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Review

Management of world energy resources (Renewable energy): Choices for the future?

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Energy enables technical innovations, and progress in health, agriculture and transportation. Socio-economic development and energy production are linked, although some energy-rich countries are poor. Developed countries are the biggest consumers. Energy consumption increases with increase in world population. Fossil energies are dominantly consumed. Nuclear energies are often decried because of serious accidents. Renewable energies, theoretically inexhaustible, often show limits and they are for the moment only energies of completion. Unequal sharing of income from energy can cause tension. Are nuclear and renewable energies the miracle solutions for the future?.

Key words: Renewable energy, non-renewable energy, energy income, energy security.

INTRODUCTION

Energy constitutes the history of humanity; it allows for technical innovations, sanitary and agricultural advancement, and increases the efficiency of transportation. Economic and social development and energy production are linked, although some energy-rich countries are poor. The most developed countries are the biggest consumers. However, the exceptional growth of emerging countries (China, Brazil, India, and South Africa) over the past decade has led to the current explosion of its demand. The consumption of energy is increasing; increase in the world population, improvement of lifestyles, and easier access to resources are due to technology development. Fossil energies are mostly consumed. The leading one is oil, whose valuation remains a geostrategic issue. Nuclear energies must be considered as non-renewable. They are often decried because they cause serious accidents. They also produce wastes whose transport and storage are dangerous, and their mastery pushes some countries to develop alarming military nuclear programs. Thus, saving becomes an imperative to reduce the consumption of non-renewable energy resources.

Renewable energies, therefore theoretically inexhaustible, are alternative energies that occupy a growing place. Nevertheless, their applications often show limits and they are for the moment only energies of completion. As a result, promoting alternative energy and reducing fossil fuel pollution are challenges. However, the unequal sharing of energy income can lead to violent social explosions in poor countries. Tensions can lead to international conflicts. Energies are indispensable resources for the development of human societies, but

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the issues are: How should they be managed to meet the continued growth of the consumption? What are the environmental impacts of non-renewable energies? Why does access to energy create geopolitical tensions? Why are the extraction and use of energy the origin of various risks (oil spill, explosion, mining accidents ...)? So many questions may perhaps allow us in this work to identify and propose a balanced management of energy resources over time.

ENERGY REQUIREMENT AND RESOURCE MANAGEMENT

Energy is essential for the economic and social development of human societies.

An increasing consumption

The causes of increase in the demand for energy are numerous. Human needs have increased as a result of the rapidly increasing world population, economic growth and changing lifestyles. Added to this is the increase in extraction techniques and the easier access to deposits due to improvement of transport modes (tube networks and the revolution of maritime transport). Around 1900, world primary energy consumption was less than one billion tons of oil equivalents per year. It now exceeds 12 billion (Aie, 2008; Rebelle, 2009) (Figure 1 and Table 1).

The domination of fossil energy resources

Most of the world's consumption is based on the use of fossil fuels, that is to say, not renewable on a human scale. The question of their replacement arises and that of reserves is a source of debate. The easy-to-use coal accounts for a quarter of primary energy production. Oil is the most consumed energy. Land, air, sea and river transport are almost totally dependent on it. Natural gas accounts for 21% of global primary energy production. Smil, (1991) The distribution of deposits is very unequal on the earth’s surface. The main coal fields are situated in the USA, Central Europe, Eastern Siberia, China and Australia. The hydrocarbon deposits are concentrated mainly in the Middle East (62% of proven global resources), far ahead of South America and Africa. In the future, most of the production will come from off-shore deposits. Russia, Central Africa and the Middle East (Qatar, Iran) have almost three-quarters of the world's natural gas reserves.

Saving resources: An imperative

The effort of developed countries is focused on energy savings. The European Union should save 20% of its energy consumption by 2025. Several factors explain this, due to the promising technical progress (use of new materials, more efficient engines, and construction of nuclear reactors of new generations) (Heradstveit and Hveem, 2004). Agenda 21 and local Agenda 21 promote forms of urbanization that are compatible with the reduction of energy uses by promoting soft traffic (bicycles, tramways) and reinforcing the thermal insulation of dwellings. The efforts already implemented have made it possible to increase energy efficiency: the same quantities of wealth are produced each year with less energy Anuta, (2006). Development has relied mainly on abundant fossil fuels, sometimes even wasted, with little concern for reserves. A more sustainable management is needed.

ENVIRONMENTAL IMPACTS AND GEOPOLITICAL TENSIONS

The awareness of the environmental impacts and depletion of fossil resources, neglected with the abundance of energy have come back to the foreground (Gueye, 2015).

Energies and various risks

The extraction and storage of coal, oil and gas pose dangers: explosion, landslides, fires, leaks and oil spills. Some pollution due to the production of energies has long-term effects on ecological balances and health of populations. Pollution can cause death, contaminate soil and water (Archer and Jacobson, 2008). Regulations can make it possible to protect oneself. They are proposed on a global scale; for example, UN conventions limit the use of resources, marine areas, define responsibilities, organize compensation in the event of pollution and legislate interventions on high seas in the event of an accident.

Energies and global warming

The combustion of fossil fuels releases a large amount of additional greenhouse gases into the atmosphere. Their concentration varied naturally in history but has been soaring since the beginning of the Industrial Revolution. Without these gases naturally present in the atmosphere, our planet would be freezing. But their excessive accumulation creates an additional greenhouse effect that would be a possible source of global warming. The largest emitters of greenhouse gases are developed countries, emerging countries and countries that supply fossil resources (oil, coal), far ahead of poor countries (Chautard, 2007; Kounou, 2006).

Energies and geopolitical tensions

Consumer countries and companies are sometimes in

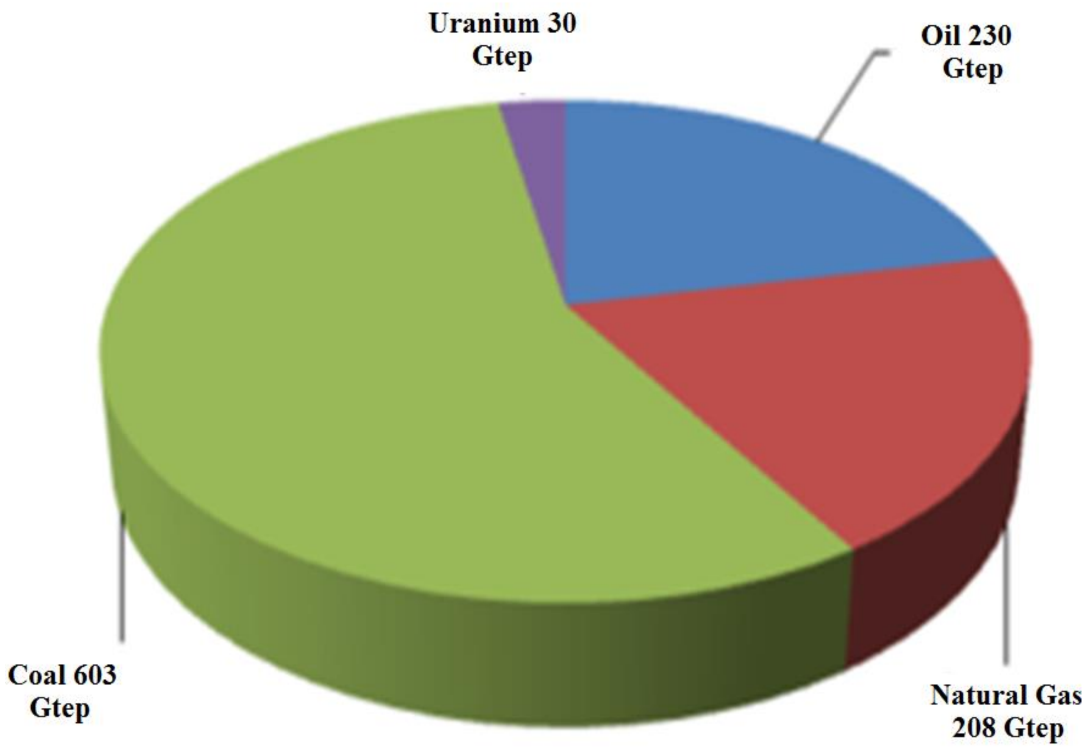

Figure 1. Global energy resources.

Table 1. World energy reserves estimated as at 2011 ending (excluding renewables)

Proven Oil Reserves by country (billions of barrels)			
Country	**End 1992**	**End 2014**	**% Total**
Venezuela	63,3	298,3	17,5%
Saudi Arabia	261,2	267,0	15,7%
Canada	39,6	172,9	10,2%
Iran	92,9	157,8	9,3%
Iraq	100,0	150,0	8,8%
Russia	n.d.	103,2	6,1%
Kuwait	96,5	101,5	6,0%
United Arab Emirates	98,1	97,8	5,8%
United States	21,0	48,5	2,9%
Libya	22,8	48,4	2,8%
Total Top 10	795,4	1 445,4	85,0%
Total of proven resources	998,4	1 700,1	100,0%

competition to access the deposits and secure their supplies. Tensions can lead to international conflicts. The unequal sharing of energy income can lead to violent social explosions in poor countries. Global flows of energy resources use terrestrial or maritime routes that must be permanently secured to ensure the smooth flow of traffic. The most vulnerable places of passage are the straits that can be easily blocked. Some oil and gas pipelines also cross unstable areas (Caucasus, Middle East), which also poses a constant threat to supplies (Laurent, 2006).

Energy is also sometimes a diplomatic weapon Cf. 129. The first oil shock of 1973 was partly related to OPEC's willingness to defend the interests of the producing countries. Nowadays, Russia does not hesitate to use its gas to put pressure on certain states (Ukraine, Belarus) under influence (Ngondi, 2008). The environmental impacts and geopolitical tensions linked to energies engage the development of present and future human societies. What are the future issues? (Rebelle, 2009).

WHAT ARE THE ENERGY CHOICES FOR THE FUTURE?

Promoting alternative energies and reducing fossil fuel pollution are challenges (International Energy Agency, 1990).

Developing renewable and clean energies

Wind energy depends on the strength of the wind frequency but sometimes wind turbines are noisy and integrate poorly into the landscape. Solar energy can produce heat and electricity. It is reliable and its operation is not costly, but its profitability is to improve Communay (2002). Biomass is mainly used in developing countries. It can be a source of risk related to its combustion (pollution, intoxication) and contributes to deforestation. Agro-fuels reduce pollution from transport to transport, but their production consumes fossil energy and crops for agro-fuels compete with those needed to feed men. Hydropower is the most used renewable energy. Very flexible in use, it produces little greenhouse gas and is very economical. In addition, dams are multifunctional (irrigation, flood prevention). But their social and environmental impact is more and more denounced Bonal and Rossetti (2007).

Reducing pollution related to fossil fuels?

Since the Kyoto Conference (1997), the states have been talking to each other to reduce greenhouse gas emissions. The protocol sets specific targets for developed countries to reduce their emissions over a period that lasted from 2008 to 2012. However, many countries are reluctant to become more involved and emerging countries are making the need to develop a priority. It is also known to capture and compress CO_2 for storage in underground sites or under the seabed. It is also possible to filter fumes generated by power plants and transport to retain some of the pollutants (Banque, 2005).

Is nuclear energy a solution?

It makes it possible to produce electricity for an acceptable cost. It is often decried because it causes serious accidents (explosions of Chernobyl in USSR in 1986, Fukushima in Japan in 2011). It produces wastes whose transport and storage are dangerous, and its control pushes some countries to develop alarming military nuclear programs. It uses uranium, the reserves of which are still abundant, and technical progress will make it possible to improve its use: new generation reactors (RNG), reprocessing and recycling of certain quantities of uranium. In the very long term, the merger could be a definitive solution, but at the cost of expensive research (Beltran, 2007). Nuclear energy must be considered as a non-renewable energy (it depends on fuels whose quantities are not unlimited), but it is also not a fossil fuel since the origin of the fuel does not result from organic material transformation Aen (2008).

Neither whole nuclear nor whole renewable

In the face of the challenge of climate change, nuclear and renewable energies can and must play an important role to reduce CO_2 emissions. Nevertheless, it must be emphasized that neither the whole nuclear nor the whole renewable or even the whole nuclear renewable constitutes a realistic solution in the short or medium term. Other technologies must complete electricity production for technical, economic and security reasons (Carton, 1999a). But in order to limit global warming, the greater use of these energies is needed. Several factors: political choices, advances in research, energy security constraints, natural data of a country, the price of hydrocarbons and CO_2 emissions will decide their respective share in the electricity production of the future. At the global level, the contribution of renewable energies will probably be greater than that of the nuclear power. However, it must be remembered that the most important potential for reducing emissions is not on the side of the electricity production, but on the side of the consumption and the energy efficiency. The ability of energy savings to reduce emissions exceeds that of the nuclear and the renewable energy combined (Chaliand, 2005; Carton, 1999b).

CONCLUSION

The extraction and use of energy are at the origin of various risks (oil spill, explosion, mining accidents ...). The additional greenhouse gas emissions from burning fossil fuels would contribute to "global warming". The dependence on oil and decline of resources are sources of competition for access to resources and political tensions to control supplies (straits, pipelines and transnational pipelines ...). Thus, the promotion of alternative energies becomes a necessity. Renewable resources (wind energy, solar energy, biomass ...) are by definition inexhaustible. However, for the moment, they are only complementary energies because their use has limits. They are also clean energies (Gueye, 2015).

However, given the dominance of polluting fossil fuels, the Kyoto Protocol called on developed countries to reduce their consumption. Nuclear energy is sometimes presented as a solution. However, it is decried by some and uses uranium whose quantities are not unlimited. In the future, neither the whole nuclear, nor the whole renewable or even all the nuclear renewable is a realistic solution in the short or medium term.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Aie (2008). World Energy Outlook, Paris, International Agency for Energy.

Aen (2008). Perspectives of the nuclear energy 2008, Paris, Nuclear Energy Agency.

Archer C, Jacobson M (2008). Evaluation of Global Wind Power, Stanford.

Anuta J (2006). Probing Question: What heats the earth's core?. https://phys.org/

Banque M (2005). Booms et gestion des recettes pétroliers 2005 Développements récents et perspectives économique.

Beltran A (2007). From coal to oil. International Questions, March - April 2007, n° 24, pp. 8-16.

Bonal J, Rossetti P (2007). Alternative Energies, Paris Omnisciences.

Carton B (1999a). Analysis of the economic and political situation of African oil-producing countries, in multinational oil companies in Africa, AITEC-GRESEA-IRENE, Paris.

Carton B (1999b). Oil in Africa: violence against the people, GRESEA, Paris.

Chaliand G (2005). Oil dependency: myths and realities of a strategic issue. Paris, Universalis 195 p.

Chautard S (2007). Geopolitic and Oil. Levallois-Perret, Studyrama perspectives. 158:648.

Communay P-H (2002). Heliothermal, the solar field. Methods and Calculations, Research and Editing Group, Toulouse 530 p.

Gueye M (2015). The International Petroleum Market from 1960 to the Present: Oil Flows and Commercial Networks. Sociology, Anthropology and Psychology Journal. University Press of Senegal.

Heradstveit D, Hveem H (2004). Oil in the Gulf: obstacles to democracy and development. Aldershot, Ashgate 180 p.

Kounou M (2006). Oil and poverty south of the Sahara. Yaoundé Edition Clé. 137 p.

Laurent E (2006). The hidden face of oil, Paris, Plon. https://inis.iaea.org/search/search.aspx?orig_q=RN:38042108

Ngondi E (2008). Oil and geopolitics in Central Africa, Paris, Harmatta.

Rebelle B (2009). Inventing the post-oil society: towards more concerted NGO action. Dans VIELAJUS, Martin The world's civil society challenged by reality. Paris, Charles Léopold Meyer pp. 273-285.

Smil V (1991). General Energetics: Energy in the Biosphere and Civilization, Wiley Articles. http://bases.bireme.br/cgi-bin/wxislind.exe/iah/online/?IsisScript=iah/iah.xis&src=google&base=REPIDISCA&lang=p&nextAction=lnk&exprSearch=75641&indexSearch=ID

International Energy Agency (1990). Energy statistics of OECD countries. Paris, OECD, IEA-AIE.

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Full Length Research Paper

Agro-ecological assessment of physico-chemical properties of soils in Kulfo Watershed, South Western Ethiopia

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Variation in physical landscape of the highlands gives rise to variations in agro-climatic and soil parent materials in Ethiopia. The aim of this research is to characterize the physio-chemical properties of soils in Kulfo watershed. For the study, primary data from transect walks, composite soil samples and GPS points and secondary data from satellite imaginaries, National Metrological Agency and Central Statistical Agency were used. 36 composite soil samples (0-30 cm depth) were collected from three agro-ecologies (upland, mid and lowland) and analyzed in soil laboratory. Accordingly, the watershed is characterized into four agro ecologies: Lowland (20.9%), midland (35.9%), highland (37.4%) and cold high mountain areas (5.8%). Soil analysis revealed that dominantly the watershed is characterized as textually clay loam to sandy loam and there are no significant textural differences among soils in all agro-ecologies. The soil reaction varies from moderately acidic (with pH 5.4) to neutral (pH 7.3). The watershed is dominated by medium organic matter, low total nitrogen, very low available phosphorus (3.83-6.65 ppm), high potassium and very low to low cation exchange capacity. Soil and water conservation measures in the upland and use of organic manure in the lowland areas could be the viable options for rehabilitation of soil productivity.

Key words: GIS, remote sensing techniques, transect walk, composite soil sample.

INTRODUCTION

Ethiopia is located in the tropics; its impressive altitudinal variations within a short distance allow the country to enjoy both temperate and tropical climates, which gives varying biophysical resources (Gashaw, 2015). Similarly, the great topographic variation of Ethiopian highlands gives rise to the formation of different physical landscapes which are in turn the causes for variations in soil parent materials, agro ecological zones, flora and fauna (Mishra et al., 2004). Thus, the success or failure of agricultural production in the Ethiopian highlands is

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highly influenced by the unique topographic settings and varying biophysical features (Chamberlin and Schmidt, 2012). Soil being basic natural resource, its wellbeing is vital for increasing agricultural productivity and sustainable farm production. Researchers agreed that no agricultural system can be claimed to be sustainable without ensuring the sustainability of soil fertility (Arshad and Martin 2002). Ethiopian highlands are receiving high amount of rainfall, which causes leaching of basic soil nutrients. In addition, rugged terrain feature has significant effect on weathering of soils (Lloyd and Anthony, 1999).

The implication of heterogeneity of landscape and soil in the Ethiopian highlands is that within a given change in terrain, climate and land use/ cover types; it is likely that the direction and magnitude of soil properties will also change. At the end this can reduce soil physical and chemical properties in different land use types as observed in Arsi highlands of Ethiopia (Shimelis, 2008). A study conducted by Kiflu and Beyene (2013) in Southern Ethiopia reported that there is change in soil chemical properties (high soil pH reaction, EC, available P, exchangeable K and Ca) in enset (*Ensete ventricosum*) fields as compared to other fields.

Characterization of soils is fundamental to soil studies, as it is an important tool for soil classification, which was done based on soil properties. It also provides information for understanding the physical, chemical, mineralogical and microbiological properties of the soils (Ogunkunle, 2005). In addition, it can help to determine the types of vegetation and land use best suited to a location. Soil classification, on the other hand, helps to organize our knowledge, facilitates the transferring of experience and technology from one place to another and helps to compare soil properties. A soil characterization study therefore is a major building block for understanding the soil, classifying it and getting the best understanding of the environment.

