from source of water	1=Yes, 0=No	-
LONPROPER	Longer production period	1=Yes, 0=No	-
AGE	Age of household head	Measured in years	-
LOWAWA	Low awareness about management	1=Yes, 0=No	-
LACKACCES	Lack access to Apple seedling	1=Yes, 0=No	-
EXPENS	Expensiveness of apple tree seedling	1=Yes, 0=No	-
DISEPES	Disease and pest	1=Yes, 0=No	-

The data obtained from all respondents 600 were considered in the model. The above explanatory variables (X_i) were included in the logit model as EDU, LABSHO, TLAHOLD, OFFFARMIN, CREDIT, EXTEN, MARPROB, DWATER, LONPROPER, AGE, LOWAWA, LACKACCESS, EXPENS, DISEPES.

Results and Discussion

Production and income from apple-based agroforestry system

In the selected districts, sampled household heads were mainly depends on crop and livestock production for their subsistence life. Among the total sampled households in Degem districts, about 87.5 Per cent of Adopters and 97.1 per cent of non-adopters rely on crop production. Whereas, in Dendi District 76.8 per cent of adopters and 77.6 non-adopters rely on crop production. Farmers in the study area plant various vegetables solely or in integration with apple tree and use the product for household consumption and/or as an income source. The mean annual production (in Quintal) and income from vegetables and apple fruit (in ETB) are summarized in Table 2-10.

Table 2 Mean total annual income from vegetable productions in the homestead farmland in Degem district

	Adopters (n = 16)		Non-adopters (n = 284)		
Vegetables	Mean	Sta. Dev	Mean	Sta. Dev	t-value
Cabbage	500.00	489.89	4411.85	4800.68	-1.98*
Potato	23818.46a	54766.04	5445.46[b]	5981.76	4.61***
Carrot	1156.50	1650.93	3026.40	2920.81	-1.19
Tomato	279.17[a]	110.02	1632.95[b]	1511.81	-2.16**
Chili	242.67	140.93	2284.93	4061.14	-0.86
Onion	1041.67	1264.49	1375.00	1124.21	-0.46
Garlic	492.00	209.57	4685.71	5254.66	-1.76
Leeks	50.00		275.00	318.19	-0.56
Beetroot	367.50[a]	467.17	1388.00[b]	1297.73	-2.16**
Gesho	4125.00[a]	3944.93	1452.38[b]	1588.26	2.38**
Enset	11245.45[a]	15387.093	2317.81[b]	2860.40	4.35***

***, ** Significant at 1% & 5% probability level; Mean values with different superscript letters along the same rows are statistically different

Cabbage (*Brassica oleracea*): Annual cabbage production of adopters and non-adopters was 1.33 quintal ha^{-1} $yr^{-1}$and 14.41quintal ha-1 yr-1, respectively. The gross financial return for adopters was 500 ETB ha^{-1} yr^{-1} and for non-adopters 4412 ETB ha^{-1} yr^{-1}. The income difference was statistically significant (P<0.01). Hence, non-adopters' income from the cabbage production exceeds adopters 9 times.

Potatoes (*Solanum tuberasum*): Annual cabbage production of adopters and non-adopters was 59.55 quintal ha-1 yr-1 and 13.53 quintal ha-1 yr-1, respectively. The gross financial return for adopters was 23,818 ETB ha^{-1} yr^{-1} and for non-adopters 5445 ETB ha^{-1} yr^{-1}. The income difference was statistically significant (P<0.01). Hence, adopters' income from the potato production exceeds non-adopters 4 times.

Tomato (*Lycopersicon esculuntum*): Annual Tomato production of adopters and non-adopters was 0.56 quintal ha-1 yr-1 and 3.56 quintal ha^{-1} yr^{-1}, respectively. The gross financial return for adopters was 279 ETB ha^{-1} yr^{-1} and for non-adopters 1633 ETB ha^{-1} yr^{-1}. The income difference was statistically significant (P<0.01). Hence, non-adopters' income from the Tomato production exceeds adopters 6 times.

Enset (*Ensete ventricosum*): Annual Enset production of adopters and non-adopters was 122.20 number ha-1 yr-1 and 24.73 number ha-1 yr-1, respectively. The gross financial return for adopters was 11245 ETB ha-1 yr-1 and for non-adopters 2317 ETB ha-1 yr-1. The income difference was statistically significant (P<0.01). Hence, adopters' income from Enset production exceeds non-adopters 5 times.

Table 3 Mean household heads total annual income from vegetable in Degem District (North Shoa Zone)

Adoption	Mean	Sta. Dev	t-value
Adopters	29277.7500^{A}	49461.83272	6.465***
Non-adopters	6768.6937^{B}	7902.64453	

*** Significant at 1% probability level; Mean values with different superscript letters along different columns are statistically different (P<0.01).

Non-adopters' annual income from the whole produced vegetables were 6768.69 ETB ha-1 yr-1 and adopters obtained 29,277.75ETB ha-1 yr-1(Table 3). An independent sample t-test was carried out to compare the mean gross annual income of adopters and non-adopters. There was a positively significant gross annual income difference between adopters and non-adopters, p = 0.001 (two-tailed).

Table 4 Total annual income from Apple fruit + vegetable in Degem District (North Shoa Zone)

Adoption	Mean	Sta. Dev	t-value
Adopters	39525.250^{a}	72483	7.08***
Non-adopters	6768.69^{b}	7902.64	

*** Significant at 1% probability level; Mean values with different superscript letters along different columns are statistically different (P<0.01).

Adopters' annual income from the whole produced vegetables and apple fruit were 39525.250ETB ha-1 yr-1, and non-adopters obtained 6768.69ETB ha-1 yr-1 (Table 4). An independent sample t-test was carried out to compare the mean gross annual income of adopters and non-adopters. There was a positively significant income difference between adopters and non-adopters, p = 0.001 (two-tailed). Apple fruit contributes 35 per cent of the income for the agri-horticultural system.

Table 5 Households' total annual vegetable productions in the homestead farmland in Dendi district

Vegetables	Adopters (n = 69)		Non-adopters (n = 231)		
	Mean	Sta. Dev	Mean	Sta. Dev	t-value
Cabbage	1730.00	1619.95	1371.02	1116.17	1.35
Ethiopian Cabbage	2860.00	5123.28	925.45	2369.75	1.06
Potato	10639.22[a]	16652.98	5136.60[b]	5601.43	3.543***
Carrot	2655.00	6206.73	1795.00	1540.40	0.64
Tomato	5466.67	4387.86	4127.27	4784.16	0.44
Chili	1422.22	1277.48	1983.33	4522.40	-0.36
Onion	4810.00[a]	5953.40	1378.57[b]	632.98	2.240**
Garlic	4453.33	5439.66	5660.78	9688.39	-0.72
Leeks	193.18	221.39	233.50	222.13	-0.48
Beetroot	1206.94	1371.02	1584.68	1167.49	-1.02
Gesho	2050.00	1533.10	1755.43	1806.23	0.70
Enset	8973.17[a]	9859.16	3791.52[b]	3267.04	4.256***

***, ** Significant at 1% & 5% probability level; Mean values with different superscript letters along the same rows are statistically different

Potatoes (Solanum tuberasum): Annual cabbage production of adopters and non-adopters was 26.86 quintal ha-1 yr-1 and 12.86 quintals ha-1 yr-1, respectively. The gross financial return for adopters was 10639 ETB ha-1 yr-1 and for non-adopters 5136 ETB ha-1 yr-1. The income difference was statistically significant (P<0.01). Hence, adopters' income from the potato production exceeds non-adopters 2 times.

Enset (Ensete ventricosum): Annual Enset production of adopters and non-adopters was 100 in number ha-1 yr-1 and 39 in number ha-1 yr-1. The gross financial return for adopters was 8973 ETB ha-1 yr-1 and for non-adopters 3791 ETB ha-1 yr-1. The income difference was statistically significant (P<0.01). Hence, adopters' income from Enset production exceeds non-adopters 2-fold.

Table 6 Mean Total annual income from vegetable in Dendi District (West Shoa Zone)

Adoption	Mean	Sta. Dev	t-value
Adopters	18869.86[a]	20823.84	5.402***
Non-adopters	8356.13[b]	11515.64	

*** Significant at 1% probability level; Mean values with different superscript letters along different columns are statistically different (P<0.01).

Adopters' annual incomes from the whole produced vegetables were 18869.86 ETB ha-1 yr-1 and non-adopters obtained 8356.13ETB ha-1 yr-1 (Table 6). An independent sample t-test was carried out to compare the mean gross annual income of adopters and non-adopters. There was a positively significant gross annual income difference between adopters and non-adopters, p = 0.001 (two-tailed).

Table 7 Mean household heads total annual income from Apple fruit + vegetable in Dendi District (West Shoa Zone)

Adoption	Mean	Sta. Dev	t-value
Adopters	20697.1[a]	20737.87	6.38***
Non-adopters	8356.13[b]	11515.68	

*** Significant at 1% probability level; Mean values with different superscript letters along different columns are statistically different (P<0.01).

Adopters' annual income from the whole produced vegetables and apple fruit were 20697.1 ETB ha-1 yr-1 and non-adopters obtained 8356.13ETB ha-1 yr-1 (Table 7). An independent sample t-test was carried out to compare the mean gross annual income of adopters and non-adopters. There was a positively significant gross annual income difference between adopters and non-adopters, p = 0.001 (two-tailed). Apple fruit contributes 8.83 per cent of the income for the agri-horticultural system.

Table 8 Households total annual vegetable productions in the homestead farmland in both district (North and West Shoa Zones)

Vegetables	Adopters (n = 85)		Non-adopters (n = 515)		
	Mean	Sta. Dev	Mean	Sta. Dev	t-value
Cabbage	1525.00[a]	1557.17	2819.04[b]	3724.45	-2.044**
Ethiopian Cabbage	2860.00	5123.28	1444.62	2927.01	0.746
Potato	13316.25[a]	28634.88	5316.35[b]	5819.97	4.828***
Carrot	2155.50	5079.63	2157.18	2074.81	-0.002
Tomato	2008.33	3398.29	2464.39	3174.62	-0.377
Chili	1127.33	1214.53	2171.83	4194.73	-0.849
Onion	3396.88[a]	4951.13	1376.79[b]	895.23	2.114**
Garlic	4003.18	5269.78	5579.52	9381.79	-1.031
Leeks	181.25	215.09	237.27	222.74	-0.709
Beetroot	948.65	1222.87	1496.88	1219.87	-1.892*
Gesho	2326.67	2037.36	1660.46	1734.62	1.655
Enset	9453.85[a]	11114.85	3131.96[b]	3167.60	6.170***

*** Significant at 1% probability level; Mean values with different superscript letters along the same rows are statistically different.

The aggregated analysis was conducted to determine households' annual income from the homestead farmland. Adopters' annual income from the whole produced vegetables and apple fruit were 24337.22 ETB ha^{-1} yr^{-1} and non-adopters obtained 7480.73 ETB ha^{-1} yr^{-1} (Table 10). An independent sample t-test was carried out to compare the mean gross annual income of adopters and non-adopters. There was a positively significant gross annual income difference between adopters and non-adopters, p = 0.001 (two-tailed). Apple fruit contributes 16.84 per cent of the income for the agri-horticultural system. Results of the present study agree with the findings of the study that was conducted at Harar to compare income obtained from fruit growing, vegetables, and cereals (sorghum and maize). The result showed annual income from fruit growing was 60,000ETB $ha^{-1}yr^{-1}$, compared to 2,000 for maize and only 1,000 for sorghum (PFMP, 2004). Furthermore, income obtained from apple contributes 17 per cent of the total income from an agri-horticultural system. Akinnifesi et al. (2008) reported that in the rural household communities of Southern Africa, a fruit contributes between 5.5-6.5 per cent of the household income. A study conducted in Northern Pakistan showed that income from fruit was 21 per cent of the farm income; the report exceeds the current study finding (Essa et al. 2011).

Table 9 Mean total annual income from vegetable in North and West Shoa Zones

Adoption	Mean	Sta. Dev	t-value
Adopters	20828.99^{a}	28366.44	8.18***
Non-adopters	7480.53^{b}	9713.30	

*** Significant at 1% probability level; Mean values with different superscript letters along different columns are statistically different (P<0.01).

Table 10 Mean household heads total annual income from Apple fruit + vegetable in North and West Shoa Zones

Adoption	Mean	Sta. Dev	t-value
Adopters	24337.22	36611.07	8.77***
Non-adopters	7480.73	9713.38	

*** Significant at 1% probability level; Mean values are statistically different (P<0.01).

Determinants of Apple Tree Adoption

Fourteen explanatory variables were identified to explain factors influencing the adoption of apple tree-based agroforestry system in North and West Shoa Zones. The effects of the independent variables on the log odds of adopting apple-based agroforestry system are reported as odds ratio alongside the parameter estimates. For an independent variable, the odds ratio (e^{β}) represent the amount by which the odds favoring the decision to adopt apple-based agroforestry system (adopter =1) changes for a change in that independent variable.

Out of fourteen explanatory variables included explaining the dependent variable three were found to be significant. Formal educational level of the household head, market problem and the problem of pest and disease were significant independent variables.

Table 11 Maximum likelihood estimate of the binary logit model for Adoption determinant factors in Degem District

Explanatory Variables	B	S.E.	Wald	P>|z|	e^{β}
Education	1.62*	.979	2.749	.097	5.068
Labor shortage	-0.23	1.004	.050	.823	.799
Total Land Holding	0.46	.894	.267	.605	1.588
Off-farm income	2.08	1.112	3.510	.061	8.030
Access to Credit	-19.61	25164.028	.000	.999	.000
Extension Service	-1.94	1.294	2.250	.134	.144
Market Problem	-2.78***	.916	9.196	.002	16.086
Water Distance	-0.29	.224	1.677	.195	.748
Longer production period	1.67	1.054	2.525	.112	5.336
Age of Household head	1.09	1.160	.886	.347	2.980
Low awareness	-0.84	.877	.917	.338	.432
Lack Access	0.64	1.142	.315	.574	1.899
Expensiveness	-1.12	.896	1.548	.213	.328
Disease and pest	-5.94***	1.571	14.295	.000	380.010
Constant	1.21	50328.057	.000	1.000	

Log-likelihood (X2) = 68. 29
Wald Chi-square=55.29***
Correctly predicted percent = 94.8, N= 300
*, **, and *** represents statistically significant at 10, 5 and 1% level of significance, respectively

The formal education level of the household head as expected had a positive influence in the adoption of apple-based agroforestry system. Keeping other factors constant, the odd ratio indicated that increase in educational level by one year increase the favor of adoption by a factor of 5.008. The endpoints of a 95% confidence interval (CI) of the odds ratio is (2.495, 10.050). However, the finding is against with the study carried out by Mwema et al. (2012) who found out that a higher level of formal schooling is associated with less collection and dependency on fruit producing trees. A higher level of education provides a wider range of employment opportunities and as a result alternative sources of income.

