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Review

Waste management in the case of Bahir Dar City near Lake Tana shore in Northwestern Ethiopia: A review

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Urbanization is a global phenomenon with more pronounced consequences on waste management in developing countries. The rate of infrastructure development is mostly outpaced by the rate of waste generation. Bahir Dar city, as a rapidly urbanizing city in the southern part of Lake Tana, is not an exception. On top of production of more wastes, the waste management practice is challenged by low prioritization of waste management, limited revenues for financing waste management with the ever-increasing population of this city. This paper reviewed the current waste management system in Lake Tana basin taking Bahir Dar as case. The mechanism of Bahir Dar municipality to coordinate the public and private sectors in the city has played a vital role in waste management. However, the daily monitoring of waste management by the community development section has not been sufficient. It is also observed that the liquid waste has an effect on the lake and its resources. Effective involvement of both private and public sectors should improve waste management and provide door-to-door collection and facilitate drainage disposable canals. Therefore, an integrated solid and liquid waste management practice should be implemented for the City Lake Tana basin and also for the surrounding environment. This has to include development plans for improving sustainable sanitation and disposal of the sewage system, and adopt the best practices of waste management for the City-Lake Tana basin ecosystem.

Key words: Development plan, finance, municipality, urbanization, wastes.

INTRODUCTION

Waste was an early problem of mankind, and a growing one that is of major concern to every nation of the world (Allende, 2009; Genemo and Yohanis, 2015). It is an issue mostly witnessed in urban areas as a result of high surge in population growth rate and increase in per capita income thus posing a danger to environmental quality and human health (Javaheri, 2006). The most common problems associated with improper management of solid waste include diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Jilani, 2002). In the previous old years', solid waste management systems have involved complex and multi- faceted trade-offs among a plethora of technological alternatives, economic

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instruments, and regulatory frameworks. These changes resulted in various environmental, economic, social, and regulatory impacts in waste management practices which not only complicate regional policy analysis, but also reshape the paradigm of global sustainable development (Ana et al., 2010).

Municipal solid waste management has thus become a major issue of concern for many underdeveloped nations, especially as populations increase (Bartone, 2000). The problem is compounded as many nations continue to urbanize rapidly. For instance, 30 to 50% of population in most developing countries is urban (Thomas, 1998) and in many African countries, the growth rate of urban areas exceeds 4% (Senkoro, 2003; Samuel and Enoch, 2014). When the governments of African countries were asked by the World Health Organization to prioritize their environmental health concerns, results revealed that solid waste was identified as the second most important problem (after water quality), less than 30% of urban populations have access to proper and regular garbage removal (Senkoro, 2003; Samuel and Enoch, 2014).

The U.S. Environmental Protection Agency issued many regulations and limitations to control unfriendly environment projects, among this regulation one is landfill site criteria, and also many agencies in different countries of the developed world were established to control this process (EPA, 1996). Developing countries just started to establish such agencies and institutions in this field (PAEA, 2006). The issue of landfill site selection is complicated and time consuming. During the last few decades and particularly when environmental planning emerged this issue became systematic and technical. The evolution of GIS made this field much easier and manageable. GIS has very distinguishing, powerful functions and it is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analyses and displays information according to user-defined specification as a result, can play an important role in decision making and planning process (Daneshvar et al., 2005). The fundamental analytical function of a GIS based spatial decision support system include query analysis, proximity or buffer analysis, overlay analysis, neighbourhood analysis and network analysis. Various combinations of these functions are commonly used during the geographical data analysis process (Bartone, 2000).

In Africa, rapid urban growth since the 1960s has put pressure on land resources within the areas surrounding cities, and has led to increased generation of waste. Although, cities function as the engine of growth in most developing countries by providing job opportunities, education, knowledge and technology and ready markets for industrial and agricultural products, unprecedented urban growth places enormous stress on natural resources, existing amenities and cause environmental deterioration (Edward 2008). The problem is aggravated by the open dump nature of disposing waste, especially in the slum areas of most African cities (Hammer, 2003). Traditionally, administrations in African states permitted uncontrolled dumping in abandoned quarry sites with no provision for sanitary landfill, causing huge health problems (Martin, 1992; Hammer, 2003). A large part of the problem is inadequate financial and data resources for site selection and management (Mwanthi et al., 1997).

Waste management is an all-encompassing term which describes several distinct processes. It includes the elimination or reduction of waste, recycling of waste material, the treatment and distraction of waste, that is, physically destroying, chemically detoxifying or otherwise rendering waste permanently harmless and disposing or depositing the material into the air, water or land (Ward and Dubos, 1972). Most of the municipal waste models identified in the literatures are decision support models and they are based on cost benefit analysis, life cycle assessment and multicriteria decision making (Morrissey and Browne, 2003).

The Federal Democratic Republic of Ethiopia Solid Waste Management (FDRE SWM) Proclamation No. 513 (2007) defines Solid Waste and Solid Waste Management (SWM) as follows: 'Solid Waste' implies anything that is neither liquid nor gas and is discarded as unwanted. 'Solid waste management' means the collection, transportation, storage, recycling or disposal of solid waste, or the subsequent use of a disposal site that is no longer operational. The term 'municipal solid waste' (MSW) covers solid wastes generated by households, commercial and industrial premises like shops, hotels, garages and agriculture, by institutions such as schools, hospital care homes and prisons and from public spaces such as streets, bus stops, parks and gardens (Christian, 2012).

As urbanization continues, solid waste management (SWM) becomes a major public health and environmental threat in urban areas. The daily life in industrialized nations can generate several pounds of waste per consumer, not only directly in home, but also indirectly in factories (Sarker et al., 2012). The problem for these societies, with their ever greater variety, amount and durability of refuse, is getting more serious. However, today, developed nations use solid waste as a multi dollar business and they can manage it to an acceptable level. On the contrary, third world countries face particular challenges in the management of solid waste, as in other aspects of environmental management (Eshun, 2002).

Therefore, even though SWM is nowhere adequately executed and is a global problem, municipalities from the developing countries are highly faced with this problem and as long as life has existed in this world, the disposal of waste has been a problem (Eshun, 2002). Agrawal (2002) has argued that collection of solid waste in urban areas is difficult and a complex job because the generation of waste from different sources in a diffuse process complicate the collection task. Especially in under developed countries, the problem of disposal of

waste is both difficult and unsolved which further leads to several illnesses caused by infectious and parasitic diseases.

According to Forum for Environment (2010), one of the challenges that the Ethiopian cities such as Bahir Dar faces is the problem of sanitation in general and SWM in particular. Bahir Dar is among the well-known cities in Ethiopia and also a center of industrial and commercial activities. Adjacently, the daily waste generation rate in the city is also increasing from time to time (FFE, 2010). But the current waste collection capacity and disposal system is not matching with the rapid expansion of the city and its corresponding waste generation. It encounters problems like shortage of containers, road side waste bins, public toilets and the absence of proper and well prepared disposal site (FUPI, 2006). Hence, the people give no or little attention to SWM and they dump wastes along the roads and open spaces and beside this, most of the industries and health centers in the city do not start treating and/or reusing their waste properly (FUPI, 2006).

Waste water results from human and animal activities that are unwanted or hazardous. Humans pollute their environment with industrial and domestic wastes. In this case, whenever people do their daily activities, they bring negative effects on the environment. Environmental pollution increases as the density of people increases. Unsanitary environments are favourable for the outbreak and spread of different types of communicable diseases. Sewage may drain directly into major watersheds with minimal or no treatment. When untreated, it has serious implications on the quality of environment and health of aqueous biota and human beings. While some chemicals, especially heavy metals and pesticides pose grave risks even at low concentration and remain a threat for long periods due to their bioaccumulation in animal/human systems, pathogens cause a variety of debilitating ailments (Suryawanshi, 2013; Tchobanoglous et al., 1997; Tchobanoglous et al., 2003).

Most of the disease-causing agents that contaminate water and food come from human and animal wastes. Without proper management, they result in communicable diseases (Suryawanshi, 2013; Bhide and Sundaresan, 1980, 1983). More than half of the population of less developed countries does not have access to sanitation and more than 80% of the waste water generated is directly discharged into surface water bodies (Suryawanshi, 2013; Bansal et al., 2007). In Bahir Dar City, the sanitation facility coverage gap remains unacceptably large and lack of space for the construction of latrines is one of the reasons. The habit of open field disposal of liquid waste is one of the main causes of soil and water contamination and consequently a cause of many communicable diseases (Shekdar, 1999).

Waste is classified differently in different contexts. But in the context of subject of this review, the following classification is adapted from Suryawanshi (2013) as:

Biodegradable waste*:* which originates from plant and animal sources, which may be broken down by microbes or other living organisms. While these wastes may appear physically different, they tend to be fairly homogeneous in biochemical composition (carbohydrates, fats and proteins) for anaerobic digestion for biogas production by virtue of their high methane potential.

Hazardous/toxic waste: Is a waste with properties that make it potentially dangerous or harmful to human health or the environment. They can be the by-products of manufacturing processes, discarded used materials, or discarded unused commercial products (cleaning fluids, pesticides).

Recyclable waste: Is the removal of items from the waste stream to be used as raw materials in the manufacture of new products (paper, glass bottles and ceramics).

Inert waste: Is consists of construction and demolition waste, dirt, rocks, debris, etc. with relatively lower environmental impact by virtue of its non-biodegradability (Suryawanshi, 2013).

Ethiopia is one of the many developing countries in sub-Saharan Africa where municipal authorities are struggling to provide adequate urban environmental services. Bahir Dar is one the fastest growing cities in Ethiopia with a current population of > 290 thousand. If the current annual population growth rate of 6.6% continues, the city population will be doubled in just 11 years and need to have adequate solid and liquid waste management system (Christian, 2012). Currently, the city records steadily growing population number, which is due to a high birth rate and migration rate, and the waste generation is increasing (UNEP, 2010).

In this regard, a review survey was carried out on the solid waste generation rate, assessment of SWM systems, waste disposal and problems of SWM. Thus, this review revised documents from books, thesis works, annual waste management conference reports, journals on waste management, newsletters, abstracts and proceedings which can properly address the main factors that strongly hinder proper waste management and the extent to which community is aware of appropriate waste disposal systems in Bahir Dar city.

Solid waste management in Bahir Dar city

Description of the study area

Bahir Dar is the capital city of the Amhara National Regional State (ANRS) in northern Ethiopia. It is located near Lake Tana, the headwaters of the Blue Nile, and is a major tourist destination (Merkuz, 2014). Bahir Dar city has a flat plateau earth structure which is located at 11°36"North latitudes and 37°23"East longitudes. The naming of the city as Bahir Dar is connection with its

proximity to the two water bodies of Lake Tana and River Abay (Nile). Hence, literally Bahir Dar means a city situated on or very close to the shore of Lake Tana and Blue Nile. Today, it is one of the fast growing and largest cities in the country. In line with its growth, different service sectors such as education, health and transport and communication have grown. The city has expanded rapidly throughout the 20th century and today sewage discharge into Lake Tana has become a serious and highly visible problem (Matthew, 2011). At the same time, as the city modernizes, it is converting more and more land into streets, parking lots, hotels, etc., increasing the amount of surfaces that cannot absorb the seasonal rains in the area. This storm runoff overflows sewage systems and creates an influx of contaminated water entering Lake Tana (Wondie, 2009).

However, waste management and disposal service problems of Bahir Dar have been identified as the second and third priority issues next to housing and flood/drainage problems (Bahir Dar City Administration, 2010). The main types of solid wastes produced in the city are household, commercial, industrial, construction leftovers and agricultural waste. The city does not have a proper landfill site; rather it has a simple open dumping place where all types of wastes are dumped in and in the vicinities haphazardly (Metaferia, 2001).

According to Rachael and Khosrow (2013), SWM has become an issue of increasing global concern as urban populations continue to rise and consumption patterns change. The health and environmental implications associated with SWM are mounting in urgency, particularly in the context of developing countries including Bahir Dar city; and therefore in the industrialized countries, public health, environment, resource scarcity, climate change, and public awareness and participation have acted as SWM drivers towards the current paradigm of integrated SWM.

Development drivers

Until 2008, Bahir Dar had a SWM system named 'bring-system' or 'communal container system' where waste was brought to a communal container on the street. The principal stakeholders in that system included the waste generators (households, commercials, institutions), the Sanitation and Beautification Team of the municipality and the informal waste collectors (Kassa, 2009).

The waste generators had the responsibility of storing the solid waste at home and have it transported by themselves, their children, house servants or by informal waste collectors from the source of generation to one of the 70 metal containers (8 m^3) capacity. The informal waste collectors went from door-to-door and collected waste either on client basis or by asking if people have solid waste to be disposed off. The reward for the collection services was either in kind (mostly food) or in cash. The payment ranged from 0.02 to 0.09 USD per each collection event, depending on the quantity of the waste and the distance to the container site (Kassa, 2009).

The municipality offered its services through provision of 70 temporary waste storage containers distributed throughout the city. Each of these metal containers was guarded by a municipality guard. To that end, 70 container guards were employed with the duty to send people away when containers were full. Another responsibility of the municipality was the transportation of these containers to the disposal site by its own trucks, in which there were two trucks; their crew included three drivers and four assistants (Christian, 2012).

A major problem in the SWM of that time was the general shortage of containers. One of the main reasons was limited space availability, which also led to the selection of inappropriate container locations (e.g. far away from densely populated areas). The container shortage combined with insufficiently frequent emptying resulted in the containers being regularly overfilled, despite the presence of guards. Some containers in the city centre needed emptying twice per day - a service the municipality could not provide. As a consequence, the people started disposing their waste in open areas which had negative impact on public health, the environment and the aesthetics of the city. In addition, the municipality had no legal ground to collect a SWM fee from residents for waste transportation and disposal, so the budget had to be obtained from other sources of tax (Kassa, 2009). SWM was a very big financial burden for the municipality (Christian, 2012; Arto, 2010).

Institutions

The main stakeholders in the MSW system in Bahir Dar includes Bahir Dar City Administration (CA), Regional Amhara Bureau of Environmental Protection, Land Administration and Use (BoEPLAU, Regional Amhara Health Bureau (BoH), Regional Amhara Government (ANRS), United Nations Development Programme (UNDP) and Federal Environmental Protection Authority (EPA, 1997) according to the study of UNEP source document for the city waste management (FFE, 2010).

Service contributors

Dream light (DL)

It is a private company responsible for collection, transportation, disposal and recycling of municipal solid waste in 8 out of 9 kebeles of Bahir Dar, UNEP, Forum for Environment (2010).

Green dream (GD)

This Community Based Organization (CBO) is comprised

of 30 female workers and responsible for solid waste collection in a door-to-door manner in one kebele (Shumabo), UNEP, Forum for Environment (2010b).

In Ethiopia, among the well-known cities, Bahir Dar is one of the fast growing tourist destination cities. It is also a center of industrial and commercial activities. Adjacently, the daily waste generation rate in the city is also increasing from time to time (Forum for Environment, 2010). But the current waste collection capacity and disposal system is not matching with the rapid expansion of the city and its corresponding waste generation. It encounters problems like shortage of containers, road side waste bins, public toilets and the absence of proper and well prepared disposal site (FUPI, 2006). Hence, the people give no or little attention to SWM and they dump wastes along the roads and in open spaces. In addition, most of the industries and health centers in Bahir Dar did not start treating and/or reusing their waste properly. Bahir Dar city has 17 kebeles (now administered in 9 administrative centers) from these kebeles, 04 commercial center, 06 heavily populated, and 17 city outskirt are obtained (Koyachew, 2016).

Informal recyclers

Koralews are informal itinerant buyers going from door to door to collect recyclable and reusable materials such as pieces of metals, plastics, glasses, corrugated iron sheets, tins, car batteries and others. They buy these materials and sell them to one of the 55 middlemen. 70 Koralews are working in Bahir Dar (Worku, 2012). The number of Koralews is increasing now in the city, contributing as waste recyclers. *Lewaches* are persons going from door to door to exchange recyclable materials especially clothes and shoes for new plastic barrels, sauce panels, spoons, etc depending on the type and oldness of the cloth and their number is increasing on wards from about 50 to more than this amount. *Lewaches* are working in Bahir Dar (Christian, 2012). Dumpsite pickers collect recyclables and reusable materials from the disposal site and sell it to either middlemen or Dream Light PLC. There are 10-15 dumpsite pickers at *Gordma* working every day except Sundays (Worku, 2012). Children and beggars living on the streets go around from door-to-door and ask for food leftovers, reusable textiles and recyclable materials that they use themselves or sell to middlemen. Many Ethiopians give away materials to the poor due to religious considerations (Christian, 2012; Arto, 2010).

Pig farmers

There are two pig farmers located in the north-east of Bahir Dar city centre. About 550 pigs (Worku, 2012) live in the larger one, while the smaller farm has about 100 pigs. Both farms have workers going around the city with mule-pulled carts to pick up for free a total amount of 2.5 t/day of kitchen waste from hotels, restaurants and theuniversities (UNEP, Forum for Environment, 2010b).

Formal recyclers

Middlemen: Parts of the recyclable materials collected by *koralews*, *lewaches,* street persons and formal waste collectors are sold to middlemen, who in turn sell them to brokers of recycling companies in Addis Ababa, the capital city of Ethiopia. There are 55 middlemen collecting and selling metals, plastics and glasses and 1 middleman for textiles and shoes (Christian, 2012). These middlemen are registered at the Bureau of Trade and Industry, thus have a license for trading materials and need to pay taxes.

Waste generators and the civil Society

***Households*:**

Bahir Dar has roughly 80’000 households (extrapolation based on CSA, 2007). They are responsible for filling their solid waste in collection bags and for payment of the service fees. The community in each Kebele Administration has the right to elect a *kebele* council. However, these *kebele* councils have very limited power in comparison with the City Administration.

Commercials

The business sector which includes shops, hotels, restaurants, markets, garages etc. has 7,040 commercials (UNEP, 2010a). They are responsible for filling their solid waste in collection bags and for payment of the service fees.

Institutions

Institutions include governmental and non-governmental bureaus, schools, universities, colleges, hospitals and clinics, training centres, prisons, churches, mosques, etc. They are responsible for filling their solid waste in collection bags and for paying the service fee*. Bahir Dar University (BDU):* There are two campuses but currently they are four of BDU, the Polytechnic Institute but now Bahir Dar Technology Institute (POLY Campus).

Forum for environment (FfE)

This NGO is actively participating in raising environmental

awareness and has initiated the development of an integrated sustainable waste management plan for Bahir Dar. FfE Bahir Dar has one paid employee (secretary) and 40 members with different backgrounds. According to the information source (UNEP, 2010a), there is no specific formal structure/platform (committee, regular meetings or specific person within the municipality) for communication of stakeholders. In the case of particular matters, the stakeholders contact each other informally mainly per phone (Fenzie, 2011; Christian, 2012).

Components of physical system in Bahir Dar

Regarding this point in Bahir Dar, the households, commercials, institutions, forum for environment (FfE) and others in which in detail are including as: Bahir Dar has roughly 80'000 households (extrapolation based on Central statistics Agency, UNFPA (2008) as the City Administration (CA) and which includes about 18 *Kebele* Administrations (KA) under it. The households are responsible for filling their solid waste in collection bags and for payment of the service fees. The Kebele Administrators have very limited power in comparison with the City Administration (UNEP, 2010). Commercials as business sector include shops, hotels, restaurants, markets, garages, etc. They are responsible for filling their solid waste in collection bags and for payment of the service fees (UNEP, 2010a). Institutions include governmental and non-governmental bureaus, schools, universities, colleges, hospitals and clinics, training centres, prisons, churches, mosques etc. They are responsible for filling their solid waste in collection bags and for paying the service fee (UNEP, 2010). Forum for Environment (FfE) which is NGO is actively participating in raising environmental awareness and has initiated the development of an integrated sustainable waste management plan for Bahir Dar. FfE Bahir Dar has one paid employee (secretary) and 40 members with different backgrounds. According to the information source (UNEP, 2010a), there is no specific formal structure/platform (committee, regular meetings or specific person within the municipality) for communication of stakeholders. In case of particular matters, the stakeholders contact each other informally mainly per phone (Fenzie, 2011; Christian, 2012).

The physical components of the solid waste system in Bahir Dar City-Lake Tana basi is divided into four parts: Generation, collection and transport, resource recovery, and disposal. The daily generation of MSW in Bahir Dar amounts to a total of 102.5 t/d, commercial waste is 28 t/d, residential waste is 54 t/d, the institutional waste is 17 t/d and the street sweepings is 2.5 t/d. From the study review of UNEP, the composition of total municipal solid waste in Bahir Dar and depicts the origins of the waste material fractions. 32% of the total MSW consists of ash and soil, 30% is food waste and 13% is made up of yard waste. The large share of ash and soil component in residential waste (47%) is explained by the predominant use of firewood and charcoal in households. The ash residues are usually disposed on the ground, later put in the waste collection bag from where it is collected by Dream Light workers. The seasonal variation is expected to be minimal due to steady consumption behavior throughout the year (Christian, 2012).

Per capita generation of waste in Bahir Dar was assessed to be 0.25 kg/day for residential and 0.45 kg/day for all residential, commercial, institutional and street sweeping waste streams. The waste projections show that the waste generation will increase similar to the population growth. Hence in 2021, when the population is doubled, waste generation will also be doubled (199 t/day) according to the stated information source of UNEP (2010a).

Based on the share of organic content (food and yard wastes) in the different waste sources (UNEP, 2010a), the sum of food and yard wastes from the residential (16 t/d), commercial (16 t/d), institutional (12 t/d) and street sweeping waste streams (1t/d) results in a total organic waste quantity of 45 tons per day, which equals 44% of the total amount of daily generated waste in Bahir Dar. According to UNEP (2010a), hazardous waste of Bahir Dar City includes: wastes from hospitals and medical laboratories, chemically contaminated containers and trimmings from agriculture, pesticide retailer shops, university and school laboratories, tanneries, textiles, printing enterprises and expired drugs, biological wastes from hospitals and biological research facilities, the dry cells from each sources and car batteries from garages, used condoms from hotels and pensions and fluorescent lamps.

Residential hazardous waste amounts to 156.6 kg/d (0.3% of total residential waste stream), commercial hazardous waste was recorded to be 124.8 kg/d (0.5% of commercial waste). Institutional hazardous waste was 120.7 kg/d (0.7%) and street sweeping hazardous waste was 0. This makes a total of 402.1 kg of hazardous waste generated per day, which is 0.4% of the total MSW in Bahir Dar according to the written document source (UNEP, 2010a).

According Koyachew (2016), the surveyed solid wastes discharged from the houses contain plastic, wood, paper and cloth (82.5%), metal (3%), food and fruit residuals (7.6%) and others (6.9%). In addition, the survey result shows that 26.6% of the household's burn wastes in their compound, 5.5% dump in a pit, 36.7% dump outside the compound on open space, ditches and roads, and the remaining 0.3% of the households recycle their waste directly. Only 30.9% of the home effluent is collected by the municipality. The new private door to door waste collection service is covering most of the city. Hence, residents will no more discharge home effluents on open spaces, ditches and roads. Further, the recycling and composting measures may generate money to the

Table 1. Type of waste sources by weight in Bahir Dar City, 2010.

Type of waste	Weight (%)
Food	86.6
Paper	3.3
Plastic, leather and plastic	2.2
Glass	0.6
Textile	2.2
Metals	0.3
Others	4.8

Source: (UNEP, 2010a, b).

municipality and private processors.

As indicated in Table 1, the waste materials of Bahir Dar city from food is 86.6% which is the highest among the rest waste sources expressed by weigh and the glass waste contains the least amount as compared to the rest wastes.

According to Figure 1, the composition quantities expressed in tone in Bahir Dar City Municipal Solid Waste of residential is high in quantity as compared to commercial and street sweeping.

Figure 2 presents an overview of the composition of total municipal solid waste in Bahir Dar and depicts the origins of the waste material fractions. 32% of the total MSW consists of ash and soil, 30% is food waste and 13% is made up of yard waste. The large share of ash and soil component in residential waste (47%) is explained by the predominant use of firewood and charcoal in households. The ash residues are usually disposed on the ground, later put in the waste collection bag from where it is collected by Dream Light workers. The seasonal variation is expected to be minimal due to steady consumption behavior throughout the year (Christian, 2012).

Table 2 described the incremental effect of municipal solid waste generation expressed in tones per year from 2010 to 2022 due to the assenting effect of total population in the city from year to year. This shows that waste generation increases from year to year as the purchasing and consumption effect of the increasing population living in the city increases. Figure 3 describes waste projections which are going up in quantity from the year 2010 to 2022 which shows that the projection increases as the urbanization, purchasing and consumption power of the residents living in the city increases. This shows that the waste generation rate is almost doubling similar to the population growth; in 2021 (when the population doubles) the waste generation will be doubled.

Based on income group classification, plastic bag waste generation rates analyzed show that a mean waste generation rate of 0.40, 0.26, 0.26 and 0.20 g Capita-day for poor, lower, middle and high income groups respectively in terms of volume, the mean plastic bag waste generation of poor, lower, 26 middle and high income groups were 1.19, 0.78, 0.78 and 0.58 cm^3, respectively (Table 3).