Several studies in Ethiopia have disclosed that deforestation, over cultivation, expansion of cultivation on marginal lands and steep slopes, and overgrazing are the causes of serious soil erosion and the resultant loss of soil fertility (Lakew et al*.,* 2005; Fock and Cao, 2002). Similarly, Young (1989) and Aklilu (2006) argued that there is a causal link among population increase, limited access to land resource, and poverty and land degradation.

In line with this, studies conducted in Northern and Southern Ethiopia reported variation in measured soil properties over different slope types and terrains (Ali et al., 2010; Dessalegn et al., 2014). A recent study conducted in Wolaita Zone also noted similar findings on variation of soil properties across varying landscape features (Kibret and Fanuel, 2015). The study revealed higher concentration of available P, exchangeable K and extractable micro nutrients (B, Cu, Fe and Zn) in the soils on flat than on steep slope terrain. Different sources also confirmed that the amount and distribution of soil nutrients of an area is dependent on biophysical conditions of the area (Ali et al., 2010; Kibret and Fanuel, 2015; Dessalegn et al., 2014).

Due to historic settlement, obsolete farming practices and encroachment of farmlands into marginal and steep slopes, the study area experiences severe degradation in the form of removing fertile top soil, soil erosion and associated constraints of soil nutrient depletion. As a result, soil nutrient depletion is one of the major problems of sustainable agricultural productivity and status of food insecurity in the area.

Agriculture being the predominant economic activity in Ethiopia needs research based information and experimental data on soil physical and chemical properties, which provides a viable information on the status of soil nutrients and soil related problems (Lekwa et al., 2004; Fasina et al., 2007)). Therefore, this research gap has initiated the researchers to conduct a study on the assessment of agro-ecological characteristics of physio-chemical properties of soil in Kulfo watershed.

MATERIALS AND METHODS

Description of the study area

The study area is part of Gamo highlands, located in the North-western margin of the Rift Valley Lakes of Abaya and Chamo, Southern Ethiopia. Astronomically, it lies between 5°58' N - 6°15'N, latitude and 37°18'E - 37°36'E, longitude covering about 434.7 km^2 (Figure 1). The altitude ranges between 1182 (on the shores of Lake Chamo in the western margin) and 3384 m above sea level (on the peak of mountain Gughe, Gamo highlands).

The landform of Kulfo watershed is characterized by extensive plateaus and hills dissected by mountain ranges in the northern parts and rift valley plains in its southern margin. The geology of the study area is of two types. Majority of the watershed including its northern part is dominated by trap series of tertiary volcanic lava of Cenozoic era, while the southern rift valley Lake areas were dominated by deposition of quaternary sediments of alluvial and lacustrine deposits. The upstream consists of alkaline basalts, with interbedded pyroclastic and rare rhyolites, porphyritic amygdaloidal and olivine basalt (Southern Regional Atlas, 1985). According to the FAO classification system (FAO, 2012), the study watershed has eight major soil types, where *orthicacrisols* (59.9%), *dystricnitisols* (13.4%), *eutric fluvisols* (11.3%) and *dystricfluvisols* (9.5%) shared 94.1% of all soil types while the remaining, such as *leptosols, eutric nitisols* and *chromic vertisols* contributed 5.9% of the

Kulfo is a perennial river which is used for domestic purposes and for small scale irrigation in its lower course. Due to East ward inclination of the landscape, all tributaries of Kulfo river (*Yeremo, Baba, Gulando, Zegende, and Ambule),* which is originated from Laka Kuyle, Kacha Wusha and Dita ridges are making their way into Lake Chamo. The dominant vegetation covers in the watershed are Bamboo, Eucalyptus globulus trees, bushes, riverine trees and short mountain grasses. In the area rainfall distribution is bimodal with an average annual rainfall of 1390 mm in the upstream and 959 mm in the lower catchment. The annual average temperature in the upstream is 16.7°C, while it is 24°C in the downstream area Degradation of watershed in recent years has brought the long-term reduction of the quantity and quality of land and water resources. Changes in watersheds have resulted from a

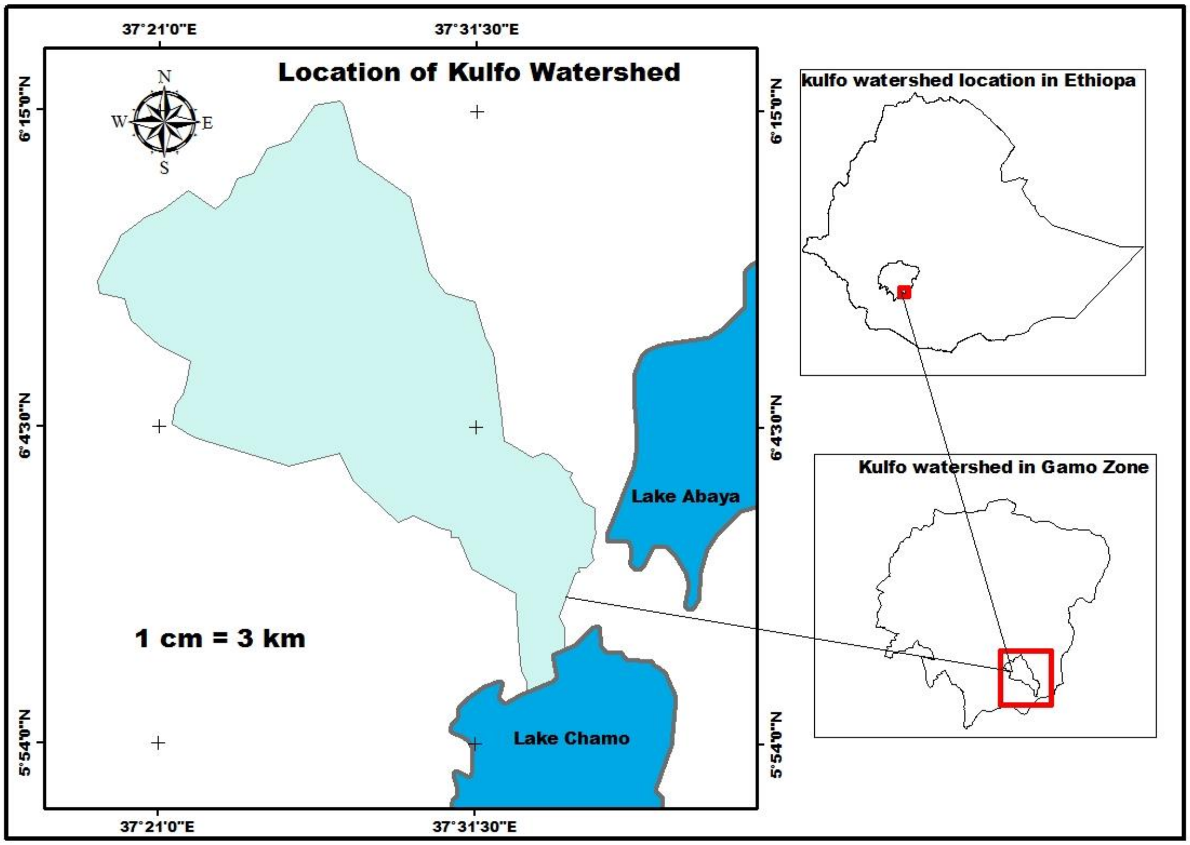

Figure 1. Location map of Kulfo Watershed, South Western Ethiopia.

range of natural and anthropogenic factors, including natural soil erosion, changes in farming systems, over abstraction of water, overgrazing and deforestation. Major land related constraints of the watershed are: cropland scarcity, soil erosion, declining pastures, deforestation and low crop yield. Small scale farming, such as barley (*Hordeumvulgare L*.), potatoes (*Solanum tuberosum L*.) and cabbage,enset (*Ensete ventricosum (Welw.)* along with livestock are the mainstay of smallholding farmers.

Data source

In order to achieve the objective of the study both primary and secondary data were used. The primary data were generated from transect walk, group discussion and soil sampling while secondary data were obtained from satellite imaginaries, climate data and Demographic data from CSA sources. Satellite imaginaries, grid based rainfall and temperature data obtained from National Meteorological Agency were used to characterize the biophysical landscape features of the study area.

Soil sampling

A first reconnaissance survey was conducted across the study area and 36 composite soil samples (0-30 cm depth) were collected in the year 2018 from the upland (18), midland (12) and lowland (6) agro ecologies of randomly selected land use/cover sites. Soil sample collection was performed by taking from each sampling category 1 kg representative composite soil in plastic bags, secured, labeled and transported to Arba Minch University Chemistry Department soil laboratory for analysis. Mainly more sample points were taken in the upstream part of the watershed (Figure 2), since it covers large area of the watershed and relatively characterized by poor productivity.

Laboratory analysis

Soil bulk density was measured using the core method (Blake, 1965). Soil texture was analyzed according to the procedures outlined by FAO (2012) using hydrometer method. The soil pH and ECe was measured using pH and EC portable meter. Soil organic carbon was determined using CNS analyzer (Blair and Carter, 1992). Potassium was determined by flame photometer. Available phosphorus was tested by Bray-1 and Olsen's method (Olsen et al., 1954). Total nitrogen was determined using modified Kjeldahl method (Jackson, 2005). The exchangeable bases (Na, K, Mg and Ca) in the soil were determined from the leachate of a 1M ammonium acetate (NH4OAc) solution. Exchangeable K and Ca were recorded from flame photometer (Rowell, 1994). Cation exchange capacity (CEC) was measured after leaching the ammonium acetate extracted soil samples with 10% sodium chloride solution. The percent base saturation of the soil samples

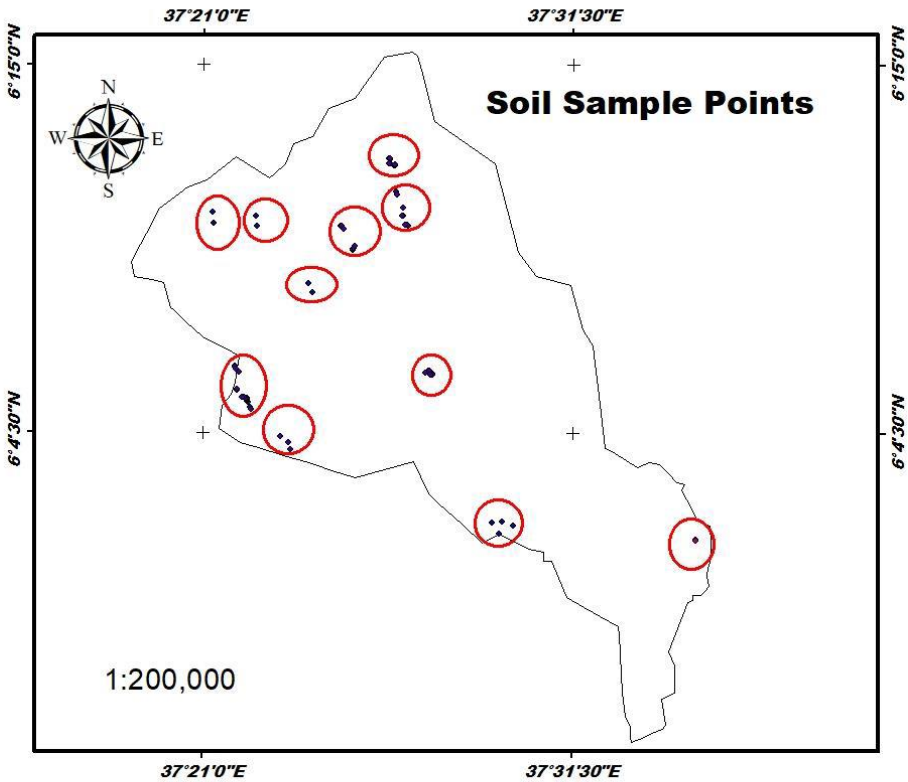

Figure 2. Sample points for soil sampling at Kulfo watershed.

was calculated from sum of the exchangeable cations (Na, K, Mg and Ca) as the percent of the CEC.

Data analysis

Climate and land use/ cover data were analyzed using GIS and Remote Sensing techniques in Arc GIS 9.3 software environment. Descriptive statistics were used to construct tables and figures to compare and contract soil nutrients across varying land use/ cover types. Based on laboratory and field data soil maps and soil nutrients were identified and presented in figures and maps.

RESULTS AND DISCUSSION

Agro-ecological zone

Kulfo watershed has diverse agro ecological zones ranging from dry *Kola* belt (500-1500 m) to a high *Dega* belt (3200-3700 m). Each belt is different in temperature and rainfall patterns. The boundaries between belts are also boundaries between agricultural crops. As shown in Figure 3, the watershed is characterized in four traditional agro ecological zones, namely Kolla (20.9%), *Weyna Dega* (35.9 %), Dega (37.4%) and High Dega, cold high mountain area (5.8%) related to the areas where soil samples were taken.

Climate condition

The degree and intensity of temperature determines the rate of evapotranspiration, soil moisture content and the humidity of the atmosphere. In the upstream the minimum and maximum temperature varies between 14.3 and 18.4°C. The annual mean temperature of the area is 16.7°C, which showed a slight annual variation (CV= 7.7%). The downstream areas got minimum (15.4^{O}C) and maximum (31.6°C) temperature in December and April months respectively. In this part of the watershed temperature condition is highly variable (CV= 50.2%) and showed a decreasing pattern from north to south (Figure 4).

The study watershed experienced two rainfall patterns. They are *Belg*, little rain season (March to May) and *Kiremt* (June, July and August), which is main rainy season. The fluctuation of rainfall in these seasons may impact on growing period and reliability of rainfall (Figure 5).

Soil characteristics

Texture

Soil texture being an important characteristic of soil which

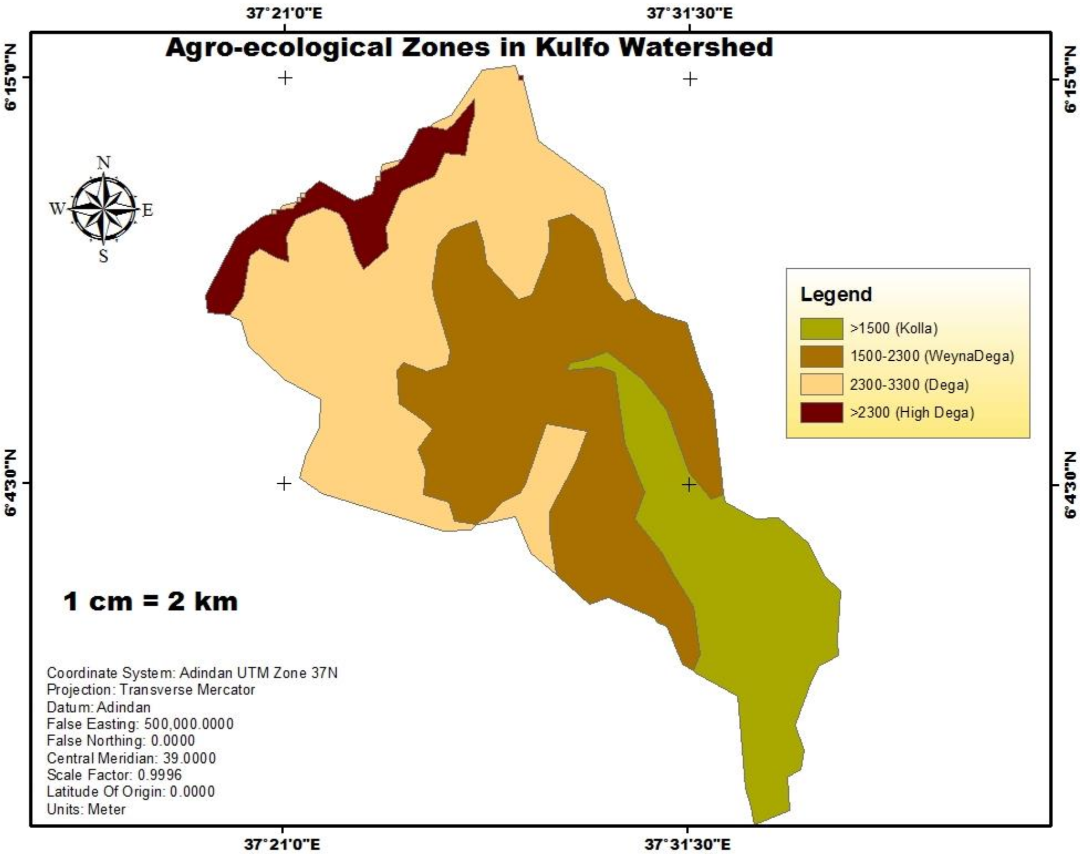

Figure 3. Agro-ecological zones of the watershed.

controls moisture holding capacity, the ease of tilling the soil and, the amount of aeration (Miller et al., 1997) is vital for soil fertility. The textural classes of surface soils on croplands are clay loam (upland) to sandy loam (downstream) as shown in Table 1. The study result revealed that soil texture classes in the upland are dominantly clay (33%) in texture, while it was sandy (65.8%) in the downstream. As stated by Miller et al. (1997) clay soil and silt soils have the ability to resist soil erosion and are less susceptible to erosion hazards. Thus from the findings it is possible to suggest that most soils in the upland areas can be grouped under less erodible soils. But poor adaptation of soil and water conservation measures is observed in the upland areas, which indicates that loss of nutrients followed by decline of the soil productivity is basic concern in the area.

Bulk density

Medium bulk density (1.11 to 1.2 g/cm^3) was recorded in three agro-ecologies; it implies the study soils have normal pore space and no limitation for aeration. The study further noted that the bulk density is not greater than the critical limits of 1.63 g/cm^3. As a result, in the study area compaction and drainage problems are minimum, it can create conducive environment for biological activity (Wemer, 1997) and infiltration.

Soil reaction

The laboratory result of soils in the croplands showed soil reaction between 5.4 (moderately acidic) to 7.3 (neutral). As stated in Table 1, most upland soils are acidic, which results from heavy rainfall condition (which leached down the soluble basic cation nutrients further down) as compared to the neutral soil behavior in the Lake shores of Lucastrine soil area. According to Smith et al. (1995) soil pH is highly sensitive to changing natural environment, repeated cultivation of the same plots and presence of heavy rainfall, which result in leaching of basic cations. As a result, soils of the uplands have lower pH and relatively acidic behavior. Contrarily, shore area soils have high pH, which is attributed to abundant soil bicarbonates. According to Brady and Weil (2008) most plants grow well in soils with pH between 6.5 and 7.5.

Thus, soils in the low-lying areas are conducive for crop

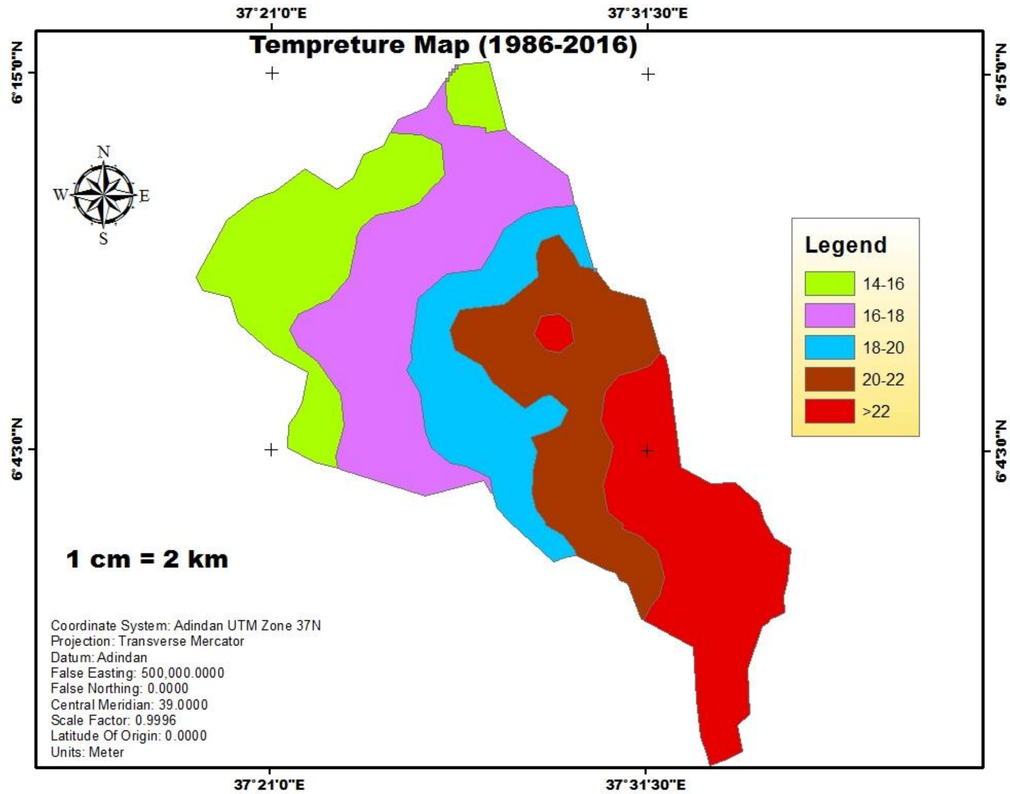

Figure 4. Temperature Map of the watershed (1986-2016).

cultivation.

