OPEN ACCESS

African Journal of Agricultural Research

10 January 2019
ISSN 1991-637X
DOI: 10.5897/AJAR
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJAR

The African Journal of Agricultural Research (AJAR) is a double blind peer reviewed journal. AJAR publishes articles in all areas of agriculture such as arid soil research and rehabilitation, agricultural genomics, stored products research, tree fruit production, pesticide science, post-harvest biology and technology, seed science research, irrigation, agricultural engineering, water resources management, agronomy, animal science, physiology and morphology, aquaculture, crop science, dairy science, forestry, freshwater science, horticulture, soil science, weed biology, agricultural economics and agribusiness.

Indexing

Science Citation Index Expanded (ISI), CAB Abstracts, CABI's Global Health Database
Chemical Abstracts (CAS Source Index), Dimensions Database, Google Scholar
Matrix of Information for The Analysis of Journals (MIAR) Microsoft Academic
ResearchGate, The Essential Electronic Agricultural Library (TEEAL)

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Agricultural Research is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

Article Copyright

When an article is published by in the African Journal of Agricultural Research the author(s) of the article retain the copyright of article. Author(s) may republish the article as part of a book or other materials. When reusing a published article, author(s) should;

Cite the original source of the publication when reusing the article. i.e. cite that the article was originally published in the African Journal of Agricultural Research. Include the article DOI

Accept that the article remains published by the African Journal of Agricultural Research (except in occasion of a retraction of the article)

The article is licensed under the Creative Commons Attribution 4.0 International License.

A copyright statement is stated in the abstract page of each article. The following statement is an example of a copyright statement on an abstract page.

Copyright ©2016 Author(s) retains the copyright of this article..

Self-Archiving Policy

The African Journal of Agricultural Research is a RoMEO green journal. This permits authors to archive any version of their article they find most suitable, including the published version on their institutional repository and any other suitable website.

Please see http://www.sherpa.ac.uk/romeo/search.php?issn=1684-5315

Digital Archiving Policy

The African Journal of Agricultural Research is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.

https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The African Journal of Agricultural Research encourages metadata harvesting of all its content. The journal fully supports and implements the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

All articles published by Academic Journals are licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0). This permits anyone to copy, redistribute, remix, transmit and adapt the work provided the original work and source is appropriately cited.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajar@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJAR

Submit manuscript online http://ms.academicjournals.org

Academic Journals

73023 Victoria Island, Lagos, Nigeria

ICEA Building, 17th Floor, Kenyatta Avenue, Nairobi, Kenya

Editors

Prof. N. Adetunji Amusa
Department of Plant Science and Applied Zoology
Olabisi Onabanjo University
Nigeria.

Dr. Vesna Dragicevic
Maize Research Institute
Department for Maize Cropping
Belgrade, Serbia.

Dr. Abhishek Raj
Forestry, Indira Gandhi Krishi Vishwavidyalaya,
Raipur (Chhattisgarh) India.

Dr. Zijian Li
Civil Engineering, Case Western Reserve University,
USA.

Dr. Tugay Ayasan
Çukurova Agricultural Research Institute
Adana,
Turkey.

Dr. Mesut YALCIN
Forest Industry Engineering, Duzce University,
Turkey.

Dr. Ibrahim Seker
Department of Zootecny,
Firat university faculty of veterinary medicine,
Türkiye.

Dr. Ajit Waman
Division of Horticulture and Forestry, ICAR-Central Island Agricultural
Research Institute, Port Blair, India.

Dr. Mohammad Reza Naghavi
Plant Breeding (Biometrical Genetics) at
PAYAM NOOR University,
Iran.

Editorial Board Members

Table of Content

Vol. 14(2), pp. 46-53, 10 January, 2019
DOI: 10.5897/AJAR2015.10599
Article Number: 950486159799
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Difficulties in adaptation to climate change by oil palm farmers in Southern Nigeria

Ojemade, A. C.[1*], Okorji, E. C.[2] and Enete, A. A.[2]

[1]Agricultural Economics Division, Nigerian Institute for Oil Palm Research (NIFOR), PMB-1030, Benin City, Edo State, Nigeria.
[2]Department of Agricultural Economics, University of Nigeria, Nsukka, Enugu State, Nigeria.

Received 2 November, 2015; Accepted 9 December, 2015

There is an increasing concern that climate change is already having an impact on poor, small scale oil palm farmers in Southern Nigeria. Researchers have shown that Nigeria is already being plagued with diverse ecological problems which have been linked to climate change. More so, increase in the severity of extreme weather events, sea level rise, coastal erosion, changes in weather pattern that affect oil palm production and changes in water availability are affecting vulnerable farmers and limiting their means of earning a living. The effect on families and communities can be devastating and adapting to these changes is essential. The paper highlights measures taken by famers to manage losses caused by climate change and difficulties encountered. A purposive and multi-stage random sampling technique was adopted in selecting 171 farmers from three states (Imo, Ondo and Delta). Both descriptive and inferential statistics were used in analyzing data. The constraints encountered by farmers in adopting climate change adaptation strategies were: high labor cost (0.759), land tenure (0.64), poor access to information (0.740), lack of training (0.767), lack of capital (0.820), limited availability of land (0.798) and lack of improved oil palm production technologies (0.438).

Key words: Constraints, climate change, oil palm farmers and adaptation.

INTRODUCTION

Empirical evidence shows that climate change is emerging as one of the most important challenges to mankind in the 21st century. The world's climate has always been changing between hotter and cooler periods due to various factors such as human (anthropogenic) and natural factors (biogeographic). These changes which constitute major challenges to humanity have been occurring for at least a century (Erda et al., 2007; Pender, 2008). Climate change affects crop production in many ways (IPCC, 2007) for instance, uncertainty and variations in the patterns of rainfall and flood cause pest and disease in response to climate change. However, recent evidence and predictions indicate that climate changes are accelerating and will lead to wide-ranging shifts in climate variables. Specifically, in 2007, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) effectively put to rest many of the debates surrounding the science of climate

*Corresponding author. E-mail: ojemadetwo@yahoo.com.

change, rendering evidence solid enough to impel action. It was found that the warming of the climate system was “unequivocal and that a number of attendant effects were already observable (Pender, 2008; UNCTD, 2009). The impact of climate change is however spatially heterogeneous across a diverse range of geopolitical scales. For instance at the international level, the risk is generally believed to be more acute in developing countries because they rely heavily on climate-sensitive sectors, such as agriculture and fisheries, and have a low gross domestic product, high levels of poverty, low levels of education and limited human, institutional, economic, technical and financial capacity, etc. (IPCC, 2007; UNFCCC, 2007; WBGU, 2008). At the national level, various ecosystems, sectors and sub-populations within a country have been identified as being more or less at-risk in a changing climate depending on length of coastline, level of emergency preparedness and economic and livelihood sensitivity to climate related elements such as rain, wind, etc (NEST, 2004; Allen Consulting, 2005; IPCC, 2007).

Uncertainty and variations in the patterns of rainfall and flood, cause cash crops like oil palm to suffer setbacks under reduced photoperiods leading to flower, fruit abortion trends that reduce yields, cause pest and disease invasion, because of climate change. The United Nations Framework Convention on Climate Change (UNFCCC, 2007) defines climate change as a change of climate which is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Nigeria has been reported to be vulnerable to the impacts of climate change largely because about 70% of Nigerians are engaged in small holder rain-fed agriculture. For Nigeria, agriculture is important because about 42% of the country’s GDP comes from agriculture and related activities. The impact of climate change is very visible in most communities in Nigeria, from the Sahel in the north to the rainforest and coastal zone in the south. The high population coupled with high poverty levels and rapid economic growth, are making huge demands on Nigeria's natural resources. Climate change impacts compound existing pressures on these resources. Nigeria’s risk are particularly high due to its low lying coastline that is highly populated with a heavy concentration of GDP generating industry and infrastructure (Nest and Woodly, 2011; DFID, 2009).

There is a possibility that risk and uncertainties which are common characteristics of farmers in Nigeria and in weather patterns, rainfall, drought and flooding events have meant that rural farmers who implement their regular annual farm business plan, risk total crop/ livestock failure due to climate change effects. These farmers are in most cases subject to climate shocks.

Mitigation and adaptation remain the most popular options to manage the impacts of climate change on agriculture in the world today. However, while neither adaptation nor mitigation actions alone can prevent significant climate change impacts, taken together; they can significantly reduce food security risks. While mitigation is necessary to reduce the rate and magnitude of climate change, adaptation is essential to reduce the damages from climate change that cannot be avoided (Ozor and Cynthia, 2010).

Adaptation options by farmers are limited by some constraints which could be economic, environmental, social or otherwise. Some of these constraints are yet to be fully understood. Accordingly, little is known in the oil palm industry about these constraints and this limits policy formulation and decision making. This prompted this paper.

The analytical framework

Adaptation measures help farmers guard against losses due to increasing temperatures and decreasing precipitation. This section identified the constraints encountered by farmers in adapting to climate change effects, in other to provide policy information on factors to target and how to encourage farmers to increase yields and incomes. The analytical approach used is exploratory factor analysis.

Principal component analysis (used to group constraint variables into constraint factors) with iteration and varimax rotation was used, the factor loading under each constraint (beta weight) represent a correlation of the variables (constraint areas) to the identified constraint factor and has the same interpretation as any correlation coefficient. However, only variables with loadings of 0.40 and above (10% overlapping variance) (Comrey, 1962) were considered in naming the factors. All significance was tested at 5% level of probability. Only variables with factor loadings of 0.40 and above at 10% overlapping variance were used in naming the factors. Variables that have factor loading of less than 0.40 were not used while variables that loaded in more than one constraints were also discarded (Madukwe, 2004). The approach has been used to identify major constraints to adaptation (Ozor and Cynthia, 2010; Enete et al., 2011; Ozor et al., 2010).

Factor analysis is used in this study to simplify the multivariate dataset in order to understand the trends and associations more clearly. Factor analysis clusters variables into similar terms, generating fewer variables (called components or factors) that explain a large percentage of the variability of the original variables. Factor analysis also removes multi-collinearity between variables and combines those that are highly correlated (positively or negatively) to reduce redundancy in the variables (Cox et al., 2006).

The problems enumerated by the respondents were grouped using principal component analysis with iteration and varimax rotation. The model is presented as:

$$Y1 = a11X1 + a12X2 + * * *+ a1nXn$$
$$Y2 = a21X1 + a22X2 + * * * + a2nXn$$
$$Y3 = a31X1 + a32X2 + * * * + a3nXn$$
$$*= \qquad *$$
$$*= \qquad *$$
$$*= \qquad *$$
$$Yn = an1X1 + an2X2 + * * + annXn$$

Where: Y1, Y2,. …., Yn = observed variables/constraints to adaptation strategies; a1 – an = constraint loadings or correlation coefficients.

X1, X2, … Xn = unobserved underlying problems constraining farmers from adapting to climate change (Enete et al., 2011). The objectives of this study were to i) Identify the socio-economic characteristic of the farmers in the study area, and ii) investigate and examine the constraints to the implementation of climate change adaptation measures by farmers in Southern Nigeria.

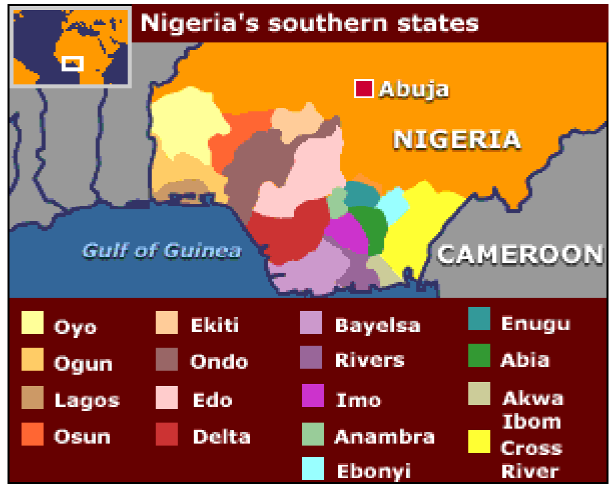

Figure 1. Map of states in Southern Nigeria.
Source: BBC News (2012)

METHODOLOGY

The study area

The study area comprises south east, south west and south south zones (Figure 1). Nigeria's geographical coordinate lies between 4°15´ to 7°N and 5 °49´to 30´E. The area towards the north of this region is largely deforested by human activities. The vegetation is characterized by median semi deciduous forest interspersed by savannah belts that support large expanses of farmlands.

Rainfall is the key climatic variable and there is a marked collection of wet and dry seasons in most areas. The rainy season usually begins in February or March as moist Atlantic air, known as the south west monsoon, invades the country and at the beginning of rains, usually marked by the incidence of high winds, heavy, but scattered squalls (Ozor et al., 2010). By April or early May in most years, the rainy season is under way throughout most of the area. The usual peak of the rainy season occurs through most of southern Nigeria in July with a dip in precipitation during the month of August (Ozor et al., 2010).

It is particularly difficult to state the requirements of the oil palm in seasonal climates, where monthly water deficits vary widely (Kee et al., 2000), and a large annual rainfall may not compensate for poor distribution, if rainy months have little sunshine. The general conclusions are as follows.

The ideal requirements are (Hartley, 1988):

1. Annual rainfall of 2000 mm or greater evenly distributed, without a marked dry season, and preferably at least 100 mm in each month
2. A mean maximum temperature of about 29-33°C and a mean minimum temperature of about 22- 24°C
3. Sunshine of 5 – 7 h/day in all months and solar radiation of 15 MJ/m² per day. Goh (2000) made a similar general list:
a. Annual rainfall of 2000- 2500mm
4. Relative humidity above 85%
5. Low vapour pressure deficit
6. No extreme temperatures or windspeed
7. Adequate sunshine hours and solar radiation of 16-17MJ/m² per day.

Climate and soil constitute the major aspect of the environment that greatly determines the yield of any crop. For oil palm cultivation in Nigeria, rainfall is clearly the most important climatic factor. As a result, oil palm cultivation is restricted to the southern one quarter (approximately) of the country with an annual rainfall of ≥ 1250 mm (Ogunkele, 1989).

The greatest total precipitation is generally in the south –south along the coast around bonny (South of Port Harcourt) and east of Calabar in cross river state, where the mean annual rainfall is more than 4,000 mm. Most of the south-south and south east receives between 2,000 and 3,000 mm of rainfall per year, and the south west receives generally between 1,250 and 2,500 millimeters per year (Ozor et al., 2010). The distribution of vegetation in Southern Nigeria is dependent on the climate, which becomes increasingly drier further inland from the coast. Climatic zones, therefore run parallel to the coast, widening or narrowing as geographical features alter the steepness of the climatic gradient. This climatic zoning, comprising the rain forest zone, the mixed deciduous and the parkland zone.

The study adopted the survey design. Multi-stage random sampling technique was adopted for this study to select respondents from 3 states, (three) southern states of Nigeria comprising one state from each of the geopolitical zone which includes: south west (Ondo), south east (Imo) and south–south (Delta) which was purposively chosen based on the fact that they are major oil palm producing areas in the zone (Oritsejafor, 1989). From each state, 2 predominantly oil palm growing agricultural zones were chosen. From each agricultural zone, a random selection of 2 local government areas each was done. Next, 2 farm communities were randomly selected from each local government area. 2 villages were then selected from each community. Lastly was a random selection of 4 oil palm farmers from each village. Out of 192 oil palm farmers selected, the enumerator retrieved information from 171 respondents representing a response rate of 89%.

Primary data (field survey data) were obtained using personal interview and administering of questionnaire to oil palm farmers in the study area. Data collected were analyzed using both descriptive and inferential statistics. Objective one was achieved using frequency and mean scores; objective two was achieved using factor analysis at 5% probability level. In this analysis, the factor loading under each constraint (beta weight) represent a correlation of the variables (constraint areas) to the identified constraint factor and has the same interpretation as any correlation coefficient. However, only variables with loadings of 0.40 and above (10% overlapping variance) (Comrey, 1962) were considered in naming the factors.

RESULTS AND DISCUSSIONS

Age distribution of the respondents

Table 1 shows that 56% of the respondents were within 46 – 55 years of age. They were aged about 52 years on the average. This suggests that the farmers were within the economically active age of below 60 years. With the current high rate of unemployment, young people may have been resorting to farming.

Marital status of respondents

Table 1 shows the marital status of the respondents. Majority (99%) were married while the remaining 1% was single. The table shows that oil palm production is mainly an enterprise of the married class. It is possible that most of the respondents were family men and women who require family income to carter for their families. The implication is that, with increase in family income, there will be improvement in their standard of living.

Educational level of respondents

The frequency distribution according to educational attainment is shown in table 1. About 4% of the respondents had no formal education, while majority (46%) had tertiary education. About 13% of them had primary education, 36% had secondary education. The result shows that about 95% of them had formal education showing that they were literate.

Farming experience

The frequency distribution of respondents according to farming experience is shown in Table 1. On farming experience, 50% of oil palm farmers had farming experience ranging from 11 to 20 years. Average years of farming experience were 15 years. Farmers in the study area were very experienced in the actual practice of oil palm farming.

Household size

Table 1 reveals the distribution of respondents according to household size. The table shows that 17.5% of farmers had household size of 1 - 4 persons, majority (62.6%) had household size of 5 - 8. The mean household size was 7.45. Large household size encourages adoption of adaptation methods (Nyangena, 2007; Dolisca et al., 2006; Birungi, 2007). The implication of this large household size implied available labor which can be provided at lowest cost.

Entries in Table 2 show the level of implementation of climate change adaptation strategies by respondents. The table shows that 50.29% of the respondents did nothing in their farm to respond to climate change effects. Climate change adaptation measures with low level of implementation include: mulching (12.28%), purchase of water for irrigation (21.63%), planting trees (12.28%), multiple intercropping (9.94%), crop diversification (12.28%), changing planting date (10.52%) and migration for income (13.45%). There was a moderate implementation of one of the measures which was use of resistant varieties (23.39%). Many farmers (50.29%) did nothing to respond to climate change effects. The low implementation of these adaptation options is expected in light of the constraints encountered by farmers in communities of Nigeria. Farmers lack capital/funds and information which if available can go a long way in tackling some climate change issues. Most of the problems or constraints encountered by farmers in adapting to climate change are associated with poverty (Ojemade, 2015).

Difficulties in adaptation to climate change impacts

Results in Table 3 show the difficulties farmers encounter in adapting to climate change impacts in southern Nigeria. Table 3 shows the Varimax rotated factors constraining farmers in the area from climate change adaptations.

Extraction method: Principal component analysis.
Rotation method: Varimax and Kaiser normalization.

From the entries in Table 3, only four factors were extracted based on the responses of the respondents. Only variables with factor loadings of 0.40 and above at 10% overlapping variance were used in naming the factors. Following this, each factor is given a denomination according to the set of variables or characteristics it was composed of. In this regard, the variables were grouped into four factors as: factor 1 (production: labor and land tenure constraints), factor 2 (information and training constraints), factor 3 (input: poor access to capital and land constraints) and factor 4 (technology constraints).

Under factor 1 (Production: labor and land tenure constraints), the specific constraining variables against climate change adaptation include high cost of farm labor (0.759) and inherited system of land ownership (0.654). Land tenure system is one major constraint that does not permit holders of capital to invest in large scale farming. In his own contribution, Benhin (2006) reported that one of the factors determining the speed of adoption of climate change adaptation measure is land tenure status. It has also been observed that high cost of farm labor is a constraint to adaptation by farmers (Adger et al., 2001; Deressa, 2008).

Under factor 2 (information and training constraints),

Table 1. Socio-economic characteristics of respondents in the study area.

Variables	Frequency	Percentage
Age (years)		
35-40	7	4
41-50	18	11
46-50	48	28
51-55	48	28
56-60	33	19
61-65	17	10
Gender		
Male	162	95
Female	9	5
Marital status		
Married	169	99
Single	2	1
Widow	0	0
Divorced	0	0
Educational level		
No Formal	7	4
Primary	22	17
Secondary	62	36
Tertiary	80	46
Occupational distribution		
Major		
Farming	149	87
Trading	14	8
Paid job	8	5
Secondary		
Agro processing	3	46
Basket weaving	3	2
Carpentry	1	1
Catering	3	2
Typing	9	5
Craftsmanship	15	9
Driving	9	5
Transportation of goods	3	2
*Multiple responses		
Farming experience		
1-5	10	6
6-10	17	10
11-15	42	25
16-20	42	25
21-15	24	14
26-30	3	2
41-45	3	2
No response	30	18

Table 1. Cont'd

Farm size		
< 1	37	22
1-3	74	43
4-6	42	25
7-9	9	5
10-12	9	5
Distance of farm		
1-5	60	35
6-10	14	8
11-15	42	25
16-20	21	12
No response	34	20
House-hold size		
1-4	30	17.5
5-8	107	62.6
9-13	32	18.7
14-18	2	1.2
Annual income		
< 300,000	39	22.8
300,001-600,000	77	45.0
600,001-900,000	32	18.7
> 900,000	11	6.4
Missing	12	7.0
Extension visit		
0	136	79
1	25	15
2	10	6
Total	171	100

Source: Field survey data 2012.

Table 2. Frequency distribution of respondents according to adaptation strategies.

Choice of practices	*No. of respondent	Percentage
Use of resistance varieties	40	23.39
Mulching	21	12.28
Purchase of water for irrigation	37	21.63
Planting trees (afforestation)	21	12.28
Multiple/intercropping	17	9.94
Crop diversification	21	12.28
Changing planting dates	18	10.52
Migration for income	23	13.45
Did nothing	86	50.29

*Multiple responses indicated; Source: Field survey data, 2012

Table 3. Constraints to climate change adaptation (rotated component matrix).

Variables	Constraints			
	Production constraints (labor and land tenure)	Information and training	Lack of inputs (poor access to capital/land)	Lack technology
Labor	0.759	0.054	0.164	-0.055
Land tenure	0.654	0.074	-0.151	0.298
Poverty	-0.581	-0.507	0.100	0.232
Lack of improved oil palm technologies	0.181	0.264	0.319	0.438
Poor access to information and knowledge	0.332	0.740	0.128	-0.044
Lack of training	-0.152	0.767	-0.106	0.068
Lack of capital	-0.079	0.128	0.820	-0.212
Poor agricultural practices	0.034	0.016	0.047	-0.915
Land	0.070	-0.152	0.798	0.304

the constraining variables against climate change adaptation were: poor access to information and knowledge (0.740) and lack of training (0.767). In their own contribution, Mark et al., (2008), Enete and Amusa (2010) and Maddison (2006) argued that lack of adaptive capacity due to constraints on resources like information may result in further food insecurity. The factors that loaded under factor 3 (Inputs: poor access to capital and land) include lack of capital (0.820) and limited availability of land (0.798). In his own contribution, Deressa (2008), in the analysis of barriers to adaptation to climate change in the Nile Basin indicates that lack of money is a major constraint to adaptation by farmers. Consequently, Benhin (2006) noted that farm size is a major determinant of speed of adoption of adaptation measures to climate change.

Under factor 4 (Technologies), only one variable was loaded: lack of improved oil palm technologies (0.438). Rural farmers are generally poor, do not have adequate technology, related skills, and cannot afford to invest in technologies to adapt to climate change or sustain their livelihood during harsh climate conditions such as drought (Sofoluwe et al., 2011; Alam et al., 2011). Technology is one of the crucial factors to adapt to climate changes (Alam et al., 2011). Poor agricultural practices were not significant under factor 4 (lack of technology). This is counter intuitive because one could expect that poor agricultural practices could be an important constraining factor in terms of technology.

RECOMMENDATIONS

Oil palm farmers have already started responding to climate change through adaptation strategies/ measures they believe are helping them counteract its negative impact. The study also observed that adaptation measures have cost implications on farmers who are the most vulnerable group because of their poor financial base.

The study revealed that respondents were using some adaptation measures which include mulching (12.28%), purchase of water for irrigation (21.63%), planting trees (12.28%), multiple intercropping (9.94%), crop diversification (12.28%), changing planting date (10.52%) and migration for income (13.45%). The study also examined constraints to the implementation of climate change impacts in southern Nigeria and observed that the major constraints to climate change adaptation in southern Nigeria were: production problems, information and training, lack of inputs and lack of improved oil palm production technologies.

The oil palm sector is largely dominated by smallholders who produce 80% of Nigeria’s output. Several million smallholders are dispersed over an estimated area of 1.65 million hectares in the southern part of Nigeria, where they inter-crop oil palm with food crops such as cassava (*Manihot* spp.), yam (*Dioscorea* spp.) and maize (*Zea* mays).

Based on the results of analysis, there is need for improvement in all areas of agricultural technology in order to provide effective adaptation/coping strategies to sustain livelihoods. While the availability of inputs and labor are adequate, smallholder oil palm farmers have limited access owed to the prohibitively high costs for each. The prices of inputs- insecticides, herbicides and fungicides are increasingly high and beyond the reach of the meager earnings of small-scale, poor resource, oil palm producers. In the past, the government subsidized inputs, thus facilitating acquisition. In order to solve the problem of low input usage, provision of credit by government and other NGOs for purchasing inputs and for hiring labor could be made.

The government, research and extension, the private sector and non-governmental organizations (NGO’s) can improve annual farm performances for small holder farms by ensuring increase in farmer training and more access to credit and aid facilities and by helping farmers acquire livestock and important farm assets can improve farm performance. Ensuring the availability and accessibility of fertilizers and crop seeds before the onset of the next cropping season can also significantly improve annual farm performances across households. Consequently, innovative specific adaptation strategies/projects that aim to climate-proof the different agro-ecologies, and develop resilience to climate change effects should be carried out so that farmers can respond to climate change effects.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adger WN, Kelly PM, Nguyen HN (2001). Environment, Society and precipitous change. In: Adger WN, Kelly PM, Nguyen HN (eds). Living with environmental change: Societal vulnerability, adaptation and resilience in Vietnam, Routledge, London 314 p.

Alam MM, Siwar C, Molla RI, Toriman ME, Talib B (2011b). Climate Change and Vulnerability of Paddy Cultivation in North-West Selangor, Malaysia: A Survey of Farmers' Assessment. Voice Academia 6(1):45-56.

Allen Consulting (2005). Climate Change risk and Vulnerability. Australian Greenhouse Office, Department of the Environment and Heritage, Canberra, Australia 159 p.

BBC News (2001). Nigerian south seeks more autonomy. Available at: http://news.bbc.co.uk/2/hi/africa/1246719.stm

Benhin JKA (2006). Climate change and South African agriculture: Impacts and adaptation options. Centre for Environmental Economics and Policy for Africa (CEEPA) Discussion paper No. 21. CEEPA, University of Pretoria, South Africa.78 p.

Birungi PB (2007). The linkages between land degradation, poverty and social capital in Uganda. PhD thesis, Department of Agricultural Economics, Extension and Rural development, Faculty of Natural and Agricultural Sciences, University of Pretoria, South Africa 160 p.

Comrey AL (1962). The minimum residual method of factor analysis. Psychological Reports 11:15-18.

Cox JR, Rosenweig C, Solecki WD, Goldberg R, Kinney PL (2006). Social vulnerability to climate change: A neighbourhood analysis of the North East US mega region. Prepared for collaborators of the union of concerned scientist, North East climate change impact study 21 p.

Department for international development-DFID (2009). Impact of Climate Change on Nigeria's Economy. Final Report Feb. 2009. Available at: www.erm.com.

Deressa T (2008). Analysis of perception and adaptation to climate change in the Nile Basin of Ethiopia. An unpublished Ph.D. Thesis, Centre for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria, South Africa. 20 p.

Dolisca F, Carter RD, McDaniel JM, Shannon DA, Jolly CM (2006). Factors influencing farmers' participation in forestry management programs: A case study from Haiti. Forest Ecology and Management 236:324-331.

Enete AA, Madu II, Mojekwu JC, Onyekuru AN, Onwubuya EA, Eze F (2011). Indigenous agricultural adaptation to climate change: A Case study of South East Nigeria. Published by African technology policy studies network Kenya. ATPS Working Paper Series 53:38.

Enete AA, Amusa TA (2010). Challenges of agricultural adaptation to climate change in Nigeria; a synthesis from literature. Journal of Field Actions Science Reports 4:22.

Erda LI, Yinlong X, Shaohong W, Hui JI, Shiming M (2007). China's National Assessment Report on Climate Change (II): Climate change impacts and adaptation. Advances in Climate Change Research 0006-06:1673-1719.

Hartley CWS (1988). The oil palm, (3rd edition). London, Longman Scientific and Technical.127 p.

Intergovernmental Panel on Climate Change-IPCC (2007). Climate Change: Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Intergovernmental Panel on Climate Change: Summary for Policymakers. IPCC Secretariat: Geneva, Switzerland. 976 p.

Kee KK, Goh KJ, Chew PS (2000). Water cycling and balance in mature oil palm agro ecosystems in Malaysia. In: Proc. Int. Planters Conf. Plantation tree crops in the new millennium: the way ahead (Ed. By Push P), Incor. Soc. Planters, Kuala Lumpur pp. 251-275.

Maddison D (2006). 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 47 p.

Madukwe MC (2004). Multivariate Analysis for Agricultural Extension Research. In: Terry AO (ed). Research methods in agricultural extension pp. 206-236.

Mark WR, Mandy E, Gary Y, Lan B, Saleemul H, Rowena VS (2008). Climate change and agriculture: Threats and opportunities. Federal Ministry for Economic Cooperation and Development, Germany 26 p.

Nest- Nigerian Environmental Study/Action Team (2004). Regional Climate Modeling and Climate Scenarios Development in Support of Vulnerability and Adaptation Studies: Outcome of Regional Climate Modeling Efforts over Nigeria. Nigerian Environmental Study/Action Team (NEST), Ibadan, Nigeria 63 p.

NEST, Woodly E (2011). Reports of pilot projects in community based adaptation in climate change in Nigeria, Building Nigeria's response to climate change (BNRCC). Ibadan, Nigeria. Nigerian Environmental study/action team (NEST) 235 p.

Nigerian Environmental Study /Action Team-NEST (2004). Regional Climate Modeling and Climate Scenarios Development in Support of Vulnerability and Adaptation Studies: Outcome of Regional Climate Modeling Efforts over Nigeria, Nigerian. Environmental Study/Action Team (NEST), Ibadan, Nigeria 142 p.

Nyangena W (2007). Social determinants of soil and water conservation in rural Kenya. Journal of Environment, Development and Sustainability 10(6):745-767.

Ogunkele AO (1989). The suitability of Nigerian land for oil palm cultivation. A case study of NIFOR main station soils. NIFOR International Conference on Palms, and Palm Products 1:278.

Ojemade CA (2015). The effects of climate change on oil palm production in Southern Nigeria. Unpublished Ph.D thesis, University of Nigeria, Nsukka 121 p.

Ozor N, Madukwe MC, Enete AA, Amaechina EC, Onokala P, Eboh EC, Ujah O, Garforth CJ (2010). Barriers to Climatic Change Adaptation among Farming Households of Southern Nigeria. Journal of Agricultural Extension 14(1):114-124.

Ozor N, Cynthia N (2010). Difficulties in adaptation to climate change by farmers in Enugu state, Nigeria. Journal of Agricultural Extension 14(2):106-122.

Oritsejafor JJ (1989). Status of the oil palm vascular wilt disease in Nigeria. NIFOR: International conference on palms and palm product. pp. 329-331.

Pender JS (2008). What is Climate Change? And how it will affect Bangladesh. Briefing Paper (Final draft) Dhaka Bangladesh. Church of Bangladesh Social Development Programme 70 p.

Sofoluwe NA, Tijani AA, Baruwa OI (2011). Farmers' perception and adaptation to climate change in Osun State, Nigeria. African Journal of Agricultural Research 6(20):4789-4794.

United Nations Frame Work Convention on Climate Change-UNFCCC (2007). Climate Change: Impacts, Vulnerabilities and Adaptation In Developing Countries. Bonn, UNFCCC Secretariat 68 p.

United Nations Conference on Trade and Development (UNCTD) (2009). Developing Country Interests in Climate Change Action and the Implications for a Post-2012 Climate Change Regime. United Nations New York and Geneva 52 p.

German Advisory Council on Global Change (WBGU) (2008). World in Transition-Climate Change as a Security Risk, German Advisory Council on Global Change, Earth scan, London and sterling, VA. 271 p.

Vol. 14(2), pp. 54-64, 10 January, 2019
DOI: 10.5897/AJAR2018.10599
Article Number: 1D26EB659801
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Effects of moisture stresses during vegetative and reproductive growth phases on productivity of six selected rain-fed rice varieties in Ifakara, Tanzania

KITILU M. J. F.[1, 2*], NYOMORA, A. M. S.[1] and CHARLES J.[1]

[1]Department of Botany, College of Natural and Applied Sciences, University of Dar Es Salaam, Tanzania.
[2]Tanzania Research Institute - Ifakara Centre, Tanzania.

Received 3 October, 2018; Accepted 6 December, 2018

In order to study the critical growth stages and the most tolerant rice varieties in both lowland and upland rainfed ecosystems, an experiment arranged in split plots based on randomized complete block design was conducted under field conditions with 3 replications. Three stress timing irrigation treatments (no stress, vegetative moisture stress, and reproductive moisture stress) were assigned as th main plots, while 6 varieties (NERICA1, NERICA2, NERICA4, TXD 306, Tai and Komboka) were assigned as sub plots. Moisture stress during reproductive phase caused the highest reduction in grain yields (between 58 - 79%) followed by stress induction during vegetative phase, with 26 - 46% yield reduction; while no stress control moisture regime caused 0% reduction, that is did not cause any reduction. All NERICA tested varieties were the most tolerant to moisture stress during vegetative; they had only 26 - 36% grain yield reduction, compared to the lowland rice varieties which had 38 - 46% reduction during the same stress period. NERICA2 was the most tolerant variety to moisture stress during reproductive phase under the upland condition (66% reduction) followed by NERICA1 (67% reduction), while NERICA4 was the last (76% reduction). Tai was the most tolerant variety under lowland condition (58% reduction) followed by TXD306 (67% reduction), while Komboka was the last in lowland varieties with 79% reduction. Moistures stress during vegetative and reproductive growth phases significantly reduced plant height, shoot dry weight, number of tillers, number of panicles, spikelets, fertile grain, 1000 grain weight and harvest index in all the varieties. It was concluded that the most critical growth stage among the tested varieties is the reproductive growth phase. Stress induction at reproductive caused more reduction of 32% - 33% in grain yield compared to stress induction during vegetative growth phases. NERICA2 and Tai are the most tolerant varieties to moisture stress during the reproductive phase and therefore are recommended in areas with rainfall scarcity.

Key words: Yield reduction, moisture stress, NERICA rice, tolerant varieties.

INTRODUCTION

Moisture stress is one of the major causes of low yields of rice grown under rainfed lowland and uplands ecologies (Sharma and De Datta, 1994; Kamoshita et al., 2000; GRiSP, 2013). These ecologies account for about 92% of Tanzanian rice growing area, with averaged grain yield between 1.5 to 2.0 tons per hectare in the lowland

*Corresponding author. E-mail: kitiluj@yahoo.com. Tel: +225 -755259776.

Table 1. Soil fertility of the experimental sites before sowing the seeds

Site	Soil texture	Soil pH	EC	OC	Total N	Available P	Exchangeable Cations (meq/100 g soil)				CEC
	Class	H_2O	mS/cm	g/Kg	g/Kg	mg/Kg	K	Na	Ca	Mg	Cmol/Kg
Katrin (UP)	Sandy loam	6.4	0.1	11.9	0.7	88.5	0.1	0.2	5.5	1.1	10.8
Katrin (LW)	Clay loam	5.4	0.2	20.2	1.8	43.4	0.4	0.4	9.0	4.5	21.4

NB; UP=upland ecology, LW= Lowland ecology.

rainfed ecologies and between 0.8 to 1.0 tons in the upland ecologies (MAFSC, 2009; GRiSP, 2013). The relatively low yields in rainfed rice ecology are partly due to moisture stress and or use of low yielding local varieties (GRiSP, 2013). Drought prone lowland and upland rice growing areas are mostly subjected to different cycles of flooding, saturated and moist aerobic and dry aerobic soil conditions (O'Toole et al*.,* 2004; Maclean et al., 2002; Wade et al*.,* 2000). According to Pirdashti et al. (2008) and Sikuku et al. (2012) when the dry spell occurred during the vegetative growth stages it was reported to reduce grain yield by 21% and 26%, while moisture stress during the reproductive phase reduced the grain yield by 50% and 67% depending on the intensity of stress. A reduction in number of effective tillers per plant, number of panicles per plant, number of spikelets per panicle, number of fertile grains, and increase in the number of aborted or sterile grains per plant were also reported due to moisture stress at vegetative and reproductive growth phases in upland and lowland rainfed ecosystems (Liu et al*.,* 2014; Sikuku et al*.,* 2012).