The market problem was statistically significant ($p < 0.01$) and had the negative relationship with the adoption of apple-based agroforestry system. Keeping other factors constant, the odd ratio indicated that as apple fruit market problem increase the favor of adoption decrease by a factor of 4.746. The endpoints of a 95% confidence interval (CI) of the odds ratio is (2.406, 9.361). Because the marketing aspects are also important to the farmer, they need to have access to information about the market (e.g. prices, demand and supply, expectations). A farmer will not decide to change their production system unless they see the security of marketing possibilities. Farmers are not likely to be interested in producing commodities if transport costs are high. They will also be reluctant to make or continue investments in agroforestry if prices fluctuate widely (Carter, 1995). Knowledge of market is critical, as it can help identify whether agroforestry interventions have the possibility of saturating them and therefore bringing prices down (Cook and Grut, 1989). During the Group Discussion that conducted in Bejiro Kebele farmers stated that the demand for apple fruit is very low and majority of the people did not even know what Apple fruit is. Besides in Degem Woreda, farmers stated to sell apple fruit they travel to Addis Ababa, which is about 125 Km far from their home. Considering the serious market problem, non-adopters became reluctant to plant apple seedlings, and one farmer among the group discussant stated "why you bother us to plant apple seedlings, what tangible benefits did adopters obtain? Rather it benefits us if we plant more vegetables in the scarce homestead farmland."

Table 12 Maximum likelihood estimate of the binary logit model for Adoption determinant factors in Dendi District (West Shoa Zone)

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)
Education	1.728***	0.497	12.081	1	0.001	5.628
Labor shortage	-0.173	0.508	0.115	1	0.734	0.842
Total Land Holding	-1.109***	0.404	7.548	1	0.006	0.330
Off-farm income	-1.178	1.401	0.707	1	0.400	0.308
Access to Credit	-0.864	1.381	0.391	1	0.532	0.422
Extension Service	0.961*	0.422	5.184	1	0.023	2.614
Market Problem	-1.005**	0.460	4.778	1	0.029	2.731
Water Distance	-0.048	0.417	0.013	1	0.909	0.954
Longer production period	-0.872	0.655	1.771	1	0.183	0.418
Age	-0.217	0.794	0.075	1	0.785	0.805
Low awareness	-0.011	0.115	0.009	1	0.926	0.989
Lack Access	-0.764*	0.445	2.945	1	0.086	0.466
expensiveness	0.961	1.029	0.872	1	0.351	2.615
Disease and pest	-3.859***	0.633	37.174	1	0.000	47.407
Constant	-4.063	2.217	3.359	1	0.067	0.017

Log-likelihood (X2) = 182.922

Wald Chi-square=80.31***

Correctly predicted percent = 85.9, N= 300

*, **, and *** represents statistically significant at 10, 5 and 1% level of significance, respectively

Disease and Pest were statistically significant ($p < 0.01$) and have negative relationship with the adoption of apple-based agroforestry system. Keeping other factors constant, the odd ratio indicated that as apple fruit infestation increase the favor of adoption decrease by a factor of 20.5. The endpoints of a 95% confidence interval (CI) of the odds ratio is (9.191, 45.723). Showing, problem that discouraged adopters and makes panic non-adopters to plant apple seedlings. During the field observation, the problem was high in West Shoa Zones as compared to West Shoa. One model farmer that lives in Gare Kebele stated that " during the first production period, I used to get a lot of money from selling of apple fruit but recently apple tree and fruit pest and disease highly caused to reduce fruit production."

Table 13 Maximum likelihood estimate of the binary logit model for Adoption determinant factors in Dendi and Degem District (North and West Shoa Zone)

Explanatory variables	B	S.E	Wald	df	Sig.	Exp(B)
Education	1.611***	0.355	20.544	1	0	5.008
Labor shortage	-0.039	0.408	0.009	1	0.924	0.962
Total Land Holding	-0.37	0.332	1.241	1	0.265	0.691
Off-farm income	-0.235	0.701	0.112	1	0.738	0.791
Access to Credit	-1.443	1.093	1.742	1	0.187	0.236
Extension Service	0.102	0.152	0.446	1	0.504	1.107
Market Problem	-1.557***	0.347	20.188	1	0	4.746
Water Distance	-0.017	0.172	0.01	1	0.919	0.983
Longer production period	0.272	0.431	0.398	1	0.528	1.313
Age	0.072	0.605	0.014	1	0.905	1.075
Low awareness	-0.082	0.081	1.043	1	0.307	0.921
Lack Access	-0.393	0.341	1.333	1	0.248	0.675
expensiveness	-0.079	0.494	0.026	1	0.873	0.924
Disease and pest	-3.020***	0.409	54.462	1	0	20.5
Constant	-4.86	2.002	5.892	1	0.015	0.008

Log-likelihood (X2) = 311.675

Wald Chi-square= 229.736***

Correctly predicted percent = 89, N= 600

*, **, and *** represents statistically significant at 10, 5 and 1% level of significance, respectively

From the result discussed above, it can be inferred that adopters of apple-based agroforestry system obtained higher gross annual income than non-adopters. Income from Potato and Onion were highest for adopter farmers in all study sites. While, for non-adopters, main income was obtained from cabbage and beetroots. The mean gross income of adopters from vegetables + apple was 3.8 times higher than the income of non-adopters from vegetables. The mean annual gross revenue of adopters from solely apple fruit production constituted about 16.84 per cent of the total income obtained from vegetable + apple.

In the study area, apple-based agroforestry system had both nutritious supplement and monetary value. However, adoption of the system was significantly influenced by different factors i.e., formal education levels (+), the market problem (-), and apple fruit and tree disease and pest (-). The current study proved that in the presence of determinant factors that limit the adoption process, apple-based agroforestry system provides the significant economic advantage for adopter as compared to non-adopters. Thus, the promotion of agroforestry technologies is important because it offers the prospect of increasing production and hence growing farmers' income. Sustainable development through agroforestry can be achieved through a concerted effort to actively and continuously encourage farmers' involvement in AF activities. Recognizing and tackling main factors that determine the participation of farmers in AF practices affects an AF project to successful local involvement. These findings are relevant to the adoption of agroforestry technologies involving economic, social and economic considerations.

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References

Akinnifesi, F., Sileshi, G., Ajayi, O., Chirwa, P., Kwesiga, F. and Harawa, R. 2008. Contributions of Agroforestry Research and Development to Livelihood of Smallholder Farmers in Southern Africa: Fruit, Medicinal, Fuel wood and Fodder Tree Systems. Agricultural Journal, 3(1): 76-88.

Amare Haileslassie, Priess, J., Veldkamp, E., Lesschen, J. P. 2006. Smallholders' Soil Fertility Management in the Central Highlands of Ethiopia: Implications for Nutrient Stocks, Balances, and Sustainability of Agroecosystems. *NutrCyclAgroecosyst*75:135–146.

Ayuk, E., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki-Manga, T. and Zekeng, P. 1999. Uses, Management and Economic Potential of Dacryodes edulis (Burseraceae) in the Humid Lowlands of Cameroon. Economic Botany, 53: 292–301.

Bellow, G., Hudson, R. and Nair, P. 2008. Adoption Potential of Fruit-Tree-Based Agroforestry on Small Farms in the Subtropical Highlands. Agroforestry Systems, 73:23-36.

Carter, J. 1995. Socio-economic factors influencing alley farming adoptability. Natural Resource Perspectives. Overseas Development Institute. London.

Cook, C. and Grut, M. 1989. Agroforestry in Sub-Saharan Africa - A Farmers' Perspective. World Bank Technical Paper No. 112, The World Bank, Washington, D.C.

DARDO, 2017. Denedi Woreda Agricultural and Rural Development office Annual Report.

DWARDO, 2017. Degem Woreda Agricultural and Rural Development office Annual Report.

Essa, M., Nizami, S., Moazzam, M., Sarwat, N., Khan, I. and Athar, M. 2011. The contribution of Agroforestry in Farmers' Livelihood and Its Impact on Natural Forest in Northern Areas of Pakistan. African Journal of Biotechnology, 10(69): 15529-15537

Franzel S., Jaenicke H., and Janssen W. 1996. Choosing the Right Trees: Setting Priorities for Multipurpose Tree Improvement. ISNAR Research Report No. 8. International Service for National Agricultural Research, The Hague, The Netherlands.

Gujarati, D. 2004. Basic Econometrics. Fourth edition. New York. The McGraw−Hill Companies.

Hellin J., Welchez L.A., and Cherrett I. 1999. The Quezungual system: an indigenous agroforestry system from western Honduras. Agrofor. Sys. 46: 229–237.

Long, S. and Freese, J. 2006. Regression Model for Categorical Dependent Variables Using Stata, 2nd Edition, A Stata Press Publication, College Station, Texas.

Mercer, D. 2004. “Adoption of Agroforestry Innovations in the Tropics.” In: Valuing Agroforestry Systems. Mercer D. (edt.). Kluwer Academic Publishing Netherland.

Mwema C., Mutai B., Lagat. K., Kibet L. and Maina M. 2012. The contribution of Selected Indigenous Fruits on Household Income and Food Security in Mwingi, Kenya. *Current Research Journal of Social Sciences*4(6): 425-430, 2012.

Negussie Achalu, 2004. Farm Forestry Decision-Making Strategies of the Guraghe Households, Southern-Central Highlands of Ethiopia. Ph.D. Dissertation, University of Dresden. Agriculture/Natural Resource Extension.

Identification of Determinant Factors for Large-Scale Timber and Pulpwood Plantation Development in Ethiopia: Stakeholders Analysis

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Abstract

The total plantation forest in Ethiopia is estimated at 1 million hectares. Only 19% of this plantation forest can be classified under large-scale plantation. The two large-scale plantation development schemes are being carried out by Oromia and Amhara region forest enterprises. Active large-scale plantation schemes seem to have ceased in Ethiopia for the past three decades. This study, therefore, has attempted to identify and analyze the most determining stakeholder and environmental factors hindering and/or promoting large-scale plantation development in the four regions (Amhara, Oromia, SNNPRS and Tigrai) of Ethiopia. The study engaged schedule surveys, KIIs, and FGDs to assess the determinant factors. Shortage of land (98%), high initial investment cost (84); long gestation period (86%), high opportunity cost (92%) and absence of incentives (73%), on the other hand, were among prominent limiting factors for plantation development in the country. Absence of well-defined national land use strategy (94%), the highly decentralized authoritative relations between regional and federal parallel sectors (82%), insecure land tenure policy (65%), as well as overlapping and conflicting land use strategies of sectors (89%) were among the most identified limiting factors for large-scale plantation development in the country. Direct governmental investment in large-scale plantation development scheme has been suggested (96%) as the best approach for future plantation development in the country. In addition, merging adjacent plots (62%), forming plantation cooperatives (65%), pre and post plantation management capacity building trainings, provision of incentives (94%) and offsetting opportunity costs by GO's and/or NGO's (96%) were identified as promoting factors to convert smallholder plantations into a large-scale plantation scheme. Ethiopia is environmentally feasible for large-scale plantation development. Close to 27 million ha of land has been identified as potentially suitable for national large-scale plantation development. Excluding the pulp and paper industries, the existing medium and large-scale wood-based industries require at least 303,000 ha of plantation for sustainable domestic consumption and import substitution. No significant difference has been observed among limiting and/or promoting factors between the four studied regions.

Key words: Determinant factors, Large-scale Plantation, Timber and Pulpwood

Introduction

The Climate Resilient Green Economy (CRGE) strategy of Ethiopia targets afforestation and reforestation of 3 million ha by 2030 with the aim of re-establishing forests for their economic and ecosystem services, including as carbon stocks (FDRE, 2011).

Large scale plantation development started in Ethiopia in the early 1970s for production of sawn wood, wood-based panels and pulp. Of the three, sawmilling is the main forest industry in Ethiopia (Bekele, 2011). Again, according to Bekele (2011), the area of forest plantations in Ethiopia was 972,000 ha in 2010. Of these, industrial plantations, which were developed for timber production for sown wood and poles, covered 190,400 ha of land (19.6%), and the non-industrial plantations, which were meant for fuelwood and construction timber production, covered 781, 600 ha of land (80.4). The tree species planted in the industrial plantations were *Eucalyptus sps.* (56.6%), *Cupressus lusitanica* (32.8%), *Pinus sps.* (2.5%), *Juniperus procera* (1.9%), *Grevillearobusta* (0.7%) and others (5.6%). The non-industrial plantation was mainly woodlots (96.6%) and the remaining 3.4% was peri-urban plantations.

The industrial scale timber and pulpwood production is faced with a number of challenges, and critical gaps in the sub-sector include the following: largely untapped plantation development potential and market opportunities given the strategic location of the country to supply various forest products to the nearby African and Asian markets, and instead Ethiopia becoming a timber trade destination, poor scaling-up of alternative timber species, lack of knowledge on timber quality of some species being widely planted, and lack of management tools, lack of proper propagation methods for some indigenous species, lack of species for large scale pulp plantations (long fiber), lack of optimum eucalypt coppice rotation and replacement techniques and untapped tree improvement potential for several timber and pulpwood species.

Hence, to improve the large-scale timber and pulpwood production, one of among many research questions need to be addressed is: What factors are limiting the development and expansion of large-scale timber and pulpwood plantations in the four regions. The study thrived to address the following two specific objectives: (1) to identify and document the socioeconomic, perceptional and attitudinal factors of major forest stakeholders on plantation development in Ethiopia and (2) to evaluate major environmental and administrative determinant factors of large-scale plantation development in Ethiopia

Materials and Methods

Defining the sampling frame and sample size

Reconnaissance survey was carried out at all relevant offices of the four regions to identify stakeholders that are engaged in wood and wood related industries. Sample size was determined after data on the number of relevant stakeholders has been collected from all the four regions. Study zones and woredas were selected using availability of plantation forest resource and abundance of tree-based forest product markets as a weighting criterion. Accordingly; sampling units were randomly selected from the respective sampling frames. The following sample sizes were targeted for the study:

- 1000 Households from among selected woredas of the study regions
- 25% medium-scale wood industries from selected zonal towns of the study regions and
- 50% Large-scale industries of the four study regions

Questionnaire survey

Questionnaires were administered to selected households depending on the size of the target population as well as ecology of the study area to gather information on social and economic public opinions parallel to establishing large-scale timber and pulpwood plantations.