Organic matter content

The analysis revealed that organic matter content of soil in the midlands and low lying areas of the croplands are medium to high in amount (2.38 to 3.21%) respectively. A study conducted by Alber and Ketterings (2008) reported that productive agricultural soils have organic content levels of 3 and 6%. Soil organic matter is an indicator of soil quality and controller of soil physical and chemical properties and source of essential plant nutrients such as N, S, P (Prasad and power, 1997).From the analysis it is possible to suggest that croplands in lowland area are agriculturally more productive as compared to the midland area probably due to the deposited nutrient rich soils materials brought from uplands by erosion and the fluvial nature of the original soil in the area.

Total nitrogen

The level of total Nitrogen in the study area is less than 0.1%, which is rated as very low in N content. Thus, according to Baize (1993) and Landon (2014) the amount of total nitrogen ranges between 0.1 and 0.2% considered as very low. Hence the result implies that surface soil in croplands of three sites requires nitrogen fertilizer for sustained crop production. As noted above, the organic matter amount of soils was medium to high, while contrary to expectation, the level of total nitrogen in all croplands was observed to be low. Thus, the amount of total nitrogen relationship in varying croplands showed weak relationship (r= 0.124). The low level of total nitrogen in three sample soils could be ascribed from low biomass return due to continuous farming and crop residue used for animal fodder and domestic purpose. This result is in line with the findings of Tuma (2013), a study conducted in Abaya-Chamo Basin and reported low level of total nitrogen and organic carbon in cropland soils due to repeated tillage.

Available phosphorus

Soil analysis revealed that available phosphorus on croplands was 3.83 and 6.65 (ppm) for midland and lowland areas respectively. This is considered to be very low to low P content and according to Baize (1993) it is below the critical minimum limit of < 7 mg/kg soil. Thus, the study soils are deficient in phosphorus nutrients and it

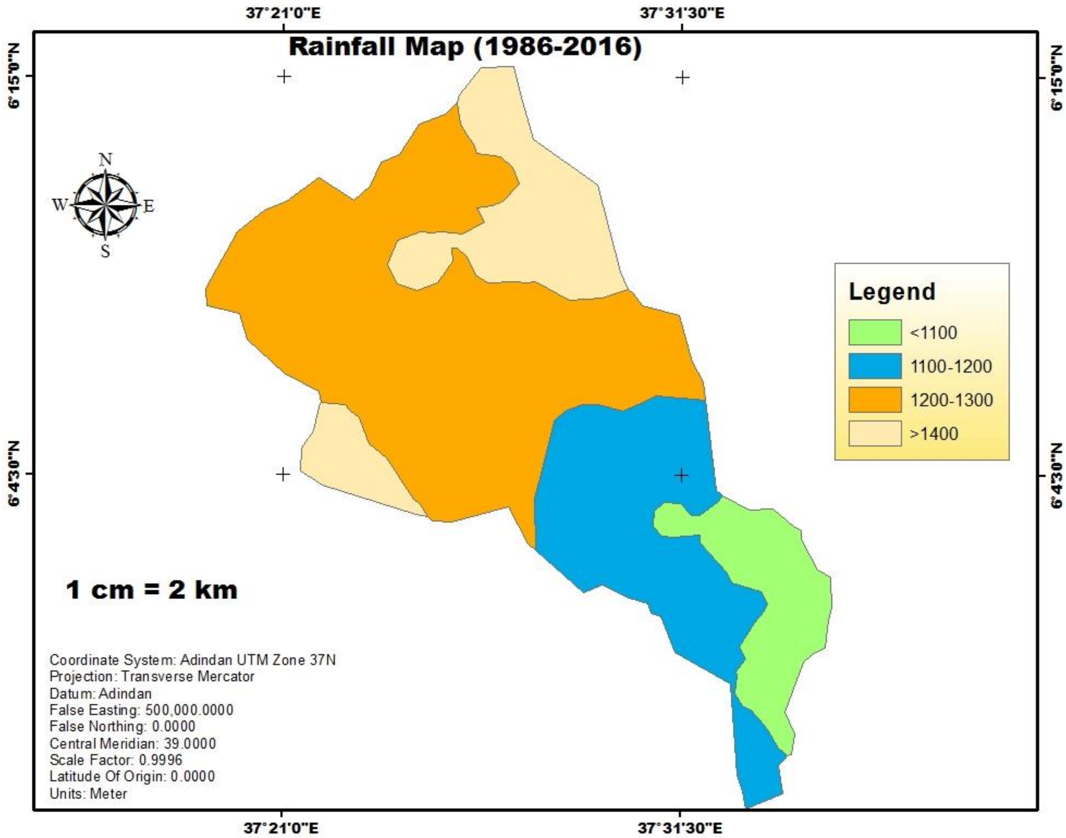

Figure 5. Rainfall Map of the watershed (1986-2016).

Table 1. Physicochemical properties of soils of Kulfo watershed respective to the agro-ecology.

Kebele	Crop land	Texture class	pH	OM	TN	AP	K^+	Ca^{2+}	Mg^2	Na^+	Bulk density	CEC
Kashaso (upland)	CL	Clay loam	5.4	2.71	0.06	4.46	2.97	3.00	13.76	0.52	1.14	4.51
MazoDoysa (midland)	CL	Clay loam	6.2	2.38	0.09	3.83	3.23	1.43	19.1	0.79	1.11	3.45
Walo (lowland)	CL	Sandy loam	7.3	3.21	0.1	6.65	5.13	7.9	19.64	1.25	1.20	7.16

CL = crop land, OM = Organic matter, TN = Total Nitrogen, AP= Available Phosphorus, CEC= cation exchange capacity.

should be supported by P fertilizer for optimum crop yields. As noted by Solomon and Lehmann (2000) the presence of sufficient amount of available P and total Nitrogen in the soil is due to management factor, soil organic matter, optimum climate (temperature and rainfall) condition of the area. Thus, it is observed from the analysis that for viable crop production the study soils have potential limitation of phosphorus soil nutrients. As reported by literature, Phosphorus, Nitrogen and Potassium are the three essential nutrients required by crop for optimum yields and physiological processes such as photosynthesis, root development and seed production (Johnson and Steen, 2000).

Cation-exchange capacity (CEC)

The result showed that the soils of the watershed have mean CEC of 5.04 cmol (+)/kg$^-$ with coefficient of variation of 0.42. This implies the amount of CEC was less variable throughout the study soils. The study further noted that the proportion of CEC (7.16) in the Lake area soils increased by 207.5% compared to midland soils, suggesting that the availability of CEC in the soil is influenced by depositional materials and fluvial soil sources in the Lake environment. According to FAO (2012) when CEC presence exceeds 10 cmol (+)/kg it is considered to be satisfactory for most crops. In this regard, the study surface soils were considered to be low, which was the reflection of low soil organic matter, relatively less clay content (33%) and low amount of cation exchange nutrients that are the major contributor of soil fertility (Oades et al., 1989; Joel et al., 2017).Thus for sustainable crop production, soil and water conservation measures and application of organic manure could be feasible options.

Exchangeable base (Ca^{2+}, Mg^{2+}, K^+ and Na^+)

According to the ratings of Baize (1993) the level of exchangeable calcium of the study soils is from low (< 5 cmo1 (+)/ kg) to medium (7.9 cmo1 (+)/ kg), showing that the development of salt is relatively minimal.

Potassium is the other essential nutrient required by crop for optimum yields. It acts as a correction to the harmful effects of nitrogen and often required for crops receiving high amount of nitrogen (Sehgal, 1996). The level of potassium in the soil was 2.97 cmo1 (+)/kg and 5.13 cmo1 (+)/kg in the upland and lowland soils respectively. According to Baize (1993), this amount was considered to be very high (> 1.2 cmo1 (+)/kg). The study results further depicted that with the increasing soil reaction the presence of potassium mineral also increases.

Furthermore, the presence of exchangeable sodium was 0.52 cmo1 (+)/kg s (low) and 1.25 cmo1 (+)/kg (medium) for upland and Lake area soils respectively. According to Landon (1991), excess soluble salt was not a problem on the studied soils.

Base saturation

The percentage of the cation exchange capacity occupied by basic cations is what is termed as base saturation. In the classification of soil, Hazelton and Murphy (2007) used base saturation as an indication of soil fertility status of an area. Accordingly, base saturation of study soils is 20.25 and 33.92% for upland and lowland soils respectively. As a result, base saturation of the study soils is rated as very low to low. This is due to the influence of acidic soils of the area. Brady and Weil (2008) reported that highly weathered and acidic soils have low concentration of base saturation. This is in line with our findings that soils in Kulfo watershed are acidic and originally they are highly weathered soils.

Conclusion

The results of this study showed that the study watershed has diverse agro ecological zones ranging from dry Kola belt (500-1500 m) to a high Dega belt (3200-3700 m) showing difference in temperature and rainfall patterns. It was ascertained that there was significant variation of soil physio-chemical properties across the watershed and that most soils are acidic and deficient in essential soil minerals. Texturally the upland area is dominantly by clay and the lowland area by sandy in texture. Almost all of the agro-ecological zones of the watershed have a medium bulk density which implies that the soils have normal pore space and no limitation for aeration. The croplands in lowland area are agriculturally more productive as compared to the midland area due to the deposited nutrient rich soils materials brought from uplands by erosion and the fluvial nature of the original soil in the area. The level of total nitrogen and available phosphorus are low in the area demanding nitrogen and phosphorus supplements for sustained crop production. Thus, erosive landscapes and low soil nutrients are common problems observed in the study area, which needs proper intervention practices. Therefore, in order to ensure the productivity of cropland, restoration of deficient nutrients, reclamation of acidic soils and use of environmental restoration measures could be a viable option. In addition, further focus shall be given for slope and land use level studies of soil nutrients in the watershed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aklilu A (2006). Caring for the Land: Best practices in soil and water conservation in Beressa watershed, highlands of Ethiopia. Thesis: Wageningen University.

Ali A, Esayas A, Beyene S (2010). Characterizing soils of Delbo Wegene watershed, Wolaita Zone, Southern Ethiopia: For planning appropriate land management. Journal of Soil Science and Environmental Management 1(8):184-199.

Blake GR (1965). Bulk Density Methods of soil analysis: Physical and mineralogical properties, including statistics of measurement and sampling. Methods of Soil Analysis, pp. 374-390.

Blair NE, Carter WD (1992). The carbon isotope biogeochemistry of acetate from a Methane organic marine sediment. Geochemical Cosmo Chemical Acta 56(3):1247-1258.

Baize D (1993). Soil science analyses: A guide to current use. The

Nature and Properties of Soils, pp. 311-358.
Chamberlin J, Schmidt E (2012). Ethiopian agriculture: Food and Agriculture in Ethiopia: Progress and policy challenges 74p.
Dessalegn D, Beyene S, Ram N, Walley F, Gala TS (2014). Effects of topography and land use on soil characteristics along the topo sequence of Ele watershed in southern Ethiopia. Catena 115:47-54.
Fasina AS, Omolayo FO, Ajayi, OS, Falodun AA (2007). Influence of land use on soil properties in three mapping units in South Western, Nigeria. Implications for sustainable soil management. Research Journal of Applied Sciences 2(8):879-883.
Food and Agriculture Organization (FAO) (2012). Harmonized World Soil Data base (version 1.2). Rome, Italy and IIASA, Austria.
Gashaw T (2015). The implications of watershed management for reversing land degradation in Ethiopia. Research Journal of Agriculture and Environmental Management 4(1):5-12.
Hazelton PA, Murphy B (2007). Interpreting Soil Test Results: Commonwealth Scientific and Industrial Research Organization Publishing.
Johnson AE, Steen I (2000). Understanding Phosphorus and its use in Agriculture. European Fertilizer Manufacturers Association, Brussels Belgium. Avenue E. van Nieuwenhuyse 4:1160.
Kibret K, Fanuel LA (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita Zone, Southern Ethiopia (Doctoral Dissertation, Haramaya University).
Kiflu A, Beyene S (2013). Effects of different land use systems on selected soil properties in South Ethiopia. Journal of Soil Science and Environmental Management 4(5):100-107.
Landon JR (2014). Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Routledge.
Lekwa MU, Anene BO, Lekwa G (2004). Chemical and Morphological Soil Characteristics in Drainage. Topo Sequence in Southeastern Nigeria.
Mishra BB, Heluf G, Kibebew K (2004). Soils of Ethiopia: Perceptions, appraisal and constraints in relation to food security. Journal of Food, Agriculture and Environment 2(3):269-279.
Oades J, Gillman GP, Oenara G, Hue NV, Wada K (1989). Interactions of soil organic matter and variable-charge clays. University of Hawaii Press, Honolulu, HI.
Ogunkunle AO (2004). Soil survey and sustainable land management. In Invited paper at the 29th annual conf. of SSSN held at University of Nigeria, Abeokuta, 6th to 10th Dec.
Sehgal J (1996). Pedology: Concepts and Applications. Kalyani publishers. (First Edition) New Delhi, India.
Shimelis G (2008). The impact of land use change on soil carbon, nitrogen and sulfur stock after grass land conversion to Pinuspatula and Eucalyptus grandis, at Arsi highlands, Ethiopia. M.Sc. Thesis, Mekelle University, Ethiopia.
Southern Regional Atlas (1985). Atlas of Southern Nations, Nationalities and Peoples Regional Atlas. Berhan ena Selam Printing Press, Addis Ababa, Ethiopia.
Tuma A (2013). Potassium Availability under Banana Based Land Use Systems in Abaya Chamo Lake Basin, south-west Ethiopia. International Journal of Scientific Research and Reviews 2(2):94-108.

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Design and construction of fixed dome digester for biogas production using cow dung and water hyacinth

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Engineered biological systems used for resource recovery often utilize anaerobic digestion to treat organic wastes by reclaiming the carbon as energy (methane gas) and a soil amendment (biosolids). This study explored the production of biogas from co-digestion of cow dung waste and water hyacinth (*Eichhornia crassipes*) using anaerobic biological conversion. Cow dung and water hyacinth biomass feedstock were collected from Abattoir and Ologbo River in Benin City, Nigeria. Samples were blended and substrate mixed in ratio 10:1 v/v due to balanced carbon/nitrogen (C: N) ratio of plant biomass and cattle rumen manure and charged into the fixed dome. Performance test was carried out after the biogas had been produced after twenty-one (21) days. The percentage composition of biogas produced shows that methane gas (CH_4) has 56.4%, carbon-dioxide (CO_2) is 35% and nitrogen (N_2) is 6.9%. Optimal production was found to be a function of temperature, hydraulic retention time, pH, concentration of bacterial population and overall design consideration of the digester. Scrubbers were fitted to rid the gas of hydrogen sulphide (H_2S), CO_2, ammonia ($NH_{3)}$ and moisture. The gas was directed through a gas pipe to a burner for cooking in the staff canteen. This study is relevant for the implementation of Sustainable Development Goals (SDGs) and strengthening of the bio-based economy with respect to waste management. This can facilitate environmental and socio-economic sustainability leading to reduced carbon foot print and reduction in solid waste accumulation.

Key words: Cow dung, water hyacinth, bio-digester, biogas.

INTRODUCTION

Biomass waste in the form of plant and livestock residues such as crop leftovers and manures are some of the largest available bioenergy sources in both rural and agro-industrial areas (Avaci et al., 2013). It is estimated that nearly 1.3 billion tonnes of food including fresh vegetables, fruits, meat, bakery, and dairy products are lost along the food supply chain (FAO, 2012). Also, the carbon footprint of food waste is estimated to contribute to the greenhouse gas (GHG) emissions by accumulating approximately 3.3 billion tonnes of CO_2 into the

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atmosphere annually (Paritosh et al., 2017). Therefore, exploring non-conventional and eco-friendly appropriate waste-to-energy technologies to mitigate the effects of climate change and reduce fossil fuel dependence has increased globally. Anaerobic digestion (AD) can be an alluring option for effective organic waste management leading towards a circular economy. It can help to foster the transition from fossil fuels dependence to more sustainable energy-producing scenarios while strengthening energy security and subsequently addressing waste management and nutrient recycling.

AD is a process in which microbial communities in the absence of oxygen convert biodegradable organic carbon (volatile solids (VS) or substrate) primarily into biogas containing the energy-rich compound methane. AD process involves four different stages (hydrolysis, acidogenesis, acetogenesis and methanogenesis) where methane is produced by methanogenic bacteria as shown in ure 1. AD is a versatile, effective and established method for the digestion of different organic wastes by the action of rumen-derived microorganisms (Verstraete et al., 2005). Biogas can be used for producing heat, electric power and vehicle fuel and therefore can serve as a means of reducing energy poverty, which has been a serious clog in the wheel of economic development in Africa (Adaramola and Oyewola, 2011). The methane and energy content of the gas generated usually varies and is dependent on the physical and chemical properties of the substrate used (Chenxi et al., 2011).

Investment in AD technology has increased due to its environmental and economic benefits (Grisel et al., 2014; Fantozzi and Buratti, 2011; Abbasi and Abbasi 2010). Sustainable waste management (SWM) is highly beneficial in terms of greenhouse gas (GHG) emissions reduction. Most of the studies highlighting the anaerobic treatment of organic waste have made significant improvements to enhance the energy recovery as a factor of biogas production and digestate (Anjum et al., 2018; Chen et al., 2018).

The biogas industry has been identified to be uniquely positioned to address nine of the 17 sustainable development goals (SDGs) – perhaps conceivably more than any other sector (WBA, 2017) (Table 1). These nine SDGs pertain to food and energy security, well-being, gender equality, sustainable water management and sanitation, resilient regions and cities, sustainable industrialization and combating the effects of climate change (Figure 1).

Despite the use of AD across the world, the overall sustainability of this process as a source of an alternate fuel (biomethane) is intrinsically linked to the successful management of one of its major byproducts, the digestate. The digestate is increasingly used to refer to the digested effluent produced in anaerobic digesters (Magrí et al., 2017). Digestate can be used as a potential fertilizer and soil amendment to improve the physical, chemical, and biological attributes of soil for crop production (Albihn and Vinneås, 2007; Lantz et al., 2007). This enables the recycling of plant nutrients, thus potentially reducing the need for fossil fuel-dependent mineral fertiliser (Holm-Nielsen et al., 2009). Producing a safe anaerobic digestate suitable for agricultural land application has become as important as producing the maximum yield of biogas. The application of organic materials to agricultural soils is a widely recommended practice not only as a source of essential plant nutrients which can provide savings in inorganic fertilizer use (Defra, 2010), but also as a means of increasing soil organic carbon (SOC) levels with associated improvements in soil biological and physical functioning (Bhogal et al., 2009).