Regarding plastic bag waste generation in Bahir Dar, the total of 24.87 ton of plastic bag waste was generated annually (Table 4). This is equivalent to more than 12 million Plastic bags per year that enter into the environment as the waste. If this number of plastic bags were made into a double plastic sheet, it would cover 1.41 square kilometer (2.82 sq km when they were made into single sheet) and if each side of plastic bag join together, it would be 466323.33 km long. The plastic bag waste generation increased from 2007 to 2016 and onwards (UNEP, 2010). According to Al-Salem et al. (2009), plastic solid waste presents challenges and opportunities to societies even in developed countries regardless of their sustain-ability awareness and technological advances. There is a possibility of advanced thermo-chemical treatment methods cover a wide range of technologies and produce either fuels or petrochemical feedstock. Currently, non-catalytic thermal cracking is receiving renewed attention, due to the fact of added value on a crude oil barrel and its very valuable yielded products, like waste as virgin monomer, as synthetic fuel gas, or as heat source (inci-neration with energy recovery and these processes avoid land filling, where the non-biodegradable plastics remain a lasting environmental burden (Anke et al., 2012).

Waste collection and transport

Since Dream Light's (Private waste collector) entry into the SWM system of Bahir Dar City in 2008, it is the waste generators responsibility to put their mixed waste into any (non-standardized) bags and place them in a designated location on their compound or along the road UNEP (2010b). Some high-standard hotels require having their wastes collected up to twice per day. There are controllers who can organize and supervise their collection team to empty the generators waste bags into push-carts or into strong plastic bags and bring them to collection points There, the workers await the Dream Light collection truck to empty the bag contents (UNEP, 2010b). According to the UNEP (2010b) study, an overall collection rate of 71% is stated, which is 73 tons/day from a total of 102.5 t/day generated. The remaining amount of 29.5 t/d is not being collected and according to UNEP (2010b), burned, buried or simply dumped on the lakesides or into rivers. There was a small business group (Million and his 55 workers) responsible for parts of the street sweeping and institutional sanitation activities (emptying of septic tanks) in Bahir Dar but recently conducted bidding-competition, a new business group (Masfen) outcompeted the other competitors and hence will be responsible for street sweeping for the next year (Christian, 2012).

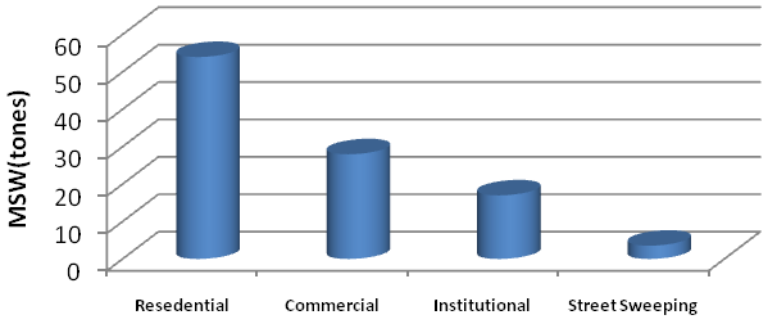

Figure 1. MSW composition quantities in tones in Bahir Dar City 2010. Source: UNEP, 2010a.

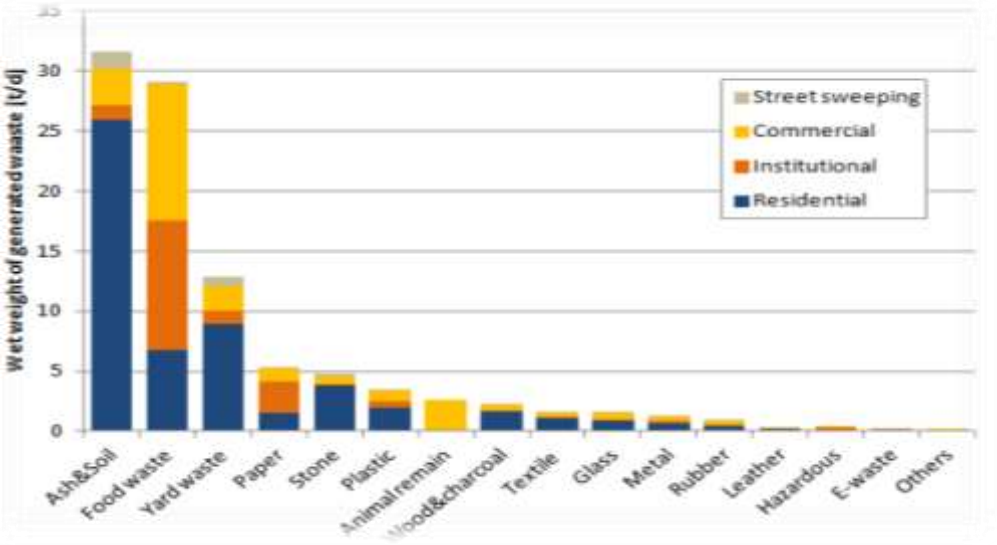

Figure 2. MSW streams in Bahir Dar City and their compositions as wet weight of generated waste. Source: Based on data from UNEP (2010a).

Some parts of the street sweeping are outsourced to 'Million & Guadegnochu' (Million and Friends), the rest are swept by the city service itself. The street sweeping workers fill the street waste into plastic bags and leave them along the streets from where they are picked up by Dream Light or Green Dream workers. Green Dream is community based organization comprised of 30 female workers and responsible for solid waste collection in a door-to-door manner in one kebele (Shumabo). Initially, Green Dream has received financial and technical assistances from the CA and EPA, whose intention was to initiate competition in the solid waste market and to avoid monopolization by Dream Light. Green Dream has no means of transporting large amounts of wastes, so they provide the waste bags for Dream Light's trucks to be picked up and disposed of (Christian, 2012).

There are informal recyclers in the city like *Koralews* who are informal itinerant buyers going from door to door to collect recyclable and reusable materials such as metals, plastics, glasses, corrugated iron sheets, tins, car batteries and others. They buy these materials and sell them to one of the 55 middlemen. There are persons gave a local name *Lewaches* going from door to door to exchange recyclable materials, especially clothes and shoes for new plastic barrels, sauce panels, spoons, etc, depending on the type and oldness of the cloth. Dumpsite pickers collect recyclables and reusable materials from the disposal site and sell it to either middlemen or Dream Light PLC. Children and beggars living on the streets go around from door-to-door and ask for food leftovers, reusable textiles and recyclable materials that they use themselves or sell to middlemen (Worku, 2012).

There are formal recyclers categorized in the norm of middlemen that collect parts of the recyclable materials collected by koralews, lewaches, street persons and formal waste collectors, and sell to middlemen, who in

Table 2. Municipal solid waste generation expected up to 2022.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Population	218975	233427	248833	265256	287763	301425	321319	342526	365333	389232	414921	442306	471498
Waste generation (tones)	98.5	98.5105	112	119.4	129.5	135.6	144.6	154	164.4	175.2	186.7	199	212.2

Source: UNEP, 2010a.

turn sell them to brokers of recycling companies in Addis Ababa. There are 55 middlemen collecting and selling metals, plastics and glasses and middleman for textiles and shoes. These middlemen are registered at the Bureau of Trade and Industry, thus have a license for trading materials and need to pay taxes (Worku, 2012). There are no officially designated waste collection locations in Bahir Dar, but about 100 widely accepted collection points on the side of the road which were selected based on easy accessibility with pushcarts, workers, collection trucks and acceptable' distance to residents in order to avoid complaints due to odour and aesthetics (Worku, 2012).

Recycling of solid wastes in Bahir Dar seems insignificant (<1%) (UNEP, 2010b). However, this is an underestimation because the UNEP study only accounted municipal composting as recycling activity and did not include informal recycling activities. Organic recycling is currently practiced as follows: the municipal composting site is located 3 km south of the city and the municipal workers transport the filled container by truck to the composting site about once per week. Thus, 8 m^3 (3t) of fresh substrate arrives approximately 4 times per month, where it is manually sorted, turned and decreased in size. After 3 to 4 months, the finished compost is picked up by the municipality and brought to the city to be used for planting of flowers (UNEP, 2010b).

According to UNEP (2010b), no treatment facilities exist in Bahir Dar. All healthcare and industries and some governmental institutions follow their own way of removal. Most of them burn their waste; while some others dispose it to the nearby river Blue Nile or into Lake Tana (UNEP 2010c). There is no documented evidence that shows the criteria used for the selection of the area as dumpsite regarding prior study of hydrology, geology, socio-economic and environmental issues. The dumpsite is surrounded by land use activities such as informal settlement and agricultural activities. The liquid human waste (from emptying of septic tanks in Bahir Dar) is also dumped in close proximity of *Gordma* landfill site (UNEP, 2010c).

Finding suitable sites for landfills is one of the most difficult tasks in solid waste management as the sanitary landfill site selection must address social, environmental and technical concerns. Therefore, GIS based assessment should be employed for different criteria including geology, soil, slope, land use, and stream network (Radwan et al., 2017). Similarly in Bahir Dar City, there are problems of solid waste disposal sites selection. There are no standard transfer stations in the city. Institutions and industries follow their way of removal of waste and the available dumping sites are not well planned. Applying and integrating GIS and remote sensing techniques to select the best possible solid wastes dumping is one way of solving the problem (Tirusew and Amare, 2013). The study has shown land use, slope, water sources, settlement and transport facilities as determining factor in order to find appropriate site for solid waste dumping. By this analysis, the most suitable sites were located in southern and south east of the town and are bare and grass lands (Figure 4).

Regarding to the suitability analysis of solid waste dumping site in Bahir Dar City to River and lake, the farther lands from lake and river banks got more preferences for solid waste dumping site suitability. In Bahir Dar town, there is a lake at the northern side, Lake Tana and the River Abbay at northwestern part. Hence, to maintain the environmental health of these water sources at least 2000 m buffered distance should be ringed through straight line calculation. Based on this, the green area is for study suitability and the blue one is for Lake Tana. Accordingly, considering only the lake, the green shaded area was the most suitable for solid waste dumping site (Figure 5).

According to Figure 5, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map. According to the degree of importance, they have the role of selecting suitable solid waste dumping site. The map (Figure 5) has four colors (classes): yellow, green, blue and violet. The most suitable area for solid waste dumping site is marked by

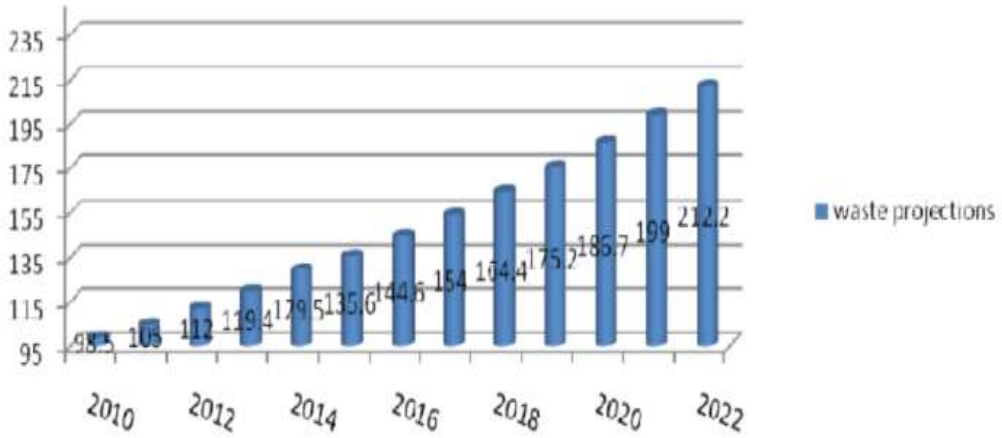

Figure 3. Waste projections for 2010-2022 years in tons in Bahir Dar City. Source: (UNEP 2010a).

Table 3. Plastic bag waste generation rates with income level, 2007.

Descriptions	Per income group			
	Poor	Lower	Middle	High
Number of households	70(66.6%)	20(19%)	8(7.6%)	7(6.8%)
Average family size	5.14	4.4	3.75	3.14
gm/capita/day	0.40	0.26	0.26	0.20
gm/house hold/day	2.1	1.14	0.98	0.63
cm^3/capita/day	1.19	0.79	0.78	0.58
cm^3/household/day	6.12	3.48	2.93	1.82
Density (gm/cm^3)	0.34	0.33	0.33	0.34

Source: Ayana (2007). Plastic bag waste generation rate in Bahir Dar City, MSc thesis, Addis Ababa University, July 2007.

Table 4. Households' plastic bag waste generation rates in a day, week and year, 2007.

Generation rate	Day		Week		Month		Year	
	Weigh	Volume	Weigh	Volume	Weigh	Volume	Weigh	Volume
Per capital	0.35 g	1.05 cm^3	2.46 g	7.33 cm^3	10.54 g	31.41 cm^3	128.26 g	382.16
Total	67.89 kg	0.2 m^3	477.19 kg	1.42 m^3	2044.54 kg	6.09 m^3	24879.8 kg	74.13m^3

Source: Ayana (2007). Plastic bag waste generation rate per capita in Bahir Dar City, M.Sc Thesis, Addis Ababa University, July 2007.

yellow color shaded. Out of the total area of the study site, about 11.9% (2528 ha) fall under this category. They are located on south and south east part of the, far away from settlement and urban center, and is covered by grass lands.

Sustainability of waste reduction

In the sustainability aspects, this sub-section provides an overview of the enabling environment for the municipal solid waste system in Bahir Dar and hence the Lake Tana Basin. It combines the results from the document 'Assessment of the SWM system in Bahir Dar City-Lake Tana basin and the gaps identified for the development of an ISWM plan' (UNEP, 2010b) with field observationsand information gathered through interviews with SWM stakeholders. Implementing waste management strategies are widely used for waste avoidance and reduction strategies which can include waste avoidance,

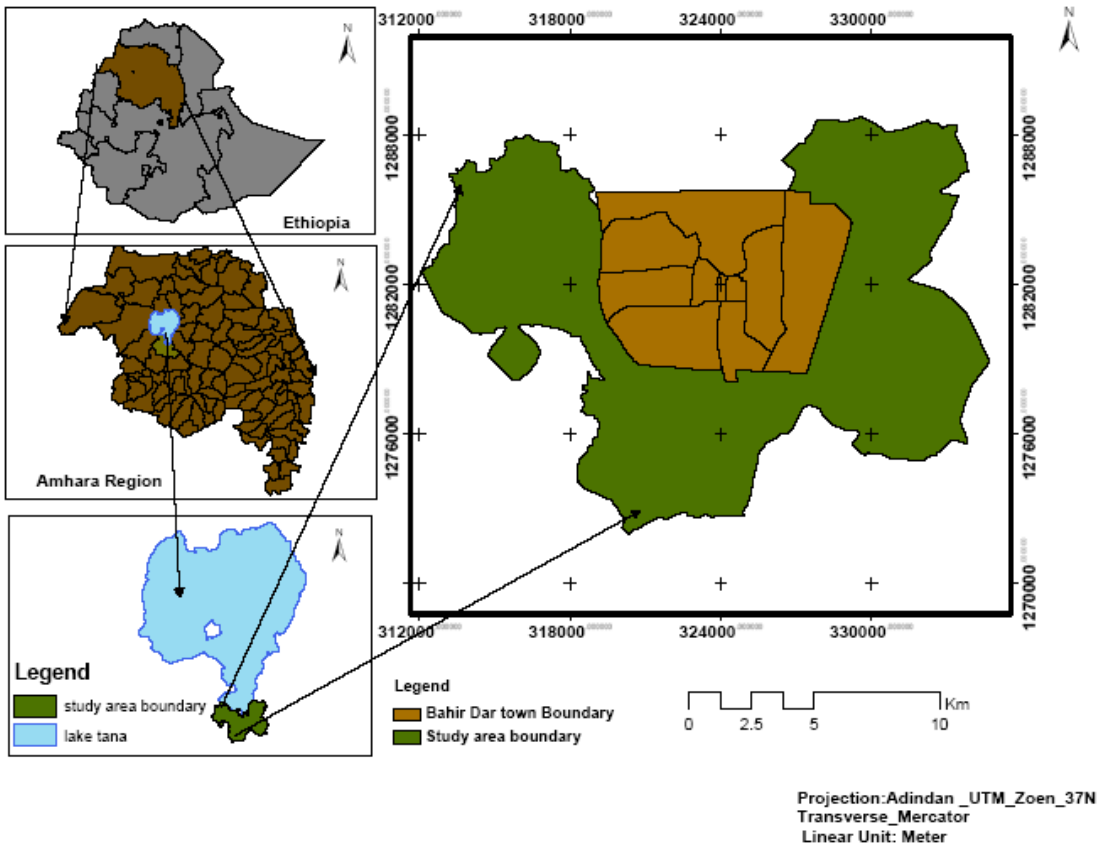

Figure 4. Map of Bahir Dar City. Source: Tirusew and Amare (2013).

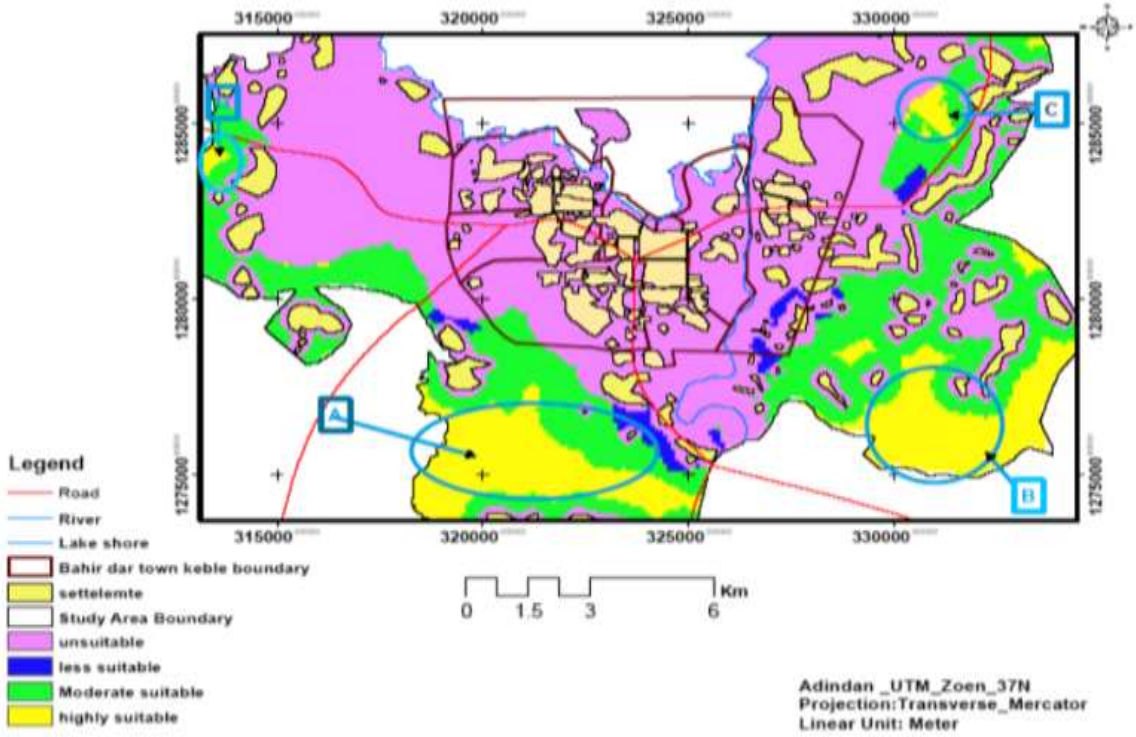

Figure 5. Final suitability map for solid waste dumping. Source: Tirusew and Amare (2013).

dispose, re-use and recycle depending on the waste type and source. To prolong sustainability, the following technical aspects should be accounted for (Christian, 2012).

Technical aspects of waste minimization

Collection and transport

With regarding to collection and transport, no waste segregation is currently practiced at source; apart from the small-scale segregation of recyclables for informal recycling .There are no standard solid waste transfer stations in Bahir Dar. As the disposal site is close enough to the city (3 to 4 km), the existence of a transfer station is financially not justified. It is difficult to designate unofficial collection points for temporary storage of waste during collection. The collection points are not allocated by the municipality but by Dream Light. In the case of frequent complaints about the location of collection points, the City Administration intervenes and tries to find other collection points more distant from the residents. Solid waste collection (71%) does not cover all solid waste generators. Based on discussions with Dream Light, the following collection rates are roughly estimated with respect to their source: 70% of the total waste generated in the households is collected, 80% from total generated in commercials, 50% from total generated waste in institutions and 70% of the total waste laying on the 35 km of asphalt road. Transportation trucks are not standardized for solid waste transportation purposes, spare parts are not locally available - they have to be imported from the capital Addis Ababa. There is no financial or technical support, no public recognition for waste recyclers. Only a small amount of organic solid waste (0.5 t/d) is used to produce compost in the municipal composting plant (Christian, 2012).

Disposal

There are no treatment facilities in Bahir Dar for MSW and it is open dumpsite (no sanitary landfill). No sound operation practices performed at disposal site. No designated cells, no machinery (compactor or graders) working at disposal site, and 71% (73t/d) of generated MSW is collected and disposed of at disposal site. According to UNEP (2010b), no treatment facilities exist in Bahir Dar. All healthcare and industries and some governmental institutions follow their own way of removal. Most of them burn their waste; while some others dispose it to the nearby river Blue Nile or into Lake Tana (UNEP, 2010c).

Environmental aspects

Dumpsite *Gordma* is close to rural settlements and leads to pollution of groundwater sources through leachate (Worku, 2012), and 29% of generated waste (29.5 t/d is not collected by Dream Light or Green Dream). This waste is either burned or buried in compounds or disposed to lakesides or into rivers, leading to pollution of environmental compartments.

Socio-cultural aspects

Participation in the current solid waste system needs to be differentiated into the following two parts: Participation required at the source of waste generation (collecting waste, putting it into bags and in the designated place to be picked up) is considered to be good, particularly considering the short time since the introduction of this new system. However, payment rate of collection fee is low (about 50%) thus considered as poor (UNEP 2010b). Awareness of public towards SWM is still considered to be low, although it has increased considerably in the last two years. When Dream Light started its business, it organized awareness raising campaigns to teach people how to handle waste. Its managers also participated to demonstrate that touching waste is neither dangerous nor despising (Christian, 2012). It took about one year until the waste collectors started to be fairly recognized for their contribution to a clean city. The working condition for waste collectors is acceptable but needs to be improved. The protection clothes (overall, gloves) are replaced by Dream Light twice per year only at pre-set dates. This means that workers have to continue working with damaged equipment until then. The salary for waste collectors (400 ETB/month) classifies the work as a low-income job, yet Dream Light considers most workers to be grateful having an income generating opportunity at all. The salary is comparable to the salary of a waiter in a good middle class hotel in Bahir Dar or of a guard working for a private company. In comparison, the controllers (group leaders of waste collectors) receive 800 ETB/month. Dream Light explicitly offers their waste collecting jobs to street persons, prostitutes and other underprivileged members of the society.

Financial-economic aspects

The payment rate for the solid waste collection service has been low until now: Only about 50% of the households pay the collection fee. About 90% of the commercials and institutions receiving waste collection services pay the fee regularly. This is on one hand due to the individual agreements Dream Light worked out with them, on the other hand, the hotels, restaurants, shops etc. are depending on a clean environment for the satisfaction of their guests and customers. As a result of the low payment rate of households, a committee comprised of different stake-holders, including City Administration, EPA, hotel association, and Dream Light,

worked for three months on the development of an improved payment system. In the old system, each household was required to pay a monthly fee of 0.68 USD to Dream Light's fee collectors who went from door-to-door to collect the fee in cash (Christian, 2012).

Commercials and institutions had individual agreements with Dream Light based on the waste quantity and frequency of collection/disposal. The new system follows the idea of the system practiced in Addis Ababa. It is based on the assumption that the water consumption correlates with waste generation, that is, a household that consumes high amounts of fresh water also generates high quantities of solid waste. Thus, the payment for water and for waste collection will be linked. This new system is possible due to the fact that all households in Bahir Dar have a water meter installed on their compound and each household is responsible to go to the Regional Bureau of Water supply once per month to pay the monthly water bill. The new progressive system is divided into four progressive categories depending on the amount of fresh water consumed per month. City Administration and Dream Light do not expect major protests due to the implementation of the new payment system (Christian, 2012).

However, special agreement will have to be arranged with recreational facilities like public swimming pools (which consume a disproportionately high amount of water). The main advantage of the new system is the leverage in case of non-payment. In addition, institutions that until now mismanaged (burned, buried and openly disposed) their waste by themselves will most likely use DL's collection service as they have to pay for it anyway. With the new payment system Dream Light expects to be able to cover all their expenses related to collection services (440'000 ETB/month). Until now, Dream Light's business was economically not sustainable. Thus, the loan of 1.6 Mio ETB UNDP provided for 4 years is not only meant to cover the expenses for the Organic Recycling Centre, but also to cover the current running costs for waste collection (Christian, 2012).