In Tanzania rainfall scarcity during the vegetative or reproductive growth phases of rainfed rice has been reported to cause yield losses under farmers' field condition, where they depend totally on rain-fed cultivation (URT, 2014). In that way varieties which are tolerant to vegetative and/ or reproductive moisture stresses are required. However, little is known on the critical growth stages of the selected rice varieties that need more moisture for attaining their yield potentials, and the information on their drought tolerance is not well known in Tanzanian conditions. Therefore, the present study analyzed the effects of moisture stresses during the vegetative and reproductive growth stages on growth and yields of selected rice varieties for establishing the most drought tolerant varieties among the selected rice varieties in each ecosystem. Critical growth stages of each variety that demands more moisture for achieving maximum productivity were also analyzed.

MATERIALS AND METHODS

Experimental design and treatment

The experiment was carried out under field conditions in a split plot design layout, in which the main plots were the stages at which irrigation withdrawals were induced and the sub-plots were the selected rice varieties. Three upland rice varieties (NERICA 1, NERICA 2, and NERICA 4) were grown in an upland rainfed condition, while three lowland rice varieties (TXD 306, Tai and Komboka) were grown under lowland rainfed condition. For both the upland and lowland rice varieties, five lines each with six hills at the spacing of 20cm x 20cm were used; the treatment was 3 varieties x 3 irrigation withdrawals in 3 replications. Five seeds were sown directly per hill. After germination the seedlings were reduced to one plant per hill. The soil fertility before the experiment was analysed and summarized in Table 1. Table 1 shows slight differences among upland and lowland fields in terms of soil texture, PH, EC, OC, Total N, available P, and K cation. All the varieties and the two sites were fertilized with the same fertilizer rate of 80kgN ha^{-1} , applied during sowing and all other field managements were maintained similarly.

Moisture stress management

All plots were irrigated uniformly to field capacity up to 30 days after seedling emergence. Then, the irrigation water was withdrawn to create moisture stresses at the vegetative growth stage; that is, from 31 to 52 days after seedling emergence, and at the reproductive growth phase the irrigation water withdrawals started from the flowering initiation stage; that is, 52 to 71 days after seedling emergence. The soil moisture content of plots was recorded at the beginning and at the end of stress period using gravimetrical method; soil samples at 3 soil level depths in each treatment (0-5 cm, 6-10 cm and 11-15 cm) were taken. The fresh soil samples were weighed and sun dried to constant weight. Then the samples were re-weighed, and the weights of dry soil samples were subtracted from the weights of fresh soil samples to obtain the weights of moisture in the soil.

Data recording and procedures

For both upland and lowland field trials, the recorded parameters included: Number of tillers per plant and plant heights, which were recorded at harvest stage by physical counting. The plant height (cm) was measured using a metre ruler; shoot dry weight (SDW) at maturity stage was recorded using a weighing balance after oven drying at 80 ºC to a constant dry weight.

Relative water contents RWC (%) of leaves

Relative leaf water content (RWC %) was recorded at the end of each respective water withdrawals. The leaf water content was calibrated using a gravimetrical method where by fresh leaves of one gram were harvested for each treatment and weighed to get the fresh weight (Wf). The leaf disks were then placed in a test tube containing distilled water for 24 h at room temperature to get the turgid weight (Wt); subsequently the disks were dried in an oven at 80 °C until a constant weight was obtained to get the oven dry weight (Wd). The relative water content (RWC) in leaves was calculated using the formula by Karrou and Maranville (1995) and Coombs et al. (1985) as follows:

$$RWC\ (\%) = \frac{\text{Fresh weight (Wf) - Dry weight (Wd)}}{\text{Turgid weight (Wt) - Dry weight (Wd)}} \times 100 \qquad (1)$$

During moisture induced stress, leaf drying rate and leaf rolling were evaluated using an IRRI Standard Evaluation System (SES) for rice (2014). The values are as follows; 0 = healthy leaves or having no symptoms; 1= leaves starting to fold (shallow v-shape) or tip slightly drying; 3= leaves folding (deep v-shape) or tip drying extended up to ¼ length in most leaves; 5 = leaves fully cupped (u-shape) or ¼ to ½ of all leaves fully dried.

The yield and yield components

The grain yield and yield components were measured at maturity (harvest). An area of about 1 m^2 was sampled for upland field trial; while in the lowland trial 3 hills from each water regime treatment were harvested for yield and yield components analyses. Plants were cut 4 cm above the ground and sun dried for 3 days to get the total biomass weights above the ground then threshed to get the grain only. The straws were separately dried at 80°C until a constant dry weight was attained. The number of panicles per plant m^{-2}, number of fertile and sterile spikelets per panicle and 1000 grains were recorded by physical counting from the threshed grains. Then 1000 grains weight were measured to get the weight of 1000 grains at 14% moisture content by the procedures described by Gomez (1972). Panicle length (cm) was measured using metre ruler. The grain yields of the selected rice varieties were obtained from the relationship by Yoshida (1981) as follows:

$$GY = (P \times SP \times FS \times 1000GW \times 10^{-5}) \qquad (2)$$

Where, GY=grain yield (tha^{-1}), P= number of panicles (m^{-2}), SP= number of spikelets per panicle, FS= percentage filled spikelet or grain and GW= 1000-grain weight (g)

And the harvest index was calculated using the relationship by Fageria et al. (2011) as follows,

$$HI = \frac{\text{Grain weight (g)}}{\text{Total weight above ground (grain + Straw) g}}$$

Statistical data analysis

The obtained data in both trials were subjected to analysis of variance (ANOVA) using Genstat (2011) and Excel (Microsoft). The irrigation and variety treatments means were separated using Tukey's significance difference test at 5% level.

RESULTS

Relative leaf water content (RWC %)

There was a significant decrease in leaf water contents at the end of irrigation withdrawals (Figure 1). A significant difference ($P \leq 0.05$) among the varieties, moisture stress treatment and stages of water induced stress was observed. Moisture stress caused a significant reduction in leaf water content; the highest reduction among the varieties occurred during reproductive growth stage compared to vegetative growth stages (Figure 1). The upland rice varieties NERICA1, NERICA2 and NERICA4 recorded the highest leaf water content as compared to the lowland rice varieties Komboka, Tai and TXD306 when subjected to moisture stress treatment during vegetative and reproductive stages (Figure 1).

Observation on leaf rolling and leaf drying

Table 2 shows that NERICA1, NERICA2, NERICA4 and Tai had the highest degree of rolling ability compared to the lowland rice varieties Komboka and TXD306 (Table 2). However, there were no differences in the drying rate among the tested varieties at vegetative and reproductive moisture stress inductions (Table 2).

Soil moisture condition during stress

The soil moisture contents during the vegetative and reproductive moisture stress in the fields decreased significantly (Figure 2). At vegetative stress the soil moisture contents at the depth of 0-5 cm decreased significantly from 100 to 19.4%, while at reproductive stress soil moisture decreased to 1.2%. At the depth of 6-10 cm, the soil water content decreased significantly from 100 to 21.4% at vegetative stress, and at reproductive stress the soil moisture decreased from 100 to 7.9%. However, at the depth of 11-15 cm, the soil moisture content decreased significantly from 100 to 22.3% at vegetative stress, while at reproductive moisture stress the soil moisture contents decreased from 100 to 12.2% (Figure 2). As a result, there was a reduction in growth and yields of all varieties with varying intensity.

Number of tillers

There was a general declining pattern in total number of tillers produced at different periods of moisture stress induction (Figure 3). There was a significant difference ($P \leq 0.05$) in number of tillers among the moisture stress regimes. The control (No stress) moisture regime had the highest number of tillers. The reduction in number of tillers at moisture stress during vegetative period was significantly higher than at moisture stress during reproductive period among the tested upland and lowland rice varieties (Figure 3). The upland rice varieties NERICA1 and NERICA4 had higher reduction in the number of tillers than NERICA2 at vegetative and

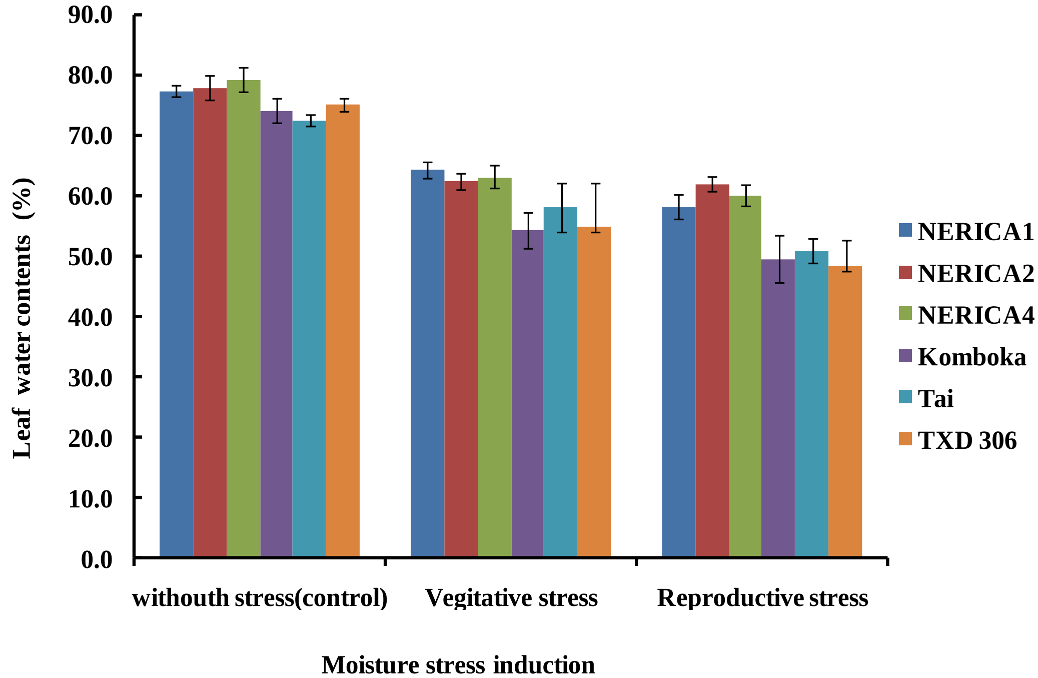

Figure 1. Leaf water content of selected rice varieties during vegetative and reproductive moisture stress.

Table 2. Effect of water induced stress on rolling and drying rate of selected rice varieties.

Moisture stress (W)	Varieties (V)	Rolling rate	Drying rate
Vegetative stress	N1	5	1
	N2	5	1
	N4	5	1
	Komboka	3	1
	Tai	5	1
	TXD 306	3	1
Reproductive stress	N1	5	3
	N2	5	3
	N4	5	3
	Komboka	3	3
	Tai	5	3
	TXD 306	3	3
Control (no stress)	N1	0	0
	N2	0	0
	N4	0	0
	Komboka	0	0
	Tai	0	0
	TXD 306	0	0

NB; According to Standard IRRI Evaluation System (SES) for rice (2014).

reproductive moisture stress when compared to the control moisture regimes (Figure 3). Generally, at the vegetative stage of development, all upland and lowland rice varieties were significantly affected (Figure 3) than at

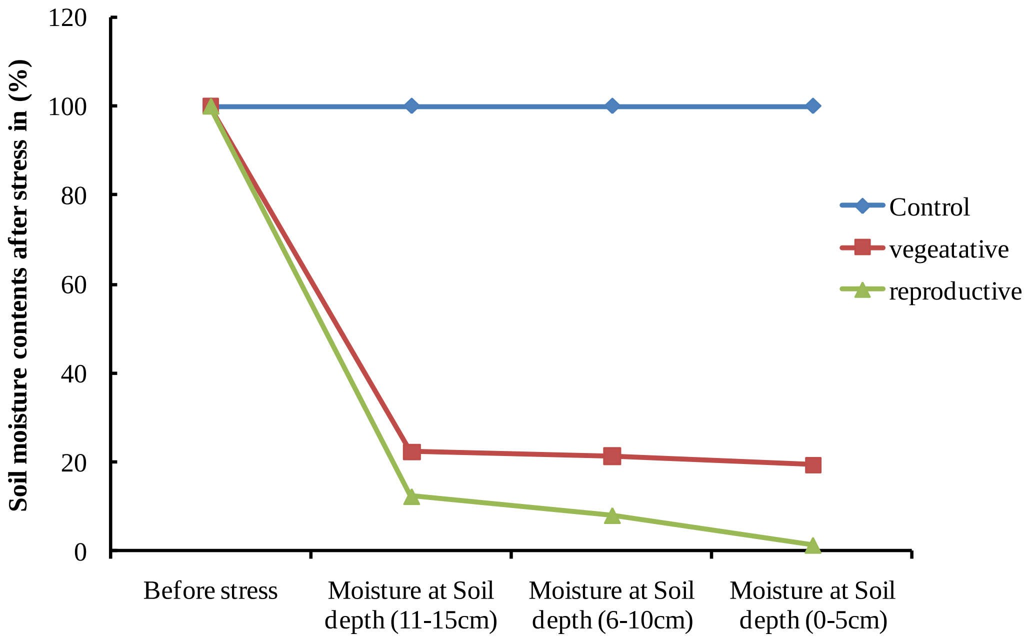

Figure 2. Mean soil water content at depth of (0-15 cm) during vegetative and reproductive moisture stresses.

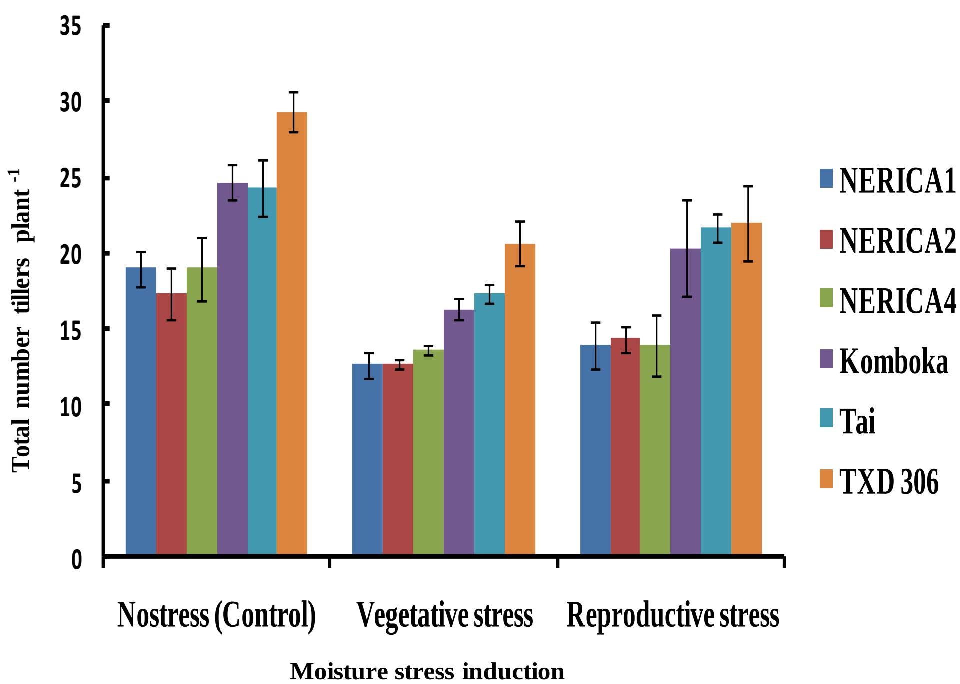

Figure 3. Total numbers of effective tillers of six rice varieties subjected to different moisture stress induction periods.

reproductive moisture stress as evidenced by the low number of tillers in all upland and lowland rice.

There was a general declining pattern in number of effective tillers produced at different periods of moisture stress induction (Figure 4). There was a significant difference ($P \leq 0.05$) in number of tillers among the

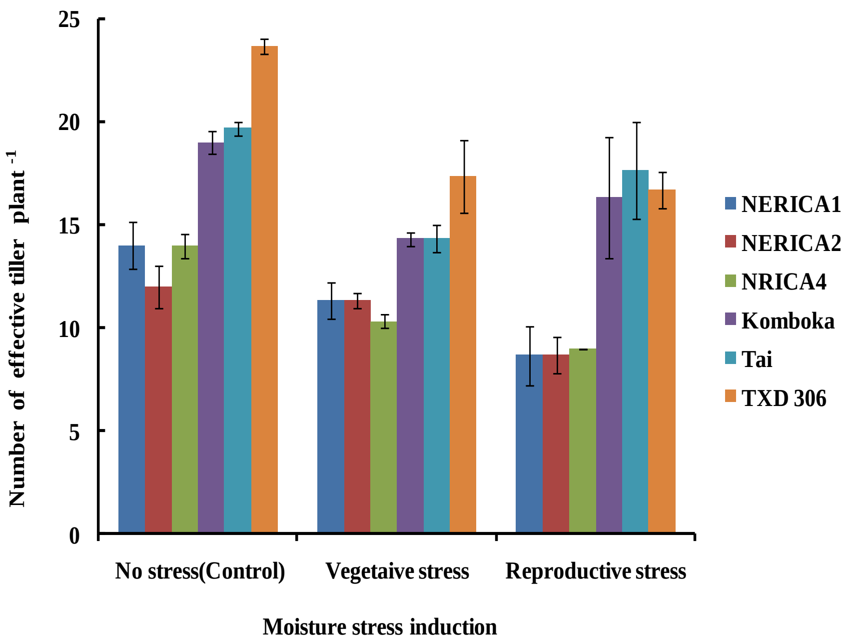

Figure 4. Numbers of effective tillers of six rice varieties subjected to different moisture stress induction periods.

moisture stress regimes. The control (No stress) moisture regime had the highest number of effective tillers. The reduction in number of effective tillers at vegetative moisture stress period was significantly higher than at reproductive moisture stress period among the lowland rice varieties tested except for TXD 306, which had relatively higher reduction at reproductive moisture stress than at vegetative moisture stress (Figure 4). In the upland rice varieties NERICA1 and NERICA4 had higher reduction in the number of tillers than NERICA2 at vegetative and reproductive moisture stress when compared to the control moisture regimes (Figure 4). At reproductive moisture stress, all the upland rice varieties were more affected than the lowland rice varieties as evidenced by the low number of tillers in all upland rice varieties and TXD306 lowland variety. However, at vegetative stress all lowland varieties were significantly affected (Figure 4.)

Plant heights

There was a general decline in plant height from control treatment (No stress) towards vegetative and reproductive moisture induced stresses in that order (Figure 5). There was a significant difference ($P < 0.05$) in plant height among the moisture stress regimes for NERICA 2 and TXD306 varieties. The control regime had the tallest plants followed by moisture stress at vegetative stage, and reproductive moisture stress had the shortest plants. The reduction in plant height was pronounced in the reproductive growth stage for all the varieties tested (Figure 5) except for NERICA2, which seemed stable.

Shoot dry weight (SDWt) at harvest

There were differences in SDWt from the control or stress free moisture regime toward vegetative and reproductive induced moisture regimes (Figure 6). Plants of the control moisture regime (No stress) had significantly higher SDWt than plants of the vegetative and reproductive moisture stress regimes. There was a significant difference ($P \leq 0.05$) in SDWt among the varieties in SDWt as shown in Figure 6. TXD 306 had the highest SDWt followed by Komboka, Tai, NERICA4, NERICA1 and lastly NERICA2 in the control and at vegetative moisture regime. At reproductive moisture stress TXD 306 had the highest SDWt followed by Tai, Komboka, NERICA1, NERICA2 and lastly NERICA4.

Grain yield and yield components of selected rice varieties

Significant differences in grain yields due to the timing of moisture stress initiation were observed. Complete moisture saturation (No stress) had the highest mean grain yield of 6.1 tons ha^{-1} followed by moisture stress during the vegetative periods, with mean grain yield of 3.7 tons ha^{-1}, while moisture stress during the reproductive resulted in the lowest mean grain yield of

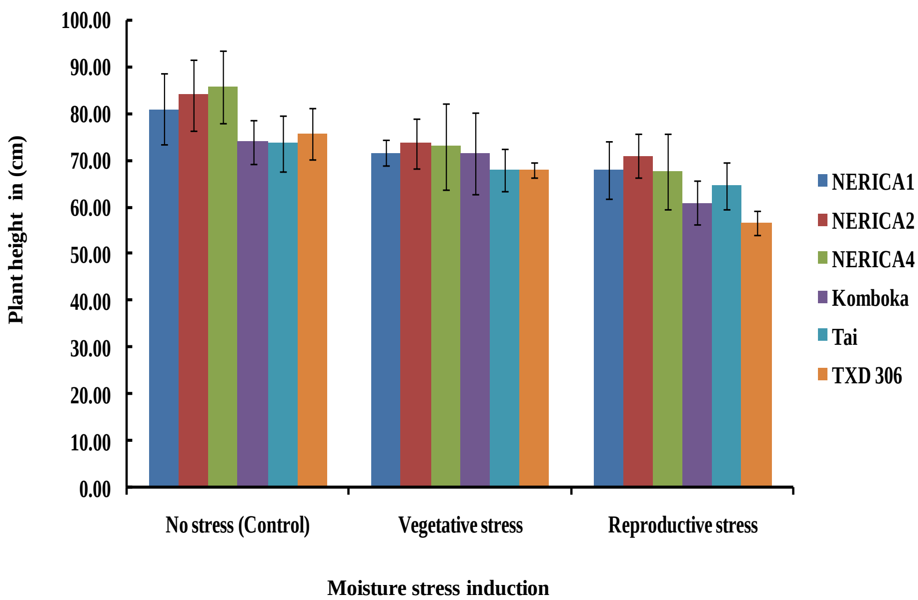

Figure 5. Plant heights under different moisture stress induction periods

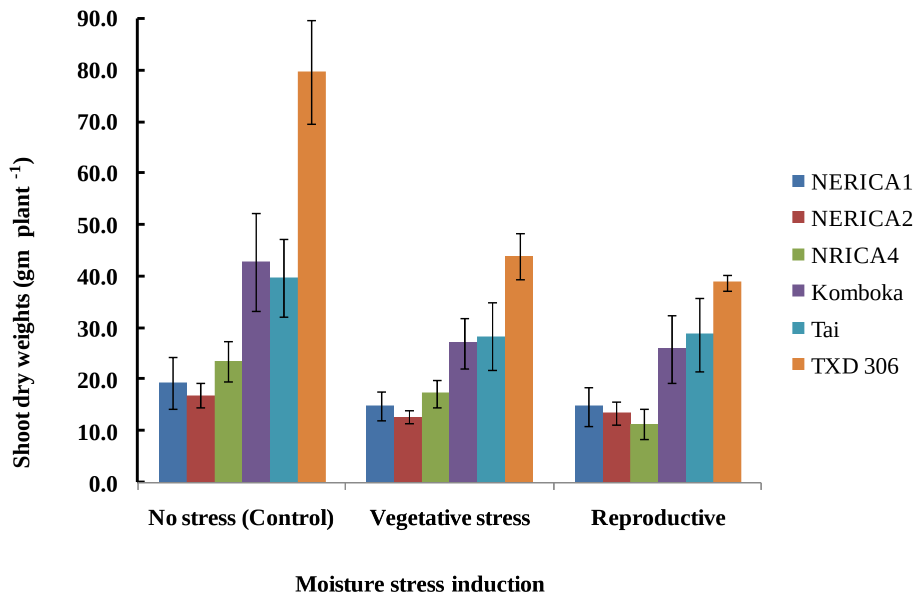

Figure 6. Shoot Dry weights under different moisture stress induction periods at maturity. **Bars** represent ± standards errors of means.

only 1.9 tons ha^{-1} (Table 3).

There were significant differences in yield components depending on the timing of stress conditions; that is, the number of panicles m^{-2}, number of spikelets panicle^{-1}, proportion of fertile grain panicle^{-1}, number of sterile grains panicle^{-1}, and 1000 grain weight (Table 3). The maximum saturated conditions (control) gave the highest number of panicles per unit area, fertile grain per panicle, % fertility ratio and 1000 grain weights. Plants stressed during the reproductive phase of growth resulted in significantly lowest yield components compared to those during the vegetative and saturated regimes in that order. However, the proportion of sterile grains per panicle was significantly higher in plants stressed during the reproductive phase (Table 3).

The lowland rice varieties indicated the highest number

Table 3. Grain yield and yield components of six rice varieties grown under three water regimes and the interaction effects (Moisture stress x Rice varieties).

Variable		Grain yield (t ha^{-1})	# panicles m $^{-2}$	# Spikelet panicle $^{-1}$	Fertile grain panicle $^{-1}$	Grain fertility ratio	1000 grain weight (gm)	# Sterile Grainpanilce^{-1}	(HI)
Moisture (W)	Vegetative stress	3.73^{b}	158^{b}	137^{b}	96^{b}	0.72^{a}	24.92^{a}	42^{b}	0.40^{a}
	Reprod stress	1.94^{c}	154^{b}	119^{c}	61^{c}	0.52^{b}	20.84^{b}	58^{a}	0.26^{b}
	Control (NST)	6.10^{a}	205^{a}	161^{a}	119^{a}	0.76^{a}	25.02^{a}	42^{b}	0.42^{a}
	(W)	*	*	*	*	*	*	*	*
Varieties (V)	NERICA1	2.63^{c}	136^{b}	97^{d}	72^{c}	0.73^{a}	25.88^{a}	25^{d}	0.38^{ab}
	NERICA2	2.81^{c}	128^{b}	120^{cd}	87^{bc}	0.72^{a}	24.10^{a}	33^{cd}	0.42^{a}
	NERICA4	3.08^{c}	133^{b}	127^{bc}	89^{bc}	0.69^{a}	23.92^{a}	38^{bcd}	0.39^{ab}
	Komboka	4.30^{b}	199^{a}	171^{a}	114^{a}	0.66^{ab}	17.91^{b}	57^{ab}	0.32^{b}
	Tai	4.53^{b}	207^{a}	147^{b}	93^{b}	0.63^{ab}	22.97^{a}	54^{abc}	0.35^{ab}
	TXD 306	6.20^{a}	231^{a}	171^{a}	97^{ab}	0.56^{b}	26.79^{a}	75^{a}	0.31^{b}
	(V)	*	*	*	*	*	*	*	*
Moisture regimes (W)	**Varieties (V)**	**Grain yield (t ha^{-1})**	**# panicles m $^{-2}$**	**# Spikelet panicle $^{-1}$**	**Fertile grain panicle $^{-1}$**	**Grain fertility ratio**	**1000 grain weight (gm)**	**# Sterile grain panilce^{-1}**	**(HI)**
Vegetative	NERICA1	2.82^{efgh}	136^{def}	93^{f}	73^{def}	0.78^{ab}	28.4^{a}	21^{de}	0.43^{abc}
	NERICA2	2.83^{efgh}	136^{def}	106^{ef}	82^{cdef}	0.78^{ab}	25.5^{a}	24^{cde}	0.47^{ab}
	NERICA4	3.15^{defg}	124^{ef}	120^{cdef}	98^{bcde}	0.82^{a}	26.1^{a}	23^{cde}	0.42^{abc}
	Komboka	4.37^{cde}	172^{bcdef}	292^{ab}	122^{ab}	0.64^{bcd}	21.0^{ab}	69^{abcd}	0.40^{abc}
	Tai	3.75^{cde}	172^{bcdef}	142^{bcdef}	97^{bcde}	0.70^{abcd}	22.4^{a}	45^{abcde}	0.35^{abcd}
	TXD 306	5.48^{bc}	208^{bcd}	170^{abc}	101^{bcd}	0.60^{abcd}	26.2^{a}	69^{abcd}	0.33^{abcd}
Reproductive	NERICA1	1.28^{gh}	104^{f}	94^{ef}	60^{ef}	0.63^{abcd}	21.6^{a}	34^{bcde}	0.26^{cd}
	NERICA2	1.43^{gh}	104^{f}	121^{cdef}	65^{def}	0.54^{bcd}	21.4^{a}	56^{abcde}	0.30^{bcd}
	NERICA4	1.18^{h}	108^{f}	118^{def}	54^{f}	0.45^{d}	20.4^{ab}	64^{abcde}	0.30^{bcd}
	Komboka	1.5^{fgh}	196^{bcde}	115^{def}	66^{def}	0.58^{abcd}	12.6^{b}	49^{abcde}	0.17^{d}
	Tai	2.89^{efgh}	212^{abc}	134^{cdef}	59^{ef}	0.44^{d}	22.7^{a}	76^{ab}	0.29^{bcd}
	TXD 306	3.36^{def}	200^{bcd}	132^{cdef}	65^{def}	0.50^{cd}	26.4^{a}	67^{abcde}	0.26^{cd}
Control (No stress)	NERICA1	3.79^{cde}	168^{bcdef}	104^{ef}	83^{cdef}	0.79^{ab}	27.7^{a}	21^{de}	0.45^{abc}
	NERICA2	4.16^{cde}	144^{cdef}	133^{cdef}	112^{bc}	0.85^{a}	25.4^{a}	20^{e}	0.49^{a}
	NERICA4	4.91^{cd}	168^{bcdef}	144^{bcde}	116^{abc}	0.80^{ab}	25.3^{a}	29^{bcde}	0.46^{ab}
	Komboka	7.02^{b}	228^{ab}	206^{a}	154^{a}	0.75^{abc}	20.1^{ab}	52^{abcde}	0.40^{abc}
	Tai	6.94^{b}	236^{ab}	164^{abcd}	123^{ab}	0.75^{abc}	23.9^{a}	40^{abcde}	0.41^{abc}
	TXD 306	9.78^{a}	284^{a}	212^{a}	124^{ab}	0.59^{abcd}	27.8^{a}	88^{a}	0.34^{abcd}
ANOVA	**(W) x (V)**	*	*	*	*	*	*	*	*
	CV (%)	15.8	14.2	11.8	13.8	13.2	11.8	32.2	17.2

Common letter(s) within the column do not differ significantly at 5% level of significance analysed by Tukey's significance test. W = indicates moisture stress regimmes, V = indicates varieties used in the experiment, CV (%) = Coefficient of variation and * = Indicates the significance different at (P < 0.05 and NS= Non-significant.

of panicles per unit area, spikelets per panicle, fertile grains per panicle and number of sterile grains per panicle compared to the upland rice varieties tested, except for % fertility ratio and 1000 grain weight, which was relatively high in the upland rice varieties in most cases (Table 3). There were significant interaction effects observed between moisture stress regimes and the rice varieties on the grain yield and the yield components at harvest as summarized in Table 3. The lowland rice varieties registered the highest number of panicles per unit area, spikelet per panicle, fertile grains per panicle and number of sterile grains per panicle compared to the upland rice varieties tested, except for % fertility ratio and 1000 grain weight, which were relatively higher in the upland rice varieties in most cases (Table 3).

DISCUSSION

There was a significant decrease in leaf water content as moisture stress treatments took effect (Figure 1). These findings are in line with the findings of Cruz et al*.,* (1986) in rice. Decline in leaf water content in our study may be attributed to loss through evapotranspiration and decreased water uptake by roots when the soil water was limiting (Figure 2). As a result, the rice growth and productivity reduced in all varieties. These findings are in line with the observation of Fukai et al. (1995, 1999b), who reported that in moisture stress conditions as water is rapidly lost from the soil surface layers, plant growth and productivity are restricted through reduced availability of water and nutrients. Based on Sah and Zamora (2005), relative water content is an important measure of plant water status.

The water content in leaf relative to maximum amount that the leaf can take under full turgidity was considered as suitable gauge of normal tissue physiological functioning and growth processes (Sikuku et al*.,* 2012). In this study, moisture stress at reproductive growth caused higher reduction in leaf water content compared to moisture stress at vegetative growth stage (Figure 1). This situation constrained the growth and plant function, which was reflected in decreasing number of effective tillers (Figure 4), plant height (Figure 5), shoot dry weights (Figure 6) and grain yields and yield components of all selected rice varieties, with different declining intensity (Table 3). Therefore, higher relative moisture contents in leaves are crucial for suitable growth and function of plants.

In the present study, varietal differences in relative leaf water content were significant between the upland and lowland rice varieties at vegetative and reproductive moisture stress treatments (Figure 1). NERICA2 and NERICA4 had the highest moisture contents in leaves among the upland rice varieties, while NERICA1 showed the lowest leaf water contents. These results may imply that NERICA2 and NERICA4 had the highest stress tolerance characteristics toward moisture stress at vegetative growth stages (Figure 1). Tai variety had significantly high leaf moisture content among the tested lowland rice varieties and hence was the most tolerant than others in lowland ecosystem. The observations from the present study are in line with the findings of Sinclair and Ludlow (1985) under moisture deficit conditions, who found that the varieties that are tolerant to drought have more relative water content at any stage of stressing. They suggested that high leaf relative water content can be employed in selecting high yielding varieties that uphold cell turgidity under moisture stress and confer relative high grain yield. Moreover, during stress the upland rice varieties NERICA1, NERICA 2, NERICA4 and lowland rice Tai varieties had the highest rolling ability compared to the lowland rice varieties Komboka, and TXD306 (Table 2). Leaf rolling characteristics in rice minimize evaporative water loss through leaf surfaces (O'Toole et al., 1979), and consequently cause a high degree of tolerance to water deficit stress. High leaf rolling in upland rice used in this study implies that they have relatively high tolerance characteristics to water stress at vegetative and reproductive growth stages compared to the lowland rice varieties investigated. However, among the lowland rice Tai variety had significant higher leaf rolling ability than Komboka and TXD306. For this reason, Tai was the most tolerant variety among the used lowland rice varieties. These results are also in line with the findings of O'Toole and Garrity (1984) who reported that a rice variety with high leaf rolling ability is regarded as drought resistant.

Reducing or draining rice fields at either vegetative or reproductive phases caused significant yield loss (Castillo et al*.,* 1992), and some researchers reported that effects of different periods of moisture stress at various growth stages would reduce yield (Salam et al., 2001; Sikuku, 2012). In the present study, moisture stress at vegetative growth stages significantly reduced grain yields by 26, 32 and 36% in NERICA1, NERICA2 and NERICA4, respectively in the upland rice varieties compared to the control moisture regime; while in the lowland rice varieties a reduction of 38, 44, and 46% in grain yield was observed for Komboka, Tai and TXD 306, respectively (Table 3). These findings are in agreement with those reported by Pirdashti et al. (2008) and Sikuku et al. (2012). In their study they found reduction in grain yield by 21 and 26% respectively, due to water deficit at vegetative growth stage. However, Boonjung and Fukai (1996) reported that grain yields could be considerably reduced to about 60% if drought occurs during flowering time. These findings are in line with the observation revealed by the present study whereby moisture stress at reproductive growth stages highly reduced the grain yields of all varieties to more than 50% of the control moisture regime. NERICA2 and NERICA1 had the lowest reduction in grain yields (66%) compared to control; NERICA4, which was highly susceptible to reproductive moisture stress, had 76% reduction in grain yields. Among the lowland rice Tai variety had the lowest reduction among all the varieties tested in reproductive moisture stress with reduction of 58%, while Komboka variety had the highest reduction in grain yield of about 79%. All were used to compare the control moisture regimes (no stress). The higher reduction in grain yield of all the varieties tested in this study are in line with the grain reduction reported at reproductive growth stages by Pirdashti et al. (2008) and Sikuku et al. (2012) who found reduction of 50 and 67%, respectively depending on the severity of stress. The lower grain yield in moisture stressed plots in the present study might be due to decreased panicle m^{-2}, spikelet panicle^{-1}, fertile spikelet's panicle^{-1} and percentage fertility ratio caused by reduced number of effective tillers; it caused remobilization of carbohydrates reserves in shoot straw to the grains as the plants compete for moisture (Table 3). The lowest yields were recorded in the reproductive moisture stress regimes compared to the vegetative moisture stress regimes (Table 3). Low relative leaf water contents at reproductive growth stage significantly reduced the fertile grain number, and thus the grain yield was significantly reduced.

CONCLUSION AND RECOMMENDATION

It was concluded that, the most critical growth stage that needs more moisture for the selected rice varieties to retain their higher yield in this study was the reproductive growth stage. Moisture stress at this stage had significantly high impact on growth, grain yield and yield components of both upland rice and lowland rice varieties investigated. Low relative water contents in leaves due to moisture stress inhibited growth and normal plant function and resulted in significant reduction in plant height, shoot dry weight, number of effective tillers, panicles, spikelets per panicle, fertile spikelets, 1000 grain weights and harvest index in all varieties tested, though with different decline intensity. The most tolerant varieties among the upland rice investigated were NERICA2 and NERICA1. While NERICA4 was relatively a susceptible rice variety to reproductive moisture stress among the upland rice varieties tested because of higher reduction in grain yield. In the lowland rice varieties Tai was found to be the most tolerant variety than all other lowland rice varieties investigated; while Komboka and TXD 306 were relatively highly susceptible to both vegetative and reproductive moisture stress regimes.

The author recommends that where possible adequate moisture should be available in soils at all developmental stages in order to achieve optimum yields of selected rice varieties. In case the area has been experiencing short period moisture stress of between 7 to 21 day at vegetative growth, all upland rice NERICA1, NERICA2, NERICA4 and Tai variety from the lowland rice varieties are recommended for production. In case the area experiences short time moisture stress at reproductive growth stages, then NERICA2 for upland and Tai variety for lowland are recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

This work was supported by the Joshua's Family fund that provided research and 50% of tuition fee, and the University of Dar es salaam (UDSM) for providing 50% of tuition fee funds for the first author to study at the university of Dar es Salaam.