The solutions of organic waste management should not only be environmentally sustainable but also cost-efficient and socially acceptable. There are several factors that influence this complex process (Table 2), which are largely intertwined. Despite the continually rising energy demands reported globally, millions of communities and households, particularly in developing countries, still lack access to basic energy services (Surendra et al., 2014). As a result, over three billion people primarily in the rural areas of developing countries rely on traditional solid fuels such as firewood, cattle manure, and crop residues for meeting cooking and heating needs (Surendra et al., 2014). Water hyacinth also known as *Eichhornia crassipes* is a rich lignocellosic biomass with other bioactive compounds that are favourable source of biofuels production (Shanab et al., 2016). More so, it is well established that biomass of aquatic macrophyte can be used for biogas production to meet energy demand (Kumar et al., 2017). In addition, *E. crassipes* is highly enriched with carbohydrates and lignin content, its impressive growth rate makes it a suitable source of lignocellulosic matter for the generation of biogas (Kumar et al., 2018). However, *E. crassipes*, is an invasive water weed and thrives in fresh water bodies causing serious environmental problems (Njogu et al., 2015). Despite a long history of research and innovation for the development and optimization of household digesters, little has been reported for the application of these in Nigeria. The aim of this study is to evaluate the co-digestion mixture of water hyacinth and livestock manures in order to boost the methane production for sustainable energy security.

MATERIALS AND METHODS

Sample collection and preparation

In this study, cattle whole rumen-derived content was obtained from evisceration unit of slaughterhouse located at Ikpoba (6^o21'5.09'N, 5^o38'34.49'N) in Ikpoba Okha Local Government Area of Edo State.

Table 1. Biogas and sustainable development goals.

Sustainable development goal	**Contribution of AD**
Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Restoring soils through the recycling of nutrients, organic matter, and carbon Increasing crop yields through use of nutrient-rich digestate bio-fertilizer Recirculating phosphorus, which is essential for the growth of plants but limited in supply
Goal 3: Ensure healthy lives and promote well-being for all at all ages	Reducing indoor air pollution by substituting solid biomass-based domestic fuels with biogas Treating and recycling sewage and organic wastes to reduce odours and the spread of diseases
Goal 5: Achieve gender equality and empower all women and girls	Reducing the burden of collecting firewood to improve the quality of women’s and children’s lives, reducing household labour in cooking
Goal 6: Ensure availability and sustainable management of water and sanitation for all	Providing decentralized, local treatment of bio-solids in remote and rural communities to reduce odours and the spread of disease Stabilizing and recycling bio-solids through AD to allow them to be applied back to land Reducing the carbon loading of wastewater to reduce impact on water bodies.
Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Reducing dependence on fossil-fuel-based energy sources by replacing with biogas Capturing waste heat from co-generating units linked to biogas plants Utilizing locally produced wastes and crops to generate energy for rural and remote communities Storing biogas to produce energy when required
Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Improving the self-sufficiency and sustainability of industries by extracting the energy from their own effluents and using it for the self-generation of electricity and/or heat Collaboration between industries and agriculture for mutual benefit Generating short-term construction employment and long-term equipment manufacturing and maintenance employment Encouraging growth of micro-enterprises by providing reliable electricity that can be stored and used when needed, that is baseload energy
Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Preventing spread of diseases through collection and proper management of organic waste Improving sanitation and hygiene through decentralized and local treatment of bio-solids Stabilizing the sludge from wastewater treatment to protect the marine environment and urban air quality Improving urban air quality by substituting fossil fuel with bio-methane in vehicles Improving urban air quality by substituting solid fuel for domestic cooking and heating with biogas Reducing greenhouse gas emissions by using biogas-based renewable energy in buildings, homes and industry
Goal 13: take urgent action to combat climate change and its impacts	Reducing carbon dioxide emissions by replacing fossil-fuel-based energy sources with biogas and commercial fertilizers with digestate bio-fertilizer Reduction of methane and nitrous oxide emissions from livestock manures Reduction of methane and generation of renewable energy from food and other organic wastes Capturing emissions from landfills Reducing deforestation by replacing solid-biomass-based domestic fuels with biogas
Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Recirculating nutrients and organic matter in organic wastes through AD and returning them to the soil in the form of digestate bio-fertilizer Substituting firewood with biogas as a domestic fuel, reducing deforestation

UN (2015).

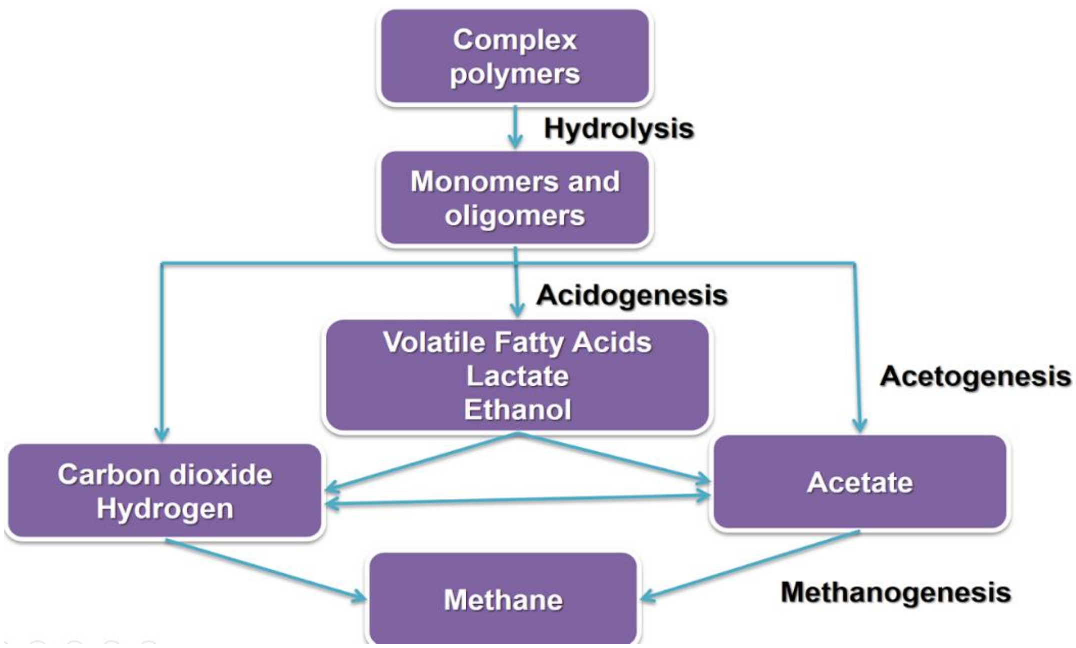

Figure 1. Simplified stages of anaerobic digestion pathways in organic waste degradation.

Table 2. Factors that influence waste management for anaerobic digestion.

Factors of waste management	Influence
Political	Political will, multi-level governance, government regulations (taxes, subsidies), data collection and monitoring
Economic	Business model, cost-benefit analysis, availability of finance, collaboration, and transparency along the value chain
Environmental	Sustainability policy, human health impact
Social	Community perception;
Technological advances	Innovation, infrastructure
Educational	Research centres, cooperation projects

Source: Malinauskaite et al. (2017).

Water hyacinth (*Eichhornia crassipes*) was harvested from Olobgo River (6°3'8.05'N, 5°39'50.48'E) also in Edo State. Sample of fresh water hyacinth (leaves, stem and root) was washed, chopped into small pieces of 2 to 5 cm pieces, and fresh rumen derived residue (10:1 ratio) was diluted and introduced into the digester. The rumen-derived microbial enriched (ME) inoculum was prepared by homogenizing water hyacinth with rumen contents using a blending machine.

The substrates respectively were mixed in the ratio of 2:1. The operational mode was the batch method using an operational mesophilic temperature. Biomethanation of these slurries was carried out for energy production in a fixed dome reactor and cumulative biogas production; slurry temperatures were monitored throughout the study. The digester was tightly corked with rubber stopper to create anaerobic condition and connected to a gasometrical chamber. The total biogas yields were determined by opening the outlet tap of the anaerobic digester and the inlet tap to the graduated burette. The biogas generated was released through the tube which then displaced the paraffin oil in the graduated burette downward. The volume of gas yield was determined by the volume of paraffin oil displaced that is gas yield was directly proportional to paraffin oil displaced. The schematic diagram of experimental laboratory set up is shown in Figure 2.

Design of fixed dome digester

The design of the fixed dome digester also known as the Chinese dome digester (CDD) or Chinese model and hydro-pressure digester was based on low-cost, long life span, and low maintenance requirements. It consists of an underground reactor with a fixed cover where the gas and input slurry are stored and an effluent displacement tank with the outlet as shown in Plate 1. The system is typically loaded semi-continuously and as gas production increases inside the reactor, the digested slurry is pushed into the displacement tank, and likewise as the gas is used, the slurry in the digester tank flows back into the reactor, creating agitation. The volume (V_D) of the digester is derived from equation 1 in

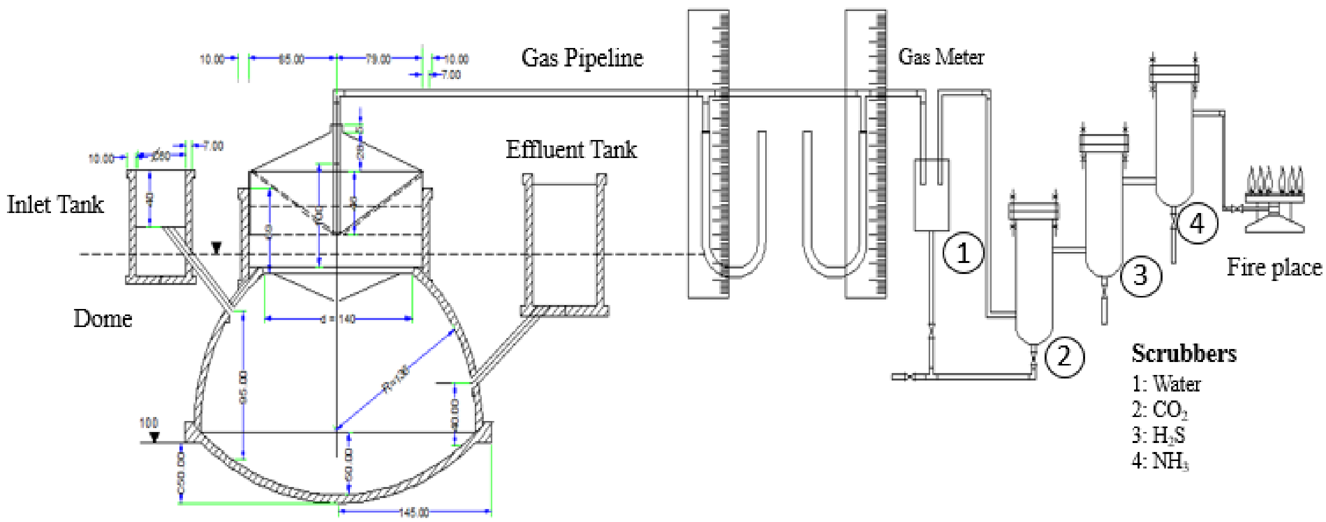

Figure 2. Conceptual diagram of a fixed dome system.

accordance with Sasse (1988) and Sasse et al. (1991), S_d is the daily fermentation slurry supplied and HRT is the hydraulic residence time.

$$V_D(L) = S_d(\frac{L}{day}) \times HRT(day) \quad (1)$$

Considering the amount of fermentation $S_d(\frac{L}{day})$ slurry consisting of cattle rumen mixed with water hyacinth at ratio 10:1 and feedstock to water at ratio 1:2 in accordance with Pachaiyappan et al. (2014). The general reaction for methane formation is shown in Equation 2 as depicted in Serrano (2011):

$$C_cH_hO_oN_nS_s + yH_2O \rightarrow xCH_4 + nNH_3 + sH_2S + (c-x)CO_2 \quad (2)$$

Where $x = \frac{1}{8}.(4c+h-2o-3n-2s)$

$y = \frac{1}{4}.(4c+h-2o-3n-3s)$ and the reaction follows exponentially in Equation 3:

$$V_{BR} = C_1.(1-e^{-C_2.t_{BR}}) \quad (3)$$

V_{BR} (m^3/d) is the biogas yield, C_1 and C_2 are constants and t_{BR} is time. Jones and Salter (2013) noted that biogas yield as a function of other process parameters that is temperature and hydraulic retention time (HRT). The effects of temperature on the rate of reaction were compared with HRT in Njogu et al. (2015) in Table 3.

In this study, mesophilic condition was considered with an average temperature of 30°C and HRT of twenty-one (21) days.

The daily slurry is;

$S_d(\frac{L}{day})$ =93L (cattle rumen) + 9L (water hyacinth) + 203L (water) = $305\frac{L}{day}$. Therefore, substituting the variables into Equation 1

$$V_D = 305\frac{L}{day} \times 21day = 6405L = 6.4m^3$$

In accordance with Sasse (1988), 1 kg of fresh cattle rumen will yield 10L(0.01m^3) of biogas in HRT of 20 days. Assume that 1L of fermentation slurry is equivalent to 1Kg of water, daily gas production can be expressed as;

$$G = 0.01W \quad (4)$$

$$G = 0.01 \times 305 = 3.05m^3$$

The volume of the digester can be expressed in accordance with Kaur et al. (2017) as shown in Equation 5.

$$V_s = HRT \times \frac{2W}{1000} \quad (5)$$

$$V_s = 21 \times \frac{2 \times 305}{1000} = 12.81m^3$$

In other words, the height and diameter of the digester can be computed. The height is related with the diameter as $D = 2H$ and from the volume of a cylindrical shape,

$$V_s = \frac{\pi}{4} \times H \times D^2 \quad (6)$$

$H = \left(\frac{V_s}{\pi}\right)^{\frac{1}{3}} = 1.598\,m$ and $D = 3.196\,m$

In Nigeria, there is growing pressure on forest reserves as most of the rural and peri-urban settlement depends on fuel wood for cooking. In other words, biogas as an alternative has the potential of reducing forest pressure and emission occasioned by fossil fuel. Assume gas consumption during cooking with biogas from 0600 to 0800 h, 1200 to 1400 h and 1800 to 2000 h respectively each day. This means that cooking is achieved within 2 h and this is expected for three meals each day, hence the duration of gas consumption is 6 h. Therefore, gas consumption is expressed as:

Plate 1. Construction stages of the fixed dome digester.

$$\frac{3050L}{6hr} = 508.3\frac{L}{hr}$$

Since biogas is produced during consumption, it is important to know the difference between consumption and production. But hourly biogas production;

$$\frac{3050L}{24hr} = 127.1\frac{L}{hr}$$

$$D_G = 508.3 - 127.3 = 381.2\frac{L}{hr}$$

If cooking is done between 0600 to 0800 h (morning) and 1800 to 2000 h (evening), it implies that 4 h biogas consumption is compulsory for each day, it is therefore vital for gas production to exceed daily consumption.

$$V_G = 381.2\frac{L}{hr} \times 4hr = 1524.8L = 1.5m^3$$

Table 3. Effect of temperature on anaerobic bacteria.

Anaerobic process	Operating temperature (°C)	HRT (days)	Microbial growth and digestion rates	Toxicity tolerance
Psychrophilic	10 - 20	>100	Low	High
Mesophilic	20 - 35	>20	Medium	Medium
Thermophilic	50 - 60	>8	High	Low

And, the required gasholder capacity C is 50%

The conceptual diagram of a fixed dome digester is as shown in Figure 2. The digester is linked with an inlet and effluent tank where feedstock is charged in and effluent discharged respectively. It is expected that biogas produced is measured using a pressure gauge and transferred through a water scrubber and furthermore, CO_2, H_2S and HN_3 scrubbers depending on the composition of the biogas. This is significant in increasing the quality of combustion at the burner.

Construction of fixed dome digester

The construction started with site investigations, which include location as well as the selection of component parts of the biogas digester. After site identification, the soil was excavated. The radius of excavation is a bit bigger than the digester radius to allow working space while at the same time ensuring that the space is not too much and result in more workload during excavation and backfilling. The system was typically made from mortar and poured concrete as sealant for the inside plastering. The biogas digester location implies proximity to the kitchen, open to atmosphere and direct sunlight, waste availability and clearance of any large tree which is similar to site selection procedure for biogas digester in (Jiang et al*.,* 2016, Samer, 2015; Rajput, 2011). The biogas digester will utilize cow dung as described in (Abarghaz et al*.,* 2011, Anaswara, 2015, Lebofa and Huba, 2011). The technical data for the biogas digester dome is as shown in Table 4. These are the data arrived at during the initial energy survey of the locality which aims at determining average household size, average household energy consumption per day and sources of energy for domestic hose connected from the digesters to the bottom of the gas collection systems. The biogas produced was channelled through moisture scrubber as shown Plat 1J to rid the biogas mixture of associated moisture. More so, CO_2 was scrubbed using activated carbon while H_2S was stripped with iron fillings. Purification of biogas is of significant importance in limiting combustion inhibitors as well as prevention of corrosion. The biogas produced was a blue flame and primarily utilized for cooking food at the staff canteen of the National Centre for Energy and Environment as shown in Plate 1K.

Composition (CH_4 and CO_2 content) of generated biogas was determined using a Gas Chromatography (GC), (HP 5890II Series USA) coupled with a Hayesep Q column (13 m × 0.5 m × 1/800) and a Split Injector/flame ionization detector (FID) to determine the percentage composition. This was carried out two times a week in duplicate from the digester using a 100 µl gas tight syringe for taking biogas samples from the digester head space after releasing the gas and followed by injecting the biogas sample into the GC. The results of the sample analyses were computed and compared with standard operating procedures for biogas and the results obtained are as shown in Figure 3. Anaerobic decomposition of waste is also known as biomethanation process. It is one of the important and sustainable techniques for treatment of the biodegradable waste in subtropical climates. In this process, activities. These are essential for material costing and labour. Biogas digester is a rural based technology, therefore, local materials for construction gets priority to minimize cost. The plan and section drawing of the biogas digester are presented in Figure 2. However, commercial biogas digester will incorporate load and stress analysis for concrete structure sited in clay (Desal et al*.,* 2013). The construction process of the dome- shaped biogas digester is as shown in Plate 1 at the National Centre for Energy and Environment (Energy Commission of Nigeria), University of Benin (6^{o}23’53.65’N, 5^{o}37’35.65’E).

Digester loading and biogas production

The feedstock water hyacinth and cattle rumen-derived content was prepared with water into slurry and introduced into the constructed fixed dome bio-digester at the National Centre for Energy and Environment. Initially, the fixed dome digester received the same type of feedstock in order to establish their baseline performance. The digester loading rate was increased progressively by adding greater volumes of water hyacinth and cattle rumen-derived content to eventually reach the maximum nominal COD loading. Samples were collected from the feed and the effluent tank for subsequent analysis. The slurry was allowed to occupy three quarter of the digester space leaving a clear height as space for the gas production.

Before feeding the reactors, the flexible hose connecting the gas outlet from the reactor to the gas holder was disconnected, such that the gas outlets from the reactors were left open. This was done to prevent negative pressure build up in the reactors. The gas was collected from the digesters through a 10 mm diameter flexible stabilization occurs, and biogas is liberated by the conversion of organic matter, which in turn can be used as energy.