Institutional aspects

Integration and coordination of the current institutional arrangement of the SWM is unsatisfactory. Each sector is working independently (UNEP, 2010b).There is no clear bridge between the federal (national) institutions and the regional (or local) in-situations. The City Administration who has outsourced waste collection, transport, treatment and disposal services to Dream Light is responsible for monitoring these activities. The Regional Bureau of Health as well as the Regional EPA expressed their pity that their advices regarding hazardous waste handling, official collection points/transfer stations and upgrading of the current open dumpsite are not taken seriously by the City Administration. In general, the cooperation of stakeholders is described by the majority as very loose (rather than conflicting) and leaves considerable room for improvements in the future (Christian, 2012).

Policy and legal aspects

The region has not yet enacted any law on environmental issues. It is rather using the federal laws but facing difficulty in implementation, enforcement and monitoring. Bahir Dar does not have its own detailed rules and regulations specific to SWM that clearly indicates the responsibilities of the actors involved in SWM. There are no clear rules and regulations pertaining to SWM apart from general guidelines, an approach which is not effective at all (Kassa, 2009).

LIQUID WASTE MANAGEMENT

In Bahir Dar, 20% of the households do not have access to latrines, using open fields and disposing waste water into the available open spaces. Because of the lack of latrines, waste disposal sites and poor collection practices, only 35% of the city's liquid waste was collected (Fesseha, 2012). In the absence of a city sewerage system, the overall drainage in the town is a problem aggravated by the plain geographical terrain and rapid urban growth. Waste water generation potential increases with increasing use of flush toilets, which in turn requires increased wastewater treatment plants. This implies the ever-growing Bahir Dar City with modern buildings using flush toilets will produce more waste water that should be treated (Fesseha, 2012). `

The waste water management practices of the major institutions of Bahir Dar City-Lake Tana basin are not also environment friendly. Felegehiwot Referral Hospital, Bahir Dar Prison, Bahir Dar University Technology Institute (POLY Compus) waste water from students' cafteria, and the old hotels like Ghion, Tana and recently built hotels like Avanti and Garnd etc, generated waste water is directly discharged towards the Lake Tana and this produces an offensive smell. The environment seems highly polluted and has not yet been looked into by the sanitation authorities of the city (Fesseha, 2012). These institutions do not have their own wastewater treatment and management systems. They simply discharge waste water into Lake Tana through tubes and open ditches. Such discharges pollute the environment and create offensive smell and aggravate the conditions for the spread of communicable diseases. There was no well-organized coordination among the concerned bodies regarding waste water management. Eutrophication, waterborne diseases, shortage of water and adequate sanitation are still a major challenge for Bahir Dar-Lake Tana basin (Goraw et al., 2011).

Table 5. Distribution of latrines availability by education, monthly income (in Birr) and space availability in Bahir Dar City.

Variables	Latrine availability		Total	X^2	P-value
	Yes (%)	No. (%)	No. (%)		
Educational status	(n=270)				
Illiterate	78(29.0)	15 (5.5)	93 (34.4)	0.84	P<0.001
Literate	139(51.5)	38 (14.0)	177 (65.6)		
*Monthly income	(n=270)				
Less than 500	139(51.5)	49 (18.1)	188 (69.6)		
501 – 750	39 (14.4)	3 (1.1)	42(15.6)	10.3	P<0.001
751 – 1000	19 (7.0)	1 (0.4)	20 (7.4)		
Above 1000	18 (6.7)	2 (0.8)	20 (7.4)		
Space availability	(n=270)				
Have space	66 (24.5)	10 (3.7)	76 (28.1)	3.9	P<0.001
Have no space	148(55.8)	46 (17.0)	194 (71.9)		

Source: Fesseha and Mekonnen (2012), Bahir Dar University.

Table 6. Logistic regression predicting likelihood of reporting for availability of latrine, March 2008, Bahir Dar City.

Variables	B	S.E.	Wald	df	Sig.	Exp (B)
Education						
Illiterate	(Ref)					
Literate	0.526	0.350	2.258	1	0.133	1.693
Space availability						
No	(Ref)					
Yes	0.751	0.407	3.398	1	0.065	2.119
Income						
Income group			9.024		0.029	
Less than 500 Birr	(Ref)					
500 -750	-1.466	0.629	5.435	1	0.020	0.231
751-1000	-1.730	1.051	2.709	1	0.100	0.177
More than 1000	-1.016	0.775	1.718	1	0.190	0.362
Constant	-2.00	10.462	18.733	1	0.000	0.135

Source: Fesseha and Mekonnen (2012), Bahir Dar University.

According to this review study, only 28% of the housing units used septic tanks to collect and treat the generated wastewater. Most of them had no space in their compound for waste water discharge, 64.3% discharged the waste water they generated into streets. In this study, 80% of the respondents had access to latrines, while 20% used open fields (Tables 5 and 6).The fecal and chemical pollution levels have been significantly increased and clearly discernible in the Bahir Dar Lake Tana basin (Goraw et al., 2011). The liquid waste disposal survey shows that 22% of the households in the study area used septic tanks, 9.1% dispose on drainage, 36.4% on open field, 12% on pit and the remaining 40.3% on the roads. This needs creating awareness on liquid waste management as well as providing regular services to collect the liquid waste (Koyachew, 2016).

Regarding to Table 6, a total of 270 respondents were interviewed at the household level, of whom 81 (30%) were males and 189 (70%) were females. Ninety three (34.4%) of the respondents were illiterates, while 177 (65.6%) were literates. One hundred eighty eight (69.6%) of the households were getting a monthly income of less than ETB 500. One hundred and ninety five (72%) of the households had no space in their compound to dispose of the wastewater they generated. Availability of empty land directly affects the collection and safe disposal of waste water. Only seventy five (28%) of the housing units used septic tanks to collect and treat the generated wastewater. Among the total respondents, who had no space in their compound for waste water discharge,

Table 7. Household facility, 2014.

Cooking place		Respondents	%
Own kitchen		87	58
Sharing with others		18	12
On open place		45	30
Latrine facility		F	%
Yes		103	68.6
No	Use public latrine	10	6.7
	Use open place and canal	37	24.7

Source: Koyachew (2016).

64.3% discharged the waste water they generated into streets. In this study, 80% of the respondents had access to latrines, while 20% used open fields. With regard to the toilet facility, 44.6% of the local area households do not have toilet, 28.8% use shared toilet and the remaining 26.6% own private toilet. Hence, the city administration is expected to construct standard communal toilets in collaboration with community organisations and development partners (Koyachew, 2016).

As shown in Table 7, the inadequacy of sanitation services resulted in defecating in open fields and discharging of raw waste water into inappropriate places and these, in turn, have created serious environmental problems.

In connection with their low income, poor housing facility of a household has also a significant impact on waste management. The facilities used to properly manage solid waste at the household level include latrine, kitchen and safe communal cooking home. However, the household survey indicated that 42% of the respondents do not have their own kitchen and among them about 30% are cooking their food in open space. The remaining 12% use kitchen by sharing with others. In addition, 31.4% of the households do not have their own latrine and 24.7% of them excrete on open spaces and channels while only 6.7% use public latrine (Table 7). In the same token, the *kebele* officers admitted the fact that most of the public latrines are removed to use the place for construction and hence a household without its own latrine may use toilet in open areas. Therefore, it should be noted that even though low income households produce wastes, they cannot afford the management costs and thus they dispose illegally.

In the city of Bahir Dar (Figure 5), there are no municipal solid waste treatment facilities and no solid waste transfer stations. Presently, the only method of disposal is open, uncovered disposal fields (FFE-Bahir Dar, 2010). Due to the city's proximity to Lake Tana, the possibility for open, unlined landfills to contaminate local drinking water, or for refuse to be washed into the lake fro storm runoff, is high (Wondie, 2009). The lake is so contaminated that many, including a woman from Bahir Dar that was interviewed, refuse to swim in it (Matthew, 2011). The maps on the following pages provide aerial views of the two cities studied for Bahir Dar City-Lake Tana basin. Nevertheless, there is evidence to suggest that waste management in Bahir Dar has improved significantly in recent years. Most notably, the city of Bahir Dar recently moved from government funded waste management collection to private sector collections, a transition that started in 2009 (Matthew, 2011). The private waste management company currently active in the city is called Dream Light Waste Management P.L.C., which was created in response to the poor cleanliness of the city. The company relies heavily on engaging the community through household waste management and house to house collections, all in return for small service fee (FFE-Bahir Dar, 2010). Household waste collection has greatly reduced the amount of open pit dumps on city streets. The local community covers about 50% of Dream Light's costs through service fees of $0.80 US dollars per household and $1-75 US dollars per commercial site (FFE-Bahir Dar, 2010).

From these findings, it is suggested that improper waste management and toilet use are associated with sickness in Bahir Dar, Ethiopia, and that these issues must be analyzed across the city kebeles/sub cities. According to Figure 6, the city of Bahir Dar is directly on a large body of water- Lake Tana which experiences large inflows of waste and runoff from the city. Governement, international organizations and local NGOs can help combat this problem by funding lined landfills with effective caps. If modern lined landfills can be built in urban areas, then water contamination would likely decrease. Additionally, covering the trash with a cap would prevent it from affecting the environment around it (FFE-Bahir Dar, 2010). There is definitely a major problem involving unlined disposal areas and drinking water contamination, which international and domestic actors can play a part in remedying. Regarding the water pollution, 5.9% of the households are subject to water pollution. The major causes of water pollution are mainly residential and commercial wastes. The residential waste accounts for 66.9% of the water pollution (liquid waste being discharged in the open field) and commercial waste accounts 33.1% (inorganic and organic waste) Figure 7 describes the whole city with centre includes the Lake Tana and this is the existing one with a big change on upgrading and huge construction of commercial buildings even if opportunities and challenges for development are highly concentrated in this city according to the study of Koyachew (2016).

CONCLUSION

This review study has attempted to analyze the status and spatial coverage of waste management service of Bahir Dar City-Lake basin in general. In particular, the study explored residents' solid waste physical composition and generation rate, resident's solid waste

Figure 6. Aerial view of Bahir Dar (Source: Wondie, 2009).

Figure 7. The whole city with centre including the Lake Tana (Source: Koyachew, 2016).

management practice, and institutional structure and capacity of sanitation, actions or practices on waste management by policy makers, municipality, peoples, private sector, Dream light and like organizations of the city.

The review shows that even though various studies and programs are undertaken to curtail the problem of solid waste, the service still falls short of the required level. Technical measures, including waste sorting, recycling and composting, and infrastructural measures for leachate collection and gas venting should be upgraded to standardize the city waste management system. Concern for financial viability and long-term planning for waste management is important indicators of sustain the strengthening of SWM planning. Similarly, the formation of the Dream Light and others with their motivating role in waste management at local level has been driving this practice towards sustainability. Therefore, it is a good practice, leading towards the fulfilment of the municipal vision of a safe and clean municipal area enable SWM practice of the Bahir Dar city - Lake Tana basin.

The municipality's mechanism for coordinating the public and private sectors has played a vital role in waste management. However, the daily monitoring of waste management by the community development section has not been sufficient. Effective involvement of both private and public sectors has made it possible to improve waste management and provide door-to-door collection. The role of the private sector in recycling is important and it can contribute to sustainable waste management by reducing the quantities of plastics and sound financial management and regular and reliable payment of the contractor is important for satisfactory private sector participation. The municipality of the city can achieve its

target of solid waste management with active involvement of the private sector, minimizing municipal expenditure by means of effective management practice. According to the review, nearly two-thirds of all households in Bahir Dar discharge waste water into streets and flood water drainages. There is a poor level of awareness about existing regulations on sanitation among the experts as well as the public. The City Service Administration Office authorities did not seem to give due attention to waste water management in the city. There is weak implementation of the regional hygiene regulations. In addition, space availability is an important factor affecting waste water management at household level in the city.

Generally, this research investigated three main factors which are exacerbating the existing unsatisfactory status of waste management service of Bahir Dar City. These are very weak institutional arrangement and capacity of sanitation due to the city administration and health office structure is twisted by long bureaucracy and delay in implementation of activities, lack of practical decentralization of power and regular interference of higher officials, absence of kebelle specific structure of the waste management department, and high burden of work with significant services solid and liquid waste management. Interms of capacity, very poor institutional capacity of the department is arising out of the very low financial capacity, absence of cost recovery mechanism and financial autonomy, insufficient manpower resource, low motivation and productivity of workers due to failure to address fundamental need of workers, scarcity of waste management facilities, weak enforcement of rules and regulations, fragile networks and linkage of the responsible department with other sectors and organization and mandate restrictions of the department.

Very poor solid waste management practices of the city residents due to the first weakness of households is poor handling of temporary storage material of their house, that is, they drop out solid waste around it and they also exposed it to rain and light, did not well covered, and placed near to residence. Second, the greater part of the city residents did not separately store solid wastes other than salable and exchangeable with Liwach and Quraleos. They did not also carry out sustainable solid management activities such as recycling, reusing and composting. Apart from this, they regularly apply temporarily illegal solid waste disposal at about the city main streets. Moreover, they have also low emphasis to clean their surrounding area and nearby road. Due to very limited participation and contribution of stakeholders, the provision of municipal solid waste management of the city is dominantly performed by municipality with very limited contribution of policy makers, municipality, peoples, private sector, Dream light and like organization, and communities. Besides this, the involvement of community base organizations, nongovernmental organizations and private sector is mandatory for practicing holistic waste management of this rapidly growing and populated city.

To reverse the adverse outcomes of the Bahir Dar City-Lake Tana basin, waste management practice the following measures need to be taken from now.

Waste management training and resource centers should be established in order to improve the standards of waste management in the city and hence the city administrator could formulate a clearer role for its sustainable waste management and resource mobilization centre and so the necessary instructions should be given to waste management in order to improve the solid waste management capacities of the city municipality. In order to increase the quality and efficiency of services in the local operational context, more research and studies in waste management should be undertaken and the established waste management and resource mobilization centre should work with the institutions which are educating urban planners at various universities in the region.

In order to implement effective waste management in the city, the administration could formulate short-term and long-term plans for waste management and the municipality could employ urban planner for urban development planning. Increasing public awareness about waste management; controlling the offenders through strict enforcement of regulations; assigning qualified environmental health workers to each kebele and sub-city to enforce the sanitation regulations and coordinating the efforts at the grassroots level should be followed. The urban health extension program should also take measures to mitigate the problems. Therefore, an integrated solid and liquid waste management should be implemented for the City- Lake Tana basin and also for the surrounding environment. This has to include development plans for improving sustainable sanitation and disposal of the sewage system, and adopt the best practices of waste management system for the City-Lake basin areas. All stakeholders in the city and around it should participate in striving towards sustainable construction in order to embark on the environmental impact issues. Since waste perceived as major obstacle particularly in the construction infrastructures, the city administrator is obligated to develop tools or model to enhance the quality of waste management during the infrastructure construction life cycle.

Scientific researches related to sustainable waste management practices should be done on waste minimization, recycling, waste conversion to energy, bio-fuels, chemicals or other useful products and this should include but not limited to the following technologies of waste-to-energy, anaerobic digestion, composting and bio-fertilizer production, other thermal or biological conversion technologies and also strategies to promote diversion to higher and better uses (e.g. organics diversion, market analysis, optimized material management, logistics, etc.) and land filling. The

researches should be applied and can include economic or cost/benefit analyses, feasibility studies for untested technologies or management strategies, life cycle analysis or inventory, and analyses of policies that relate to the above (e.g. extended producer responsibility, recycling goals, carbon legislation, bottle bills, etc).

Therefore, this review study did not attempt to measure the amount of waste water generated, the degree of environmental pollution, or its impact on underground water and the soil. Nearly two-thirds of all households in Bahir Dar discharge waste water into streets and flood water drainages. There is a poor level of awareness about existing regulations on sanitation among the experts as well as the public. The City Service Administration Office authorities did not seem to give due attention to waste water management in the Town. There is weak implementation of the regional hygiene regulations. In addition, space availability is an important factor affecting waste water management at household level in the city. Therefore, the following measures need to be taken to reverse the adverse outcomes: increasing public awareness about waste management; controlling the offenders through strict enforcement of regulations; assigning qualified environmental health workers to each *kebele*/sub-city to enforce the sanitation regulations and coordinating the efforts at the grassroots level. The urban health extension program should also take measures to mitigate the problems. Finally, a more comprehensive systematic study should be conducted on the impact of waste water that is generated in the city into Lake Tana.

An investigation of waste management practices in the cities of Bahir Dar has underscored the challenges of waste management and the potential for private sector involvement in urban areas. It is recommended that private sector waste management be promoted by financing private sector companies in urban areas. Dream Light Waste Management Company operating in Bahir Dar has been shown to be more effective than previous practices in waste collection, and at a lower expense to the local people. That said, while improving the amount of waste collected from households, Dream Light may still contribute to environmental and health problems by placing waste in unlined, uncovered, disposal sites in the city. The city of Addis Ababa meanwhile is a prime candidate for private sector involvement in waste management as effective household collection will reduce the amount of open disposal sites/bins on city streets. The main issues in both urban areas are the lack of lined, covered landfills available to receive waste. If government and NGO actors are also able to construct modern lined, capped landfills, then unlined drinking water sources can be better protected, lowering rates of water contamination, and preventing disease and illness. The unprotected water sources like boreholes are at a high risk of being contaminated by waste through groundwater percolation. Sources of drinking water are causing sickness at a varying scale across all regions, specifically in rural areas. If lined disposal sites are created in rural villages, they can handle waste without contaminating groundwater. Government and NGOs can also help protect ground water by building latrines in rural areas, which will greatly reduce human waste from contaminating water sources. International donor involvement in the financing and building of lined landfills and latrines could greatly reduce the contamination of groundwater and sickness rates in urban and rural areas alike.

RECOMMENDATIONS

Based on the findings of this review study, the following measures are very important to overcome waste management problem of Bahir Dar City.

Preparing and delivering waste management or disposal techniques should be done for the city youths particularly for women in each kebele administrations to structure and dissiminate gender

Preparing sound Dream Light institutional arrangement that is free from high interference of higher officials and bureaucracy, which has both horizontal and vertical integration and kebelle specific teams, allows stakeholders participation, and characterized by real decentralization of tasks and authority. The city Dream Light should give priority to fulfill infrastructure facilities, that is, place back the public solid waste containers and introduce dust bins with a close supervision, frequent emptying of waste and even distribution, and also organize efficient controlling mechanism and sanitation agent to prevent illegal solid waste disposal.

Increase Dream Light revenue by employing different revenue means like introducing user charges, penalties for persons who illegally dispose their waste, employing resource recovery activities, and government subsidies. But the department should also introduce cost accounting financial monitoring and financial evaluation. Improve solid waste collection by preparing permanent programs, increasing the number of collection trucks, by employing other methods of collection like block and curbside collections, control and supervision field workers, increase human resource of the department, increase the number and strength of Dream Light.

Improve the number and productivity of sanitation workers by giving reasonable salary increment, perdiam payment, moral respect, training, promotion opportunities, changing their requirement type, and providing health insurance and health protection facilities. Prepare specified rules and regulations that focused on local problems such as institutional issues about the town's waste management service responsible body, stakeholder's participation and sustainable solid waste management options, and strictly enforce this rules and regulation under close supervision and inter

organizational linkage.

For the stakeholder related measures, the Dream light open its door to private sectors and also ensure their involvement in planning and implementation of municipal solid waste management activities. Promote and initiate communities and different community based organizations of the town to involve in waste management. In addition, organize voluntary groups that work on municipal waste management by giving different incentives and providing necessary equipments that are used for waste management.

Due to urbanization, inequality, and economic growth; cultural and socio-economic aspects; policy, governance and institutional issues; and international influences have complicated SWM in developing countries including Bahir Dar City. This has limited the applicability of approaches that were successful along the SWM development trajectories of industrialized countries, and therefore it is very important for finding new SWM approaches for developing country contexts in the post-normal science and complex, adaptive systems thinking.

Therefore, Dream Light of the town should create interaction with nongovernmental organizations (NGOs) and donor agencies and watch these bodies as partner for delivery of waste management; because they are one means's to get financial support for purchasing different solid waste management facilities, managerial and technical skill building trainings. In addition, they can also provide awareness rising and skill building support to community based groups (private sector, Dream light and organization of youth and women), informal sectors, formal sectors, and also to the Dream Light itself. Recognizing and encouraging the emerging role of handcrafts through reduction of taxes, and by providing space and equipments to produce recycled materials and creation of market for it.

All these new processes should be emerged and practiced slowly by injecting compatible technologies, that is, advanced mechanical recycling of plastic waste as virgin or second grade plastic feedstock, and thermal treatments to recycle the waste as virgin monomer, as synthetic fuel gas, or as heat source (incineration with energy recovery) as these processes avoid land filling, where the non-biodegradable plastics remain a lasting environmental burden. Considering systems analysis models and tools in a synergistic way will certainly provide opportunities to develop better solid waste management strategies leading to conformity with current standards and foster future perspectives for both the waste management industry and government agencies and also the urbanizing cities.

Biological treatment of solid, liquid and gaseous wastes is probably the only way that leads to sustainability. All biodegradable wastes can be treated by product-oriented processes of bioconversion in facilities using advanced technology. Regulating and speeding up natural biological processes, for example short-time composting, can be one of the steps to achieve an optimal system for processing organic waste. The products like compost or biofertilisers of desired quality can be used as growing medium or horticultural substrate, substitute for peat in a container medium for the nursery plants, soil improvements that influence the physical, chemical and biological properties of the soil.

Regarding policy recommendation, the city shall follow a multi-sectoral approach to waste management as a matter of urgency, incorporating principles of ecosystem based management from the watersheds into the nearby water bodies, connecting sectors that will reap immediate benefits from better solid and liquid waste management. Successful and sustainable management of waste requires a cocktail of innovative approaches that engage the public and private sector at local, national and transboundary scales. Planning processes should provide an enabling environment for innovation, including the community level. Innovative financing of appropriate waste infrastructure should incorporate design, construction, operation, maintenance, upgrading and/or decommissioning. Financing should take into account, the fact that there are important livelihood opportunities in improving waste treatment processes. In light of rapid global change, communities should plan waste management against future scenarios, not current situations. Solutions for smart waste management must be socially and culturally appropriate, as well as economically and environmentally viable in the future. Education and awareness must play a central role in waste management and in reducing overall volumes and harmful content of waste produced, so that solutions are sustainable.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Review

Evaluating the environmental law and energy policy dimensions of land-grabbing

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This article seeks to investigate whether concern for food security and investment liberalization are the principle drivers of land-grabbing in Africa. The investigation demonstrates that, in addition to food security concern, climate change and energy security considerations have been key catalysts arousing hunger for farmland, forests, and fisheries resources in Africa. In particular, certain provisions of the *United Nations Framework Convention on Climate Change, the Convention on Biological Diversity*, and Directive 2009/28/EC of the European Parliament have rendered tree planting, agro-biofuel cultivation, and forest conservation attractive investments in Tanzania and Uganda. This finding challenges the prevailing discourse that links land-grabbing, solely, to global demand for food and the liberalization of investment. The recommendation from this outcome is that African governments must not always embrace reforestation and forest conservation projects as technologies to fight climate change and protect biological diversity, given their potential to undermine the rights and opportunities of local people to meet their basic human needs. The governments of Tanzania and Uganda should rather embark on legislative and policy measures to protect the rights of indigenous peoples and local community members, while striving to combat climate change and achieve environmental sustainability.

Key words: Land-grabbing, environmental laws, energy policies, Tanzania, Uganda.

INTRODUCTION

Recent years have seen the creation of a fertile environment for agricultural corporations and some environmental groups to acquire millions of hectares of lands (including water, pasture, fisheries, and forests resources), through numerous mechanisms and agendas. For example, Oxfam International stated that since 2001 “227 million hectares of land, an area the size of Western Europe, has been sold or leased,” mostly to international investors (Zagema, 2011). These acquisitions are commonly termed “land-grabbing” because they involve “taking possession of and/ controlling a scale of land [and forest resources] for commercial and industrial agricultural production that is disproportionate in size in comparison to the average land holding in the region” (Odeny et al., 2010). Large- scale commercial land transactions have been criticized because they frequently

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lead to violation of globally recognized human rights, particularly the rights to food, water, housing, free, prior, and informed consent, as well as the principle of self-determination of local peoples (Cotula et al., 2008; International Land Coalition, 2011; De Schutter, 2011; Sama 2016). Among others, former UN Special Rapporteur on the right to food, Oliveier De Schutter, reported that most, if not all, of these dealings result in the pervasive devastation of ecosystems and natural resources that are crucial for societal well-being, with accompanying cultural, economic, and social destruction, including local food insecurity and landlessness (De Schutter, 2011, Shiva, 2014; Peebles, 2014). If subsistence farmers continue to lose the basis of their existence (farmland) to agricultural corporations, realizing the UN goal to leave no one behind by 2030 may be difficult (UNDRIP, 2007).