KII

In depth interviews were carried out with selected key informants. A separate checklist was prepared to guide the interview.
List of key informant institutions and organizations:

- Federal Government officials (policy and decision makers),
- Directors working on relevant ministries,
- Relevant regional officials,
- Zonal officials and experts working on NRM
- Woreda officials and experts
- Local and international NGOs' NRM officers
- Heads or representatives of individuals working on wood industries
- Heads or representatives of Forest Enterprises
- Representatives of CBOs' organized on NRM related (eg PFMs)
- Cultural and religious leaders of target areas etc

FGDs

Focus group discussions were held at all level with relevant groups. The FGD contained 8-12 individuals comprised of pertinent authorities, professionals, age and sex groups, cultural and religious sects, local and international NGOs, CBOs, wood industries, and so on depending on the context that called for FGD.

Perceptional investigation

Perception of key actors on environmental impeding factors for large-scale plantation has been investigated using both open and close ended questionnaires.

Result and Discussion

Determinant Factors of large-scale plantation development in Identified major stakeholders

To identify the underlying limiting/promoting factors of large-scale plantation development, this study has identified two major groups of stakeholders: 1) Smallholder plantation owners and tree products traders and 2) Small, medium and large-scale wood industries owners

Smallholder Plantation Owners and tree product traders

Relative household contribution of tree products

Farmers owning smallholder plantations does so with a primary objective of selling tree products as a means for subsistence (99% of tree growers). The most preferred tree species by tree grower farmers are Eucalyptus (100%), and *Acacia decurrens* (13%). Though *Grevillea robusta* and *Cupressus* species were also recorded during the study their occurrences were insignificant in the plantation agro-climatic zones (mid and high altitudes). However, the momentum of *Acacia decurrens* expansion has been promising particularly in the mid and high-altitude zones of Amhara region. The mean planting space between trees was found to be 0.5 meters, the range of it being from 0.4 meters to 1 meter. Average land allocated for tree planting has been 0.31 ha (Ranging from 0.2 to 1.75 ha). In general, the major types of tree products sold at farm gates, local market and loaded to zonal, regional and national central markets are tree poles, charcoals, firewood and split woods. Twigs and branches are either dominantly consumed (87%) or sold in local markets (46%). Among the tree products tree poles lead in terms of sell volume (91%) followed by firewood (31%) and charcoal (27%) in the wood market. The mean annual relative contribution of these tree products in terms of their income generation potential for a household has also been calculated at 41,570 ± 21,200 for tree poles, 4120 ± 4589 for firewood, 3700 ± 4320 for charcoal and 4590 ± 2340 for split woods. In aggregate construction poles (tree poles) take a lion share (79%), followed by split wood (9%), firewood (7%) and charcoal (5%) as means of income generation (see figure below).

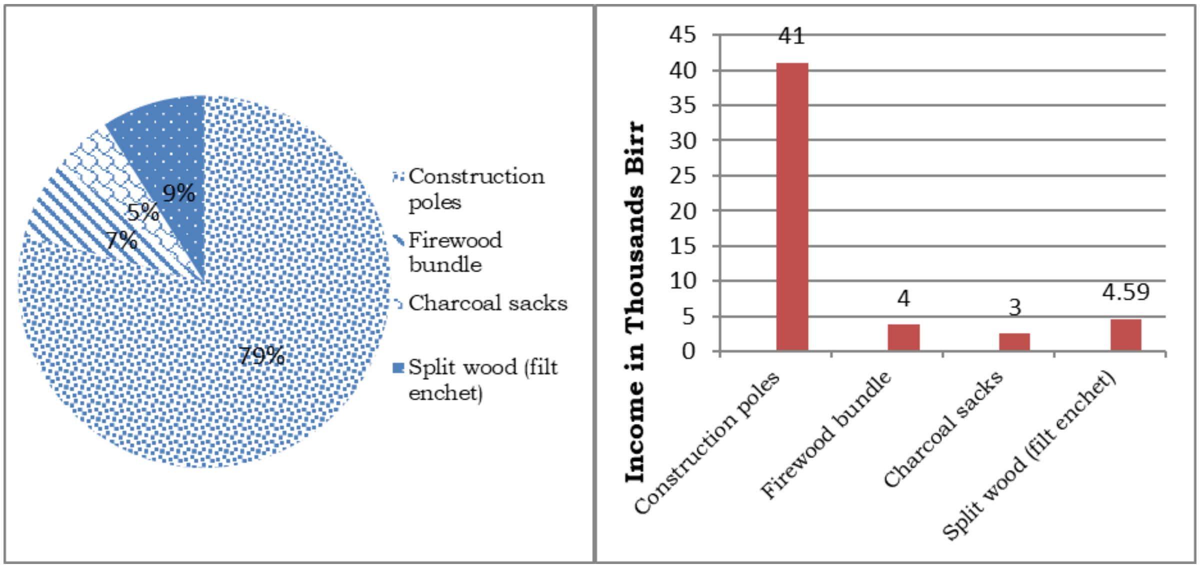

Figure 1 Relative income contribution of tree products by smallholder plantation owners and traders

Tree grower farmers' species preferences have also been evaluated in this study. Growth performances of preferred species, their timber qualities, market prices of tree products, and ease of management have been used as factors for evaluations. Accordingly, Eucalyptus (99%) and *Acacia decurrens* (100%) have been preferred the most for their fast-growing potentials. On the other hand, smallholder plantation owners prefer *G. robusta* (94%) and *Cupressus* lusitanica (93%) for their high timber qualities. No significant difference of preference was observed between prioritized species in terms of their economic return potentials (87% for Eucalyptus, 83% for *G. robusta*, 94% for *C. lusitanica,* and 80% for A. *decurrens*). Significant difference was observed in choices of species in accordance of ease of tree management. Both *Eucalyptus* and *A. decurrens* (98%) have received farmers' highest choice for their ease of management from planting to harvesting periods. The least preferred species for its difficulty of management between planting and harvesting has been *C. lusitanica* (57%).

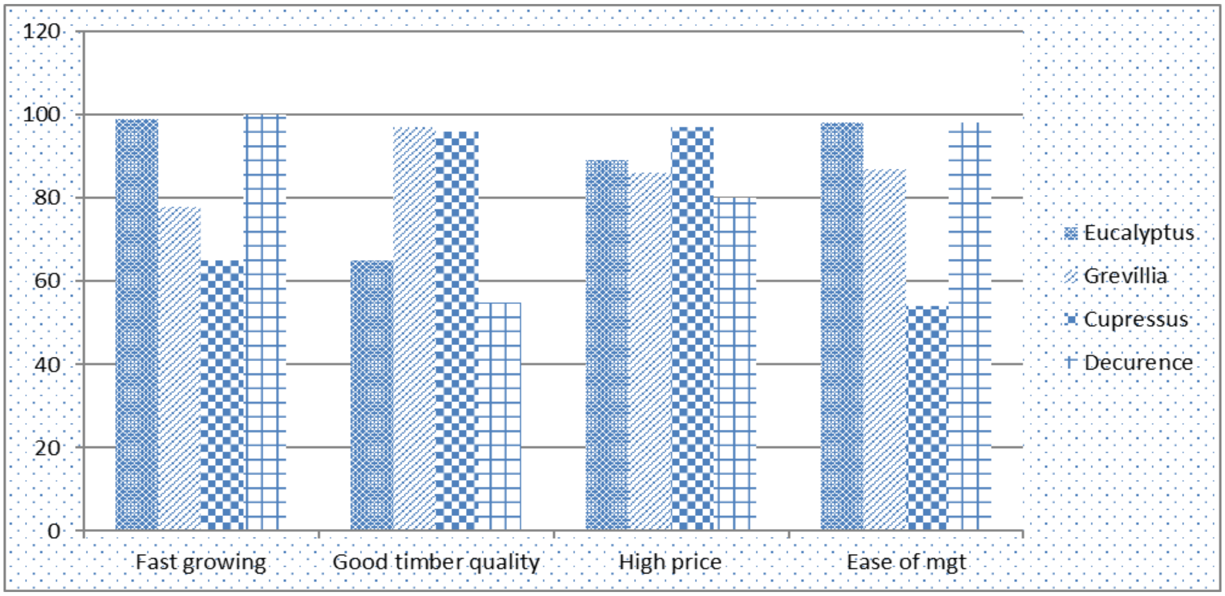

Figure 2 Species preference (Aggregate mean of the four regions)

Reasons for decision to own smallholder plantation of preferred tree species in the four regions (Amhara, Oromia, Tigray and SNNPRS) were also assessed. Income, decline of agricultural production, utilization of marginal lands, and offsetting household wood demands have been used as measuring variables to estimate tree growers' perception. It has been identified that smallholder plantation owners grow trees in all the four regions principally because they prospected returns from sell of tree products could significantly improve their household income (100% confirmation percentage in Amhara, Tigray and SNNP regional states and 90% yes percentage in Oromia). However, perceptional variation was observed with respect to their decision to plant because of decline of their agricultural plots. Strong agreement reaction (100% yes) for reasons to plant trees because of decline in agricultural production was found in Tgray region. Decision to plant tree for only utilize marginal lands, on the other hand has received little agreement (2%) in the same region. Contrary, tree growing respondents in Oromia region has affirmed (68%) planting trees to make use of their marginal lands. Though there is a slight degree of variation between regions all smallholder plantation owners agreed to the reason of planting trees for offsetting household wood demands (82% Tigray, 70% Amhara, 63% Oromia and 60% SNNPRS).

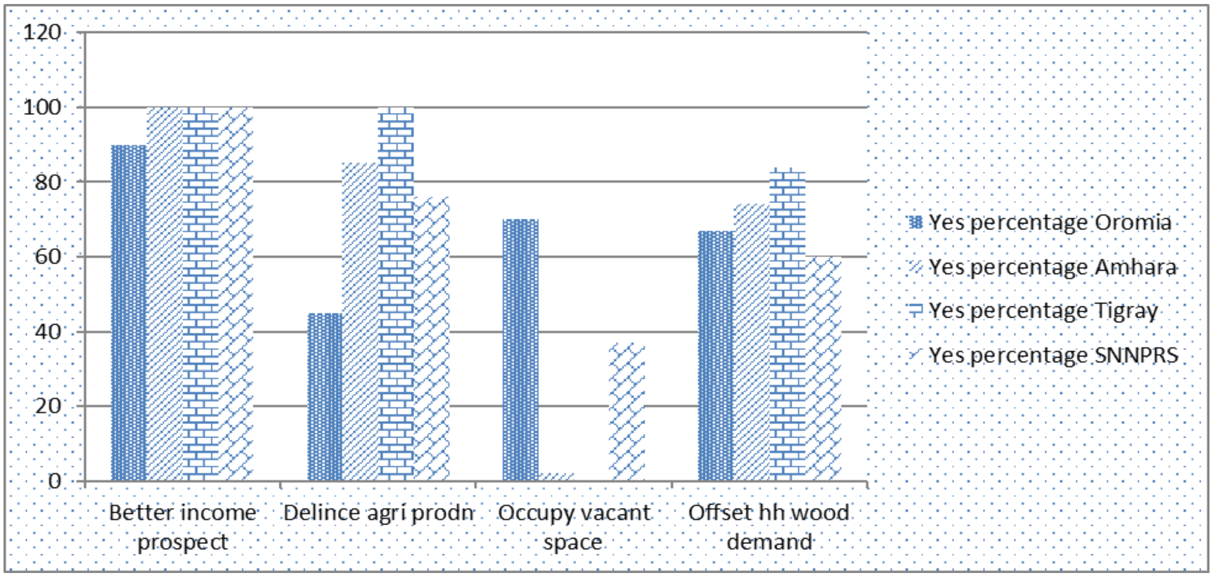

Figure 3 Confirmation percentage for decision to establish smallholder plantation

The following table summarizes smallholder plantation owners' reason (agreement level) on the tradition of using narrow spacing (mean of 0.5 meters) between trees.

Table 1 Reason of smallholder plantation owners' on the tradition of using narrow spacing

Reasons	**Waited Rank**			
	Oromia	Amhara	Tigray	SNNPRS
Increase no. of trees per space	2	1*	1	1
Shortage of plating space	2	1	1	1
Shortage of initial investment capital to expand	1	2**	2	3***
Save space for agricultural crops	1	1	1	2

Note: 1* -Strongly agree, 2**-Agree, 3***- Neutral, 4****Disagree, 5***** strongly disagree

Assessments of smallholder farmers' future expansion plans of their woodlots size have revealed that all (100%) of smallholder plantation owners are willing to increase the size of their woodlots' possession. Calculated national average size for expansion was found to be 1.21 hectares. The range for land size of expansion has been between 0.75

hectares and 3 hectares. The maximum ranges of the need for extension of smallholder plantation sizes have been dominant in Amhara and SNNPRS regions (73% of respondents in Amhara and 65% in SNNPRS). Assumed strategic plans for expansion of woodlot sizes forwarded by tree growers have also been analyzed. Plans to convert portion of their remaining agricultural plots into smallholder plantation has been found to be 86% in Amhara, 76% in Oromia, 68% in Tigray and 82% in Tigray. The national average for this strategy was calculated at 78%. Aggregate average for expansion strategy through purchasing additional from neighboring or adjacent farm lands has been 65%. On the other hand, the national mean percentage for expansion through renting land plots from neighboring or adjacent farmers' land was 75%. Additionally, smallholder plantation owners wish to expand their tree holding size through leasing lands from local government investment and land administration offices has been 86%. In general, setting aside the problems of acquiring lands through any of the means it has been identified that smallholder plantation owners predominantly had the desire to expand their plantation possessions. Scaling up of farmers woodlots size through organized cooperation have received a varying level of agreements in the four assessed regions. Two major organized expansion strategies were forwarded to smallholder plantation owners: 1) Forming community managed plantation cooperatives and 2) engagement in out grower's schemes. The national agreement level to engage in the formation of community managed plantation cooperatives was found to be 65%. On the other hand, engagement in out growers' scheme has received a higher level of conformity (a national average of 82%). Expansion strategy through merging adjacent smallholder plantations has also been assessed. The following figure illustrates level of confirmation to merge adjacent woodlots in the four regions.