RESULTS AND DISCUSSION

Fixed digester construction

The fixed dome digester is a semi batch reactor composed of a fermentation chamber for anaerobic digestion, feed and digestate pipes, and a fixed dome on the top for biogas storage. The reaction and biogas storage chambers are connected. The dome is built mainly with granite, sharp sand, iron rods and cement which is similar to fixed dome digester constructed in India. Some of the important design consideration includes local climate, amount of waste and water available to input into the anaerobic digester daily. The lower part of the digester contains a layer of biosolids and a layer of liquid above the biosolids. As the anaerobic microbial processes take place, volatile solids are

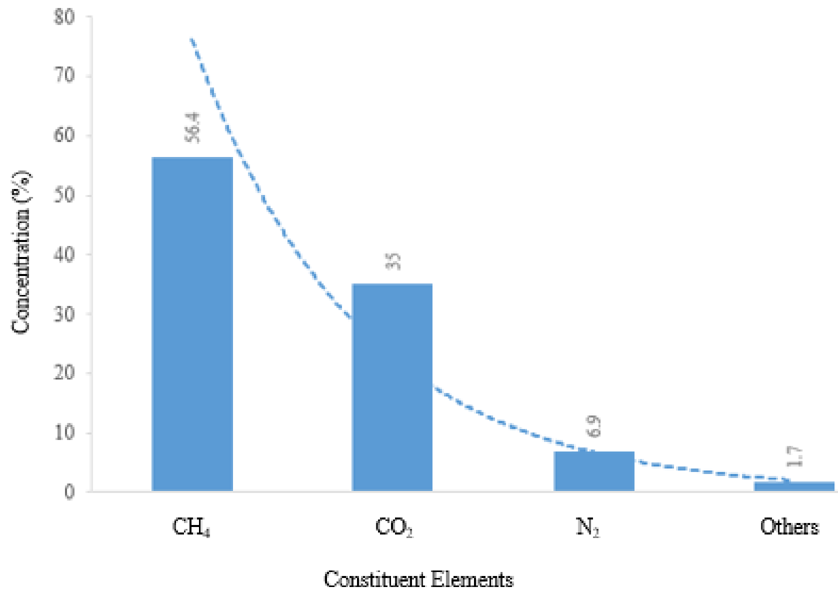

Figure 3. Percentage biogas composition.

Table 4. Technical specification for NCEE fixed dome biogas plant.

S/N	Item	Description
1	Feedstock type	Faecal waste (Rumen content) from Ikboba Abattoir
2	Source of water	Functional borehole
3	Soil type	Hard clay, no rock, level land, low water table
4	Hydraulic Retention Time (HRT)	21 days
5	Volume of digester (V_D)	6.4 m^3
6	Height of the digester (H)	3.196 m
7	Volume of fermentable slurry (V_s)	12.81 m^3
8	Volume of gas consumption (V_G)	1.5 m^3
9	Gasholder capacity (C)	50%
10	Gas production (G)	3.05 m^3
11	Faecal waste required per day	93 kg
12	Water required per day	203 L
13	Density of slurry	1003 kg/m^3
14	Digester shape	Cylindrical
15	Gasholder shape	Domed
16	Flame temperature	870°C
17	Ignition temperature	700°C
18	C:N Ratio	29:1

consumed, and methane and carbon dioxide are produced. The fixed-dome digester was constructed inside a pit dug in the ground, which protects the structure, provide insulation, and provides open space for other uses above ground (GTZ/GIZ, 1999).

The construction was in accordance with key specifications as shown in Table 4. Essentially, the design considerations are in line with CAMARTEC model of biogas digester by GTZ as published by Sasse et al. (1991). The design computations were in consonance with Kaur et al. (2017) on the design and construction of 10m^3 scale fixed dome digester. Nonetheless, while they both examined a cylindrical based digester, this design adopted a flat based casted concrete. The result of performance shows 56.4% CH_4 as dominant compound amidst CO_2 (35%), N_2 (6.9%) and other trace elements as shown in Figure 3. This result corroborates that published by IRENA (2016) on the comparison of biogas to CH_4 equivalent. Produced biogas was purified using activated carbon and iron fillings to respectively remove CO_2 and H_2S while the moisture was separated by scrubbing in consonance with Zhao et al*.* (2010).

Energy is an important indicator of socio-economic development of modern society (Surendra et al*.,* 2014) which has impacts on a wide range of development indicators, including health, education, food security, gender equality, livelihoods, and poverty reduction. It is an important factor in the economic, social and political development of any nation (Ojolo et al*.,* 2012). The use of biogas will reduce the workload for farmers, who would otherwise have to collect firewood for heating and cooking (Xiaohua et al*.,* 2007).

Gas and methane production rates

AD technology is extensively acceptable as an efficient process to treat and utilize food waste because it has been proven to be promising method for waste reduction and energy recycling (Zhou et al., 2014). It has become popular and is widely used due to its ability to produce renewable energy from wastes. The gas production rate (GPR) and methane production rate (MPR) are two major performance indicators in the anaerobic process. The GPR and MPR, expressed as the volume of biogas or methane produced daily per unit reactor volume. The quantity of biogas produced from the co-digestion water hyacinth and cattle rumen-derived content over a period of 60 days SRT is shown in Figure 3. The result of performance shows 56.4 % CH_4 as dominant compound amidst CO_2 (35%), N_2 (6.9%) and other trace elements. Produced biogas was purified using activated carbon and iron fillings to respectively remove CO_2 and H_2S while the moisture was separated by scrubbing in consonance with the results of Zhao et al*.* (2010).

The rate of biogas production was observed on the fifth day and increased gradually until the maximum values were recorded on the 30^{th}. Apart from the 30th day when sudden increase was observed, biogas production dropped progressively after the day 40. It was observed that the digester temperature fluctuated between 28 and 36.7°C while the pH of the medium changed progressively from acidic to slightly alkaline fluctuating optimally between 6.5 and 7.8. The high biogas production could also be attributed to the high content of carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorous, potassium, calcium, magnesium and a number of trace elements in the water hyacinth feedstock. Also, the result shows that cattle rumen derived content could have attributed to multiplication of microbial organism within the methanogenesis stage. The biogas produced is a function of bacterial growth. The higher and faster biogas generation could be attributed to the faster rate of decomposition of water hyacinth and cattle rumen derived content which have already undergone a form of digestion in the digestive system of the cows. Therefore, the action of bacteria on this category of waste is fast relative to the water hyacinth which contains fibrous tissues like lignin, suberin, cutin etc. which may not have been completely degraded during the pre-fermentation stage prior to anaerobic digestion.

The fluctuations observed in the volume of biogas produced may be attributed to the change in metabolism of the bacteria in response to the fluctuations in the temperature and pH of the digestion medium. Thus, the drop observed after the 40^{th} day could be attributed to the progressive fall in both the digester and ambient temperatures observed during the second halve of the digestion period. Usually, biogas production rate in batch condition is directly equal to specific growth of methanogens (Nopharatana et al., 2007). This result corroborates IRENA (2016) on the comparison of biogas to CH_4 equivalent.

Despite the diverse applicability and rapid expansion of biogas globally, some factors including process complexity, poor stability, inefficient biodegradability, substrate complexity, and low productivity impede methane production from AD. Numerous ways to overcome operational shortcomings suppressing methane yield have been suggested in previous studies, where the innovative approaches like three-stage digester (Zhang et al., 2017), novel enzyme addition (Dollhofer et al., 2015) and continuous microbial growth analysis (Sasidharan et al., 2018) have been developed and implemented successfully. In parallel, optimization of the process performance by manipulating operational variables (Hublin et al., 2012) such as feedstock choice, pretreatment, co-digestion, reactor type, temperature, pH and HRT (Hydraulic retention time) (Ward et al., 2008) have been widely considered.

Dioha et al*.* (2012) examined different types of biogas digesters and their operability as well as financing potentials in Nigeria. In other words, it is of significant importance to match a range of physical parameters as shown in Table 4 with operating parameters, that is feedstock size, feeding rate, average household, cost of construction, maintenance cost etc. In the recent times, there exist biogas online calculators (Wu et al*.,* 2016) and other computational dynamics for calculating biogas yield. In this case, the designed volume of expected biogas was validated with measurement of the actual biogas produced. However, other variables which may not be completely defined by a model or online calculator exists e.g. the feedstock history and type, plant capacity, HRT and temperature as noted by IRENA (2016).

Conclusion

A fixed dome digester was designed and constructed and charged with cow faecal and water hyacinth for biogas production. Daily gas production G is 3.05 m^3 with gasholder capacity of 50%. Biogas (CH_4) was produced from the blend of water hyacinth and cow faecal. Optimal production was found to be a function of temperature, HRT, pH, concentration and overall design consideration of the digester. Scrubbers were fitted to rid the gas of H_2S, CO_2, NH_3 and moisture. The gas was directed through a gas line to a burner for cooking in the staff canteen. Apart from the availability of biogas feedstock, biogas is cheaper than natural gas derived from fossils. This is because the plant uses cow dung as feed material. The production cost of 1 kg of bio-CNG (compressed natural gas) is about USD 0.23–0.24 which is much cheaper than the petro-based CNG (compressed natural gas) (The Hindu, 2016). In other words, it can be readily produced and deployed in individual/cluster homes for cooking and for power generation as stand – alone or grid. In addition, biogas production from abattoir waste, mainly cattle rumen potentially provides cleans up for the environment as most of the attendant waste is converted to useful energy. On the other hand, water hyacinth, a prolific sea weed commonly found in most of the rivers within the South-South Niger Delta can be curbed when utilized for energy production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ABBREVIATIONS

CO_2, Carbon dioxide;**CH_4,** Methane; **H_2S,** Hydrogen Sulphide; **NH_3,** Ammonia; **G7,** Seven Advance Economies (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States); **G20,** International forum for the governments and central bank governors from 19 countries and the European Union (EU); **UN,**United Nation; **EU,** European Union; **REN21,** Renewable Energy Policy Network for the 21^{st} Century; **AD,** Anaerobic digestión; **IRENA,** International Renewable Energy Agency; **NCEE,** National Centre for Energy and Environment; **ECN,** Energy Commission of Nigeria; **HRT,** Hydraulic Retention Time; **V_D,** Volume of Digester; **S_d**, Daily Fermentation Slurry; **G,** Gas; D, Diameter; **H,** Height; **D_G,** Daily Gas Production; **V_G,** Gas Volume; **C,** Gas Holder Capacity; **CAMARTEC,** Centre for Agricultural Mechanization and Rural Technology; **GTZ,** Deutsche Gesellschaft für Technische Zusammenarbeit.

REFERENCES

Abarghaz Y, Mali M, Werner C, Bendaou N, Fekhaoui M (2011). Evaluation of formula to calculate biogas production under Moroccan conditions. Sustainable Sanitation Practice, pp. 19-24.

Abbasi T, Abbasi SA (2010) Biomass energy and the environmental impacts associated with its production and utilization. Renewable and Sustainable Energy Reviews 14(3):919–937.

Adaramola MS, Oyewola OM. (2011). Wind Speed Distribution and Characteristics in Nigeria. ARPN Journal of Engineering and Applied Sciences 6(2):82-86. Retrieved March 5, 2013 from www.Arpnjournals.Com/Jeas/Research_Papers/Rp.../Jeas_0211_458.Pdf.

Albihn A, Vinnerås B (2007). Biosecurity and arable use of manure and biowaste- Treatment alternatives. Livestock Science 112(3):232-239.

Anaswara MG (2015). Design and fabrication of low-cost biogas digester using poultry waste and pig manure. International Research Journal of Engineering and Technology 2(4):1923-1930.

Anjum M, Qadeer S, Khalid A (2018). Anaerobic Co-digestion of Catering and Agro-Industrial Waste: A Step Forward Toward Waste Biorefinery. Frontiers in Energy Research 6:116. doi: 10.3389/fenrg.2018.00116.

Avaci AB, de Souza SNM, Werncke I, Chaves LI (2013). Financial economic scenario for the microgeneration of electric energy from swine culture-originated biogas. Renewable and Sustainable Energy Reviews *25*:272-276.

Bhogal A, Nicholson FA, Chambers BJ (2009). Organic carbon additions: effects on soil bio-physical and physico-chemical properties. European Journal of Soil 60(2):276-286. doi: 10.1111/j.1365-2389.2008.01105.

Chen YD, Ho SH, Nagarajan D, Ren NQ, Chang JS (2018). Waste biorefineries – integration of anaerobic digestion and microalgae cultivation for bioenergy production. Current Opinion in Biotechnology 50:101-110. doi: 10.1016/j.copbio.2017.11.017.

Chenxi LPC, Champagne P, Anderson BC (2011). Evaluating and modelling biogas production from municipal fats, oil and grease and synthetic kitchen wastes in co-anaerobic digestion. Bioresource Technology 102(20):9471-9480.

Defra (2010). The Fertiliser Manual (RB209). Norwich: The Stationary Office. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwiAmJ-fysHmAhWyy4UKHTxHCykQFjACegQIBRAC&url=http%3A%2F%2Fsciencesearch.defra.gov.uk%2FDocument.aspx%3FDocument%3DIF0114_9232_FRA.pdf&usg=AOvVaw3J9EcRdSsdFXll0TUvefry

Desal SR, Vijaykumar P,Rajeshwar M (2013). Performance Evaluation of Fixed Dome Type biogas plant for solid state digestion of cattle dung, Karnataka Journal of Agricultural Sciences 26(1):103-106.

Dioha E, Dioha J, Nfor B. (2012). Operating and financing biogas plant. Journal of Energy Technologies and Policy 2(5):25-37

Dollhofer V, Podmirseg SM, Callaghan TM, Griffith, GW, Fliegerová K (2015). Anaerobic fungi and their potential for biogas production. In Biogas Science and Technology; Springer: Berlin, Germany pp. 41-61.

Fantozzi F, Buratti C (2011) Anaerobic digestion of mechanically treated OFMSW: Experimental data on biogas/methane production and residues characterization. Bioresource Technology 102(9):8885-8892.

FAO (Food and Agriculture Organization of the United Nations) (2012). Towards the Future we Want: End Hunger and Make the Transition to Sustainable Agricultural and Food Systems, Food and Agriculture Organization of the United Nations Rome.

GTZ/GIZ. (1999). Biogas digest: Volume 2: Biogas application and product development. GTZ.

Hublin A, Zoki´c TI, Zeli´c B (2012). Optimization of biogas production from co-digestion of whey and cow manure. Biotechnology Bioprocess Engineering 17(6):1284-1293.

IRENA (2016). *Measuring small-scale biogas capacity and production,* International Renewable Energy Agency (IRENA), Abu Dhabi.

Jiang L, Zheng A, Zhao, He F, Li H, Wu N (2016). The comparison of obtaining fermentable sugars from cellulose by enzymatic hydrolysis and fast pyrolysis. Bioresource Technology 200:8-13.

Jones P, Salter, A (2013). Modelling the economics of farm-based anaerobic digestion in a UK whole-farm context. Energy Policy 62:215-225.

Kaur H, Kumar Sohpal, VK, Kumar S (2017). Designing of Small-Scale Fixed Dome Biogas Digester for Paddy Straw. International Journal of Renewable Energy Research 7(1):422-431.

Kumar S, Smith SR, Fowler G, Velis C, Kumar SJ, Arya SR, Kumar R, Cheeseman C (2017) Challenges and opportunities associated with waste management in India. Royal Society Open Science 4:1-11.

Kumar V, Singh J, Nadeem M, Kumar P, Pathak VV (2018). Experimental and kinetics studies for biogas production using water hyacinth (*Eichhornia crassipes* [Mart.] Solms) and sugar mill effluent. *Waste and Biomass Valorization*. https://doi.org/10.1007/s12649-018-0412-9, (ISSN: Online: 1877-265X; Print: 1877-2641).

Lantz M, Svensson M, Bjornsson L, Borjesson P. (2007) The prospects for an expension of biogas systems in Sweden-Incentives, barriers and potentials. Energy Policy 35(3):1830-1843.

Lebofa M, Huba E. (2011). Biogas systems in Lesotho: an effective way to generate energy while sanitizing waste water, Sustainable Sanitation Practice**.** https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiuhuf6wsHmAhVMxhoKHVd6BQEQFjAAegQIBBAC&url=http%3A%2F%2Fwww.ecosan.at%2Fssp%2Fissue-09-biogas-systems%2FSSP-09_Okt2011_10-17.pdf%2Fat_download%2Ffile&usg=AOvVaw1KMCm3vyux4474g7tR-VoF

Magrí A, Giovannini F, Connan R, Bridoux G, Béline F (2017). Nutrient management from biogas digester effluents: a bibliometric-based analysis of publications and patents. International Journal of Environmental Science and Technology 14(8):1739-1756. doi: 10.1007/s13762-017-1293-3.

Malinauskaite J, Jouhara H, Czajczynska D, Stanchev P, Katsou E, Rostkowski P, Thorne RJ, Colon J, Ponsa S, Al-Mansour F, Anguilano L, Krzyzynska R, Lopez IC, Vlasopoulos A, Spencer N (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. Energy 141:2013-2044.

Njogu P, Kinyua R, Muthoni P, Nemoto Y (2015). Biogas Production Using Water Hyacinth (*Eicchornia crassipes*) for Electricity Generation in Kenya. Energy and Power Engineering 7(5):209.

Nopharatana A, Pullammanappallil PC, Clarke WP (2007). Kinetic and dynamic modelling of batch anaerobic digestionof municipal solid waste in a stirred reactor. Waste Management 27(5):595-603.

Ojolo SJ, Orisaleye JI, Ismail SO, Abolarin SM (2012). Technical potential of biomass energy in Nigeria. Ife Journal of Technology 21(2):60-65.

Pachaiyappan S, Elamvazhuthi P, Dhamodharan M, Sundaram S (2014). Biogas production from water hyacinth blended with cow dung. Indian Journal of Energy 3(1):134-139.

Paritosh K, Kushwaha SK, Yadav M, Pareek N, Chawade A, Vivekanand V (2017). Food Waste to Energy: An Overview of Sustainable Approaches for Food Waste Management and Nutrient Recycling. BioMed Research International. Article ID 2370927, 19. dx.doi.org/10.1155/2017/2370927.

Rajput RK. (2011). A textbook of *Power Plant Engineering*, New Delhi, Laxmi Publications Limited.

Samer M (2015). *Biogas Plant Constructions*, Cairo University, Faculty of Agriculture, Department of Agricultural Engineering, Egypt, pp. 343-368, Retrieved 10 April 2015 from http://www.intechopen.com.

Sasidharan K, Martinez-Vernon AS, Chen J, Fu T, Soyer O (2018). A low-cost DIY device for high resolution, continuous measurement of microbial growth dynamics. bioRxiv, 407742.

Sasse L, Kellner C, Kimaro A. (1991). Improved biogas unit for developing countries. Vieweg and Sohn, Germany.

Sasse L (1988). Biogas Plants. A Publication of the Deutsches Zentrum für Entwicklungstechnologien - GATE in: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), pp. 17- 23.

Serrano RP (2011). Biogas Process Simulation using Aspen Plus. Master Thesis, Spring semester, Department of Chemical Engineering, Biotechnology and Environmental Technology, Syddansk Universitet. https://upcommons.upc.edu/bitstream/handle/2099.1/14429/Biogas%20Process%20Simulation%20using%20Aspen%20Plus%20v3.pdf?sequence=1&isAllowed=y

Shanab SM, Hanafy EA, Shalaby EA (2016). Water hyacinth as non-edible source for biofuel production. Waste and Biomass Valorization https://doi.org/10.1007/s1264 9-016-9816-6.

Surendra KC, Takara D, Hashimoto AG, Khanal SK (2014). Biogas as a sustainable energy source for developing countries: Opportunities and challenges. Renewable and Sustainable Energy Reviews 3:846-859.

United Nations (2015). Sustainable Development Goals. Available@: http://www.un.org/sustainabledevelopment/sustainable-consumption-production/ (Accessed on 30 November 2015).