ABBREVIATION

MAFC, Ministry of Agriculture Food security and Cooperatives; **GRiSP**, Global Rice Science Partnership; **URT**, United Republic of Tanzania; **IRRI**, International Rice Research Institute.

REFERENCES

Boonjung H, Fukai S (1996). Effects of soil water deficit at different growth stage on rice growth and yield under upland conditions. 2. Phenology, Biomass and yield. Field Crops Research 48:47-55.

Castillo EG, Buresh RJ, Ingram KT (1992). Lowland rice yields as affected by timing of water deficit and nitrogen fertilization. Agronomic Journal 84:152-59.

Coombs J, Hind G, Leegood RC, Tieszen LL, Vonshak A (1985). Analytical Techniques, In: Techniques in Bioproductivity and photosynthesis 2nd edition (Eds) J. Coombs, D.O. Hall, S.P. Long and J.M.O. Scurlock, Pp 219-220, Pergamon Press 1985.

Cruz RT, Turner NC, Dingkuhn M (1986). Responses of seven diverse rice cultivars to water deficits, osmotic adjustment, leaf elasticity, leaf extension, leaf death, stomatal conductance and photosynthesis. Field Crop Research 13:273-186.

Fageria NK, Moreira A, Coelho AM (2011). Yield and Yield components of upland rice as influenced by nitrogen sources. Journal of Plant Nutrients 34:361-370.

Fukai S, Cooper M (1995). Development of drought resistant cultivars using physio-morphological traits in rice. Field Crops Research 40:67-86.

Fukai S, Inthapanya P, Blamey FPC, Khunthasuvon S (1999b). Genotypic variation in rice grown in lowland fertile soils and drought-prone, rainfed lowland environments. Field Crops Research 64:121-130.

GenStat (2011). Statistical package. Fourteenth Edition. VSN International Ltd. http://www.genstat.co.un/

Gomez KA (1972). Techniques for field experiments with rice. International Rice Research Institute, Los Baños Philippines.

Global Rice Science Partnership (GRiSP) (2013). Rice almanac, 4th edition. Los Baños Philippines: International Rice Research Institute 280 p.

IRRI (International Rice Research Institute) (2014). Standard Evaluation System for rice (SES), 5th edition. Los Baños (Philippines): International Rice Research Institute.

Kamoshita A, Wade LJ, Yamauchi A (2000). Genotypic variation in response of rainfed lowland rice to drought and rewatering: III. Water extraction during the drought period. Plant production Science

3(2):189-196.

Karrou M, Maranville JW (1995). Response of wheat cultivars to different soil nitrogen and Moisture regimes: III. Leaf water content, stomatal conductance and photosynthesis. Journal of Plant Nutrition 18(4):777-791.

Liu Qui-hua, Wu Xiu, CHEN Bo-cong, MA Jia-qing, GAO Jie (2014). Effects of low Light on Agronomic and Physiological Characteristics of Rice including Grain Yield and Quality. Rice science 21(5):243-251.

MacLean JL, Dawe DC, Hardy B, Hettel GP (2002). Rice Almanac: Sourcebook for the most Important Economic Activity on Earth, third ed. CABI Publishing, Wallingford, England, Published in association with: International Rice Research Institute, West Africa Rice Development Association, International Center for Tropical Agriculture, and Food and Agriculture Organization of the United Nations pp. 1-253.

Ministry of Agriculture Food security and Cooperatives (MAFSC) (2009). National Rice Development Strategy. Available at http://www.Rice for Africa.Org/downloads/NRDS/Tanzania. En pdf (Verified) accessed 17th Dec, 2017.

O'Toole JC, Cruz RT, Singh JN (1979). Leaf rolling and transpiration. Plant Science Letters 16(1):111-114.

O'Toole JC, Garrity DP (1984). Upland rice soil plant - water relationship. In: An Overview of upland rice research. Los Baños Philippines: International Rice Research Institute pp. 395-441.

O'Toole JC (2004). Rice and Water: The Final Frontier. The first International Conference on Rice for the Future. Bangkok, 31 August-2 September 2004. 26.

Pirdashti H, Zinolabedin TS, Sanavy SAMM, Hamidreza B (2008). Study of water stress effects in different growth stages on yield and yield components of different rice (*Oryza sativa* L.) cultivars. Pakistan Journal of Biological Sciences 13:1303-1309.

Sah SK, Zamora OB (2005). Effects of water deficit at vegetative and reproductive stages of Hybrid open pollinated variety and local maize (*Zea mays* L.). Agriculture and Animal Science 26:37-42.

Salam MA, Islam MR, Haque MM (2001). Direct seeded rice genotypes for drought prone upland area. Pakistan Journal of Biological Sciences 4:651-653.

Sharma PK, De Datta SK (1994). Rainwater utilization efficiency in rain-fed lowland rice. Advanced Agronomy 52:85-120.

Sikuku PA, Onyango JC, Netondo GW (2012). Yield Components and Gas Exchange Responses of NERICA Rice varieties (*Oryza sativa* L.) to vegetative and reproductive stage water deficit. Global Journal of Science Frontier Research (D) 12(3):1.

Sinclair T, Ludlow M (1985). Who taught plants thermodynamics?. The unfulfilled potential of plant water potential. Australian Journal of plant physiology 12:213-217.

United Republic of Tanzania (URT) (2014). Agriculture Climate resilience plan 2014-2019. Ministry of Agriculture Food Security and Cooperatives, 83 p. (Available online athttp://www.kilimo.go.tz/publications/english%20docs/ACRP_TANZANIA_ENDORSED.pdf.)

Wade LJ, Kamoshita A, Yamauchi A, Azhiri-Sigari T (2000). Genotypic variation in response of rainfed lowland rice to drought and rewatering. I. Growth and water use. Plant production Science 3:173-179.

Yoshida S (1981). Fundamentals of rice crop Science. International Rice Research Institute, Los Baños Philippines.

Vol. 14(2), pp. 65-68, 10 January, 2019
DOI: 10.5897/AJAR2016.11667
Article Number: E84F49059803
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Responses of *Moringa oleifera* root growth to container size during overwintering in temperate regions

Phatu W. Mashela

Green Technologies Research Centre, University of Limpopo, Private Bag X1106, Sovenga 0727 South Africa.

Received 5 September, 2016; Accepted 17 October, 2016

Due to its fast growth rates, *Moringa oleifera* is being grown as an annual crop in temperate areas with freezing winter temperatures. Seedlings are raised under greenhouse conditions for overwintering and then transplanted outside at the beginning of spring, which allows for several cuttings prior to onset of the subsequent winter. However, there is limited information on container-size for overwintering of *M. oleifera* seedlings under greenhouse conditions. The objective of this study was to determine the responses of *M. oleifera* root growth to different container-sizes during overwintering in temperate regions under greenhouse conditions. Uniform two-month old seedlings were hardened-off and transplanted into five different container-sizes, measured in volume. Seedlings were fertilised once at transplanting and irrigated through scheduling with moisture meter. Six months after the treatment, container-size had highly significant effects on root length and crown girth, contributing 91 and 60% to total treatment variation of the respective plant variables. Root length and container-size exhibited quadratic relations, with optimum container-size computed to be 300 ml. In contrast, crown girth and container-size exhibited linear relations. In conclusion, the findings in this study suggested that a much smaller container (300 ml) than the one currently used (750 ml) would allow optimum overwintering of *M. oleifera* seedlings, thereby reducing production costs.

Key words: Container-cost, crown girth, labour-cost, *Moringa* species, shoot dormancy, root development.

INTRODUCTION

Moringa oleifera has attained the status of a ‘developmental tree’ of choice in sub-Sahara Africa (Leone et al., 2015). ‘Developmental trees’ are those used by governments to intervene in various socio-economic challenges. Due to its demand-driven attributes in improving socio-economic challenges and its most promising status for nutraceutical bioactive and industrial products (Anwar et al., 2007; Agyepong, 2009; Hassan and Ibrahim, 2013; Leone et al., 2015), *M. oleifera* is viewed as the ‘miracle tree’ (Fuglie, 2001). The tree is grown under a wide range of marginal environments, with extreme seasonal changes such as drought and frost (Leone et al., 2015).

Moringa species originated in tropical regions (Leone et al., 2015) and is adapted to warm climatic regions (Palada and Chang, 2003). In temperate regions with limited freezing winters, moringa trees enter dormancy for overwintering (Palada and Chang, 2003). Also, the plant

E-mail: phatu.mashela@ul.ac.za. Tel: +27152682190. Fax: 27152682892.

has the ability to tolerate limited frost and drought (Leone et al., 2015), particularly during overwintering. Generally, plant species respond to their environments in a manner that optimises their resource use (Ågren and Franklin, 2003). When soil and aboveground conditions are optimum, root and shoot flushes alternate (McMahon et al., 2005), with more resources being shunted to the organ where growth is taking place (Andrews et al., 1999).

In temperate areas of South Africa with limited frost, moringa seedlings are raised in greenhouses for overwintering and transplanted soon after winter (Muhl 2009). Apparently, moringa enters dormancy in response to day-length since the phenomenon could not be prevented by increasing greenhouse temperatures, but could be prevented through increasing photoperiod at 28°C (unpublished data). During the warm growing seasons, *M. oleifera* seedlings in the greenhouse are raised for transplanting in 750 ml plastic containers. Due to limited information on container-size and the behaviour of moringa roots during overwintering, the same containers (750 ml) as used during the normal growing season are used for overwintering purposes. The overwintering process is initiated by sowing seeds at the beginning of winter (April-June) to mid spring (July-September), when seedlings are hardened-off and transplanted in open fields for harvesting prior to setting in of the next winter. The objective of this study was to determine the responses of *M. oleifera* root growth to different container-sizes during overwintering in temperate regions under greenhouse conditions.

MATERIALS AND METHODS

Study location/area

The study was conducted at the Greenhouse, Green Technologies Research Centre, University of Limpopo, Limpopo Province, South Africa (23°53'10"S, 29°44'15"E). Ambient day/night temperatures averaged 28/5°C, with maximum temperatures controlled using thermostatically-activated fans. The trial was conducted during winter (April-June) to mid spring (July-September) in 2015 and validated in 2016.

Procedure, treatments and experimental design

Seeds of *M. oleifera* were sown on Hygromix-T (Hygrotect, Pretoria North, South Africa) in 160-hole polystyrene seedling trays under greenhouse conditions. Two-month-old uniform seedlings were hardened-off outside the greenhouse for two weeks and transplanted in 250, 500, 750, 1000 and 1250 ml plastic bags filled with steam-pasteurised (300°C for 1 h) loam and river sand, mixed with Hygromix-T at 3:2:1 (v/v) ratio. Seedlings were allowed to establish until leaf abscission sets in and plants of uniform height were arranged in a randomised complete block design, with seven and eight replications in 2015 and 2016 trial seasons, respectively. Treatments were blocked for wind speed from the cooling fans, which create heterogeneous conditions in the greenhouse. Seedlings were placed on the greenhouse benches at 20-cm inter-row and 20-cm intra-row spacing.

Cultural practices

Each container was originally irrigated to field capacity and thereafter, five Hadeco Moisture meters (Hadeco Magic^R, RSA) were randomly installed each in a different container-size and plants irrigated with 250 ml tapwater when readings averaged below 2 units. At transplanting, seedlings were fertilized with 3 g 2:1:2 (43) NPK fertiliser mixture to provide 0.70 mg N, 0.64 mg K, 0.64 mg P, 1.8 mg Mg, 1.5 mg Fe, 0.15 mg Cu, 0.7 mg Zn, 2 mg B, 6 mg Mn and 0.14 mg Mo/ml tap water and 2 g 2:3:2 (22) NPK fertilizer mixture with 5% Ca.

Data collection

At six months after initiating the treatment, plant height was measured. Plants were taken out of the containers and soil particles rinsed in a 20-L container half-filled with water. Roots were pressed between two pieces of paper towel to remove excess water. Diameter of crown girth was measured at the soil line using a digital Vernier caliper. Roots were separated from shoots and length of taproot and lateral roots per treatment were measured and combined. Roots and shoots were dried in air-forced ovens at 70°C for 72 h and the mass measurements used to calculate the root/shoot ratios.

Data analysis

Root length, crown girth, plant height, dry root mass, dry shoot mass and root/shoot ratio were subjected to analysis of variance (ANOVA) using SAS software (SAS, 2015). The degrees of freedom and their associated sum of squares were partitioned to provide the total treatment variation (TTV) for variables measured. Mean separation was achieved through Fisher's least significant difference test at 5% level of probability. Unless otherwise stated, results were discussed at 5% level of probability.

RESULTS

The seasonal interactions for 2015 and 2016 for plant variables were not significant and data were pooled (n = 75) and subjected to ANOVA. The effects of container-size were highly significant on root length and crown girth, contributing 91 and 60% in TTV of the respective variables (Table 1). However, the treatments had no effects on plant height, dry root mass, dry shoot mass and root/shoot ratio. The longest root length was in the 1250 ml container, followed by the 1000 ml container, whereas those in the standard and the smaller containers did not differ (Table 2). Relative to the 750 ml standard container, root length was significantly reduced by 18-28% in the smaller containers, but increased by 28% in the largest container (Table 2). In contrast, crown girth was increased by 11% in the smallest container.

The largest crown girth occurred in the 250 ml container, which was much smaller than the 750 ml standard, whereas the smallest was in the largest 1250 ml container (Table 2). Growth of root length and container-size during overwintering exhibited quadratic relations, with the relationship being explained by 94% of the model (Table 2). Using the relation $x = -b_1/2b_2$ from

Table 1. Partitioning sum of squares for root length and grown diameter of *Moringa oleifera* seedlings in five different plastic bag sizes at 65 days after transplanting (n = 75).

Source	DF	Root length		Crown diameter		Root/shoot ratio	
		MS	TTV (%)[z]	MS	TTV (%)	MS	TTV (%)
Replication	14	439.013	5	9.048	25	32.116	52
Treatment	4	8396.513	91**	21.530	60**	16.926	27[ns]
Error	56	372.517	4	5.436	15	12.952	21
Total	74	9208.021	100	36.014	100	61.994	100

[z]TTV = Total treatment variation; ***highly significant at P ≤ 0.01, [ns]not significant at P ≤ 0.05.

Table 2. Responses of root length and crown diameter in *M. oleifera* seedlings to plastic container-size during winter under greenhouse conditions at 60 days after transplanting (n = 75).

Container size (ml)	Root length (cm)		Crown girth (mm)	
	Variable[x]	RI (%)[y]	Variable	RI (%)
750[z]	107.47[b]± 4.2	-	17.31[bc]±0.7	-
250	77.87[c]±3.5	-28	19.21[a]±0.4	11
500	83.40[c]±4.3	-18	18.05[ab]±0.8	4
1000	108.80[b]±5.1	1	17.31[bc]±0.6	0
1250	137.20[a]±7.4	28	15.92[c]±0.6	-8
Relation	Quadratic		Linear	
R^2	0.94		0.92	

[x]Column means ± SE followed by the same letter were not different (P ≤ 0.05) according to Fisher's least significant difference test. [y]Relative impact (RI) = [(treatment/control) – 1) × 100. [z]standard plastic bag size for *M. oleifera* seedlings.

the quadratic equation, $Y = -0.00003x^2 + 0.0182x + 71.23$ (Gomez and Gomez, 1984), the optimum container-size for root length was 300 ml. In contrast, crown girth and container-size exhibited linear relation (Table 2), which was explained by 92% of the model.

DISCUSSION

In the current study, as shown by root length and crown girth, physiological activities continued in moringa seedlings during overwintering under greenhouse conditions. The overwintering process is generally gradual, thereby allowing carbohydrates and various mobile essential nutrient elements in affected plants to be partitioned in root systems (McMahon et al., 2005). Limited information is available on how much of the partitioned materials are stored in root systems of moringa seedlings during overwintering, since most of the focus had previously been on chemical composition and nutrient content of leaves (Leone et al., 2015). The partitioned and stored materials in roots are essential since they are indispensable for flowering and foliation in early spring for most plant species that have overwintering capabilities (McMahon et al., 2005). The latter capabilities are conspicuous in temperate plant species (McMahon et al., 2005).

The observed positive curvilinear quadratic relations between root length and container size is indicative that the relation follows the density-dependent growth (DDG) patterns (Salisbury and Ross, 2005). The DDG patterns are observed when organisms are subjected to increasing abiotic and biotic factors (Salisbury and Ross, 2005) and are generally characterised by three phases, namely, stimulation, neutral and inhibition phases (Mashela et al., 2015). In the current study, smaller containers stimulated the generation of lateral roots and thereby improve overall root length, whereas the largest containers had the opposite effects. Similar stimulation effects were reported when plants were subjected to increasing concentrations of allelochemicals (Liu et al., 2003) and phytonematicides (Mashela et al., 2015).

In the current study root length was the sum of the length of the taproot and the lateral roots. Apparently, as elongation of the taproot is limited by the depth of the container, more lateral roots are generated (Richards and Rowe, 1977), thereby increasing the collective overall root length. The importance of the observed positive curvilinear quadratic relation was that the generated quadratic equation allowed the computation of the optimum container-size using the $x = -b_1/2b_2$ relation (Gomez and Gomez, 1984). Similarly, the opposite argument could be advanced for the increased crown diameter in smaller containers as was previously reported under root restrictions in peach seedlings (Richards and Rowe, 1977).

In the current study, the optimum container-size for overwintering of *M. oleifera* seedlings under greenhouse was approximately 300 ml, which was more than twice smaller than the standard container used in the study. At the proposed optimum container-size, the crown diameter would not be limited since the variable and the container-size exhibited a linear relationship. Raising moringa seedlings for overwintering in containers larger than the optimum would increase overall production costs, which include container-, growing medium-, water-, electricity-, fertiliser-, greenhouse space- and labour-costs. In contrast, raising moringa seedlings for overwintering in containers smaller than the optimum is not recommended since root growth would be much restricted.

Conclusions

The results of this study suggested that the smaller containers (300 ml) than those (750 ml) currently used would be suitable for overwintering of *M. oleifera* seedlings in regions with frosts, where this high-nutrition value crop is grown as an annual vegetable. These containers would reduce the production costs for overwintering seedlings.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

ACKNOWLEDGEMENT

This work was supported by the Agricultural Research Council-Universities Collaboration Centre.

REFERENCES

Ågren GI, Franklin O (2003). Root/shoot ratios, optimisation and nitrogen productivity. Annals of Botany 92:795-800.

Agyepong AO (2009). The possible contribution of *Moringa oleifera* Lam. Leaves to dietary quality in two Bapedi communities in Mokopane, Limpopo Province. MSc Dissertation, University of South Africa.

Andrews M, Sprent JI, Raven JA, Eady PE (1999). Relationships between shoot root ratio, growth and leaf soluble protein concentration of *Pisum sativum*, *Phaseolus vulgaris* and *Triticum aestivum* under different nutrient deficiencies. Plant, Cell and Environment 22:949-958.

Anwar F, Latif S, Ashraf M, Gilani AH (2007). *Moringa oleifera*: A food plant with multiple medicinal uses. Phytotherapy Research 21:17-25.

Fuglie JW (2001). The miracle tree: *Moringa oleifera*, natural nutrition for the tropics. Training Manual. Dakar, Senegal; Church World Service. P. 172.

Gomez KA, Gomez AA (1984). Statistical procedures for agricultural research. New York, Wiley.

Hassan FG, Ibrahim MA (2013). *Moringa oleifera*: nature is most nutritious and multi-purpose Tree. Sudan. International Journal of Scientific and Research Publications 3:2250-3153.

Leone A, Spada A, Batterrati A, Schiraldi A, Aristil J, Bertoli S (2015). Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: An overview. International Journal of Molecular Sciences 16:12791-12835.

Liu DL, An M, Johnson IR, Lovett JV (2003). Mathematical modeling of allelopathy. III. A model for curve-fitting allelochemical dosage responses. Nonlinearity in Biology Toxicology and Medicine 1:37-50.

Mashela PW, Dube ZP, Pofu KM (2015). Managing the phytotoxicity and inconsistent nematode suppression in soil amended with phytonematicides. In: Meghvansi MK, Varma A (eds) Organic Amendments and Soil Suppressiveness in Plant Disease Management, Soil Biology 46. Switzerland, Springer International Publishing pp. 147-173.

McMahon MJ, Kofranek AM, Rubatzky VE (2005). Hartmann's plant science: Growth, development and utilisation of cultivated plants. Upper Saddle River, New Jersey, Prentice Hall.

Muhl QE (2009). Seed germination, tree growth and flowering responses of *Moringa oleifera* Lam. (Horseradish Tree) to temperature. MSc Dissertation, University of Pretoria: Pretoria.

Palada M, Chang L (2003). Suggested cultural practices for Moringa. International. pp. 3-545.

Richards D, Rowe RN (1977). Effect of root restriction, root pruning and 6-benzylaminopurine on the growth of peach seedlings. Annals of Botany 41:729-740.

Salisbury FB, Ross CW (2005). Plant physiology. New York, Wiley.

SAS Institute Inc. (2015). SAS/STAT 9.2 Qualification tools user's guide. Cary (NC), SAS Institute.

Vol. 14(2), pp. 69-77, 10 January, 2019
DOI: 10.5897/AJAR2018.13076
Article Number: 73EDF8E59805
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Assessment of technical conformity of bench terraces for soil erosion control in Rwanda

Eric Derrick Bugenimana[1]*, Emmanuel Mhache Patropa[2], Charles Karemangingo[1] and Theoneste Bimenyimana[1]

[1]Department of Agricultural Engineering, Faculty of Agriculture, University of Kibungo, P. O. Box 6, Ngoma, Rwanda.
[2]Department of Geography, Faculty of Arts and Social Science,Open University of Tanzania, P. O. Box 23409 Dar es Salaam, Tanzania.

Received 23 February, 2018; Accepted 16 March, 2018

The purpose of this paper was to evaluate technical conformity of bench terraces in the Eastern Province of Rwanda. A sample of 180 actual bench terraces from 12 sites located in this Province was tested against technical standards and models provided for by the Ministry of Agriculture of Rwanda and Food and Agriculture Organization of the United Nations. The results showed that many sites have been constructed with no consideration of these technical guidelines. Terraces were built on land slopes lower or higher than standards while terrace riser slopes above 90% and height above 2.9 m were frequent. Findings indicated weak correlation coefficient (r=0.314), although very significant, between field-measured and Agriculture Organization model-computed vertical intervals, and very weak but significant correlation coefficient (r = 0.194) between terrace measured and model-derived widths. In such circumstances, land terracing might have increased risks of landslide and erosion with no sustainable benefit for soil erosion control and crop production.

Key words: Bench terraces, soil erosion, technical efficacy, Eastern province.

INTRODUCTION

More than 80% of the world's agricultural land suffer moderate to severe soil erosion. Worldwide, the mean annual soil erosion loss on cropland has been estimated at about 30 Mg/ha, while reported values vary from 0.5 to over 400 Mg/ha per year (Pimentel and Kounang, 1998). Recent soil erosion loss estimates from the intensively cultivated highlands of the upper Akagera River indicated average amounts of 35.1 tons/ha in southern Rwanda and 19.2 tons ha^{-1} in northern Burundi (Karemangingo et al., 2014). The history of bench terraces in Rwanda is linked to policies and regulations by the Government and to interventions by Non-Government Organizations (NGOs) (Bizoza and de Graff, 2012). A unique method of back-slope terracing was originally introduced by missionaries growing wheat. Other soil and water conservation techniques had been established earlier, such as hedgerows and slow-forming terraces (progressive terraces). In order to maintain the top soils, which are rich in nutrients, and to keep the riser of the terrace intact, a bench terrace is constructed by breaking up the 25 to 55% slope gradient into several shorter and levelled segments (Posthumus, 2010).

*Corresponding author. E-mail: isimbiella@gmail.com.

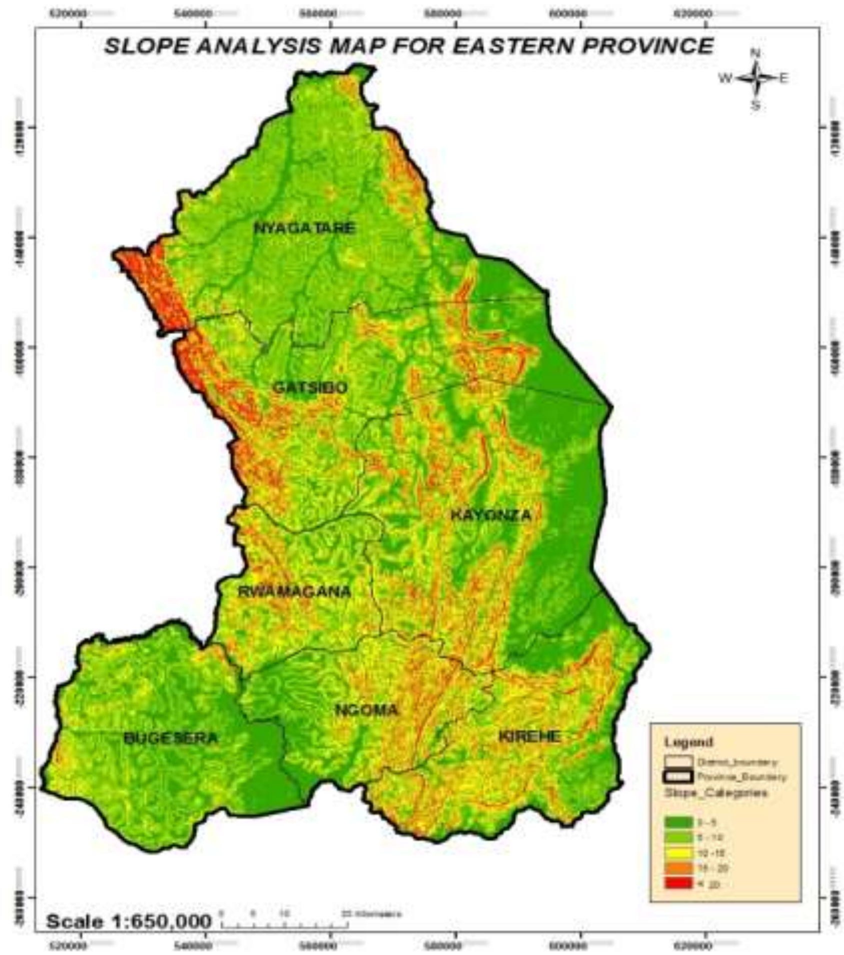

Figure 1. Slope analysis map of the Eastern Province.

In Rwanda some of the bench terraces are constructed on slopes or cuts with sandy or rocky soils, shallow soils, non-cohesive or highly erodible soils, or decomposing rocks including moraines and high slopes. In addition, all soils are not reorganized and fertilized by organic manure and lime after bench terracing as recommended by both Ministry of Agriculture and Animal Resources of Rwanda (MINAGRI) and Food and Agriculture Organization (FAO) norms. Consequently, several areas of the country have experienced floods and landslides on some constructed bench terraces while some terraced lands have been abandoned by farmers after terracing. Around 23.55% of terraced land at national level is not under exploitation (Pimentel and Kounang, 1998). Since land terracing is very expensive but profitable (Pimentel and Kounang, 1998), it was very important to understand the causes of soil infertility, frequent terrace riser destruction, and abandoning of terraced land. This research therefore aimed at analyzing technical efficacy of bench terraces vis-a-vis the standards established by both FAO and MINAGRI (Land and Water Husbandry Service) of Rwanda.

METHODOLOGY

The research was carried out in Eastern Province of Rwanda. The land surface of Rwanda is 26388 km^2 and the country has a population of about 11.78 million (National Institute of Statistics Rwanda (NISR), 2012). The least densely populated districts are found in the Eastern Province. The country is very hilly with steep slope lands and devastating soil erosion exacerbated by over stripping, deforestation, and inadequate use of land improvement techniques (National Institute of Statistics Rwanda (NISR), 2012). The soils of the eastern Province are naturally fragile. They result from the physical and chemical alteration of schistose, quartzite, gneiss, granite, which forms the surface geology of the country. The general geomorphology is a plateau characterized by localized steep slopes (Figure 1) which causes erosion and landslide (Ministry of Lands, Environment, Forests, Water and Mines 2004).

Four Districts were selected out of seven Districts of this Province to host the study as in Table 1. Selected terraced terrains were 25 ha wide or more. Three sites were identified by agro-ecological zones by District for a total of 12 sites. In addition, each selected site must have been terraced under the supervision of either Land

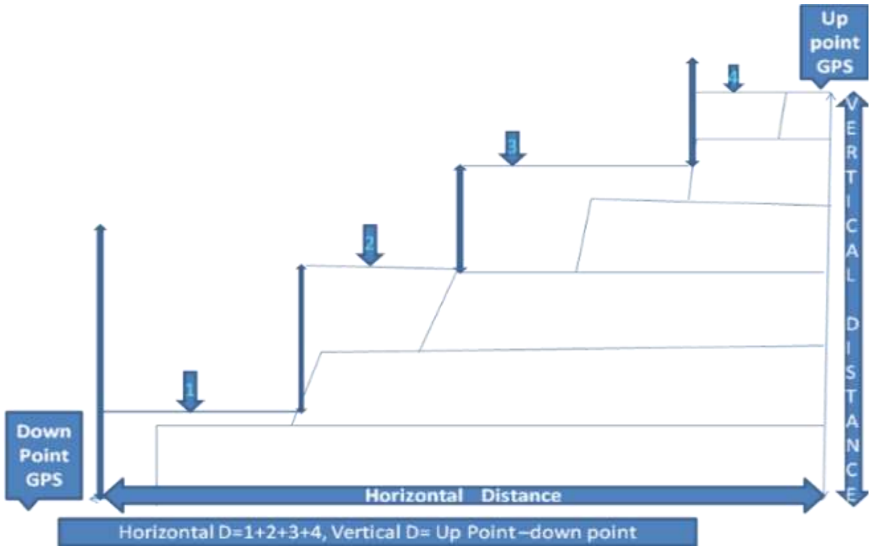

Figure 2. Site slope measurement

Table 1. Selection of study sites in the Eastern Province.

Districts	Sites	Location /Sector
Ngoma	3	Jalama/Musera/Rurenge
Kirehe	3	Kirehe/Mahama/Gatore
Rwamagana	3	Musha/Gahengeri/Mwurire
Kayonza	3	Murund and Mukarange
Total	12	

and Water Husbandry service (LWH), private companies (PC) or Village Umurenge Program (VUP), a national program for local development. Data collection consisted of field observations and technical measurements of implemented bench terraces and their comparison to FAO and LWH standards. Collected data included bed slope, terrace width, vertical interval, heights of risers, and riser slope.

(i) Slope of land was measured as the ratio of the horizontal distance of the land (Figure 2), and the vertical distance as follows:

$$\textbf{Slope}\ (\%) = \frac{\textbf{Vertical Ditance}}{\textbf{Horizontal Distance}}\textbf{x100} \quad (1)$$

(ii) The width terrace: The width terraces were measured in order to find the average width of benches for selected terraces, the total length of the terrace was firstly measured. Therefore, the average width of the bench was calculated by taking different width measurements along that terrace at 5 m interval. The actual mean width is then compared to the expected width as per FAO and MINAGRI models calculated as follows:

$$\boldsymbol{Wb = VI \times (100 - (S \times U))/S} \quad (2)$$

Where VI: vertical interval, in m;
S: slope in percentage (%);
Wb: Width of bench (flat strip), in m;
U: Slope of riser (using value 1 for machine-built terraces, 0.75 for hand-made earth risers and 0.5 for rock risers)

(iii) The vertical interval: Based on LWH, the vertical interval for slopes between 16% and 40% is 1.5 m (Sheng, 2002). For FAO, the width of benches on a specific slope category is equal to the vertical interval. Using this approach, the vertical intervals corresponding to the widths of benches were calculated and compared to LWH guidelines using 1.5 m of vertical interval. Using the below formula, the vertical interval was calculated as follows:

$$VI = \frac{S \times Wb}{100 - (S \times U)} \quad (3)$$

Where VI: vertical interval, in m;
S: slope in percentage (%);
Wb: Width of bench (flat strip), in m;
U: Slope of riser (using value 1 for machine-built terraces, 0.75 for hand-made earth risers and 0.5 for rock risers. The 0.75 value was used because the bench terraces of our case study were hand-made by human labor.

(ii) Heights of riser: After vertical interval was obtained it is easy to figure out the height of riser of the terraces. For level terrace, *VI* equals the height of the riser. For reverse sloped terraces, the *VI* needs to add a reverse height to get the total height. The reverse height was calculated by the following equation:

$$Hr = \text{Wb x0.05} \quad (4)$$

Where *RH* is reverse height;
Wb is width of bench;
5% is the reverse slope.

(iii) The slope of risers: The slope of risers were measured on 15 terraces of the up as the samples, the medium terraces and the lower terraces means 5 terraces for each level and the mean was made for each site and calculated. Figure 3 shows the procedure used in measuring of slope of risers.

$$\textbf{Slope}\ (\%) = \frac{\textbf{Vertical distance of riser}}{\textbf{Horizontal distance of riser}}\boldsymbol{x}\textbf{100} \quad (5)$$

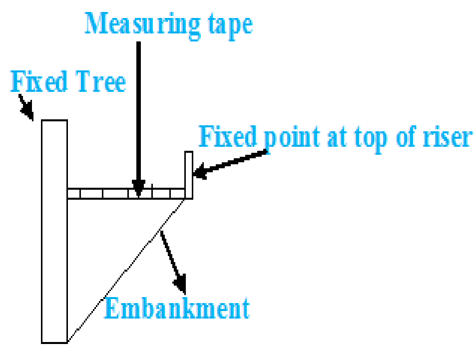

Figure 3. Measurement of embankment slope.

Figure 4. Mean slope of the study sites as monitored for each implementer by District

RESULTS

Land mean slope

Land slope determination is the imperative criteria in selecting soil conservation and management practices for soil erosion control. In that regard, Figure 4 illustrates the study site mean slopes for each implementer (LWH, VUP and PC) by district. The results refer to the measured mean slope of terraced sites in eastern Rwanda by implementer for each one of the four Districts.

Slope of bed and height of embankment

The results in Table 2 represent field-measured terrace parameters by District and by implementer.

Pearson correlations between the parameters

A correlation matrix was calculated between field and expected parameters using the existing FAO models, and the results are presented in Table 3. The parameters include vertical interval measured on field (VIF), vertical interval calculated using the FAO formula (VIFAO), width measured on field (WBF), and width calculated using FAO formula (WBFAO). The results notably represent correlation coefficients between field-measured vertical interval (VIF), model-estimated vertical interval (VIFAO), field-measured bench width (WBF), and model-estimated bench width (WBFAO). The correlation coefficient of 0.314 (with $P < 0.01$) between vertical interval measured on the field and vertical interval calculated using the FAO formula indicates a weak but significantly positive relationship. In the same way, the correlation coefficient of 0.194 (with $P < 0.05$) between field measured width and width calculated using the FAO formula represents a very weak positive correlation between the two variables.

DISCUSSIONS

Land slope and embankment

The land slope is key in selecting the type of soil conservation and management practices. In particular, the slope gradient is important for choosing bench

Table 2. Slope of bed and height of risers.

District	Implementer	Slope of bed (%)	Slope of riser (%)	Height of riser (m)
Ngoma	LWH	3.5	61.4	1.7
	PC	4.1	61.3	1.1
	VUP	2.2	66.0	2.7
Mean		**3.26**	**62.9**	**1.83**
Kayonza	LWH	4.4	68	1.2
	PC	3.47	90	0.88
	VUP	3.07	74.5	2.9
Mean		**3.64**	**77.5**	**1.6**
Kirehe	LWH	2.6	68.87	2.23
	PC	N/A	N/A	N/A
	VUP	2.0	69.63	2.44
Mean		**2.3**	**69.25**	**2.3**
Rwamagana	LWH	4.0	65.1	1.2
	PC	1.8	74.1	1.3
	VUP	2.7	70.6	2.1
Mean		**2.83**	**69.9**	**1.53**

Table 3. Correlations between parameters.

		VI-FAO	VIF	WB-FAO	WBF
VI_FAO	Pearson Correlation	1.000			
	Sig. (2-tailed)				
	N	165			
VIF	Pearson Correlation	0.314**	1.000		
	Sig. (2-tailed)	0.000			
	N	165	165		
WB_FAO	Pearson Correlation	-0.071	-0.080	1.000	
	Sig. (2-tailed)	0.364	0.310		
	N	165	165	165	
WBF	Pearson Correlation	-0.172*	0.065	0.194*	1.000
	Sig. (2-tailed)	0.028	0.407	0.013	
	N	165	165	165	165

terraces. The study results in this paper as presented in Figure 4 indicated that bench terraces were chosen regardless of the land slopes for some sites. Land slope steepness is above or below recommended levels for terraces. That is notably true for terraces located in Kayonza district where some were constructed on 44% slope gradient while others were established on 11% slope gradient. The success of terraces above 40% slope gradient is doubtful because of high risk for riser collapse while cheaper and equally efficient conservation measures such as soil bunds are available below 15% slope gradient. According to Azene (2011), soil bunds must be implemented on soils with slope ranging between 10 to 15% whereas bench terraces must be established on soils having between 16 to 40% slope gradient and forestation is appropriate for the land above

Plate 1. (1) The embankment started cracking few weeks after terracing, (2) abandoned terraces are actually used as pasture land
Source: Field Data (2015)

40% slope gradient. However, FAO (2013) stated that the bench terraces are only recommended for sites whose slope categories range between 12 to 47% and stated that it depends on construction materials used in construction (tractors or hand). Hence, all the terraces in Rwanda have been constructed by hand.