It is true that the food price crisis of 2008 and demand to grow more food and animal feed, and to liberalize trade and investment have pushed foreign investors and rich governments of food-importing and land-scarce countries to invest in plantation agriculture abroad (Akram-Lodhi, 2015; Murphy, 2013; Daniel and Mittal, 2009). Daniel reported that reinvesting in agriculture in countries with crop-producing potential now seems to be the strategy in Gulf States to improve their food security and reduce their rising food import bills (Daniel, 2011). Notwithstanding, this article seeks to clarify that concerns for food, feed, and financial security are not the only factors arousing hunger for land, forests, and fisheries resources, and hence promoting land-grabbing in developing countries. The author argues that the phenomenon of land-grabbing has been promoted, greatly, by conservation projects and climate resilience and low greenhouse gas emissions developments; this is what this article sets to draw attention to. So, this paper will highlight the role of law and policy in land-grabbing in developing countries, directly through some environmental laws and energy policies which have been creating a fertile environment for the conversion of farmland and forest resources into a new kind of global commons**.** The focus is on Africa, as it is the major recipient of foreign agricultural investments. A World Bank study (Deininger and Byerlee, 2011) indicates that 70% of global land deals have happened in Africa, a continent where 60 to 70% of the population depends on land for their livelihoods, including access to food (FAO, 2006; Friends of the Earth, 2010; Hall, 2011; Hoffmann, 2001). Specifically, six of the top 10 countries targeted by investors for agribusiness are in Africa; by the end of 2013, total large-scale land deals documented in Africa stood at about 40 million hectares (Oram, 2014), roughly the land area of Switzerland. Furthermore, three-quarters of all global land acquisitions have occurred in Sub-Saharan Africa (Peebles, 2014).

Following the article discuss the key features of the *1992 Convention on Biological Diversity* (CBD), the the *1992 United Nations Framework Convention on Climate Change* (UNFCCC), and the Directive 2009/28/EC of the European Parliament (Directive, 2009/28/EC) that have been inciting tree and energy plantations, and forest conservation investments. Drawing on available data, subsequently the analysis of four case studies across two African countries was presented, in order to highlight different ways in which indigenous peoples and members of the local public can easily forfeit their land, forests, and fisheries resources; the source of their livelihood to investors of agro fuel, tree plantation, and forest conservation. The expectation is that this article will make a strong case for African governments to disregard any form of global propaganda to use the farmland of the poor and most vulnerable to mitigate climate change or promote energy security.

LAWS, POLICIES, AND AGRICULTURAL INVESTMENT FLOWS

The law is “a body of rules that governs the behavior of whomever, or whatever, is subject to it” (Muldoon et al., 2009). Seen from this perspective, law should lead us to the direction of justice, be it environmental, economic, or social, so that we may be protected from dangerous projects and programs. Yet, injustice may be supported by command and control forms of regulation. Environmental laws, for example, have received a lot of criticisms, given the ways they are implicated in injustice (Chertow and Esty, 1997; Cohen, 1997; Golub, 2000). Law has been used to justify, administer, and sanction Western conquest and plunder, resulting in massive global disparities” (Mattei and Nader, 2008). Thus, “…the rule of law frequently legalizes and legitimates the dispossession of the powerless’’ (Peluso and Lund, 2011). This part of the report unlocks the potential of environmental laws and energy policies to inspire foreign investments in farmland, fisheries and forest resources in Africa.

Environmental laws

Among others, African countries are members in international agreements that have provisions for large-scale investments in farmland, fisheries, and forest resources. The most relevant of those and the number of African nations that are members in them are (1) the 1992 *Convention on Biological Diversity* that was adopted at Nairobi on 22 May 1992 (Secretariat of the Convention on Biological Diversity 2005) and signed by 150 government leaders at the 1992 Rio Earth Summit (CBD) and (2) the *United Nations Framework Convention on Climate Change* (UNFCCC) that was adopted at the

United Nations Headquarters, New York on the 9 May 1992 (UNFCCC). At present, there are 197 parties of the UNFCCC, among which are African governments (UNFCCC Status of Ratification). These agreements are among the greatest happenings of the 1992 Rio Conference on Environment and Development. Like any other international agreement, signing and ratifying the CBD and UNFCCC signified State Parties` pledge to promote 'rationale/sustainable exploitation of their respective countries' diverse natural resources in their individual development efforts' (Fuo and Sama, 2012). African governments, therefore, have a responsibility to enhance sustainable (agricultural) development in the continent.

The convention on biological diversity

In ratifying the Convention on Biological diversity (CBD), African governments devoted themselves to undertake measures designed at achieving three objectives: (1) The conservation of biological diversity; (2) The sustainable use of its components; and (3) The equitable sharing of benefits arising out of the utilization of genetic resources (CBD, Article 1). Article 2 of the CBD defines sustainable use as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations." This definition encourages the use of genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity in a manner that does not prevent others from meeting their needs from such resources.

To translate these three objectives into mandatory obligations, Article 6 of the CBD calls on State Parties to develop national biodiversity strategies, action plans or programmes for the conservation and sustainable use of biodiversity (NBSAPs) (CBD, Article 6). By 2002, a decade after the CBD was opened for signature and at the sixth Conference of the Parties (COP 6), State Parties have developed their NBSAPs and further committed to homogenizing measures for conservation and sustainable use into their national plans, programmes and policies (Convention on Biological Diversity, COP 6 Decision VI/26). As of 4 April 2008, 160 of the 190 parties of the CBD have finalized NBSAPs (Convention on Biological Diversity and IUCN, 3). It should be emphasize that Article 8 of the CBD deals with in-situ conservation. In view of that, contracting parties are required to establish areas where special measures need to be taken to conserve biological diversity, protect natural habitats, rehabilitate and restore degraded ecosystems, and promote the recovery of threatened species (CBD).

Stallworthy (2008) notes "many aspects regarding conservation are premised upon what amounts to encouragement of appropriate protection measures". This suggests that the CBD has a critical function in the context of the conservation and sustainable use of plants and animals, and their habitats. As can be seen, parties to the CBD have committed to integrate goals and targets for conserving biodiversity and promoting their sustainable use into their national policies and plans. Particularly, African governments have supported tree planting programmes and projects (by a wide group of players in the continent) in their efforts to translate articles 6 and 8 of the CBD and hence ensure the sustainable use of land, forests, and fisheries resources.

The framework convention on climate change

The UNFCCC was targeted at mitigating greenhouse gas (GHG) emissions and promoting equity between developing and developed countries. In its Article 4(1) the UNFCCC states that all Parties shall "promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans ...'' (UNFCCC). The *Kyoto Protocol to the United Nations Framework Convention on Climate Change* (Kyoto Protocol) that was enforced February 16th, 2005 translates the UNFCCC (Kyoto Protocol, 1998). It does so by setting emission reduction targets for industrialized nations and establishing three "flexible mechanisms" such as the Clean Development Mechanism (CDM), Emissions Trading Mechanism, and Joint Implementation Mechanism to enable implementation of the UNFCCC (Kyoto Protocol, 1998, Articles 6, 12, 17).

The CDM has two objectives. First, to assist developing countries in achieving sustainable development and in contributing to the objective of the UNFCCC, which is to reduce or prevent emissions of greenhouse gas emissions (GHG) (Kyoto Protocol, 1998, Article 12). Next, to assist Annex I countries in achieving compliance with their quantified emission limitation and reduction commitments (Kyoto Protocol, 1998, Article 12). Under article 10 of the Kyoto Protocol all Parties are mandated to formulate cost-effective programmes containing measures to improve the quality of local GHG emission factors, mitigate climate change, and facilitate adequate adaptation to climate change. According to the Kyoto Protocol, such strategies include measures relating to the energy, transport, agriculture, forestry, and waste management industries/sectors (Kyoto Protocol, 1998, Article 10).

Article 3(3) of the Kyoto Protocol upholds reforestation and afforestation activities as appropriate for the CDM.

During its 7th session that was held at Marrakesh from

29 October to 10 November 2001, the Conference of the Parties (COP) serving as the meeting of the Parties to the Kyoto Protocol adopted a draft decision on land use, land use change and forestry, and requested the Subsidiary Body for Scientific and Technological Advice to develop definitions and modalities for including afforestation and reforestation project activities under the CDM (UNFCCC Report of the Conference of the Parties on its Seventh Session). While reforestation refers to "direct human-induced conversion of non-forested land back to forested land on land which was subject to another land use as of December 31, 1989…" (Gillespie, 2003) afforestation is equated to "direct human induced conversion of non-forested land back to forested land that has not been covered by forest for at least 50 years" (Gillespie, 2003).

Participation under the CDM "may involve private and/or public entities, and is to be subject to whatever guidance that may be provided by the executive board" of the CDM (Kyoto Protocol, 1998; Article 12). This may entail a partnership of actors of diverse legal character. Specifically, it will involve parties, national and international organisations, agencies and other entities, as well as profit and non-profit private entities (Steward et al., 2000: 85). Forest projects such as foreign direct investment in tree plantation, and those which circumvent deforestation and conservation projects would appear therefore to be consistent with the UNFCCC parameter whereby initiatives dealing with climate change are cost-efficient, as some have argued that such investments may provide very low-cost emission credits (Brander, 2003).

Aside from the CDM, the United Nations Programme on reducing emissions from deforestation, reducing emissions from forest degradation, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks (REDD+) is another policy instrument that was developed by the COP and finally launched in 2010 at COP-16 (Voigt, 2016). It was formulated to act as a mechanism under the UNFCCC to encourage developing countries to scale up their efforts in implementing the UNFCCC and adapting to a changing climate. REDD+ aims to incentivize "mitigation action in developing countries and at capturing and channeling developed countries` financial resources to do so" (Voigt, 2016).

On the face of it, there is a close connection between the objectives and commitments of the CBD and those of the UNFCCC and its implementing instruments. This relationship indicates the significant role that afforestation (tree planting) and forest conservation play within these agreements, and provides a legal basis for incorporating tree planting and forest conservation under the CDM and REDD+. The crucial concept in this regard is "sink", which mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere" (UNFCCC, Article 1). The premise of the CDM is that emissions of GHG occurring in country A can be offset by processes, activities or mechanisms which sequester or removes a GHG in country or region B. Nonetheless, is this achievable without correspondingly promoting land-grabbing, the dispossession of local and indigenous peoples of lands and resources that their survival depends on? This is the question the study intends to answer subsequently.

Energy policies

It is said that global drive for biofuel production derived from two alliances, which quite frequently represent differing interests: "States that are concerned about their energy security and environmentalists who are concerned about environmental degradation due to carbon dioxide ($CO_{2)}$ emissions" (Skarstein, 2011). Europe does not have a policy that unambiguously indorses foreign agricultural investment. Yet, European Union agribusinesses and pioneers do retort to legislative incentives. Article 1 of the European Union Directive to promote the use of renewable sources (Directive 2009/28/EC) establishes a framework to promote energy from renewable sources, and sustainability criteria for bioliquids and biofuels. Biofuels are a type of fuel obtained from solid biomass (feedstock) through chemical or biological processing (Gasparatos et al., 2012).

Each Member State, under this directive, shall ensure that the "share of energy from renewable sources, in gross final consumption of energy in 2020 is at least its national overall target for the share of energy from renewable sources in that year" (Directive 2009/28/EC). This Directive defines "energy from renewable sources' to include, *inter alia*, biomass, the biodegradable fraction of products, waste residues from biological origin from agriculture, forestry and related industries" (Directive 2009/28/EC). Also, it obligates Member States to support schemes and "measures of cooperation between different Member States and with third countries for achieving their national overall targets" (Directive 2009/28/EC).

Unlike aggressive renewable energy percentages that European Union Member States have, the federal government of the United States has no clear targets for renewable energy generation. Yet, tackling energy-related GHG emissions, in particular, and climate change in general may constitute an essential priority. Renewable energy policies, such as the Renewable Portfolio Standards (RPS) (Government of Oregon) and Mandatory Green Power Options (MGPO) (Carley, 2009) require electric utilities providers to generate electricity from renewable sources and/or exchange renewable the UNFCCC defines as "any process, activity or energy credits or certificates, in order to meet RPS and MGPO. At the federal level, the US *Energy Independence and Security Act*, which was revised in 2007, calls for the

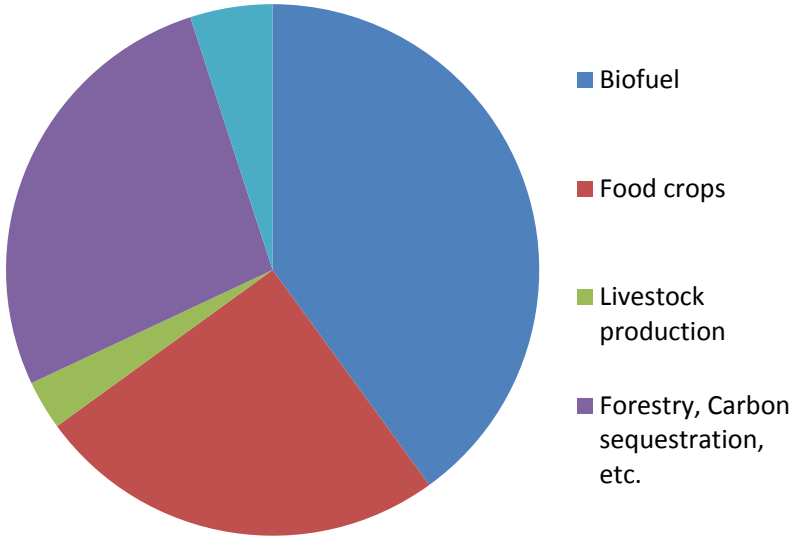

Figure 1. Global land acquisition by sector. Source: Adapted from Anseeuw et al. (2012).

use of 36 billion gallons of biofuels by 2022, up from about 7 billion gallons in 2007 (Earley and McKeown, 2009). In addition the European Union and the United States, an increasing number of countries in Africa, Asia, and Latin America are becoming significant manufacturers and installers of renewable energy technologies (REN21, 2015). There is therefore a general agreement among members of the international community that biofuels would improve energy security and help reduce global dependency on oil.

AFRICA AS CONTEXT: LAND GRABBING WITHIN AFRICA

The literature review shows that Africa has been the target of land-grabbing for biofuel cultivation. Statistics from a study conducted by the International Land Coalition indicates that 40% of global land deals are for the production of biofuels, 25% are for food crop production, 5% for other nonfood crops, and 3% for the production of livestock (Anseeuw et al., 2012). According to these figures which have been represented in Figure 1, 73% of land acquisitions in the world is for farm production, compared with 27% for carbon sequestration, forestry, and others. Compared with global land deals, land acquisition for biofuel production in the African continent is slightly higher. The study also shows that whereas 15% of land deals are for food crop production, 60% of the agreements are to produce biofuel (Anseeuw et al., 2012). Although it is unclear what is responsible for the remaining 15% of land agreements, the finding shows that the percentage of land acquired for biofuel production outweighs that for food. In other words, the 2007 to 2008 food price crises is a contributor, but not the primary driver, to the recent rush by foreign investors in Africa, considering the reasonably high percentage of farmland allocated for the production of biofuels.

Another study by the Center for International Forestry Research (CIFOR) indicates that biofuels-related activities accounted for 2/3 of the total land area acquired for plantation agriculture in Sub-Saharan Africa (Schoneveld, 2011, 15). In particular, 43% of the alienated land in sub-Saharan Africa is envisioned solely for biofuels, 25% is for export food production, 20% for both biofuels and export food, and approximately 9% is for tree plantations (Schoneveld, 2011:9). According to this study, the percentage of land acquired for biofuels production supersedes that for food, and thus, challenges the prevailing discourse that links land deals, solely, to food price crisis. CIFOR also claims that Western companies from the United Kingdom, Denmark, Sweden, Finland, France, and the United States have been at the forefront to accumulate land for agro-biofuel cultivation, especially, in Madagascar Ghana, Liberia, Mozambique, South Sudan and Zambia (Schoneveld, 2011:15). These countries jointly account for about 2/3 of the total land area acquired for the cultivation of biofuels (Schoneveld, 2011:15).

Biofuels in Tanzania

Within the past ten years, interest in biofuel development in Tanzania has been on the rise. The International Institute for Environment and Development (IIED)

Table 1. Land-grab for biofuel cultivation in Tanzania by 2009.

Investor	Crop	Hectare acquired
African Biofuel and Emission Reduction Co. TZ. Ltd	Croton megalocarpus	20,000
African Green Oils	Oil palm	860
BioShape	Jatropha	34,000
CMC Agriculture Bio-energy Tanzania	White sorghum	25,000
Donesta Ltd and Savannah Biofuels Ltd	Jatropha	2,000
FELISA	Oil palm	4,258
InfEnergy Co. Ltd	Oil palm	5,818
Kapunga Rice Project	Jatropha	50,000
Kikuletwa Farm	Jatropha and Aloe vera	400
Prokon BV	Jatropha	10,000
SEKAB BT	Sugarcane	22,500
Shanta Estates Ltd	Jatropha	14,500
Sun Biofuel	Jatropha	8,211
Tanzania Biodiesel Plant Ltd	Oil palm	16,000
Trinity Consultants/ Bioenergy TZ Ltd	Jatropha	16,000

Sources: Adapted from Sulle and Nelson (2009, 7).

Table 2. Land-grab for biofuel cultivation in Tanzania by 2013.

Company	Crops	Hectares
Safe Production Ltd	Maize	3,500
InfEnergy Co. Ltd	Oil palm	5,818
Africa Biofuel and Emission Reduction Co.'TZ. Ltd (Wilma Group)	Croton	20,000
AgriSol Energy LLC US	Maize	80,317
AgriSol Energy LLC US	Maize	219,800
Sithe Global Power, LLC	Oil palm	50,000
African Green Oils	Oil palm	30,000
CHAWAGWA	Jatropha	200
Donesta Ltd & Savannah Biofuels LTD	Jatropha	2,000
Eco Green Fuels Tanzania Ltd		500
RUBANA Farm	Jatropha	400
SAVANA Biofuel	Jatropha	5,000
Shanta Estates Ltd	Jatropha	14,500
Tanzania Biodiesel Plant Ltd	Oil'palm	16,000
Trinity Consultants/Bioenergy TZ'Ltd	Jatropha	16,000

Source: Adapted from Sulle and Nelson (2009).

reported in 2009 that over 4 million hectares of farmland have been requested for jatropha, sugarcane, and palm oil investments (Sulle and Nelson, 2009, 18). By the end of 2008 640,000 hectares of the 4 million hectares had been allocated (Sulle and Nelson, 2009). Table 1 is a summary of current biofuel investments in Tanzania, illustrating that by 2009, some 229,547 ha of land had been transferred to biofuel companies, including SEKAB BT, sun biofuels, among others, to grow biofuels such as sugarcane, oil palm, jatropha, and white sorghum. Sulle and Nelson (2009) also cited 15 biofuel investors that are currently operating maize, oil palm, jatropha and sorghum plantations in Tanzania as shown in Table 2. It goes without saying that these land deals will prevent local Tanzanians from farming, fishing, hunting, or harvesting of non-timber forest products on land that has been allocated to biofuel investors.

Sun Biofuels

Sun Biofuels, headquartered in London, is an agrofuel

company. In 2008, Sun Biofuels established a jatropha plantation on a land area estimated at 8,211 ha that were leased from 11 villages in the Kisarawe district in Dar es Salaam, Tanzania (Oakland Institute, 2012, 1). In return, Sun Biofuels promised financial compensation, water wells, 700 jobs, improved schools, health clinics and roads to the affected households (Oakland Institute 2012, 1). Studies have shown that biofuels farming could, indeed, provide different forms of benefits to the host communities and countries, including opportunities for rural development, the new export market for land-rich countries, and long-term energy security (Cotula et al., 2008). However, the case of the Sun Biofuels project was somehow different, as the project left lots of indigenous and local peoples in anguish as they became landless and hopeless about the future.

To begin with, the property allocated to Sun Biofuels, according to the Oakland Institute, was jointly held forest and bush land. The land in question accommodated the communities` social and economic activities, including grazing, charcoal production, and harvesting of timber, poles, firewood, wild food, fodder, and medicine (Oakland Institute, 2012, 4). These are additional activities that community members depended on to enhance their food and income security beyond subsistence farming. Statistically, up to 70% of the household income of some of the affected families came from the land in question (Oakland Institute, 2012, 4). It was obvious that, sooner or later, the establishment of the Sun Biofuels investment on land that the local populations historically had access to graze animals, cultivate crops, and engage in traditional practices would cause the villagers to lose access to these additional sources of income and traditional way of living.

The villagers were displaced, and their lives shattered, chiefly because Sun Biofuels, after grabbing their land, refused to fulfill its promises, including the pledge to compensate for lost wages. Having acquired about a quarter of the villagers' farmland, the Guardian newspaper wrote, Sun Biofuels was still unwilling to provide the affected villagers with (adequate) compensation. For example, one family received barely 13 million Tanzanian shillings (£4,835) for 670 ha of his farmland that was lost to Sun Biofuels (The Guardian, 2011). The promise to provide new classrooms, books, and materials to the affected communities was never appropriately honored. For those who agreed to become agricultural workers, their wages were dishearteningly little to compensate for the loss of income previously received from subsistence farming (The Guardian, 2011).

A few months after some of the displaced villagers rushed to take jobs at Sun Biofuel's plantation, the promised £42-a-month salary turned out to be a scam. While trying to inquire why the agreed wage did not materialize, Saidi Abasi (a community member) received this response from his employer (Sun Biofuels): "if you want to work, work. If you don't, get out" (The Guardian, 2011). As if the degrading situation of the employees was not enough, plantation workers were asked to spray pesticides without protective equipment (The Guardian, 2011), an act that is associated with severe health impacts according to the World Health Organization (Phung et al., 2012).

One of the plantation laborers claimed he was not paid the full severance pay due for his 18 months of service after his contract was terminated (The Guardian, 2011). Beside farmland, the establishment of the project led to an excessive loss of access to water and other non-timber forest resources such that the villagers started buying charcoal and water (Oakland Institute 2012, 4), resources which were generously accessible before the establishment of the project in the area plantation. Some of those affected by this investment see their predicament as "the return of colonialism" in the country (The Guardian, 2011).

The company initially announced that the investment would generate 1,000 to 4,000 jobs for each village participating in the project, paying USD 1,095/person/year (Habib-Mintz, 2010: 3985-3987). It, however, became evident, as the investment proceeded that the pledged wages could not be attained, perhaps because jatropha oil was not as profitable as initially projected (Romijn and Caniëls, 2011). In 2011 Sun Biofuels closed down its company in Tanzania due to economic concerns (Gasparatos et al., 2012, 33). The company's shares were bought by 30° East, which then lay off about 600 employees of Sun Biofuels, to mothball the project. At the time the Oakland Institute was conducting its research, 3D East had just 35 workers (Oakland Institute, 2012).

Considering all of the above, it could be said that overall the populations affected by the Sun Biofuels investment eventually became financially worse off. The media has also captured many other biofuel schemes in other parts of Africa that have been left in limbo. In Ghana, for illustration, profits generated through jatropha-related investments could not offset losses from other revenue sources in the affected communities (Schoneveld et al., 2011, 10). Most of these projects appear to have harmed the people they were supposed to help by causing them to lose their farmlands, supply of potable water, access to non-timber forest products, and the promised employment opportunities and social amenities. There are no signs that the plantations will be returned to the former users which is the affected communities.

SEKAB Bioenergy Tanzania Limited

SEKAB BioEnergy Tanzania Limited (SEKAB BT) was formed to engage in the production of bioethanol in Dar es Salaam, Tanzania (SEKAB BioEnergy (T) Limited 2008). It is important to mention here that SEKAB BT is a

subsidiary of Swedish Ethanol Chemistry AB (SEKAB). SEKAB belongs to four energy companies in Sweden (Skellefteå Kraft, OK, Örnsköldsvik Energi, and Umeå Energi (SEKAB BioEnergy (T) Limited 2008), and produces and distributes ethanol in large quantities. SEKAB represents 15% of the European Union ethanol market and 75% of the Scandinavian ethanol market, in addition to providing low blends, E85, ETBE, and bus fuels (SEKAB BioEnergy (T) Limited, 2008). Moreover, the majority of the ethanol fuel that will be produced in Tanzania by SEKAB BT will be exported (SEKAB BioEnergy (T) Limited, 2008).

There are viewpoints that the creation of SEKAB BT in Tanzania was facilitated by the governments of Tanzania and Sweden through the Swedish International Development Cooperation Agency, a government agency of the Swedish Ministry of Foreign Affairs (SIDA) (Hakiardhi, 2011). In particular, SEKAB BT was created to develop a sugar cane plantation and ethanol production plant in Razaba in Bagamoyo district, among other parts of Tanzania. SEKAB BT claims that the Razaba estate "will be the first in the development of BioEthanol/BioElectricity projects in Tanzania." Besides, the company estimated that, to achieve this objective, 15,000 ha at Razaba will be planted with sugar cane, with yields estimated at 90 to 110 tons/ha. In fact, the project kick-started in 2007 when the company established a seed cane nursery of 240 ha of the acquired land area (SEKAB BioEnergy (T) Limited, 2008).