Verstraete W, Morgan-Sagastume F, Aiyuk S, Waweru M, Rabaey K, Lissens G (2005). Anaerobic digestion as a core technology in sustainable management of organic matter. Water Science and Technology 52(1-2):59-66.

Ward AJ, Hobbs PJ, Holliman PJ, Jones DL (2008). Optimisation of the anaerobic digestion of agricultural resources. Bioresource Technology 99(17):7928-7940.

WBA (2017). *Fact Sheet 3:* How to achieve the sustainable development goals through biogas. Available from: http://www.worldbiogasassociation. org/wp-content/uploads/2017/07/WBA-SDGs-Biogas-factsheet-3.pdf.

Wu A, Lovett D, McEwan M, Cecelja F, Chen T (2016). A spreadsheet calculator for estimating biogas production and economic measures for UK-based farm-fed anaerobic digesters. Bioresource Technology 220:479-489 doi: http://dx.doi.org/10.1016/j.biortech.2016.08.103.

Xiaohua W, Chonglan D, Xiaoyan H, Weiming W, Xiaoping J, Sangyun J. (2007). The influence of using biogas digesters on family energy consumption and its economic benefit in rural areas-comparative study between Lianshui and Guichi in China. Renewable and Sustainable Energy Reviews 11(5):1018-1024.

Zhang J, Loh KC, Lee J, Wang CH, Dai Y, Tong YW (2017). Three-stage anaerobic co-digestion of food waste and horse manure. Scientific Reports 7(1):1269.

Zhao Q, Leonhardt E, MacConnell C, Frear C, Chen S. (2010). Purification Technologies for Biogas Generated by Anaerobic Digestion. Climate Friendly Farming Puyallup. WA: Center for Sustaining Agriculture and Natural Resources.

Zhou Q, Shen F, Yuan H, Zou D, Liu Y, Zhu B, Jaffu M, Chufo A, Li X (2014). Minimizing asynchronism to improve the performances of anaerobic co-digestion of food waste and corn stover. Bioresource Technology 166:31-36. http://dx.doi.org/10.1016/j.biortech.2014.04.074

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Evaluation of stream flow under land use land cover change: A case study of Chemoga Catchment, Abay Basin, Ethiopia

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For human beings, land and water are vital. To enhance agricultural productivity and socio-economic development in the agricultural catchment, irrigation development is an important issue. The present study aims to evaluate the stream flow under land use land cover (LULC) change for surface irrigation in Chemoga catchment part of Abay River Basin. To accomplish the objectives of this study, the watershed model SWAT (Soil and Water Assessment Tool) was used based on organization and website data sources. LULC classification was performed using ERDAS imagine 2014 which was used for further analysis of streamflow in SWAT to evaluate surface irrigation. The selected LULC years, 1994 and 2013 were used to assess the impact on streamflow. The result depicts that in wet season streamflow increases and in the dry season the stream flow decreases respectively for the LULC of 1994 and 2013. The performance of the model during calibration and validation period was good. So watershed management approach should be done in the catchment to improve surface irrigation potential.

Key words: Chemoga catchment, streamflow, land use land cover, SWAT model, surface Irrigation.

INTRODUCTION

Land and water are indispensable for the existence of human beings (FAO, 2016). Considering the available water and land resources of the country, Ethiopia has huge potential in expanding irrigated agriculture. The country is gifted with sufficient water resources with an estimated volume of 122 and 2.6 billion m^3 of annual surface runoff and groundwater potential respectively (Awulachew et al., 2007); the land irrigation potential is 5.3 million ha (Mha) of which 3.7 Mha can be developed using surface water sources, and 1.6 Mha using groundwater and rainwater management. Belay and Bewket (2013) reported that the current irrigation development in Ethiopia varies between 1.5 to 4.3 Mha, averaged about 3.5 Mha (Makombe et al., 2011). However, the actual and potential irrigated land is not precisely investigated; estimates of irrigable land in

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Ethiopia vary from study to study such as Awulachew et al. (2007) 0.16 - 0.2 Mha; Awulachew and Mekonnen (2011) 0.7 Mha; and MoA (2011) reported that 10 - 12% of the total irrigable land that is from 0.53 - 0.64Mha are currently under production using traditional and modern irrigation schemes. This shows that evaluation of the actual potential of stream water flow is not consistent; reliable and well-studied. Appropriate watershed management and selection of the applicable irrigation method is a pre-condition for the utilization of scarce physical resources in terms of land and water. To ensure adequate watershed management and design of a particular irrigation system, a well-developed and suitable database is quite important. Thus, it should be able to deal with spatially and temporally varying stream flows evaluation is important for irrigation potential assessment.

Streamflow is an important hydrological variable needed for water resource development, planning and design; this hydrological event has a strong connection with LULC. The trend of deforestation in the Chemoga watershed has been increasing; due to the reason for expansion of residential area and increasing of agricultural land which aggravates the LULC change of the catchment. This continuous of LULC change has influenced the water balance of the catchment by changing the magnitude and pattern of the components of streamflow that are surface runoff, lateral flow and groundwater flow, which results increasing in the extent of the water management problem (Tekleab, 2015). To improve the livelihood of the people irrigation development is essential. However, the water availability of the catchment; irrigable land areas and the water requirement of crops commonly grown in the catchment and also the availability of stream flows under LULC change for surface irrigation development point of view have not been identified so far. LULC change impact on water resource for irrigation point of view is still very much at an early stage throughout the country.

Therefore, this present study intended to evaluate the impact of LULC change on streamflow in the context of surface irrigation development in Chemoga Catchment, Abay Basin, Ethiopia. With this respect, the hydrological model which is soil water assessment tool (SWAT) and geographic information system (GIS) facilities were extensively used. The model was used in Ethiopia in the watershed or sub-watershed level (Welde and Gebremariam, 2017; Abebe and Gebremariam, 2019; Setegn et al., 2009; Mengistu and Sorteberg, 2012). The SWAT is a distributed parameter model designed to simulate water, sediment in watersheds and large river basins with varying climatic conditions, soil properties, stream channel characteristics, land use and agricultural management practices (Arnold et al., 1996; 1998). It is a continuous time-scale model, capable of simulating long-term effects of change in land use and land cover; and agricultural management, which uses readily available input data.

METHODOLOGY

Study area

The Chemoga River catchment (Figure 1) is a tributary of the Abay/Upper Blue Nile basin, located south of Lake Tana, and extended between approximately 10°10'00'' to 10°40'00''N latitude and 37° 30'00'' to 37°54'00''E longitude. The river flow starts from the Choke Mountain at an elevation of 4000 m above mean sea level (Moriasi et al., 2007).

Data collection

To properly accomplish this study, Universal Tranvers Mercator (UTM) converter, Google Earth, geographic information system (GIS), and Soil and Water Assesment Tool (SWAT), ERDAS Imagine 2014 and geographic positioning system (GPS) were used.

Hydro-meteorological data

The meteorological data, such as (daily precipitation, maximum and minimum air temperature, sunshine hours, relative humidity and wind speed) were collected from Ethiopian National Meteorological Agency. The hydrological flow data were collected from the Ministry of Water, Irrigation and Electricity of Ethiopia from the hydrology department.

Spatial (LULC, Soil and DEM) data

Spatial data were one of the inputs for the SWAT model. These are digital elevation model (DEM) (Figure 2), LULC and soil map. The DEM of the study area was downloaded from Shuttle Radar Topographic Mission (SRTM) which is available at USGS website with the resolution of 30 m which is void filled data and provide open distribution of this high-resolution global data set (https://earthexplorer.usgs.gov). The 1994 and 2013 LULC satellite data were downloaded from the USGS website (https://earthexplorer.usgs.gov). The digital soil map of Chemoga catchment was obtained from the Ministry Agriculture of Ethiopia in the shapefile format.

Agronomic data

Irrigation Efficiency, Irrigation Calendar and Dominant Crop were collected from Ethiopian Ministry of Agriculture, Abay basin master plan, East Gojjam zone agriculture office and FAO guideline.

Data analysis

The SWAT model requires readymade data and therefore, before using the data for the simulation, the data should be prepared as needed of the model.

LULC and soil data analysis

The LULC dataset for the year of 1994 and 2013 consisting of seven and eleven image bands respectively and the Landsat image

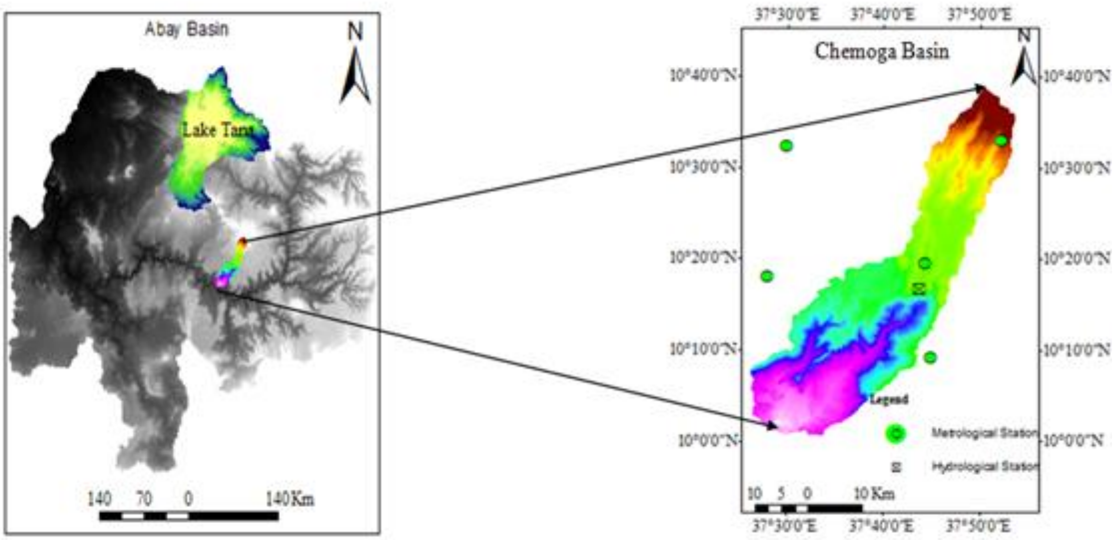

Figure 1. Location map of the study area.

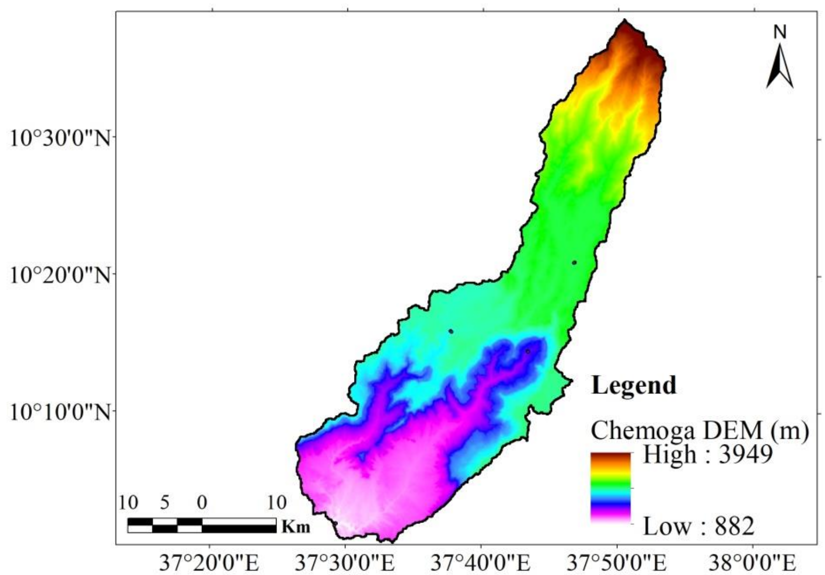

Figure 2. DEM of Chemoga catchment.

provide complete coverage of Chemoga catchment. To represent the LULC conditions in the year of 1994 to 2013, TM and OLI_TIRS of Landsat sensor were selected for mapping of Chemoga catchment. To avoid a seasonal variation in vegetation pattern and distribution throughout the year, the selection of data sets were made as much as possible in the same annual and dry season from the two images of acquired years.

Image pre-processing

In order to analyse remotely sensed images, the different images representing different bands must be stacked, that is, band 1 to 7 and band 1 to 11 for LULC 1994 and LULC 2013 satellite images respectively are overlaid using layer stacking syntax in ERDAS imagine 2014.

Image classification

The LULC change studies usually need the development and the definition of homogeneous LULC units before the analysis started. It is differentiated using the available data source such as remote sensing, Google earth, ground control points and the previous local

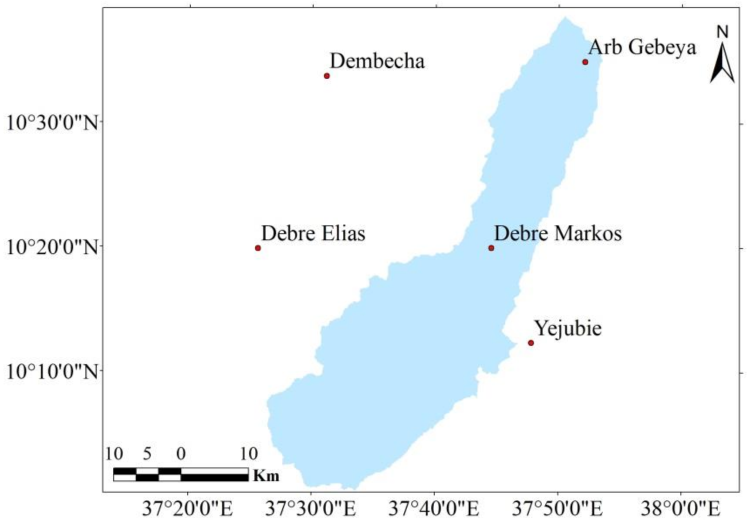

Figure 3. All climate stations selected in the watershed.

knowledge.

Following this, the tool, ERDAS imagine 2014 software was used for classification of the LULC image of the catchment. Image classification is a difficult and time taking task, and it is the process of assigning pixels of a continuous raster image to the predefined LULC classes. In remote sensing, there are various image classification methods, that is, supervised and unsupervised. For this study, we used the most common type of classification technique, supervised classification type. First, Google earth was taken as a signature for the classification. Second, we performed the classification using the maximum likelihood classifier. Lastly, the accuracy assessment was performed using Google earth image for the LULC 1994 and 193 random points were generated in Arc GIS. Following these procedures, random points were converted to KML (Keyhole Markup Language (Hengl et al., 2015)) in order to display in Google Earth. Whereas, the accuracy assessment of 2013 LULC map was used ground truth points as a reference and 195 points were taken to validate the classification; which was built in 12/05/2016. The analysis result was performed using confusion/ error matrix. The physical and chemical properties soil data is one of the major input data for the SWAT model. In SWAT, these properties of the soil govern the movement of water or air through the soil profile and have a major impact on the cycling of water within hydrologic response units (HRU), and used to set initial levels of the different chemicals in the soil respectively.

Hydro-meteorological data analysis

Meteorological data are among the main demanding input data for the SWAT model simulation. The observed meteorological input data required for SWAT simulation includes daily data of precipitation, minimum and maximum air temperature, sunshine hours, wind speed and relative humidity from January 1990 to December 2014. 8 metrological stations in and nearby the watershed is found, due to discontinues of climatic data only five stations in and around the Chemoga catchment selected (Figure 3).

Filling missing precipitation and temperature

There are a number of methods available for estimating missing precipitation data (Chow et al, 1988; Singh, 1994; Lam, 1983 and De Silva, 1997). For this study, we used the normal ratio method; due to the rainfall measured at a different station in the catchment shows greater than 10 % variation (Equation 1).

$$P_x = \frac{N_x}{n}\left(\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} + \cdots + \frac{P_n}{N_n}\right) \quad (1)$$

Where**:-** P_x = missing rainfall data at station x, N_x = missing data station's normal annual rainfall (N_1, N_2 N_3…..N_n = normal annual rainfall at stations i and n is the number of nearby gauges). Moreover, the percent of difference (Equation 2) was used to decide the appropriate methods.

$$\text{Percent of difference} = \left(\frac{N_x - N_i}{N_x}\right) x100 \quad (2)$$

In which N_x is the normal annual rainfall amount from the missing data station and N_i is the normal annual rainfall amount from one of the nearby stations (Richards, 1998). The normal ratio method was adopted to fill missing air temperature data.

Homogeneity and consistency

In order to test the rainfall homogeneity, the homogeneity of the stations was made by the rainbow model (Figure 4).In order to check the inconsistency of rainfall, the double mass curve (DMC) technique was used. Therefore, as shown in Figure 5 the computed DMC for the study area, which is a straight slope and R2 is 0.999 for four stations and 0.997 for one station. This indicates that there is no significant change in slope relative to the original slope. There is no data divergence between the meteorological stations, so the recorded data is consistent and there is no need for correction of the original data. The homogeneity test of the streamflow data for Chemoga river at the gauged site was checked by the rainbow model (Figure 6) and has a good quality of streamflow data. Taking the catchment similarities into account (McIntyre et al., 2005 and

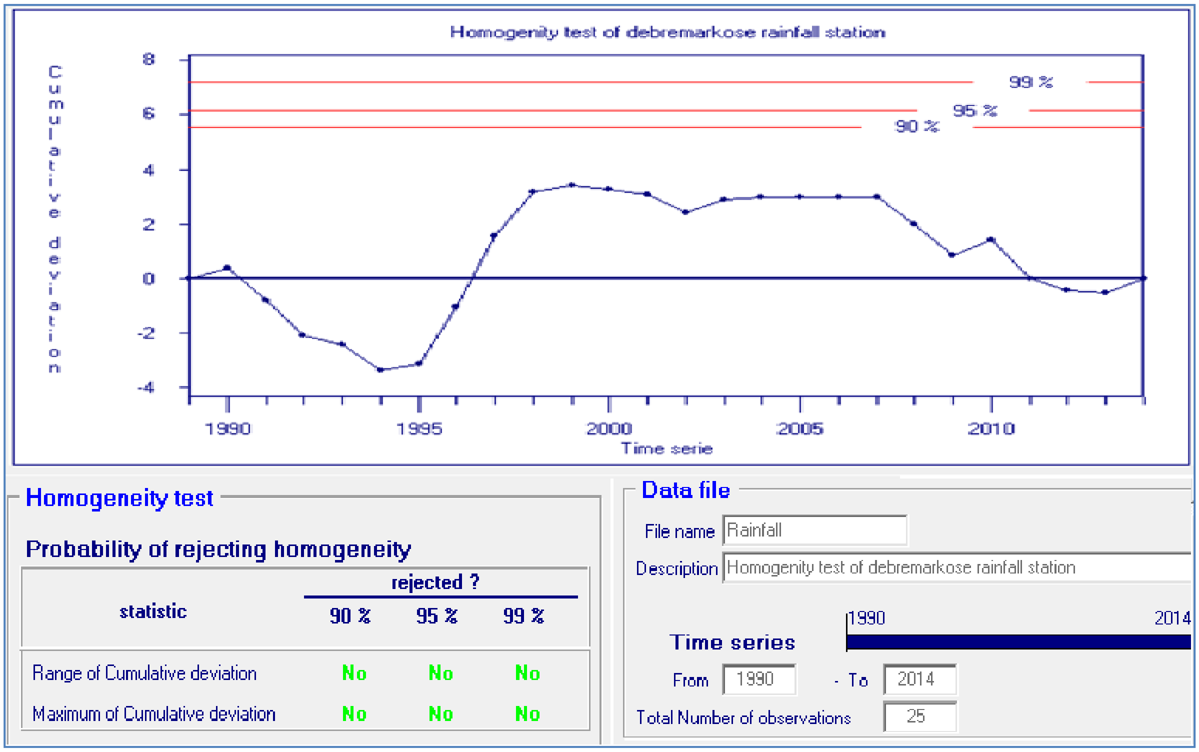

Figure 4. Homogeneity test of time series rainfall data for Debre Markos station.

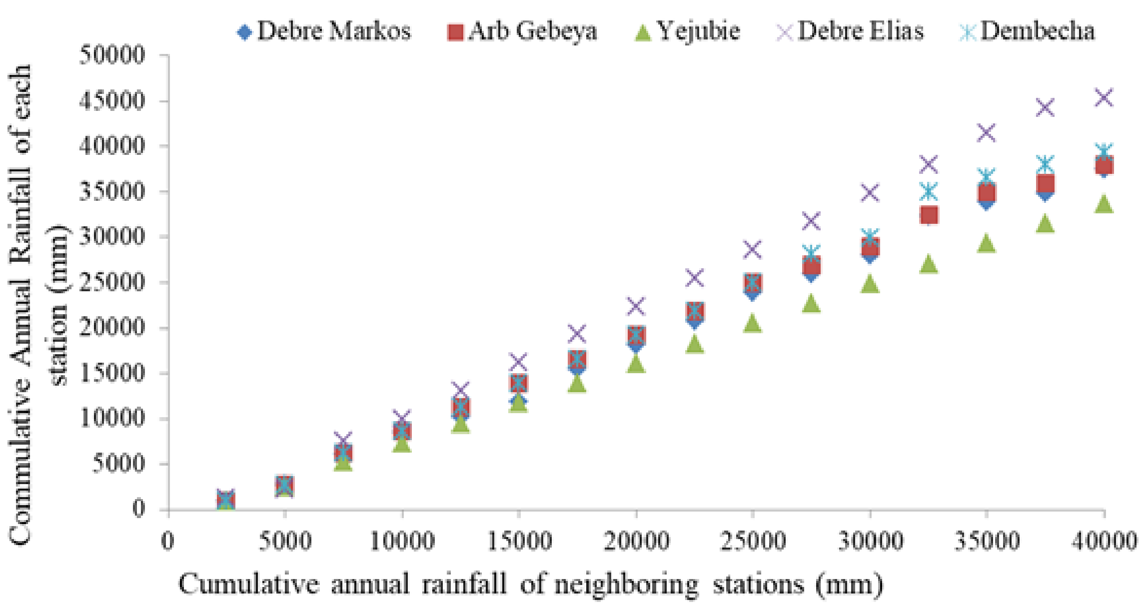

Figure 5. Consistency test for the five stations by DMC.

Oudin et al., 2010), the streamflow data of the gauging site was transformed to the outlet of Chemoga river catchment using catchment area-ratio method. Estimation of streamflow at catchment outlet was developed by a relation provided in Equation 3.

$$Q_{outlet} = Q_{gauged} * \left(\frac{A_{outlet}}{A_{gauge}}\right)^n \quad (3)$$

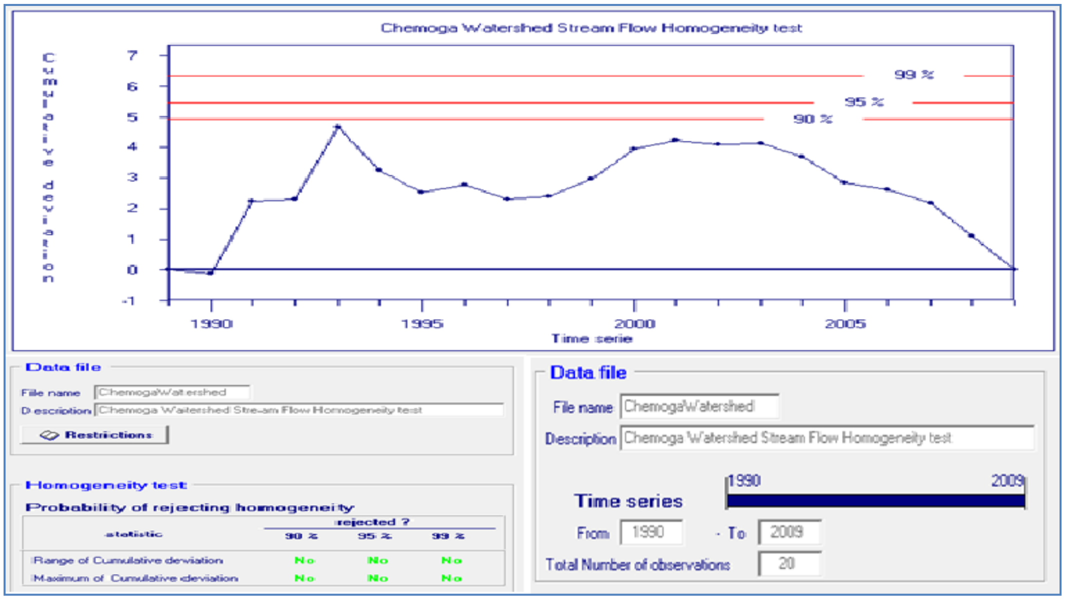

Figure 6. Homogeneity test of time series streamflow data of Chemoga catchment.

Where, A_{outlet} is area upstream of the ungauged site (km^2), A_{gauged} is area upstream of the gauged site, Q_{outlet} streamflow value at catchment outlet (m^3/s) and Q_{gauged} streamflow value at gauge site (m^3/s). The ratio of the ungauged site area to gauged site area is 0.8 to 1.2 or is made so that the exponent of $\left(\frac{A_{outlet}}{A_{gauged}}\right)$ is 1 and n is assumed as equal to 1 (Douglas et al., 2005).

Selection of physical catchment characteristics

The physical catchment characteristics (PCCs) used for this study were grouped as physiography, soil and LULC condition. The developed approaches in this study taken into account both the gauged and ungauged catchment PCCs, that is, the relation between the two variables examined using correlation coefficient for developing area-ratio method to transfer the streamflow from gauged to ungauged areas. PCCs were determined using Arc GIS integrating with Arc SWAT for the calibrated and validated streamflow results of 2013 LULC of the catchment. LULCs are cultivated land, forestland, grassland, woodland, water and marshy land, shrub land and urban land.

Soil

There are haplic alisols, eutric cambisols, eutric leptosols, haplic luvisols, eutric vertisols and urban.

Hydrological modeling

Simulation of the hydrological process in SWAT is based on the following water balance Equation 4 (Neitsch et al., 2005).

$$SW_t = SW_o + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{lat} - Q_{gw}) \qquad (4)$$

Where; SWt is the final soil water content [mm water], SWo is the initial soil water content [mm water], t is the time [days], Rday is the amount of precipitation on day i [mm water], Qsurf is the amount of surface runoff on day i [mm water], Ea is the amount of evapotranspiration on day i [mm water], Wseep is the amount of water entering the vadose zone from the soil profile on day i [mm water], Qlat is lateral flow from soil to channel and Qgw is the amount of return flow on day i [mm water].

Surface runoff is estimated by using a modified soil conservation service (SCS) curve number method (SCS, 1972), which estimates the amount of runoff based on local LULC, soil type, and antecedent moisture condition (Neitsch et al., 2005). Three methods can be used to estimate potential evapotranspiration (1) the penman-monteith method (Monteith, 1965), (2) the Priestley Taylor method (Priestley and Taylor, 1972), and (3) the Hargreaves method (Hargreaves and Samani, 1985), depending on data availability. In this study, we used the Penman-Monteith method because of the presence of class one station in the centroid of the watershed. Groundwater flow contribution to total streamflow is simulated by routing a shallow aquifer storage component to the stream (Arnold and Allen, 1996). Channel routing is simulated by using the variable storage or Muskingum routing equation (Williams, 1969).

Model setup, calibration and validation

Evaluation of streamflow under LULC change at Chemoga catchment was created in SWAT model using the 1994 and 2013 LULC satellite map, meteorological data, observed monthly streamflow data, soil map and DEM. Potential evapotranspiration (PET), surface runoff, and channel routing were simulated with Penman-Monteith, Curve Number, and Variable Storage methods (Neitsch et al., 2011), respectively. Using the Chemoga catchment DEM, the watershed was first divided into 9 sub-watersheds based on the topographic analysis of flow direction and accumulation; then all sub-watersheds were further subdivided into 139 HRUs for 1994 LULC and 105 HRUs for 2013 LULC using a 5% threshold value

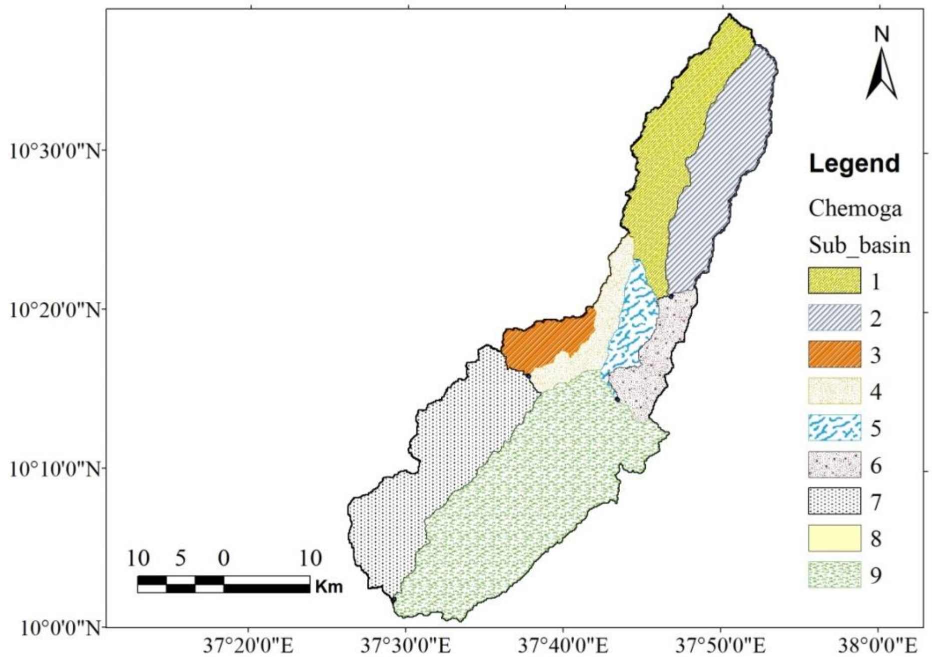

Figure 7. Distribution of Chemoga sub-watershed/sub-basin.

for land use, 10% threshold value for soil and slope (Figure 7).

The results from simulation cannot be directly used for further analysis but to sufficiently predict the amount of streamflow should be evaluated based on sensitivity analysis, calibration and validation processes. Sensitivity analysis was done prior to the calibration and validation process in order to identify important hydrologic parameters for model calibration. The average monthly streamflow data of 35 years from 1980 to 2014 of the catchment were used to compute the sensitivity of the hydrologic parameters and the first two years of which was used as a warm-up period (Daggupati et al., 2015). Following this, model calibration was done from 1990 to 2004 using automatic calibration. The measured data of average monthly streamflow data of 5 years from 2005 to 2009 were used for the model validation process.

Model performance evaluation

The goodness of fit can be quantified by the coefficient of determination (R^2), Nash-Sutcliffe Efficiency (ENS) and relative volume error (RVE) (equations 8-10) respectively. R^2 is an indicator of the linear relationship between the observed and simulated values. ENS indicates that how well the plots of observed versus simulated data fit the 1:1 line.

$$R^2 = \left\{ \frac{\sum_{i=1}^{n} \left(Q_i^{obs} - Q_{ave}^{obs}\right)\left(Q_i^{sim} - Q_{ave}^{sim}\right)}{\left[\sum_{i=1}^{n} \left(Q_i^{obs} - Q_{ave}^{obs}\right)^2 \sum_{i=1}^{n} \left(Q_i^{sim} - Q_{ave}^{sim}\right)^2\right]^{0.5}} \right\}^2 \quad (8)$$

$$NSE = 1 - \frac{\sum_{i=1}^{n} \left(Q_i^{obs} - Q_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Q_i^{obs} - Q_{ave}^{sim}\right)^2} \quad (9)$$

$$\mathrm{RVE} = \frac{\sum_{n=1}^{N} (\mathrm{Q_{obs}} - \mathrm{Q_{sim}})}{\sum_{n=1}^{N} \mathrm{Q_{obs}}} \; x100 \quad (10)$$

Where, Q_i^{obs} is Observed value [m^3/s], Q_{ave}^{obs} is the average observed value of n value, Q_i^{sim} is simulated value [m^3/s], Q_{ave}^{sim} is average simulated of n value and n is the number of observations

LULC change impact on streamflow

The evaluation variability of the streamflow due to LULC changes for the study period, two independent simulation runs were conducted on a monthly basis using both 1994 and 2013 LULC maps, keeping other input parameters unchanged. There was streamflow variability for 1994 and 2013 LULC on seasonal flow and streamflow components (surface runoff, lateral flow and groundwater flow) based on the two simulation outputs due to LULC change assessed (Table 1).

RESULTS AND DISCUSSION

Physical characteristics of the catchment

The physiographic characteristics of the catchment, and the correlation result between gauged and ungauged physical characteristics were greater than 0.9 (Douglas et al., 2005). There is a good correlation between each physical characteristic in the sub-catchment. Based on the result, we can conclude that the gauged and ungauged sub-catchments have similar physiographic

Table 1. Model parameters performance.

Variable	Performance ratings			
	Unsatisfactory	Satisfactory	Good	Very good
R^2	<0.5	0.5-0.6	0.6-0.7	0.7-1
ENS	<0.5	0.5-0.65	0.65-0.75	0.75-1
±RVE	>25	25-15	15-10	<10

Moriasi et al., (2007).

Table 2. Confusion matrix for the LULC classification of the 2013 map.

		Reference/ground data 2013								
		UB	WL	WB	GL	FL	SL	CL	Total	UA (%)
Classification data	UB	14	0	1	1	0	0	0	16	87.5
	WL	0	17	0	0	0	1	0	18	94.4
	WB	0	0	7	1	0	0	0	8	87.5
	GL	1	0	0	26	2	1	1	31	83.9
	FL	1	0	0	0	10	1	0	12	83.3
	SL	0	0	1	0	0	48	2	51	94.1
	CL	0	2	0	0	0	0	57	59	96.6
	Total	16	19	9	28	12	51	60	195	
	PA (%)	88	90	78	92.9	83	94	95		OA% 91.8

UA: user accuracy, PA: producer accuracy, OA: over all accuracy.

characteristics (Rodriguez and Escobar, 1982; Sreenivasulu and Bhaskar, 2010; Berger and Entakhabi, 2001).

LULC analysis

Accuracy assessment of LULC classification was performed using ground truth points for the LULC map of 2013 as a reference. This is done by confusion/error matrix (Fitzgerald and Lees, 1994 and Lark, 1995) and the analysis result is presented in Table 2. Table 2 shows the overall accuracy is 91.8% and the kappa index agreement (K) is 0.9023. This implies that the classification process is avoiding 90.23% of the errors that completely random classification generates. This means the results of overall accuracy and kappa index coefficient are within the recommended value range (Jenness and Wynne, 2005).

The map of each LULC type and percentage of area coverage of the Chemoga catchment is presented in Figure 8 and Table 3 for 1994 and 2013. Table 3 depicts that, cultivated land is the maximum area coverage both in 1994 and 2013 LULC and showed expansion for cultivated lands. On the other hand, urban land is increased in the change of LULC in the time trend; but water and marshy land is the least LULC cover in both years of LULC. This is mainly because of the population demand increase for new cultivation land which in turn resulted in shrinking of other types of LULC of the area. This is most probably because of the deforestation activities that have taken place for the purpose of agriculture.

Hydrological modelling on a monthly timescale

For this analysis, 26 parameters were considered and only 8 more sensitive parameters were identified to have a significant influence in controlling the streamflow in the catchment. Table 4 reveals parameters that result in greater relative mean sensitive values for average monthly streamflow data of the catchment.

Generally, the effects of the sensitive parameters are related to groundwater (Alpha_Bf, Revapmn and Gwqmn), surface runoff (CN2, Esco and Canmx) and soil process (Sol_Z and Sol_Awc) and thus influence on the streamflow of the catchment. From the sensitivity result, curve number (CN2) is identified to be highly sensitive parameters and given to high priority for calibration.

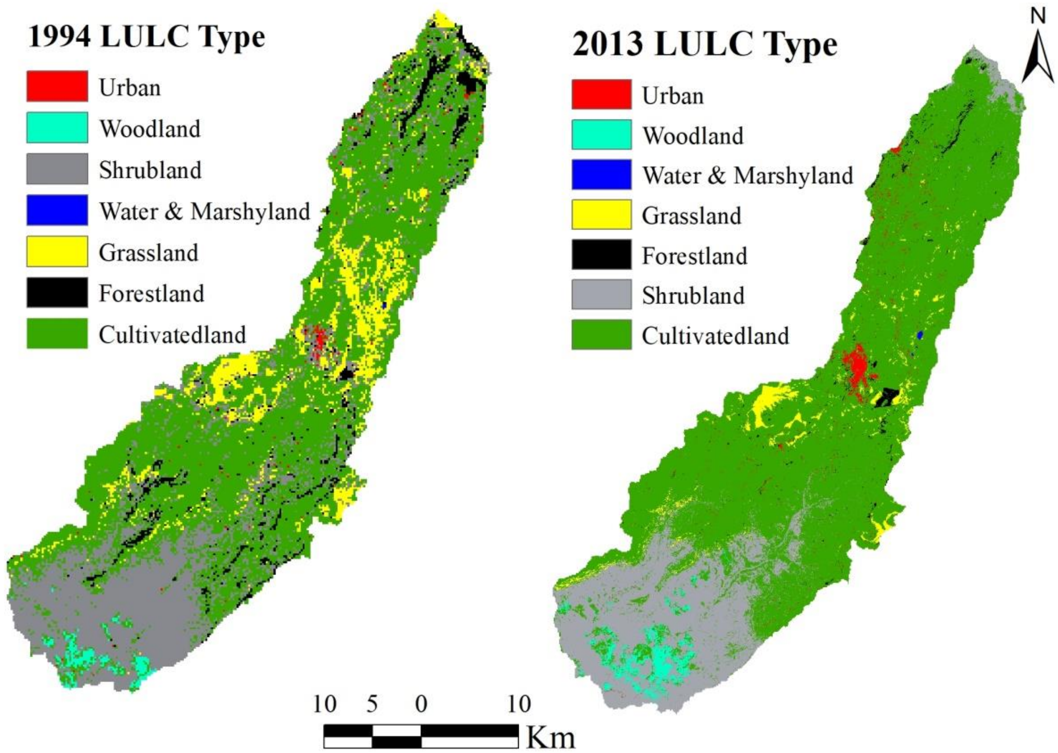

Figure 8. LULC map of Chemoga catchment.

Table 3. LULC types and percentage area coverage of 1994.

Land use land cover type	1994		2013		% change
	Area (ha)	Total (%)	Area (ha)	Total (%)	
Cultivated land	66099	56.1	83930	71.3	15.14
Forest land	5360.6	4.55	1088.3	0.92	-3.63
Woodland	2499.4	2.12	1395.5	1.18	-0.94
Shrub land	32393	27.5	27183	23.1	-4.42
Grassland	10796	9.16	2709.5	2.3	-6.86
Urban	626.4	0.53	1448.9	1.23	0.7
Water and Marshy land	25.97	0.02	45.03	0.04	0.02

Whereas other parameters such as soil evaporation compensation factor (Esco), total soil depth (Sol_Z), baseflow recession constant (Alpha_Bf), maximum canopy storage (canmx), threshold depth of water in the shallow aquifer for revap to occur (Revapmn), soil available water capacity (Sol_Awc), threshold depth of water in the shallow aquifer required for return flow (Gwqmn) are identified to be medium sensitive parameters. The remaining 18 parameters were not considered during the calibration process because the model simulation result was not sensitive parameters in the catchment.