Concerning the riser slopes and heights, the results field-measured or calculated from field collected data showed that about 85% of investigated terraces have not complied with the established norms. In general, the inclination of riser slope between 30 and 60% results in stability and sustainability of terrace embankments while steeper risers should be planted with grasses to give them same stability (FAO, 2013). The assessment results indicated that, for most of sites constructed by private companies and VUP program, terrace risers are beyond recommendations established by LWH and FAO. Embankment slopes of 77 and 90%, instead of 60 to 70% as recommended by LWH and 30to 60% recommended by FAO, were surveyed in some sites of Rwamagana and Kayonza. Thus, steeper riser is runoff-prone or subject to land slide. It is also an indicator of poor quality embankments which in the future can lead to sudden embankment collapse and destruction. , The embankment gets more fragile as the riser height increases (Sheng, 2002). Tied closely with slope gradient is the gentle slopes receiving storm runoff from above which may have a much higher erosion hazard than very steep slopes near a ridge top. Brian (1990) stated that the experience shows the overall height of a riser should not exceed 1.8 to 2 m; above which the maintenance work will become difficult (Azene, 2011).

Hence if the riser is taller, steep and poorly protected, it effectively becomes an erosion hazard in itself (Sheng, 2002). Therefore, terrace risers become a very important component of terraced hillsides, and their significance increases with steepness of the landscape. Where risers are not protected, they present a distinct erosion hazard. When height of riser is great, it can reduce the cultivable area. Therefore, farmers cut away at the base of risers, primarily to increase cultivable area as shown by Plate 1. The farmer destroyed the risers because they needed to increase the cultivable area while cultivating and planting, but this may also trigger some extra erosion through destabilization of the riser. Secondly, and significantly in certain situations, there are riser failures, where slumping occurs usually when an unstable riser becomes saturated [14]. Grasses should be grown well on the risers. Any small break or fall from the riser must be repaired immediately. Cattle should not be allowed to trample on the risers or graze the grasses. Runoff should not be allowed to flow over the risers on reverse-sloped terraces (Sheng, 2002).

It is obligatory to shape and plant grasses as soon as possible after cutting a terrace. Field observations have shown that some sites were well protected (for instance those constructed by LWH), while many terraces constructed by VUP and CP are not well protected at all. The sites constructed by LWH are well maintained, some of them are projected by fruits trees and agro-forestry trees. Although tall grasses may produce considerable forage for cattle, they require frequent cutting and attention. The rhizome-type of local grass has proved very successful in protecting risers. Stones, when available, can also be used to protect and support the risers (FAO, 2013; Sheng, 2002). Risers require regular care and maintenance. If a small break is neglected, large-scale damage will result (Sheng, 2002).

Plate 2. The old and new risers destroyed by farmers for increasing the cultivation area (photo taken on the field)

The slopes of bed

The benches (Inward Sloping Bench Terrace) are made with inward slope to drain off excess water as quickly as possible (Suresh, 2009). It is essential to keep the excess runoff towards hill (original ground) rather than on fill slopes. These inwardly sloping bench terraces have a drain on inner side, which has a grade along its length to convey the excess water to one side, from where it is disposed-off by well stabilized vegetated waterway.

From the field results, the mean inward bed slope values range from 2.3 to 3.6%. These results are in range with recommended values; but if we consider site by site, several concerns are raised: some terraces constructed by VUP and PC are subjects to destruction by farmers' activities, few of them have been made outward instead of inward slope, some are used by farmers for burning charcoal (Plate 2) and free-grazing their cattle graze (Plate 3).

The bed slope or inverse slope should be between 3 and 7% (Azene, 2011; FAO, 1985), it should be adopted because inverse slope when used for a long term did not provide a sustainable land use management, since few years after construction, this slope is almost removed due to continuous natural process such as drop and rain borne strong runoff speed, velocity and volume which quickly makes runoffs to move downhill thus destroying embankments of concerned terraces and adversely effecting terraces in its southwards path way direction (Suresh, 2009). Complying with LWH and FAO recommended bed slopes, as they play their role in breaking the run-off will result in the long-term sustainability of bench terraces as a soil erosion control practice. It is also expected that reduced runoff water will result in increased infiltration and increased water availability to crop, and ultimately sustainable bench terraces will result in increased crop yields. These suggestions are in line with FAO (1985) who reported that, interfering with runoff and its speed results in increased infiltration rate which ultimately reflect in an increasing crop yield, soil and water conservation and sustainable land use management.

Vertical interval and width of bench

Terrace spacing and width of the bench are normally expressed in terms of the vertical interval at which the terraces are constructed. They depend upon factors like slope, soil type and surface condition, grade and agricultural use. Therefore, the width and vertical interval of bench terraces are crucial parts of bench terraces as quality assessment parameters which, once inaccurately calculated, affect the position and size of terraces on sites. In that regard there is a very close relationship between both width and vertical interval of bench terrace. Terrace spacing depends mainly upon land slope (FAO, 1985). However, it also depends upon the soil and climate. While the cross section will have some effect on the horizontal spacing, the crops to be grown and the machinery that will be used should also be considered. In this respect, the results of this study are in range with the predictions with the exception for few sites. For instance, on the field we measured 1.4 m instead of 0.62 m given by FAO formula found in Kirehe sites and 1.9 instead of 2.7 m on Rwamagana site, respectively constructed by private companies and Vision Umurenge Programme.

Furthermore, FAO has established theoretical standards (which range between 12 to 32% of land slope) to refer when one does not consider the use of formula for example it is the reason why for bench width of 4 m the corresponding vertical interval was 0.94 m in our case. On some sites, the land slopes standards were not considered but the vertical interval and width of the bench

Plate 3. a) The farmers started burning charcoal on new terraces, b) the cattle grazing on bench of terraces (photo taken on Mugesera and Mushasites-Rwanda).

were calculated because few land slopes in this study comply between 10.7 of PC to 44% of VUP implementer. Unfortunately, FAO and LWH did not specify for sites with slopes categories beyond 32% and below 12% (Sheng, 2002). The area dedicated to growing crops will be reduced and it will reduce the yield which could be obtained from those terraces. Poor vertical interval affects position and sequence of bench terraces to be implemented and interfere with agriculture purpose, of which they were implemented (Sheng, 2002). The effective cultivated length of slope between terraces varies with the type of cross section; the back slope of the broad base cross section can be cultivated and therefore is a part of the effective length (FAO, 1985).

CONCLUSION AND RECOMMENDATIONS

The severity of soil erosion in Rwanda motivates the government to invest more in soil conservation for sustaining agricultural production and environment protection. Various agronomic and physical soil conservation measures have been taken and the government continues to put more efforts in soil erosion control. This research carried out in eastern Province of Rwanda evaluated the compliance level of institutions in charge of the implementation of bench terraces across the Province with regard to LWH and FAO norms for bench terrace construction.

The results revealed that some terraces have been built with no consideration of neither LWH recommendations nor FAO norms and standards. In that regard the land slopes are over or under the norms (standards) of bench terraces for some sites. For instance, one site of Kayonza was terraced although the land slope was above 40% (44% exactly) while a 10.7% slope site was terraced instead of using alternative and cheaper practices. Moreover, the slopes and heights of bench riser measured on the fields show that about 85% of sites visited had terrace risers higher than the standards. In addition, many of them were not protected with grasses for improved stabilization as recommended. Therefore, steeper riser is runoff-prone with increased risk of land slide or collapse. In general, the bed slope values are within recommended ranges from 2.3 to 3.6%. Also, vertical intervals and width of the benches were generally within recommended ranges, but few sites existed which the widths are seriously threatened by farmers looking for increased cultivable land (Plate 2) while other farmers use the beds for charcoal burning (Plate 2). Several sites have no waterways and no cut-off drains and some sites without water way and cut-off drains are located below roads and at risks of destruction by the water flow from the roads. It was noted that most of the terraces constructed by LWH were well in compliance with the norms and well protected.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest

REFERENCES

Azene B-T (2011). Assessment of the quality of comprehensive of land-husbandry works at LWH project sites. Kigali-Rwanda.

Bizoza AR, de Graff J (2012). Financial cost-benefit analysis of bench terraces in Rwanda. Land Degradation and Development 23:103-115.

Brian C (1990). Terracing re-examined in the light of recent findings in Nepal and Indonesia Research Needs and Applications to Reduce Erosion and Sedimentation. In Tropical Steep lands (Proceedings of the Fiji Symposium, June 1990): IAHS-AISH Publ. No.192, 1990. Gibsons, British Columbia, Canada.

Food and Agriculture Organization (FAO) (1985). Method of erosion control. Rome, Italy.
Food and Agriculture Organization (FAO) (2013). Green manure/cover crops and crop rotation in Conservation Agriculture on small farms. Rome, Italy.
Karemangingo C, Bugenimana ED, Bimyebebe M (2014). Development of catchment management plan for Akanyaru sub-catchment, Nyaruguru district, Rwanda, Kigali-Rwanda
Ministry of Lands, Environment, Forests, Water and Mines (2004). National Land Policy, Kigali/Rwanda.
National Institute of Statistics Rwanda (NISR) (2012). Rwanda 4th Population and Housing Census, Kigali/Rwanda.
Pimentel D, Kounang N (1998). Ecology of soil erosion in ecosystems. Ithaca, New York
Posthumus H (2010). To terrace or not: the short term impact of bench terraces on soil properties and crop response in the Peruvian Andes.

Sheng CT (2002). Bench Terrace Design Made Simple, 12th ISCO Conference, Beijing.
Sheng T/C (2002). Bench Terrace Design Made Simple. Beijing Department of Earth Resources Colorado State University Fort Collins, CO 80523, USA.
Suresh N (2009). Soil and Water Conservation Engineering, Standard Publishers, New Delhi.
Van Dijk AIJM, Bruijnzeel LA (2011). Terrace erosion and sediment transport model: a new tool for soil conservation planning in bench-terraced steep lands. Environmental Modelling and Software 18:839-850.

Vol. 14(2), pp. 78-91, 10 January, 2019
DOI: 10.5897/AJAR2018.13615
Article Number: 7AD0D6059807
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Levels of some selected metals (Fe, Cu and Zn) in selected vegetables and soil around eastern industry zone, central Ethiopia

Dagne Bekele Bahiru[1*] and Endale Teju[2]

[1]Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia.
[2]Department of Chemistry, Faculty of natural and computational science, Haramaya University, Haramaya, Ethiopia.

Received 9 October, 2018; Accepted 5 December, 2018

The purpose of this study was to determine the concentration of selected metals (Fe, Zn and Cu) in vegetables and the soil contaminating levels due to irrigation, using Flame Atomic Absorption Spectrophotometer (FAAS). The wet digestion and sequential fractionation extraction procedures were employed to solubilize the metals from the collected samples. The results obtained from this study showed overall concentration of selected metals Fe, Zn and Cu respectively, in the range of (358.17 to 547.17), (45.63 to 62.46) and (10.20 to 15.07) (mg /Kg) in the edible parts of sampled vegetables whereas, concentrations (mg/kg) of the metals in the soil samples were found to be in the ranges of (12051 to 20065), (69.37 to 123.77) and (68.47 to 146.10) for Fe, Zn and Cu, respectively. The modified Tessier sequential extraction procedure was used to fractionate the above three metals from the soil samples into five fractions. In this study the detected metals were predominantly concentrated in residual fraction (F5); zinc was mainly associated with the residual fraction (F5) (87.14 to 96.40%) which is highly stable. The mobility factors of Zn, Fe and Cu were 0.908 to 3.044, 0.216 to 0.443 and 0.314 to 1.968, respectively. The concentrations of Fe and Cu in the soil and vegetable samples were above the recommended limit of both WHO and FAO; also, Zn vegetable samples was above the limit. However, Zn for the soil samples was smaller than WHO and FAO recommended limit. Based on facts obtained from this study, it was suggested that concerned official body (ies) take the necessary precaution measures to clean the polluted area.

Key words: Metals, sequential fractionation, soil, vegetables, quantity.

INTRODUCTION

Metals are elements, present in chemical compounds as positive ions, or in the form of cations (+ ions) in solution. Heavy metals are among the most serious environmental pollutants due to their high toxicity, abundance and ease of accumulation by various plant and animal organisms. Increase of heavy metals in the soil can be attributed to the contribution of effluent from waste water treatment plants, industries, mining, power stations and agriculture (Guevara-Riba et al., 2004). Heavy metals are one of a range of important types of contaminants that can be

*Corresponding author. E-mail: ddagnebbk19@gmail.com.

found on the surface and in the tissue of fresh vegetables. Heavy metals, such as cadmium, copper, lead, chromium and mercury, are environmental pollutants, particularly in areas under irrigation with wastewater (Garcia et al., 1981). Plants take up heavy metals by absorbing them from airborne deposits on the parts of the plants exposed to the air from the polluted environments as well as from contaminated soils through root systems. Also, the heavy metal contamination of fruits and vegetables may occur due to their irrigation with contaminated water (Al Jassir et al., 2005).

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, sewage sludge pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan et al., 2008). Heavy metal contamination in agricultural soils may lead to the disorder of soil functionality and retardation of plant growth, and influence human health through a contaminated food chain (Khan et al., 2008).

Sequential fractionation extraction techniques are commonly used to fractionate the solid-phase forms of metals in soils. Many sequential extraction procedures have been developed, particularly for sediments or agricultural soils, and despite numerous criticisms, they remain very useful (Christian et al., 2002). The mobility and bioavailability of heavy metal depend absolutely on their speciation or chemical forms. These forms are determined by sequential extraction technique, this method gives vivid information about metal affinity to the soil components together with the strength to which they are bound to the soil matrix. Also heavy metal fractions can give detail about soil origin, biological and physicochemical availability, and their mode of occurrence, mobility and transportation of trace metals (Kotoky et al., 2003). Some methods used in heavy metal analysis are AAS, EDXRF and ICP (Abolino et al., 2002). For analysis of various fractions obtained by sequential extraction, AAS, ICP-MS and ICP- AES and ICP-OES are used (Iwegbue, 2007). In addition, Milkessa (2013) used FAAS. ICP-MS and AAS are most preferred because they are not prone to polyatomic interferences and are less affected by matrix suppression (Harrison et al., 1981).The method used in the present study for analysis was AAS due to its availability. AAS is simple, sensitive and selective and has the advantage of being a fast method of analysis (Katz, 1984).

The aim of this study was to detect and determine the concentrations of beneficial as well as toxic metals viz. Fe, Cu and Zn in samples of soils and selected vegetables from irrigation farms around Eastern Industry Zone, in which pesticide, fertilizer, municipal and industrial sewage effluents are known to be discharged into surrounding irrigation farms. Cabbage, lettuce, and tomato were selected and most commonly consumed edible vegetables, which are cultivated by using effluent wastewater, due to lack of clean irrigation water. The study is necessary, as a large number of people consume the vegetables grown in this area. To date there is enough information research report on the levels of selected metal concentrations in soils and vegetables, to elucidate the extent of the problems posted by agricultural practice and this industry zone on the environment.

MATERIALS AND METHODS

Description of the study area

This study was conducted around EIZ in Dukem, Ethiopia. Dukem Town was founded in 1914 and is one of the 18 special zones of the Oromia Regional State of Akaki Woreda which is located at 37 Km distance from Addis Ababa City. It is a town in central Ethiopia, to the South of Addis Ababa and 10 Km to North West of Bishoftu Town. Its astronomical location is 08º45'25"-08º50'30" North Latitude and 38º51'55" 08º56'5" East Longitude (Abebe, 2012).

The EIZ of Ethiopia is located at 35 km southeast of Addis Ababa, and 680 Km from the port of Djibouti with 200 hectares of land in Dukem. For Ethiopia, EIZ is the first and largest-scale industrial park. The Ministry of Industry of Ethiopia requires the EIZ to focus on Chinese companies in the area of textile, apparel, building materials (including east steel, cement factory), mechanical manufacturing, and agricultural processing. Currently, 26 Chinese firms are operational and producing different products for export markets having agreement with EIZ in all targeted areas. In addition to the present 26 manufacturing industries, more than 20 other manufacturing industries are about to join the EIZ (Gebregeorgis, 2016). This implies that more municipal waste, gasses and wastewater from various industry of EIZ is discharged to the surrounding environment.

Chemicals, reagents and instruments

The instruments used for this study was FAAS, Agilent technology with model no. 210 for toxic heavy metal determination of vegetable and soil samples and a Mcroprossecer based PH-EC-TDS Meter; Model 1615 was used for the determination of soil pH and conductivity.

All the chemicals used were analytical reagent grade. Deionized water and distilled water were used for all preparation and dilution purposes throughout the study. Nitric acid, HNO_3 (69%), ammonium acetate (NH_4Ac) Sodium acetate (NaAc), potassium chloride (KCl), acetic acid (HAc), magnesium chloride ($MgCl_2$), hydroxide hydrochloride ($NH_2OH.HCl$), sulphuric acid, H_2SO_4 (98%) and hydrogen peroxide, H_2O_2 (30%) and hydrochloric acid (HCl) were used for digestion. Stock standard solutions of 1000 ppm were prepared for the selected metals (Fe, Cu and Zn).

All sample containers and glassware used in the present study were washed in detergent and soaked in 30% nitric acid for 2 h to leach out adsorbed metal ion. They were then rinsed in tap water followed by deionized water before drying in dust free area (APHA, 1999).

Sample collection and preparation

The soil, and vegetable samples were collected from vegetable samples in February, 2017: about 1 kg edible part of cabbage (*Brassica oleracea*), lettuce (*Lactuca sativa)* and tomato (*Lycopersicon esculentum Miller*). To this effect, three farmer farmlands were selected and three subsamples were taken for collecting representative edible parts of the vegetables. The collection was done manually. The representative reputable samples were thoroughly mixed to give a composite sample as representative fraction of the vegetables. The bruised or rotten portions were removed and the remaining samples were packed in polyethylene bags for transporting to the Debre Zeit Agricultural Research Center Agricultural Chemistry lab (DZARC ANRL). In the laboratory, the collected plant samples were washed with tap water and then with distilled water to eliminate adsorbed dust and particulate matters. The vegetable samples were cut and chopped into small pieces, using plastic knife in order to facilitate drying. Accordingly, the samples were air-dried for six days and further dried in hot air oven at 50-60°C for 24 h, to remove moisture and maintain constant mass. The dried samples were ground into powder using acid washed commercial mortar and pestle and then sieved to 2 mm mesh size. The sieved samples were finally stored in polyethylene bags and kept in desiccators until the time of digestion.

Soil samples (about 1 kg) were collected from 0-20 cm depth from the site where the vegetables were grown (for each vegetable type) with an auger (Poggio et al., 2008) and the control soil sample was collected 2 km away from the study area. Then the samples were placed in clean polyethylene bags and transported to the DZARC ANRL for pretreatment and analysis. The composite soil samples were air-dried in a dry and dust-free place at room temperature (25 ^{0}C) for 5 days, followed by oven drying to constant weights. The samples were then ground with a mortar and pestle to pass through a 2-mm sieve and homogenized. The dried, sieved, and homogenized soil samples were stored in clean and dry containers till digestion.

Digestion of soil and vegetable samples

The 0.5 g dried and homogenized soil samples were transferred in to 100 mL digestion flask in triplicate. In each of these flasks, 5 mL of deionized water and 30 mL of a mixture HNO_3 (69%) and 37% HCl with volume ratio of 5:1 were added. The sample dissolved in the acid mixture was digested in digestion hood (at 200°C) for 1 h and kept to cool. After adding 2 mL of H2O2 to the cold digestion mixture, the final, the mixture was filtered out through Whatman No. 42 filter paper to a 100 mL volumetric flask and finally diluted to the mark with distilled water (Loon, 1985). The varying filtrates obtained above were analyzed for the total content of each heavy metal by FAAS in Holeta Agricultural Research Center Chemistry Lab. The blank reagent was also digested following the same procedure as the soil sample.

A 0.5 g of homogenized powdered vegetables sample was placed in borosilicate digestion flask to which 10 mL of acid mixture containing HNO3- HCl-H2O2 (8:1:1, v/v/v) ratio were added. The mixture was heated at 120°C over 3 h on block digester. After digestion was completed, the clear and colorless solution was filtered out into 100 mL volumetric flask. Each digestion tube were rinsed with distilled water to collect any possible residue, and added to the volumetric flask and finally made up to volume with distilled water. All the dilute samples were stored in 100 mL plastic bottles (high density polyethylene) until analysis. Each vegetable sample was digested and analyzed in triplicate to confirm precision of the result. The blank solution was prepared by taking a mixture of 8 mL HNO3, 1 mL HCl and 1 mL H2O2 and treating similarly as that of the sample (Street, 2008). The heavy metal concentrations were analyzed by FAAS in Holeta Agricultural Research Center Chemistry Lab.

Heavy metal fractionation in soil samples

The modified Tessier's procedure, Ma and Rao (1997) and Yoseph (2015) was used to determine operationally defined chemical species of the metals from soil. Five operationally defined fractions of the metals were removed by these sequential extractions. The SEP operationally groups heavy metals into five fractions: Soluble and Exchangeable Fraction (F1), the Fraction Bound to Carbonates (F2), the Fraction Bound to Iron and Manganese Oxides (F3), the Fraction Bound to Organic Matter (F4) and the Fraction Bound to Soil Matrix (Residual Fraction) (F5).

Method detection limit

Method detection limit is defined as the minimum concentration of analyte that can be measured. In other words, it is the lowest analyte concentration that can be distinguished from statistical fluctuations in a blank (Gezahegn, 2013). Three replicate blank samples were digested following the same procedures utilized for digesting the soil and vegetable samples. Each blank were assayed for its metal contents Fe, Zn and Cu by FAAS. The standard deviation (SD) of the three replicate blanks was calculated to determine the MDL (David and Terry, 2008). Method detection limit (MDL) was then calculated according to equation indicated below:

MDL = YB +3SD

Where, YB = Blank mean.

Method validation

In the present study due to the absence of certified reference materials for soil and vegetable samples in our laboratory, the validity of the digestion procedure, precision and accuracy of FAAS were assured by spiking soil and vegetable samples with standard of known concentration. The spiked and non spiked vegetables and soil samples were digested following the same procedure empl oyed in the digestion of the respective samples and analyzed in similar condition as shown in Appendix Table 1. Then the percentage recoveries of the analytes were calculated by:

$$\mathbf{Recovery} = \left(\frac{\text{CM in the spik samples} - \text{CM in the non spik sample}}{\text{Amount added}}\right) x\ 100$$

Where, CM = concentration of metal of interest.

Statistical analysis

The analyses of variance ANOVA were performed to examine the significance level of all parameters measured. Least Significant Difference (LSD) test was used for means comparison. The level of significance for mean comparison was $p<0.05$. Methodological precision was therefore evaluated with standard deviation (SD).

RESULTS AND DISCUSSION

Physico-chemical analysis of soil samples

Conductivity is a measure of the ability of aqueous solution to carry an electric current that depends on the presence and total concentrations of ions, their mobility and valance and on the temperature (Mulugeta, 2014). In this work, conductivities of the soil samples collected from EIZ irrigation farmlands were determined at 25°C. In the collected soil samples growing tomato, cabbage

Table 1. Selected physico-chemical properties of soils samples from lands irrigated with wastewater around the Eastern Industry Zone.

Parameter		Soil sample type				LSD (0.05)
		ST	SC	SL	C	
pH (1:25)		7.90 ± 0.02^{b}	7.05 ± 0.03^{c}	7.13 ± 0.02^{c}	8.30 ± 0.10^{a}	0.11
EC in mS/cm		0.78 ± 0.08^{a}	0.50 ± 0.01^{b}	0.43 ± 0.04^{b}	0.84 ± 0.01^{a}	0.10
%OM		3.15 ± 0.14^{a}	3.25 ± 0.02^{a}	3.05 ± 0.25^{a}	1.65 ± 0.03^{b}	0.30
%MC		1.88 ± 0.14^{b}	2.10 ± 0.17^{ab}	2.18 ± 0.13^{a}	0.96 ± 0.03^{c}	0.28
CEC in (cmol(+)/Kg soil		46.70 ± 2.49^{a}	42.45 ± 1.56^{b}	38.99 ± 0.93^{c}	32.26 ± 0.53^{d}	3.36
Texture	%clay	46.67 ± 0.42^{b}	48.27 ± 0.61^{b}	53.47 ± 0.61^{a}	53.07 ± 2.57^{a}	2.75
	%silt	34.73 ± 0.31^{b}	39.73 ± 1.10^{a}	32.67 ± 0.31^{b}	34.07 ± 3.21^{b}	2.90
	%sand	18.60 ± 0.40^{a}	12.00 ± 0.53^{c}	13.87 ± 0.81^{b}	12.87 ± 1.10^{bc}	1.27
Class		Clay	Clay	Clay	Clay	

Where ST, SC and SL refer to soil sample taken from tomato, cabbage, lettuce growing farm land, respectively and C is control sample. Values are given as means of triplicates ± SD. The mean values in the same row having different superscript letters are significantly different from each other at 5% confidence interval.

and lettuce the conductivities were found to be 0.78±0.08, 0.50±0.01, and 0.43±0.04 mS/cm, respectively, and the control soil showed 0.84 ±0.01 mS/cm, which is significantly higher than cabbage and lettuce grown soil (Table 1). The relatively low electrical conductivity was observed in lettuce soil and relatively highest electrical conductivity was observed in tomato soil. Therefore, lettuce-growing soils are able to give a toxic amount of metal from a small amount of soil. In line with this, Murray and McBride (1994) indicated that soils with low electrical conductivity (EC) are able to give a toxic amount of metal from a small amount of soil (Hizkeal, 2012).

The pH value of the soils ranged from 7.13±0.02 to 8.30±0.10 (Table 1). According to Hizkeal (2012) soils with pH range of 5.6- 6.0, 6.1-6.5, 6.6-7.4, 7.4-7.8 and 7.8-8.4 are moderately acidic, slightly acidic, neutral or nearly neutral, slightly alkaline and moderately basic respectively, similarly soil with pH above 8.5 are strongly alkaline. Based on this, soil samples collected from tomato growing areas were moderately basic and soil samples collected from cabbage growing areas were nearly neutral whereas soil samples collected from lettuce growing areas were nearly neutral. Therefore, it indicates that the alkaline ranges of soils are known to limit the mobilization of heavy metals and thus minimize the uptake of heavy metals by plants (Sharma et al., 2007). Generally, most of the heavy metals are less available to plants under alkaline conditions than under acid conditions. pH is one of the factors which influence the bioavailability and the transport of heavy metal in the soil and heavy metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes (Uduma, 2013). Heavy metals are generally more mobile at pH <7 than at pH >7. The amount of heavy metals mobilized in soil is a function of pH, properties of metals, redox conditions, soil chemistry, organic matter content, clay content, cation exchange capacity and other soil properties (Uduma, 2013).

Soil organic matter is a principal variable that affects the spatial distribution of heavy metals in soil (Afshin and Farid, 2007). Increase in soil organic matter content leads to elevation of soil adsorption capacity hence enhancing the accumulation of trace metals. Organic matters can therefore, be considered as an important medium through which heavy metals are incorporated into the soil (Afshin and Farid, 2007). Soil found in all type of samples investigated generally contained very high organic matter content with the highest for cabbage soil (3.25±0.02%). The organic matter content of the soil in this study area was generally higher when compared to that obtained by Inobeme et al. (2014); Gilbert and Osibanjo (2009) in a similar study for the control soil sample was 1.65±0.03%.

Cation exchange capacity (CEC) is a measure of the quantity of cations that can be adsorbed and held by a soil. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect ground-water from cation contamination. CEC is dependent on the organic carbon and clay in soil. In general, the higher the organic carbon and clay content, the higher the CEC. CEC is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching (Landon, 1991). The vegetable growing soil samples were obtained very high CEC in range 32.26±0.53 to 46.70±2.49 cmol (+)/kg soil indicating its very high capacity to retain the cation. According to Metson (1961), the CEC were very high (> 40 cmol (+)/ Kg, high (25 to 40 cmol (+)/ Kg), moderate and (12 to 25 cmol (+) /Kg) ranges Generally, CEC is derived from the clay and organic matter (OM) fractions (Landon, 1991) and can be affected by the different soil management practices such as cultivation, pesticide, fertilization and irrigation (Gao and Chang, 1996).

Table 2. Mean concentration of Zn, Fe and Cu of soil sample in wet digestion method (n = 3, ± SD mg/kg).

Sample Code	Zn	Fe	Cu
Soil for tomato	114.86±10.33[ab]	20065±149.64[a]	146.10±3.08[a]
Soil for cabbage	108.44±8.52[b]	18318±60.39[b]	142.77±3.23[ab]
Soil for lettuce	123.77±7.71[a]	12051±4.65[c]	140.33±2.01[b]
Control soil	69.37±2.00[c]	7140.00±133.32[d]	68.47±1.10[c]
LSD	12.23	212.03	4.37
FAO/WHO	300	5000	100
USEPA, 2002	300	-	140
EU, 2002	200	-	50

FAO/WHO (2001) values are given as means of triplicates ± SD. The means in the same column having different superscript letters are significantly different from each other at 5% confidence interval

The texture class was also determined using the 'textured triangular diagram. Soil suspension at a given depth becomes less as the particle settles. Its value at different time is related empirically to particle size, so that, by selection of times, a density can be a measure of sand, clay and silt. As indicated in Table 1, soil texture was similar for all samples. The particle size distribution of the soil showed that the soil contained higher composition of clay than silt and sand in all soil samples. Trace metals have preferential accumulation in the clay and silt fractions of soil. Generally, the concentrations of heavy metal in soil increase with decrease in the sizes of the soil particles (Inobeme et al., 2014).

Levels of heavy metals in soil samples

The concentrations of Zn, Fe and Cu in the digested samples of soil were determined by FAAS. The concentrations of these metals are presented with their respective SD in Table 2, samples iron were much higher than others in all soil types.

As shown in Table 2, the recorded results of accumulated metals in soil showed that iron and copper showed relatively higher values for lands irrigated with wastewater around the Eastern Industry Zone compared to zinc. This indicates that the wastewater might contain more sources of these metals.

Zinc in soil samples

The natural range of zinc in soils is 10 to 300 mg/kg (Eddy et al., 2006). Zinc is the basic component of a large number of different enzymes and plays structural, regulatory, and catalytic functions. It also has very important role in DNA synthesis, normal growth, brain development, bone formation, and wound healing. However, at high level, Zinc is neurotoxin (Adelekan and Abegunde, 2011). As shown in Table 2, the soil concentration of zinc in this study was within these natural ranges with values ranging between 108.44±8.52 mg/kg to 123.77±7.71 mg/kg. In the similar, Milkessa (2013) reported the concentration of zinc in soil samples range between 60.09-414.12 mg/kg. The soil of lettuce had the highest contents (123.77±7.71 mg/kg) of Zn, while the soil of cabbage had the smaller concentration (108.44 mg/kg) of Zn. The WHO/FAO permissible limit of zinc in soil is 300 mg/kg. So, the concentration of zinc obtained is found to be below the permissible limit set by WHO/FAO (2001).

Iron in soil samples

Iron is the most abundant and most essential constituent for all plants and animals. On the one hand, at high concentration, it causes tissues damage and some other diseases in humans. It is also responsible for anemia and neurodegenerative conditions in human being (Fuortes and Schenck, 2000). As shown in Table 2, the results indicate that soil samples contained Fe in the concentration range of 12051±4.65 and 20065±149.64 mg/kg. This is lower than the value of iron the content reported by McGrath et al. (2001) as 80000 mg/Kg for certain contaminated soil. However, other studies indicated lower values of iron as compared to what was obtained in this study. The WHO/FAO (2001) permissible limit of iron in soil is 5000 mg/kg. Therefore, the concentration of iron found in the three soil samples from lands irrigated with wastewater around the Eastern Industry Zone might be harmful for human health. Comparison of iron level in the soil samples with that of the control soil sample (7140.00±133.32 mg/kg) indicates that the higher levels obtained from all samples could possibly be attributed to the high levels of iron in the wastewater discharged from the industry zone.

Copper in soil samples

Copper is an essential trace element, it is necessary for

Table 1. Mean concentration of Zn Fe and Cu of vegetable samples in wet digestion method (means ± SD mg/kg), n=3.

Vegetable	Zn	Fe	Cu
Tomato	45.63±4.37^{b}	358.17±3.33^{c}	10.20±0.40^{c}
Cabbage	51.53±0.60^{b}	571.33±13.50^{b}	11.87±0.31^{b}
Lettuce	62.46±1.43^{a}	547.17±8.00^{a}	15.07±0.31^{a}
LSD	6.73	12.03	0.92
WHO (1999)	1.5	150	2.0
CMH (2005)	-	-	-
FAO (1985)	2.00	-	0.20

many enzymes. It is needed for the normal growth and development. High concentration of Cu causes hair and skin discolorations, dermatitis, respiratory tract diseases, and some other fatal diseases in human beings (Khan et al., 2008). Copper content was determined in three vegetable originated soil samples. All the tested samples contained the significant amount of Cu. As shown in Table 2, above, highest level (146.10 ±3.08 mg/kg) of Cu was found in tomato soil and the soil of lettuce had the smallest level (140.33±2.01 mg/Kg) of Cu. WHO/FAO (2001) permissible limit of lead in soil is 100 mg/kg. In addition, the concentration of copper was above the concentration permissible limit set by EU (2002); USEPA (2010) as shown in Table 2. Therefore, the concentration of copper found in the three soil samples from farmlands irrigated with wastewater around the Eastern Industry Zone might be harmful for human health. Comparison of copper level in the soil samples with that of the control soil sample 68.47±1.10 mg/Kg) indicates that the higher levels obtained from all samples could possibly be attributed to the high levels of copper in the wastewater discharged from the industry zone.

Heavy metal concentration in vegetable samples

Vegetables like cabbage (*Brassica oleracea* L.), lettuce (*Lactuca sativa* L.) and tomato (*Lycopersicon esculentum Miller*) were analyzed for total metals content. The level of heavy metals in vegetables varies by the ability of plants to selectively accumulate some of these elements. Bioavailability of the elements depends on the nature of their association with the constituents of a soil. Additional sources of these elements for plants are rainfall, atmospheric dusts, plant protection agents and fertilizers that can be absorbed through the leaf blades (Gezahegn, 2013). The concentrations of, Zn, Fe and Cu in sample of vegetables (cabbage, lettuce and tomato) that grown with wastewater discharges of factories around EIZ irrigation farm land were presented in Table 3. From the study, it is revealed that most of the metals were accumulated to greater or lesser extents in the vegetable samples with compared to WHO standard as shown below in Table 3. The vegetables are consumed by the urban population of the city of Dukem and cities present near Dukem like Addis Ababa, Debre Zeit, etc. thus exposing the population to dangerous levels of heavy metals. The results presented demonstrate that there is a risk associated with consumption of vegetables grown on these irrigation land farm, with the vegetable still looking apparently healthy and growing well despite accumulating heavy metals to concentrations, which substantially exceed maximum values considered safe for human consumption.

The results of this study, heavy metal concentrations in vegetable samples were compared with WHO permissible values Source, WHO (1999), CMH: Chinese Ministry of Health. The means in the same column having different superscript letters are significantly different from each other at 5% confidence interval.

Distribution of zinc in vegetables

In this study, results show that the levels of zinc in the vegetables studied had a range of 45.63±4.37-62.46±1.43 mg/kg and WHO (1999) permissible limit is 1.50 mg/kg (Table 3). All the ventures exhibited very high concentration compared to the permissible limit set by WHO (1999); CMH (2005); FAO (1985). The concentration of Zn in vegetables was found to be in the order of Lettuce > Cabbage > Tomato. The high concentration of Zn and other trace heavy metals present in the parts of the vegetables may be due to the absorption ability of the plants to get the trace heavy metals from the polluted soils.