Identified Limiting/Promoting Factors among Smallholder Plantation owners and small-scale tree and tree product traders

The ever-increasing market prices for tree poles, split woods, firewood, and charcoal has been the basic driving factor for accelerated expansion of smallholder plantation owners in Ethiopia. All interviewed small holder plantation owners and tree products traders (100%) have agreed over the factor of the presence of high market demand for tree products as promoting factor for their initiative to establish their woodlots. The ease of management from planting to harvesting (78% agreement level) of the highly preferred tree species, Eucalyptus and *A. decurrens*, has also been identified as an encouraging feature for engagement to establish their smallholder plantation. The presence of favorable climatic condition and good soil conditions has been the other

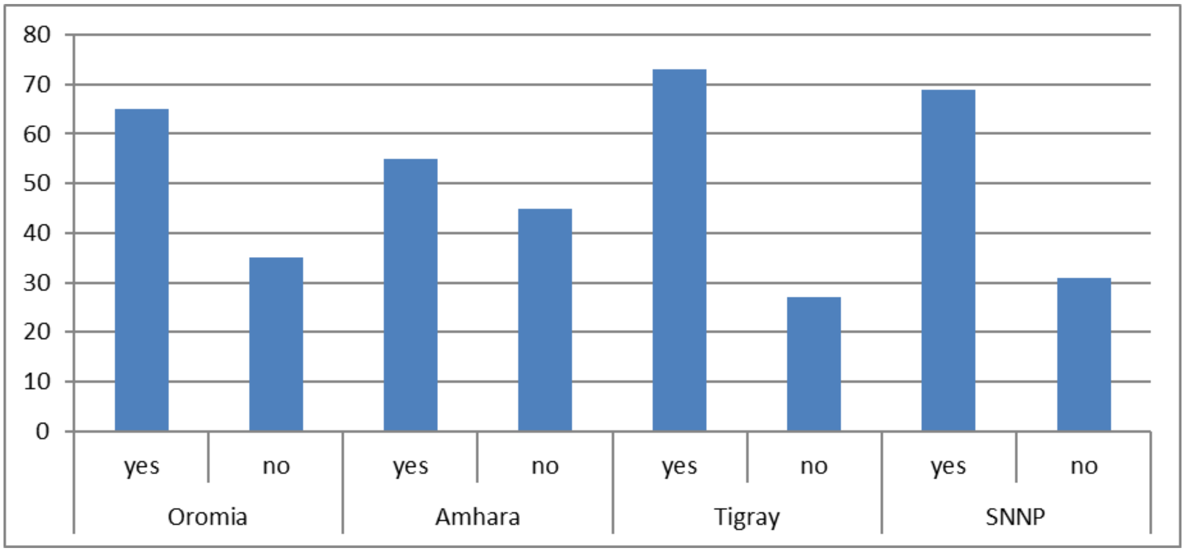

Figure 4 Agreement level of smallholder plantation owners to expand their holding sizes through merging their adjacent woodlots

major helpful factor for farmers endeavor to own woodlots. The advancement in communication technology (televised audio and visual Medias) has also been mentioned as an additional encouraging reason for their commitment in the enterprise. Clarifying their perception, these communication technologies have helped them to have updated information on market prices of their wood products and easily access their clients.

On the other hand, it has been known that the limiting factors that have been hindering endeavors of smallholder plantation owners from escalating their tree planting enterprises by far outweighs. Shortage and unavailability of lands, high initial plantation establishment costs, and high opportunity costs were some of the identified reasons as setbacks in the plantation development venture. Accordingly, a national average of ninety-eight percent (98%) of the respondents confirmed that shortage and in some cases unavailability of land for tree plots expansion has been a key limiting factor. High initial woodlot establishment and management costs were also mentioned by 84% of the respondents as a hindering factor. Misuse of available vacant lands by responsible local governmental administrative offices has been spotted as a reason holding them back to further expand their woodlot sizes (54% national average). Instance like giving communal grazing lands, wetlands and mountain hills to organized youth groups for other purposes under the pretext of development was mentioned as example by respondents. Shortage and in some scenarios, total absence of input materials like seedlings has been described by 78% of the respondents deterring them from scaling up their plantation holdings. Long gestation period of tree crops and protracted return period have also been limiting factors to 86% of the respondents discouraging them from further expansion of their woodlots. This has been also the major reason for farmers that have yet not established their own woodlots from participating in the tree product selling business. About 98% of the respondents have also linked this to a high opportunity cost holding their decision back from setting aside the remaining portion of their agricultural plot for tree planting. Lack of incentives and support from governmental and non-governmental agencies to offset opportunity costs was also pointed out as a set back by 94% of interviewed households. The sluggish bureaucratic process to those that wish to lease additional lands for tree plantation has been pointed out by 52% of the household heads as additional limiting factor.

Conclusions and Recommendations

The ever increasing local as well as cross-border regional market demand for tree poles, firewood and charcoal was the major driving factor for expansion of smallholder plantation in Ethiopia. Shortage and unavailability of lands, high initial plantation establishment costs, and high opportunity costs were some of the identified reasons as setbacks in the plantation development venture. Lack of incentives and support from governmental and non-governmental agencies to offset opportunity costs was also pointed out as a major limiting factor. The sluggish bureaucratic process to those that wish to lease additional lands for tree plantation has been pointed as additional restraining factor. Misuse of vacant spaces like wetlands, mountain hills, marginal lands and other land use types that should have been covered with tree plantation by local administration was also a drawback. Over dependence of wood and furniture industries on imported timber and other wood products and fear of additional investment cost by wood industry owners to establish their own production forest were also hindering factors among potential investors. Long gestation period of trees to produce returns have also created fear of risk to invest in the sector. Little or total absence of compelling pre-requisites to wood industry investors to develop own plantation have also contributed for the lack of plantation development in the country. Poor infrastructural development in the rail, road, electricity, telecommunication and other service sector has also discouraged investment in the forest industry. Tenure insecurity, weak law enforcement and lack of confidence in legal protection from government side have also wall-blocked investment in large-scale plantation development in Ethiopia.

Reference

AFF 2011. African Forest Forum Working Papers Serious, Volume 1, Serious 12, 2011

Berhanu Gebremedhin, J Pender, Tesfay G. 2003. Community natural resource management: the case of woodlots in Northern Ethiopia. Environment and Development Economics 8: 129–148.

Dereje Jenbere. 2009. The expansion of Eucalyptusus plantation by small holder farmers and its drivers: the case of Arsi Negelle district, southern Oromia Ethiopia. MSc thesis,

Hawassa University, Wondo Genet College of Forestry and Natural Resources, Awassa.
Desalegn, R. 1994. Land tenure and land policy in Ethiopia after the Derg. In Proc. Second workshop of the land tenure project, Trondheim. Centre for environment and development unit, University of Trondheim, Norway.
Feyera Senbeta, Demel Teketay. 2001. Regeneration of indigenous woody species under the canopy of tree plantations in Central Ethiopia. Tropical Ecology 42: 175–185.
Feyera Senbeta, Demel Teketay, B Å Näslund. 2002. Native woody species regeneration in exotic tree plantations at Munessa-Shashamane forest, Southern Ethiopia. New Forests 24: 131–145.
Gebremedhin Teklu. 2003. Expanse of plantation forest in Ethiopia: An outcome of more than half a century's effort. MoA, Addis Ababa, Ethiopia.
Gessesse Dessie, Teklu Erkossa. 2011. Eucalyptusus in East Africa, Socio-economic and environmental issues
Melaku Bekele. 2003. Forest property Rights, the Role of the State, and Institutional Exigency: the Ethiopian Experience. Doctoral Dissertation, Swedish University of agricultural sciences, Uppsala, Sweden
Million Bekele 2011. Forest Plantation and Woodlots in Ethiopia. A Platform for Stakeholders in African Forestry, 2011
Meselle Negash. 2002. Socio-economic aspects of farmers' Eucalyptusus planting practices in the Enset-Coffee based agroforestry system of Sidama, Ethiopia. The case of Awassa and Shebedino Districts. MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg, Sweden.
Mesfin Abebe, Wubalem Taddesse. 2014. Eucalyptusus in Ethiopia, Risk or Opportunity, proceedings.
Minda Teshome. 2004. Economics of growing *Eucalyptusus globulus* on farmers' woodlot: the case of Kutaber District, South Wollo, Ethiopia. MSc thesis, Hawassa University, Wondo Genet College of Forestry, Awassa.
Mulugeta Lemenih. 2004. Effects of land use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia. Implications for sustainable land management. Acta Universitatis Agriculturae Sueciae, Silvestria, vol 306, PhD thesis, Swedish University of Agricultural Sciences, Department of Forest Soils, Upsala, Sweden
Mulugeta Lemenih, F Bongers. 2010. The role of plantation forests in fostering ecological restoration: experiences form east Africa. In: Bongers F, Tennigkeit T (eds) Degraded forests in Eastern Africa: management and restoration. Earthscan Publ. pp. 171-220
Mulugeta Lemenih, Demel Teketay. 2005. Effect of prior land use on the recolonization of native plants under plantation forests in Ethiopia. Forest Ecology and Management 218: 60–73.
REDD+_Secretariat (2016) Ethiopia's Forest Reference Level Submitted to UNFCCC (preliminary submission), Ministry of Environment, Forest and Climate Change.
Tekalign Simeneh. 2013. Value Chain analysis of Eucalyptusus from Small Woodlots in Ethiopia: Tha case of West Gojjam Zone, Mecha District
Woldeamlak Bewket. 2002. Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile basin, Ethiopia. Mountain Research and Development 22: 263–269.

Woldeamlak Bewket. 2003. Household level tree planting and its implications for environmental management in the northwestern Highlands of Ethiopia: a case study in the Chemoga Watershed, Blue Nile basin. Land Degradation and Development 14: 377–388

Zenebe Mekonnen, Habtemariam Kassa, Mulugeta Lemenih, B Campbell. 2007. The role and management of Eucalyptusus in Lode Hetosa District, Central Ethiopia. Forests, Trees and Livelihoods 17: 309-323.

Zerihun Kebebew, Getachew Ayele. 2002. Profitability and household income contribution of growing Eucalyptusus globulus by smallholder farmers. MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg, Sweden.

Factors Affecting Farmer's Participation in Technology Adoption: The case of Highland Bamboo Silvicultural Management Practices in Dire Inchine Woreda of Oromia National Regional State

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Abstract

Technology adoption through a participatory process has been promoted since late 1980s and early 1990s parallel with the growing recognition of farmer participatory research (FPR) and participatory technology development (PTD) approaches. This study aims to identify factors, which hinder farmer's participation in forest technology adoption. A multi-stage sampling technique was conducted to collect data from 305 farmers in Dire Inchineworeda, west Showa zone of Oromia national region state, Ethiopia.Our study used binary probit model to identify determinant factors for farmer's participation inHighland Bamboo silvicultural management technology promotion (HBSMTP). The analysis indicated that sex of household head, marital status, training participation and land holding are factors that significantly determine farmer's participation on forest technology promotion. It appears that farmer's awareness regarding forest technology can be increased by giving equal chance for both sex on any extension interventions. According to the model, a farmer who has access to training is about 2 times more likely to participate in forest related technology adoption than none. Similarly, farmers who owned large land size has 8.5 % probability to participate in forest related technology promotioncompared to farmers who own less land size. Moreover, technology promotion efforts should give due attention to the participation of resource poor farmers, and youth participation in project intervention specially the active participation of marginalized farmers.

Key words: participatory technology adoption, silvicultural management, technology, farmers, training.

Introduction

Top down approaches of resource management and technology adoption have been recognized as ineffective and unsustainable for so long ago. Bottom–up approaches that view beneficiaries as partner, utilize local experience and endeavor to empower target beneficiaries have been promoted in the past few decades (Chambers, 1983; Kumba, 2003). Participatory resource management approach is particularly important in the context of forestry where most of the resources are managed under a *communal* *tenure*. Communal tenure refers to situations where groups or communities have well defined, exclusive rights to jointly own and/or manage particular areas of forest.For instance, in Oromia over one million hectares of forests are currently managed under Participatory Forest Management (PFM) arrangement (FDRE, 2017). Participatory forest management scheme is playing crucial role in reversing deforestation, sustaining ecosystem services such water, soil and biodiversity conservation,carbon sequestration, andimproving rural household through income generation and employment.

Like PFM, participatory research and technology adoption have become important in forestry in recent years. These approaches aim at overcoming barriers that hinder researchers from the economically and socially disadvantaged communities. Participatory research and technology adoption are also important to study local problems, with the goal of taking action to improve local conditions (Gaventa, 1988; Chambers, 1997). Within the growing recognition of the importance of participatory research and technology adoption, the Ethiopian Environment and Forest Research Institute (EEFRI) has implemented highland bamboo management technology pre-scaling-up project since 2016

In Ethiopia, forestry is one of the four pillars of the Climate Resilience Green Economy (CRGE) strategy where the sector believed to have an abatement potential of 130 Mt CO_2e by 2030. The CRGE forest sector goals will be achieved through protection of existing forests and re-establishment of lost or degraded forest resources. In this strategy, Ethiopia has recognized the need to establish different types of productive forests to reduce pressure on natural forests/woodlands, to satisfy the rising demands of timber and non-timber products as well as to maintain sustainable ecological services. In this regard Bamboo has been given due attention to reclaim degraded lands and CO2 sequestration. Bamboo’s fast-growing and renewable stands sequester carbon in their biomass – at rates comparable to or superior than many tree species. (INBAR, 2017).

Ethiopia has the largest area of bamboo in Africa; but it has been poorly managed and exploited. Only a small number of people are involved in cultivating and processing bamboo in Ethiopia. The use of bamboo is restricted to the household level. There is only a very limited market for bamboo handicrafts that are not presently being developed (Herald, 2018). Getaneh (1999) mentioned that farmers around Dire Inchine district have less emphasize on protecting and undertake management practice of natural forests. Thus, overcome this problem both scientific and systematic approached needed. According to GIZ, 2018 report, to alleviate the current forest degradation in Ethiopia, it is vital to participate communities in each interventions. The performance of agriculture related projects highly depend on identifying factors which delaminate farmer’s participation in a project (FArid et al., (2009). Moreover, Nxumalo and oladel (2013) revealed that the role of individual and group participation for self –reliance and better stand of living. And they also mentioned that without stakeholder's participation there would not be development. Farmers can participate in a projects can be nominal, consultative, action-oriented or collegial.

Anumber of improved forest technologies has been released and demonstrated in the last four decades. Highland Bamboo silvicultural management technology (HBSMP) pre-scaling-up was implemented by Ethiopia environment and forest research institute. It was implemented in west Showa, Dire Inchine woreda Wald HinePeasant association. The aim of the project was to demonstrate highland bamboo silvicultural management to farmers and creating bamboo market linkage among stakeholder. Farmers were selected based on their willingness to participate in the projects. This paper therefore attempts to examine the factors that determine farmer's participation in forest technology adoption considering specifically the case of HBSMP.

Methodology

Study area

Dire Enchine (formerly known as TikureInchine) woreda is one of the west part of Oromia National Regional State covering a total area of 53,806 square Km. and found around 165 Km away form a capital city of Ethiopia. According to CSA (2007), the district had 71,417 populations and the number of women and men population is almost equal. Temperature ranges from 6 to 24 °C the mean annual rainfall ranges from 2200 and 3023mm. This range of climatic and other conditions explains the diversity of agro ecological zones in the area. The current forest coverage of the area is around 9.4% of the total area of the district. According to zonal planning report (2007), from the current vegetation cover a quarter of land is covered byhigh forest. And one fifth of andmore than one tenth of lands are bush/shrubs and wood land. Indigenous forest trees are mainly found in mountain side and plateaus areas. Bamboo tree, locally known as 'shimelaa' covered the largest area (40%) than other species.