Calibration and validation of streamflow simulation

The simulation of the model with the default value of parameters in the Chemoga catchment was from 1983-2011. SWAT model calibration was performed for 1994 LULC and 2013 LULC separately. There were two years of the warm-up period, 1983-1984 for 1994 LULC and 2002-2003 for 2013 LULC. The calibration covers 1985-1989 and 2004-2007 for 1994 and 2013 LULC respectively. The validation period covers 1990-1993 and 2008-2011 for 2013 LULC. The calibration result showed relatively weak matching between the simulated and

Table 4. Sensitive parameters for streamflow.

Parameter name	Relative sensitive values	Sensitivity rank	Significance
Cn2	0.253	1	High
Esco	0.193	2	Medium
Sol_Z	0.151	3	Medium
Alpha_Bf	0.125	4	Medium
Canmx	0.111	5	Medium
Revapmn	0.0968	6	Medium
Sol_Awc	0.0653	7	Medium
Gwqmn	0.0606	8	Medium

Table 5. Default and calibrated value of the sensitive flow parameters.

Parameter name	Parameter value range	Default value	Fitted value
r_Cn2	±25%	default	+13.98%
v_Esco	0-1	0	0.194
r_Sol_Z	±25%	default	-24.23%
v_Alpha_Bf	0-1	0.048	0.889
v_Canmx	0-10	0	9.215
v_Revapmn	0-500	1	12.25
r_Sol_Awc	±25%	default	+2.13%
v_Gwqmn	0-5000	0	37.5

r_ means the existing parameter value is multiplied by 1 + a given value and v_ means the default parameter is replaced by a given value.
Source: swat-cup manual.

observed streamflow hydrographs. Hence, calibration was done for sensitive flow parameters with observed average monthly streamflow data using table and scatter plots (Figure 9 and Table 5).

The performance of the calibration and validation simulations was checked by R^2, NSE and RVE. The scatter plot of R^2 reported in Figure 9 and confirms reasonable streamflow results of the model simulation of calibration and validation period for each LULC. On the other hand, in Table 6, ENS and RVE showed the streamflow simulation was well agreed with the observed value for each LULC. This illustrates that further application of the SWAT model to evaluate streamflow for irrigation and other related waterworks in the catchment could have a minimum bias. The agreement between observed and simulated hydrological components is largely dependent on the meteorological, LULC conditions and soil data in the catchment and model assumptions. After calibration, the agreement between observed and simulated discharges is good, under-estimations and over-estimations are inherent in the simulation (Figures 10 and 11). This is because of the fact that the observed discharge and model-simulated flows during the calibration and validation are biased.

Evaluation of stream flow due to LULC change

The evaluation of surface water availability was done in terms of LULC change impact on seasonal (wet and dry) and the major components of streamflow, that is, surface runoff, groundwater flow and lateral flow; the other input (climate, soil and other) variables are the same during the study period.

Based on the result, the LULC change has an impact on the seasonal streamflow of the catchment. The result has shown that there is an increase of streamflow in the wet season and a decrease in the dry season (Baker and Miller, 2013). The evaluation result of the LULC change impact on the major components of streamflows, surface runoff (SurfQ), groundwater flow (GWQ) and lateral flow (LatQ) is given in Table 7. In the main dry season, the streamflow gets the source from groundwater and lateral flow and in the wet season from surface runoff.

Table 8 depicts the SURQ, GWQ and LATQ components of the streamflow simulated using the 1994 LULC map were 52.52, 24.81 and 22.97% while using the 2013 LULC map were 61.98, 22.95 and 15.06% respectively. The contribution of SURQ has increased by 9.46% while GWQ and LATQ have decreased by 1.86

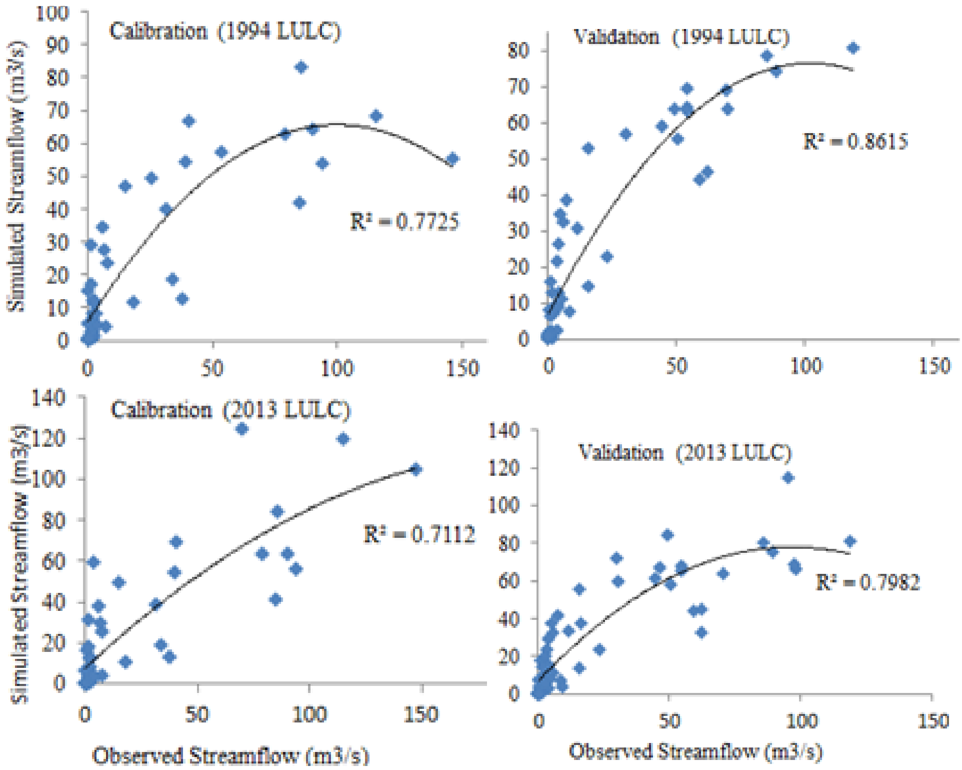

Figure 9. Scatter plot of the calibration and validation periods respectively.

Table 6. Summary of calibrated and validated performance of ENS and RVE.

Performance criteria	Calibration		Validation	
	1994 LULC	2013 LULC	1994 LULC	2013 LULC
ENS	0.84	0.82	0.80	0.84
RVE	-7.53	-2.75	-9.33	-3.23

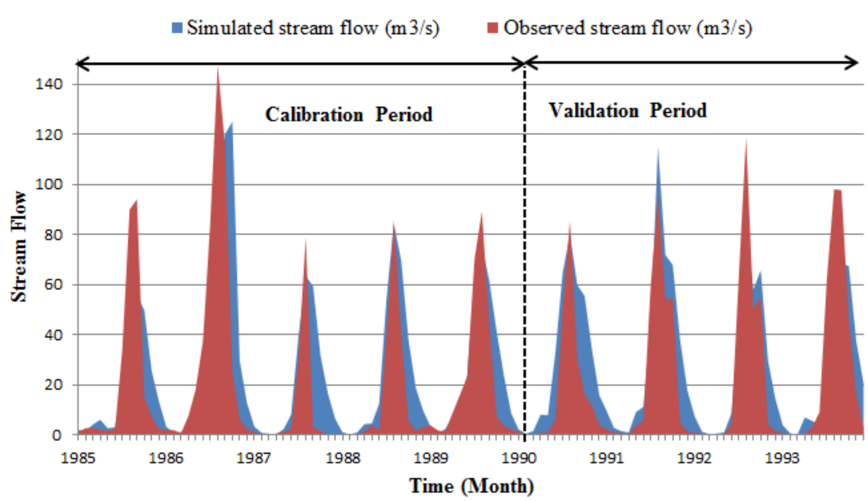

Figure 10. Streamflow hydrograph of calibration and validation period for 1994 LULC.

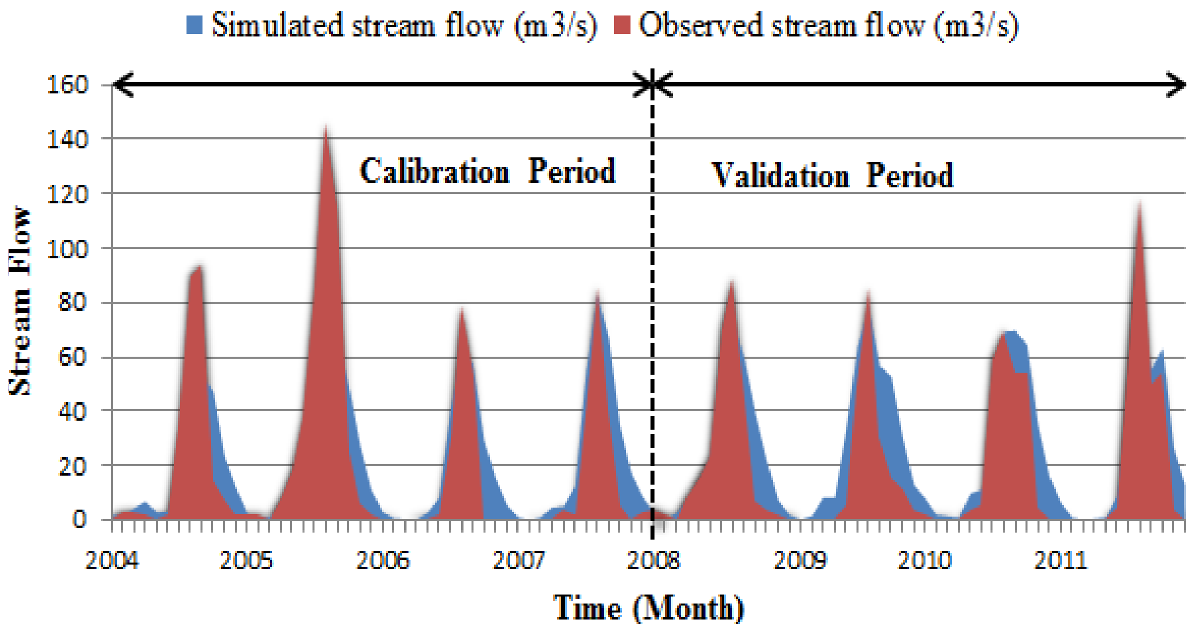

Figure 11. Streamflow hydrograph of calibration and validation period for 2013 LULC.

Table 7. Mean monthly seasonal (wet and dry) streamflow variability.

Main season	1994	2013	Flux detection
Main dry season (Nov-Feb) (m^3/sec)	5.57	3.06	-2.51
Main rainy season (Jun-Sep) (m^3/sec)	46.95	58.18	+11.23

Table 8. Mean annual major components of streamflow due to LULCCs.

Item	LULCCs_1994	LULCCs_ 2013	Flux Detection
Surface runoff SURQ (mm)	322.78	367.50	+44.72
Groundwater flow GWQ (mm)	153.35	136.09	-17.26
Lateral soil flow LATQ (mm)	142.00	89.32	-52.68

and 7.91% respectively due to LULC change. As seen in the result, the streamflow in the dry season decreases, and the decline of water affects the crop grown in the area. To compromise this shortage, water harvesting structures are needed and in the wet season, the flow increases. The result will be high flooding and erode the land surfaces. In such a condition, it is difficult to practice surface irrigation development in the catchment. From this study, it can be understood that the land surface of the catchment needs soil and water conservation practices. In turn, it helps with surface irrigation development. So, generally to improve the hydrology of the Chemoga catchment different watershed management approaches should be implemented.

Conclusion

The aim of this study is to evaluate the LULC change impact on catchment hydrology. The LULC data were detected using Landsat images from USGS earth explorer. The classified LULC performed on ERDAS imagine supervised classification was integrated with GIS data. The gauged catchment of Chemoga has similar physical characteristics with the whole ungauged catchment. The correlation results of this PCCs depict a value greater than 0.9. From this result, it can be concluded that regionalization of streamflow at the outlet of the catchment using catchment area-ratio method was acceptable. Streamflow was dependent on LULC changes

changes; hence in Chemoga River catchment it is shown that the LULC change implied a change in the amount of streamflow in the catchment. The streamflow increased in the wet season but decreased in the dry season during the study period due to conversion of forest lands, shrublands and grasslands to cultivation sites. And also increase in cultivated land in wet season increases surface runoff while in dry season lateral and groundwater flow decreases. During the study period, an increase of the cultivated land by 15.14% (17830.3 ha) resulted in an increase in streamflow by 11.23 m3/s in the wet season and a decrease of 2.51 m3/s in the dry season.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abebe T, Gebremariam B (2019). Modeling runoff and sediment yield of Kesem dam watershed, Awash basin, Ethiopia. SN Applied Sciences1:446.

Arnold JG, Srinivasan R, Muttiah RS, Williams JR (1998). Large area hydrologic modeling and assessment part I: model development. Journal of the American Water Resources Association 34:73-89.

Arnold JG, Williams JR, Srinivasan R, King KW (1996). Soil and Water Assessment Tool, Users' Manual. USDA Agriculture Research Service, Blackland Research Center, Texas Agricultural Experiment Station: TX.

Arnold JG, Allen PM (1996). Estimating Hydrologic Budgets for Three Illinois Watersheds. Journal of Hydrology 176: 57-77.

Awulachew SB, Mekonnen A (2011). Performance of irrigation: an assessment at different scales in Ethiopia. Cambridge University Press. 47(S1):57-69.

Awulachew SB, Yilma AD, Loulseged M, Loiskandl W, Ayana M, Alamirew T (2007). Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute 78 p.

Baker TJ, Miller SN (2013). "Using the Soil and Water Assessment Tool (SWAT) to assess land use impact on water resources in an East African watershed. Journal of Hydrology 486:10011.

Belay M, Bewket W (2013). Traditional irrigation and water management practices in highland Ethiopia: Case study in Dangila woreda. Irrigation and Drainage 62(4):435-448.

Berger KP, Entekhabi D (2001). Basin hydrologic response relations to distributed physiographic descriptors and climate. Journal of Hydrology 247:169-182.

Chow VT, Maidment DR, Mays LW (1988). Applied Hydrology, Mc Graw Hill Book Company, ISBN 0-07-010810-2.

Daggupati P, Pai N, Ale S, Douglas-Mankin KR, Zeckoski RW, Jeong J, Parajuli PB, Saraswat D, Youssef MA (2015). A recommended calibration and validation strategy for hydrologic and water quality models. Transactions of the ASABE 58(6):1705-1719.

De Silva RP (1997). Spatiotemporal Hydrological Modeling with GIS for the Upper Mahaweli Catchment, Sri Lanka. PhD Thesis (Unpublished), Silsoe Campus, Cranfield University, UK.

Douglas GE, Aldo VV, Ann LD (2005). Evaluation of Drainage-Area Ratio Method Used to Estimate Stream flow for the Red River of the North Basin, North Dakota and Minnesota. Scientific Investigations Report 2005-5017. U.S. Department of the Interior. U.S. Geological Survey, Reston, Virginia.

Food and Agriculture Organization (FAO) (2016). AQUASTAT website. Food and Agriculture Organization of the United Nations (FAO).

Fitzgerald RW, Lees BW (1994). Assessing the classi- fication accuracy of multiresource remote sensing data. Remote Sensing of Environment 47:362368.

Hargreaves GH, Samani ZA (1985). Reference crop evapotranspiration from temperature Applied Engineering in Agriculture 1(2):96-99.

Hengl T, Roudier P, Beaudette D, Pebesma E (2015). plotKML: Scientific visualization of spatio-temporal data. Journal of Statistical Software 63(5):1-25.

Jenness J, Wynne JJ (2005). Cohen's Kappa and classifi cation table metrics 2.0: an ArcView 3x extension for accuracy assessment of spatially explicit models: U.S. Geological Survey Open-File Report of 2005-1363. U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, AZ. Oudin L, Kay A, Andréassian V, Perrin C (2010). Are seemingly physically similar catchments truly hydrologically similar? Water Resources Research 46 p.

Lam NS (1983). Spatial Interpolation Methods review. The American Cartographer 10:129-149.

Lark RM (1995). Components of accuracy of maps with spe- cial reference to discriminant analysis on remote sensor data. International Journal of Remote Sensing 16:1461-1480.

Makombe G, Namara R, Hagos F, Awulachew SB, Ayana M, Bossio D (2011). A comparative analysis of the technical efficiency of rainfed and smallholder irrigation in Ethiopia. Colombo, Sri Lanka: International Water Management Institute P 37.

Mengistu DT, Sorteberg A (2012). Sensitivity of SWAT simulated streamflow to climatic changes within the Eastern Nile River basin. Hydrology and Earth System Sciences 16(2):391-407.

Minstry of Agriculture (MOA) (2011). Guideline on Irrigation Agronomy. Natural Resources Management Directorate, Natural Resource Sector and the Ministry of Agriculture, Ethiopia.

Monteith JL (1965). Evaporation and environment. The state and movement of water in living organisms, G. F. Fogg, ed., Cambridge University Press, Cambridge, UK pp. 205-234.

Moriasi DN, Arnold JG, Van Liew MW, Binger RL, Harmel RD, Veith T (2007). Model Evaluation Guidelines for Systematic Quantification of Accuracy in watershed simulations, Transactions of the ASABE, 50(3), 885-900.

McIntyre N, Lee H, Wheater H, Young A, Wagener T (2005). Ensemble predictions of runoff in ungauged catchments. Water Resources Research 41(12):W12434.

Neitsch SL, Arnold JG, Kiniry JR, Williams JR (2011). Soil and Water Assessment Tool theoretical documentation: Version 2009. USDA–ARS, Grassland, Soil and Water Research Laboratory, Temple, TX; and Blackland Research and Extension Center, Texas AgriLife Research, Temple, TX. Texas Water Resources Institute Technical Rep. 406, Texas A&M University System, College Station, TX.

Neitsch SL, Arnold JG, Kiniry JR, Williams JR (2005). SWAT theoretical documentation, version 2005.

Priestley CHB, Taylor RJ (1972). Assessment of Surface Heat Flux and Evaporation using Large-Scale Parameters. Monthly Weather Review 100:81-92.

Richards HM (1998). Hydrologic Analysis and Design. Department of Civil Engineering University of Maryland, Prentice Hall Upper Saddle River, New Jersey 07458, 2nd Edition.

Rodriguez-Iturbe I, Escobar LA (1982). The dependence of drainage density on climate and geomorphology. Hydrological Sciences Journal 27(2):129-137.

Setegn SG, Srinivasan R, Dargahi B, Melessa AM (2009). Spatial

delineation of soil Vulnerability in the Lake Tana Basin, Ethiopia. Hydrological Processes 23:3738 -3750.
Singh VP (1994). Elementary Hydrology. Prentice Hall of India: New Delhi.
Soil Conservation Service (SCS) (1972). National engineering handbook, section 4: hydrology. Department of Agriculture, Washington, DC 762 p.
Sreenivasulu V, Bhaskar PU (2010). Estimation of catchment characteristics using remote sensing and GIS techniques. International Journal of Engineering Sciences and Technology 2(12):7763-7770.
Tekleab W (2015). Understanding catchment processes and hydrological modelling in the abay/upper Blue Nile Basin, Ethiopia. CRC Press/Balkema.ISBN:978-1-138-02792-3.
Williams JR (1969). Flood routing with variable travel time or variable storage coefficients. Transactions of the ASAE 12(1):100-103.
Welde K, Gebremariam B (2017). Effect of land use land cover dynamics on hydrological response of watershed: Case study of Tekeze Dam watershed, Northern Ethiopia.

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