Distribution of iron in vegetables

In this study, Fe concentration from the plants sites varied between 358.17±3.33-571.33±13.50 mg/kg and WHO (1999) permissible limit is 150 mg/kg (Table 3). Akubugwo et al. (2012) reported an even higher iron metal content of up to 147.41 mg/Kg in the Amaranthus hybridus vegetables. The concentration of Fe was almost

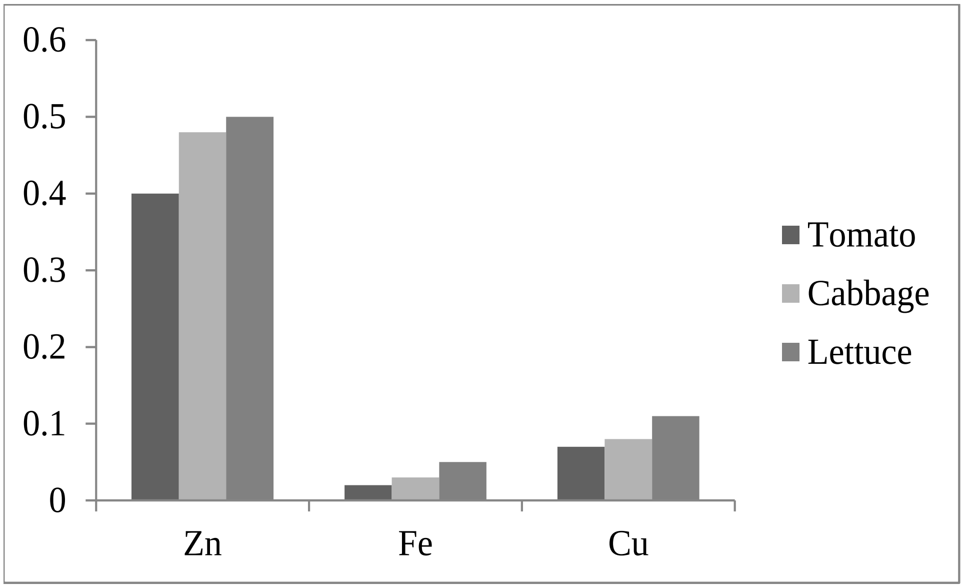

Figure 1. Transfer factors (TF) for heavy metals from soil to vegetable.

all the ventures exhibited very high concentration compared to its permissible limit. By this way, the concentration of iron in vegetables was found to be in the order of Cabbage > Lettuce > Tomato. The high concentration of Fe and the other trace heavy metals present in the parts of the plants may be due to the absorption ability of the plants to get the trace heavy metals from the polluted soils. Iron as an essential element for all plants has many important biological roles in the processes as diverse as photosynthesis, chloroplast development and chlorophyll biosynthesis (Marschner 1995). In humans, increased body stores of iron have been shown to increase the risk of several estrogen-induced cancers (Liehr and Jones, 2001).

Distribution of copper in vegetables

In this study, Cu concentration from the vegetable sites varied between 10.20±0.40-15.07±0.31 mg/kg and WHO (1999) permissible limit is 2.0 mg/kg (Table 3). The concentration of Cu in the study vegetables were ventures exhibited high concentration compared to its permissible limit set by WHO (1999); CMH (2005); FAO (1985). The concentration of copper in vegetables was found to be in the order of Lettuce > Cabbage > Tomato. The high concentration of Cu present in the parts of the plants may be due to the absorption ability of the plants to get the trace heavy metals from the polluted soils. Cu is especially important in seed production, disease resistance, and regulation of water. Copper is indeed essential, but in high doses it can cause anaemia, liver and kidney damage, and stomach and intestinal irritation (Martinez and Motto, 2000).

Heavy metal transfer factor (TF) from soil to vegetables

The transfer coefficient is therefore calculated by dividing the concentration of heavy metals in vegetables by the total heavy metal concentration in the soil (Tasrina et al., 2015).

$$\mathbf{TF} = \frac{CMV}{CMS}$$

Where, CMV = Concentration of metal in edible part of vegetable and CMS = Concentration of metal in soil.

In the present study, the TF of different heavy metal from soil to vegetable are presented in Figure 1. Higher transfer factors reflect relatively poor retention in soils or greater efficiency of vegetables to absorbs metals. Low transfer factor reflects the strong sorption of metals to the soil colloids (Wierzbicka, 1995). The TF or PCF value ranges were: Zn (0.40 to 0.50), Fe (0.02 to 0.05) and Cu (0.07 to 0.11) and the trend of TF for heavy metal in vegetable samples investigated are in order: Zn > Cu > Fe.

The mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of vegetable species, and is altered by innumerable environmental and human factors (Alloway and Ayres, 1997; Tasrina et al., 2015). The highest TF values were found to be 0.50 for Zn. These might be due to higher mobility of these heavy metals with a natural occurrence in soil and the low retention of them in the soil than other toxic cations (Alloway and Ayres, 1997; Tasrina et al., 2015). According to the soil to plant transfer factor (TF) calculated for tested metals and leafy vegetables consumed by the local residents, it can be concluded that Zn is high accumulator among the investigated metals. However, the higher concentrations of this metal are due to the waste water irrigation, solid waste combustion, agrochemicals and vehicular exhausts.

Comparison of metals in the plants and soil samples

Mostly, the concentrations of essential and non-essential metals are higher in soils than vegetables grown on the same soils. This indicates that only a small portion of soil metals is transferred to the vegetables and the root acts as a barrier to the translocation of heavy metals within plant (Davies and White, 1981). The concentrations of metals in the vegetables and their corresponding soil samples are given in Appendix Table 2 for the study sites. The concentrations of detected metals were found to be higher in the soil samples than in the vegetables. This may reveal that the main source of metal contents of vegetables is from their corresponding soil content, which might be affected by industrial effluent, the environmental interferences like pesticides, fertilizers, and other additives that farmers use. Variations in transfer factor among the different vegetables may be attributed to differences in the concentration of metals in the soil and differences in element uptake by different vegetables (Deribachew et al., 2015).

Determination of the concentrations of selected heavy metals in the five chemical fractions of soils

Soil has long been regarded as a repository for society's wastes. Gradually mobilized by biogeochemical processes, soil contaminants can pollute water supplies and consequently enter the food chains. Metals, such as Zn, Fe and Cu are all potential soil pollutants. Soils consist of heterogeneous mixtures of organic and inorganic solid components as well as a variety of soluble substances. Therefore, metal distribution among specific forms varies widely based on the metal's chemical properties and soil characteristics (Milkessa, 2012). Thus, it is important to evaluate the availability and mobility of metals to establish environmental guidelines for potential toxic hazards and to understand chemical behavior and fate of heavy metal contaminants in soils (Milkessa, 2013).

The sequential extraction used in this study is useful to indirectly assess the potential mobility and bioavailability of heavy metals in the soils. The five chemical fractions are operationally defined by an extraction sequence that follows the order of decreasing solubility (Tessier et al., 1979).

Assuming that bioavailability is related to solubility, then metal bioavailability decreases in the order: exchangeable > carbonate > Fe-Mn Oxide > organic > residual. This order is just a generalization and offers only qualitative information about metal bioavailability. Based on the above information, one can further assume that metals in the non-residual fractions are more bioavailable than metals associated with the residual fraction. The non-residual fraction is the sum of all fractions except the residual fraction. The highest amounts of metal were concentrated in the residual fraction Appendix Table 3. This indicates that metals were mostly associated with more stable soil fractions and should be less available to growing plants. The statistical analysis (ANOVA) performed on the results obtained from the sequential extraction procedure showed that metal concentrations in soil were significantly different ($P < 0.05$) from each other.

Zinc in soil fractionation

Percentage of zinc present in soil samples were F5 > F3 > F4 >F2 > F1 (Table 4). The greater level of zinc in the residual fraction probably indicates the greater tendency for zinc to become unavailable once it is in soils.

The mobility and bioavailability of zinc in the samples is found to be in the order of lettuce originated soil > tomato originated soil > cabbage originated soil > control sample (Table 6). Zn was mostly associated with the residual fractions and Fe-Mn Oxide fractions. Zn has the lowest concentration in the exchangeable and carbonate fractions (Table 4). The strong association of Zn with residual and organic fraction was also reported by Fayun et al. (2008) in soil collected around industrial zone. Zn has the lowest concentration in the carbonate, exchangeable and Fe-Mn oxide fractions were reported by Adekola et al. (2012).

Iron in soil fractionation

Percentage of iron present in soil samples were F5 > F3> F4 > F2 > F1 (Table 4). The greater level of iron being in the residual fraction probably indicates the greater tendency for iron to become unavailable once it is in soils. A metal in F1 and F2 (soluble and exchangeable and carbonate bound) fraction is the most mobile and is readily available for biological uptake by the plant. The mobility and bioavailability of iron in the samples is found to be in the order of tomato originated soil > lettuce originated soil > cabbage originated soil > control sample. Adekola et al. (2012) reported Fe was found to be most concentrated in the residual fraction as well as in the organic and Fe-Mn oxide bound fractions to a lesser degree. However, Navas and Lindhorfer (2003) also reported Fe to be most concentrated in the residual fraction.

Copper in soil fractionation

Percentage of copper present in soil samples were F5 >

Table 4. Chemical fractionation of Fe, Zn and Cu (mg /kg) in soil samples from irrigated lands around the EIZ (n = 3, ± SD mg/kg).

Metal	Sample code	F1	F2	F3	F4	F5	F1+F2+F3+F4+F5
Zn	Soil for tomato	0.36±0.01[b]	1.64±0.03[a]	5.08±0.21[c]	4.44±0.12[c]	89.56±0.63[c]	101.08±1.00
	Soil for cabbage	0.45±0.03[b]	0.75±0.01[c]	9.02±0.10[a]	6.41±0.01[a]	115.56±0.41[a]	132.19±0.56
	Soil for lettuce	2.04±0.06[a]	1.32±0.12[b]	6.07±0.04[b]	4.77±0.30[b]	96.18±0.16[b]	110.38±0.71
	Control soil	0.09±0.00[d]	0.63±0.01[c]	0.09±0.00[d]	1.64±0.03[d]	65.55±0.21[d]	68.00±0.25
	LSD	0.08	0.13	0.18	0.31	0.75	
Fe	Soil for tomato	19.96±0.14[c]	63.63±0.45[a]	1796.40±1.74[c]	954.50±10.05[c]	16040.74±9.91[a]	18875.23±22.29
	Soil for cabbage	18.56±0.21[b]	15.96±0.12[b]	2487.87±10.52[a]	1657.20±16.38[a]	11820.73±113.89[b]	16000.32±141.12
	Soil for lettuce	20.41±0.11[a]	20.33±0.15[c]	2107.87±5.03[b]	1170.75±21.28[b]	11830.67±115.54[b]	15150.03±142.11
	Control soil	10.71±0.53[d]	8.08±0.02[d]	466.53±22.76[d]	163.47±5.14[d]	6153.27±3.95[c]	6802.10±32.40
	LSD	0.46	0.39	29.35	28.61	172.96	
Cu	Soil for tomato	0.78±0.02[a]	1.83±0.21[a]	8.90±0.20[c]	21.40±0.10[b]	99.7±0.70[b]	132.61±1.23
	Soil for cabbage	0.54±0.01[b]	0.97±0.12[b]	14.50±0.10[a]	31.10±0.20[a]	77.10±2.00[c]	124.21±2.43
	Soil for lettuce	0.46±0.01[c]	0.29±0.01[c]	11.33±0.15[b]	17.20±0.20[c]	123.43±1.60[a]	152.71±1.97
	Control soil	0.11±0.00[d]	0.10±0.00[c]	0.21±0.00[d]	5.19±0.02[d]	61.19±0.74[d]	66.80±0.76
	LSD	0.03	0.27	0.20	0.27	2.59	

Table 5. Comparison between fractional extraction and wet digestion results in mg/kg (mean ± SD) where n = 3.

Element		TS	CS	LS	C	WHO
Zn	WD	114.86±10.33	108.44±8.52	123.77±7.71	69.37±2.00	300
	FE	101.08±1.00	132.19±0.56	110.38±0.71	68.00±0.25	
Fe	WD	20065±149.64	18318±60.39	12051±4.65	7140.00±133.32	5000
	FE	18875.23±22.29	16000.32±141.12	15150.03±142.11	6802.10±32.40	
Cu	WD	146.10±3.08	142.77±3.23	140.33±2.01	68.47±1.10	100
	FE	132.61±1.23	124.21±2.43	152.71±1.97	66.80±0.76	

Where, WD= Metal from wet digestion, FE= Metal from fractional extraction.

F4 > F3 > F2 > F1 (Table 4). The greater level of copper in the residual fraction probably indicates the greater tendency for copper to become unavailable once it is in soils. The mobility and bioavailability of copper in the samples is found to be in the order of tomato originated soil > cabbage originated soil >lettuce originated soil > control sample. Many researchers have reported varying concentrations of Cu in different fractions. Adekola et al. (2012) reported high percentage concentration of Cu in organic matter, Fe-Mn oxide and residual fraction. The dominance of Cu in the organic phase has also been reported by others (Chukwujindu, 2007).

Comparison between result of fractional extraction a nd wet - digestion procedures

As depicted in Table 5, for all of the samples, the concentration of Zn, Fe and Cu determined in wet digestion method are found to be greater than the total concentration obtained from fractional analysis, except Fe for the cabbage soil (CS) and lettuce soil (LS) and Cu for lettuce soil. In a similar study, Yoseph (2015) reported that concentration of lead and cadmium in wet digestion method are greater than total concentration obtained from fractional analysis.

Element recoveries

Validation of the analytical results was tested by recovery experiments because there was no standard reference material (SRM), which is more preferential or needed to control the accuracy of the method studied, in our laboratory. An important consideration in the reliability of a sequential extraction data is the percentage recovery relative to a single digestion using a mixture of strong mineral acids or generally, a mixture of strong acids at the digestion of the residual phase of the sequential extraction protocol employed (Boch et al., 2002).

Table 6. The bioavailability and mobility Factor of Metals in soil sample fractionation (n = 3).

Elements	Sample code	F1	F2	Sum of F1 and F2	Sum of Fraction	Bioavailability Factor	Mobility Factor
Zn	ST	0.36	1.640	2.000	101.080	0.020	1.979
	SC	0.45	0.750	1.200	132.190	0.009	0.908
	SL	2.04	1.320	3.360	110.380	0.030	3.044
	C	0.09	0.630	0.720	22.870	0.011	1.059
Fe	ST	19.96	63.630	83.590	18875.230	0.004	0.443
	SC	18.56	15.960	34.520	16000.320	0.002	0.216
	SL	20.41	20.330	40.740	15150.030	0.003	0.269
	C	10.71	8.080	18.790	2802.060	0.003	0.276
Cu	ST	0.78	1.830	2.610	132.610	0.020	1.968
	SC	0.54	0.970	1.510	124.210	0.012	1.216
	SL	0.46	0.290	0.750	152.710	0.005	0.491
	C	0.11	0.100	0.210	26.800	0.003	0.314

Recovery is defined as follows:

$$\textbf{Recovery} = \left(\frac{\sum \text{ n Sequential etraction procedure}}{\text{Single digesion with strong acids}}\right) x\ 100\ \%$$

Where, n is the concentration of a given element and the single digestion with strong acids used for reference was a mixture of strong acids used in the residual fraction digestion (Boch et al., 2002). The analytical results acquired are depicted in Appendix Table 4.

Comparison of Heavy Metals Concentration from the Current Study with those Reported on the Literature

The detected metals (Zn Fe, and Cu) levels in vegetables samples (tomato, cabbage and lettuce) from fields irrigated with the Eastern Industry Zone were compared with different literature reported in Appendix Table 5.

Bioavailability and mobility factors of heavy metals

The sequential fractionation extraction procedures results provided information on the potential mobility and bioavailability of the elements investigated in this research. The distribution of heavy metals in the sample allows us to predict their mobility and bioavailability. The bioavailability factor was expressed as the ratio of the available concentration of a metal in soil to its total concentration. It shows the potentials of a particular metal from the soil matrix to enter the soil solution from which it can be absorbed by plants. MF was expressed as percentage of the Bioavailability factor (Kabata and singh, 2001).

$$\textbf{BF} = \frac{F1+F2}{F1+F2+\cdots+F5}$$

$$\textbf{MF} = \frac{F1+F2}{F1+F2+\cdots+F5}\ \ x\ 100$$

Table 6, shows the mobility, and bioavailability factors for all the sequential extractions steps. The high MF and BF values of soil Zn may be interpreted as symptoms of relatively high liability and biological availability of the metals in soil. Similar characteristics distribution patterns were observed for Cu (Table 6). The average mobility of Zn Fe and Cu levels in all the five fraction fractions were in the order: Zn> Cu > Fe.

Conclusion

As stated earlier, the major purpose of this study was to find out the level of metals in soil, from three-farmer farm and three subsamples from each farm for each edible part of the vegetables (tomato, cabbage and lettuce) were determined. The soil and vegetable samples were subjected to wet-digestion, sequential extraction and the concentration of detected metals were determined via FAAS. The concentration of these metals in the soil display the following decreasing trend: Fe > Cu > Zn. These concentrations of Fe and Cu except Zn in soil samples were above the recommended level set by FAO/WHO (2001), EU (2002) and USEPA (2002) for irrigation soil. The concentration of heavy metals in the vegetable samples display the following decreasing trend: Fe > Zn > Cu. The study revealed that the concentrations of all metals in the vegetables were found to be above the safe limits set by different international organizations for consumption, posing a serious health hazard to humans. Therefore, regular monitoring of soils and vegetables are essential to prevent excessive build-up of the toxic heavy metals in food. Thus, the health risk and the extent of metal contamination can be reduced. The soil–plant transfer factor (TF) decreased in the following order- TFZn > TFCu > TFFe. A sequential fractionation extraction procedure was used to fractionate Fe, Cu and Zn present in soils of tomato, cabbage and lettuce and reference (control) soils. The mobility and bioavailability of these metals were studied and a very high amount of these metals were concentrated at the residual, organic and Fe-Mn Oxide fractions. However, a very small concentration of these heavy metals was also found at the exchangeable and carbonate fractions. Mobility factor of, Fe, Cu and Zn in soil samples ranged from 0.216-0.443, 0.491-1.968 and 0.908-3.044, respectively.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abebe A (2012). Assessment of urban expansion in the case of Dukem town using remote sensing and GIS techniques. MSc thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Abolino O, Aceto M, Mentasticti E, Sarzanini C, Petrella F (2002). Assessments of metal availability in contaminated soil, by sequential extraction. Water Soil and Air Pollution 49:345-557.

Adekola FA, Inyinbor AA, Raheem AMO (2012). Heavy metals distributions and speciation in soil around a Mega Cement Factory in North-Central Nigeria. Ethiopian Journal of Environmental Studies and Management 5(1):11-12.

Adelekan BA, Abegunde KD (2011). Heavy metals contaminations of soil and groundwater at automobile mechanic village in Ibadan, Nigeria. International Journal of Physical Sciences 6(5):1045-1058.

Afshin K, Farid D (2007). Statistical analysis of accumulation and sources of heavy metals Occurrence in agricultural soil of Khoshk River banks, Shiraz Iran. America-Eurasian Journal of Agriculture and Environment 5:565-573.

Akubugwo EI, Obasi A, Chinyere GC, Eze E, Nwokeoji O, Ugbogu EA (2012). Phytoaccumulation effects of Amaranthus hybridus L grown on buwaya refuse dumpsites in Chikun, Nigeria on heavy metals. Journal of Biodiversity and Environmental Sciences 2:10-17.

Al Jassir MS, Shaker A, Khaliq MA (2005). Deposition of heavy metals on green leafy vegetables sold on roadsides of Riyadh City, Saudi Arabia. Bulletin of Environmental Contamination and Toxicology 75(50):1020-1027.

American Public Health Association (APHA) (1999). American water works association, Water environment federation. Standard methods of the examination of water and wastewater, 20thed. New York: American Public Health Association, APHA, AWWA, and WPCF.

Christian G, Sylvaine T, Michel A (2002). Fractionation studies of trace elements in contaminated soils and sediments: A Review of sequential extraction procedures. Trends in Analytical Chemistry 21:451-467.

Chukwujindu MAI (2007). Metal fractionation in soil profiles at automobile mechanic waste dumps. Waste Management Research 25:585-593.

David AA, Terry P (2008). Limit of blank, limit of detection and limit of quantitation. Clinical Biochemist Review 29:49-52.

Dingkwoet DJ, So Danladi SM, Gabriel MS (2013). Comparative study of some heavy and trace metals in selected vegetables from four local government areas of Plateau State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology 6(3):2319-2399.

Eddy NO, Odoemelem SA, Mbaba A (2006). Elemental composition of soil in some dumpsites. Journal of Environmental Agricultural Food Chemistry 5:1349-1365.

European Union (EU) (2002). Heavy metals in wastes, European Commission on Environment (http: //ec.europa.eu/environment/waste/studies/pdf/heavy metals report.pdf).

Food and agriculture organization (FAO) (1985). Water Quality for Agriculture. Irrigation and drainage paper No. 29, Rev. 1. Food and agriculture organization of the United Nations, Rome.

FAO/WHO (2001). Food additives and contaminants. Joint codex alimentarius commission, FAO/WHO Food standards Program 34:745-50.

Fuortes L, Schenck D (2000). Marked elevation of urinary zinc levels and pleural-friction rub in metal fume fever. Veterinary and Human Toxicology 42(3):164-165.

Gao G, Chang C (1996). Changes in cation exchange capacity and particle size distribution of soils associated with long term annual applications of cattle feed lot manure. Soil Science 161:115-120.

Garcia WJ, Blessin CW, Inglett GE, Kwolek WF (1981). Metal Accumulation and crop yield for a variety of edible crops grown in diverse soil media amended with sewage sludge. Journal of Environmental Science and Technology 15(7):793-804.

Gebregeorgis AK (2016). Ethio-China economic relations: nature of China's foreign direct investment in Ethiopia. MSc thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Gebrekidan A, Weldegebriel Y, Hadera A, Van der Bruggen B (2013). Toxicological assessment of heavy metals accumulated in vegetables and fruits grown in Ginfel river near Sheba Tannery, Tigray, Northern Ethiopia. Ecotoxicology and Environmental Safety 95:171-178.

Gezahegn L (2013). Chemical fractionation of selected metals in the soil of waste disposal sites of Dire Dawa Textile Factory and their contents in the sweet potato Leaves. MSc. Graduate research project, Haramaya University, Haramaya, Ethiopia.

Gilbert U, Osibanjo O (2009). Assessment of soil pollution by slag from an automobile battery manufacturing plant in Nigeria. African Journal of Environmental Science and Technology 3(9):239-250.

Girmaye BR (2012). Heavy metal and microbial contaminants of some vegetables irrigated with wastewater in selected farms around Adama town, Ethiopia. MSc. Graduate project, Haramaya University, Haramaya, Ethiopia.

Guevara-Riba A, Sahuquillo A, Rubio R, Rauret G (2004). Assessment of metal mobility in dredged harbour sediments from Barcelona, Spain. Science of the Total Environment 321:241-255.

Harrison RM, Laxen DPH, Wilson SJ (1981). Environmental science and technology. Journal of Environment 38:25-32.

Hizkeal T (2012). Determination of copper, zinc, cadmium, and lead concentrations in traffic density roadside soils in some selected town of east Ethiopia. MSc. Graduate project, Haramaya University, Haramaya, Ethiopia.

Inobeme A, Ajai AI, Iyaka YA, Ndamitso M, Uwem B (2014). Determination of physicochemical and heavy metal content of soil around paint industries in Kaduna. International Journal of Scientific and Technology Research 3(8):221-225.

Iwegbue CMA (2007). Determination of trace metal concentrations in soil profiles of municipal waste dumps in Nigeria. Waste Management Resource 25:585.

Kabala C, Singh BR (2001). Fractionation and mobility of copper, lead, and zinc in soil profiles in the vicinity of a copper smelter. Journal of Environmental Quality 30(2):485-492.

Katz SA (1984). Determination of heavy metals in sewage sludge. Environmental Chemistry 3:78-953.

Khan MJ, Jan MT, Farhatullah, Khan NU, Arif M, Perveen S, Alam S, Jan AU (2011). The Effect of using Wastewater for Tomato. Pakistan Journal of Botany 2:1033-1044.

Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG (2008). Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environmental Pollution Series 152(3):686-692.

Khan SA, Liu X, Shah BR, Fan W, Li W, Khan SB, Ahmad Z (2015).

Metals uptake by wastewater irrigated vegetables and their daily dietary intake in Peshawar, Pakistan. Ecological Chemical Engineering Science 22(1):125-139.

Kotoky P, Bora BJ, Baruah NK, Baruah J, Baruah P, Borah GC (2003). Chemical fractionation of heavy metals in soil around oil installation, Assam. Chemical Speciation and Bioavailability 15(4):115-125.

Landon JR. (1991). Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. John Wiley and Sons Inc., New York.

Liehr JG, Jones JS (2001). Role of iron in estrogen-induced cancer. Current Medicinal Chemistry 8:839-849.

Liu WX, Li HH, Li SR, Wang YW (2006). Heavy metal accumulation of edible vegetable cultivated by people’s of Republic of China. Bullet of Environmental Contamination and Toxicology 76:163-170.

Loon JC (1985). Selected methods of trace metal analysis biological and environmental samples. New York 5:3685-3689.

Ma LQ, Rao GN (1997). Chemical fractionation of cadmium, copper, nickel, and zinc in contaminated soils. Journal of Environmental Quality 26(1):259-264.

Marschner H (1995). Mineral nutrition of higher plants, 2nd edition. Academic Press, Toronto.

Martinez CE, Motto HL (2000). Solubility of lead, zinc and copper added to mineral soils, Environmental Pollution 107(1):153-158.

McGrath SP, Zhao FJ, Lombi E (2001). Plant and rhizosphere process involved in phytoremediation of metal-contaminated soils. Plant Soil 232(2):214.

Milkessa MA (2013). Chemical fractionation of selected heavy metals in the soils in The Vicinity Of Waste Water Disposal Sites in Dire Dawa Textile Factory. MSc. project work, Haramaya University, Haramaya.

Mohod CV (2015). A review on the concentration of the heavy metals in vegetable samples like spinach and tomato grown near the area of Amba Nalla of Amravati City. International Journal of Innovative Research in Science, Engineering and Technology 4(5):2788-2792.

Mulugeta E (2014). Determination of levels of some essential and nonessential metals in municipal water supply of west Shoa zone, Ambo town, Ethiopia. MSc. Graduate thesis, Haramaya University, Haramaya, Ethiopia.

Murray B, McBride MB (1994). Environmental chemistry of soils, 1st edition. Oxford.

Navas A, Lindhorfer H (2003). Geochemical speciation of heavy metals in semi-arid soils of the central Ebro valley (Spain). Journal of Environment International 29(1):61-68.

Perveen S, Samad A, Nazif W, Shah S (2012). Impact of sewage water on vegetables quality with respect to heavy metals in Peshawar Pakistan. Pakistan Journal of Botany 44(6):1923-1931.

Poggio M, Hepperle E, Marsan FA (2008). Metals pollutions and human bioaccessibility of topsoils in Grugliasco, Italy. Environmental Pollution 157:680-689.

Sharma RK, Agrawal M, Marshall F (2007). Heavy metal contamination of soil and vegetables in sub urban areas of Varanasi, India. Elsevier Inc. 6:357-362.

Street RA (2008). Heavy metals in South African medicinal plants research center for plant growth and development, PhD Dissertation, University of KwaZulu-Natal, Pietermaritzburg, South African.

Uduma AU (2013). Sequential extraction procedure for partitioning of lead, copper, cadmium and chromium in contaminated arable soils of Nigeria. American Journal of Environment, Energy and Power Research 1(9):186 208.

United State Environmental Protection Agency (USEPA) (2010). Risk-based concentration table. United State Environmental Protection Agency, Washington, DC, USA.

World Health Organization (WHO) (1999). Permissible limits of heavy metals in soil and plants (Geneva: World Health Organization), Switzerland.

Yoseph Y (2015). Chemical fractionation of heavy metals in soil around Tinshu Akaki River Addis Ababa, Ethiopia. MSc. Graduate research project, Haramaya University, Haramaya, Ethiopia.

Appendix Table 1. Values of the recovery analysis for method validation (X ± SD, n = 3) for soil, tomato, cabbage and lettuce samples.

Heavy Metal	Concentration before spiking(M± SDs) (ppm)	Concentration after spiking (M± SDs)	Amount added (ppm)	%Recovery
Values of the recovery analysis (X ± SD, n = 3) for soil sample				
Zn	67.60±0.70	69.47±0.49	2	93.33
Fe	6965.00±31.74	6967.42±30.13	2	120.83
Cu	66.87±2.20	69.03±2.22	2	108.33
Values of the recovery analysis (% R ± SD, n = 3) for tomato sample				
Zn	45.63±4.37	45.81±4.38	0.2	90
Fe	361.50±13.70	361.67±13.71	0.2	86.67
Cu	10.14±0.33	10.35±0.35	0.2	105
Values of the recovery analysis (% R ± SD, n = 3) for cabbage sample				
Zn	51.53±0.60	51.73±0.62	0.2	100
Fe	593.33±5.86	593.53±5.87	0.2	100.17
Cu	11.72±0.24	11.90±0.24	0.2	93.67
Values of the recovery analysis (% R ± SD, n = 3) for lettuce sample				
Zn	62.46±1.43	62.64±1.43	0.2	90
Fe	557.33±8.62	557.54±8.60	0.2	105
Cu	15.11±0.18	15.29±0.20	0.2	90

Appendix Table 2. Heavy metals concentration comparison in the vegetables and their corresponding soil samples of the vegetables origin in mg/Kg.

Code	Cr_v	Cr_s	Cd_v	Cd_s	Zn_v	Zn_s	Fe_v	Fe_s	Pb_v	Pb_s	Cu_v	Cu_s
T	2.97	50.50	2.20	45.33	45.63	114.86	358.17	20065	4.60	63.00	10.20	146.10
C	2.90	66.30	3.20	42.33	51.53	108.44	571.33	18318	5.47	64.87	11.87	142.77
L	3.77	62.23	3.68	45.00	62.46	123.77	547.17	12051	5.50	63.33	15.07	140.33

Where, V = Vegetable, S = Soil, T = Tomato, C= Cabbage and L = Lettuce.

Appendix Table 3. Chemical fractionation of heavy metals in (mg /Kg) in soil sample collected from lands irrigated with wastewater around the EIZ (n = 3).

Sample Code		Zn	Fe	Cu
ST	Residual	89.56	16040.74	99.70
	Non-residual	11.52	2834.49	32.91
	Sum	101.08	18875.23	132.61
	% Non-residual	11.40	15.02	24.82
	% Residual	88.60	84.98	75.18
SC	Residual	20.42	2153.27	21.19
	Non-residual	2.45	648.79	5.61
	Sum	22.87	2802.06	26.80
	% Non-residual	10.71	23.15	20.93
	% Residual	89.29	76.85	79.07
SL	Residual	96.18	11830.67	123.43
	Non-residual	14.20	3319.36	29.28
	Sum	110.38	15150.03	152.71
	% Non-residual	12.86	21.91	19.17
	% Residual	87.14	78.09	80.83

Appendix Table 3. Contd.

	Residual	20.42	2153.27	21.19
	Non-residual	2.45	648.79	5.61
C	Sum	22.87	2802.06	26.80
	% Non-residual	10.71	23.15	20.93
	% Residual	89.29	76.85	79.07

Appendix Table 4. The percentage recovery of sequential extraction of soil samples relative to a single digestion method.

Element	sample code	Sum of fraction	Single acid digestion	% Recovery
Zn	ST	101.08	114.86	88.00
	SC	132.19	108.44	121.90
	SL	110.38	123.77	89.18
	C	68.00	69.37	98.03
Fe	ST	18875.23	20065	94.07
	SC	16000.32	18318	87.35
	SL	15150.03	12051	125.72
	C	6802.10	7140.00	90.46
Cu	ST	132.61	146.1	90.77
	SC	124.21	142.77	87.00
	SL	152.71	140.33	108.82
	C	66.80	68.47	97.56

Appendix Table 5. Comparison of metal concentration in the vegetables with other reports in similar studies.

Vegetable	Source of Heavy metals	Metals			Reference
		Zn	Fe	Cu	
Tomato	Industrial effluents	45.63	358.17	10.20	resent study
	Agricultural activities	-	-	201.75	Liu et al., 2006
	Wastewater	3.80	-	0.05	Mohod (2015)
	Wastewater	4.97	118.40	3.68	Khan et al. (2011)
	Swage water	-	-		Perveen et al. (2012)
	Industrial effluents	51.53	571.33	11.87	Present study
Cabbage	Swage water	-	-	-	Perveen et al. (2012)
	Wastewater	-	-		Girmaye (2012)
	Wastewater	1.38	12.84		Khan et al. (2015)
	Transport & Market	-	310.50		Dingkwoet et al. *(*2013)
	Tannery effluent	-	-		Gebrekidan et al. (2013)
	Industrial effluents	62.46	547.17	15.07	Present study
Lettuce	Wastewater	-	-	-	Girmaye (2012)
	Swage water	-	-	-	Perveen et al. (2012)
	Wastewater	0.84	13.20	-	Khan et al. (2015)
	Transport and Market	-	584.90	-	Dingkwoet et al. (2013)
	Tannery effluent	-	-	-	Gebrekidan et al. (2013)

The detected metals (Zn Fe, and Cu) levels in vegetables samples (tomato, cabbage and lettuce) from'fields irrigated with the Eastern Industry Zone were compared with different literature reported.

Vol. 14(2), pp. 92-101, 10 January, 2019
DOI: 10.5897/AJAR2018.13324
Article Number: 1E8499759809
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Levels of some toxic heavy metals (Cr, Cd and Pb) in selected vegetables and soil around eastern industry zone, central Ethiopia

Dagne Bekele Bahiru[1*], Endale Teju[2], Tesfahun Kebede[2] and Negash Demissie[1]

[1]Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia.
[2]Chemistry Department, Faculty of Natural and Computational Science, Haramaya University, Haramaya, Ethiopia.

Received 13 June, 2018; Accepted 13 July, 2018

The purpose of this study was to determine the concentration of heavy metals (Cr, Cd and Pb) in vegetables and the soil contaminating levels as a result of irrigation using Flame Atomic Absorption Spectrophotometer (FAAS). The wet digestion and sequential fractionation extraction procedures were employed to solubilize the metals from the collected samples. The results obtained from this study showed overall concentration of heavy metals Cr, Cd and Pb respectively, in the range of (2.90-3.77), (2.20-3.68) and (4.60-5.50) (mg/Kg) in the edible parts of sampled vegetables. Whereas, concentrations (mg/Kg) of the metals in the soil samples were found to be in the ranges of 22.37-66.30, 27.93-45.33 and 18.82-64.87 for Cr, Cd and Pb, respectively. The modified Tessier sequential extraction procedure was used to fractionate the above three metals from the soil samples into five fractions. In this study the heavy metals were predominantly concentrated in residual fraction (F5); since lead was mainly associated with the organic matter bounded fraction (F4) (34.33-43.45%), it was found to be more bioavailable and mobile than the other investigated heavy metals. The concentrations of heavy metals (Cr, Cd and Pb) in the soil and vegetable samples were above the recommended limit of both WHO and FAO. But Pb for the soil samples was smaller than WHO and FAO recommended limit. Based on facts obtained from this study we suggests concerned official body (ies) to take the necessary precaution measures for cleaning the polluted area.

Key words: Heavy metals, sequential fractionation, eastern industry zone.

INTRODUCTION

Heavy metals are extremely persistent in the environment. They are non-biodegradable and non-thermo degradable and therefore readily accumulate to toxic levels. Vegetables are rich sources of vitamins, minerals, and fibers and also have beneficial antioxidative effects. However, the intake of heavy metal contaminated fruits

*Corresponding author. E-mail: ddagnebbk19@gmail.com.

and vegetables may pose a risk to human health; hence the heavy metal contamination of food is one of the most important aspects of food quality assurance (Radwan and Salama, 2006; Khan et al., 2008).

Unlike many other pollutants associated with the environments, metals are nonbiodegradable and can undergo biomagnifications in living tissues. Uptake and accumulation of heavy metals by plants is either via the roots and foliar surfaces (Sawidis et al., 2001). Some factors which affect metal uptake include soil pH, metal solubility, soil conductivity nature, stages of plant growth and plant species type (Ismail et al., 2005; Sharma et al., 2006).

Soil contamination with anthropogenic heavy metals, mainly from industrial activities, agricultural practices and atmospheric deposition, has received increasing attention in recent years. Heavy metal contamination in agricultural soils may lead to the disorder of soil functionality and retardation of plant growth, and influence human health through a contaminated food chain (Khan et al., 2008).

Dry-ashing and wet-digestion are the common methods of soil, plant and water sample digestion for elemental analysis. Dry-ashing methods are comparatively simpler and safe than wet-digestion methods but may introduce error due to volatilization, especially for arsenic (As), selenium (Se), cadmium (Cd) and mercury (Hg). In addition, dry ashing may be problematic with pyrolytic organic materials as they may resist thermal decomposition at temperatures of about 550°C and analyte reactions with the crucible material and sample contamination from combustion residues (Hoeing et al., 1998).

Wet-digestion methods are preferable because of the speed with which sample is processed. These techniques utilize strong inorganic acids ($HClO_4$, NHO_3, H_2SO_4 and HCl) and in some cases hydrogen peroxide (H_2O_2) to decompose the samples. Perchloric acid ($HClO_4$) was commonly used some time ago because of its strongly oxidizing ability but has largely been avoided because of handling issues, its capacity to react violently with organic compounds, and the possibility of explosion when dry. Additionally, the use of $HClO_4$ requires special ventilation equipment. Nitric acid (HNO_3) in combination with hydrogen peroxide (H_2O_2) is an effective substitute for $HClO_4$, with the benefit of increased safety (Enders and Lehmann, 2012).