SEKAB BT argues in its EIA report that the plantation represents a carbon sink and that a cessation of the project would mean increased atmospheric GHG emissions from transportation in the region (SEKAB BioEnergy (T) Limited, 2008). Two important factors that directly relate to the environmental impacts of the project need to be outlined are: First, the EIA report shows that the project will be a monoculture, involving the use of fertilizer. The Union of Consent Scientists has asserted that monoculture agriculture is highly reliant on synthetic fertilizers and pesticides, and can adversely impact the environment, economy, and health of subsistence communities (Union of Consent Scientists). Next, the SEKAB BT project will be irrigated with water from the Wami/Ruvu River basin, two of the main river basins that provide water to the local communities (SEKAB BioEnergy (T) Limited, 2008). Given its location, the probability that this project will likely impact water quantity and quality is high. It is plausible that rare and endemic species and sensitive habitats that are found in the forest thickets, including mangrove ecosystems that are present at the estuaries of these rivers, and that helps in sedimentation will be adversely impacted.

The District Game Officer at Bagamoyo, Tanzania, in addition to other researchers, has argued that biofuel projects (such as the one that SEKAB BT) is operating in the Bagamoyo area would, generally, encroach into reserve buffer zones, mangrove areas, and migration routes (Larsen, 2013). Other Tanzania officials have pointed to prevailing conflicts over water supply between local users, particularly in neighborhoods where agricultural production is more intense (Larsen 2013). The World Wide Fund for Nature (WWF) is also worried about the amount of irrigation water and the effects of farm run-off of this project on local water supplies and ecosystems (Larsen, 2013). However, SEKAB BT has disregarded these concerns, arguing that water is abundant at the site's downstream location and that the "use of water at this location … is a benefit as the water would anyway have drained to the ocean" (Larsen, 2013).

The company also claimed that adopting the no project alternative would mean "missing all the positive benefits such as increased revenue, better and quality services, introduction of a new cash crop and employment opportunities" (SEKAB BioEnergy (T) Limited, 2008). In 2009, the parent company, SEKAB was awarded the prestigious "Sustainable Bioethanol Award" in recognition of the company's effort to promote sustainable development in, among other countries, Tanzania. Nadim Chaudhry, Managing Director of Green Power Conferences, is of the viewpoint that the award was created "in order to promote the tangible benefits of biofuel and to encourage additional focus on sustainability criteria throughout the biofuel value chain" (Sustainability Award for SEKAB, 2009).

On the other hand, concerns about how SEKAB and its subsidiary, among other biofuel investors, valued land and livelihoods have been raised by many different analysts, including the Stockholm Environment Institute (SEI) and Action Aid. SEI reported that the project will contribute to loss of local land rights and access to farmland, as well as grounds for fishing, hunting, grazing, and collection of forest resources. Four particular points of concern to the affected villagers have been underlined. These are that (1) land valuations excepted the fact that the villagers might lose access to customary land upon which they rely for livelihood, (2) the valuation process undervalued significant fruit trees, among other resources on the land that provided additional income as well as food, (3) on-farm investments in, for example, soil and water conservation, were not fully considered, and (4) farmers were given land plots of smaller size and of lower quality during relocation (Larsen, 2013).

As indicated in the EIA report that was conducted for this project, Bagamoyo District had a total population of 228,967 in 2002 (SEKAB BioEnergy (T) Limited, 2008). The report also suggests that the project area, before the establishment of this project, was populated by farmers, hunters, traders, and fishers. These groups of people undoubtedly depended on the project area for grazing, farming, hunting, charcoal production, and collection of forest resources, some of which are of high medicinal value (SEKAB BioEnergy (T) Limited, 2008). Government

officials at the Rufiji Basin Development Authority have also reported that the "upper areas are characterized by high population densities and a hospitable climate and that land use is dominated by smallholder farming systems that produce mainly cassava, banana, cashew nut, maize, rice and pineapples." The middle part of the basin has typically been under pastoralist land use, although increasing competition for land has pushed ranchers to the bottom of the basin (Larsen, 2013).

The SEI report shows that farmers, about 600 families, who formerly worked on the Razaba farm while it was operational, have since continued to live there (Larsen, 2013). While analyzing the impacts of the SEKAB BT project, Action Aid noted that the project was likely to displace 185 households (approximately 350 to 500 people) living in the project impact area (Gama Makaani) in 2011 (Ross and McDiarmid 2015). The Tanzanian government has refused to explicitly recognize the customary rights held by the indigenous peoples and others affected by this project as mandated by international human rights law, arguing the land formally belongs to the government (Ross and McDiarmid, 2015). Because they have lived on the land and depended on the fruit trees planted on it by their ancestors for over half a century, the affected populations are entirely convinced that they are the rightful owners of the land that was allocated to this investor (Larsen 2013).

It is unfortunate that after EcoEnergy bought the shares of SEKAB BT in Tanzania (Larsen, 2013), the new company "came with warnings and posters saying that the locals were not allowed to do any agricultural activities in this area." On the one hand EcoEnergy acknowledged that the project involved 'involuntary' resettlement, and promised to provide financial and material compensation to each household that has been affected, physically and economically (Ross and McDiarmid, 2015). On the other hand, the affected villagers have complained about the quality of the compensation, including the land being offered and the absence of binding commitments from EcoEnergy (Ross and McDiarmid, 2015). It has also been reported that some of the 185 affected households in the company's concession have refused to accept resettlement and initiated a legal dispute with EcoEnergy over what they claim is their right to the land (Ross and McDiarmid, 2015).

It was expected that EcoEnergy would honor its predecessor's promises on social development such as the building of schools in the affected communities. It must have been difficult to hold the company accountable for these undertakings, given that some of them were disputable, given they were unwritten according to Action Aid report (Ross and McDiarmid, 2015). Enforcing an oral agreement may be challenging if there is no written document signed by the concerned populations to whom these pledges have been made and the company making the commitments. After its fact-finding mission in Tanzania, WWF-Sweden reported that the absence of knowledge among villagers suggests a "special responsibility for investors to ensure that local livelihood compensation and social development are adequately addressed" (Roberntz 2009:21). It is unfortunate that EcoEnergy, despite hopes to address the issues of the local people that it inherited from SEKAB, withdrew in 2010 due to complications and conflicts with the affected villagers (Larsen, 2013). At this point, it is doubtful whether the land will be returned to the villagers or will be resurrected.

Tree planting in Uganda

Like Tanzania and many other African countries, Uganda is experiencing an increasing number of large-scale land investments, mostly by private agricultural investors and wealthy nations who are mainly driven by, among different stimulus, the motive to establish tree plantations over thousands of hectares of croplands and forest reserves, with the objective of capturing emissions of carbon dioxide from the atmosphere and storing it, in return for carbon credits. The Ugandan Carbon Bureau (UCB), a firm created to advise and support carbon credit buyers, among others wanting a better understanding of climate change and the carbon emissions trading markets, says Uganda is one of Africa's "leaders in the fast developing carbon finance markets" (Ugandan Carbon Bureau). While selling trees for carbon credits is good for the environment, increasing evidence points to such investments as unable to deliver net benefits to indigenous peoples and local community members. Such investments can forbid local peoples to graze animals, hunt, fish, farm, burn charcoal, collect firewood, or cut trees in the project area. In some cases, primary forest is being replaced with secondary forests (Eucalyptus and pine plantations).

Green Resources (AS)

Green Resources (AS) is a Norwegian-owned carbon offset company that has acquired land and established tree plantations through its Ugandan subsidiary- Busoga Forestry Company, to generate timber products and carbon credits. This investor holds two licenses over 11,864 hectares of two forest reserves in Uganda (Bukaleba Forest Reserve in eastern Uganda in 1996 and the Kachung Forest Reserve in northern Uganda in 1999). The proposed project is a reforestation activity: the company plan is to reforest part of the acquired land for carbon sequestration and conserve the remainder of the property (Green Resources Busoga Forestry Company Ltd .

It should be mentioned that these plantations have been validated as an afforestation and reforestation projects under the Forest Stewardship Council (FSC), the Verified Carbon Standard (VCS) in 2012, the Climate Community and Biodiversity Standards (CCBS) in 2011, and the Clean Development Mechanism (CDM) (Green Resources, Busoga Forestry Company Ltd.). This is to say that Green Resources is committed to complying with these internationally recognized conventions, guidelines, and standards related to the company's line of businesses. Again, this project is a carbon and forest offset projects under the CDM, FSC, CCBS and VCS.

Green Resources aims to have an overall positive impact on the environment, surrounding communities, and stakeholders (Green Resource, Environmental and Social Impact Report, 2016). In particular, Green Resources seeks to ensure that its activities are environmentally sustainable, and believes its activities continue to have a positive environmental effect (Green Resource, Environmental and Social Impact Report, 2016). Accordingly, Green Resource, through its subsidiary, will, while striving to reduce its greenhouse gas emissions, evaluate the impacts of its operations on ecosystem, biodiversity and vulnerable communities. Put differently, the company is determined to promote a sustainable socio-economic development and environmental protection, in addition to obtaining an FSC certification. Green Resources is convinced that the project will sequester GHG emissions through the establishment and sustainable management of tree plantations in areas that meet conditions for CDM eligibility.

On its Project Idea Note of 2010 Green Resources states: "the project area is predominantly grassland with a few scattered primary trees with less than 10% of crown cover…" It further notes that the Bukaleba Central Forest Reserve is in a degrading state due to "forest offorest remnants which were cleared…through encroachment from local communities' (VCS, Bukaleba Forest Project). Encroachment activities would include cultivation, grazing, bushfires…and charcoal production". Green Resources also declared that "most of the plantation area underwent deforestation for conversion to subsistence agriculture which gave way to shrubland and grass after it was abandoned by community members. According to Green Resources, "the project activity will establish and manage exotic and indigenous reforestation on approximately 2,061 ha of degraded shrub and grassland" (VCS Project Database).

However, a 2014 report by the Oakland Institute (that was aimed to give voice to the affected villagers) shows that the concession was never abandoned as the company claims. According to the report, the affected villages "are traditionally dependent on shifting cultivation and small-scale subsistence farming and fishing for their livelihoods" (Oakland Institute, 2014:5). This information proposes that the affected populations were farmers and fishermen and were actively involved in non-mechanized farming, cultivating food and cash crops. In particular, the populations cultivated beans, pigeon peas, groundnuts, cassava, sweet potato, millet, maize, sorghum, rice, among other food and cash crops (Oakland Institute, 2014:5) that are critical for their survival, an indication that the land in question was not neglected as the company claims.

Framtiden (The Future in our hands - FIOH) is the largest Norwegian environmental organization that works for a fair distribution of the world's natural resources. This group reported in 2012 that "approximately 8000 farmers and fishermen were living inside the reserve, and thus inside the company's concession area," which is estimated at 9165 ha of land in the Mayuge district in Uganda (Framtiden i våre hender). Local leaders in the affected villages reported that "Hunger is a problem…There is no land where we can cultivate our crops…Some of us are employed [with the Green Resources] but getting through a whole month without food is difficult…" (Framtiden i våre hender). It has been difficult to meet their basic needs as, according to the villagers, Green Resources "harasses us. They don't want us to cultivate food. Some of us have a few animals, but they chase us and the animals away" (Framtiden i våre hender). In the area where the villagers "cultivated food they have removed the crops, we ask the company to let the remaining areas persist, so that we can cultivate food there" (Framtiden i våre hender).

To Green Resources, however, "forestation is one of the most effective ways to generate superior return for its shareholders, provide an excellent working environment for its employees, protect the environment and help develop the local communities where it operates" (Green Resources Objectives and Goals). The company is determined to become the "preferred partner for subsistence communities in the affected areas and be "Africa's best and the world's best positioned forest and carbon credit (Green Resources, Objectives and Goals). Because thousands of farmers and fishermen, etc. lived within Green Resources' concession area and supported themselves by means of farming, cattle, and fishing as these reports show, establishing a pine and eucalyptus plantation in the concerned property will only help to deteriorate the environmental, social, and economic conditions for the affected villagers. Specifically, it will reduce local access to the land, water, and other resources that were available to the locals to cultivate their crops and carry out other activities that are necessary for their survival. Green Resources, by 2014 had suffered three fatalities because of road traffic accidents (Green Resources Environmental and Social Impact Report) which left the company's continued focus on accident prevention, health and safety training, and the provision of a safe working environment questionable.

Green Resources' first carbon credits were purchased by the Swedish Energy Agency to offset the country's pollution (Green Resources, Ugandan Plantations). So, on the one hand the Government of Norway is using Green Resources to meet the country`s emissions reduction targets under the climate change regime and the company is benefiting from earnings from selling carbon credits. On the other hand poor villagers are the ones to suffer the loss (losing farmlands, and grazing lands, and forest resources) associated with combating climate change and mitigating its impacts. This context is similar to what justice advocates called 'environmental injustice,' a concept that Francis Adeola (2000) defines as "any undue imposition of environmental burdens on innocent bystanders or communities not parties to the activities generating such burdens".

Moreover, the establishment of this project is in violation of the rights of indigenous peoples (and villagers), including the right not to be subjected to the destruction of their culture under internationally recognized environmental and human rights laws. The United Nations Declaration on the rights of indigenous peoples (UNDRIP), under its 8th article, condemns actions which have the aim or effect of dispossessing local and indigenous communities of their lands, territories or resources (UNDRIP, 2007). States shall, under this declaration, provide mechanisms for the prevention of land and resource grabbing, cultural degradation, and forced population transfer which has the objective of undermining any of indigenous and local rights (UNDRIP, 2007).

New Forests Company in Uganda

Licenses were granted in 2005 over plantation areas to London-based New Forests Company (NFC) by the Ugandan National Forestry Authority (NFA) to allow for NFC`s carbon offset projects. NFA embarked on procedures (between 2006 and 2010) to remove the former residents who have been described as "illegal encroachers" (Grainger and Geary, 2011). Archival research by Oxfam illustrates that the over 22,000 people that were under threat of eviction to make way for NFC's operations had lived in the concession company since the early 1970s (Grainger and Geary, 2011).

Some of the villagers that were affected by the NFC project claimed that they had lived on the land for decades: The land in question was allocated to them during the Idi Amin regime in acknowledgment of their ancestors having fought in the British army during World War II. They also claimed that they were "strong and thriving permanent communities" that had been paying taxes to the government (Grainger and Geary, 2011). The villages had functioning government structures, including schools, local council systems, health centers, churches, permanent homes, and farms on which they cultivated crops to sustain their families and sell the surpluses on the domestic market (Grainger and Geary, 2011). Francis Longoli, Oxfam claims (Grainger and Geary, 2011), is one of those that were evicted from their farmlands, houses, and other resources to allow for NFC's carbon offset projects. He claims:

"I remember my land, three acres of coffee, many trees - mangoes and avocados. I had five acres of banana,' Francis Longoli articulates. "I was given awards as a model farmer. I had cows for milk, ten beehives, two beautiful permanent houses. My land gave me everything from my living to my children's education. People used to call me Omataka –someone who owns land. Now that is no more. I am one of the poorest now."

Oxfam International's report, which was confirmed in REDD-Monitor, The Guardian, The New York Times, and Al Jazeera, shows that "the people evicted from the land are desperate," having been driven into poverty and landlessness (REDD-Monitor). Claims by the company that the displaced people "voluntarily and peacefully" evacuated the area have been challenged: One of the evictees told Oxfam that the company took their land, adding that the firm's employees and the "Ugandan security forces enforced the evictions, setting fire to homes and crops and in some cases beating and imprisoning people" (Guardian). It must have been a painful time for the villagers, especially the ones that saw "gun-toting soldiers and an 8-year-old child burning to death when [a] home was set ablaze by security officers" (New York times). Residents who were evacuated say they now live in extreme poverty (AL JAZEERA). This case is yet another instance of local communities that are losing out as a result of foreign land-based investments.

CONCLUSION

The objective of this article was to clarify whether concerns for food security and trade and investment liberalization were the only factors arousing hunger for land, forests, water, and fisheries resources in Africa. The investigation demonstrates that considerations for energy security and climate change have been key drivers in the African land-grab over the past few years. Certain provisions of the *United Nations Framework Convention on Climate Change, the Convention on Biological Diversity*, and the EU Renewable Energy Directive have encouraged foreign investment in agriculture and forest conservation in Africa. The majority of the alienated land in sub-Saharan Africa is envisioned solely for biofuels and forest conservation, suggesting that the percentage of land acquired for the production of biofuel and sequestration of greenhouse gas emissions outweighs

that for food. This challenges the prevailing discourse that links land-grabbing, solely, to food price and global food security and financial crises: Tree planting, agro-biofuel cultivation, and forest conservation have made acquisition of land attractive investments in Tanzania and Uganda.

As reported in 2012 by Fuo and Sama, the main challenge for African countries, therefore 'remains the need to balance environmental sustainability and short and long-term development imperatives'. Large-scale investments in agricultural and conservation projects have the potential to promote unsustainable developments by threatening the rights and opportunities of local and indigenous peoples to meet their basic human needs. Therefore, African governments must not always perceive and embrace carbon offset and biofuels projects as the only technologies to combat climate change and adapt to its impacts. Without effectively considering the socio-economic and cultural impacts of energy and climate policies, realizing the 2030 SDG to leave no one behind will be difficult. The governments of Tanzania and Uganda should embark on measures, both legislative and policy measures, to protect fundamental human rights, including rights to food, housing, water, etc. while striving to achieve environmental sustainability and sustainable development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Spatio-temporal dynamics of land use practices on rivers in tropical regions: A case study of Ruiru and Ndarugu Basins, Kiambu County, Kenya

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Land use dynamics are known to cause considerable modifications to the environment with broad and sometimes severe impacts on water quality and aquatic natural resources. In this study, the impacts of land use practices on water quality were estimated during the dry and wet seasons in Ruiru and Ndarugu Rivers, Kenya using remote sensing, geographic information systems and statistical techniques. A total of 12 sampling sites associated with three different land use types (forest, agriculture and urban) were selected. All water quality parameters were measured *in situ* in two dry seasons and two wet seasons and subjected to Kruskal Wallis statistical analyses. Significant variations were seen in water quality parameters between land use types. Higher temperatures were associated with urban dominated sub-basins, while dissolved oxygen was highest in forest sites. Turbidity was highest in agricultural sites and lowest in forested sites, but pH did not differ significantly across all sites. Seasonal impacts were recorded for most water quality parameters tested in all land use types, with agriculture and urban land use showing stronger impacts on water quality in the wet season than in the dry season. This study indicates that both agricultural and urban land use are key factors that affect water quality change. Land-use specific water conservation measures should be enhanced to limit both point and non-point sources of pollution in the study area.

Key words: Land use, water quality, seasons, Ruiru and Ndarugu Rivers, water conservation measures.

INTRODUCTION

Rivers are susceptible to land use change and continuous exploitation (Withers and Jarvie, 2008; Vörösmarty et al., 2010). Deterioration of rivers in terms of water quality as a result of unsustainable human activities has become a major environmental concern (Chen and Lu, 2014), which are directly reflected in land use and land cover characteristics (Kang et al., 2010). To make meaningful decisions for effective water quality management, there

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is need to understand the relationship between land use and water quality as this relationship can be used to target critical land use areas and to institute appropriate measures to minimize pollutant loading in water resources (Abler et al., 2002). Population expansion in Kenya is closely associated with a massive increase in demand for land, which is highly related to urban growth and increased agricultural activities. Kenya is classified as one of the water-scarce countries in the world (UNESCO, 2006), and land use implications on water systems have been shown to cause far-reaching consequences, both ecologically and economically. Agriculture accounts for the highest demand for freshwater resources in Kenya, with demand predicted to rise from 3,965 million m³/day in 1990 to 8,138 million m³/day in 2010 (UNESCO, 2010). It is expected that the large and growing proportion of the population living in urban areas will put considerable pressure for continued transfers of water out of agriculture to supply growing urban centers (World Bank, 2010). Other competing uses of water in Kenya include hydroelectricity, protection of aquatic ecosystems, and recreation. The high population expansion and intense land utilization in the catchment are attributed to increased land degradation, leading to degradation of water resources, one of the critical ecosystem services. Additionally, increased demand for food leads to intensive farming practice and increased destruction of forest cover to open up areas for cultivation.

The rapid land use degradation, especially in developing countries will continue to be one of the crucial factors that must be considered in the human dimension of the 21st century (Torrey, 1998). The lack of basic knowledge of the landscape attributes to hydrology and its ecological impacts has made us unable to asses, much less to manage and restore limited water resources in the country. Therefore, timely and accurate estimation of implications of population systems to land use attributes is of considerable significance for decision makers in watershed planning and for a better understanding of the relationships between population growth, economic and environmental conditions (Yu and Changshan, 2004). Despite these dire needs to monitor ecosystems, the ecological and health values of the Ndarugu and Ruiru Rivers catchment, particularly within the settlement and agricultural areas are not yet fully addressed.

Since ecosystems have been degraded worldwide leading to loss of valuable environmental services that they provide, there has been a growing search for practical solutions. The rapid land use degradation, especially in developing countries will continue to be one of the crucial factors that must be considered in the human dimension of the 21st century (Torrey, 1998). The lack of basic knowledge of the landscape attributes to health problems and its ecological impacts has made us unable to asses, much less to manage and restore limited water resources in the country. Therefore, timely and accurate estimation of implications of population systems to land use attributes is of considerable significance for decision makers in watershed planning and for a better understanding of the relationships between population growth, economic and environmental conditions (Yu and Changshan, 2004). Despite these dire needs to monitor ecosystems, the ecologic and health values of the catchment of Ndarugu and Ruiru Rivers, particularly within the settlement and agricultural areas are not yet entirely addressed.

MATERIALS AND METHODS

Study area

The Ruiru River (1° 4'43.90"S, 36°50'54.24"E) and Ndarugu River (1° 0'49.80"S, 36°55'8.86"E) are major tributaries of Athi-Galana River, the second longest river in Kenya. Both rivers are located in Kiambu County in the central part of Kenya. The rivers originate from Gatamaiyo Forest, the southern-most tip of the Aberdare Ranges (Figure 1). The drainage area of the Ruiru and Ndarugu Rivers are, approximately, 367 and 230 km^2; length of the main river channels 40 and 48km; and average gradients of about 0.057 and 0.054, respectively. Rainfall is predominantly influenced by altitude, with the mean annual rainfall ranging from 500 mm in the lower parts and increasing gradually to 2000 mm in the upper region. The rainfall regime is bimodal, where long rains fall in April and May. This is followed by a cool dry season in July and August, before short rains which fall from October to December. The mean maximum temperatures range from 26 to 28°C in the eastern and southern parts, and 18 to 20°C in the Northwest; while the mean minimum temperatures vary between 14 and 16°C in the eastern parts and 6 to 8°C in the north western parts. The study area is mainly composed of volcanic rocks of varying ages (Saggerson, 1967). To the northeast, geology varies from Miocene to Pleistocene volcanics while intermediate and basic lavas are found in the south. Land use consists of smallholder mixed farming, large holder farming (mainly tea and coffee), grazing, nature conservation and human settlements. The main economic activity is agriculture in tea, coffee, dairy, poultry, and horticulture farming.

Landsat multispectral scanner (MSS), thematic mapper (TM) and enhanced thematic mapper plus (ETM+) imagery for the years 2005, 2010 and 2015 were collected from Global Land cover Facility (University of Maryland, 2016), and US Geological Survey (USGS, 2015) and employed for analyzing the spatial and temporal changes in land use-land cover in the study area. Other available reference data such as aerial photography and topographic maps, and ancillary data were also acquired from Survey of Kenya. Historical land use classifications from Food and Agricultural Organization (FAO), Africover data (International Livestock Research Institute- ILRI data base) on land use and land cover classification for Kenya were also used as reference. Additionally, review of different documents on land management; conservation legislations in forest, watershed services, wetland management and urban development plan were used to support a better understanding and get reference data on land use and land cover in the region.