Data and sampling procedures

Before conducting the survey, questioner was pretested and administered to bamboo farmers in Dire Inchine district. All project participant (116) and non-participant farmers (189) randomly selected and interviewed. A total of 305 sampled farmers were enumerated in this study. To analyze the collected data, Binary probit model was used by this study to estimate factors that influence farmer's participation in forest projects using the case of HBSMP. Farmers' participation in the HBCMP was taken as dummy variable. The value of '1' allocated for willing to participate in a project and '0' others.

$$Y_i^* = \begin{cases} 1 \, if Y_i^* \succ \Upsilon \\ 0 \, if Y_i^* \le \Upsilon \end{cases} \quad (1)$$

Where ϒ = a threshold which is assumed to be zero for this study.

Assuming a normal distribution of errors and following from Greene (2003), the probability of a farmer participation in the HBCMP is given by;

$$\Pr(\mathrm{Y} = 1) = \int_{-\infty}^{\beta' x} \phi(\mathrm{t})\,\mathrm{dt} = \Phi(\beta' x) \quad (2)$$

Where φ (.) = standard normal distribution, (Y = 1) implies that a farmer is participating in the HBSMP and *x* represent the exogenous variables likely to have an influence on farmers participation. In addition to estimating the probabilities, the study also estimates the marginal effects which are used for the discussion of the results. The marginal effects are more informative and easier to understand and explain. Following from Nyaupane and Gillespie (2011), the marginal effects for continuous variables are estimated using equation 3;

$$\frac{\partial E\left[Y \mid x\right]}{\partial x} = \phi(\beta' \mathrm{x})\beta \quad (3)$$

Marginal effects for dummy variables are however estimated using equation 4

$$\Pr\left[Y = 1 \mid \bar{x}., d = 1\right] - \Pr\left[Y = 1 \mid \bar{x}., d = 0\right] \quad (4)$$

Where ẍ. refers to the mean values of all continuous variable. Empirically, determinants of farmer's participation in the HBSMP is specified as;

$$Y = \beta_0 + \sum_{i=1}^{9} \beta_i x_i \quad (5)$$

Where β_0 is the constant term or intercept and β_i represent the parameters to be estimated. The maximum likelihood estimates of the parameters are generated using the STATA software

Description of explanatory variable

Being male and female has a positive and negative effect on the decision to participate in the forest related technology promotion. In many cases female farmers has better social relation than male farmers, more likely to have links with forest projects. On the other hand, male farmers are usually decision maker and access to control resources in the household therefore these favored them to participate in forest projects. Nxumalo and Oladele (2013) observed that male farmers are more likely to participate in agricultural projects. Nnadi and Akwiwu (2008) did not, however, find any significant relationship between sex and farmers participation in an agricultural project.

A younger farmer most probably participate in forest project because in many cases younger farmers are more risk taker and need to try new ideas. In stead, farmers appear a higher level of experience can have a better knowledge and evaluate the benefit of participating in a project with better precision. A more experienced farmer may have a lower level of uncertainty about the innovation's performance Tadesse (2008). Oladejo et al., (2011) did not however observe any significant relationship between age and participation in agricultural projects.

Married farmers can share ideas with their spouse and may therefore be more likely to participate in forest projects compared to a farmer who is not married. Nnadi and Akwiwu (2008) noted that marriage increases a farmer's concern for household welfare and food security which is therefore likely to have a positive effect on their decision to participate in an agricultural project. Oladejo*et al*. (2011). However, found a negative relationship between marriage and farmers participation in agricultural projects.

It was assumed that a better educated farmer can understand the information very easily and internalize the information transferred from development agents, researchers, NGOs and other development stakeholders compared to less educated farmers. Farmers who have more family size are likely to participate in forest related technology promotion. Because forest activities, by nature, demand more labor at establishment stage. Economically, many farmers couldn't able to afford for labor as they needed, therefore this limited them to participate on a project.

Access to credit significantly affects the participation of farmers in forest related project. This financial institution supports the farmers to have a credit and liaisons efficiently utilize their money. Moreover, farmers who have access to credit are more risk taker than those who don't have. Contact with development agents is expected to have a positive effect on farmer's decision to participate in forest projects. Many project undertake with a consultation of development agents hence the likelihood of a farmer being informed and primed to participate in a project increase with contact with an extension agent.

Land is an important resource for forest development. Farmers who have large land size could show the possibility of an individual farmer to participate in forest projects. This indicated also that farmers can easily diversify and change land use patter in his own field than farmers owned lesser size of land.

Result and discussion

Socio demographic characteristics of respondents

As shown in Table 1, farmers who have access to training are about two-times more likely to participate in forest related technology adoption. The majority farmers who participate in the technology adoption have large family size and land holding than non-participant farmers. About twofifth of participant are married. Married farmers are more likely to take a longer time to reach a decision as compared to unmarried farmers. Married farmers may have to either consult or reach a consensus with their spouses before making decision such as participating in technology adoption. Even though,the number of family size weresignificantamong the two groups, they have on average 7 family members per household and it is still higher than the national family size, which is 5.1.Although participant and non-participant farmers significantly differ by access to training, family size, marital status and family size; there is no any significant difference regarding access to credit, age, and educational status among the sampled household.

Table 1 Demographic characteristics of respondents

characteristics		percent		
		Willing to participate	Unwilling to participate	overall
sex	Female	2.3	3.9	6.2
	Male	35.7	58	93.8
Married		37.4*	18*	95.4
credit		17.4	8.5	25.9
Training		34.1***	14.1***	48.2
Mean				
Age		45	43	44
Education		3	3	3
Total family size		7**	6**	7
Total land holding		1.9***	1.4***	1.6

*, ** and *** represent statistically significance at 10%, 5% and 1% respectively

Determinants of Farmers' Participation in forest related technology promotion

As indicated in Table 2, the maximum likelihood estimated logs indicate high significant value, which means with predictors is to be preferred over the model without predictors.

Sex, age, marital status, number of years in a school, number of family member, and access to credit, training participation, and total land holding are selected factors that determine farmers' participation on forest related technology adoption in Dire Inchine woreda.

The marginal effects of sex on the probability and intensity of participating in forest related technology promotion was -80% and 42 % respectively. According to Nkamleu and Manyong (2005), sex has a positive effect on the adoption of agroforestry technologies, at 1% significance level. In other words, male headed households have better probability to participate in forest related projects than female counterparts. Hence, mainly men farmers are frequently travel to the city and able to get new and updated information from their friends and development agents

Table 2 Marginal effect estimation of the probit model

participation	Coef.	Std. Err.	P>z
Sex	-.8031894**	.4201445	0.056
Age	-.0019972	.0074761	0.789
Marital	-.5199061**	.2361622	0.028
Education	-.0550942	.0810936	0.497
Familsize	-.0023098	.0378238	0.951
credit	-.2531391	.2035609	0.214
Training	2.008499***	.1952338	0.000
Land	.1578747*	.0858882	0.066
Number of observation	305		
LR chi2 (9)	154.68		
Prob > chi^2	0.000		
Pseudo R^2	0.3818		
Log likelihood	-125.24749		

*, ** and *** represent statistically significance at 10%, 5% and 1% respectively

Married farmers can share ideas with their spouse. Therefore, more likely to participate in forest related projects compared to a unmarried farmers. Similarly, probability of married farmers in participating in forest related projects was -51.9% than single. That means married households mainly willing invest for long term return than shortly gained benefits.

A farmer who has access to training is about 2 times more likely to participate in forest related technology adoption. Farmers are mainly participating on trainings delivered by Ministries of Agriculture (MOA). Even though, many trainings are geared towards crop, it raised farmers' awareness and perception on improved technologies including forestry. Farmers who have large land size are more likely to participate in forest technology promotion than those who have less land holdings. The probability and intensity of participating in forest related technology promotion activitieswere about 16% and 8.5 % respectively. These figures indicated that farmers who owned large land size have high probability to change land use pattern to raise profit and avoid uncertainties.

Conclusion and recommendation

This study used the binary probit model to identify and examinethe probability of farmers'participation in the highland bamboo silvicultural management technology promotion practices. Sex of households, marital status, participation on trainings, and total land holding were significantly affecting the participation of farmers in forest technology promotion activitiesin the study area. A farmer with large farmland has 16% probability of participating in forest related technology promotion. A farmer who has access to training is about 2 times more likely to participate in the forest technology promotion activities. Similarly, the probability of married farmers in participating on forest related technology adoption is about 51.9% higher than single farmers. Male headed households have 80% probability to participate in forest related technology adoption than female counterparts. To boostfarmer's participation in forest related technology promotion, there is a need to make gender balance and address gender related barriers. Women are less exposed for new information, which constrain their participation in forest technology adoption compared to men. Moreover, marginal farmers and youth should be targeted in such project intervention to enhance group dynamics.

Reference

Chambers, R. (1983). "Rural development: Putting the last first. Essex". Addison Wesley Longman Limited.

Climate Resilient Green Economy (CRGE) Strategy Document (2011).

CSA, 2007. Population and housing census of Ethiopia. Results for Oromia Region. Statistical report on population size and characteristics, Vol. I: part I. June 2008, A.A.

FAO data for 2017 indicates a contribution of 5.2% of the Ethiopian forestry sector to GDP

Farid, K.S., L. Mozumdar, M.S. Kabir and U.K. Goswami (2009). "Nature And Extent of Rural Women's Participation in Agricultural and Non-Agricultural Activities". *Agricultural Science Digest* 29(4): 254-259

Greene H. W. (2003). *Econometric Analysis*. 5th Edition, Pearson Education, Inc., Upper Saddle River, New Jersey, USA.

INBAR,2018,http://www.inbar.int/five-ways-bamboo-can-fight-climate-change/

Nnadi, F. N., and C. D. Akwiwu (2008). "Determinants of Youths' Participation in Rural Agriculture in Imo State, Nigeria". *Journal of Applied Sciences* 8(2): 328-333.

Nxumalo, K. K. S., and O. I. Oladele (2013). "Factors Affecting Farmers' Participation in Agricultural Programme in Zululand District, Kwazulu Natal Province, South Africa". *Journal of Social Science* 34(1): 83-88.

Nyaupane, N. P., and J. M. Gillespie (2011). “Factors Influencing Producers’ Marketing Decisions in the Louisiana Crawfish Industry”. *Journal of Food Distribution Research* 42(2): 1-11.

Nkamleu, Guy &Manyong, Victor. (2005). Factors affecting the adoption of agroforestry practices by farmers in Cameroon. Small-Scale Forestry. 4. 135-148.

Oladejo, J. A., S. O. Olawuyi, and T. D. Anjorin (2011). “Analysis of Women Participation in Agricultural Production in Egbedore Local Government Area of Osun State, Nigeria”. *International Journal of AgriculturalEconomics and Rural Development* 4(1): 1-11.

Bamboo Utilization Practices and Challenges of Cottage Industries: The Case of Selected Towns in Ethiopia

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Abstract

Large amount of bamboo resource is found in both highland and lowland areas of Ethiopia. Even though the uses of bamboo stems culms are numerous, its utilization in Ethiopia has been limited due to lack of awareness about bamboo resource utilization, scarce technologies, scientific knowledge about the species and it's susceptibility to biological and physical deterioration. This study is therefore, intended to describe the status and constraints of bamboo furniture producing industries. The survey was done by adopting purposive sampling procedure in selected cities/towns. Snowball sampling was used for this study due to absence of registered information on Bamboo industries. Both quantitative and qualitative data were collected mainly from primary sources. Closed and open-ended structured questionnaires were used, for collecting both quantitative and qualitative data. Data analysis was done using Statistical Package for Social Sciences (SPSS). Descriptive statistics and inferential statistics were applied to calculate frequency and other tests of significance. The study found that bamboo was one of the most neglected sector and its industries have low capacity and produce low quality of furniture products due to various barriers. Lack of training on improved bamboo technologies for drying and treatment during processing and producing furniture was found by survey result. Moreover, the most common problems confronted were the borer attack on bamboo furniture and raw materials, shortage of production space and lack of capacity about tools/machine and finance. The study implied the need to intervene and train bamboo cottage industries practitioners on improved bamboo technologies and capacity building.

Keywords: Bamboo, cottage industries, challenges, practices

Introduction

Ethiopia is known for its large amount of bamboo found in both highland and lowland areas of the country. The high land bamboo is *Yushania alpine K. Schum (Arundinoideae)* and the law land bamboo *is Oxytenantheria abyssinica (A.Rich.) Munro*

(*Bambusoideae*) (Azene, B., 1993; Kassahun E. 2003; Getachew, D. and Melaku, A., 2012). Though there are different estimates on bamboo coverage of Ethiopia, latest documents report that it is about one million ha, which is about 67 per cent of African bamboo forest cover and 7 percent of the world's total (Teshome, 2015). As reported by Luso Consult (1997), out of the total hectares of bamboo; highland and lowland bamboo resources, accounts for about 15 per cent and 85 per cent respectively. The high land bamboo (*Y. alipina*) is found in north western, central, south and southwestern high lands of Ethiopia. The low land bamboo (*O. abyssinica*) grows only in the western of Ethiopia's low lands.

Bamboo has numerous benefits in day-to-day uses for the local communities where the species is growing. According to Zhaohua (2001), over 1500 distinct uses of bamboo have been recorded around the world. INBAR (2010), stated that an economy of 2.5 billion people come from bamboo-related activities. In different parts of the world, it is used as a source of raw material for fodder, construction materials, paper production, laminated boards, energy, food, beverage and medicine due to their easy workability, strength, straightness, lightness, range of size, abundance, short period in which they attain maturity (Woldemichael, 1980; Ensermuet*et al*., 2000; Seyoum, 2008).

Even though the uses of bamboo Culms are numerous, its utilization in Ethiopia is limited to construction, fences and some rudimentary furniture and household utensils (Arsema, 2008; Tefera *et al*., 2013). According to literature, some of the major constraints in the sector are lack of awareness about bamboo resource utilization, scarce technologies/scientific knowledge about the natural properties of the species, its susceptibility to biological and physical deterioration and lack of control measures against bio-deteriorating agent's damage (Kassahun, 2000; Seyoum, 2008; Getachew*et al.,* 2012). According to Seyoum (2008), if there is a good understanding on natural properties of bamboo, it is possible to utilize them successfully and efficiently for multiple uses.