Sequential selective extraction techniques are commonly used to fractionate the solid-phase forms of metals in soils. Many sequential extraction procedures have been developed, particularly for sediments or agricultural soils, and despite numerous criticisms, they remain very useful (Christian et al., 2002). The mobility and bioavailability of heavy metal depend absolutely on their speciation or chemical forms. These forms are determined by sequential extraction technique, this method gives vivid information about metal affinity to the soil components together with the strength to which they are bound to the soil matrix. Also heavy metal fractions can give detail about soil origin, biological and physicochemical availability, and their mode of occurrence, mobility and transportation of trace metals (Kotoky et al., 2003). Extraction procedures of soil are used both for the single-stage leaching and the sequential extraction. Among various methods of the sequential extraction of soil, Tessier's method is most often used both in case of soil samples, as well as sediments (Yoseph, 2015)

Some methods used in heavy metal analysis are AAS, EDXRF and ICP (Abolino et al., 2002). For analysis of various fractions obtained by sequential extraction, AAS, ICP-MS and ICP- AES and ICP-OES are used (Iwegbue, 2007). Also Milkessa (2013) used FAAS. ICP-MS and AAS are most preferred because they are not prone to polyatomic interferences and are less affected by matrix suppression (Harrison et al., 1981).The method used in the present study for analysis was AAS due to its availability. AAS is simple, sensitive and selective and has the advantage of being a fast method of analysis (Katz, 1984).

The aim of this study was to detect and determine the concentrations of toxic metals viz. Cr, Cd and Pb in samples of soils and selected vegetables from irrigation farms around Eastern Industry Zone, in which pesticide, fertilizer, and municipal and industrial sewage effluents are known to be discharged into surrounding irrigation farms. Cabbage, lettuce, and tomato were selected and most commonly-consumed edible vegetables which are cultivated by using effluent wastewater, due to lack of clean irrigation water. The study was necessary as a large number of people consume the produce and no research has been conducted to elucidate the extent of the problem in the area.

MATERIALS AND METHODS

Description of the study area

This study was conducted around Eastern Industrial Zone in Dukem, Ethiopia. Dukem Town was founded in 1914 and is one of the 18 special zones of the Oromia Regional State of Akaki Woreda which is located at 37 Km distance from Addis Ababa City. It is a town in central Ethiopia, to the South of Addis Ababa and 10 km to North West of Bishoftu Town. Its astronomical location is 08°45'25"-08°50'30" North Latitude and 38°51'55" 08°56'5" East Longitude (Abebe, 2012)(Figure 1).

The Eastern Industrial Zone (EIZ) of Ethiopia is located at 35 km southeast of Addis Ababa, and 680 Km from the port of Djibouti with 200 ha of land in Dukem. For Ethiopia, EIZ is the first and largest-scale industrial park. The Ministry of Industry of Ethiopia requires the EIZ to focus on Chinese companies in the area of textile, apparel, building materials (including east steel, cement factory), mechanical manufacturing, and agricultural processing. Currently, 26 Chinese firms are operational and producing different products for export markets having agreement with EIZ in all targeted areas. In addition to the present 26 manufacturing industries, more than 20 other manufacturing industries are about

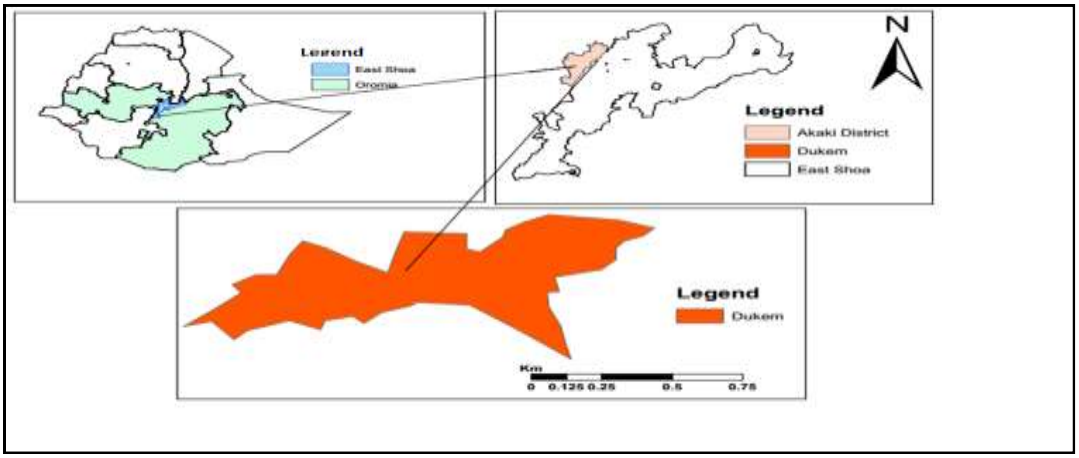

Figure 1. Location of study area.

to join the EIZ (Gebregeorgis, 2016). This implies that more municipal waste, gasses and wastewater from various industry of EIZ is discharged to the surrounding environment.

Chemicals, reagents and instruments

The instruments used for this study was FAAS, Agilent technology with model no. 210 for toxic heavy metal determination of vegetable and soil samples and a Mcroprossecer based PH-EC-TDS Meter; Model 1615 was used for the determination of soil pH and conductivity. The common laboratory apparatus which were used during the study include; different sized beakers, erlenmeyer flasks, funnels, volumetric flasks, block digester, fume hood, centrifuge, hydrometer, shaker, droppers, glass pipettes, spatula, measuring cylinders, plastic knife, vinyl gloves, steel less steel auger, stirrer, polyethylene bags, analytical balance, conical flasks and oven.

All the chemicals used were analytical reagent grade. Deionized water and distilled water were used for all preparation and dilution purposes throughout the study. Nitric acid, HNO_3 (69%), ammonium acetate (NH_4Ac) Sodium acetate (NaAc), potassium chloride (KCl), acetic acid (HAc), magnesium chloride ($MgCl_2$), hydroxide hydrochloride ($NH_2OH.HCl$), sulphuric acid, H_2SO_4 (98%) and hydrogen peroxide, H_2O_2 (30%) and hydrochloric acid (HCl) were used for digestion. Stock standard solutions of 1000 ppm were prepared for the selected heavy metals (Cr, Cd and Pb). All sample containers and glassware used in the present study were washed in detergent and soaked in 30% nitric acid for 2 h to leach out adsorbed metal ion. They were then rinsed in tap water followed by deionized water before drying in dust free area (APHA, 1999).

Sample collection and preparation

The soil, and vegetable samples were collected from vegetable samples were collected in February, 2017. About 1 kg edible part of cabbage (*Brassica oleracea*), lettuce (*Lactuca sativa)* and tomato (*Lycopersicon esculentum* Miller). To this effect, three farmer farmlands were selected and three subsamples were taken for collecting representative edible parts of the vegetables. The collection was done manually. The representative reputable samples were thoroughly mixed to give a composite sample as representative fraction of the vegetables. The bruised or rotten portions were removed and the remaining samples were packed in polyethylene bags for transporting to the DZARC ANRL (Debre Zeit Agricultural Research Center Agricultural Chemistry lab). In the laboratory, the collected plant samples were washed with tap water and then with distilled water to eliminate adsorbed dust and particulate matters. The vegetable samples were cut and chopped into small pieces using plastic knife in order to facilitate drying. Accordingly, the samples were air-dried for six days and further dried in hot air oven at 50-60°C for 24 h, to remove moisture and maintain constant mass. The dried samples were ground into powder using acid washed commercial mortar and pestle and then sieved to 2 mm mesh size. The sieved samples were finally stored in polyethylene bags and kept in desiccators until the time of digestion.

Soil samples (about 1 kg) were collected from 0-20 cm depth from the site where the vegetables were grown (for each vegetable type) with an auger (Poggio et al., 2008) and the control soil sample was collected 2 km away from the study area. Then the samples were placed in clean polyethylene bags and transported to the DZARC ANRL for pretreatment and analysis. The composite soil samples were air-dried in a dry and dust-free place at room temperature (25°C) for 5 days, followed by oven drying to constant weights. The samples were then ground with a mortar and pestle to pass through a 2 mm sieve and homogenized. The dried, sieved, and homogenized soil samples were stored in clean and dry containers till digestion.

Digestion of soil and vegetable samples

The 0.5 g dried and homogenized soil samples were transferred in to 100 mL digestion flask in triplicate. In each of these flasks, 5 mL of deionized water and 30 mL of a mixture HNO_3 (69%) and 37% HCl with volume ratio of 5:1 were added. The sample dissolved in the acid mixture was digested in digestion hood (at 200°C) for 1 h and kept to cool. After adding 2 mL of H_2O_2 to the cold digestion mixture, the final, the mixture was filtered out through Whatman No. 42 filter paper to a 100 mL volumetric flask and finally diluted to the mark with distilled water (Loon, 1985). The varying filtrates obtained above were analyzed for the total content of each heavy metal by FAAS in Holeta Agricultural Research Center Chemistry Lab. The blank reagent was also digested following the same procedure as the soil sample.

A 0.5 g of homogenized powdered vegetables sample was placed in borosilicate digestion flask to which 10 mL of acid mixture containing HNO_3- HCl-H_2O_2 (8:1:1, v/v/v) ratio were added. The mixture was heated at 120°C over 3 h on block digester. After digestion was completed, the clear and colorless solution was filtered out into 100 mL volumetric flask. Each digestion tube were rinsed with distilled water to collect any possible residue, and added to the volumetric flask and finally made up to volume with distilled water. All the dilute samples were stored in 100 mL plastic bottles (high density polyethylene) until analysis. Each vegetable sample was digested and analyzed in triplicate to confirm precision of the result. The blank solution was prepared by taking a mixture of 8 mL HNO_3, 1 mL HCl and 1 mL H_2O_2 and treating similarly as that of the sample (Street, 2008). The heavy metal concentrations were analyzed by FAAS in Holeta Agricultural Research Center Chemistry Lab.

Heavy metal fractionation in soil samples

The modified Tessier's procedure, Ma and Rao (1997) was used to determine operationally defined chemical species of the metals from soil. Five operationally defined fractions of the metals were removed by these sequential extractions. The SEP operationally groups heavy metals into the following five fractions:

(i) Soluble and exchangeable fraction (F1): The soluble and exchangeable metals from each of 2.5 g soil samples were extracted, into wide mouthed polypropylene bottle; 20 mL of 1 M $MgCl_2$ solution adjusted to pH of 7.0 were added. The bottles were shaken for 1 h at room temperature by an end-over end mechanical shaker. The extracts were separated from the solid residue by centrifugation (5000 rpm) for 15 min and filtered through Whatman No. 42 filter paper into 100 mL volumetric flask and kept for metal analysis.
(ii) The fraction bound to carbonates (F2): The carbonate bound metals in the residue left from the previous step were extracted with 20 mL of 1.0 M NaAc (CH_3COONa) solution adjusted to pH of 5.0 with HAc (CH_3COOH) by continuously shaking for 4 h at room temperature. It was then centrifuged for 15 min at 5000 rpm and filtered into 100 mL volumetric flask through Whatman No. 42 filter paper and kept for metal analysis.
(iii) The fraction bound to iron and manganese oxides (F3): Metals bound to iron and manganese oxides were extracted from the residue of the second extraction by shaking with 50 mL of 0.04 M $NH_2OH.HCl$/25 % HAc solution and placed in to a water bath for 5.5 h at 96°C, then centrifuged for 15 min at 5000 rpm and filtered through Whatman No. 42 filter paper into 100 mL volumetric flask and stored for metal analysis.
(iv) The fraction bound to organic matter (F4): Metals bound to organic matter were extracted by pouring 7.5 mL of a 0.02 M HNO_3 solution and 12.5 mL of a 30% H_2O_2 solution adjusted to a pH of 2.0 onto the residue from 3.6.3 and heated for 2 h in water bath at 85°C. After cooling, additional volume of 7.5 mL of 30% H_2O_2 solution adjusted to pH of 2.0 was added while maintaining continuous agitation and at a temperature of 85°C for another 3 h. These solutions were then cooled to room temperature. Then aliquot of 12.5 mL of 3.2 M NH_4Ac/ 20% HNO_3 solution was added and shaken for 30 min, then centrifuged for 15 min at 5000 rpm and filtered through Whatman No. 42 filter paper into 100 mL volumetric flask and stored for metal analysis.
(v) The fraction bound to soil matrix (residual fraction) (F5): The residues from 3.6.4, were quantitatively transferred into a digestion vessel and treated with aqua regia (7 mL of 10 M HCl and 2.3 mL of 15.8 M HNO_3). The temperature of the reaction mixture was slowly raised until reflux conditions and maintained for 2 h, centrifuged, at 5000 rpm for 15 min and then filtered through Whatman No. 42 filter paper into 100 mL volumetric flask. All dilutions were made to 100 mL with 2% (v/v) HNO_3. For each fraction a blank was subjected to the same procedure.

Method detection limit

Method detection limit is defined as the minimum concentration of analyte that can be measured. In other words, it is the lowest analyte concentration that can be distinguished from statistical fluctuations in a blank (Gezahegn, 2013). Three replicate blank samples were digested following the same procedures utilized for digesting the soil and vegetable samples. Each blank were assayed for its metal contents Cr, Cd and Pb by FAAS. The SD of the three replicate blanks was calculated to determine the MDL (David and Terry, 2008). Method detection limit (MDL) was then calculated according to the equation indicated below.

$$MDL = YB + 3SD$$

Where: YB = Blank mean

Method validation

In present study due to the absence of certified reference materials for soil and vegetable samples in our laboratory, the validity of the digestion procedure, precision and accuracy of FAAS were assured by spiking soil and vegetable samples with standard of known concentration. The spiked and non-spiked vegetables and soil samples were digested following the same procedure employed in the digestion of the respective samples and analyzed in similar condition. Then the percentage recoveries of the analytes were calculated by:

$$\text{Recovery} = \left(\frac{\text{CM in the spik samples} - \text{CM in the non spik sample}}{\text{Amount added}}\right) x\ 100$$

Where, CM = concentration of metal of interest.

Statistical analysis

The analyses of variance ANOVA were performed to examine the significance level of all parameters measured. Least Significant Difference (LSD) test was used for means comparison. The level of significance for means comparison was $p<0.05$. Methodological precision was therefore evaluated with standard deviation (SD).

Total metal concentrations in soil samples

FAO/WHO (2001) values are given as means of triplicates ± SD. The means in the same column having different superscript letters are significantly different from each other at 5% confidence interval. As shown in Table 1, heavy metals (Lead (Pb), and cadmium (Cd)) have no beneficial effects in humans, and there is no known homeostasis mechanism for them. They are generally considered the most toxic to humans and animals; the adverse human health effects associated with exposure to them, even at low concentrations, are diverse and include, but are not limited to, neurotoxic and carcinogenic actions (Vieira et al., 2011).

Chromium in soil samples

Chromium plays a vital role in the metabolism of

Table 1. Mean concentration of **Cr, Cd and Pb** of soil sample in wet digestion method (n = 3, ± SD mg/kg).

Sample code	Cr	Cd	Pb
Soil for tomato	50.50±0.53^{c}	45.33±1.53^{a}	63.00±2.26^{a}
Soil for cabbage	66.30±2.46^{a}	42.33±0.58^{b}	64.87±0.45^{a}
Soil for lettuce	62.23±2.35^{b}	45.00±1.00^{a}	63.33±3.58^{a}
Control soil	22.37±0.31^{d}	27.93±0.61^{c}	18.82±0.08^{b}
LSD	3.16	1.83	4.07
FAO/WHO	50	3	100
USEPA, 2002	150	3	300
EU, 2002	-	3	300

cholesterol, fat, and glucose. Its deficiency causes hyperglycemia, elevated body fat, and decreased sperm count, while at high concentration it is toxic and carcinogenic (Chishti et al., 2011). As shown in Table 1, the Cr contents in the soil samples were found to be within the range of 50.50±0.53 and 66.30±2.46 mg/kg. The highest and lowest contents of Cr occurred in the soils of cabbage and tomato, respectively. The WHO/FAO (2001) permissible limit of chromium in soil is 50 mg/kg. So, the concentration of chromium found in the three soil samples from lands irrigated with wastewater around the Eastern Industry Zone might be harmful for human health. Major sources of Cr contamination include releases from electroplating processes and the disposal of Cr containing wastes (Smith et al., 1995).

Cadmium in soil samples

Cadmium is also a non-essential heavy metal. It is extremely toxic even at low concentration. It causes learning disabilities and hyperactivity in children (Hunt, 2003). As shown in Table 1, the experimental results showed that Cd concentration in soil samples occurred in the range of 42.33±0.58 and 45.33±1.53 mg/kg. The tomato soil observed to have the highest level (45.33±1.53 mg/kg) of Cd, while the cabbage originated soil had the smaller level (42.33±0.58 mg/kg) of Cd. Being a non-essential metal, it can be considered very toxic. So, the concentration of cadmium found in the three vegetables growing soil samples from lands irrigated with wastewater around the Eastern Industry might be harmful for human health. Comparison of cadmium level in the soil samples with that of the control soil sample (27.93±0.61 mg/kg) indicates that the higher levels found in all samples could possibly be attributed to the pesticide, fertilizer, and municipal and industrial sewage effluents are known to be discharged into surrounding irrigation farms. It is used in nickel cadmium batteries, PVC plastic and paint pigments. It can be found in soils because insecticides, fungicides sludge, and commercial fertilizers that use cadmium are used in agriculture (Okoro et al., 2012).

Lead in soil samples

Lead is one of the more persistent metals and is estimated to have a soil retention time of 150 to 5000 years (Sobolev and Begonia, 2008). It is a non-essential heavy metal. Pb causes oxidative stress and contributes to the pathogenesis of lead poisoning by disrupting the delicate antioxidant balance of the mammalian cells. High level accumulation of Pb in body causes anemia, colic, headache, brain damage, and central nervous system disorder (Rehman et al., 2013). As shown in Table 1, the soil samples contained Pb concentrations in the range of 63.00±2.26–64.87±0.45 mg/kg. The WHO/FAO (2001) permissible limit of lead in soil is 100 mg/kg. This is within ranges of soils studies by Premarathna et al. (2011) who reported a range of 15 to 311 mg/kg. However, Awokunmi et al. (2010) reported very high levels of lead in soils collected from various dumpsites ranging between 3500-6860 mg/kg. Aluko et al. (2003) also reported high values of lead in soil ranging from 1340-1693 mg/kg.

Lead has been known to have harmful health effects even at lower levels and there is no known safe exposure level. It is appropriate to note that exposure to amount of lead above 0.01 mg/kg is detrimental to health, as it may result in possible neurological damage to fetuses, abortion and other complications in children under three years (Asemave et al., 2012). So, the concentrations of lead found in all three soil samples collected from farmlands irrigated with wastewater around the Eastern Industry Zone might be harmful for human health. Comparison of lead levels in the soil samples with that of the control soil sample (18.82±0.08 mg/kg) indicates that the higher levels obtained from all samples could possibly be attributed to the high levels of lead in the pesticide, fertilizer, and municipal and industrial sewage effluents are known to be applied into surrounding irrigation.

Metal concentrations in soil fractions

The metal distribution among specific forms varies widely based on the metal's chemical properties and soil

Table 2. Chemical fractionation of Cr, Cd and Pb (mg /kg) in soil samples from irrigated lands around the EIZ (n = 3, ± SD mg/kg).

Metal	Sample code	F1	F2	F3	F4	F5	F1+F2+F3+F4+F5	Wet-digestion
	Soil for tomato	0.61±0.03[c]	0.26±0.02[c]	0.96±0.04[c]	2.81±0.03[b]	32.27±1.65[b]	36.86±1.73	50.50±0.53
	Soil for cabbage	0.79±0.05[b]	0.44±0.02[a]	1.62±0.40[a]	4.23±0.23[a]	29.05±0.01[c]	36.13±0.71	66.30±2.46
Cr	Soil for lettuce	0.91±0.03[a]	0.37±0.03[b]	1.15±0.02[b]	4.46±0.05[a]	35.27±0.39[a]	42.52±0.52	62.23±2.35
	Control soil	0.19±0.01[d]	0.21±0.00[d]	0.21±0.00[d]	0.30±0.02[c]	20.35±0.09[d]	21.26±0.12	22.37±0.31
	LSD	0.05	0.04	0.07	0.26	1.73		
	Soil for tomato	0.41±0.01[a]	0.35±0.01[a]	0.48±0.02[b]	19.13±0.05[a]	18.84±0.02[a]	39.21±0.11	45.33±1.53
	Soil for cabbage	0.35±0.12[b]	0.20±0.02[b]	0.42±0.02[c]	18.85±0.02[b]	18.81±0.03[a]	38.63±0.21	42.33±0.58
Cd	Soil for lettuce	0.22±0.02[c]	0.13±0.01[c]	0.53±0.03[a]	18.85±0.00[b]	18.83±0.10[a]	38.56±0.16	45.00±1.00
	Control soil	0.14±0.01[d]	0.11±0.00[c]	0.09±0.00[d]	8.34±0.01[c]	18.13±0.14[b]	26.81±0.16	27.93±0.61
	LSD	0.03	0.03	0.03	0.06	0.19		
	Soil for tomato	12.27±0.42[a]	12.00±0.20[a]	7.87±0.31[c]	26.93±0.1[a]	13.36±0.04[a]	72.43±1.09	63.00±2.26
	Soil for cabbage	10.33±0.12[b]	10.40±0.60[b]	9.20±0.02[b]	24.87±0.1[b]	9.9±0.10[b]	64.70±0.96	64.87±0.45
Pb	Soil for lettuce	5.12±0.11[c]	6.47±0.31[c]	10.57±0.04[a]	23.87±1.2[b]	8.91±0.01[c]	54.94±1.76	63.33±3.58
	Control soil	0.32±0.02[d]	1.50±0.2[d]	0.70±0.30[d]	5.53±0.04[c]	8.06±0.04[d]	16.11±0.60	18.82±0.08
	LSD	0.46	0.63	0.36	1.34	0.10		

characteristics (Milkessa, 2013). The sequential extraction used in this study is useful to indirectly assess the potential mobility and bioavailability of heavy metals in the soils. The five chemical fractions are operationally defined by an extraction sequence that follows the order of decreasing solubility (Tessier et al., 1979).

Cr is mostly present in the residual fraction of all the samples (Table 2). The abundance of Cr in the residual phase is 20.35-35.27 mg/kg but in other geochemical phases was very low indicating that Cr was more stable in this environment than the other metals. Cd is obviously higher in abundance of the three elements in the last two fractions with compared to its concentration (Table 2). The abundance of Cd in the F4 and F5 were 8.34-19.13 mg/kg and 18.13-18.84 mg/kg respectively. The high proportion of the chemically reactive forms of Cd implies a high ecological risk (Zhang and Shan, 2008). Pb is obviously higher in abundance of the three elements in the F3 fraction Table 2. Soil OM has a large surface negative charge/ cation exchange capacity and elements such as Pb are observed to accumulate in the organic-rich, surface horizons (Zimdahl and Skogerboe, 1977).

Bioavailability and mobility factors of heavy metals

Assuming that bioavailability is related to solubility, then metal bioavailability decreases in the order: exchangeable (F1) > carbonate (F2) > Fe-Mn Oxide (F3)> organic (F4)> residual (F5). This order is just a generalization and offers only qualitative information about metal bioavailability. Based on the above information, one can further assume that metals in the nonresidual fractions are more bioavailable than metals associated with the residual fraction. The nonresidual fraction (NRF) is the sum of all fractions except the residual fraction (RF). The highest amounts of cadmium and lead were concentrated in the non-residual fraction but for chromium (89.80-82.95) and (79.62-83.78%) which was concentrated in the residual fraction (Figure 2).

The bioavailability factor was expressed as the ratio of the available concentration of a metal in soil to its total concentration. It shows the potentials of a particular metal from the soil matrix to enter the soil solution from which it can be absorbed by plants. Mobility factor was expressed as percentage of the Bioavailability factor (Kabata and Singh, 2001).

$$\text{BF} = \frac{F1+F2}{F1+F2+\cdots+F5}$$

$$\text{MF} = \frac{F1+F2}{F1+F2+\cdots+F5} \times 100$$

Table 3, shows the mobility, and bioavailability factors for all the sequential extractions steps. The high MF and BF values of soil Pb may be interpreted as symptoms of relatively high liability and biological availability of the metals in soil. Similar characteristics distribution patterns were observed for Cu Cd, Cr and Zn (Table 3).

Heavy metal concentration in vegetable samples

Vegetables like cabbage (*Brassica oleracea* L.), lettuce

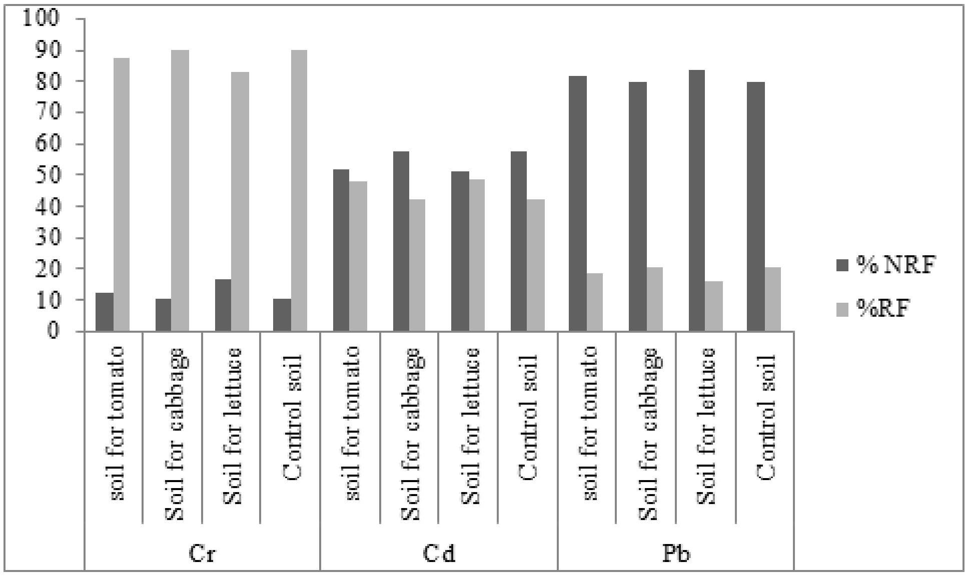

Figure 2. Chemical fractionation of heavy metals in (mg /kg) in soil sample collected from irrigated land around the EIZ (n = 3).

Table 3. The bioavailability and mobility Factor of Heavy Metals in soil sample fractionation (n = 3).

Elements	Sample code	F1	F2	Sum of F1 and F2	Sum of fraction	Bioavailability factor	Mobility factor
Cr	Soil for tomato	0.61	0.260	0.870	36.860	0.024	2.360
	Soil for cabbage	0.79	0.440	1.230	36.130	0.034	3.404
	Soil for lettuce	0.91	0.370	1.280	42.520	0.030	3.010
	Control soil	0.19	0.210	0.400	7.260	0.019	1.881
Cd	Soil for tomato	0.41	0.350	0.760	39.210	0.019	1.938
	Soil for cabbage	0.35	0.200	0.550	38.630	0.014	1.424
	Soil for lettuce	0.22	0.130	0.350	38.560	0.009	0.908
	Control soil	0.14	0.140	0.280	15.110	0.010	1.040
Pb	Soil for tomato	12.27	12.000	24.270	72.430	0.335	33.508
	Soil for cabbage	10.33	10.400	20.730	64.700	0.320	32.040
	Soil for lettuce	5.12	6.470	11.590	54.940	0.211	21.096
	Control soil	0.32	1.500	1.820	8.380	0.113	11.297

(*Lactuca sativa* L.) and tomato (*Lycopersicon esculentum* Miller) were analyzed for total metals content. The level of heavy metals in vegetables varies by the ability of plants to selectively accumulate some of these elements. Bioavailability of the elements depends on the nature of their association with the constituents of a soil. Additional sources of these elements for plants are rainfall, atmospheric dusts, plant protection agents and fertilizers that can be absorbed through the leaf blades (Harris, 1982; Gezahegn, 2013). The concentrations of, Cr, Cd and Pb in sample of vegetables (cabbage, lettuce and tomato) grown around EIZ irrigation farm land were presented in Table 4. From the study, it is revealed that most of the metals were accumulated to greater or lesser extents in the vegetable samples with compared to WHO standard as shown in Table 4.

The vegetables are consumed by the urban population of the city of Dukem and cities present near Dukem like Addis Ababa, Debre Zeit, etc. thus exposing the population to dangerous levels of heavy metals. The results presented demonstrate that there is a risk associated with consumption of vegetables grown on

Table 4. Mean concentration of Cr, Cd and Pb of vegetable samples in wet digestion method (means ± SD mg/kg), n=3.

Element	Vegetable			LSD	WHO (1999)	CMH (2005)	FAO (1985)
	Tomato	Cabbage	Lettuce				
Cr	2.97±0.21[b]	2.90±0.10[b]	3.77±0.12[a]	0.20	1.2	0.5-1.0	-
Cd	2.20±0.10[c]	3.20±0.10[b]	3.68±0.06[a]	0.22	0.2	0.05-0.2	0.01
Pb	4.60±0.10[b]	5.47±0.35[b]	5.50±0.40[a]	0.87	0.5	0.1-0.3	5.00

these irrigation land farm, with the vegetable still looking apparently healthy and growing well despite accumulating heavy metals to concentrations which substantially exceed maximum values considered safe for human consumption. The results of this study, heavy metal concentrations in vegetable samples were compared with WHO permissible values Source, WHO (1999), CMH: Chinese Ministry of Health. The means in the same row having different superscript letters are significantly different from each other at 5% confidence interval.

Distribution of chromium in vegetables

Exposure of human to chromium may occur through breathing, drinking, or eating food containing chromium or even through skin contact. Exposure to elevated levels chromium leads to skin irritation, ulceration, damage to circulatory and nerve tissues which cause health problems. However, daily uptake of it within a certain range of concentrations (up to 200 μg/day) by human beings and animals is considered to be essential for carbohydrate and lipid metabolism (Girmaye, 2012). In this study the chromium contents in vegetable samples were obtained to have ranged from 2.90±0.10-3.77±0.12 mg/kg and these result were higher than permissibility level set by WHO (1999) is 1.2 mg/kg (Table 4).

Distribution of cadmium in vegetables

The vegetable samples collected around EIZ irrigation farmlands contained Cd concentrations in the range of 2.20±0.10-3.68±0.12 mg/kg as shown in Table 4. The concentration of Cd was maximum (3.68±0.12 mg/kg) in lettuce sample and the minimum (2.20±0.10) was found in the tomato sample. According to WHO/FAO (1999) permissible level is 0.2 mg/kg. The high concentration of Cd in the vegetables might be due to the use of pesticide, fertilizer, and municipal and industrial sewage effluents. Applications of untreated industrial effluent build up concentration of metal into the soil (Chary et al., 2008). From the soil, metals can transfer to the vegetables and accumulate in the tissues of vegetables. Several compounds of Cadmium are used in chemical industries and in the manufacture of pesticides, herbicides used in agriculture (Ogundele et al., 2015). Cd is more soluble as compared to other metals so, it can accumulate more into the vegetables tissues (Farid et al., 2015).

Distribution of lead in vegetables

Results show that the levels of lead in the vegetables studied had a range of 4.60±0.10 to 5.50±0.40 mg/kg as shown in Table 4. Data showed that in all vegetables, lead concentration is more than permitted level, so they are not suitable for consumption. Lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human (Bigdeli and Seilsepour, 2008). In leafy vegetables the accumulation of airborne lead largely exceeds the soil borne part taken up via roots. Air borne lead is mainly accumulated at the leaf surface and can be removed to a larger extent by washing of the vegetables (Tyagi, 2014).

Comparison of heavy metals concentration from the current study with those reported on the literature

The heavy metal (Cr, Cd and Pb) levels in vegetables samples (tomato, cabbage and lettuce) from‘fields irrigated with the Eastern Industry Zone were compared with different literature reported in Table 5.

SUMMARY AND CONCLUSION

As stated earlier, the major purpose of this study was to find out the level of heavy metals in soil, from three farmer farm and three subsamples from each farm for each edible part of the vegetables (tomato, cabbage and lettuce) were determined. The soil and vegetable samples were subjected to wet-digestion, sequential extraction and the concentration of heavy metals were determined via FAAS. The concentration of heavy metals in the soil display the following decreasing trend: Cr > Pb > Cd. These concentrations of heavy metals in soil samples were above the recommended level set by FAO/WHO (2001), EU (2002) and USEPA (2002) for

Table 5. Comparison of metal concentration in the vegetables with other reports in similar studies.

Vegetable	Source of heavy metals	Heavy metals in mg/k			References
		Cr	Cd	Pb	
Tomato	Agricultural activities and Industrial effluents	2.97	2.20	4.60	Present study
	Agricultural activities	0.34	0.11	5.25	Liu et al., 2006
	Wastewater	-	0.20	5.50	Mohod, 2015
	Wastewater	0.33	0.03	4.40	Khan et al., 2011
	Swage water	2.12	13.56	6.80	Perveen et al., 2012
Cabbage	Agricultural activities and Industrial effluents	2.90	3.20	5.47	Present study
	Swage water	1.20	16.71	48.00	Perveen et al., 2012
	Wastewater	0.57	0.22	0.31	Girmaye, 2012
	Wastewater	0.38	0.26	2.24	Khan et al., 2015
	Transport & Market	16.28	6.17	22.76	Dingkwoet et al., 2013
Lettuce	Agricultural activities and Industrial effluents	3.77	3.68	5.50	Present study
	Wastewater	1.86	0.36	0.53	Girmaye, 2012
	Swage water	2.20	15.25	2.20	Perveen et al., 2012
	Wastewater	0.41	0.51	1.52	Khan et al., 2015
	Transport & Market	11.07	-	37.81	Dingkwoet et al., 2013

irrigation soil. The concentration of heavy metals in the vegetable samples display the following decreasing trend: Cr > Pb > Cd. The study revealed that the concentrations of all metals in the vegetables were found to be above the safe limits set by different international organizations for consumption, posing a serious health hazard to humans. Therefore, regular monitoring of soils and vegetables are essential to prevent excessive build-up of the toxic heavy metals in food. Thus, the health risk and the extent of heavy metal contamination can be reduced. The soil–plant transfer factor (TF) decreased in the following order- TFPb > TFCd > TFCr. A sequential extraction procedure was used to fractionate Cr, Cd and Pb present in soils of tomato, cabbage and lettuce and reference (control) soils. The mobility and bioavailability of these metals were studied and a very high amount of these metals were concentrated at the residual, organic and Fe-Mn Oxide fractions. However, a very small concentration of these heavy metals was also found at the exchangeable and carbonate fractions. Mobility factor of, Cr, Cd and Pb in soil samples ranged from 1.881-3.404, 0.908-1.938 and 11.297-33.508, respectively.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abebe A (2012). Assessment of urban expansion in the case of Dukem town using remote sensing and GIS techniques. MSc thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Abolino O, Aceto M, Mentasticti E, Sarzanini C, Petrella F (2002). Assessments of metal availability in contaminated soil, by sequential extraction. Water Soil and Air Pollution 49:345-557.

Aluko OO, Sridha MKC, Oluwande PA (2003). Characterization of leachates from a municipal solid waste landfill site in Ibadan, Nigeria. Journal of Environmental Health Research 2:32-37.

American Public Health Association (APHA) (1999). American water works association, Water environment federation. Standard methods of the examination of water and wastewater, 20thed. New York. https://www.mwa.co.th/download/file_upload/SMWW_1000-3000.pdf

Asemave K, Ubwa ST, Anhwange BA, Gbaamende AG (2012). Comparative Evaluation of Some Metals in Palm Oil, Groundnut Oil and Soybean Oil from Nigeria. International Journal of Modern Organic Chemistry 1(1):28-35.

Awokunmi EE, Asaolu SS, Ipinmoroti KO (2010). Effect of leaching on heavy metals concentration of soil in some dumpsites. African Journal of Environmental Science and Technology 4(8):495-499.

Bigdeli M, Seilsepour M (2008). Investigation of metals accumulation in some vegetables Irrigated with wastewater in Shahre Rey-Iran and toxicological implications American-Eurasian, Journal of Agriculture and Environmental Science 4(1):86-92.

Chary NS, Kamala CT, Raj DSS (2008). Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol and Environ Safety 69:513-524.

Chinese Ministry of Health (CMH) (2005). Maximum Levels of Contaminants in Foods. CMH, Beijing, China. GB2762 _2005. https://gain.fas.usda.gov/.../Maximum%20Levels%20of%20Contaminants%20in%20F.

Chishti KA, Khan FA, Hassan SSM (2011). Estimation of heavy metals in the seeds of blue and white capitalism's of silybum marianum grown in various districts of Pakistan. Journal of Basic and Applied Science 7(1):45-49.

Christian G, Sylvaine T, Michel A (2002). Fractionation studies of trace elements in contaminated soils and sediments: A Review of sequential extraction procedures. Trends in Analytical Chemistry 21:451-467.

David AA, Terry P (2008). Limit of blank, limit of detection and limit of quantitation. Clinical Biochemist Review 29:49-52.