Several image processing procedures were employed for this study including image pre-processing, classification, accuracy assessment and time-series analyses. Landsat 7 bands 4, 5, 3-Red, Green, and Blue (RGB) were composited, as well as

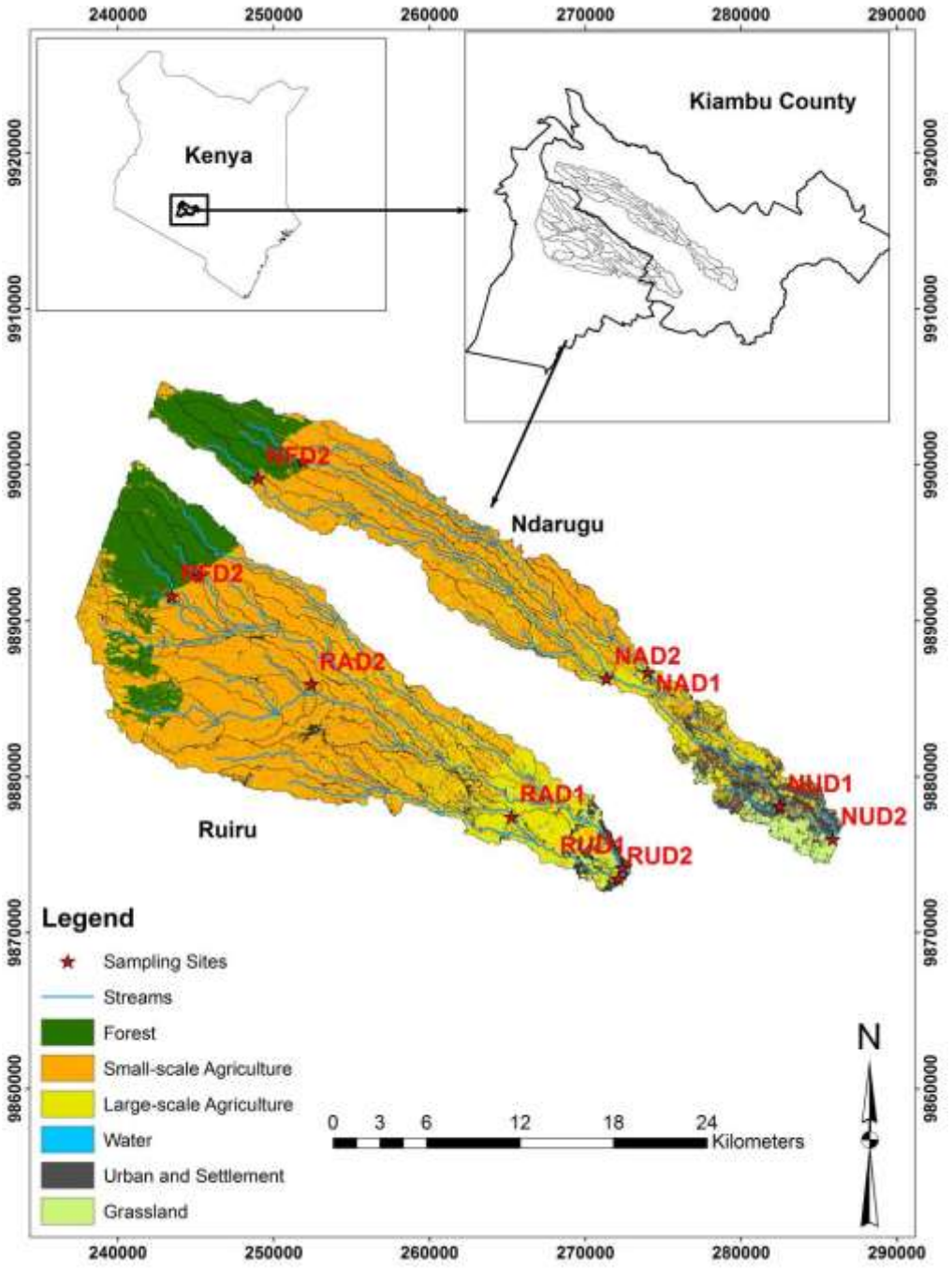

Figure 1. Map of the study area.

corresponding Landsat 8 bands (5, 6 and 4 RGB). Geometric rectification and radiometric normalization were performed for image pre-processing. The Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm was adopted to identify clusters from image data. In ISODATA analysis, unsupervised classification was first conducted to identify spatial clustering of different classes. The image was segmented into unknown classes depending on its statistical similarities by using a suitable clustering algorithm. Supervised classification was done, by taking sample points in stratified random sampling scheme for ground truth data and with the support of field knowledge and ancillary data for land use. Those classes were labeled to the relevant land use/land cover patterns by a posteriori analysis. This technique implies a grouping of pixels in multi-spectral space. Pixels belonging to a particular cluster are therefore spectrally similar. In order to quantify this relationship, Euclidean distance was used as a similarity measure.

Table 1. Land use classification scheme.

Indicator	Class name	Description
Vegetation	Forest	Areas under forest mainly on the higher altitudes to the north-west of both Ruiru and Ndarugu watersheds
	Grassland	Areas vegetated with grass and herbaceous species, with relatively low occurrence of shrubs
Agriculture	Small-scale agriculture	Areas under subsistence farming, typically less than 5 hectares in size
	Large-scale agriculture	Areas under commercial large-scale farming
Built up areas	Urban and settlement	Areas characteristic of highly developed town/ urban areas, residential areas at the urban fringes, roads, and other built-up areas
Hydrology	Water	Dam reservoir, lakes, rivers and streams.

Table 2. Description of sampling sites for water quality assessment.

Sampling site	Altitude (metres)	Location	Dominant Land use
RFD1	2231	0° 58.582'S, 36° 42.026'E	Natural Forest
RFD2	2226	0° 58.793'S, 36° 41.690'E	Natural Forest
RAD1	1655	1° 6.474'S, 36° 53.438'E	Small scale Agriculture dominated by tea and coffee bushes
RAD2	1971	1° 1.866'S, 36° 46.514'E	Large-scale Agriculture (flowers)
RUD1	1551	1° 8.257'S, 36° 57.270'E	Urban areas and settlement
RUD2	1482	1° 8.495'S, 36° 57.325'E	Urban areas and settlement
NFD1	2140	0° 54.858'S, 36° 44.628'E	Natural Forest
NFD2	2135	0° 54.705'S, 36° 44.696'E	Natural Forest
NAD1	1608	1° 1.464'S, 36° 58.139'E	Small scale Agriculture dominated by tea and coffee bushes
NAD2	1630	1° 1.666'S, 36° 56.724'E	Large-scale Agriculture (flowers)
NUD1	1500	1° 6.113'S, 37° 2.712'E	Urban areas and settlement
NUD2	1487	1° 7.257'S, 37° 4.546'E	Urban areas and settlement

Finally based on reference data which was gathered during field work, accuracy assessment was employed to measure the reliability or the overall accuracy of the classification. The reference classes were compared with the result of classification and the ratios of correctly versus incorrectly classified pixels was calculated for each class. The accuracy assessment was conducted through a standard method described by Congalton (1991) Table 1.

Water quality was assessed from a total of 12 sites (6 in each watershed Sites were selected based on land use characteristics to encompass a variety of land uses based on near-stream land use activities. Sites were chosen across the entire basin to ensure results would not be tied to local characteristics. Sites were selected based on land use classes derived from image classification as indicated in Table 2. Fieldwork was carried out four times: Twice during the dry season (mid-January 2014 and 2015) and twice during the wet season (mid-April 2014 and 2015) under stable flow conditions. The following physical-chemical parameters were measured *in situ* using an ecolab multi-parameter water quality meter: pH, temperature, electrical conductivity (EC), turbidity and biological oxygen demand (BOD).

Statistical analysis

For class-specific and overall accuracy estimates, cross tabulation of classified image with ground truth data was used, where a total of 60 ground truth samples were used. An error matrix was used to assess the accuracy of image classification. For water quality measurements, not all of the water quality parameter data met the parametric assumptions, and therefore the Kruskal-Wallis test was used to determine whether the values of the water quality parameters differed significantly between the dry and wet seasons as well as land use types (Bu et al., 2014; Hively et al., 2014). Five variables for the water quality datasets were analyzed: (1) Dissolved oxygen (DO), (2) Temperature, (3) pH, (4) Turbidity, and (5) Electrical conductivity. All dry season and wet season data collected in 2014 and 2015 was pooled. The design therefore included two main fixed factors: (1) "Land use" (with 3 levels; i. forest, ii. agriculture, iii. urban), and (2) "Season" (with two levels; wet vs. dry). The water quality datasets were also subjected to principal component analysis (PCA) multivariate analysis to explore and separate various water quality variations with land use systems. Additionally, discriminant function analysis was used to allow simultaneous examination of the influences of land use variables on all water quality parameters investigated. Discriminant function analysis enabled the computation of two important outputs: (1) The correlations of land use variables with canonical axes, which indicate what land use variables have the largest influence on the ordination; (2) The variance proportions (%) of the water quality parameters that are explained by canonical axes and

Table 3. Land cover classification accuracies computed from ground truth reference points over the 2015 maximum likelihood-classified image.

Reference data	Forest	SSA	LSA	Water	Urban/settlement	Grassland	Row total	Commission accuracy
Forest	8	1	0	0	0	0	9	0.89
SSA	0	13	0	0	1	0	14	0.93
LSA	0	0	10	0	1	0	11	0.91
Water	0	0	0	7	0	0	7	1.00
Urban/settlement	0	0	0	0	6	0	6	1.00
Grassland	0	1	0	0	0	8	9	0.89
Column total	8	15	10	7	8	8	52	
Omission accuracy	1.00	0.87	1.00	1.00	0.75	1.00		
Overall accuracy		0.87						
Kappa coefficient		0.84						

individual land use variables (Sliva and Williams, 2001).

RESULTS AND DISCUSSION

The image error matrix shown in Table 3 gave a Kappa coefficient value of 84% while the overall classification accuracy for the classification was 87%. The classes with the highest user accuracy (commission) were urban and grassland, while those with the highest producer accuracy (omission) were forests, large scale agriculture and water. Using ground truth data and high resolution imagery from google earth, the output of maximum likelihood was further refined to achieve a better representation of land cover types in the study area.

In all the time steps, small-scale agriculture dominated the landscapes of both Ruiru and Ndarugu Watersheds, with a range of 56.455 to 60.93% for Ruiru Watershed, and 54.02 to 55.96% for Ndarugu Watershed.

An expansion of urban areas is attributed to a reduction in areas under grasslands, and along major infrastructural facilities (roads) to the east of the landscape as shown in Figure 3. In these areas, grasslands decreased significantly, and this is attributed to the urbanization process whereby areas previously occupied by grasslands are gradually being taken up by built-up areas. These grasslands have been observed to be ranging ground for wildlife, and have also been used by pastoralist communities as dry-season grazing grounds. The grasslands are located in the drier parts and have not provided the much needed land for cultivation. The fact that urban and settlement areas mainly increase in the eastern part of the catchment may be due to better accessibility (e.g. highway). In addition, being a relatively drier area, the alternative to use the area for settlement than agriculture is reasonable. An increase in built-up areas can lead to an increase of the water yield and decrease in evapotranspiration as has been found in several studies (Im et al., 2009; Wijesekara et al., 2012; Wagner et al., 2013). Numerous valleys in the area classified as large-scale farms are covered with reservoirs. These reservoirs account for a large proportion of areas under water.

From the analysis of classified imagery, a general shift from other land use types to urban and settlement is being observed in both watersheds as indicated in Figure 3. This pattern is strongly consistent with results of Thuo (2013) as well as Kiio and Achola (2015). Parts of the study area, and particularly the lower reaches of Ruiru and Ndarugu basins form part of the Nairobi-Thika urban-rural fringe. The rural-urban fringe, or hinterland, is sometimes described as the landscape interface between town and country, and is often characterized by a mix of urban and rural landscape characteristics. Rapid urbanization of the rural-urban fringe has led to new income opportunities for the people who originally worked in farms as farmers or labourers (Thuo, 2013). A visual analysis of high resolution NASA and Digital Globe Imagery from Google Earth show that urban land use replaced areas previously occupied by grasslands. An increase in stone quarrying activities is also an indicator of high demand for building materials. Immigrating population from other areas presents the local residents with new opportunities, such as establishing of businesses and construction of rental houses to accommodate the immigrant population. In addition to new opportunities, residents have interacted with new comers who have brought in new technology and skills. Thuo (2013) observes that as a result of land use change, small-holder farming systems have been negatively affected as there is less availability of labour to work in the farms. There is also a general shift from growing of traditional food crops to crops such as kales, spinach and tomatoes which have a ready market among the residents.

Traditionally, the area has undergone land sub division

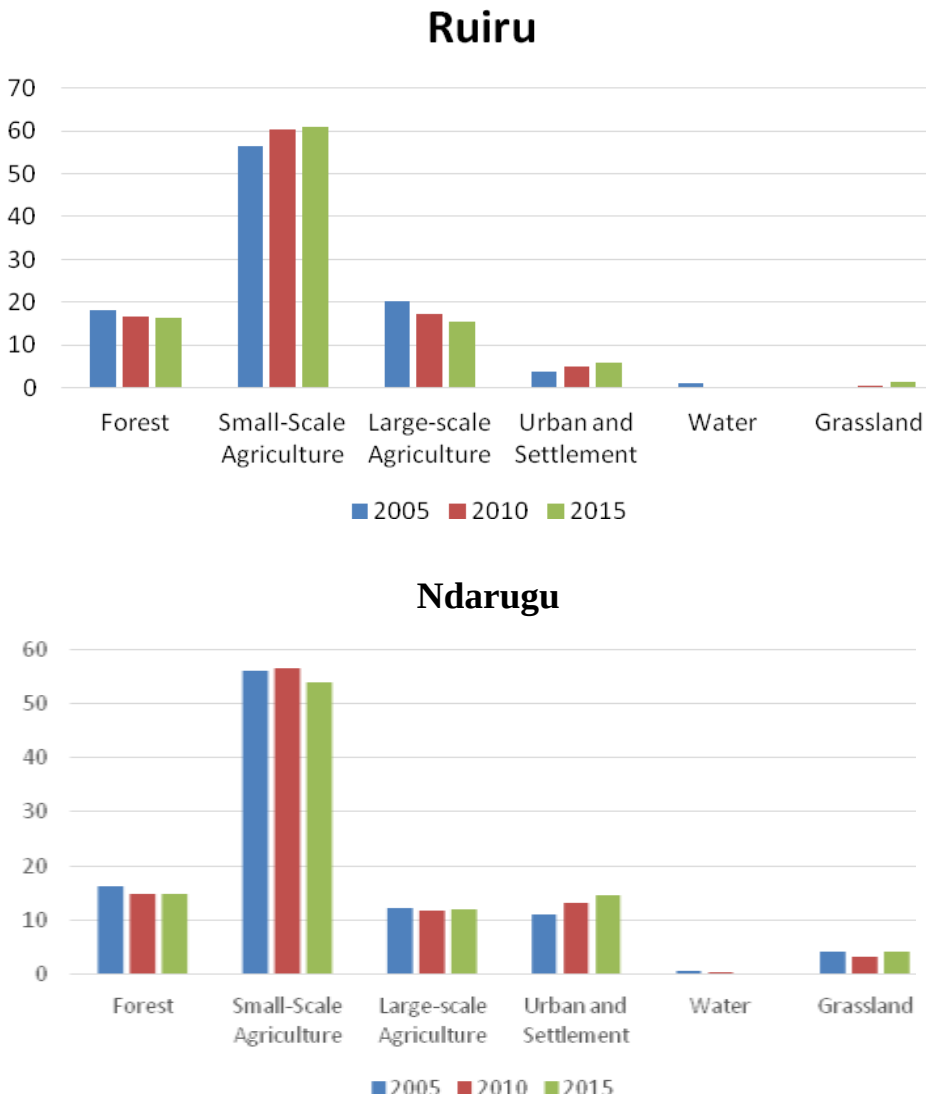

Figure 2. Land use change in Ruiru and Ndarugu Watersheds (2005 to 2015).

to smaller pieces of land. Consequently, this new mode of farming is suitable for the smaller land parcels. The image analysis evidence of surface water scarcity in the area is already visible (Figure 2), with numerous boreholes that have been sunk. The Ruiru-Juja Water and Sanitation Company rations water as part of the management strategy to curb the problem of surface water availability.

The increasing population is leading to pressure for conversion of more farmland to residential areas (Figure 3). In future, opportunity for farmers to increase production by buying additional parcels of land in their locality will be unavailable. Demand for high value horticultural produce by urban consumers can stimulate production by small farmers (Tacoli, 2002), but expansion of urban centres leads to competition over the use of essential natural resources, particularly land and water.

The concentrations of measured water quality parameters in the dry and wet seasons across sampling sites are shown in Table 4. The Kruskal-Wallis tests revealed significantly higher values of DO ($H = 24.71$, $p < 0.01$) and EC ($H = 7.98$, $p < 0.01$) in the dry season than in the wet season. Temperature ($H = 6.92$, $p < 0.01$) was significantly lower in the wet season than in the dry season. The concentrations of pH and turbidity showed no significant differences in the two seasons. Multiple comparisons of water quality parameters revealed wide variations between Urban, Agriculture and Forest groups as shown in Figure 4.

Results of the PCA analysis revealed that three

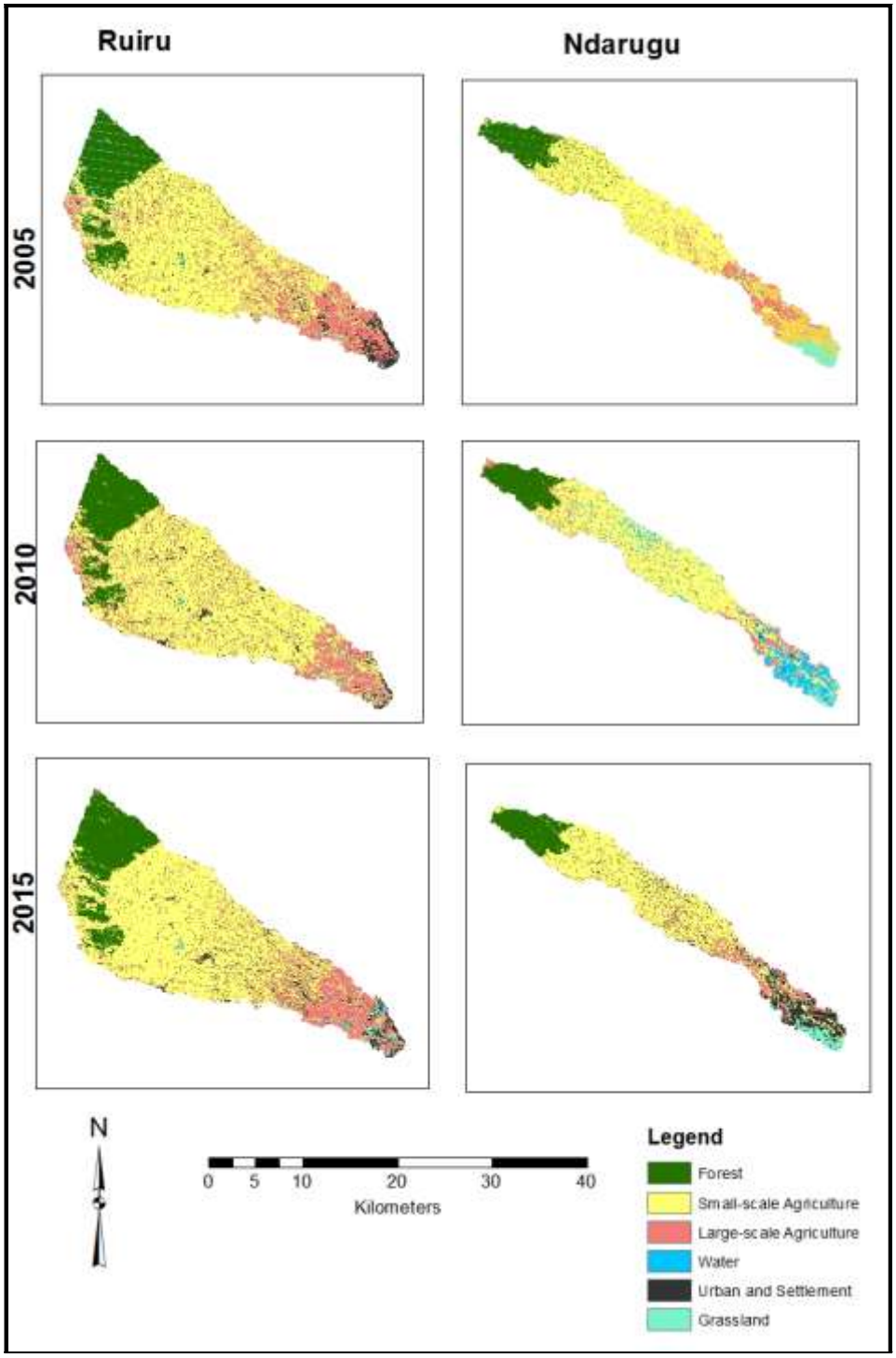

Figure 3. Land use and land cover characteristics of Ruiru and Ndarugu watersheds in 2005, 2010 and 2015.

components explained 77.7% of the variance: Component 1 (32.5%), component 2 (26%) and component 3 (18.8%). Component 1 distinguished temperature, component 2 distinguished pH, turbidity and electrical conductivity while component 3 distinguished dissolved oxygen (Figure 5).

Table 4. Surface water quality between the dry and wet seasons in the Ruiru and Ndarugu Rivers, Kiambu County.

Parameter	N	Dry season (Mean± SD)	Wet season (Mean± SD)	Kruskal Wallis H	p Value
TEMP	48	17.9±2.35	16.27±1.87	6.92	0.009
DO	48	11.30±1.28	15.77±3.07	24.71	0.000
EC	48	75.40±42.82	102.26±42.36	7.98	0.005
TURB	48	23.94±18.40	36.99±28.52	2.65	0.103
pH	48	6.81±0.55	6.75±0.60	2.08	0.1488

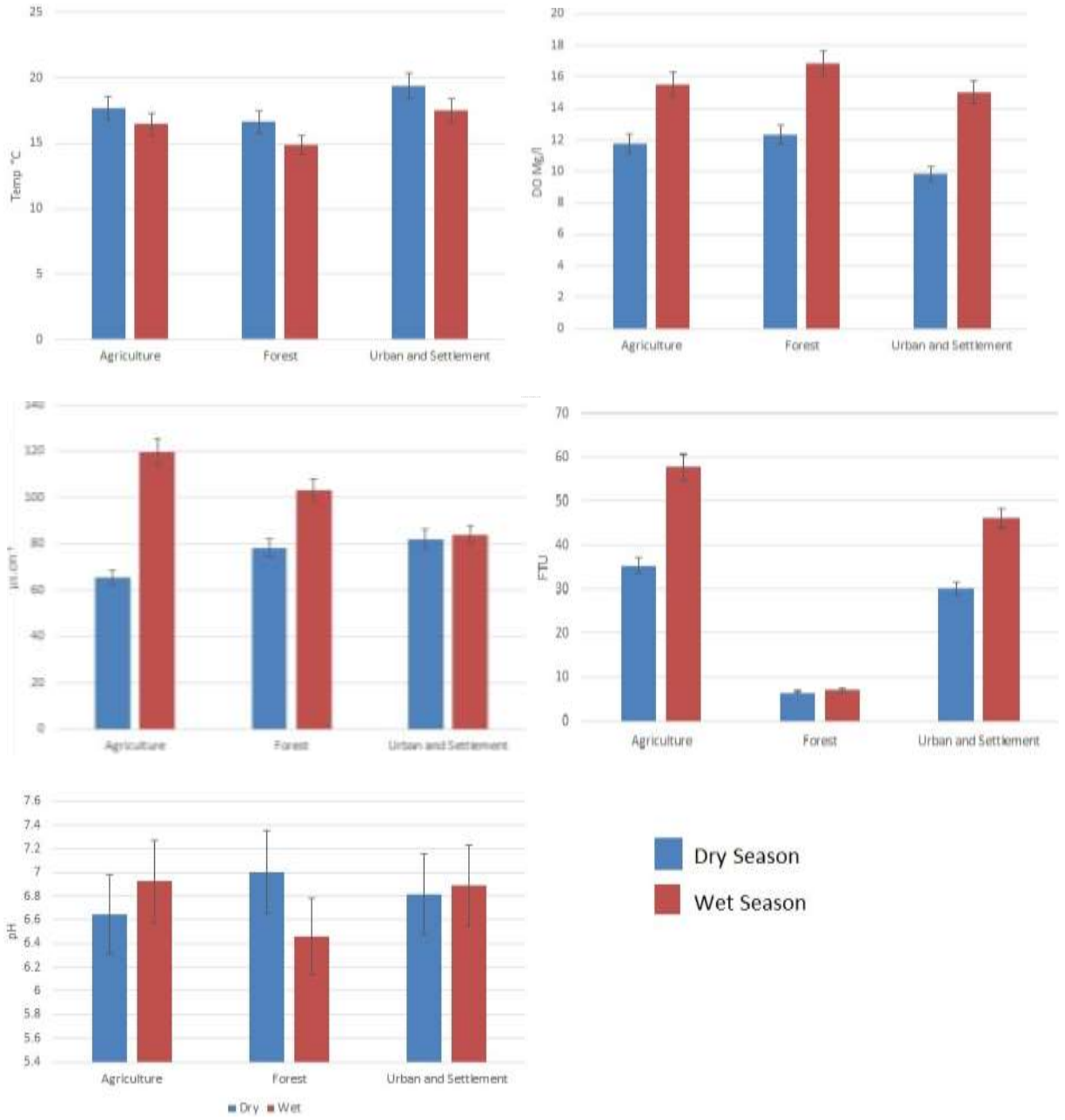

Figure 4. Mean ± standard error values for the water quality parameters among three land use-based site groups in Ruiru and Ndarugu Watersheds.

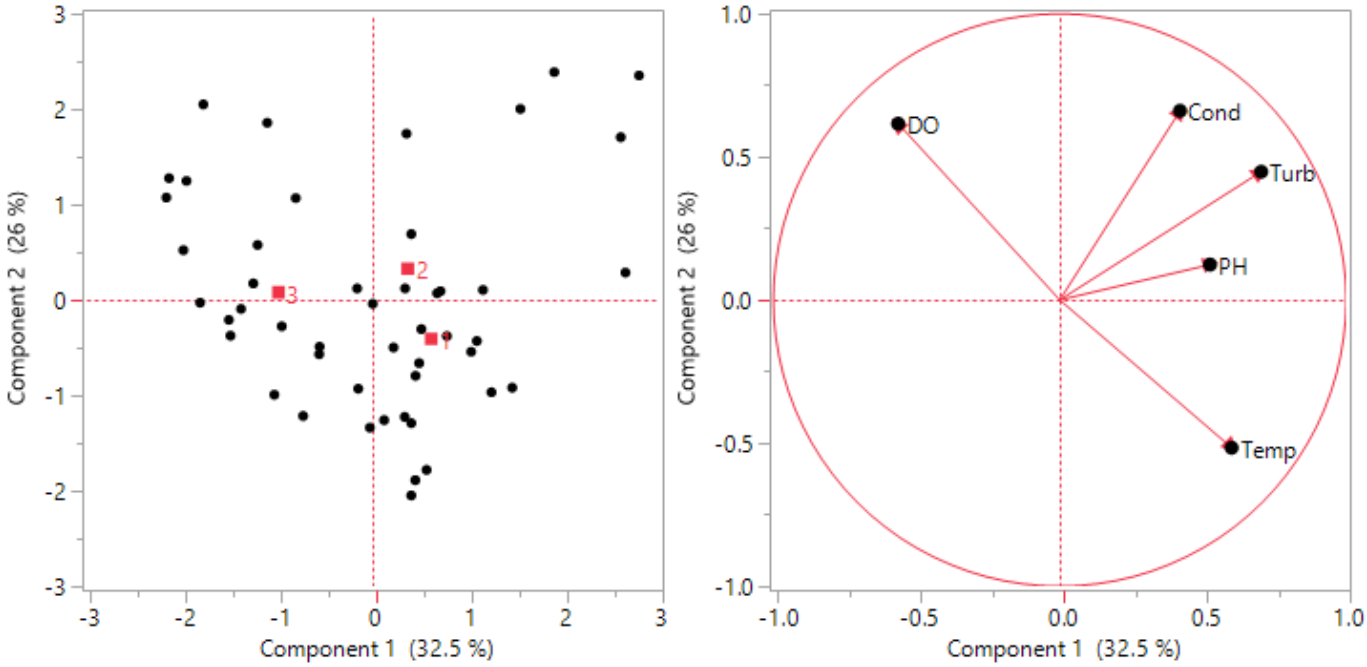

Figure 5. PCA analysis of water quality parameters across land use systems in Ruiru and Ndarugu basins, Central Kenya. The first two axis components 58.5% of the variation: Component 1 (32.5%) and Component 2 (26%).

Results indicate land use and land cover have significant impacts on water quality in the two basins. Forested areas have better water quality than either agricultural dominated and urban dominated landscapes in both wet and dry seasons as shown in Figure 6. This may be attributed to low anthropogenic inputs in forested lands. The variation in physico-chemico characteristics in Ruiru and Ndarugu basins are shown were found to vary across different land use and land cover types, depending on season. The relatively high variation between water quality parameters associated with different land use types are characteristics that can be used to inform or predict water quality aspects in rivers that lack data. In the dry season, farmers in the study area have been practicing irrigation using water abstracted from the rivers and streams. As areas under agriculture are gradually being taken up by urbanization, agricultural intensification is observed. This includes increased farming activities in the dry season, which abstracts water from the rivers. Urbanization on the other hand, is known to result in more runoff during rainy season due to the increase of paved surface area.

In the study area, and most other regions in the country, agricultural activities are strongly tied to seasons. The onset of the long rains triggers a flurry of farm-based activities. The application of farm-based inputs, including fertilizers and chemicals, are also expected to follow this seasonal pattern. Thus, this may aggravate the imbalance between water quality parameters and lead to seasonal water quality variations. In this study, urbanization has been identified as the main driver of change in the study area. There is a general increase of urban/settlement areas more to the east than to the west in both watersheds. The eastern parts are generally drier, and settlement areas are cropping up there. In this study, measured levels of dissolved oxygen are higher in the wet season than in the dry season in all the land use types as shown in Figure 4. Although this trend is consistent with observations from other studies (Schneider et al., 2000), some studies have recorded lower DO levels in the dry season than in the wet season. For example, in a study conducted in lowveld sand river system in South East Zimbabwe, dissolved oxygen concentration levels were higher in the dry season compared to the wet season (Tafangenyasha and Dzinomwa, 2005), and this was attributed to the loss of photosynthetic aquatic plants by faster current. However, the study was conducted in a semi-arid region, where ecological patterns could be different from areas that are wet, such as in the present study area. Other factors that could result in variation in DO levels may include oxygen depletion resulting from the eutrophication of natural water that receives excessive amounts of nutrients normally limiting to plant growth (Dodds, 2006; Breitburg, 2002; Brosnan and O'Shea, 1996). Such nutrients are sometimes associated with urban land use. In this study,

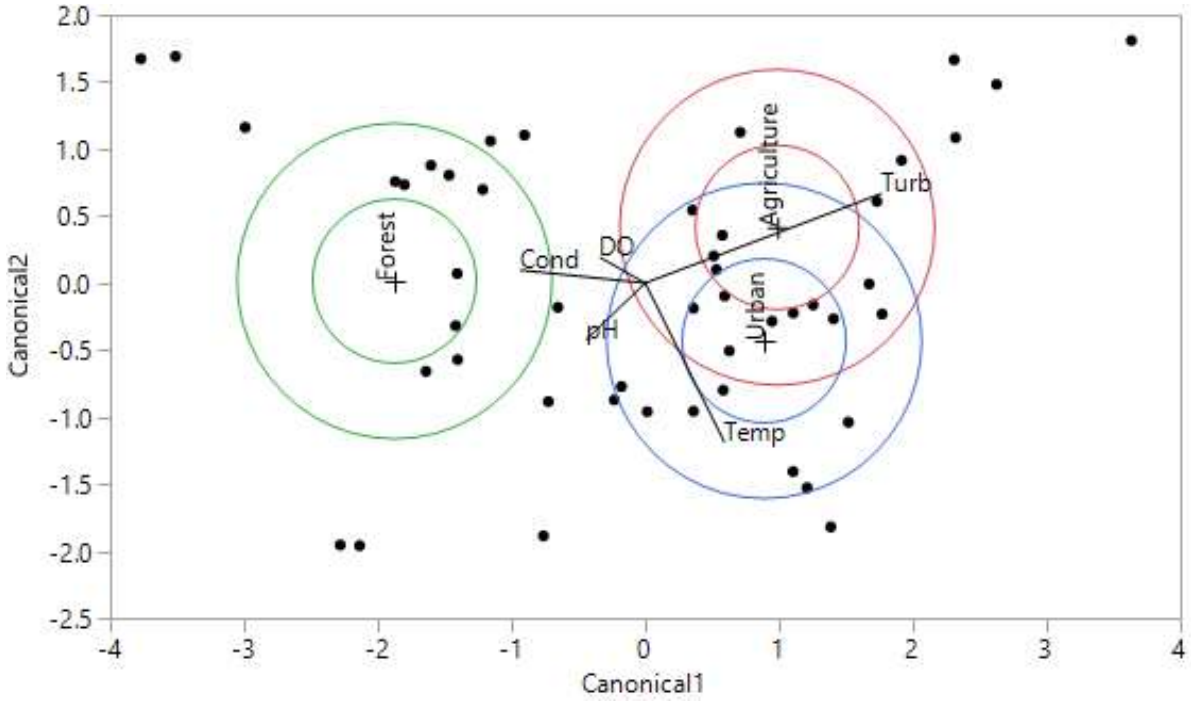

Figure 6. Discriminant analysis on measured water quality parameters across land use types on two canonical axes showing water quality parameters and their associated land use types.

urban/settlement land use recorded lower levels of DO as indicated in Figure 4 compared to both agriculture and forested land in both the dry and wet seasons. This is associated with sewage effluent from urban and settled areas, which increases nutrient inflows in rivers and streams (Carpenter et al., 1998). As the human population increases due to immigrating population from other areas, pressure is exerted on the current sewer infrastructure, which is already overstretched. In all sampling stations, pH did not deviate from the 6.1 to 8.2 range expected for most surface freshwater systems, but vary seasonally in different land use types. In the dry season, pH was higher in forests compared to urban/settlement land uses and agriculture. The wet season recorded higher pH levels in urban/settlement areas and agriculture, and lower values in forest. This suggests that although land use and seasonal changes may be a factor that influences pH, other external factors may also be major determinants of pH measurements in rivers. A number of factors may affect the proportion of major ions (hence pH) in a landscape, including geological, atmospheric, biological and anthropogenic activities (Fawzi et al., 2002). For example, consumption of carbon dioxide by aquatic plants results in an increase in pH during photosynthesis, while during respiration and decomposition, released carbon dioxide results in decreased pH (Schneider et al., 2000).

Theoretically, biological activity and human activity would be the primary determinants of pH, whereby the human activities trigger nutrient loading while biological activity plays a secondary role (Tafangenyasha and Dzinomwa, 2005). The Ruiru and Ndarugu basins are enriched with nitrate while passing through agricultural dominated areas, then and then they receive sewage effluent rich in phosphate from an urban/settlement areas as shown in which could support algal blooms.

Turbidity was highest in agricultural dominated sites and lowest in forest sites (Figure 4). Forested landscapes generally have less erosion and runoff. In forested sites, turbidity levels were minimal between the wet and dry seasons, but strongly variant in agricultural and urban/settled sites. Surface runoff, and its erosive action, is attributed to an increase in turbidity in the dry season in both agricultural areas and urban/settled areas. This periodic input of sediment into the rivers leads to decreased water clarity, thereby inhibiting light penetration and leading to reduced biological activity. Highly turbid waters have more suspended solids and are prone to oxygen depletion (Vesilind et al., 1994).

As shown by this study, the wet season increases erosive conditions in agricultural and urban/settled areas as rains and flood waters increase. This may lead to an overshoot on the recommended threshold of turbidity levels in surface water, set at less than 5 nephelometric

turbidity units (NTU) for drinking water, according to World Health Organization Water Quality Standards (WHO, 2016). The influence of seasons and land use may be compounded by other factors, such as the composition and solubility of materials in the rock, soil, primary production and inflows that the water flows through (Tafangenyasha and Dzinomwa, 2005). Although this study reported that land use and seasonal aspects have a great influence on turbidity and other physico-chemical patterns of rivers, the impacts from natural river processes may also have an influence.

Conclusion

This study has demonstrated that land use systems are rapidly changing in the Ruiru and Ndarugu watersheds, and are having a direct impact on water quality parameters in rivers as a result of anthropogenic activities associated with land use types. The study highlights the important effects of agriculture and urbanization areas on surface water quality, and the potential risks that they may cause on dwindling water resources. Identification of sustainable land management systems that help maintain acceptable levels of surface water quality to optimize sustainability in water resources management are needed in this region. As demonstrated by this study, forested areas present a land use system associated with better water quality, and efforts should therefore be made to promote agriculture/urban land uses that mimic or incorporate forested areas (e.g. agroforestry and development of green areas in urban areas respectively). Such land use systems would have a favorable effect on the surface water quality in streams and rivers, which in turn may assist in reducing the risks associated with poor water quality including human health. Research on how such systems can be developed is urgently needed. In addition, this study supports Intergrated Water Resources Management (IWRM) and the potential of agricultural/urban areas to be better managed for sustainable development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Spatial analysis of elements at risk and household vulnerability to landslide hazards on Mt. Elgon, Uganda

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Landslide hazards have in the last 10 years become more prominent on the Mt. Elgon ecosystem in Uganda often culminating into disasters. In this study, the community was assessed on their vulnerability to landslide hazards and the efficacy of existing institutional mechanisms with a view of improving resilience and disaster risk reduction. The study area was selected based on historical information of landslide occurrence from Manafwa District Disaster Management Committee during site reconnaissance. Household interviews were conducted on 255 respondents using a pretested questionnaire to capture the community perceptions and elicit data on some vulnerability. The household interviews were enriched with Focused Group Discussions (FGDs) and Key Informant Interview guide. Also information on elements at risk to landslides in the catchment was captured and mapped out using GIS techniques and a Global Positioning System (GPS) receiver. Vulnerability to landslides was determined by considering the combined results of the thirteen weighted indicators and five weighting scores. Results revealed that the communities in the study area are highly vulnerable to landslide hazards (95%). Landslide hotspots are largely found on slopes: (45%) steep slope, medium slope (30%) and low lying (23%), and this was categorized into; low, moderate and high. Within the landslide hot spots, the major elements at risk to landslides was; agricultural land (36%), houses (22%), population (20%), livestock (13%) and infrastructure (9%). There were 6 households, 19 households and 91 households within very high, high and moderate hazard zones respectively.

Key words: Landslide vulnerability, elements at risk, hazard.

INTRODUCTION

Landslide hazards are increasingly becoming prominent on the Trans-boundary Mt. Elgon ecosystems particularly on the Ugandan side (Yao et al., 2013; Mugagga, 2011; Kitutu et al., 2009; Kitutu, 2010). The government of Uganda is grappling with the challenge of sustainability addressing the landslide related disasters on Mt. Elgon. The initial intervention of throughresettlement of people from the landslide prone sites on Mt. Elgon to Kiryandongo in the South-western part of the country has not been very successful. An investigation as to the

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cause of this reveals that people are not very willing to move to new areas due to change in socio-economic regimes, loss of political power, productivity differences and strong socio-cultural ties. Alternative policy paradigms have advocated for intra development of urban centers within the mountain ecosystem were communities can be safely resettled however this may prove to be very expensive to the government as the initial establishment of the urban setting will need lump sum capital investment. In Uganda, property worthy million USD has been lost due to landslides, although a precise quantitative national monetary estimate of losses attributed to landslides is lacking. A synthesis of recent landslide hazards reveals a gigantic loss of life and property. It is estimated that the loss of lives due to landslides between 1964 and 2006 was at 130 compared to 2007 to 2011 which stands at 956 deaths; in total 1086 deaths have been recorded (online Uganda DisInventor, 2012). It is therefore important to undertake measures to reduce landslide related disasters.

Effective disaster risk reduction requires information on hazards dynamics and community knowledge on vulnerability to landslide hazard. Previous studies on landslides on Mt. Elgon (Claessens et al., 2007; Kitutu et al., 2009; Knapen et al., 2006) focused on hazard zonation. However scientific research covering the risk suite of both landslide hazard vulnerability, that informs disaster occurrence on Mt. Elgon is lacking.

In this study, community was assessed on their vulnerability to landslide hazards and the efficacy of existing institutional mechanisms with a view of improving resilience and disaster risk reduction. The study area was selected based on historical information of landslide occurrence from Manafwa District Disaster Management Committee during site reconnaissance. Household interviews were conducted on 255 respondents using a pretested questionnaire to capture the community perceptions and elicit data on vulnerability.

The general objective of the study was to contribute to improved resilience of mountain communities to natural hazards. This was achieved through identifying elements at risk and assessing the community vulnerability to landslide hazards and evaluating the existing institutional mechanisms for landslide risk reduction in Manafwa District.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Manafwa District covering three Sub-Counties namely; Bumbo, Bupoto and Sibanga (Figure 1). Manafwa District is bordered by Bududa District to the north, the Republic of Kenya to the east and south, Tororo District to the southwest and Mbale District to the west. The center geographical coordinates is at approximately 0º 58' 49.2'' N, 34 º 58' 49.2'' E (UTM Zone 36, WGS 84 Spheroid with 7 m accuracy). The geology of the study area is associated with the caldera volcanoes. Mt. Elgon is the oldest solitary volcano in East Africa (Bamutaze et al., 2009; Scott, 1994), it rests on dissected peneplain of Precambrian bedrock of the Trans Nzoia plateau; Precambrian Basement Complex (MCEP, 1997).

Research design

Interactive interviews were held with key informants (KIs) (District Environment Officer and Local Chairperson) consisting of opinion leaders from the study area. The interview guide were sought to identify the causes of landslides, specific areas that are mostly affected, impact of landslide, community resilience capacity, potential sign of occurrence of landslide, institutions involved in combating landslide, and institutional framework for landslide risk reduction. Interview with the secretary for Manafwa District Disaster management committee was vital in reviewing the current policies that purportedly support communities for disaster mitigation, their strength and weaknesses analyzed and recommendation for improvement were captured too.

Observation checklist was constructed and systematic observations were made in the villages with the help of a checklist. They focused on household vulnerability factors, land use, human activities, location of settlements, landslide scars and their location, landslide resilience and mitigation related activities in the area. Other information gathered by field observation of land degradation particularly soil erosion and landslides in relation to slope angle. The primary reason for using the observation method was to check for the accuracy of the information got from the interview method (Mulhall, 2003). Field observation were undertaken to get an insight into the spatial distribution, characterize landslides and identify the landslide hotspots.

Vulnerability assessment

Social vulnerability

Social vulnerability to landslide was determined was done by considering the existing socio-economic characteristics of the study area. This was incorporated in the landslide vulnerability model indicator ranking and weighting parameters namely: Age, nature of the population density, education level, rural population, income levels, nature of building materials and type, availability of medical services, availability of insurance cover and disaster funds, regulatory control available, hazard mapping, early warning system, and emergency respond. The above variables were divided into five indicators; each indicator was then ranked and assigned a rank value based on the level of vulnerability the area faces. The rank values ranged from 1 to 5, where 1 indicates the lowest level of vulnerability and 5 indicates the highest level of vulnerability. This range (that is, five possible rank values) was selected arbitrarily (it was normalized to the range 0 to 1 later).

The landslide vulnerability model considers the combined results of the thirteen weighted indicators (socio economic data identified above) by use of the formulae as follows:

$$\mathrm{Vt} = \sum_{i=1}^{n} Wi \qquad \sum_{i=1}^{n}(\mathrm{Vi} * \mathrm{Wi}) \tag{1}$$

where Vt is the total vulnerability score of the region, n is the number of indicators, Wi is the weighting value and Vi the vulnerability rank of each individual indicator. However, in order to be incorporated into the risk model (along with the regional

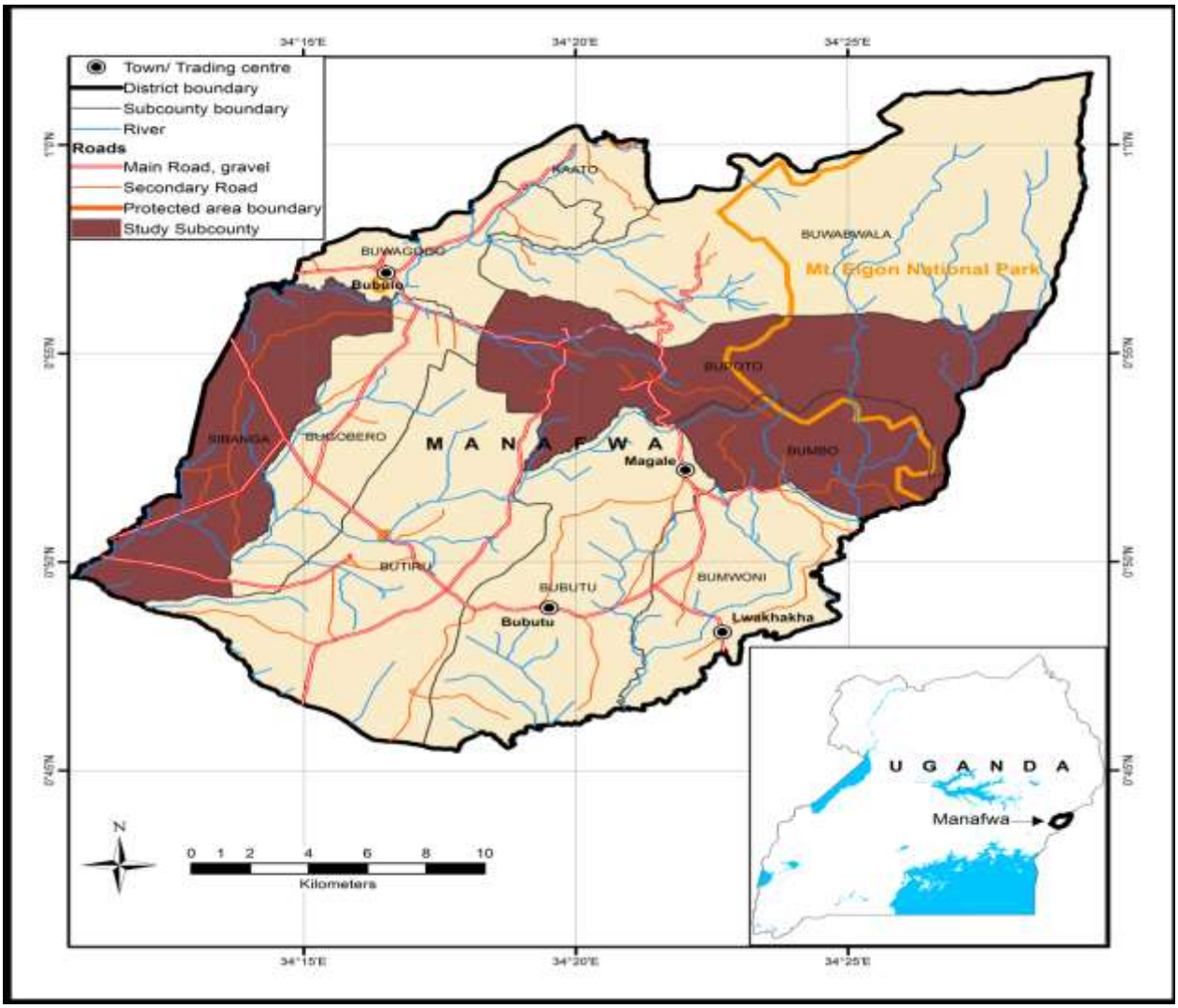

Figure 1. Location of the study area.

probability of slope failure, pf) the total vulnerability score, Vt, was normalized to lie between 0 and 1, where 0 is lowest possible score and 1 is the highest. This is achieved by dividing the total vulnerability score by the highest possible value of Vt (obtained by simply setting all ranks to 5). Thus, the final landslide vulnerability score is given by the formulae as follows:

$$v = \frac{\left(\frac{\sum_{i=1}^{13}[v_i \cdot w_i]}{25}\right)}{\left(\frac{[3(5\cdot3)+6(5\cdot2)+4(5\cdot1)]}{25}\right)} = \frac{\sum_{i=1}^{13}[v_i \cdot w_i]}{125} \quad (2)$$

The ranking metric used for each of the vulnerability indicators is shown in **Figure 2.**

Social vulnerability ranking

Each of the indicators was individually weighted, on a scale of 1 to 3, based on their degree of relevance to the assessment. A score of 3 indicates the highest level of relevance to the vulnerability assessment. The total vulnerability score is computed as the sum of the weighted indicators (that is, the indicator rank, from Table 1, times the weighting value) divided by the sum of the weights. For this model the weights have been assigned based on educated judgment and extensive literature review. The indicators deemed most influential include: (3c) building type, (5a) regulation control and (5c) hazard evaluation, and so they have each been assigned the highest weight of 3. The indicators: (1a) age, (3a) rural population, (3b) GDP per capita (personal income), (4b) insurance and disaster funds, (5b) early warning systems and (5d) emergency

Table 1. Social vulnerability assessment.

Category/ indicators	Variable	Assumption	Rank (R)	Weight (W)	R x W	Result	Unit
Demography	Age	≤12 years ≥60 are vulnerable	4	2	8	53.6% are vulnerable	Years
	Urban	Urbanized area is likely to be greatly impacted	2	1	2	0ver 90% in Low hazard zone	-
Social	Education level	Higher education level better prepared and quickly recover	5	1	5	95% had no formal education	-
	Level of integration	Highly integrated society is less vulnerable	2	1	2	Weak community ties	
Economic Indicators	Rural population	Depend on natural resources, highly impacted	5	2	10	Highly vulnerable due to dependence on natural resources	
	GDP per capita	High GDP quick recovery and resilient	5	2	10	96.1% far below average monthly income for the region	
Recovery Indicators	Building type	Permanent structures resistant to landslide impacts	5	3	15	96% of the building are temporal structures	
	Quality of medical services	Better medical services quick recovery	4	1	4	Poor medical services and not accessible average of 23 km from affected areas	
	Insurance and disaster funds	Availability of insurance and disaster fund quick recovery and Resilient	5	2	10	No insurance and disaster funds available	
Administrative Indicators	Regulation Control	Implementation of legislation minimizes community exposure	5	3	15	No regulatory control	
	Early warning system	Early warning system minimizes community exposure to landslide	5	2	10	No early warning system	
	Hazard evaluation	Designated hazard zones help people keep away from prone areas	5	3	15	No hazard evaluation has been done	
	Emergency Response	Quick response saves lives and property	4	2	8	Poorly coordinated emergency response system and there are no resource allocated to potential existing hazard	
Total					**118**		

response were considered moderately influential and assigned weights of 2. Finally the remaining indicators: (1b) urban population, 2a) education level, (2b) level of integration and (4a) quality of medical services were regarded as least influential and each assigned a weight of 1 (Table 1).

Physical vulnerability

Geospatial techniques were used to identify and map the elements at risk of landslide hazard in Manafwa. The elements at risk included roads, schools, trading centers, health centers, churches and mosques, housing units, agricultural fields, livestock, community water points and people. The dimensions of the landslides were obtained by participatory GIS method with the help of ground measurements and truthing using GPS. For settlement areas a topographical map of Manafwa District (Uganda Bureau of Statistics (UBOS, 2012) at a scale 1:25,000 was obtained and geo-referenced, settlements and road were then digitized using ArcGIS 9.3 software. Houses were digitized as point map showing the distribution of housing units in the study area, land use cover (agricultural fields) was obtained from National Biomass Land use cover 2005 by slicing them off the general land use map. The slope gradient was derived from a Digital Elevation Model obtained from National Forest Authority. This was re-classified into the following percentage rise of slope gradient: 0 - 15°: very low, 15 - 25°: low, 25 to 35°: moderate, 35 - 45°: high, 45 - 60°: very high. Once these were obtained, they were crossed over with the landslide hazard map in a GIS environment to obtain the map

showing the elements at risk to landslides in Manafwa District. In addition to this, community social map on landslide area coverage was prepared with the help of the local people; a number of houses that were within the landslide scar were mapped out and characterized. During the group discussions the participants were asked to show and delineate the areas susceptible to landslide hazards. The investigator further explored if the local people had the knowledge of coping, adaptation and mitigation strategies before the previous landslides.

Spatialization of vulnerability

This was done by considering the elements at risk occurring within the landslide prone areas and the accrued loses. The degree of losses was associated with human injuries, material damages and monetary losses and structural dysfunctions. The study region is characterized by permeable and impermeable alternating sedimentary rocks, monoclinal geological structure and hilly relief with higher precipitation of about 1500 mm/year, rising to 1,700 m and even more in some rainy season. The study area was associated with high population density coupled with increasing human pressure on lands especially within the encroached boundaries of Mt. Elgon National Park. The spatial background consisted in the Digital Elevation Model and all derived maps (slope, aspect, shading), realized based on the topographical plans and maps (1:5000). The second step was to realize the spatial inventory of elements at risk (vector format), based on the topographical map of the study area (1:5000) and field investigations. All elements have been classified using attribute databases: Residential buildings (single or multiple dwellings), other buildings according to their functionality, main and feeder secondary roads.

Determining elements at risk

Transect walk, field survey, interview coupled with observation were used in determining element at risk. Transect walk was done staring from the point of origin of the landslide for the landslide scar and from the existing land cracks outwards in for direction (where possible) covering a radius of 1 km. This was done after spatialization of the vulnerability. A number of infrastructures were identified within the landslide prone areas, namely: Houses, community access roads, churches, mosques, maize mill and store, community wells, spring and water tanks.

Statistical analysis

We obtained the geo-referenced household vulnerability status from procedures explained previously. The indicators were entered in a GIS environment and overlayed with the layers of the 5 physical parameters.

The spatial data collected over coverage of landslide and the elements at risk was done using ArcGIS (Version 9.3). This was done to generate and characterize landslides and identify and map potential elements at risk; hence facilitating in the understanding of key aspects landslide vulnerability within Manafwa District. In addition GIS environment was used to map landslide prone areas and come up with landslide hazard map. The geospatial analysis entailed a range of overlay analysis and spatial modelling to derive the elements at risk and map the vulnerability hotspots. The social economic information gathered from field in regard to people and institutional perspectives of occurrence of landslides were coded and fed in social scientist statistical package (SPSS Version 16) for analysis. Regression analysis was done to determine the major determinant of people's willingness to be moved to safe area and what is the major factor that influences

people's choice of coping strategies to reduce landslide hazards. Descriptive statistics including the mean, percentages, coefficient of variation were also used in the analysis. Frequency distribution and cross tabulation tables, charts and bar graphs were generated from the frequency distribution using Ms Excel software.

RESULTS

Community vulnerability assessment by weighting and indicator ranking

Vulnerability determination by weighting system using age, nature of the population density, education level, rural population, income levels, nature of building materials and type, availability of medical services, availability of insurance cover and disaster funds, regulatory control available, hazard mapping, early warning system, and emergency respond (Table 2) revealed that the community in the study area are highly vulnerable to landslide hazards (95%).

$$=118/25$$
$$=4.7 \quad \text{(i)}$$

$$= 118/125 \text{ (normalized equation)}$$
$$= 0.95 \text{ or } 95\% \quad \text{(ii)}$$

This result is expected since the majority of the societal and physical indicators are either not available at all. The areas is characteristically rural area with high number of less educated (97%) for example 22 and 75% attained no education at all and primary education respectively. In addition there is no early warning systems, no emergency response procedures, no coverage of insurance, no regulatory enforcement; no hazard evaluation has ever taken place and poor housing materials due to low income in the area (60 and 37% of the people earn less than 50,000 and 100,000 UGX per month respectively).

Physical vulnerability

Using five classes of percentage increase of slope gradient (0 - 15, 15 - 25, 25 - 35, 35 - 45 and 45 -60°) and in relation to elevation, a hazard map (Figure 2) revealed the presence of very highly vulnerable areas (mostly encroached forest land) on altitude ranging from 1800 to 2000 m above sea level. This zone was characterized with a number of landslide events in the past years. Research finding indicates those areas with slope gradient ranging between: 35 - 45, 25 - 35 and 15 - 25º to be highly, moderately and lowly vulnerable to landslide, respectively. However, there were human settlements on both very high and highly vulnerable areas; this may be

Table 2. Elements at risk to landslide.

Hazard zone	Household	Road (m)	Trading Centers	Water points	Area (m^2)
Very low	1792	24492.42	23	28	7203
Low	224	5155.77	1	4	8680
Moderate	91	486.32	1	2	2690
High	19	0	0	0	1003
Very high	6	0	0	0	149
Total	**2132**	**30134.53**	**25**	**34**	**19725**

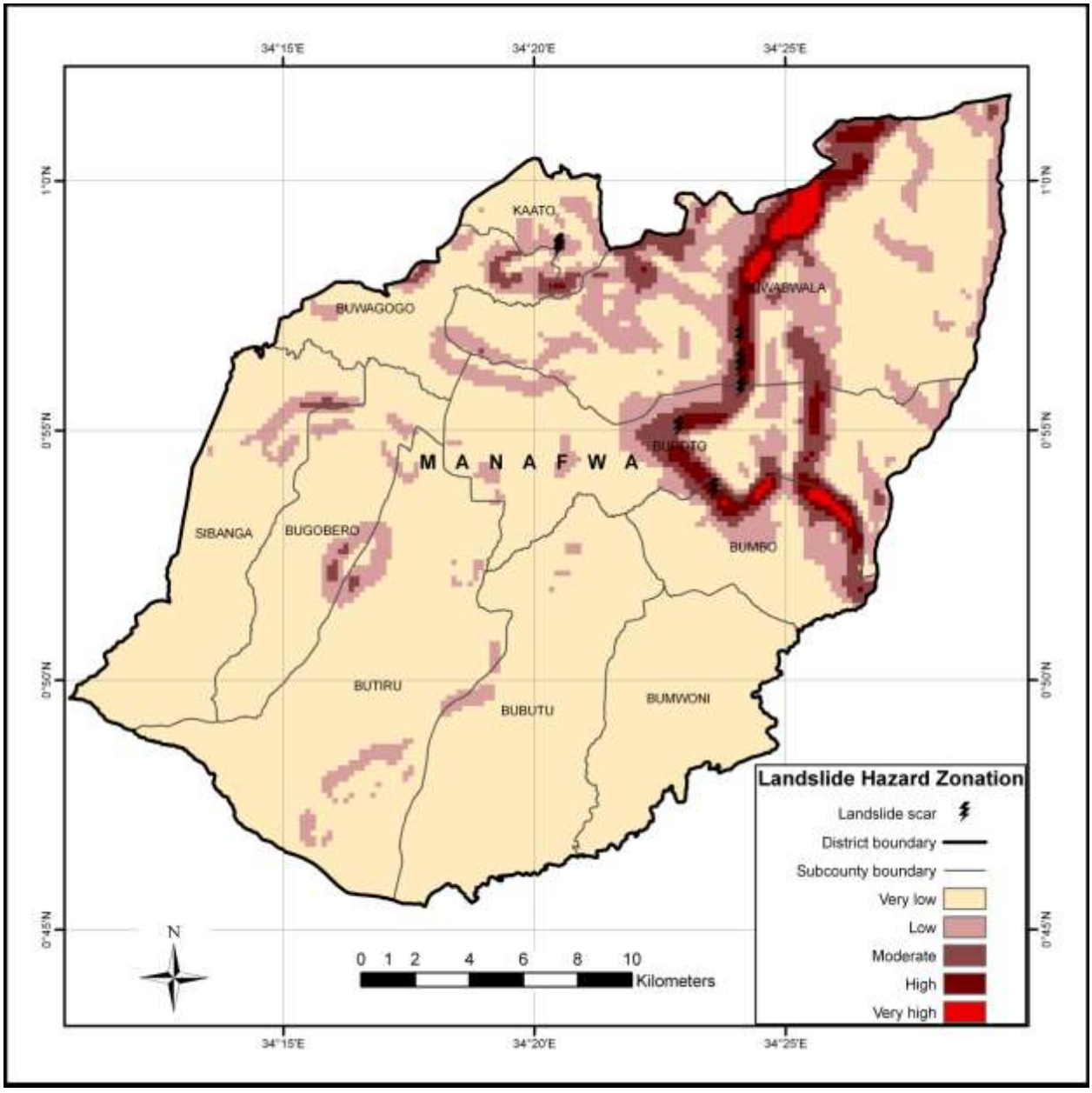

Figure 2. Landslide vulnerability map.

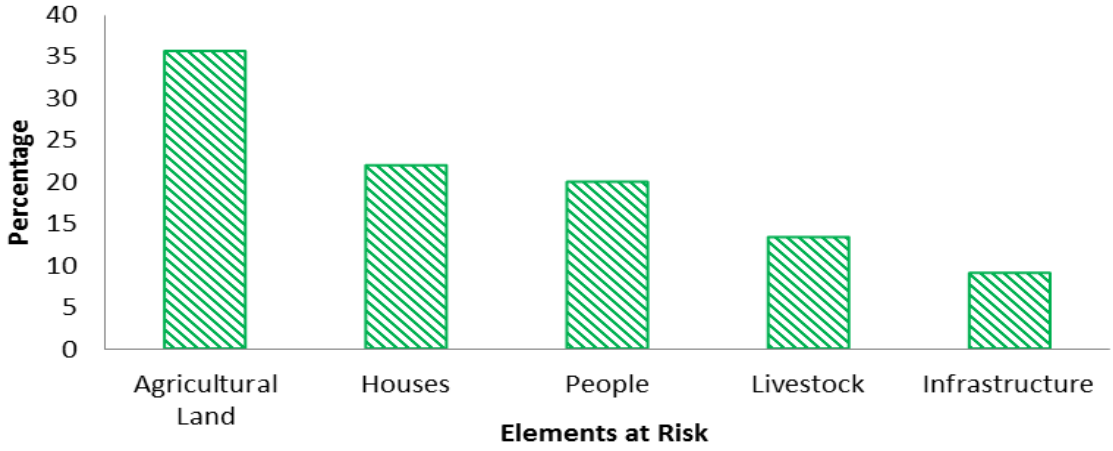

Figure 3. Elements at risk due to landslide.

attributed to the presence of fertile volcanic soils and the accessibility to the protected forest land for community harvesting of natural resources specifically “Malewa” (a delicacy of bamboo shoot) and firewood.

Elements at risk to landslide

The identified elements at risk to landslides in Manafwa District were; agricultural land (36%), houses (22%), people (20%), livestock (13%) and infrastructure (9%). Their quantitative and spatial extent is illustrated in Figures 3 and 4, respectively. Agricultural land is the most affected due to cultivation on the steep slopes of Mt. Elgon coupled with other anthropogenic factors. Houses and People accounted for almost the same count due to the correlation existing between the two elements at risk, whenever houses are affected, people are equally affected. The community members within the study area mainly cultivate crop with limited number of livestock (31% of the sampled population had livestock). Infrastructures in the study area are poorly developed and or not available in some area. They include: Community access roads, churches, mosques, maize mill and store, community wells, spring and water tanks. All sampled house had no piped water or electricity. The access roads to the study area are poor and in many areas it is totally non-existence hence less affected by landslides.

Detailed evaluation of the Land use cover revealed that small scale farmland accounts for 75.4% (35,355 ha of land) followed by wood land 10.2% (6,612 ha of land), other land use cover were too small.

In order to show the vulnerability level of community members to landslide hazard, a map showing elements at risk was overlaid with a hazard map to form an integrated map (Figure 4). Areas bordering Mt. Elgon National Park were identified as landslide prone areas; these areas were zoned out as “high and very high” zone. Different elements at risk within the study area (Table 1) revealed that there were no Trading Centres, water points and road within high and very high hazard zone. However, there were 6, 19 and 91 households within very high, high and moderate hazard zones respectively.

Interaction of social and physical vulnerability

Community vulnerability to landslides is increased due to; (a) construction of houses along the hazard path way/slop/below rock fall; (b) occurrence of vulnerable group; (c) cultivation on landslide prone area; (d) loosely held soil type; (e) interference with slope angle; (f) destruction of vegetation cover. Field observations indicated that where many houses in the study area is constructed on sites which are arguable in the paths of slope failure. The area is also characterized by many vulnerable groups such as the children, youth, women and aged people who constitute approximately 70% of the population. Research further revealed that, community members have encroached on the forest land leading to the destruction of vegetation cover. Vegetation cover plays a crucial role of holding firm the loosely held soil in landslide prone areas. When loosely held soil is subjected to cultivation any triggering factors for example rainfall will lead to occurrence of landslide. Many farmers in the study area accept that houses are constructed on steep slopes. House construction involves creating a flat surface on the slope, which disrupts the slope and forms a hanging wall without support. During seasons of intense rainfall, the soil above the slope of the house collapses on the houses. 96% of the respondents were

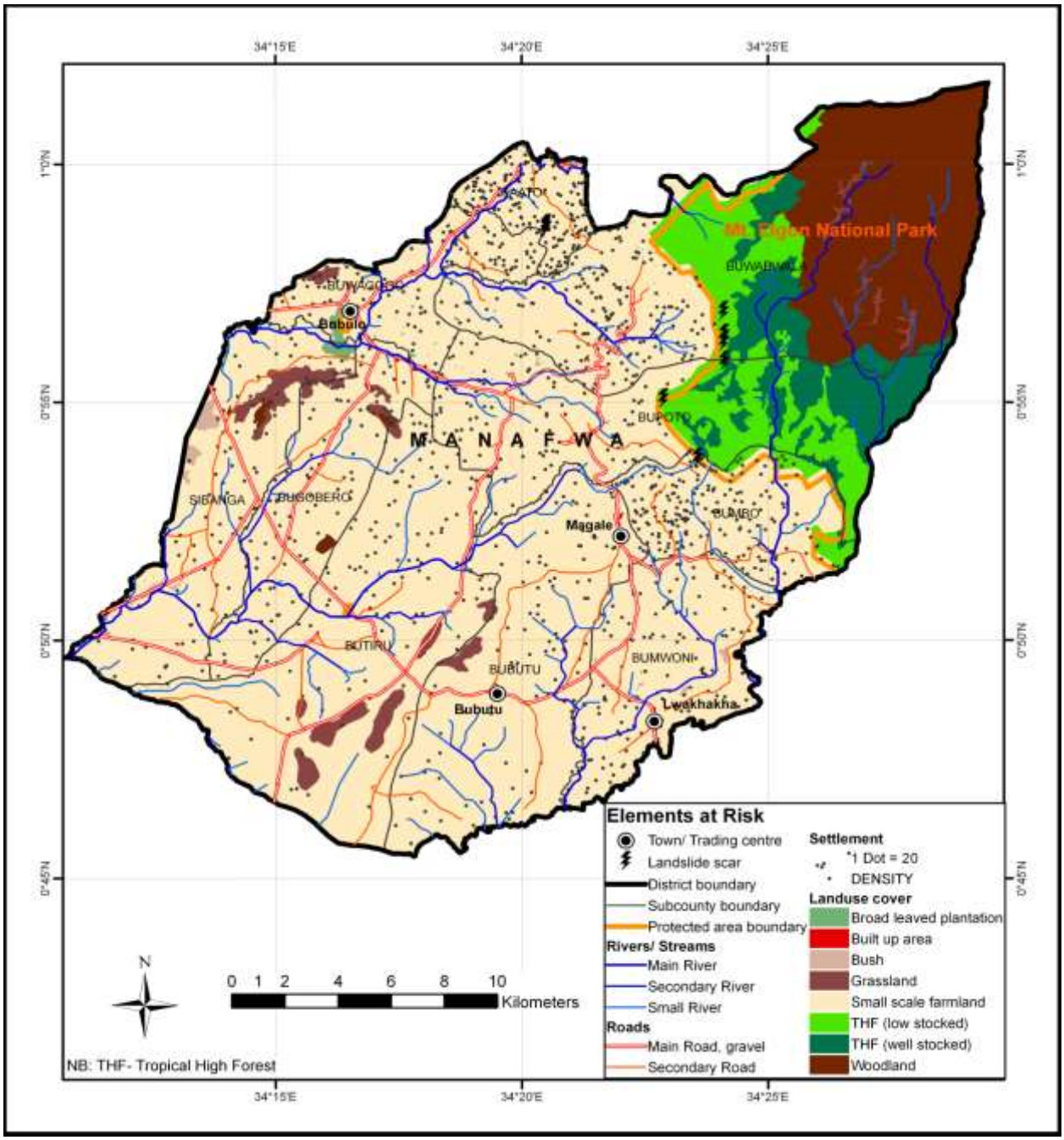

Figure 4. Spatial location of elements at risk.

categorized as low income earners; they earn below the eastern regional average monthly income for rural area of 151,400 (UBOS, 2010). From the monthly income, one can deduce that high income earners are less vulnerable since they can affect the degree to which protection can be built for example constructing preventive measures and building strong homes. The low or medium income earners cannot afford to protect themselves to the same degree. Majority of the women interviewed were housewives who depended on their husbands' monthly income.

Evaluation of the percentage coverage of the land area (hazard zonation) revealed that the large percentage of the area is very lowly (78.4) vulnerable to landslide, followed in the sequence from low, moderate, high and very high with percentage coverage of 14.4, 4.5, 2 and

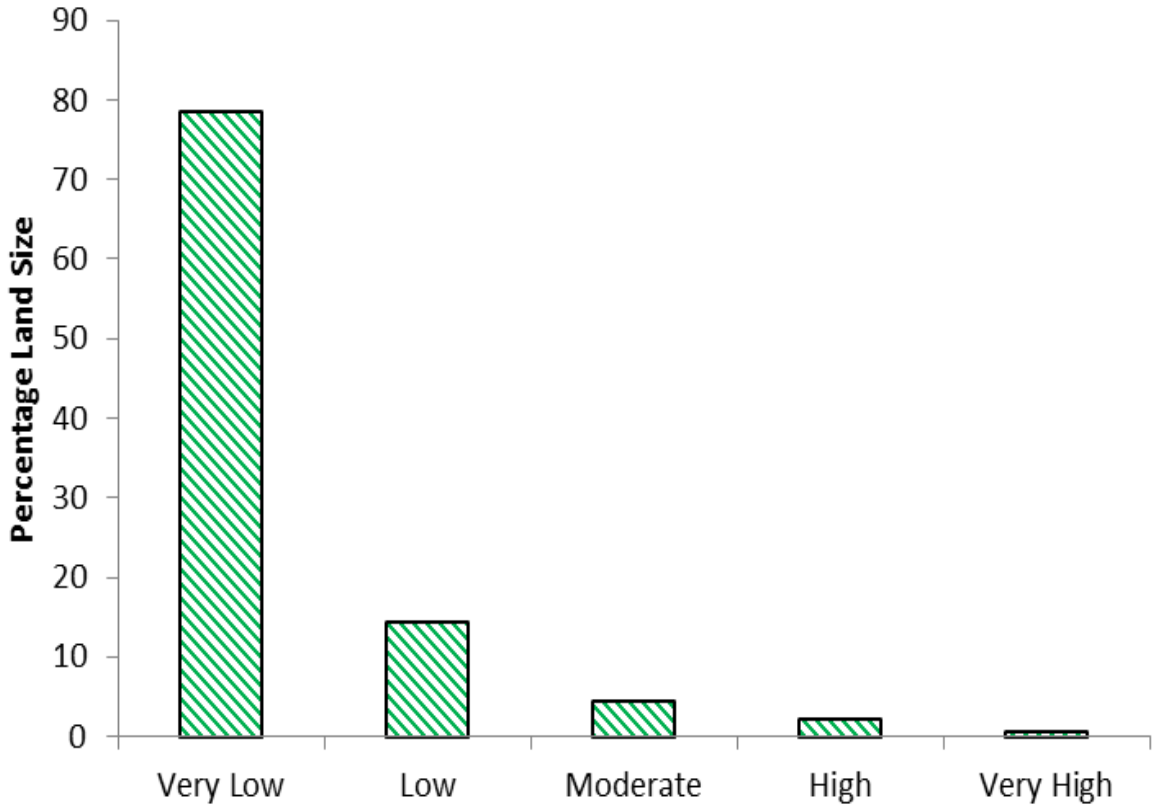

Figure 5. Land size coverage at different hazard zonation.

0.6% (Figure 5). However, the lowly vulnerable areas are less congested (population) compared to high and very high areas.

DISCUSSION

The vulnerability of elements at risk is high due to topographical position of elements at risk along hazard path (Glade, 2003) and poor or lack of land use planning. Most of the affected areas were occurring between 1500 and 2100 ma.s.l; this is evident by the landslide scars along this area. Knapen et al. (2006) observed that the effect of settlement on slopes of Mount Elgon in Uganda had increased the load on the deeply weathered basements thereby altering the balance of forces operating on the slope. The high population in the area attracted by the fertile agricultural soils and high rainfall has resulted in increased pressure on land and other resources causing instability on the slope (Ekotu, 2012).

The total landslide vulnerability assessment for the study area had a score of 95%, this is quite higher compared to a research done by Amanda Mclean in Norway (2010), in two areas Skien and Strada was at 20.4 and 39.3%, respectively. This is due to the fact that whereas there is no well-prepared landslide mitigation measures in Uganda; Norway is well prepared with institutions actively involved on landslide hazard mitigation. Ranging from early warning systems, emergency response procedures, coverage of insurance, regulatory enforcement, well documented hazard evaluation and use of quality materials in the construction industry. Lack of early warning system has led to the death of many people in entire Mt. Elgon region (Ekotu, 2012). He further observed that, early warning systems could reduce damage to property and minimize loss of lives.

High vulnerability of the communities to landslides may be attributed to a high income dependency ratio that is a function of income and the total number of dependents and level of education (Babirye, 2010). The study areas had a high income dependency ration of income less that 100,000 UGX but supporting large family of more than six dependents. This concurs with UBOS (2010) statistics which show that 55.8% of rural population depends on the productive work force. This situation is worsened by the fact that 60% of the respondents were peasant farmers dependent entirely on agricultural produce as a source of livelihood. According to UBOS (2010) community member in the study area earn (monthly

income) much lower than eastern regional average monthly income for rural area of 151,400 UGX hence making them to entirely depend on natural environment and become more vulnerable.

Conclusion

The study has shown that agricultural land, houses and human population are most vulnerable elements at risk compared to livestock and other social infrastructures. The study further revealed that 95% of community in Manafwa District are vulnerable to landslide hazards. Community vulnerability to landslide hazard is high due to occurrence of houses along the landslide path, use of poor construction material (mud, tree poles and banana fibres) for houses, modification of slope angles, poor farming activities, lack of early warning system and lack of adequate resources. Community members attributed heavy rainfall and deforestation as the major cause of landslides in Manafwa District. The predominant coping mechanisms to landslides implemented at household level albeit with limited success are afforestation (57%) and relocation (28%) on a short timescale. Institutional structures both at policy level and community level were found to be weak in reducing the risk to landslides.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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