Recently, bamboo based small and medium businesses are growing in Ethiopia. However, the level of their utilization is still very limited (Getachew and Melaku, 2012). Further, the authors argued that among the limitations in bamboo utilization its susceptibility to biological and physical deterioration is the most important one. Biological degradation can affect the usage, strength, utility, service life and value of the bamboo/bamboo products (Kassahun *et al*, 2003). Although various treatments are available to increase its service life, people are unaware of utilizing these technologies. Therefore, bamboo is considered as a perishable material and, hence, useless, which has led to its neglect as a useful renewable resource. Although bamboo has quite high distribution and is widely utilized by large number of local communities in Ethiopia, little information exists on its utilization practices and challenges hindering its utilization practices in bamboo industries. This study is therefore, intended to understand the practices and challenges of bamboo industries producing furniture. Specifically, the base line information is collected to describe the status and constraints on bamboo furniture producing industries.

Methods

Study area and Sampling method

Survey was done in purposively selected cities and towns considering the availability and utilization of bamboo in the area. These cities were Addis Ababa, Hawassa, Injibara, BahirDar, Hagereselam and Shashamane. Snowball sampling technique was used for this study due to absence of legally registered bamboo firms in selected cities and towns.

Data source and collection technique

The study is based on mixed research approach using both quantitative and qualitative descriptive methods. Quantitative method was used to apply frequency percentage and mean of respondents of data collected through questionnaire. Qualitative method was also employed to describe and analyze the information obtained from interviews conducted among the owners and employees of bamboo cottage industries.

Closed and open-ended structured questionnaires were used, for data (both quantitative and qualitative) collection from bamboo cottage industries in selected cities and towns. During data collection, the owner or other responsible technical employees were requested to fill the questionnaires. Data from direct observation during bamboo, processing and furniture making from bamboo was taken. In addition, several related relevant textbooks, manuals, journals and reports regarding bamboo were reviewed.

Data Analysis

Data collected were checked, corrected, coded and entered in Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics were applied to calculate summations, averages and percentages. One sample non-parametric test like chi-square test for goodness of fit for categorical variables, and Kolmogorov-Smirnov test to compare mean distribution were applied. The key features and challenges hindering the bamboo processing cottage industries of Ethiopia including their capacities, raw material availability, quality of finished products and their general bamboo utilization practices were analyzed.

Results and Discussion

General Characteristics of Bamboo Industries

As there is no attention to the bamboo resource and its industries in Ethiopia, all the bamboo cottage industries are registered under the wood industries categories. According to survey result, most of the industries have been operating for one to five years. With exception of Addis Ababa, the average duration of operation of industries in surveyed towns was four years. It can be concluded that the bamboo cottage industries are largely new start-ups as business sector. The survey indicated the male and female staff composition in various categories in administration, technical works and daily wage labourers. Though women seem to be under-represented in the work force, few women in Addis Ababa and Hawassa are business owners. With majority technical workers in industries, the average distribution of employees in industries varies from three to six. There is variation about employee work experience in different surveyed towns. The average work experience of employees in Hawassa, Addis Ababa and BahirDar towns indicated highest experience while, employees in Injibara, Hagarselam and Shashamane showed low experience (Table 1).

Table 1 Mean distribution of industries years of operation, number of employees and experience

Categories	Location of Bamboo Furniture Industries				
	Addis Ababa Mean	Hawassa Mean	Injibara Mean	BahirDar Mean	Others Mean
Years of Industries operation	6	4	4	4	4
Number of employees	3	6	5	3	4
Work experience of employee	9	10	5	7	4

Source: Primary data estimates (2017)

Bamboo Culm Utilization

The survey result indicated that 86.7 per cent of the cottage industries use highland bamboo while only 13.3 per cent use both high land and low land bamboo for the furniture production. Those industries using both high land and low land bamboos were only industries found in Addis Ababa. Though data was collected from high land bamboo dominant areas, there was implication that lowland bamboo was not conducive for furniture production. Most industry owners (83.3%) are aware of the bamboo availability from Sidamo, Guraghe, Injebera, and others (like DirreInchine and Jimma). The utilization of bamboo localities in bamboo industries depends up on the proximity to the locality and accessibility of that bamboo species. The survey result showed that most of industries in Addis Ababa use bamboo from Guraghe due to the proximity of the locality. Industries in Hawassa, Hagereselam and Shashamanne used Sidamo bamboo. While Industries found in Bahridar and Injibara used bamboo from Injibera. However, most of industries indicated that they preferred Sidamo bamboo due to it is relative resistance to attack by bio-degrading agents, its culm nature and size.

Regarding bamboo resource availability, except industries in Hawassa most industries found in other cities/towns indicated that there was no scarcity of the bamboo resource. As bamboo workers reported in Hawassa, there was the scarcity of bamboo supply in the town due to broker's interventions and no customs of marketing bamboo culm in the town. Most of the industries (66.7%) dried bamboo by stacking culms horizontally until they use it. The survey showed that Industries lacked information on appropriate drying and storing methods.

The most common bamboo furniture produced in last two years by these industries were chair, shelf, table, sofa, stool, bed and bowl. With exceptions of table, bowl and sofa, other types of furniture produced did not show significant variation. The most preferred furniture by customers was sofa, chair and shelf equally, and table respectively (Table 2). There were no significant differences for preferences in furniture. However, qualitative data indicated that all bamboo products furniture were affordable in comparison to wood furniture, aethestically attractive design and indicated cultural significance. The sofa and shelf were largely preferred in homes and traditional houses, while stool, chair and table were preferred by mini coffee houses and cafes.

Bamboo workers skill and bamboo culm selection

Majority of bamboo workers (73.3%) acquired furniture making skills through experience with an exception of Hawassa town, and partly Hagereselam and shashamanne towns, indicative of informal training (Figure 1). There was significant difference among categories provided for acquiring skills in bamboo furniture making. The Chi-square result (χ^2= 17.304, P-value = 0.000) shows that there is significant differences at less than one per cent probability level.

To produce high quality bamboo furniture, most industries considered culm size, age and locality as conditions to select bamboo raw materials in multiple responses. Thus, owners in Addis Ababa furniture industries gave priority for locality of bamboo, Hawassa furniture industries equally for culm size and locality, Injibara furniture industries for both culm size and age of the culm, BahirDar furniture industries for culm size, and Industries in other towns for age of the culm. As shown in the Table 3 below, there is significant difference for culm size and price being as either condition for selection of bamboo culm or not.

Table 2 Quantity of furniture produced in last two years by Industries

Type of furniture	N	Mean	S.D	1 sample K-S test	P-Value
Chair	24	393.67	379.09	1.179	0.124
Table	25	341.76	401.64	1.400**	0.040
Bed	25	49.36	58.41	0.995	0.275
Child bed	25	70.96	82.94	1.075	0.198
Bowl	25	880.20	2339.52	1.840***	0.002
Stool	23	526.17	492.84	1.326	0.059
Shelf	25	271.04	268.49	1.130	0.155
Sofa	24	169.17	208.31	1.478**	0.025

Primary data estimates (2017), ***and ** are significant at≤ 1% and <5% probability level

Table 3 Multiple response for bamboo culm selection across different town**s**

Conditions for row bamboo Culm selection		Location of Bamboo Furniture Industry						Binomial Test	p-value
		Addis Ababa	Hawassa	Injibera	Bahridar	Others	Total		
Culm	F	4	5	5	5	2	21		
size	%	44.4	100	83.3	83.3	50	70	21.000**	.045
Locality	F	6	5	-	1	3	15		
	%	66.7	100	-	16.7	75	50	15.000	1.000
Age	F	2	4	5	4	4	19		
	%	22.2	80	83.3	66.7	100	63.3	19.000	.201
Price	F	2	1	-	2	1	6		
	%	22.2	20	-	33.3	25	20	6.000***	.002
Moisture	F	1	3	3	2	2	11		
content	%	11.1	60	50	33.3	50	36.7	19.000	.201

Source: Primary data estimates (n=30), ** and *** significant difference at < 5% and 1% level respectively

Most of furniture industries (88.9%) procured bamboo as raw material in green condition. Accordingly, the survey result indicated that with a few exceptions industries in Addis Ababa and Injibara, all furniture industries in Bahir Dar, Hawassa, and other towns acquired bamboo culm in its green condition. Approximately,93.3 percent industries did not consider its present moisture content during bamboo processing, owing to lack of awareness of the necessity of drying and moisture content removal.

The chi-square (χ^2 = 24, p-value= 0.000) test showed that there was difference between getting bamboo culm as green and dry conditions at less than one percent probability level (Table 4). The study highlights the following in the bamboo industrial sector: non-use of drying techniques, raw bamboo stocked in open air, piled horizontally one over the other without considering the traditional drying techniques and limited storage space for bamboo raw materials and finished furniture. Relatively, bamboo furniture industries found in Hawassa had better spaces for bamboo processing and bamboo culm storage.

Table 4 Nature of bamboo Culm procured by Bamboo Furniture Industry

In what condition did you get bamboo Culm?		Location of Bamboo Furniture Industry					Total
		Addis Ababa	Hawassa	Injibara	Bahirdar	Others	
Green	F	7	4	4	5	4	24
	%	77.8	100	80	100	100	88.9
Dry	F	2	-	1	-	-	3
	%	22.2	-	20	-	-	11.1
χ^2							24***
P-value							0.000

Primary data estimates: *** significant at <1% probability level

In Addis Ababa, partly in BahirDar and other towns, the survey result showed that there was problem when joining parts together to produce furniture. Other problems confronted include: problems of splitting, lack of correct dimensional measurement and shrinkage problem while and after joining parts. Except in Hagerselam and Shashamanne, most of furniture industries mixed bamboo with wood and metal to produce furniture. Industries used manual method for finishing and did not have separate rooms for finishing materials application. Most of the industry owners thought that their products had good quality with respect to design, joints and finishing.

Researchers observed that there was a problem of borer attack on stocked raw materials as well as finished furniture due to lack of appropriate treatment methods. Except for Hawassa furniture industries, most of respondents in other towns implicated that they did not use improved technologies due to lack of training (Table 5). Furniture industries in Hawassa have informal training especially on furniture design but they reported that there was lack of profitability on bamboo furniture in comparison to wood furniture due to lack of awareness among customers.

Source of Bamboo Culm

The major source of bamboo for Industries was market. However, few industries had access to bamboo through farmers. BahirDar furniture industries got bamboo culms exclusively from market. There was also an exceptional case for Hawassa, which had access to bamboo through brokers and suppliers (Table 6). With an exception of Addis

Ababa, bamboo culm was available on time for Industries in surveyed towns. The survey also indicated that industry owners purchased the amount they need every year. Moreover, in case of Addis Ababa, majority of respondents said bamboo was not available on time and are also unable to purchase amount they need every year. The possible reasons for this case were shortage of supplier and bamboo farm being at a far distance from Addis Ababa in comparison to other towns.

Table 5 Reasons for not using improved technologies by Industries

Reasons for not using improved technologies		Location of Bamboo Furniture Industries					Total	Binomial Test	P-value
		Addis Ababa	Hawassa	Injibara	Bahirdar	Others			
Lack of	F	-	2	-	2	-	4		
awareness	%	-	40	-	33.3	-	13.3	29***	0.000
Not	F	5	1	4	5	4	19		
trained	%	55.6	20	66.7	83.3	100	63.3	11	.201
Time	F	1	-	1	1	2	5		
taking	%	11.1	-	16.7	16.7	50	16.7	25***	.001
Not	F	4	4	-	-	-	8		
profitable	%	44.4	80	-	-	-	26.7	8**	.018
Other	F	-	-	1	-	-	1		
problem	%	-	-	16.7	-	-	3.3	29***	.000

Source: Primary data estimates (n=30), ** and *** are significant difference at <5% and ≤1% level

Table 6 Source of bamboo for workshop Industries in different Towns

Source of bamboo for Industries		Location of Bamboo Furniture Industry					Total	Binomial Test	P-value
		Addis Ababa	Hawassa	Injibara	Bahirdar	Others			
Market	F	9	3	4	6	3	25		
	%	100	60	66.7	100	75	83.3	25***	.001
Farmers	F	1	2	3	-	2	8		
	%	11.1	40	50	-	50	26.7	22**	.018
Other	F	-	2	-	-	-	2		
sources	%	-	40	-	-	-	6.7	28***	.000

Source: Primary data estimates (n=30), ** and *** are significant difference at <5% and ≤1% level

Credit and Utilization

The survey result indicated that majority of industries faced cash shortage to purchase inputs with an exception of those of Hawassa, which had access to government loan and save money (Table 7). This was entirely the case for respondents of Addis Ababa Industries. There was an indication for cash shortage owing to high house rent. Addis Ababa and Bahir Dar industry owners solve cash shortage by borrowing money from friends and relatives. While Injibara industry owners, solve such case partly by borrowing money from friends and relatives too as well as through money lenders, and in Hagerselam and Shashamane through pre-payment from customers to ease cash shortage.

Table 7 Cash shortage by Location of bamboo Industries

Have you cash shortage to purchase inputs?		Location of Bamboo Furniture Industry					Total	Binomial Test	P-value
		Addis Ababa	Hawassa	Injibara	Bahirdar	Others			
Yes	F	9	2	5	5	3	24		
	%	100	40	83.3	83.3	75	80	24***	.002
No	F	-	3	1	1	1	6		
	%	-	60	16.7	16.7	25	20		

Source: Primary data estimates, *** significant at < 1% level

Access to Market and Price of Furniture

The study highlighted poor market access Majority of industries in Addis Ababa indicated poor access to market, while industries in Hawassa indicated a balance between medium and poor, Bahir Dar and Injibera inclined to medium response and others a majority resorted to poor response (Table 8). The chi-square test ($\chi^{2=}$ 5.600, p-value= 0.61) shows difference among category at < 10 percentage level.

Most of the industries sold their bamboo products to local people without any intervention. Nevertheless, most of the furniture industries in Addis Ababa and other towns like Hagereselam and Shashamanne thought that they were not getting fair price for their products. In Bahir Dar and Injibara, the survey depicted a balance between responses; i.e., on getting fair price and not. However, industries found in Hawasa were relatively getting fair prices for their bamboo products. As most of industries indicated that the reasons for the low price were due to lack of awareness among consumers for the bamboo products. Particularly in Addis Ababa, the primary reason was due to less market niche available while industries in Injibara indicated that the most likely problem was lack of effective promotion. Generally, the test statistic (Binomial Test= 20, p-value=0.100) showed that there was no significance difference between group responses.

Table 2 Access to market by Industries across different Towns

How do you see the access to market in your area?	Location of Bamboo Furniture Industry						Total
	Addis Ababa		Hawassa	Injibara	BahirDar	Others	
Good	F	-	1	1	1	1	4
	%	-	20	16.7	16.7	25	13.3
Medium	F	2	2	3	4	1	12
	%	22.2	40	50	66.7	25	40
Poor	F	7	2	2	1	2	14
	%	77.8	40	33.3	16.7	50	46
χ^2						5.600	
P-value						0.061*	

Source: Primary data estimates

Almost all furniture industries sold bamboo products at their workshop except for few industries in Hawassa and Injibara, which sold their products at showrooms. There was no significant difference among most of similar bamboo furniture's unit price in different industries of different towns. However, sofa and childbed depicted a significant difference at less than five per cent (Table 9). Except industries in Injibara, most industries had the opinion that the input price was too expensive. Industries in all cities accomplished new furniture designs and modifications based on market condition to attract customers.

Table 9 Type of furniture sold with unit price in last two years

Type of furniture	N	Mean	S. D	1sample K-S Test	P-value
Chair	25	264.80	157.013	.888	.410
Table	23	261.65	160.644	.771	.592
Bed	18	1951.94	1480.305	.958	.318
Sofa	24	1470.83	1669.282	1.581**	.013
Stool	16	130.94	61.731	.946	.332
Child bed	18	754.44	658.074	1.554**	.016
Shelf	24	457.29	275.196	1.072	.200

Source: Primary data estimates, ** significant difference at<5% level

Labour Supply and Extension contact person

Most industries in Addis Ababa, Hawasaa, and other towns like Hagerselam and Shashamanne recruited employees through personal acquaintance, while industries in Injibara and Bahir Dar recruited employee through brokers. Some industries considered experience and professionalism for an employment, although largely work ethics like free from drug abuse and motivation for work was the crucial consideration. Industries in Bahir Dar and partly in Hagerselam and Shashamane towns experienced labour shortage. There was no extension contact person and few get advice other than extension agent on producing bamboo furniture. Only furniture industries of Hawassa are getting advice from technical colleges, University and Kaizen Institute on bamboo utilization with metal and wood as well as space and product management.

Bamboo Worker Perception

Bamboo workers perception was collected on both traditional and improved practices. Approximately, 90 per cent of respondents agreed and indicated the significance and relevance of improved bamboo practicing. With the exception of a few industries in Addis Ababa, bamboo practitioners believed that it is worth practicing modern bamboo technology than the traditional methods adopted. Similarly, it was believed that using improved bamboo technology increases the quality of bamboo products, which could serve as an alternative raw material for furniture making in place of wood. Nearly all bamboo industry owners valued the role of researchers in endorsing an increase and change in the ways of bamboo production and utilization practices.

Conclusion and Recommendation

The study found that bamboo was among the neglected sectors and its industries have low capacity and produce low quality of furniture products due to various barriers. Industries in surveyed towns were unregistered and merged in the wood working sector. However, industries started as new business startups and operated relatively for few years. There were various factors and challenges for its development. Majority of bamboo industry practitioners did not avail any training in appropriate technologies like bamboo culm selection, drying and treatment. Furthermore, industries did not consider its moisture content during bamboo processing, due to a lack of awareness regarding drying and moisture content removal. In addition to lack of training, the most common problems reported by all industries included the borer attack on bamboo furniture and raw materials, shortage of production space and lack of capacity with regard to tools/machine and finance.

The survey results also indicated that majority of industries practitioners faced cash shortage to purchase inputs with exception of those of Hawassa, which had access to government loan. Majority of bamboo industry owners and practitioners in all cities did not participate on bamboo related meetings, workshop or seminars. Majority of the industries in surveyed towns thought they were not getting fair price for their products, and access to market by industries seemed to be poor. Almost all furniture Industries sold bamboo products at their workshop except for few industries in Hawassa and Injibara, which sold their products at show rooms. There was no extension contact and few get advice other than extension agent on producing bamboo furniture in surveyed towns.

To improve bamboo Industries, attention should be given to the sector by government and other development actors. Bamboo sector need to be separated from wood industry sector independently. There should be separate registration of bamboo industries and support for the improvement of the sector. Bamboo practitioners should trained on knowledge and skill about improved bamboo technologies like appropriate selection of its culm, drying, treatment and storage. Addressing other bottlenecks of the industries like space for processing, access to credit and loans, and market promotion could pave for bamboo industry development. Therefore, all sectors working on bamboo should cooperate and engage by involving all stakeholders for the development of the sector.

References

Arsema, A. 2008.Value Chain Analysis for Bamboo Originating from Shedem Kebele, Bale Zone

Azene, B. 1993. Useful trees and shrubs of Ethiopia, identification, propagation and management or agricultural and pastoral com munities. Technical Hand book No. 5. Regional Conservation Unit, SIDA, Nairobi, Kenya

Ensermu, K., Tamrat, B, Alemayehu, G and Gebremedhin, H. 2000. Ethiopia and Eritrea, Volume 7, Addis Ababa, Ethiopia and Uppsala, Sweden.

Getachew, D. and Melaku, A., 2012 Increasing the Service Life of Bamboo Culms as Construction and Furniture Material by Controlling Biodeterioration and Rational Utilization

Getachew, D., Melaku, A., Demel, T. and Alemu, G., 2012 Commercial timber species in Ethiopia: characteristics and uses : a handbook for forest industries, construction and energy sectors, forestors and other stakeholders

INBAR (International Network for Bamboo and Rattan). 2010. Study on Utilization of Lowland Bamboo in BenishangulGumuz Region, Ethiopia. Beijing, China.

Kassahun, E. 2000. The indigenous bamboo forests of Ethiopia: an overview. *Ambio*29, 518–521

Kassahun, E. 2003. Ecological aspects and resource management of Bamboo forests in Ethiopia. Doctoral dissertation, ISSN 1401-6230, Swedish University of Agricultural Sciences, Uppsala, Sweden

Kibwage, J., Odondo, A., &Momanyi, G. 2008. Structure and performanceof formal retail market for bamboo products in Kenya. Scientific Research and

LUSO CONSULT. 1997. Study sustainable Bamboo Management: Second Interim Report.

Oberoi, V.S. 2004. “The Bamboo Book”. National Mission on Bamboo Applications, New Delhi: pp150-177.

Seyoum, K. 2008. Testing of Two Ethiopian Bamboo Species for Value add Products. Forestry Research center, Addis Ababa, Ethiopia.

Tefera, B. E., André, L. and Jürgen, P., 2013 Indicators and Determinants of Small-Scale Bamboo Commercialization in Ethiopia

Woldemichael, K., 1980. The Bamboo Potential of Ethiopia, Addis Ababa.

Yenesew, A., Yihenew, G. and Belayneh, A..2013. A Socio-Economic Contribution of High Land Bamboo (YushaniaAlpina) For Household Livelihood in Banja District, Northwestern Ethiopia. Journal of Agriculture and Biodiversity Research, 154-156.

Zhaohua, Z., 2001. Sustainable Development of the Bamboo and Rattan Sectors in Tropical China.Proceedings No. 6. International Network for Bamboo and Rattan (INBAR), Beijing, Chin

Socio-economic and Institutional Lessons on Rehabilitation of Degraded lands in Ethiopia

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Abstract

Several socio-economic constraints hinder decisions to invest and sustain appropriate practices for overcoming environmental and land degradation. A better understanding of the socioeconomic and institutional aspects helps to establish whether the purposes of the restoration efforts are in line with the motivations, expectations, and demands of the concerned stakeholders. To this end, we reviewed and compiled a number of published and unpublished documents in order to draw socio economic and institutional lessons on rehabilitations of degraded lands. This study also incorporated the views of people from the previous land rehabilitation interventions areas. Our results indicated that socio-economic and institutional factors are equally important as biophysical techniques to mitigate land degradation. The key lessons identified were active participation of local community in the rehabilitation program, integrating locally acceptable set of land management practices, improving marketing and finance access, giving high priority to demand driven livelihood programs, improving extension capacity, capacity building and improving community land tenure right. The exchange of information and experience sharing will also help to build confidence and to reassure the participants that the land rehabilitation program is relevant to community needs and ensures they have a sense of responsibility towards the project or any intervention efforts. Moreover, local administrative structure, and informal institutions like “Iddir and Mahber” found as get way to society for inception and implementation of the program. Therefore, it is imperative to inform stakeholders at all levels to address socio-economic and institutional aspects that could ensure sustainability of land rehabilitation interventions.

Keywords: Land rehabilitation, Social, Economic, Institutional lessons, Ethiopia

Introduction

Ethiopia has given much attention to rehabilitation of forest and land degradation in recent years as part of supporting key development goals. As part of Bonn challenge, Ethiopia made new pledge to restore 22 million hectares of degraded lands and hence signed the New York Declaration in September 2014 (Brasser & Ferwerda, 2015). The Environmental Policy of Ethiopia has overall policy goal to arrest environmental degradation and combat desertification (Adugna, A., n.d.).One of its pillars to build Climate Resilient Green Economy (CRGE) is protecting and re-establishing forests as carbon stocks (FDRE, 2011). Hence, the government has put a number of initiatives in place to restore degraded ecosystems. However, the biggest challenge is to ensure that such interventions are sustainable (Bori, 2016).

Many socio-economic constraints hinder decisions to invest and sustain appropriate practices for overcoming environmental degradation. Among the most important appear to be poverty, land tenure, local market development, local institutional and organizational development, and farmers' perceptions and attitudes (Lakew, Menale, Benin, & Pender, 2000). According to Birhanu (2014), poverty is one of the fundamental problems affecting environmental resources management, which causes enormous environmental damage as the poor forced to mine the rapidly deteriorating natural resources in their surroundings. The main consequences of land degradation negatively affect human livelihoods and environment, which reduces land productivity and affects food security(Blay et al., 2004). Land degradation process also increases competition for scarce resources with possible conflicts between users (Appanah, Shono, & Durst, 2015).

A better understanding of the socioeconomic aspects helps to establish whether the purposes of the restoration projects are in line with the motivations, expectations, pressures and needs of the concerned stakeholders. Issues associated with policies, institutions, and social are often more important than technical issues (Birhanu, 2014). Chirwa (2014), pointed out rehabilitating of specific degraded areas depends first on the priorities and management objectives of stakeholders followed by the costs and benefits as well as the economic, social, and environmental values of the land resources in their current and desired future states. However, mostly attention of the Development Agents and other stakeholders has been focused on biophysical impacts of rehabilitation of degraded lands, while economic and social well-being of the households have often been neglected (Lemenih, Negash, & Teketay, 2007). Research into entitlements, environmental justice and vulnerability suggests that tackling desertification is not just about adopting physical remedies. Social remedies such as economic and social impacts are need to be tackled collectively in an integrated manner, rather than separately (Low, 2013). It is suggested that Policy makers and practitioners need to move from a purely environmental orientation towards also ensuring socio-economic benefits for sustaining intervention(Lemenih & Kassa, 2014). According to Lemenih et al., (2007), understanding the social and economic system of the local people is the starting point for successful rehabilitation.

Ethiopian Environment and Forest Research Institute has implemented project on rehabilitations of degraded lands on various sites. There were biophysical improvements of degraded lands due to rehabilitation effort using tree plantation with soil and water conservation techniques. However, there was no study conducted on socio economic and institutional aspects. Therefore, this study aimed to draw lessons on socio economic and institutional aspect of different literatures accompanied by views of people in previous Institute`s intervention sites. From the review and people views several socio-economic and institutional lessons have been drawn that provide the basis for recommendations to guide the way forward in land rehabilitation effort in future.

Methods

Several published and unpublished research articles, case studies and reports related to rehabilitation of degraded land were collected and selected for this review. To support the review, brief visit to previous Ethiopian Environment and Forest Research Institute intervention sites was done at Bishoftu, Guder and Debreberhan sites. Focus group discussion with farmers and key informants was conducted, who involved during interventions based on check lists developed. The selection of participants in focus group discussions was done purposively, who actively involved in the intervention from the community around intervention sites. Similarly, for the key informants three local authorities, one biophysical researcher and three technical assistants, who organized and played facilitation role during intervention were interviewed. In the presence of the chosen discussants, the whole thing was open for discussion and the informants were participating to point out, and answer issues raised in any way based on the context of their villages. The key socio-economic and institutional lessons were assessed through a qualitative approach based on available literatures and interview through FGDs and KIIs.

Literature Finding

Projects considered successful if it addresses community participation; creating sense of ownership; capacity building; land tenure right; market and finance; indigenous knowledge; extension and communications; and institutional problems.

Community Participation

Community participation is the process of encouraging the local people to apply their initiative and energy in sustainable integrated watershed management (AMAREW, 2007). The involvement and empowerment of local communities at all level of the decision making process in natural resource management has been found to be more sustainable and beneficial (UNDP, 2014; Birhanu,2 014; Berry, n.d.). Blay et al., (2004) states the need for stakeholder consultation and involvement about causes and consequences of land degradation, and benefit sharing of land rehabilitation. Chirwa (2014) reveals that natural regeneration through active involvement of local communities promoted under PFM is the most successful and promising option for restoration of degraded lands. According to Gashaw (2015),participatory natural resources management accompanied with sustainable livelihood would greatly contribute for rehabilitation of degraded environment. Strong community participation and a demand-driven approach are among the driving forces of successful watershed management (Giordano & Langan, n.d.). According to Deichert *et al*., (2014), participatory approach promotes collective action and ownership of the people involved and can address obstacles in a targeted way. On the other hand, poor participation of especially local communities in the establishment and management of natural resources might compromise results and sustainability (Birhane et al., 2017). Little emphasis to community participation in management and decision-making can contribute to the community's sense of alienation and indifference and ultimately to the failure of rehabilitation endeavors (Lemenih et al., 2007). In case studies in Amhara high land, lack of active participation of the communities in general and women in particular in all processes of watershed development lowered its sustainability. For instance, the role of communities was predominantly limited to the construction of soil and water conservation measures (Woldeamlak,2001; Tatek *et al*., 2015) .

Demand driven program

Literature indicates that project needs to have a clear potential to deliver tangible and short-term benefits to community. According to Appanah et al., (2015), natural resources can be better managed when viewed from a broader perspective, considering and involving the perceptions, needs and interests of all stakeholders, including local communities and individual land users. Balancing public goods and services provision with private benefits is key to ensuring the long- term sustainability of the restored landscapes. Birhanu (2014) maintains long-term sustainability is more likely achieved if development is driven from the bottom-up and if it addresses farmers' and communities' immediate needs and constraints. According to Blay *et al*., (2004) and Tatek *et al*., (2015) case studies in Amhara and Tigray regions show that rehabilitation projects which use high-value trees or which improve livestock management practices is likely to be more successful than projects which restrict their objectives to the repair of biophysical degradation. Deichert *et al.,* (2014) recommended sustainable use of wood and non-timber forest products (NTFPs) as an integral part of the approach to productive landscapes. Lemenih & Kassa (2014) put forward that ensuring re-greening practices generate enough economic incentives for a community is a key for sustainability. They emphasized when individuals are likely to generate direct and tangible benefits, they will be motivated to participate in re-greening initiatives, be it individually or collectively. Participants in focus group discussions have also indicated that the need for community benefit on rehabilitated land. For instance, community in Debraberhan site have getting income from planted eucalyptus trees, where as in Bishoftu sites use grass for their cattle as forage and cut agricultural tools.

Creating Awareness and Sense of ownership

Studies show that throughout project design and implementation there is need for community awareness raising. Blay *et al* (2004), pointed out rehabilitation activities should be preceded by creation or raising the awareness of the stakeholders. By using various approaches, it is essential that the causes and consequences of land degradation, feasible rehabilitation techniques and benefits of rehabilitation need to be covered. According to Birhanu (2014), lack of environmental awareness concerning the linkage between environment and development is one challenges of Ethiopia face now days. Community should pay for environmental services, which would feel owning and sustaining assets. When people make real contributions of their own resource, they would insure the implementation of the planned activities(AMAREW, 2007). Blay et al., (2004) state equitable sharing of costs and benefits within communities and government give communities a sense of ownership. Similarly, Birhane *et al*., (2017), noted that equitable sharing helps create a sense of ownership and smooth implementation of management plans by community members. They explained unfair and less transparent benefit-sharing mechanisms degrade the sense of ownership among community members and encourage community members to engage in illegal activities. The FGD results also indicated that the communities were reluctant to participate in rehabilitation effort of degraded lands at the beginning. The technical assistants and researchers have acknowledged that the need for approaching community through existing structure like kebele administration and "Iddir" for creating of sense of ownership.

Land and Forest tenure

Clear definition of land and forest tenure, and rights of access to forest and wood land resources for restoration of degraded forest and tree resources as well as woodland areas contribute to both peoples' livelihoods and environmental quality (Chirwa, 2014). The existence of a favorable political and policy environment that provides a clear legal framework for ownership and/or usufruct rights of local communities over their natural resources encourage restoration (Blay et al., 2004). According to Appanah *et al*., (2015), secure land tenure is particularly important for achieving sustainable land management and boosting livelihoods. A policy research focusing on the link between rural poverty, food insecurity and environmental degradation in Ethiopia found that a crucial possible link between all three was land ownership. One of the best ways to provide farmers the incentives to increase productivity and to protect natural resources is, to give them security of land through ownership (Adugna, A. (n.d.). Well-defined and secure tenure is critical for the sustainable management of natural resources (Birhane et al., 2017). Better tenure security, clear user rights, and devolution of responsibilities to lower levels of organization (individual household or smaller community) help facilitate collective action for better re-greening initiatives in communal systems (Lemenih & Kassa, 2014). For instance, it argued that the best tenure for exclosure is for it to be communal and suggested community-based management as the best management strategy. Farmers in this group feared that individuals might change the land use system. Both formal and informal rules and regulations are very important for the sustainable management of exclosures. Therefore, community-based comprehensive rules and regulations that are binding are required (Birhane et al., 2017).

Creating economic incentive and Subsidy

Review literature show that the need to create incentive and subsidize people for benefit loss from land under rehabilitation effort. Chirwa (2014) pointed out the need to associate the forest and land restoration/rehabilitation implementation with forest enterprise development (e.g. Farm Forestry/Out-growers) and payment of environmental services. Lemenih et al., (2007) suggest the dependency of local people for grazing and fuel wood can be reduced through introduction of agroforestry practices, energy-efficient stoves, and woodlots at the farm level. Adugna, A. (n.d.) recommended that incentives and regulatory policies to compensate for externalities that may adversely affect natural resources: for instance, the use of price-based incentives such as subsidies, taxes, and other incentives are preferable to direct regulation. According to Lemenih & Kassa (2014), poor households can hardly afford to lose short-term economic gains for long-term environmental benefits unless they are properly compensated for that loss. Research evidence for effective exclosure in Halla district of Tigray region show that people should aware of its benefits for their cattle and fuel wood. Due to this, encroachment for forage grass, fuel wood and pole is common (Asres, n.d.).

Market and Finance

Poor marketing and financial arrangements can prevent large-scale investment in trees and land restoration whereas innovative financial tools that provide early rewards can be drivers of investment in forest and land rehabilitation (Appanah et al., 2015). According to Berry (n.d), better market access and credit services can have positive impacts on land improvements and resource and welfare conditions, indicating that 'win-win' development strategies can reduce land degradation and poverty. Markets have been the major driving force behind the expansion of small-scale plantations across the highlands of Ethiopia. High return on investment in plantations is driving the conversions of even farm and grazing lands to woodlots in some areas in the central and western highlands. In some cases, however, markets especially the labor market may negatively influence plantations by increasing the opportunity cost of labor (Lemenih & Kassa, 2014). The need for diversification of income generating activities and adding value through developing markets and marketing has advantage (Blay et al, 2004).

Extension and communication

According to Birhanu (2014), poor coordination among research, extension and education has affected formal technology development and the transfer of technologies from researchers to local experts and local communities, particularly the farmers. He noted though the decentralization of the administration system down to woreda level, no clear and strong linkages for information exchange and sharing. Appropriate information on the resource base, the extent of environmental degradation, the costs and benefits of applying sustainable environmental management as well as information on the nature of the different practices available is required to make decisions at different levels. In addition to lack of proper information and poor communication, the absence of clear up-scaling mechanisms hinders up-scaling of successful sustainable land management practices in the country (Zeleke et al., 2006). They noted in their study lack of an appropriate forum to share information and access to modern information communication systems. Birhane *et al*., (2017) found that the local administrators and experts have played significant roles in disseminating information on the practices and roles of exclosures. Blay *et al*., (2004) put forward dissemination of technologies in close partnership with existing governmental and non-governmental agricultural extension services of improved technologies are needed for rehabilitation of degraded lands. The researchers propose sharing information and experiences has value in rehabilitation effort. Inter and intra project sites along with visits to share experiences among community members, have taught the community new ways of doing things (UNDP, 2014). According to kebele administration of Bishoftu site, experience sharing visit done to Amhara region has great impetus to play facilitation role in rehabilitation site.

Institutional stability

The structuring of institutions dealing with natural resources management undermines a sense of ownership by program staff, results in high staff turnover, wastes institutional capacity, and causes discontinuity of activities and initiatives and loss of institutional memory (Birhanu, 2014). According to Zeleke *et al.,* (2006), the cost of institutional instability in the country is immeasurable. They notified Ethiopian policy makers have been busy revising institutional set-ups for nearly three decades and appear not to consider the damage this inflicts on the country's economic development. More over Low, P.S.(ed), (2013) put forward the need to understand the institutional settings in which land users make decisions that may lead to or avoid desertification. He noted that the rate of desertification could be reduced if societal institutions were audited to check for constraints that lead to poor people degrading land instead of managing it sustainably. Appanah *et al*., (2015) indicated stability of local and national-level institutions could support local processes by providing adequate governance structures, encourage equitable participation of stakeholders, and ensure necessary technical and financial support.

Indigenous Knowledge and Practices

Review literature show that indigenous knowledge and practices would support natural resource management. Local communities are rich in indigenous knowledge and practices that can further enhance better chance of success for sustainable land resource management (Woldeamlak, 2001; Birhanu, 2014). Blay *et al*., (2004) emphasized that rehabilitation methods are simple and inexpensive if it related as much as possible to local knowledge and practice. According to Zeleke *et al*., (2006), lack of proper integration of introduced practices with indigenous knowledge of the different communities during introduction of technologies are some of the other factors reported by stakeholders as negatively affecting the success and improvements to land resource management. Giordano & Langan(n.d.) noted that farmers have enormous indigenous knowledge and creativity, which many externally driven developments programs often fail to consider. For instance, Adugna (n.d) found that an ecological study compared the land degradation assessment techniques used by indigenous ecological knowledge (IEK) of the Borana pastoralists to the techniques used by trained ecologists concluded that IEK was effective to determine landscape suitability and potential grazing capacity of individual landscapes and regional levels.

Capacity building

Capacity building interventions are necessary for community level initiatives. The aim of building the capacity of the community is to manage their resources and to guarantee sustainability of interventions of land rehabilitation program. The role of government and donors should focus on creating an enabling environment and then communities have high interest in rehabilitating natural resources (AMAREW, 2007). Blay *et al*., (2004), emphasize Local communities should empowered through functional institutional frameworks at village level to oversee planning, implementation and monitoring; Capacity building to enable communities to implement the projects; and equitable sharing of both costs and benefits within the communities and between them and the government. Deichert et al., (2014), found positive results in a multi-level approach through the provision of capital investment, technical assistance and capacity building for smallholder farmers in the watersheds management. According to Blay *et a*l., (2004) capacity building needs to take account of the holistic approaches, experience sharing, skill development and planning for sustainability. He noted the importance of developing the skills of individuals and communities in planning, organization, management and accounting through training has paramount importance.

Conclusions and Recommendations

Study indicated that addressing socio economic and institutional factors as physical techniques are equally important to mitigate land degradation. To arrest land degradation, issues like Indigenous knowledge and practices; improving marketing and finance access; give high priority to need based and livelihood programs; improve extension capacity; and develop land tenure right should keep into consideration. Greater participation of local community in the identification of local land degradation issues and their remediation has to be addressed. The exchange of information and partnership will help build confidence and to reassure all that the programs are relevant to their needs and ensures they have a sense of responsibility towards the project.The provision of economic incentives is important for local people for their involvement and management practices as well as for any loss of environmental services from the land under intervention. The government should introduce land and tree tenure policy to promote land rehabilitation programs. Land and tree tenure should give landowners and farmers the guarantee to plant and own the forests.

Local people awareness on ecological and socio-economic importance of rehabilitated sites is needed, which in turn ensure the long-term desired management, conservation and sustainable utilization of benefits of the land. Moreover, training and dissemination of improved technologies for rehabilitation of degraded lands should be implemented in close partnership with existing governmental and non-governmental extension services. The need for institutional stability and its capacity to disseminate appropriate knowledge regarding natural resource management and rehabilitation effort is important. Therefore, it is imperative to inform stakeholders at all levels neglecting socio economic aspects could not ensure sustainability of land rehabilitation interventions.

References

Adugna, A. (n.d.). Lesson 4 Ethiopia : Population and the Environment.

AMAREW (Amhara Micro-enterprise development, Agricultural Research, Extension, and Watershed management) Project in Ethiopia. (2007). Terminal report (July 2002 - December 2007)

Appanah, S., Shono, K., & Durst, P. B. (2015). Restoration of forests and degraded lands in SoutheastAsia. *Unasylva*, *66*(245), 52–63. https://doi.org/http://dx.doi.org/10.1108/17506200710779521

Asres, H. G. (n.d.). Effectof Exclosure on Environment and Its Socio Economic Contributionsto Local People : in the Case Study of Halla Exclosure ,

Berry, L. (n.d.). Land Degradation in Ethiopia : Its Extentand Impact.

Birhane, E., Mengistu, T., Seyoum, Y., Hagazi, N., Putzel, L., Rannestad, M. M., & Kassa, H. (2017). Exclosures as forest and landscape restoration tools : lessons from Tigray Region , Ethiopia, *19*, 37–50.

Birhanu, A. (2014). Environmental Degradation and Management in Ethiopian Highlands: Review of Lessons Learned. *International Journal of Environmental Protection and Policy*, *2*(1), 24. https://doi.org/10.11648/j.ijepp.20140201.14

Blay, A. D., Bonkoungou, E., Chamshama, S. A. O., Chikamai, B., Wood, E. P., & Yapi, A. M. (2004). Rehabilitation of Degraded Lands in Sub- Saharan Africa : Lessons Learned from Selected Case Studies.

Bori, W. M. (2016). Sustainable approaches to degraded land restoration in rural Ethiopia.

Brasser, A., & Ferwerda, W. (2015). 4 Returns From Landscape Restoration. *Commonland Foundation*, 1–59.

Chirwa, P. W. (2014). Restoration practices in degraded landscapes of Eastern Africa. *African Forest Forum Working Paper Series*, *2*(11), 55. Retrieved from www.afforum.org

Deichert, G., Krämer, F., & Schöning, A. (2014). Turning degraded land into productive landscapes, Ethiopian highlands. *Etfrn News*, *56*, 82–87.

FDRE (Federal Democratic Republic of Ethiopia) 2011. Climate Resilient Green Economy: Mission Statement. Addis Ababa, Ethiopia.

Gashaw, T. (2015). The implications of watershed management for reversing land degradation in Ethiopia. *Research Journal of Agriculture and Environmental Management*, *4*(1), 5–12.

Giordano, M., & Langan, S. (n.d.). *An Assessment of Integrated Watershed Management in Ethiopia*.

IFPRI (International Food Policy Research Institute), WUR(Wageningen University and Research Center) and EEPFE(Environmental Economics Policy Forum of Ethiopia). 2005. Poverty and Land Degradation in Ethiopia : How to Reverse the Spiral ?, 1–13.

Lakew Desta, Menale Kassie, Benin S. and Pender J. 2000. Land degradation and strategies for sustainable development in the Ethiopian highlands : Amhara Region.*Socio-Economics and Policy Research*, (32), ILRI (International Livestock Research Institute), Nairobi, Kenya. 122 pp.

Lemenih, M., & Kassa, H. (2014). Re-greening Ethiopia: History, challenges and lessons. *Forests*, *5*(8), 1896–1909. https://doi.org/10.3390/f5081896

Lemenih, M., Negash, M., & Teketay, D. (2007). Rehabilitation of degraded forest and woodland ecosystems in Ethiopia for sustenance of livelihoods and ecosystem services, 299–313.

Low, P.S. (ed) (2013) Economic and Social impacts of desertification, land degradation and drought. White Paper I. UNCCD 2nd Scientific Conference, prepared with the contributions of an international group of scientists. Available from: http://2sc.unccd.int (accessed 26 March 2013.)

Tatek, A. E., National, A., State, R., Dar, B., Resources, N., & Heritage, N. (2015). Socio Economic Constraints affecting the Implementation of Land Rehabilitation Programsinthe High- Lands of Ethiopia.

UNDP(United Nations Development Program(2014).Unlocking the Development Potential of Drylands : Lessons from Ethiopia and Uganda. (n.d.).

Woldeamlak Bewket (2001).The Need for a Participatory Approach to Soil and Water Conservation (SWC) in the Ethiopian Highlands: A Case Study in Chemoga Watershed, East Gojjam.

Zeleke, G., Kassie, M., Pender, J., & Yesuf, M. (2006). Stakeholder Analysis for Sustainable Land Management (SLM) in, (January).

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