Dingkwoet DJ, So Danladi SM, Gabriel MS (2013). Comparative study of some heavy and trace metals in selected vegetables from four local government areas of Plateau State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology 6(3):2319-

2399.
Enders A, Lehmann J (2012). Comparison of wet-digestion and dry-ashing methods for total elemental analysis of Biochar. Communications in Soil Science and Plant Analysis 43:1042–1052.
European Union (EU). 2002. Heavy metals in wastes, European Commission on Environment. Available at: http://ec.europa.eu/environment/waste/studies/pdf/heavy_metalsreport.pdf
Food and agriculture organization (FAO) (1985). Water Quality for Agriculture. Food and agriculture organization of the United Nations, Rome. Irrigation and drainage Paper 29:1.
FAO/WHO (2001). Food additives and contaminants. Joint codex alimentarius commission, FAO/WHO Food standards Program 34:745-50.
Farid G, Sarwar N, Saifullah Ahmad A, Ghafoor A, Rehman M (2015). Heavy metals (Cd, Ni and Pb) contamination of soils, plants and waters in madina town of Faisalabad Metropolitan and Preparation of Gis Based Maps. Advances in Crop Science and Technology 4(1):1-7.
Gebregeorgis AK (2016). Ethio-China economic relations: nature of China's foreign direct investment in Ethiopia. MSc thesis, Addis Ababa University, Addis Ababa, Ethiopia.
Gezahegn L (2013). Chemical fractionation of selected metals in the soil of waste disposal sites of Dire Dawa Textile Factory and their contents in the sweet potato Leaves. MSc. Graduate research project, Haramaya University, Haramaya, Ethiopia.
Girmaye BR (2012). Heavy metal and microbial contaminants of some vegetables irrigated with wastewater in selected farms around Adama town, Ethiopia. MSc. Graduate project, Haramaya University, Haramaya, Ethiopia.
Harris DC (1982). Quantitative Chemical Analysis, 4^{th} edition. W.H. Freeman and Company.
Harrison RM, Laxen DPH, Wilson SJ (1981). Environmental science and technology. Journal of Environment 38:25-32.
Hoeing M, Baeten H, Vanhentenrijk S, Vassileva E, Quevauviller PH (1998). Critical discussion on the need for an effective mineralization procedure for the analysis of plant material by atomic spectrometric methods. Analytica Chimica Acta 358:85-94.
Hunt JR (2003). Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. American Journal of Clinical Nutrition 78(3):6335-6395.
Ismail BS, Farihah K, Khairiah J (2005). Bioaccumulation of heavy metals in vegetables from selected agricultural areas. Bulletin of Environmental Contamination and Toxicology 74:320-327.
Iwegbue, C.M.A., (2007). Determination of trace metal concentrations in soil profiles of municipal waste dumps in Nigeria. Waste Management Resource, 25:585.
Kabata C, Singh BR (2001). Fractionation and mobility of copper, lead and zinc in soil profile in the vicinity of a copper smelter. Journal of Environmental Quality 30:485-492.
Katz SA (1984). Determination of heavy metals in sewage sludge. Environmental Chemistry 3:78-953.
Khan MJ, Jan, MT, Farhatullah Khan NU, Arif M, Perveen S, Alam S, Jan AU (2011). The Effect of using Wastewater for Tomato. Pakistan Journal of Botany 2:1033-1049.
Khan SA, Liu X, Shah BR, Fan W, Li W, Khan SB, Ahmad Z (2015). Metals uptake by wastewater irrigated vegetables and their daily dietary intake in Peshawar, Pakistan. Ecological Chemical Engineering Science 22(1):125-139.
Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG (2008). Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environmental Pollution Series 152(3):686-692.
Kotoky P, Bora BJ, Baruah NK, Baruah J, Baruah P, Borah GC (2003). Chemical fractionation of heavy metals in soil around oil installation, Assam. Chemical Speciation and Bioavailability 15(4):115-125.
Liu WX, Li HH, Li SR, Wang YW (2006). Heavy metal accumulation of edible vegetable cultivated by people's of Republic of China. Bullet of Environmental Contamination and Toxicology 76:163-170.
Loon JC (1985). Selected methods of trace metal analysis biological and environmental samples. New York 5:3685-3689.
Ma LQ, Rao GN (1997). Chemical fractionation of cadmium, copper, nickel, and zinc in contaminated soils. Journal of Environmental Quality 26(1):259-264.
Milkessa MA (2013). Chemical fractionation of selected heavy metals in the soils in the vicinity of waste water disposal sites in Dire Dawa Textile Factory. MSc project work, Haramaya University, Haramaya.
Mohod CV (2015). A review on the concentration of the heavy metals in vegetable samples like spinach and tomato grown near the area of Amba Nalla of Amravati City. International Journal of Innovative Research in Science, Engineering and Technology 4(5):2788-2792.
Ogundele DT, Adio AA, Oludele OE (2015). Heavy metal concentrations in plants and soil along heavy traffic roads in North Central Nigeria. Environmental Analytical Toxicology 5(6):1-5.
Okoro KH, Fatoki SO, Adekola AF, Ximba JB, Snyman GR (2012). A Review of Sequential Extraction Procedures for Heavy Metals Speciation in Soil and Sediments. Open Access Scientific Reports 1(3):1-9.
Perveen S, Samad A, Nazif W, Shah S (2012). Impact of sewage water on vegetables quality with respect to heavy metals in Peshawar Pakistan. Pakistan Journal of Botany 44(6):1923-1931.
Poggio M, Hepperle E, Marsan FA (2008). Metals pollutions and human bioaccessibility of topsoils in Grugliasco, Italy. Environmental Pollution 157:680-689.
Premarathna HM, Hettiarachchi GM, Indraratne SP (2011). Trace metal concentration in crops and soils collected from intensively cultivated areas of Sri Lanka. Pedologist 54(3):230-240.
Radwan MA, Salama AK (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. Journal of Food and Chemical Toxicology 44(8):1273-1278.
Rehman A, Ullah H, Khan RU, Ahmad I (2013). Population based study of heavy metals in medicinal plant Capparis decidua. International Journal of Pharmacy and Pharmaceutical Sciences 5(1):108-113.
Sawidis T, Chettri MK, Papaionnou A, Zachariadis G, Stratis J (2001). A study of metal distribution from lignite fuels using trees as biological monitors. Journal of Ecotoxicology and Environmental Safety 48(1):27-35.
Sharma RK, Agrawal M, Marshall FM (2006). Heavy metals contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. Environmental Contamination and Toxicology 77:311-318.
Smith A, Means JL, Chen A (1995). Remedial options for metals-contaminated sites, Lewis Publishers, Boca Raton, Fla, USA.
Sobolev D, Begonia MFT (2008). Effects of Heavy metal contamination upon soil microbes: lead-induced changes in general and denitrifying microbial communities as evidenced by molecular markers. International Journal of Environmental Research in Public Health 5(5):451-459.
Street RA (2008). Heavy metals in South African medicinal plants research center for plant growth and development, PhD Dissertation, University of KwaZulu-Natal, Pietermaritzburg, South African.
Tessier A, Campbell PGC, Bisson M (1979). Sequential extraction procedure for the speciation of particulate traces metals. Analytical Chemistry 51(7):844-851.
Tyagi R (2014). Assessment of the uptake of toxic heavy metals on cultivation of vegetables of family Solanaceae in contaminated soil. PhD Graduate Thesis University of Kota, Kota, Rajasthan.
World Health Organization (WHO) (1999). Permissible limits of heavy metals in soil and plants (Geneva: World Health Organization), Switzerland.
U.S. Environmental Protection Agency (USEPA) (2002). PRG Tables. Preliminary Remediation Goals. Solid and Hazardous Waste Programs, Region 9, U.S. Environmental Protection Agency. [Online]. Available: http://www.epa.gov/Region9/waste/sfund/prg/s1_01.htm.
Yoseph Y (2015). Chemical fractionation of heavy metals in soil around Tinshu Akaki River Addis Ababa, Ethiopia. MSc. Graduate research project, Haramaya University, Haramaya, Ethiopia.
Zhang WJ, Jiang FB, Ou JF (2011). Global pesticide consumption and pollution: with China as a focus. Proceedings of the International Academy of Ecology and Environmental Sciences 1(2):125-144.
Zimdahl RL, Skogerboe RK (1977). Behaviour of lead in soil. Environmental Science Technology 11:1202-1207.

Vol. 14(2), pp. 102-117, 10 January, 2019
DOI: 10.5897/AJAR2018.13672
Article Number: 8D23CA159811
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Land Use Land Cover Change Trend and Its Drivers in Somodo Watershed South Western, Ethiopia

Fasika Alemayehu[1*], Motuma Tolera[1] and Gizaw Tesfaye[2]

[1]Department of Watershed management, School of Natural Resource and environmental Science, Hawassa University, Wondo Genet College of Forestry and Natural Resources, Ethiopia.
[2]Ethiopian Institute of Agricultural Research, Jima Agricultural Research Center. P. O. Box 192, Ethiopia.

Received 25 October, 2018; Accepted 5 December, 2018

Land use land cover (LULC) dynamics are a widespread, accelerating, and significant process driven by human actions. LULC changes analysis is one of the most precise techniques to understand how land was used in the past, what types of changes are to be expected in the future, as well as the forces and processes behind the changes. This study was carried out to evaluate the historical and future trends as well as driving forces of LULC changes in Somodo watershed South Western, Ethiopia. It was accompanied using satellite image of Landsat5 TM 1985 and 1995, Landsat7 ETM+ 1999, 2005 and Landsat8 OLI/TIROS 2017. In addition, field observations, Key informant interview (KII) and Focus Group Discussion (FGD) were also conducted. ERDAS Imagine 9.1, QGIS 2.18 and IDRSI Selva 17.00, software were used for satellite image processing, map preparation, and LULC change prediction respectively. During the 32 year period between 1985 and 2017, the proportion of area covered by forest and agriculture was decreased by 60.57 ha (12.7%) and 5.22 ha (1.1%) respectively. In contrast, home garden Agroforestry/settlement and grassland were increased by 49.77 ha (7.5%) and 16.02 ha (6.7%) respectively. If the existing rate of LULC change lasts, in 2029 agriculture and forestland are predicted to increase by 91.24 ha and 20.52 ha respectively, while grassland and home garden Agroforestry/settlement are predicted to decrease by 99.97 ha and 11.79 ha respectively. LULC change in the study area is an outcome of several proximate and underlying drivers. The major proximate driving forces of LULC change in the watershed are illegal logging and fuel wood extraction, Expansion of plantation, expansion of settlement, agricultural expansion, and construction of infrastructures. Demographic, Economic, Technological, Institution and policy, and Biophysical factors constitute the major underlying drivers of LULC change in the study area. Population growth is the major underlying cause for LULC change in the study area. Then, Participatory Forest Management through plantation and community nursery expansion is required for forest cover improvement in the watershed. This study also suggests further study on the impact of LULC change in the area.

Key words: Drivers, geographic information system (GIS), Land use/Land cover Change prediction, Somodo Watershed.

INTRODUCTION

Throughout the course of human history, the land has been tightly attached to economic, social, infrastructure and other human activities (Lambin et al., 2003). Land use and land cover (LULC) are distinct yet closely linked characteristics of the Earth's surface (Solomon, 2016). Land use describes the way and the purposes for which human beings employ the land and its resources (Alemayehu et al., 2009).

While land cover refers to the ecological state and physical appearance of the land surface (such as Closed forests, woodlands or grasslands) (Mwavu and Witkowski, 2008). Land use/cover is a composite term, which includes both categories of land cover and land use (Ioannis and Meliadis, 2011). The land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by the man in time and space (Zubair, 2006).

Land cover change occurs through conversion and intensification by human intervention, altering the balance of an ecosystem, generating a response expressed as system changes (Dale, 1997). For centuries, humans have been altering the earth's surface to produce food through agricultural activities (Assefa, 2012). In the past few decades, conversion of grassland, woodland, and forest into cropland and pasture has risen dramatically, especially in developing countries where a large proportion of human population depends on natural resources for their livelihoods (FAO, 2005). The increasing demand for land and related resources often results in changes in land use/cover (Assefa, 2012) and it has local, national, regional and global causes (Olson et al., 2004). Land use/cover dynamics are widespread, accelerating, and significant process driven by human actions (Leh et al., 2011) but also producing changes that impact humans (Agarwal et al., 2002).

Factors driving LULC change include an increase in human population and population response to economic opportunities (Lambin et al., 2001). Population growth is a major driving force in land cover change and contributes to resource degradation (Woldamlak, 2002). Deforestation and forest degradation have been influenced by a combination of underlying driving forces, including unclear land tenure, poor economic conditions, population growth, market (wood extraction), and socio-political factors (Bekele, 2003; Dessie and Christiansson, 2008). On top of the rapid change in LULC of forestland, grazing land or bushlands to cultivated lands is becoming a common practice in most parts of Ethiopia (Amanuel and Mulugeta, 2014).

Other important drivers of LULC change includes policies related to human settlement and land tenure (Murphree and Cumming, 1993) and agricultural (Reed, 1996); changes in technology (Grübler, 1994), culture (Rockwell, 1994) and political or socio-economic institutions (Midagso, 2008). The size of Ethiopian population was 40 million in 1984, 53.4 million in 1994, 73.7 million in 2007, 84.2 million in 2012, 85.89 million in 2013 as projected by (CSA), this population become nearly 100 million in 2015 (BTI, 2016). Rain fed agriculture is the major economic activity of the country providing employment for over 85 percent of the population (Devereux, 2000). Ethiopia's forests have suffered severe deforestation and degradation from an increased demand for fuel wood, construction wood, and cropping and grazing land (Wogayehu, 2003).

Understanding the dynamics and driving forces behind LULC changes at the local level is fundamental to development planning, and the analysis of land-related policies (Tekle and Hedlund, 2000), and understanding of possible future choices (de Sherbinin, 2002). LULC changes have increasingly become a key research priority for national and international research programs examining global environmental change and impact analysis of the changes, which is a standard requirement for land use planning and sustainable management of natural resources as highlighted by many researchers (Petit et al., 2001). Determining the effects of LULC changes on the ecosystem requires knowledge of past land use practices, current LULC patterns, and future projections (Woldamlak, 2002). LULC changes studies are proven essential for the qualification and quantification of central environmental processes and environmental change (Verburg et al., 2002). It is also vital for the influence of environmental management on biodiversity, water budget, radiation budget, trace gas emissions, carbon cycling, livelihood (Verburg et al., 2002), urban and rural agricultural land use (Lambinet al., 2003); Muzein, (2008), and a wide range of socio-economic and ecological processes (Ozbakir et al., 2007). Which on the aggregate affect global environmental change and the biosphere (Fashona and Omojola, 2005).

LULC changes can affect biodiversity, biogeochemical cycles, soil fertility, hydrological cycles, energy balance, land productivity, and the sustainability of environmental services (Lupo et al., 2001). Hence, there is a need for continuous monitoring of the changes and prediction (Kindu et al., 2013). It is so pervasive that when aggregated globally, it significantly affects the functioning of the earth's systems directly contributing to climate change (Lewis, 2006). LULC changes result in soil erosion and the formation of gullies, which are among the major cause of land degradation (Selamyihun, 2004). The highest average rates of soil loss are from previously cultivated lands, which are presently unproductive because of degradation and improper land use (Midagso, 2008).

Land through inappropriate agricultural practices, high human and livestock population pressure have led to severe land cover change. In Ethiopia, also most population lives in rural areas and depends directly on land for their livelihood (Tesfaye et al., 2014). The heavy dependence of households on woody biomass fuel (Kalkidan et al., 2017). As a result, soil erosion,

*Corresponding author. E-mail: yeelfayaalex@gmail.com. Tel: +251-9-17794763.

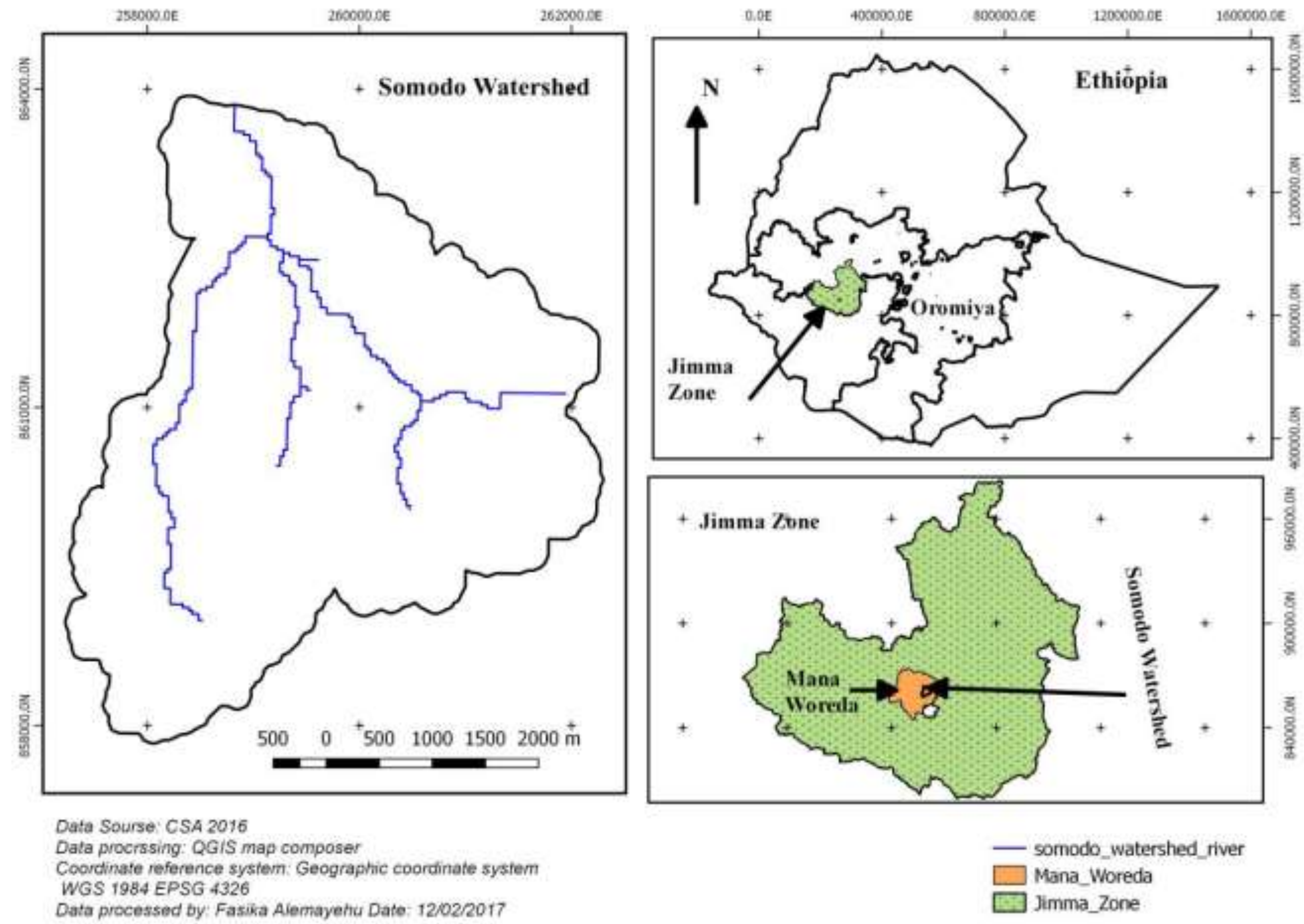

Figure 1. Study area map of Somodo Watershed.

biodiversity loss, and land degradation occur in the study area. Soil erosion will again lead to loss of groundwater due to poor infiltration capacity and washed away of the soil nutrient and desertification will occur. This all will contribute to low productivity leading to poverty.

Therefore, a systematic analysis of LULC change is so crucial to exactly comprehend the extent of the change. Studies of LULC changes in Ethiopian highlands concentrate in the Northern Ethiopian highlands areas early settled and where population pressure is relatively high (Belay, 2002). There have been very limited studies LULC change and driving forces in the southwestern regions of the country. Even if there are a few studies conducted in Southwestern Ethiopia, there is no study on land use land cover change in Somodo watershed. LULC change is basic data on the extent and trend in the study area that would help for planning and the adoption of sustainable land management practices. In addition, it help to understand the extent and the trend of LULC changes dynamics and its impact on communities' livelihood. Such studies are scanty in the present study area. Therefore, this study is mainly aimed to analyze the trend and driving forces of land use land cover change in the watershed.

MATERIALS AND METHODS

Description of the study area

Somodo watershed is located at the upper part of Didessa catchment in Blue Nile river basin in Jimma zone, Mana district/woreda, Southwestern part of Ethiopia. It lies between 7o46'00'' - 7o47'00''N latitude and 36o47'00''-36o48'00''E longitude with altitude ranging from 900- 2050m a.s.l. (Figure 1). ManaWoreda is located 368 km southwest of Addis Ababa and 20 km west of Jimma town. The Somodo watershed covers 1848 ha, the dominant soil is Nitisol, and about 68% of the watershed soil is extremely acidic (Kalkidan et al., 2017).

Method and data acquisition

Both primary and secondary data were used for the work. The fieldwork was started with a reconnaissance visit to the study area and followed by primary data collection. During reconnaissance survey, ground information was acquired, in order to define the nature of the ground covers such as Natural forest, Plantation forest, grassland, cultivated land, home garden Agroforestry, and settlement. Field samples from each land use type were collected using GPS. The history of each land use type was collected from local peoples by focus group discussion and key informant interview in the study area.

Secondary data, spatial and written information (Maps and reports, respectively), were acquired through downloading from freely available institutional web pages like United States Geological Survey (USGS) and Global Land Cover Facility (GLCF) websites. The DEM was acquired from USGS and used to create the watershed boundary, using the GRASS GIS module available in QGIS as plugins. The secondary data was collected from satellite imageries, which were selected based on political and social changes; such as 1985, the upcoming of Derg regime and the occurrence of large-scale investment and settlement; 1995, the upcoming of FDRE; 1999/2000-2005, and the starting of ADLI (agricultural development led industry); 2016/2017, starting of GTP-2 to look into the outcome of GTP-1.

Four major LULC types were identified by using the field data and satellite images of Landsat TM, 1985 and OLI, 2017. Rivers, streams, and springs were not included in the classification because of the low resolution of the images (30 m). In the classification, the class forest included plantation forest, riverine forests, and dry evergreen forest. Definition of each land use land cover is described in Appendix Table 12. This is because as they had the same spectral nature on the images, it was difficult to differentiate one from the other.

Data analysis

Satellite image analysis

The geographical positioning system (GPS) is used to take control (ground truth) points; ERDAS Imagine 9.1 was used for image processing and classification. QGIS 2.18 Software was used for GIS raster and vector data analysis and mapping. IDRSI Selva 17.00 was used for prediction of LULC change. IBM SPSS 20 was used for socio-economic data analysis and graph preparation.

Satellite imageries of 1985, 1995, 1999, 2005 and 2017 were downloaded from USGS and GLCF (http://earthexplorer.usgs.gov/). These images were already orthorectified using ground control points and digital elevation model (DEM) data to correct for relief displacement. The satellite image data were imported to Erdas Imagine 9.1 image processing software to create a layer stack for each year. The Coordinate Reference System of all images was UTM Zone 37 with the WGS84 datum. Image subsetting and image enhancement (histogram equalization) techniques were applied to the raw TM, ETM+, and OLI Landsat images.

The unsupervised classification was performed before and during the fieldwork to understand the general land cover classes of the study area. After fieldwork, maximum likelihood supervised classification was applied on Erdas imagine 9.1 using training sites. Training sites for the recent image (OLI/TIRS) were defined by using ground truth points collected from the field. For the old images (TM and ETM+), training sites were defined by using a spectral value of a recent image, result of unsupervised classification, ancillary data (Google earth) and information obtained from elder individuals. Totally, of 200 Ground Truth Points collected during the fieldwork 40% or 80 Ground Truth Points (20 from each LU/LC types) were used to support classification of recent year image (OLI/TIRS), while the remaining 60% (120 Ground Truth Points) were used for classification accuracy assessment of the 2017 image. The image classification was carried out to produce land cover layer through a supervised image classification method applying the training samples created using the field data and interoperation of the images (Google earth and stacked images for the different years).

Accuracy assessment

For classification accuracy, assessment error matrix was produced for all images in this study. GPS points used in the classification accuracy assessment were independent of ground truth points used in the classification. According to Anderson et al. (1976), the recommended standard of accuracy in the identification of LULC change mapping from the remote sensing data should be 85 to 90%. The Kappa coefficient was also used to assess the classification accuracy (Peesapati and Harinarayan, 2015). It expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Congalton, 1991). The Kappa statistic incorporates the off-diagonal elements of the error matrices (that is, classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance.
The overall accuracy and Kappa statistics is calculated by using (Jensen, 2003) formula as follows:

Overall accuracy = Number of pixels correctly classified/ Total number of pixel

Kappa (Kˆ): It reflects the difference between actual agreement and the agreement expected by chance and estimated as:

$$\hat{K} = \frac{Po - Pe}{1 - Pe}$$

Where Po = proportion of correctly classified pixels and determined by diagonal in error matrix; Pe = proportion of correctly classified pixels expected by chance and incorporates off-diagonal.

LULC change detection analysis

LULC change detection analysis was computed in three different ways:

1) Total LULC change in hectare calculated by as:

Total LULC = Area of a final year - Area of initial year

Positive values suggest an increase whereas negative values imply a decrease in extent.

2) Percentage LULC change calculated using the following equation:

$$\text{PercentageofLULC} = \frac{\text{Area of a Final Year} - \text{Area of Initial Year}}{\text{Area of Initial Year}}$$

3) An annual rate of LULC change: computed using the following simple formula

$$r = \frac{Q2 - Q1}{t}$$

Where: r, Q2, Q1, and t indicates the rate of change, recent year LULC in ha, initial year LULC in ha and interval year between initial and recent year respectively.

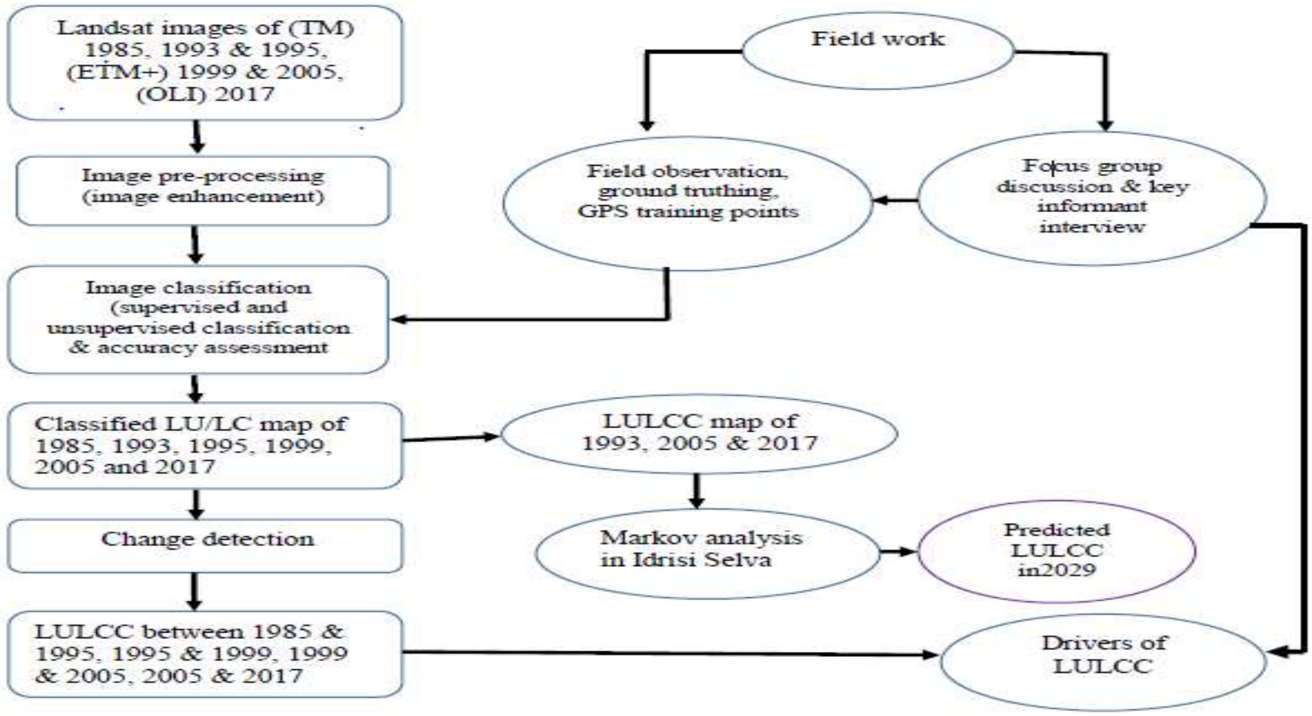

Figure 2. A flowchart that shows the general methodology of this research.

LULC change modeling

For this study, the Markov Chain Model (MCM) implemented in IDIRIS Selva were used to predict LULC change for the year 2029. Conversion matrixes were analyzed for each period to clearly show the source and destination of the major LULC changes. Analysis of conversion matrix was computed by overlaying classified images of two study years on ERDAS image 9.1. MCM provides a transition probability matrix, a transition areas matrix and a set of conditional probability images.Prior to predicting future LULC in 2029 the predictive power of the model was first validated by predicting the LULC for the year 2017. Accordingly, the LULC for the year 2017 was predicted considering the LULC map of 1993 and 2005. Then the predicted LULC areas of 2017 were compared with the actual areas interpreted from 2017 satellite image and the result was tested with the actual values using Chi-square (X^2) test with 0.05 error under 95% confidence interval. After validating the performance of the model, a real "prediction" for the year 2029 was carried out. LULC change maps for the year 2005 and 2017 were used to predict the land requirement in 2029. The year 2029 is selected for prediction since Markov chain model requires the same time interval between base year (2017) and predicted year (2029) to be equivalent with the time interval between the initial year (2005).

General methodology applied

Landsat imageries were downloaded from Geological Survey (USGS) and Global Land Cover Facility (GLCF) for the specified years and pre-processed using ERDAS IMAGINE 9.1 and classified through supervised and unsupervised image classification system with the help of QGIS. Accuracy analysis of classified image was performed using Kappa coefficient and LULC change detection between 1985, 1995,1999, 2005 and 2017 was done. With the help of Markov analysis in Idrisi Selva LULC in 2029 were projected. In addition, major causes and drivers of LULC change were assessed through focus group discussion and key informants interview (Figure 2)

RESULTS AND DISCUSSION

Land use/Land covers of the study area

Overall accuracy for the five years land use/ land cover classification of this study was 87.33, 92.00, 94.00, 88.00 and 88.00% for the respective years of 1985, 1995, 2005, and 2017 with kappa coefficient or statistics of 0.8208, 0.8781, 0.9101, 0.8289 and 0.8303 (Appendixes 2) respectively. In 1985 HG agroforestry/settlement were the dominant LULC types with the area of 663 ha. By 2017 these LULC types were dominantly increased to 713 ha (Table 1).

LULC analysis from the Landsat imagery of TM and ETM+ showed that starting from the mid-1980s to mid-2000s agricultural land continuously increased. However, in the year 2005, this land use type decreased. Agricultural land accounted for 472 ha (26%), 519 ha (28%) and 567 ha (31%) of the total area of Somodo watershed in the years 1985, 1995 and 1999 respectively (Table 1). However, LULC analysis from the ETM+ imagery of 2005 indicated that the area coverage of grassland and forestland were increased as compared to their previous area coverage. Forestland covered about 414 ha (22%) of the study area in 2017 (Table 1).

In contrast, during the same period, home garden agroforestry/settlement covered 713 ha (39%) of the

Table 1. Areas of LULC types in Somodo watershed (1985 – 2017).

LULC category	1985		1995		1999		2005		2017	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	472	26	519	28	567	31	396	21	466	25
Forest	474	26	377	20	362	20	401	22	414	22
Grass	239	13	112	6	63	3	330	18	255	14
Home garden Agroforestry	663	36	839	45	856	46	721	39	713	39

Table 2. Rate and percentage change of LULCs in Somodo watershed.

LULC category	1985-1995		1995-1999		1995-1999		2005-2017		1985-2017	
	Rate (ha/yr)	%	Rate (ha/yr)	%	Rate (ha/yr)	%	Rate (ha/yr)	%	Rate (ha/yr)	%
Agriculture	47.7	10.1	47.7	9.2	-170.73	-43	70.11	17.7	-5.22	-1.1
Forest	-97.2	-20.5	-15.48	-4.1	39.51	9.8	12.6	3.2	-60.57	-12.7
Grass	-126.81	-53.2	-48.96	-43.8	266.85	80.9	-75.06	-22.8	16.02	6.7
Agroforestry	176.31	26.6	16.74	1.9	-135.63	-18.8	-7.65	-1.1	49.77	7.5

study area. On the other hand, during the entire study periods starting from 1985 to 2017, the smallest portion of the land in the study area was covered with grassland (Table 1). Grassland accounted for 239 ha (13%), 112 ha (6%), 63 ha (3%), 330 ha (18%) and 255 ha (14%) of the total area of Somodo watershed in the years 1985, 1995, 1999, 2005 and 2017 respectively. On the map of 1985, home garden agroforestry/settlement land predominates and followed by forestland, agriculture land, and grassland of the total area coverage. In 2017 home garden agroforestry/settlement land, still dominate the coverage followed by agriculture land.

The trend of LULC change in Somodo Watershed

Somodo watershed experienced different LULC changes between 1985 and 2017. The area of forestland, agricultural land, home garden agroforestry/settlement and grassland showed a fluctuating trend between the study periods (Figure 4). Forestland showed the largest decline with a rate of 60.57 ha and Home garden agroforestry/settlement showed the highest increase inclining by an estimated 49.77 ha in the period from 1985 to 2017 (Table 2).

In the period between 1985 and 1995 the land under Agriculture increased by 47.7 ha (10.1%) and the land under home garden Agroforestry/settlement increased by 176.31 ha (26.6%), while forestland decreased by 97.2 ha (20.5 %) and grassland decreased by 126.81 ha (53.2%) (Figure 4 and Table 2). As reported from discussion and interview with focus groups and key informants the rise of agriculture and home garden Agroforestry with the settlement between 1985 and 1995 was linked with resettlement program from other areas and the influx of illegal migrants during the Derg regime around 1985. As stated by FGDs and KIIs the enormous reduction of vegetation between 1985 and 1995 was during the transitional period (1990/1991). It is for the reason that during this transitional period, the new government was not settled well and no one was in charge of protecting the natural resources of the country.

The efforts to improve agricultural systems by the Derg regime similarly played a great role in the expansion of agriculture. Following the end of the battle, local peoples participating in the battle were returned to their previous area and consequently cleared the forest and convert grasslands into agriculture and home garden agroforestry to satisfy their livelihood necessities. The result for the second period (1995-1999) indicated that the land under forest and grassland continued to decrease by 15.48 ha (4.1%) and 48.96 (43.8%), the land under agriculture and home garden agroforestry/settlement continued to increase by 47.7 (9.2%) and 16.74 (1.9%). The increment of agriculture during this period is due to the starting of ADLI around 1999/2000. The reason for other LULC types changes are due to the same reason with the second period as the gap between 1995 up to 1999 is 4 years too short for other changes to come.

The result for the third period (1999-2005) indicated that the land under forest and grassland increased by 39.51 ha (9.8%) and 266.85 ha (80.9%) respectively as compared to the second period (1995 - 1999). During this period grassland was increased at the expense of other LULC categories mainly agriculture and HG agroforestry/ settlement. This is due to that after the high conversion of

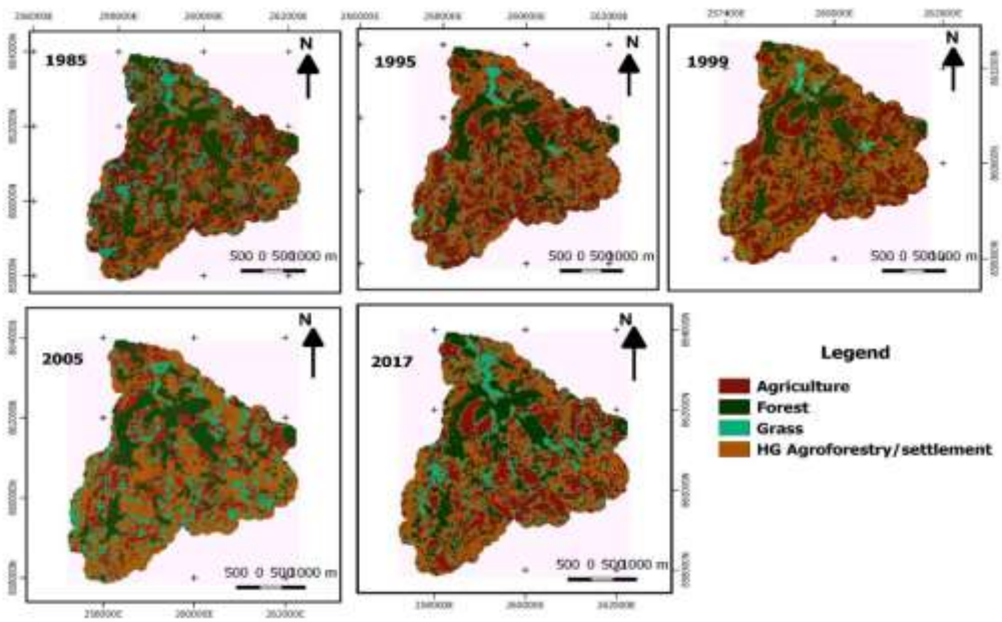

Figure 3. Map of LULC types of Somodo watershed produced based on satellite images obtained from USGS and GLCF.

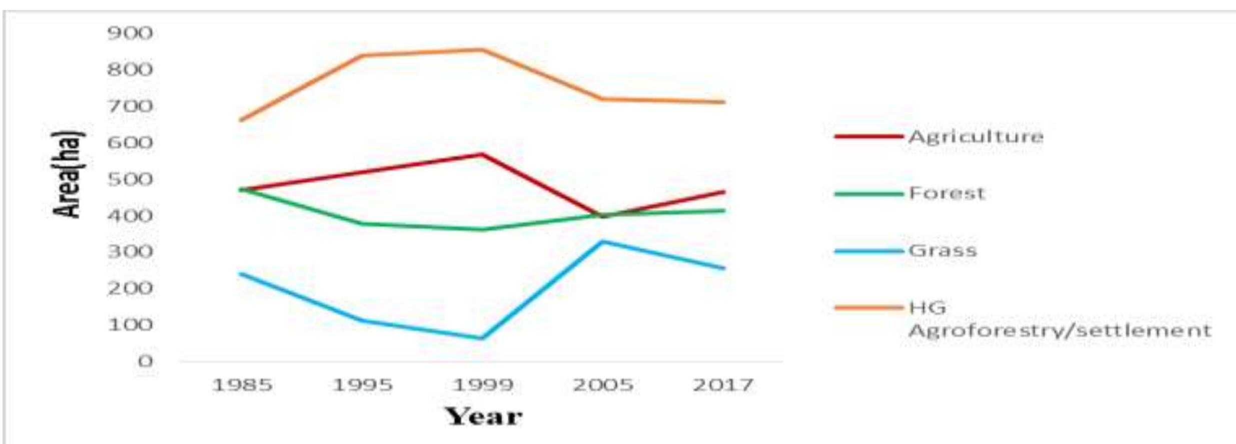

Figure 4. The trend of LULC change in Somodo watershed.

forestland into agriculture the land becomes degraded and soil erosion occurred. Therefore, that to regenerate the soil fertility and to get more yields from the cropland, conversion of agriculture into grassland were done by fallowing the land for some years. On the other hand, agriculture and home garden agroforestry/settlement decreased in the third period due to the occurrence of soil erosion and the following of croplands.

Increase in forest resource during this period linked todifferent factors. The foremost reason is integrated and participatory forest management project was implemented in the country by the current government around 1999-2005/2006. Also as a result of the starting of ADLI (Agricultural Development Led Industry) with the aim of regenerating the soil fertility, to decline soil erosion, to raise crop productivity and gaining the fertility of the land by planting trees and leaving the croplands to grow grass. Therefore, those extensive plantations were carried out by the project and by smallholder farmers in the watershed. In agreement to the result of this study, Tesfaye et al. (2014) reported increment in forest cover between 1986 and 2008 in GilgelTekeze catchment, Northern Ethiopia. As the researcher appealed the increment in forest, cover was due to tree plantation activities. According to Desalegn et al. (2014), the rise in forest cover between 1975 and 1986 is owing to the implementation of huge afforestation campaign by the Derg government in the central highlands of Ethiopia.

According to the discussant of FGD, the increment in grassland was an outcome of shifting cultivation practices subsidized for conversion of agricultural land to grassland. It was also clarified that in some cases, cultivated lands also permanently left for grazing. In line with Shiferaw, (2011) expansion of grassland at the expense of forest and shrubland in BorenaWoreda of South Wollo Highlands, between 1985 and 2003. Alemayehu (2015) also reported the expansion of grassland at the expense of agricultural land in FagitaLekomaWoreda, Awi Zone, Northwestern Ethiopia between 1973 and 2015. The fourth period (2005-2017) result shows that agricultural land increased by 70.11 ha (17.7%) and forestland increased by 12.6 ha (3.2%). In contrast, grassland and home garden agroforestry/ settlement decreased by 75.06 ha (22.8%) and 7.65 ha (1.1%). According to discussants of Somodo watershed, agricultural land increased at the expense of grassland, due to that the degraded cropland fallowed in the past for grasses to grow regenerates soil fertility.

Consequently, farmers in the study area converted the land back into agriculture. In line with this study, Tefera and Sterk (2008) reported from the western highlands, the Fincha watershed cropland was endlessly expanding from comparatively flat areas in 1957 and 1980 too steep lands in 2001 at the expense of grazing land.

The starting of Participatory integrated watershed management project by Jimma Agricultural Research Center (JARC) in 2011 was the reason for forestlands to increase as the information obtained from the discussion in the study area. Similar to this study Tefera and Sterk (2008) stated a minor increase of forest cover from 1980 to 2001, probably to be due to reforestation activities carried out since the 1980s in Fincha'a watershed, western Ethiopia. During the 32 year period between 1985 and 2017, the proportion of area covered by forest and agriculture was decreased by 60.57 ha (12.7%) and 5.22 ha (1.1%) respectively. In contrast, home garden agroforestry/settlement and grassland were increased by 49.77 ha (7.5%) and 16.02 ha (6.7%) respectively (Table 2). The major findings from the analysis of Landsat images revealed a great reduction in the area of forest and a corresponding increase in the area of home garden agroforestry/settlement over the 32-year period. Focus group discussions and interviews conducted in Somodo watershed also support this trend showing an increase in land under home garden Agroforestry/settlement over time, with a corresponding reduction in land under forest and grass cover. This is because, during the last time the area was characterized as relatively low population some extent undisturbed environmental condition. However, the largest part of lands that were covered by forest before 32 years is now replaced by home garden Agroforestry and settlement. In agreement to the findings of this research, Dessie and Christiansson (2008) also reported a significant forest decline in parts of the south Central Rift Valley region due to the introduction of coffee farming between the late 1800s to about 1930. However, it is contrary to the work of Alemayehu (2015) who reported the expansion of forestland between 1973 and 2015 with the corresponding reduction of cultivated land in Fagita Lekoma Woreda, Awi Zone, Northwestern Ethiopia.

Generally, the information obtained from FGD participants and key informants, confirmed that the major reasons for the continual expansion of home garden agroforestry/settlement between 1985 and 2017 in the watershed are rapid population growth, illegal logging and fuel wood collection, gradual change in the economic activities of communities in the area, soil erosion, resettlement policies, an institution such as the appearance of research center. In addition, the reason for the increment of grassland between 1985 and 2017 was low productivity of cultivated lands. The farmer's awareness of. Over 87.3 ha of grassland in 1985 was again used for crop production in 2017 (Table 3). In addition, the afforestation programs in the study area contributed its share for the conversion of grassland into Agroforestry during the fourth study period, which is as much as 88.02 ha (Table 3). The farmers are giving more attention for covering of their land by trees and cash crops because of its economic advantage.

Land Use/Land cover change matrix

Results of the LULC change matrix analysis are presented under Appendix Table 1. During the study period between 1985 and 2017 about 901.35 ha (48.7%) of the study area landscape remained unchanged. This implies 946.4 ha (51.2%) of the total landscape of the study area was converted from one LULC type to the other (Table 3). From all LULC types, grassland experienced the lowest persistence, whereas home garden Agroforestry land was the most persistent cover type. The net persistence for forest and grassland was large (relatively far from zero), whereas agriculture and home garden agroforestry/settlement were closer to zero (Table 3). The net persistence closer to zero indicates the higher tendency of LULC types to persist rather than decline or increase.

Land Use/Land cover change projection

The table below shows the statistic of LULC projection for 2029. As indicated from (Table 4), Agroforestry/ settlement still maintains the highest position in the class whilst grassland retains its least position in 2029. Agricultural land takes up the second position, followed by Forestland. The state of 2029 LULC depends only on

Table 3. LULC change matrix between 1985 and 2017.

LULC category	Agriculture	Forest	Grass land	Agro forestry	Total	Loss
Agriculture	**205**	24	89	153	472	266
Forest	17	**302**	23	132	474	173
Grass land	87	9	**54**	88	239	184
Agroforestry	157	78	88	**340**	663	323
Summary					**901.35**[1]	
Total 2017	466	414	255	713	1848	
Gain	261	112.05	200.34	373.05		
Net change (NC)[2]	-5.22	-60.57	16.02	49.77		
Net persistence (Np)[3]	-0.02541630	-0.20065593	0.29519071	0.146451271		

[1]sum of diagonals and represents the overall persistence, 2 NC = gain−loss. 3 NP = net change/diagonals of each class.

Table 4. Projected LULC for 2029 and Predicted Change between 2017 and 2029 in Somodo Watershed.

Years	Classes	Agriculture	Forest	Grass	Agroforestry	Total
2029	Area(ha)	557.62	434.43	154.64	701.1	1848
	Area (%)	30.18	23.51	8.37	37.94	100.00
2017-2029 change	Area(ha)	91.24	20.52	-99.97	-11.79	
	Area (%)	19.6	4.9	-39.3	-1.65	

the state of 2017 and the time is uniform in duration between 2005-2017 and 2017-2029. As stated by Araya, (2009) trend of the LULC change in the future time can be detected when predicted LULC at time t2 compared with LULC of the base year at time t with reference to the class area metrics. Therefore as compared to the base year 2017 in 2029 agriculture and forest are predicted to increase by 91.24 ha and 20.52 ha respectively, while grassland and home garden Agroforestry/settlement are predicted to decrease by 99.97 ha and 11.79 ha respectively. The growth of agriculture is expected to come largely at the expense of grassland and home garden Agroforestry/settlement respectively. This is because it is seen in the probability matrix (Appendix Table 1) the probability of these LULC categories to change to agriculture is high i.e. 0.5485and 0.2048 with this order.

Drivers of LULC changes in Somodo watershed

LULC change in the Somodo watershed is a result of several proximate and underlying causes.

Proximate (Direct) causes

The FGD participants and key informants in the study area indicated that five major proximates (direct) driving forces appear to explain a large part of LULC change in Somodo watershed. These are: (i) illegal logging and fuelwood extraction (ii) Expansion of plantation (iii) expansion of settlement (iv) agricultural expansion (v) and construction of infrastructures such as school, road and research center (Table 5).

In the watershed, Kalkidan et al. (2017) reported average annual biomass fuel consumption per households was 4813.48kg/year which is estimated total per capita consumption per day was12kg. The per capita consumption of wood was higher than estimated (2.6kg) provided by the cooperation agreement in the energy sector (CESEN, 1987). However, the heavy reliance on biomass energy has become a threat to forest ecosystems and a major cause of land degradation in the area. On the other hand, some farmers clear the forest and change the land into agricultural activities due to the expansion of settlement in the study area. After the appearance of participatory integrated watershed management by Jimma Agricultural Research Center in the watershed, forest/plantation cover showed improvement.

Underlying causes

The above-mentioned proximate causes were triggered by different underlying causes of LULC change. As shown in the Figure 6 population of ManaWoreda

Table 5. Summary of proximate causes of LULC change in Somodo watershed.

Drivers	Frequency	%	Rank
Agricultural expansion	7	14.6	4
Expansion of settlement	8	16.7	3
Expansion of plantation	9	18.75	2
Illegal logging and fuelwood collection	11	22.92	1
Fire	2	4.17	7
Overgrazing	5	10.42	6
Infrastructure	6	12.5	5
Total	12	100	

Table 6. Summary of underlining drivers of LULC change in the study area.

Drivers category	Frequency	%	Rank
Demographic	11	28.95	1
Economic	9	23.7	3
Technological	3	7.9	5
Institution and policy	10	26.32	2
Biophysical	5	13.16	4
Total	12	100	

increased with time. According to the discussants in the watershed, population growth is the major driver compared to others. In line with this study, Binyam (2015) stated that agricultural expansion got more severe in the 1980s when large numbers of people moved to South West Ethiopia in the scope of organized resettlement programs.

According to key informants and FGDs during the Derge regime, the resettlement policy and villagization policy or which is called "Sefera" contributed to the expansion of settlements and agriculture. The other main policy contributed to the agricultural expansion in the study area during the Derge regime was "Land to Tiller" where by privatization of communal lands was carried out. National and regional policies on land use and economic development such as infrastructural development (such as roads and schools, etc.), attaining food self-sufficiency through investment on agriculture are the other factors contributing to LULC change.

Lack of proper land use plans is also the policy related driver of forest and grassland cover change. It is characterized by the encroachment of vegetated lands especially forest and grasslands for settlement and agriculture, cultivation of steep slope and the opening of very dense forest areas through road construction. In order to survive, farmers in the study area convert forestlands in to agriculture and agroforestry, since as the information gained from FGD and KII revealed that the farmers of somodo watershed does not have alternative income source other than coffee and Khat from their home garden agroforestry's yield, the agricultural crop yields, the firewood and the charcoal they vend. As the information gathered from KII and FGD soil erosion is the biophysical driver of LULC change in the study area. Due to agricultural expansion, illegal logging and fuelwood extraction forestlands has been degraded. When the forestland becomes degraded, the soil loses its protective layer, so that wind and water erosion easily occur.

CONCLUSION AND RECOMMENDATION

Somodo watershed has been experiencing different LULC changes. The main finding of this study revealed that a fluctuated change of LULC types between 1985 and 2017 due to some proximate and underlying drivers in the study area. During 32 years period home garden agroforestry/settlement and grassland were increased respectively, with a corresponding decline in the area of forestland and agriculture. Findings of the LULC change analysis between 2005 and 2017 showed expansion of agriculture and forestland while reduction of grassland and home garden agroforestry with differing rate was observed. In 2029, agriculture and forestland are expected to increase respectively. On the other hand grassland and home garden, agroforestry/settlement are predicted to shrink respectively. According to discussants of Somodo watershed agricultural land increased at the expense of grassland, due to that the degraded cropland which was followed in the past for grasses to regain soil fertility consequently, farmers in the study area converted the land back into agriculture.

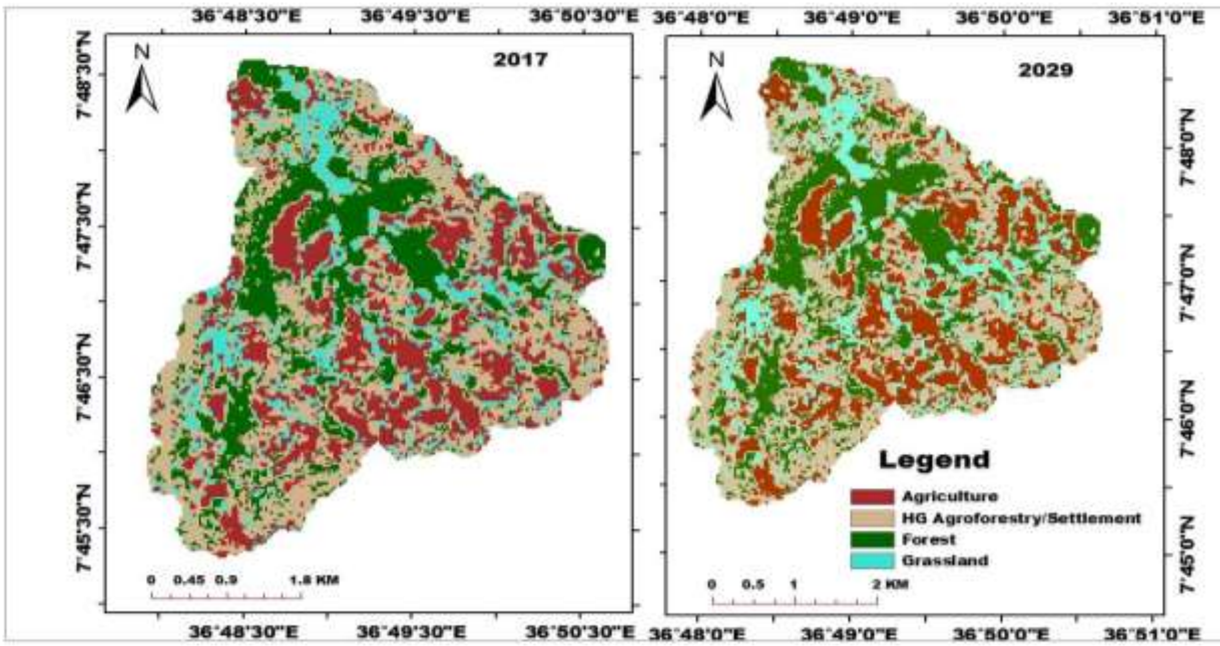

Figure 5. Classified image (2017) & projected image (2029) map of LULC change in Somodo watershed.

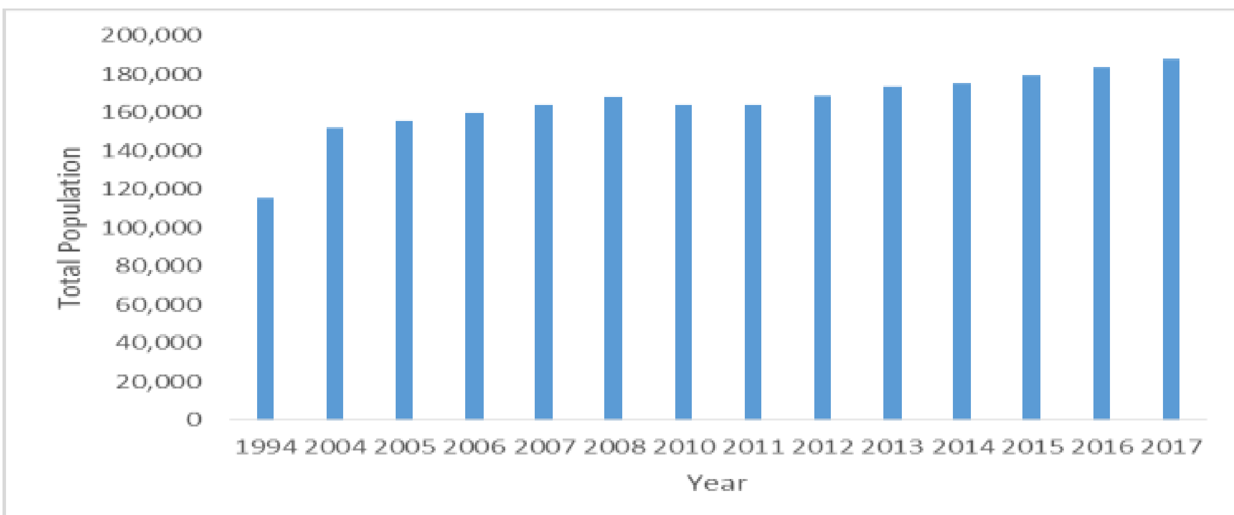

Figure 6. Population growth in ManaWoreda from (1994-2017) derived from Central Statistical Agency (CSA).

LULC change in Somodo watershed is a result of different interactions between proximate and underlying causes. The major proximate driving forces of LULC change in the study area are illegal logging and fuelwood extraction, expansion of plantation, expansion of settlement, agricultural expansion, and construction of infrastructures. On the other hand, the major underlying driving forces are Demographic, Economic, Technological, Institution and policy and Biophysical factors were identified by the key informant and focus group discussants of this study.

The study highly recommends Participatory Forest Managementstarted by Ethiopian Institute of Agricultural Research, Jimma agricultural research center should be practiced by all stakeholders to improve forest coverage of the watershed. This study also suggests further study on the impacts brought by land use land cover change (especially, watershed hydrology and climate), since this study addressed only the change in land use land cover change and driving forces behind the change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Agarwal C, Green GM, Grove JM, Evans TP, Schweik CM (2002). A Review and Assessment of Land-Use Change Models: Dynamics of Space, Time, and Human Choice. General Technical Report NE-297. Newtown Square, Pennsylvania: U.S. Department of Agriculture, Forest Service, Northeastern Research Station 61 p.

Alemayehu F, Taha N, Nyssen J, Girma A, Zenebe A, Behailua M, Deckers S, Poesen J (2009). The impacts of watershed management on land use and land cover dynamics in Eastern Tigray (Ethiopia). Resources, Conservation and Recycling 53:192-198.

Alemayehu B (2015). GIS and Remote Sensing Based Land Use/Land Cover Change Detection and Prediction in FagitaLekomaWoreda, Awi Zone, North Western Ethiopia. MSc. thesis, Addis Ababa University, Ethiopia.

Amanuel A, Mulugeta L (2014). Detecting and Quantifying Land Use/ Land Cover Dynamics in NaddaAsendabo Watershed, South Western Ethiopia.Journal of Environmental Science 3 (1):45-50.

Anderson JR, Hardy EE, Roach JT, Witmer RE (1976). A land use and land cover classification system for use with remote sensor data; Geological Survey Professional Paper 964. Washington.

Araya YH (2009). Urban Land Use Change Analysis and Modeling: a Case Study of Setúbal and Sesimbra, Portugal. MSc. thesis, University of Münster.

Assefa B (2012). Land use /land cover change and its effect on Existing forest condition, the case of Shakiso Natural forest, southeast Ethiopia. Hawassa University, Wondo Genet College of forestry and natural resources, Wondo Genet, Ethiopia.

Bekele M (2003). Forest property rights, the role of the state, and institutional exigency: the Ethiopian experience. Ph.D. Thesis.Department of Rural Development Studies, Swedish University of Agricultural Sciences, Uppsala.

Belay T, 2002. Land-Cover/Land-Use Changes in the Derekolli Catchment.Eastern Africa Social Science Research Review 18(1):1-20.

Bertelsmann Stiftung's Transformation Index (BTI) (2016). Ethiopia Country Report.Gütersloh: Bertelsmann Stiftung, 2016.

Binyam A (2015).The Effect of Land Use Land Cover Change on Land Degradation in the Highlands of Ethiopia. Department of Soil and Water Resources Management, College of Agriculture, Wollo University: Journal of Environment and Earth Science 5(1).

Central Statistics Authority of Ethiopia (2012).Reports of the 1994 and 2007 Population and Housing Census and the 2012 Inter-censual Survey.

Congalton RG (1991). A review of assessing the accuracy of classifications of remotely sensed data, Remote Sensing of Environment 37:35-46.

Cooperation Agreement in the Energy Sector (CESEN) (1987).Rural-urban energy survey of 81 settlements Technical report7.Ministry of mines and energy of Ethiopia and CESEN-Ansaldo/ Finmeccanica group. Addis Ababa, Ethiopia.

Dale V (1997).The relationship between land use change and climate change.Ecological Applications 7(3):753-769.

De Sherbinin A (2002). Land-use and land-cover change, a CIESIN thematic guide. Center for International Earth Science Information Network of Columbia University, Palisades, NY.*http://sedac.ciesin.columbia.edu/tg/guide_frame.jsp?rd=LU&ds=1.*Accessed 20 May 2006

Desalegn T, Cruz F, Kindu M, Turrión MB, Gonzalo J (2014). Land-Use/Land-Cover (LULC) Change and Socioeconomic Conditions of Local Community in the Central Highlands of Ethiopia.*International* Journal of Sustainable Development and World Ecology.

Dessie G, Christianson C (2008). Forest decline and its causes in the South-Central Rift Valley of Ethiopia: human impact over a one hundred year perspective. Ambio 37:263-271

Devereux S (2000). Food insecurity in Ethiopia. A discussion paper for DFID. Institute of Development Studies, Sussex .

Food and Agriculture Organization (FAO) (2005). Global Forest Resources Assessment.Progress towards sustainable forest management.*FAO* forestry paper 147*.* Rome*.*

Fashona M, Omojola A (2005). Climate change, human security and communal clashes in Nigeria. In: Int'l workshop on human security and climate change. Oslo, Norway.

Grübler A (1994). Technology. In Changes in Land Use and Land Cover: A Global Perspective pp. 287-328. Edited by W.B. Meyer and B.L. Turner. Cambridge University Press, Cambridge.

Ioannis M, Meliadis M (2011). Multi-temporal Landsat image classification and change analysis of land cover/use in the Prefecture of Thessaloniki, Greece. Department of Forest Management and Remote Sensing, School of Forestry and Natural Environment, Aristotle University of Thessaloniki: NAGREF-Forest Research Institute, GR570 06.

Jensen JR (2003). Introductory Digital Image Processing, a Remote Sensing Perspective.3rd edition pp 505-508.

Kalkidan F, Yalemtsehay D, Gizaw T (2017). Assessment of Woody and Non-Woody Fuel Biomass Resource Availability and Rate of Consumption in the Somodo Model Watershed South-Western Ethiopia.Jimma Agricultural Research center, P.O. Box 192, Jimma, Ethiopia.Journal of Environment and Earth Science 7(4).

Kindu M, Schneider T, Teketay D, Knoke T (2013). Land use/land cover change analysis using object-based classification approach in Munessa-Shashemene Landscape of the Ethiopian Highlands. Remote Sensing 5(5): pp.2411-2435.

Lambin E, Turner B, Geist H, Agbola S, Angelsen A, Bruce J, Coomes O, Dirzo R, Fischer G, Folke C, George P, Homewood K, Imbernon J, Leemans R, Li X, Moran E, Mortimore M, Ramakrishnan P, Richards J, Skånes H, Steffen W, Stone G, Svedin U, Veldkamp T, Vogel C, Xu J (2001). The causes of land-use and land-cover change: Moving beyond the myths. Global Environmental Change 11:261-269. DOI: 10.1016/S0959-3780(01)00007-3

Lambin EF, Geist HJ (2003). Global land-use and land-cover change: what have we learned so far? Global Change News Letter (46):27-30.

Leh M, Bajwa S, Chaubey I (2011). Impact of land use change on erosion risk: an integrated remote sensing, geographic information system, and modeling methodology. Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville, AR, USA.

Lewis S (2006). Tropical forests and the changing earth system. Philosophical Transactions of the Royal Society.*Biological Sciences* 361(1465**)**:195-210.

Lupo F, Reginster I, Lambin EF (2001). Monitoring land-cover changes in West Africa with SPOT vegetation: impact of natural disasters in 1998–1999. International Journal of Remote Sensing Sens 22:2633-2639.

Midagso J (2008). Land use/Land cover change and its impact on agricultural productivity in Fande catchment of Shalla District, West Arsi zone of Oromia Regional state. MSc theses, Hawassa University, Wondo Genet College of Forestry and Natural Resources, Wondo Genet, Ethiopia.

Murphree MW, Cumming DHM (1993). Savanna land use: policy and practice in Zimbabwe. In The World's Savanna's: Economic Driving Forces, Ecological Constraints and Policy Options for Sustainable Land Use*.* pp. 139-178. Edited by M.D. Young and O.T. Solbrig. UNESCO and Parthenon Publishing Group, Paris.

Muzein B (2008). Remote sensing and GIS for land cover/land use change detection and analysis in the semi-natural ecosystem and agriculture landscapes of the Central Ethiopian Rift Valley. FakultätForst- Geo-und HydrowissenschaftenInstitutFernerkundung

Olson J, Misana S, Campbell J, Mbonile M, Mugisha S (2004). The spatial patterns and root causes of land use change in East Africa. LUCID Project Working Paper 47.

Ozbakir B, Bayram B, Acar U, Uzar M, Baz I, Karaz I (2007). The synergy between shoreline change detection and social profile of waterfront zones: a case study in Istanbul. In: Conference paper at the international conference for photo grammetry and remote sensing, Istanbul, Turkey 16-18 May.

Peesapati SM, Harinarayan T (2015). Accuracy Assessment of Land Use Classification A Case Study of Ken Basin. Department of

WRDM, IIT Roorkee, India 2(12):1199-1206.
Petit C, Scudder T, Lambin E (2001). Quantifying processes of land-cover change by remote sensing: resettlement and rapid land-cover changes in southeastern Zambia. International Journal of Remote Sensing 22:3435-3456
Reed D (1996). Structural Adjustment, the Environment, and Sustainable Development. Earth Scan Publications, London.
Rockwell RC (1994). Culture and cultural change. In Changes in Land Use and Land Cover: A Global Perspective. Edited by W.B. Meyer and B.L. Turner. Cambridge University Press, Cambridge pp. 357-381.
Selamyihun K (2004). Using Eucalyptus for soil and water conservation on the highland Vertisols of Ethiopia.Ph.D. Thesis, Wageningen University, the Netherlands.
Shiferaw A (2011). Evaluating the Land Use and Land Cover Dynamics in BorenaWoreda of South Wollo Highlands, Ethiopia.Journal of Sustainable Development in Africa 13 (1):87-107.
Solomon M (2016). Effect of Land Use Land Cover Changes on the Forest Resources of Ethiopia.International Journal of Natural Resource Ecology and Management 1(2):51-57. doi: 10.11648/j.ijnrem.20160102.16
Tefera B, Sterk G (2008). Hydropower-induced land use change in Fincha'a watershed, western Ethiopia: Analysis and impacts. Mountain Research and Development 28:72-80.
Tekle K, Hedlund L (2000). Land cover changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. Mountain Research and Development 20:42-51.
Tesfaye S, Guyassa E, Joseph Raj A, Birhane E, Wondim GT (2014). Land use and land cover change, and woody vegetation diversity in the human-driven landscape of GilgelTekeze Catchment, Northern Ethiopia. International Journal of Forestry Research 2014.
Verburg P, Soepboer W, Veldkamp A, Limpiada R, Espaldon V, Mastura S (2002). Modeling the spatial dynamics of land use: the CLUE-S model.Environ Manage 30(3):391-405
Wogayehu B (2003). Economics of Soil and Water Conservation: The theory and empirical application to subsistence farming in eastern Ethiopia high lands. Doctoral Thesis, Swedish University of Agricultural Sciences, Uppsala.
Woldamlak B (2002). Land Cover Dynamics since the 1950s in Chemoga Watershed, Blue Nile Basin, Ethiopia.
Zubair AO (2006). Change detection in land use and land cover Using remote sensing data and GIS: A case study of Ilorin and its environs in Kwara State. Unpublished (Master's thesis), University of Ibadan, Ibadan.

Appendix

Land Use/Land Cover Change Matrixes

Appendix Table 1. LU/LCC matrix between 1985 and 1995.

LU/LC category	Agriculture	Forest	Grass land	Agroforestry	Total
Agriculture	**259.38**	10.44	21.96	179.82	471.6
Forest	6.57	**318.51**	4.14	145.26	474.48
Grass land	109.8	0.81	**36.72**	91.26	238.59
Agroforestry	143.55	47.52	48.96	**423.09**	663.12
Total	519.3	377.28	111.78	839.43	1847.79

Appendix Table 2. LU/LCC matrix between 1995 and 1999.

LU/LC category	Agriculture	Forest	Grass land	Agroforestry	Total
Agriculture	**390.96**	0	8.1	120.24	519.3
Forest	0.45	**316.71**	0.36	59.76	377.28
Grass land	22.86	0.81	**24.12**	63.99	111.78
Agroforestry	152.73	44.28	30.24	**612.18**	839.43
Total	567	361.8	62.82	856.17	1847.79

Appendix Table 3. LU/LCC matrix between 1999 and 2005.

LU/LC category	Agriculture	Forest	Grass land	Agroforestry	Total
Agriculture	**215.82**	0.36	189.63	161.19	567
Forest	8.28	**317.7**	3.06	32.76	361.8
Grass land	10.89	0.63	**23.94**	27.36	62.82
Agroforestry	161.28	82.62	113.04	**499.23**	856.17
Total	396.27	401.31	329.67	720.54	1847.79

Appendix Table 4. LU/LCC matrix between 2005 and 2017.

LU/LC category	Agriculture	Forest	Grass land	Agroforestry	Total
Agriculture	**171.54**	14.67	99.99	110.07	396.27
Forest	0.45	**320.58**	3.6	76.68	401.31
Grass land	174.6	5.94	**53.82**	95.31	329.67
Agroforestry	119.79	72.72	97.2	**430.83**	720.54
Total	466.38	413.91	254.61	712.89	1847.79

Appendix Table 5. Transitional probability area matrix derived from LU/LC map of 2005 and 2017.

LU/LC category	Agriculture	Forest	Grass	Agroforestry	Total
Agriculture	171.27	18.9	106.6	144.09	440.86
Forest	36.37	324.63	5.94	125.01	491.95
Grass	205.62	4.5	35.28	74.61	320.01
Agroforestry	144.36	86.4	6.82	357.39	594.97
Total	557.62	434.43	154.64	701.1	1847.79

Appendix Table 6. Transitional probability matrix derived from LU/LC map of 2005 and 2017.

LULC category	Agriculture	Forest	Grass	Agroforestry
Agriculture	**0.3684**	0.0407	0.2809	0.3099
Forest	0.0018	**0.6785**	0.0144	0.3053
Grass	0.5485	0.0176	**0.1392**	0.2947
Agroforestry	0.2048	0.1225	0.1657	**0.507**

Error Matrixes

Appendix Table 7. Error matrix for the LU/LC map of 1985.

Reference data						
Classified	**Agriculture**	**Forest**	**Grassland**	**Agroforestry**	**Total**	**Users accuracy** (%)
Agriculture	36	0	0	6	42	85.71
Forest	1	28	0	5	34	82.35
Grassland	0	1	15	0	16	93.75
Agroforestry	1	2	3	52	58	89.66
Total	38	31	18		63	
Producers Accuracy	94.74%	90.32%	83.33%		82%	
Overall Classification Accuracy = 87.33%						
KAPPA (K^) STATISTICS						
Overall Kappa Statistics = 0.8208						

Appendix Table 8. Error matrix for the LU/LC map of 1995.

Reference data						
Classified data	**Agriculture**	**Forest**	**Grassland**	**Agroforestry**	**Total**	**Users accuracy (%)**
Agriculture	36	0	0	1	37	97.30
Forest	0	37	0	1	38	97.37
Grassland	0	0	3	0	3	100.00
Agroforestry	3	7	0	62	72	86.11
Total	39	44	3		64	
Producers Accuracy	92.31%	84.09%	100.00%		97%	
Overall Classification Accuracy = 92.00%						
KAPPA (K^) STATISTICS						
Overall Kappa Statistics = 0.8781						

Appendix Table 9. Error matrix for the LU/LC map of 1999.

Reference data						
Classified data	**Agriculture**	**Forest**	**Grassland**	**Agroforestry**	**Total**	**Users accuracy (%)**
Agriculture	46	0	0	1	47	97.87
Forest	2	31	0	0	33	93.94
Grassland	0	0	4	0	4	100.00
Agroforestry	1	3	2	60	66	90.91
Total	49	34	6		61	
Producers accuracy	93.88%	91.18%	66.67%		98%	
Overall Classification Accuracy = 94.00%						
KAPPA (K^) STATISTICS						
Overall Kappa Statistics = 0.9101						

Appendix Table 10. Error matrix for the LU/LC map of 2005.

Reference data						
Classified data	**Agriculture**	**Forest**	**Grassland**	**Agroforestry**	**Total**	**Users accuracy (%)**
Agriculture	21	0	0	1	22	95.45
Forest	1	37	0	2	40	92.50
Grassland	0	0	19	5	24	79.17
Agroforestry	5	4	0	55	64	85.94
Total	27	41	19		63	
Producers Accuracy	77.78%	90.24%	100.00%		87%	
Overall Classification Accuracy = 88.00%						
KAPPA (K^) STATISTICS						
Overall Kappa Statistics = 0.8289						

Appendix Table 11. Error matrix for the LU/LC map of 2017.

Reference data						
Classified data	**Agriculture**	**Forest**	**Grassland**	**Agroforestry**	**Total**	**Users accuracy (%)**
Agriculture	42	0	2	4	48	87.50
Forest	1	30	0	0	31	96.77
Grassland	1	0	12	2	15	80.00
Agroforestry	4	4	0	48	56	85.71
Total	48	34	14		54	
Producers Accuracy	87.50%	88.24%	85.71%		89%	
Overall Classification Accuracy = 88.00%						
KAPPA (K^) STATISTICS						
Overall Kappa Statistics = 0.8303						

Definition of LULC

Appendix Table 12. Description of major LULC types identified in somodo watershed.

LULC types	Description
Forest	Vegetation cover that is dominated by woody species and naturally or artificially grown and has high cover density.
Agriculture	The cultivated plants that cover the land for certain season of the year and irregular reflectance due to variation in species composition includes areas allotted to rain-fed cereal crops (such as Corn, Barley, Chickpea, and Wheat).
Home garden agroforestry/settlement	Made to include areas allotted to cash crops (chat), coffee and horticultural crops particularly vegetables (such as onion, potato, and cabbage) and fruit trees (Mango, Avocado and orange) including some forest trees. Scattered settlements surrounded by home garden agroforestry are classified as home garden agroforestry/settlement since the low spatial resolution Landsat imagery fails to separate the scattered rural settlements with agroforestry lands.
Grassland	Grass-dominated the land. It has some uniformity in land coverage and thus possibly reflects solar radiation in a relatively uniform manner.

Related Journals: