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African Journal of Environmental Science and Technology

Full Length Research Paper

Effect of spilled engine oil on soil quality indicators and physiological performance of maize, cowpea and sorghum

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Soil contamination through oil spillage accumulates in the soil and affect plant growth. The study was conducted to examine the effect of spilled engine oil on soil nutrients and germination of seed in the in the Central region of Ghana. Ten samples were collected randomly from selected mechanic and fitting sites in the Elmina municipality. A randomized complete block design using three test crops was used to evaluate soil quality indicators such as N, P, K and soil pH on the polluted soil using standard methods. Maize recorded 3.67, 18.5 and 3.7% germination in contaminated soils from Aponkyedasoro, Nippon and Afitafum, respectively. Cowpea and sorghum recorded no germination in these soils. The three crops showed higher germination rates in the control soils, with the highest being recorded in sorghum (72.2%), followed by cowpea (70.4%) with the least being recorded in maize (66.6%). The results showed that nitrogen (N) level in the experimental soil was very low (0.065-0.075%) as compared to the control (0.115%) in this study. However, polluted soil from Aponkyedasoro, Afitafum and Nippon recorded a higher level of phosphorus (60.84-31.58 µg/g) and potassium (0.52-0.58 µg/g) than control (P=20.97 µg/g; K=0.43 µg/g) despite having a low germination rate. Copper, zinc, sodium and iron concentration were higher in the engine oil-polluted soil. The study revealed that the concentration of heavy metals and spilled engine oil in the soil has a higher effect on plant development; hence, public awareness should be created of its detrimental effect on the ecosystem.

Key words: Contamination, germination, heavy metals, soil fertility.

INTRODUCTION

Land and water are precious natural resources on which rely the sustainability of agriculture and civilization of mankind (Ghassemi et al., 1995; Asiamah et al., 2020a, b). Unfortunately, they have been subjected to maximum exploitation and severe degradation due to anthropogenic activities (Apori et al., 2018; Essien and John, 2010). The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicles, exhaustion and metals from smelting and mining, as well as nonpoint sources such as soluble salts (natural and artificial) (Kayode et al., 2009; Vwioko and Fashemi, 2005). Moreover, the use of insecticides/pesticides, disposal of industrial and municipal waste in agriculture, and excessive use of fertilizer stimulate loss of soil fecundity (Rowell, 1994). Each source of contamination has its own damage to plants and animals and ultimately to human health, but those that add heavy metals and spilled engine oil to soil and water are of serious concern, due to their persistence in the environment and carcinogenicity to plants growth (Vwioko and Fashemi, 2005). Studies have revealed a lower rate of plant germination, lower absorption of water and lower temperature of the soil environment as a result of oil contamination (Milala et al., 2015). Research has further concluded that water deficiency as well as insufficient aeration of the soil because of the displacement of air and water from the space between soil particles by oil retarded early germination and seedling growth coupled with chlorosis of leaves and dehydration of plant (Cutforth et al., 1986).

In Ghana, there are a lot of mechanic, fitting and welding shops, which are haphazardly located all over the country. Their works deal with changing the oil in cars, leading to the spilling of used engine oil (dirty oil) and heavy metals (Michael, 2015). These engine oils are derived from petroleum-based and non-petroleum-synthesized chemicals which often contaminate the environment. These oils are dumped in open plots of lands, into sewage and drainage ditches which usually enter into the aquatic chain through surface runoff (Milala et al., 2015). Infiltration of this affected runoff by spilled engine oil into the soil affects soil microbial diversity thereby decreasing its function regarding organic matter decomposition and microbial remediation of toxic contaminants (Cunningham et al., 1996). Small scale farmers and garden owners most often find their lands affected by this discarded engine oil, making soil unsatisfactory for plant growth. This research focused on major mechanic sites in the municipality of Elmina, in the central region of Ghana, where lands have been seriously contaminated by heavy metals and spilled engine oil at Aponkyedasoro, Nippon and Afitafum (Benz fitting shops). This work aims at investigating the effect of spilled engine oil polluted soil on plant development.

MATERIALS AND METHODS

Study area and experiment

The experiment was carried out in the botanical gardens of the University of Cape Coast (UCC) between January and April 2015. The experimental (polluted) soil samples were taken from three (3) mechanic and fitting sites in the Elmina municipality in the Central region of Ghana, namely, Aponkyedasoro, Afitafum (Benz fitting shops) and Nippon. Experimental soil samples were randomly fetched from the sites of study Aponkyedasoro, Afitafum (Benz fitting shops) and Nippon at a depth of 20 to 40 cm. Fifty-four slope-sided plastic pots with a lower and upper diameter of 20.7 and 27 cm respectively, the height of 23.5 cm and a total volume of 14000 cm^3 were used for the pot experiment. The base of each pot was perforated to allow for water drainage. Each pot was filled with 14.4 kg of fine earth fraction (< 2 mm) polluted soil. Twenty-seven (27) plastic pots were filled with control soil and twenty-seven (27) plastic pots were each filled with the experimental soil from the different experimental sites (that is nine (9) plastic pots for soil from each contaminated site) at an average weight of 14.4 kg. Three (3) different plant seeds (sorghum, maize and cowpea) were planted in each of the polluted and control soil. Both the experimental and the control soil were replicated 3 times for each of the plants. They were arranged in an independently randomized complete design according to the experimental sites. The soil was irrigated a day before planting. Four seeds were sown per pot for both the polluted and the controlled soil. After sowing, all cultural practices were observed (that is watering, thinning out).

Soil evaluation

The pH and electrical conductivity of the soil were measured in deionized water with a soil-to-deionized water ratio of 1:2:5 (w:v) following the DINSO standard 10390 for soil pH and conductivity measurements (Maghanga et al., 2012). For the pH, 0.5 g of soil was put in a test tube. 25 mL of deionized water was added and shaken for 1.5 h using a mechanical shaker. After shaking, it was allowed to settle for 5 min in which the pH meter was used to measure the pH. The electronic conductivity determination was also conducted on the same sample as used for the determination of the pH. Available P was analyzed using the Bray No. 1 acid extracting method (Maghanga et al., 2012). Potassium analyses were done using the NH_4O extract (Rhoades, 1982).

Total nitrogen was determined by the Kjeldahl method (Bashour and Sayegh, 2007). Micro-Nutrients (Zn^{2+}, Fe^{2+} and Cu^{2+}) were determined by Atomic Absorption Spectrophotometer (AAS) [8].

Fe (µg/g) = C × solution volume / Sample weight

Cu (µg/g) = C × solution volume / Sample weight

Zn (µg/g) = C × solution volume / Sample weight

where C = concentration obtained from AAS.

Plant evaluation parameters determination

The chlorophyll content was taken every 2 weeks using the chlorophyll meter (CCM-200, Apogee) for 6 weeks. Plant growth parameters e.g. plant height, the number of leaves, stem diameter and chlorophyll content were determined by a method proposed by Kayode et al. (2009).

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Table 1. Germination rate of cowpea, sorghum, and maize in soils from the experimental sites.

Crop	Control	Aponkyedasoro	Nippon	Afitafum
Cowpea	70.4 ± 17.01	00±00	00±00	00±00
Sorghum	72.2± 10.71	00±00	00±00	00±00
Maize	66.6 ± 20.03	3. 67 ± 3.18	18.5 ± 32.0	3.7 ± 6.41

Values are means ± standard deviation of means of three (3) replicates. Means of polluted soil are significantly different from control ($p < 0.05$), two weeks after planting.

Table 2. Stem girth (cm) of cowpea, sorghum, and maize in soils from the experimental sites.

Plant	Control	Aponkyedasoro	Nippon	Afitafum
Cowpea	1.34± 0.12	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Sorghum	2.99 ± 0.16	0. 00 ± 0.00	0. 00 ± 0.00	0. 00 ± 0.00
Maize	2.96 ± 0.06	0.14 ± 0.30	0.00± 0.00	0.093 ± 0.246

Values are means ± standard deviation of means of three (3) replicates. Means of polluted soil are significantly different from control ($p < 0.05$), five weeks after planting

Table 3. Number of leaves of cowpea, sorghum, and maize in soils from the experimental sites.

Plant	Control	Aponkyedasoro	Nippon	Afitatafum
Cowpea	23.8± 3.89	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Sorghum	10.7 ± 0.61	0. 00 ± 0.00	0. 00 ± 0.00	0. 00 ± 0.00
Maize	10.2 ± 0.10	0.53 ± 0.99	0.07 ± 0.26	0.4 ± 1.06

Values are means; ± is the standard deviation of means of three (3) replicates. Means of polluted soil are significantly different from control ($p < 0.05$), five weeks after planting.

Data analysis

Data presented are means ± standard deviation (SD) of three independent replicates. Data were analyzed using a one-tailed analysis of variance. Means of significant difference were separated by Tukey's multiple range tests at $p < 0.05$.

RESULTS

Effects of oil spilled soil on plant physiological performance

Generally, the three crops showed least or no significant ($p < 0.05$) rate of germination when grown on spilled engine oil polluted soil. Only maize recorded 3.67, 18.5 and 3.7% germination in contaminated soils from Aponkyedasoro, Nippon and Afitafum, respectively (Table 1). The rate of germination of maize was higher in contaminated soil samples from Nippon than in all the soil samples. Cowpea and sorghum recorded no germination in these soils. The three crops, however, showed higher germination rates in the control soils, with the highest being recorded in sorghum (72.2%), followed by cowpea 70.4%) with the least being recorded in maize (66.6%) ((Table 1).

No growth of cowpea and sorghum on the polluted soil, obviously had no stem (Table 2). Maize recorded stem girth of 0.14 and 0.09 cm on the polluted soils from Aponkyedasoro and Afitafum, respectively. Growing maize in soil from Nippon died three weeks after sowing. Stem girth of maize in Nippon was approximately zero. The three crops, however, showed higher stem girth in the control soils, with the highest being recorded in sorghum, followed by maize with the least being recorded in cowpea (Table 2).

Furthermore, maize recorded the mean number of leaves of 0.53, 0.07 and 0.04 in polluted soils from Aponkyedasoro, Nippon and Afitafum, respectively as shown in Table 3. The three crops, however, showed a higher record of the number of leaves in the control soils, with the highest being recorded in cowpea (23.8), followed by sorghum (10.7) with the least being recorded in maize (10.2) (Table 3).

The plant height for maize, sorghum and cowpea, when grown in the various experimental and control soils, was recorded two weeks after sowing (Table 4). Maize recorded mean heights of 0.06, 0.05 and 0.47cm in polluted soils from Aponkyedasoro, Nippon and Afitafum,

Table 4. Plant height of cowpea, sorghum, and maize in soils from the experimental sites.

Plant	Control	Aponkyedasoro	Nippon	Afitatafum
Cowpea	13.6 ± 1.73	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Sorghum	46.2 ± 4.99	0. 00 ± 0.00	0. 00 ± 0.00	0. 00 ± 0.00
Maize	41.67 ± 2.66	0.06 ± 0.16	0.05 ± 0.21	0.47 ± 1.23

Table 5. The chlorophyll content of cowpea, sorghum, and maize in soils from the experimental sites.

Plant	Control	Aponkyedasoro	Nippon	Afitatafum
Cowpea	66.65 ± 20.0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Sorghum	7.48 ± 2.12	0. 00 ± 0.00	0. 00 ± 0.00	0. 00 ± 0.00
Maize	45.44± 0.33	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Values are means; ± is standard deviation of means of three (3) replicates. Means of polluted soil significantly different from control ($p < 0.05$), three (3) weeks after planting.

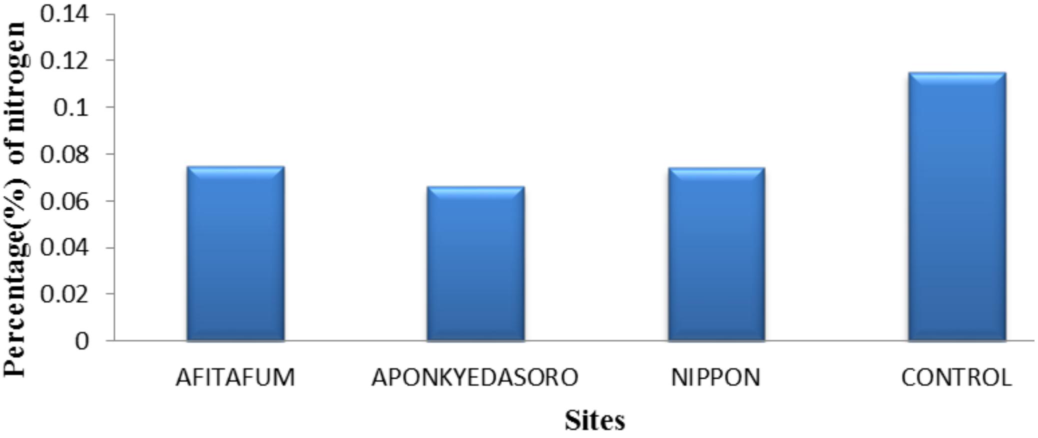

Figure 1. The percentage means of nitrogen (N) of soils from Aponkyedasoro, Nippon and Afitafum.

respectively. The three crops, however, showed a higher record of plant height in the control soils, with the highest being recorded in sorghum (46.2 cm), followed by maize (41.67 cm) with the least being recorded in cowpea (13.6 cm) (Table 4).

Moreover, maize grew on the polluted soil, but after two (2) weeks of germination, the maize plant turned brownish and was dying off, it recorded approximately zero chlorophyll content. However, there was a significantly higher chlorophyll content in the control soils, with the highest being recorded in sorghum (66.65), followed by cowpea (45.44) and maize (7.48) (Table 5).

Effect of oil spilled on soil quality indicators

Nitrogen

It can be observed that the percentage means of soil from the contaminated sites (Aponkyedasoro, Nippon and Afitafum) have low nitrogen content as compared with the control. Among the polluted soil, soil from Afitafum showed the highest concentration of nitrogen, having means of 0.075%, followed by the soil from Nippon (0.074%) and Aponkyedasoro, respectively (0.067%) (Figure 1).

Phosphorus and potassium

It can be observed that the concentration of phosphorus was higher in the polluted soil than in the control soil. Soil from Aponkyedasoro exhibited a significantly higher concentration of phosphorus having a mean of 60.38 µg/g, followed by the soil from Nippon (having a mean of 45 µg/g) and Afitafum (having a mean of 31.579 µg/g), respectively (Figure 2). The concentration of potassium

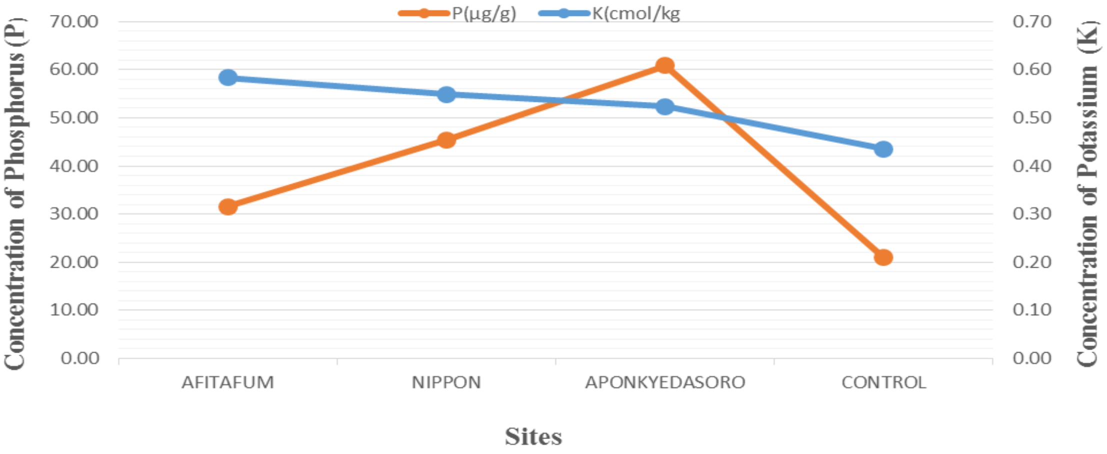

Figure 2. Mean concentration of phosphorus (P) in the soils from Aponkyedasoro, Nippon and Afitafum.

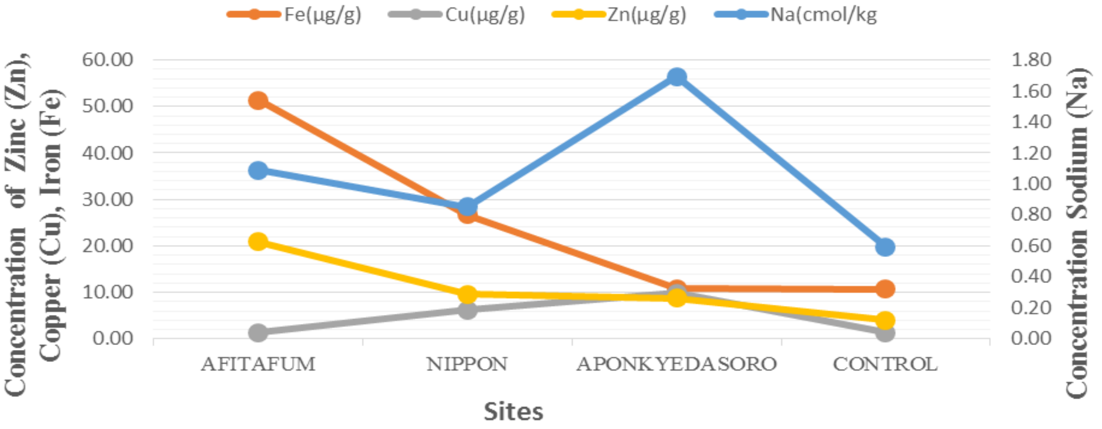

Figure 3. Concentration of Copper (Cu), Zinc (Zn) and Iron (Fe) in the soils from Aponkyedasoro, Nippon and Afitafum.

was higher in the polluted soil samples than in the control soil. Generally, there is a significant difference between the control soil and the polluted soil samples. Soil from Afitafum recorded the highest concentration of potassium (0.583 cmol/kg) followed by the soil from Nippon having a mean of concentration of 0.548 cmol/kg and soil from Aponkyedasoro having a mean of 0.523 cmol/kg, respectively (Figure 2).

Copper, zinc and iron

Figure 3 shows a multi axes graph representing the mean concentration of Copper (Cu), Zinc (Zn) and Iron (Fe) in the soils from Aponkyedasoro, Nippon and Afitafum. It was observed that soil from Afitafum recorded the highest concentration of Zn followed by Nippon and Aponkyedasoro, having mean values of 20.85, 9.567 g and 8.800 µg/g, respectively. Soil from Aponkyedasoro and Nippon recorded nearly the same concentration of Zinc (Figure 3).

Moreover, the soils from the polluted sites contain significantly higher concentration of sodium (Na) than the control soil. Soil from Aponkyedasoro recorded the highest concentration of Na having a mean of 1.692 cmol/kg, followed by the soil from Afitafum and soil from Nippon having a mean of 1.087 and 0.087 cmol/kg, respectively. However, the concentration of Na in soil from Aponkyedasoro was significantly different from soil from Nippon and Afitafum (Figure 3).

Soil from Afitafum recorded the highest concentration of Iron (Fe) having a mean concentration of 51.291 µg/g and the control soil recorded the lowest concentration of Fe having a mean concentration of 10.86 µg/g. However, the polluted soils were significantly different from each other but there was no significant difference between the

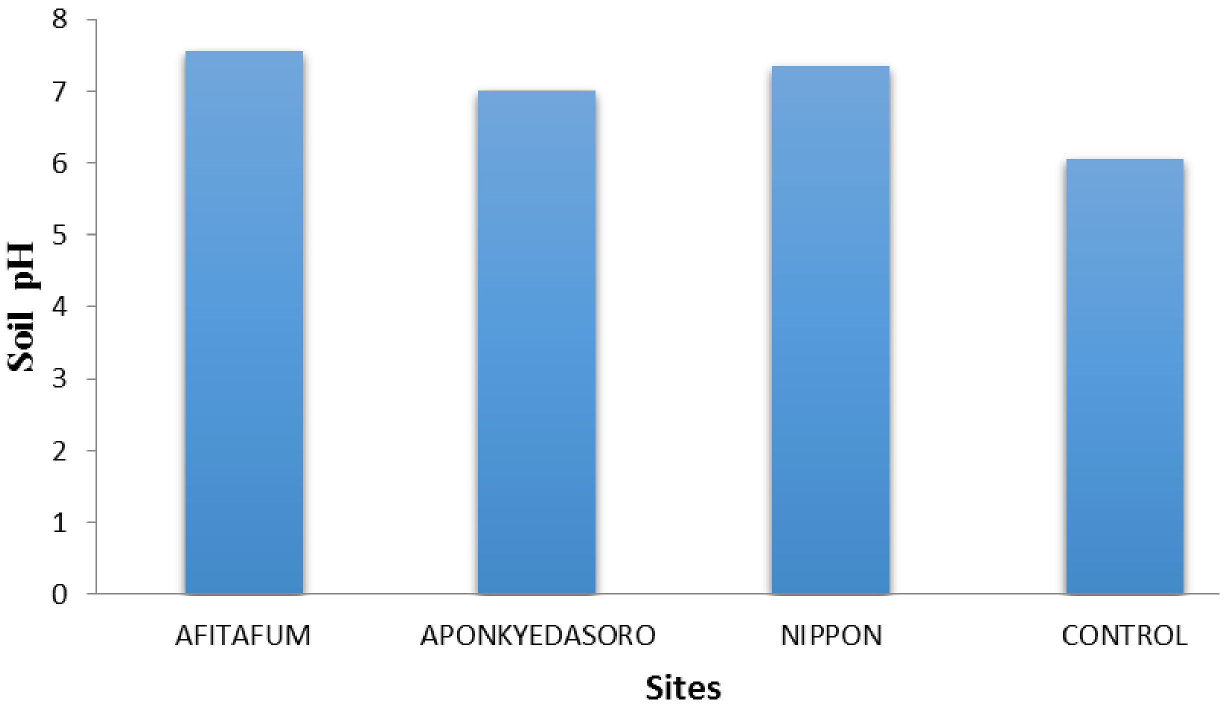

Figure 4. Mean concentration of Copper (Cu), Zinc (Zn) and Iron (Fe) in the soils from Aponkyedasoro, Nippon and Afitafum.

mean concentration of Fe in soil from Nippon and the Aponkyedasoro which recorded 26.55 and 27.72 µg/g, respectively. There was a significant difference between soil from Aponkyedasoro and the control (Figure 3).

Furthermore, Aponkyedasoro recorded the highest concentration of copper (Cu) having a mean concentration of 9.86 µg/g, followed by Nippon and Afitafum having mean concentrations of 6.24 and1.390 µg/g, respectively. Cu concentration in soil from Aponkyedasoro and Nippon was significantly different from the control soil, having a mean concentration of 9.86, 6.242 and 1.390 µg/g, respectively.

pH

The pH of the polluted soil was higher than that of the control. However, there was no significant difference among polluted soil in terms of pH. Soil from Afitafum recorded the highest pH of 7.6 followed by Nippon and Aponkyedasoro recording 7.4 and 7.0, respectively (Figure 4).

DISCUSSION

Soil is the most important component of the agriculture ecosystem and environmental sustainability largely depends on proper soil maintenance and management (Glaser et al., 2002). Sustainable use of soil on which agriculture depends is necessary for optimal agricultural productivity. It was observed clearly from this experiment that heavy metals and spilled engine oil in agricultural soils affect the development of plants grown on them. This is in line with the report by several researchers that, heavy metal and spilled engine oil pollution in whatever form is toxic to the plant and soil microenvironment (Gomes et al., 2013; Kayode et al., 2009; Nicholls and Mal, 2003; McGill, 1976). Generally, it was observed that there was a high significant ($P< 0.01$) difference between agronomic performance of crops grown on control soil and polluted soil. The level of soil nutrients in the experimental soils had a massive effect on plant germination. The nitrogen (N) level in the experimental soil was very low as compared to the control in this study. However, experimental (polluted) soil from Aponkyedasoro, Afitafum and Nippon recorded a higher level of phosphorus (P) and potassium (K) than control but yet germination of cowpea and sorghum were not recorded in this study (Table 1). Hill and De Saussure (2014), reported that, without proper aeration, mineral nutrients and other factors, plants may not be able to absorb phosphorus and potassium from the soil. The study confirmed the conclusion made from the research of Hill and De Saussure (2014), because even though experimental soil from the three polluted sites recorded a higher level of phosphorus and potassium, the presence of engine oil may have prevented proper aeration and other factors that prevented cowpea and sorghum from taking up nutrient for development. Even though maize was able to germinate, it died a few weeks after later.

The presence of heavy metal in the soil had a serious effect on germination in the present study, Vwioko and Fashemi (2005), reported that one of the more important differences between new and used engine oil is the metal content. This aligns with the outcome of this study as there was a measurable presence of heavy metal (Cu, Zn, Fe, and Na) in the spilled engine oil-polluted soil from the three (3) sites. From this study, it was observed that the presence of heavy metals was approximately higher in the polluted soil than in the control. This may have accounted for the inability of cowpea and sorghum to germinate and maize to survive. Jadia and Fulekar (2009) reported that some of the direct toxic effect caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structure due to oxidative stress. This conclusion he made may be the cause of the inability of the cowpea to grow on the polluted soil. Moreover, the negative influence heavy metals, such as Zn, Cu, and Fe, have on the growth of soil microorganisms due to higher metal concentration may lead to a decrease in organic matter decomposition leading to a decline in soil nutrients. Again, enzyme activity useful for plant metabolic activities may be hampered due to heavy metal interference with the activities of soil microorganisms.

Soil from the polluted sites recorded the highest level of Zn, Cu and Fe as compared to the control. This was due to the welding activity mostly seen at the site alongside the fitting and mechanic work. Maize development in terms of girth and germination rate was low as compared with the others on this soil. Soil from Nippon was very dark and containing a higher amount of engine oil, accounting for it has the lowest ability to support maize development among the experimental soils. Kayode et al. (2009) reported that when the soil is polluted by oil, the effects range from blanketing of the soil to the displacement of pore spaces in the soil. This modifies the rate of water drainage and gaseous exchange and destroys soil texture, structure and microbial profile. The decrease in height, girth, number of leaves of the plant in experimental (polluted) soil may be due to the non-availability of adequate water, which possibly affected the nutrient uptake and mobility.

Soil pH is considered more important because it influences several soil factors affecting plant growth, such as soil microorganisms, nutrient leaching, nutrient availability, toxic elements and soil structure (Perry, 2003). Bacterial activity that releases nitrogen from organic matter and certain fertilizer is particularly affected by soil pH because bacterial operate best in the pH range of 5.5 to 7.0. It can be observed in this study that, as pH increases (pH >7) of soils from Afitafum (pH = 7.55) and Nippon (pH=7.35), the nitrogen content of soil from Afitafum and Nippon decreases by 0.08 and 0.07, respectively. However, as pH decrease in control soil (6.0) the nitrogen content increased 0.115%. This confirms the conclusion made by Perry (2003) and may be the cause of the soil's inability to support plant development.

Conclusion

This study had revealed that the introduction of heavy metals and spilled engine oil into agricultural soil, adversely and severely inhibits agronomic growth and development of plants, affecting its germination rate, stem girth, height, chlorophyll content and leaves production. All the plants (cowpea and sorghum) did not germinate in the contaminated soils, except maize which grew but turned brownish and died a few weeks after germination. Soil analysis shows that there is a higher concentration of heavy metals in polluted soils and a low concentration of soil nutrients (NPKs). Heavy metals such as iron, zinc, and copper were higher in all the polluted soil as compared to the control. This concludes the concentration of heavy metals and spilled engine oil in the soil has a higher effect on plant development. Therefore, contamination of agricultural soils with heavy metals and spilled engine oil should be avoided and public awareness should be made on the detrimental effect of heavy metals and spilled engine oil pollution in our terrestrial ecosystem. Innovative and environmentally-friendly remediation strategy should be carried out on our agricultural soils that have been grossly polluted by heavy metals and spilled engine oil.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Apori O, Hanyabui E, Asiamah Y (2018). Remediation Technology for Copper Contaminated Soil: A Review. Asian Soil Research Journal pp. 1-7.

Asiamah JY, Kyei F, Obeng Apori S, Agbeko R, Hanyabui E, Danquah A, Balde I (2020a). The Potential of Biodiversity Utilization and Sustainable Development in Ghana 22(1):229-240. ISSN: 1520-5509

Asiamah YJ, Tachie-Menson JW, Agyirifo DS, Agbeko R, Essem F (2020b). Pesticides; A necessary evil in the agricultural value chain– A review. STED Journal 2(1):53-63.

Bashour II, Sayegh AH (2007). Methods of Analysis for Soils of Arid and Semi-Arid Regions. Rome, Italy pp. 1-128.

Cunningham SD, Todd A, Anderson A, Paul S, Hsu FC (1996). Phytoremediation of soils contaminated with organic pollutants. Advances in Agronomy 56(1):55-114.

Cutforth HW, Shaykewich CF, Cho CM (1986). Effect of soil water and temperature on corn (*Zea mays* L.) root growth during emergence. Canadian Journal of Soil Science 66(1):51-58.

Essien O, John I (2010). Impact of crude-oil spillage pollution and chemical remediation on agricultural soil properties and crop growth. Journal of Applied Sciences and Environmental Management 14(4).

Ghassemi F, Jakeman AJ, Nix HA (1995). Salinisation of land and water resources: human causes, extent, management and case studies. CAB international pp. 5-7.

Glaser B, Lehmann J, Zech W (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review. Biology and Fertility of Soils 35(4):219-230.

Gomes HI, Dias-Ferreira C, Ribeiro AB (2013). Overview of in situ and ex situ remediation technologies for PCB-contaminated soils and sediments and obstacles for full-scale application. Science of the Total Environment 445:237-260.

Hill JF, De Saussure T (2014) "Translator's Introduction" Chemical research on plant growth. New York: Springer. Retrieved 7 November 2014). http://ndl.ethernet.edu.et/bitstream/123456789/73454/1/341.pdf.

Jadia CD, Fulekar (2009). MH Phytoremediation of heavy metals: recent techniques. African Journal of Biotechnology 8(6).

Kayode J, Olowoyo O, Oyedeji A (2009). The effects of used engine oil pollution on the growth and early seedling performance of *Vigna uniguiculata* and *Zea mays*. Research Journal of Soil Biology 1(1):15-19.

Maghanga K, Justin KL, John SKF (2012). Comparison of soil phosphorous extraction by Olsen and double acid methods in acid soils of Western Kenya. East African Journal of Pure and Applied Science 2(1):1-5.

McGill WB (1976). An introduction to field personnel act of oil spills on soil and some general restoration and clean up procedures. Albert Institute of Petrology. AIP publisher No. C-76-1.

Michael A (2015). Modern automobile vehicle repair practices in micro, small and medium scale garages in Ghana. International Journal of Science, Technology and Society *2*(6):216-222.

Milala MA, Blessing D, Abdulrahman AA (2015). Effects of spent engine oil on soil physico-chemical properties of and microorganism (Bacteria). Asian Journal of Science and Technology 6(2):1032-1035.

Nicholls AM, Mal TK (2003). “Effects of lead and copper exposure on growth of an invasive weed, Lythrum salicaria L. (Purple Loosestrife). Ohio Journal of Science 103(5):129-133.

Perry L (2003). pH for the Garden. UVM Extension system. University of Vermont extension, Department of Plant and Soil Science, Available on: http://pss.uvm.edu/ppp/pubs/oh34 htm.

Rhoades JD (1982). Cation exchange capacity. In: A.L. Page (ed.) Methods of soil analysis. Part 2: Chemical and microbiological properties. (2nd ed.) Agronomy 9:149-157.

Rowell DL (1994). Soil Science: Methods and Applications, Longman group, UK Ltd.

Vwioko D, Fashemi D (2005). Growth response of Ricinus communis L (Castor Oil) in spent lubricating oil polluted soil. Journal of Applied Sciences and Environmental Management 9(2):73-79.

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Groundwater resources for domestic and irrigation purposes in Melong (Littoral Region, Cameroon): Hydrogeochemical constraints

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Groundwater is a valuable natural resource whose quality is threatened by natural and man-made pollutants. This study aims to perform a hydrochemical characterization of groundwater resources used for domestic and irrigational activities in Melong (Littoral Cameroon). Thus, 26 subsurface water samples were collected in the dry season (six sampling points) and rainy season (seven sampling points) of the years 2019 and 2020. Physical water quality parameters were measured on the field while ionic constituents and bacteriological parameters were determined in the laboratory. The main findings revealed that the pH of the water samples was slightly acidic to neutral, fluctuating from 5.3 to 7.1; electrical conductivity ranged from 0.03 to 0.33 µS/cm and turbidity varied from 0.5 to 33.7 NTU revealing that the water is weakly mineralized. The ionic constituents were such that $Ca^{2+} > K^{+} > Mg^{2+} > Na^{+}$ for cationic constituents while anions appeared as $HCO_3^{-} > NO_3^{-} > Cl^{-} > PO_4^{3-}$. The major ions fell within the acceptable limits of World Health Organisation (WHO) drinking water standards. Bacteria indicators of faecal pollution were identified in all the water samples, including Enterobacteria, *Escherichia coli,* Streptococcus, Salmonella, Shigella, Staphylococcus and Vibrio. This indicates an exposure of water sources to unhygienic conditions that may place consumers at risk of water-borne diseases, hence necessitating basic treatment of the water before consumption.

Key words: Hydrochemistry, Melong, groundwater quality, bacteriological analysis, Littoral Cameroon.

INTRODUCTION

Water, an essential constituent of life, is vulnerable to tremendous stress as a result of rapid urbanization, agricultural innovations and industrialization (Sudha, 2007; Yıldız, 2017; Olalekan et al., 2018; Raimi et al., 2019). Groundwater alone provides a substantial amount of about 97% out of all potentially available fresh water resources for human use (Annapoorna and Janardhana, 2015; Olalekan et al., 2020). It is one of the most prominent and reliable sources of fresh water all over the world, owing to its high quality and potential availability (Kemper, 2004; Nickson et al., 2005; Sujay and Paresh, 2015; Raimi and Sabinus, 2017; Morufu and Clinton, 2017). Access to safe drinking water is a fundamental right of all human beings (Gift et al., 2020; Gift and Olalekan, 2020). Therefore, sustainable management as well as development of underground water is primordial to ascertain the provision of adequate water supply (Macdonald et al., 2012; Olalekan et al., 2019). The issue of sustainability and maintenance of drinking water sources is a major challenge to developing countries, including Cameroon where groundwater is currently the main reserve for domestic water supply and irrigation, amongst other uses. Despite the country's richness in water resources (Katte et al., 2003; Molua and Lambi, 2006), most communities cannot boast of adequate supply of potable water for various activities as a greater proportion of the rural population, especially in rural settings, use precarious water sources for drinking (Kuitcha et al., 2010; Raimi et al., 2017; Olalekan et al., 2018; Raimi et al., 2019). Groundwater is increasingly being exploited for domestic use in many urban and peri-urban communities which necessitates a thorough hydrogeochemical investigation. Also, most surface water reservoirs are progressively deteriorating as a result of inadequate waste management facilities and uncontrolled usage of agrochemicals in agricultural fields (Isah et al., 2020a, b; Morufu, 2021; Hussain et al., 2021a, b). Related studies have been carried out in several other areas of Cameroon in the past years including, among others, the works of Katte et al. (2003) reporting the quality of water for domestic activity in Dschang, Ako et al. (2011) documenting nitrate contamination in the Banana Plain, Tita et al. (2013) highlighting microbial pollution in the Mezam River basin, Akoachere and Ngwesse (2017) unfolding the occurrence of water borne diseases in Kumba while Alakeh et al. (2017) carried out spring water assessment in Awing village.

The population of Melong (Littoral Region of Cameroon), made up mostly of low income peasant farmers, relies entirely on subsurface water for their daily provision and there is currently no water quality monitoring mechanism to assess the potability of the water sources. This therefore necessitates monitoring the quality of the various groundwater sources in this Municipality. Thus, this research was conceived to evaluate the suitability of various water sources for drinking and irrigation, as well as to identify the hydrogeochemical processes influencing water quality in this locality. The data obtained will provide groundwater quality information in the area thus contributing to the sustainable management of groundwater resources.

MATERIALS AND METHODS

Study area description

The town of Melong in the Moungo Division of the Littoral Region (Cameroon) is found between latitudes 5°3′30″ and 5°9′0″ N and longitudes 9°54′0″ and10°3′0″ E (Figure 1). This town covers a total surface of about 590 km^2 and is elevated at 790 m above sea level. The climate is the Guinean equatorial type, composed of two seasons (Molua and Lambi, 2006): a longer rainy season of seven months (from April to October) and a shorter dry season of about five months (from November to March). Temperatures vary between 21 and 23.8°C and the average annual precipitation is about 2484 mm. The relief of the area has an influence on the drainage pattern with rivers such as Ngoedi and Marrigo draining the area. The major channels are characterized by rapids, representing exposed lava flow fronts and flanks. The major soils in Melong area the red ferrallitic soils formed mainly on volcanic material while the lowlands are occupied by hydromorphic soils.

Geologically, the study area lies on the flanks of Mount Manengouba (2411 m above sea level), which consists of a mountainous chain of two stratovolcanoes affected by double subsidence that resulted in the formation of two calderas: the Eboga and the Elengoum (Itiga et al., 2004). Studies by Sato et al. (1990) have shown that Mount Manengouba is a polygenic volcano characteristic of Ocean Island Basalts (OIB). Detailed geochemical studies of basaltic lavas from Mount Manengouba are reported by Kagou et al. (2001) (Figure 1).

Data collection

Twenty six water samples were collected from seven sampling points in the wet period and six sampling points in the dry period in 0.5 L polyethylene containers; July for the wet season and February for the dry period. Six water samples were rather collected during the dry period because sampling point MS7 was an intermittent spring and had dried up. Two water samples were collected from each sampling point in view of physicochemical and bacteriological analyses. The sampling containers were initially cleansed using distilled water and finally with the water from the respective sampling points. Each sampling point was then georeferenced using a Garmin 78 Global Position System. Samples from shallow wells were obtained with the use of a bucket to which a rope was fastened while water samples from the spring and tap were collected directly into the sampling containers. After collection, the sampling bottles were immediately capped, labeled and placed in an ice-cooled flask to maintain the temperature at 4°C (APHA, 1995) and were conveyed to the laboratory for analyses within 24 h. The various water sources, sample codes and coordinates are compiled in Table 1.

Physical properties

Some physical properties of water, such as, pH, electrical conductivity and turbidity were measured *in situ* with the aid of a

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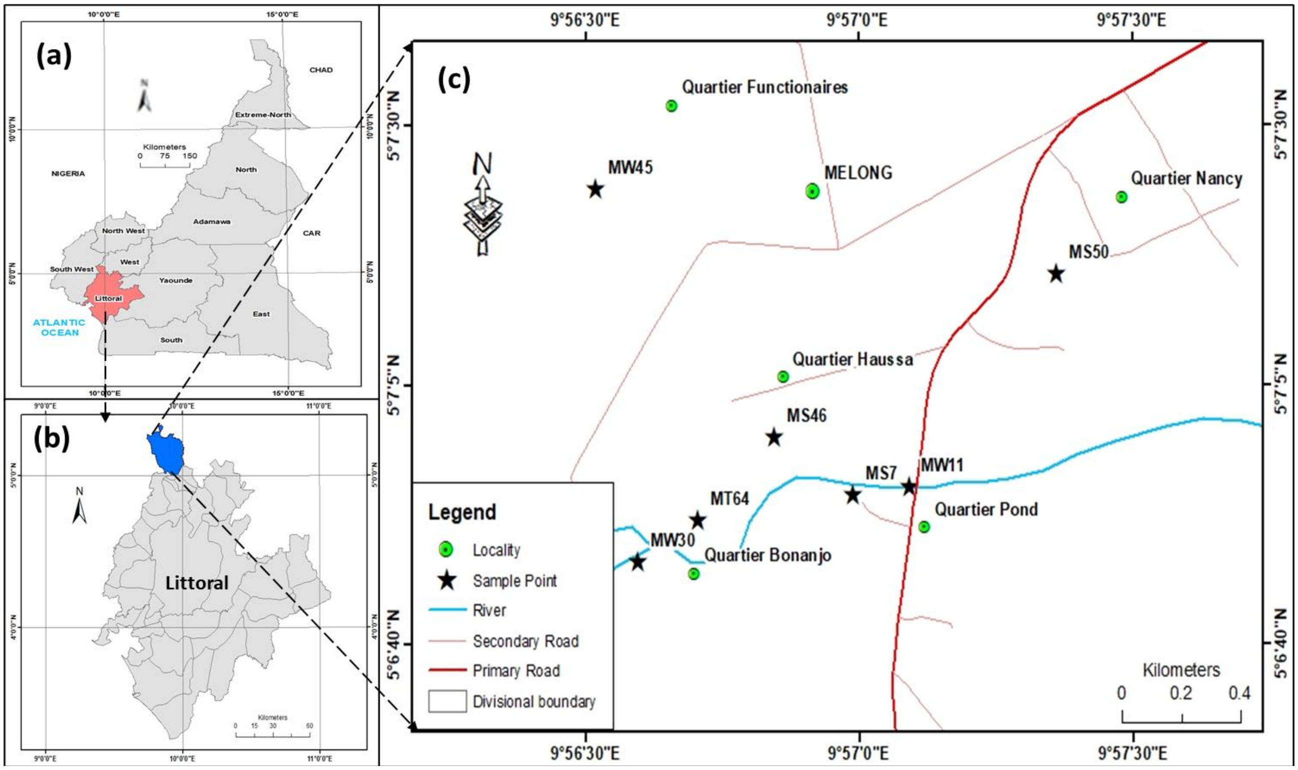

Figure 1. Representation of sampling points on map of Melong: MW11, MW30, MW45, MS7, MS46, MS50, MT64.

Table 1. Sampling points and their coordinates.

Sample code	Neighbourhood	Coordinates	Elevation (m)	Description
MW11	Quartier Pond	N05° 06΄ 55.1″ E009°5705.2″	835	11 m deep, dug in basaltic rocks
MW30	Quartier Bonanjo	N05°06΄ 48.0″ E009°56΄35.5″	847	1.5 m deep, poorly constructed besides a polluted stream and is susceptible to floods in the wet period
MW45	Quartier Functionaries	N05°07΄ 23.9″ E009°56΄350.9″	882	32 m deep, found at an uphill direction to habitation and its water appeared clear.
MS7	Quartier pond	N05°06΄ 54.4″ E009°56΄59.1″	830	Intermittent spring with much waste littered in its surroundings.
MS46	Quartier Hausa	N05°07΄ 00.0″ E009°56΄50.4″	842	Poorly constructed well with no protection. Pit latrines at less than 10 m away as well as dump sites. Used widely by the population for domestic chores including drinking.
MS50	Quartier Nancy	N05°07΄15.7″ E009°57΄21.4″	796	Situated in a thickly populated area, with farmland around. Used widely by the population for domestic chores.
MT64	Quartier Bonanjo	N05°06΄ 52.0″ E009°56΄42.1″	835	Reference sampling point. Used widely by the population for domestic chores including drinking.

multi-parameter probe (PC Stestre 35).

Chemical properties

Ionic constituents (cations and anions) of the water samples were dosed in the Research Unit of Soil analysis and Environmental Chemistry (URASCE) of University of Dschang, Cameroon. Sodium (Na^+) and Potassium (K^+) ions were determined by flame photometry method. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were analysed by titration as described by Hounslow (1995). Chloride ion (Cl^-) and bicarbonate ion (HCO_3^-) were dosed by titration according

Table 2. Summary statistics of physicochemical parameters of the sampled groundwater.

Parameter	Unit	Wet season				Dry season				WHO range
		Max	Min	Mean	STDEV	Max	Min	Mean	STDEV	
pH		6.6	5.5	5.94	0.46	7.1	5.8	6.43	0.53	6.5-8
EC	µS/cm	0.08	0.03	0.05	0.02	0.33	0.03	0.13	0.11	<1000
Turbidity	NTU	6.6	0.5	2.54	2.36	33.7	0.5	7.27	13.09	5NTU
K^+	mg/L	5.78	0	2.18	2.62	4.04	0.66	1.36	1.33	20
Na^+	mg/L	2.45	0.63	1.12	0.7	0.12	0.07	0.08	0.02	200
Ca^{2+}	mg/L	6.4	2.1	3.37	1.83	7.04	1.6	4.18	2.37	75
Mg^{2+}	mg/L	2.19	0.97	1.3	0.47	2.43	0.21	0.79	0.85	200
Fe^{2+}	mg/L	0	0	0	0	0.4	0.05	0.05	0.4	0.03
HCO_3^-	mg/L	152.5	12.2	42.26	49.51	219.6	67.1	97.6	60.14	125-350
NH_4^+	mg/L	0	0			0	0	0	0	0.5
NO_3^-	mg/L	17.37	0	6.38	5.84	19.85	7.44	11.95	5.07	50
CO_3^{2-}	mg/L	0	0			0	0			250
Cl^-	mg/L	42.6	17.75	0	0	3.55	0	2.26	4.53	200
PO_4^{3-}	mg/L	0	0	0	0	11.45	0	0	0	
SO_4^{2-}	mg/L	0	0	0	0	0	0	0	0	

to Trivedy and Goel (1985), nitrate (NO_3^-) and phosphate ions (PO_4^{3-}) were determined by calorimetry while sulphate ion (SO_4^{2-}) was analyzed by turbidimetry method. The total hardness of the water samples was gotten from Equation 1 whereas the sodium adsorption ratio (SAR) was obtained using Equation 2.

$$TH = 2.497\ Ca^{2+} + 4.115\ Mg^{2+} \quad (1)$$

$$SAR = Na^+/\sqrt{½}\ (Na^+ + Mg^{2+}) \quad (2)$$

Bacteriological analysis

Indicator bacteria such as Enterobacteria, *Escherichia coli,* Streptococcus, Salmonella, Shigella, Staphylococcus and Vibrio were detected by the membrane filtration procedure as described by APHA (1995) and results are given in CFU/100 ml.

Analysis of data

Data were analysed using Microsoft Excel and Aquachem Scientific software version 1.5.

RESULTS AND DISCUSSION

Physical parameters

Statistical data of the physicochemical characteristics of the water waters are compiled in Table 2. Mean values of pH were below neutrality and ranged from 5.3 to 7.1 (Table 2). The highest pH value (7.1) was observed in the dry season at MW30 and the lowest (5.3) was noted in the rainy season at MW11 (Figure 2a). The pH values revealed that only 16.67% of the studied groundwater samples fell in permissible limits of 6.5 to 8.0 for domestic use as prescribed by WHO (2017) while 83.33% fell outside the limits. The slightly acidic nature of the groundwater might stem from precipitation and dissolution of minerals, as well as the degradation of organic matter by microorganisms in the aquifer system (Winter et al., 1998). Similar results have been documented by Ako et al. (2011) in the Njombe-Penja area, Sabrina et al. (2013) in the Logone Valley (North-Cameroon), Magha et al. (2015) and Akoanung et al. (2019) in Bamenda (North West Cameroon). The pH of water can disrupt many biogeochemical processes and absorption of some ions like ammonium ion as well as limit biodiversity allotment in water bodies (Dirisu et al., 2019). The values of electrical conductivity fluctuated between 0.03 and 0.33 µS/cm. Higher values were generally recorded in the dry period while lower values prevailed in the wet period (Figure 2b). The values of EC were much lower when compared with the recommended levels of WHO (2017). The insignificant values of EC are an indication of minimal dissolved components in the aquifer system. These results corroborate with those of Alakeh et al. (2017) on spring water in Awing (Bamenda Highlands, North West Cameroon). On the other hand, turbidity values fluctuated from 33.7 NTU at MW30 in the dry season to 0.5 NTU at MS46 in the rainy season (Figure 2c). 15.38% of the analysed water samples recorded turbidity values above the recommended value (5 NTU) of WHO (2017). Turbidity can seriously impede the efficiency of disinfection by providing protection for organisms.

Chemical characteristics

Ammonium ion, carbonate and sulphate ions were absent in the analysed water samples throughout the campaign period (Table 2).

Cations

Major cations were ranked thus: Ca^{2+}>K^+>Mg^{2+}>Na^+. The highest concentration (5.78 mg/L) of potassium ion (K^+) during the rainy period was recorded at MW30 and MS46 while the highest level (4.04 mg/L) in the dry period was noted at MW30. The highest average value of 4.91 mg/L was observed at MW30 and the lowest (0.33 mg/L) was observed at MW45 and MS50 (Figure 2d). The K^+ could probably come from the hydrolysis of K-feldspar (albite) or K-fertilizer from nearby farmlands (Appelo and Postma, 2005). The higher (2.45 mg/L) concentrations of sodium ion (Na^+) were noted in the wet period whereas the lowest value of 0.07 mg/L was reported in the dry period (Figure 2e). The highest average value of 1.45 mg/L was observed at MS7 while the lowest one (0.35 mg/L) was noted at MW11, MW45 and MT64. A higher (7.04 mg/L) concentration of Ca^{2+} was measured during the dry period while the lowest value (6.4 mg/L) was obtained in the wet period (Figure 2f). The highest average value (4.62 mg/L) was noted at MW11 and the lowest (2.06 mg/L) at MS50. The highest value was noted for Mg^{2+} in the wet period (2.43 mg/L) whereas the lowest value of 0.97 mg/L was observed in the dry period (Figure 2g). The highest average Mg^{2+} concentration (1.7 mg/L) was observed at MT64 meanwhile, lowest one (0.59 mg/L) was noted at MW11. The Ca^{2+} may stem from the dissociation of gypsum in the aquifer system (Gountié et al., 2017). In both seasons the levels of Ca^{2+}, Mg^{2+}, Na^+ and K^+ were by far lower than the permissible limits of WHO (2017) for drinking water and therefore would not pose any threat on the health of the consumers.

Anions

The HCO_3^- was detected in the water samples in both seasons with the highest value of 219.6 mg/L noted during the dry period while the lowest value of 12.2 mg/L was observed during the wet period. The highest average value (186.05 mg/L) was observed in MW30 whereas the lowest value of 18.30 mg/L was recorded at MS7 (Table 2). Just 15.38% of the analysed samples recorded HCO_3^- in the permissible limit of 152 to 350 mg/L as stipulated by WHO (2017) for drinking water. HCO_3^- could stem from input from the atmosphere as well as the biodegradation of organic compounds like petroleum and hydrocarbons (Winter et al., 1998). This may be a reflection of the extent to which hydrogeochemical processes take place in aquifers (Zheng et al., 2004). The NO_3^- concentration, on the other hand, was higher in the dry season (19.85 g/L) compared to the rainy season (6.20 mg/L). The highest average value (18.61 mg/L) was observed at MS46 while the lowest (6.20 mg/L) was obtained at MS7. The NO_3^- was noted in almost all the sampled water throughout the research period, except for MW45 and MS50. Nitrates could result from the breakdown of organic and inorganic constituents in the aquatic system, oxidation of nitrogen compounds, animal feed lots and from domestic waste water. Human activities can increase nitrate concentration up to about 1 to 5 mg/l in water sources (Eneke et al., 2011). The NO_3^- level was below the permissible level of WHO (2017) of 50 mg/L. The highest value of the chloride ion of 42.6 mg/L was noted in the wet period meanwhile the lowest value of 3.55 mg/L was gotten during the dry period. The highest average value (17.75 mg/L) was recorded at MT64 and the lowest (8.87 mg/L) at MW11. The average values of Cl^- in the water samples were above WHO (2017) permissible level of 5 mg/L. The Cl^- ions might stem either from the disintegration of Cl^- minerals that are in contact with the water in the aquifer or from human-induced activities through disinfection of wells as owners often pour chlorine in wells to treat the water after a certain time interval. The analysed water was devoid of phosphate ion during the wet period meanwhile during the dry period, it was recorded from all sampling points except for MS46 and MT64. Agriculture is practiced extensively in the area, in addition to septic tanks, pit latrines and domestic effluent and may contribute to the input of HCO_3^-, Cl^-, Na^+, K^+, NH_4^+, NO_3^- to the groundwater.

Hydrogeochemical facies

In order to better appreciate the chemical facies of the water samples, the Piper diagram (Piper, 1944) (Figure 3a and b) and Durov's plot (Durov, 1948) (Figure 4a and b) were plotted. From the Piper trilinear diagrams, it was observed that 85.7% of the analysed water plotted in the Ca-Mg-Cl-SO_4 domain in the rainy period, while 14.3% fell in the Ca-Mg-HCO_3 domain; this is indicative of the abundance of alkaline earth metals. In the dry period, on the other hand, all water samples fell inside the Ca Mg-HCO_3 field (Figure 3b).

Durov's diagrams (Figure 4a and b) enabled the confirmation of the existence of mixed water type as most of the samples plotted along the dissolution or mixing and ion exchange fields. On the basis of a classification by Artimes et al. (2011), the pattern could be assigned to freshly recharged water displaying simple mixing without any dominant ionic constituent.

Mechanism controlling water chemistry

The dissolved load of ionic constituents in aquifer systems is a function of geochemical processes operating in the aquifer. Plots of $Na^+/(Na^++K^++Ca^{2+})$ and $Cl^-/$ $(Cl+HCO_3^-)$ in relation to TDS are used to elucidate the possible origin of dissolved components in aquifers.

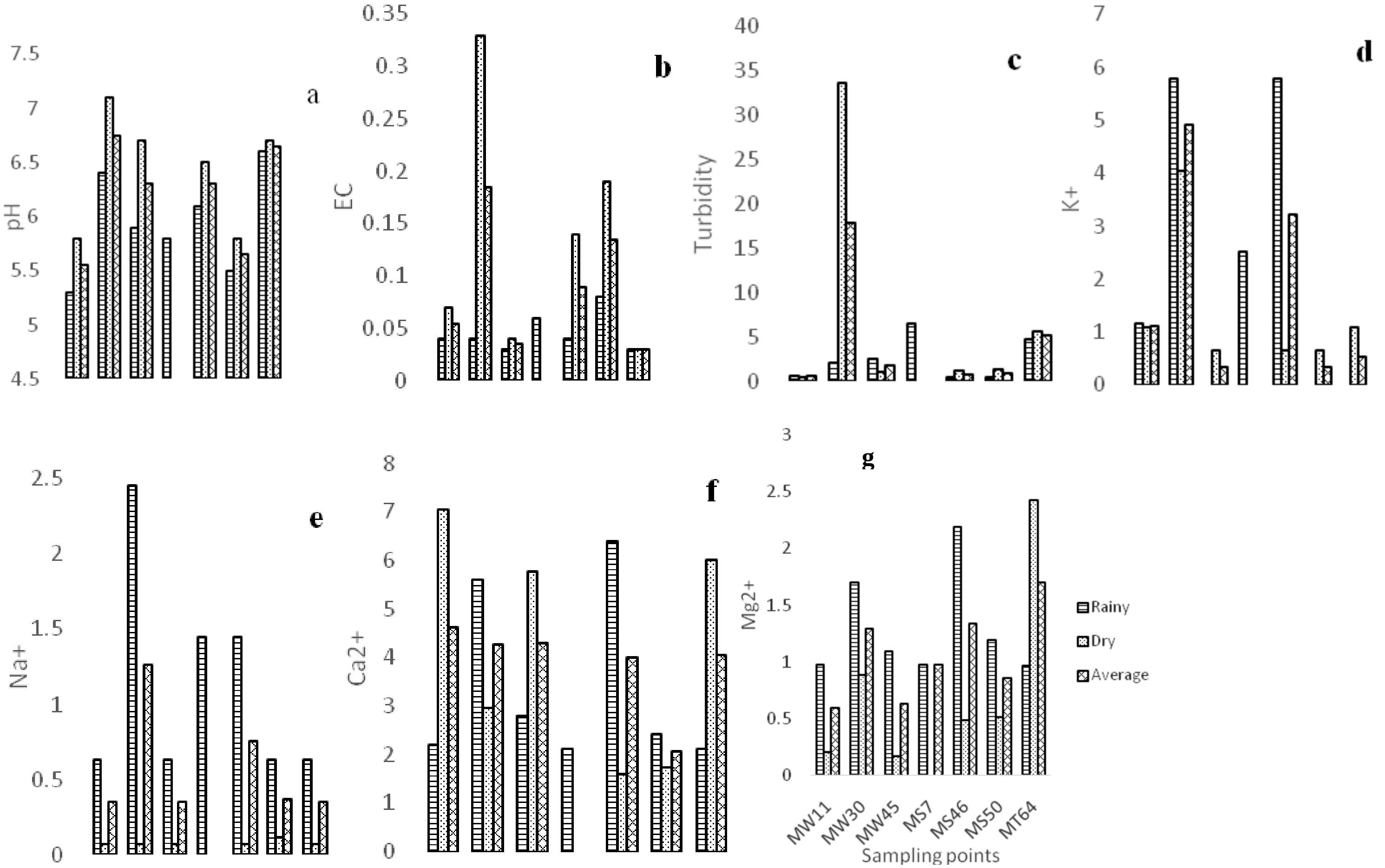

Figure 2. Temporal and spatial variation in physicochemical properties: a) pH, b) EC, c) Turbidity, d) K^+, e) Na^+, f) Ca^{2+}, g) Mg^{2+}. The labeling of the x- axis of Figure 2g serves as a legend for Figure 2 a to f.

The chemistry of subsurface water is a reflection of the geology of the surroundings, the residence time of the water, deposition from the atmosphere as well as diffuse pollutants from point and non-point sources (Lloyd and Heathcost, 1985). Studies carried out by Gibbs (1990) revealed an intrinsic link between water chemistry and hydrochemical processes in the aquifer. From Figure 5, it is evident that the principal control of subsurface water chemistry in Melong is rock-weathering as supported by all the cations and anions plotting in that field for both seasons.

Bacteriological characteristics

The bacteriological properties of the analysed water are presented in Table 3. Species indicative of faecal pollution were detected from most of the sampled water with elevated counts recorded

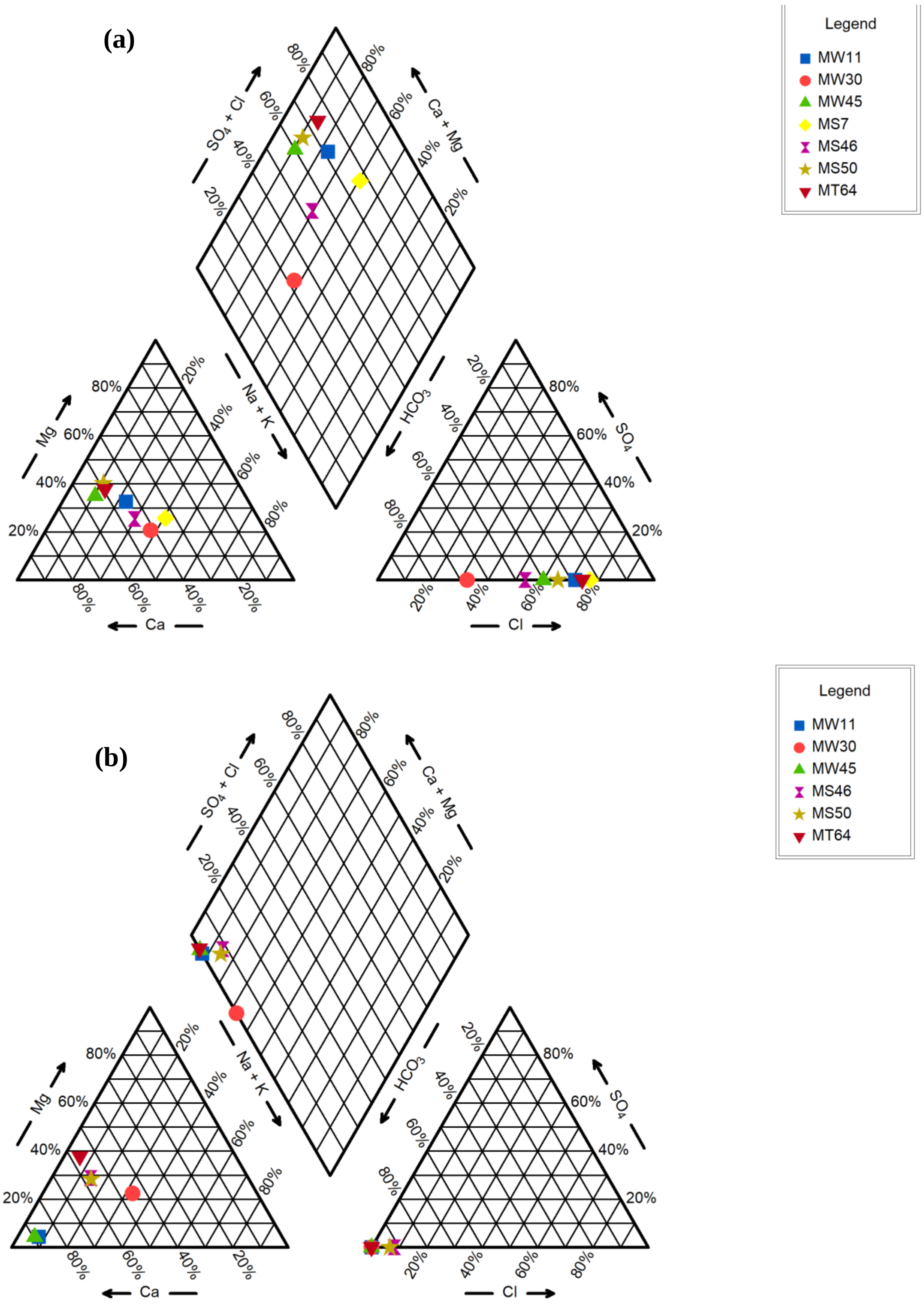

Figure 3. Piper's plots of groundwater in Melong for the rainy season (a) and dry season (b).

during the wet period and lower counts during the dry period. The highest count of *Enterobacteria* (700 CFU/100 ml) was obtained during the wet period in sample MS7 and the lowest value (50 CFU/100 ml) was obtained from sample MW11 in the dry period. *E. coli* counts were higher during the wet period in sample MS7

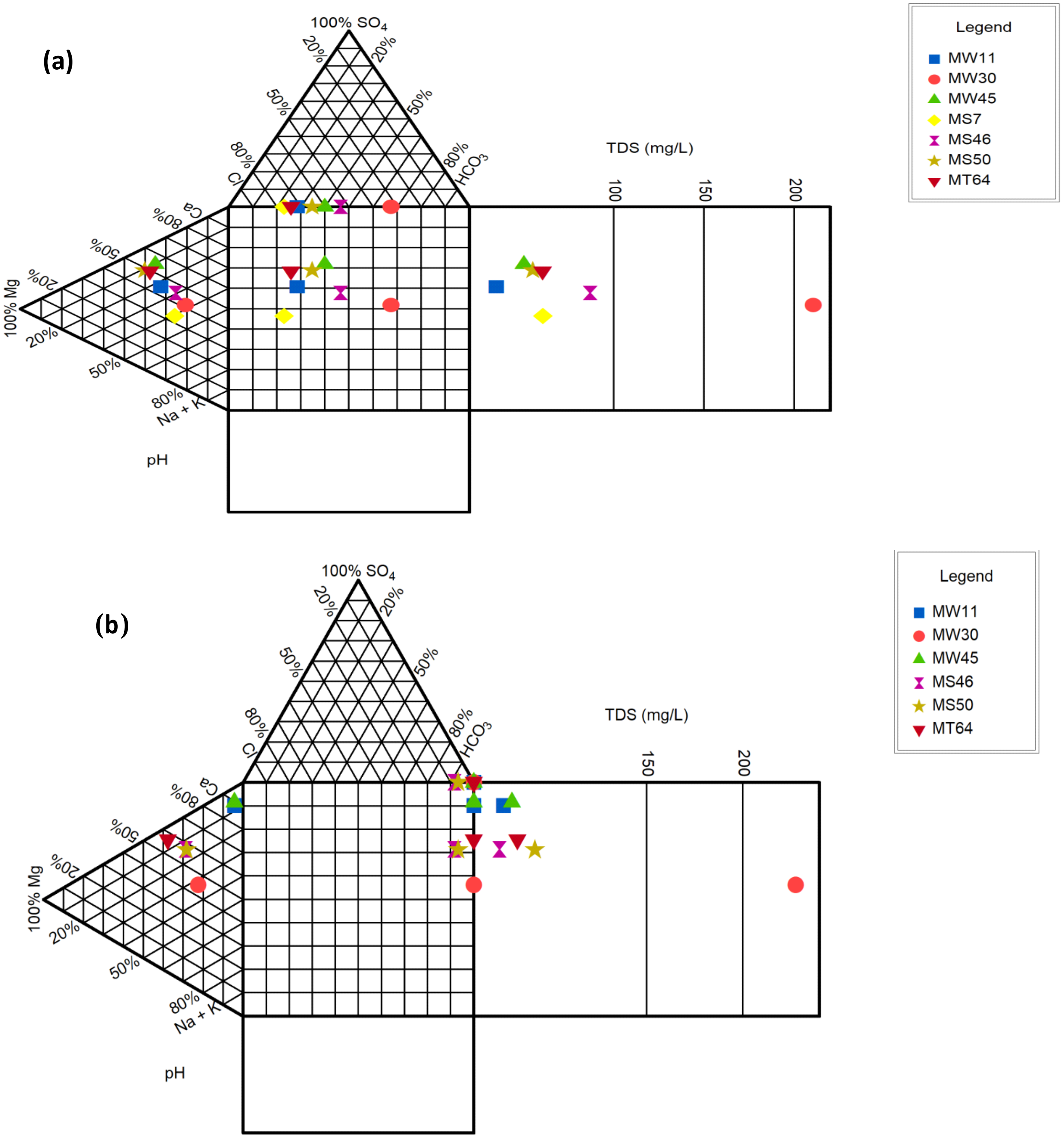

Figure 4. Durov plot of Melong water samples for the rainy season (a) and dry season (b).

(500 CFU/100 ml) and the lowest value (10 CFU/100 ml) was noted in sample MW11 in the dry period. *Streptococcus* count was also higher during the wet period in sample MS7 (150 CFU/100 ml) and lowest in sample MS46 (5 CFU/100 ml) in the dry period. *Salmonella* spp. was highest during the wet period in sample MT64 (300 CFU/100 ml) and lowest (15 CFU/100 ml) during the dry period in sample MW11. The highest load of *Shigella* during the wet period was noted in sample MS7 (50 CFU/100 ml) and the lowest in sample MW30 (10 CFU/100 ml) during the dry period. The highest value of *Staphylococcus* (300 CFU/100 ml) during the wet period was gotten from sample MS7 and the lowest from sample MS46 (5 CFU/100 ml) in the dry

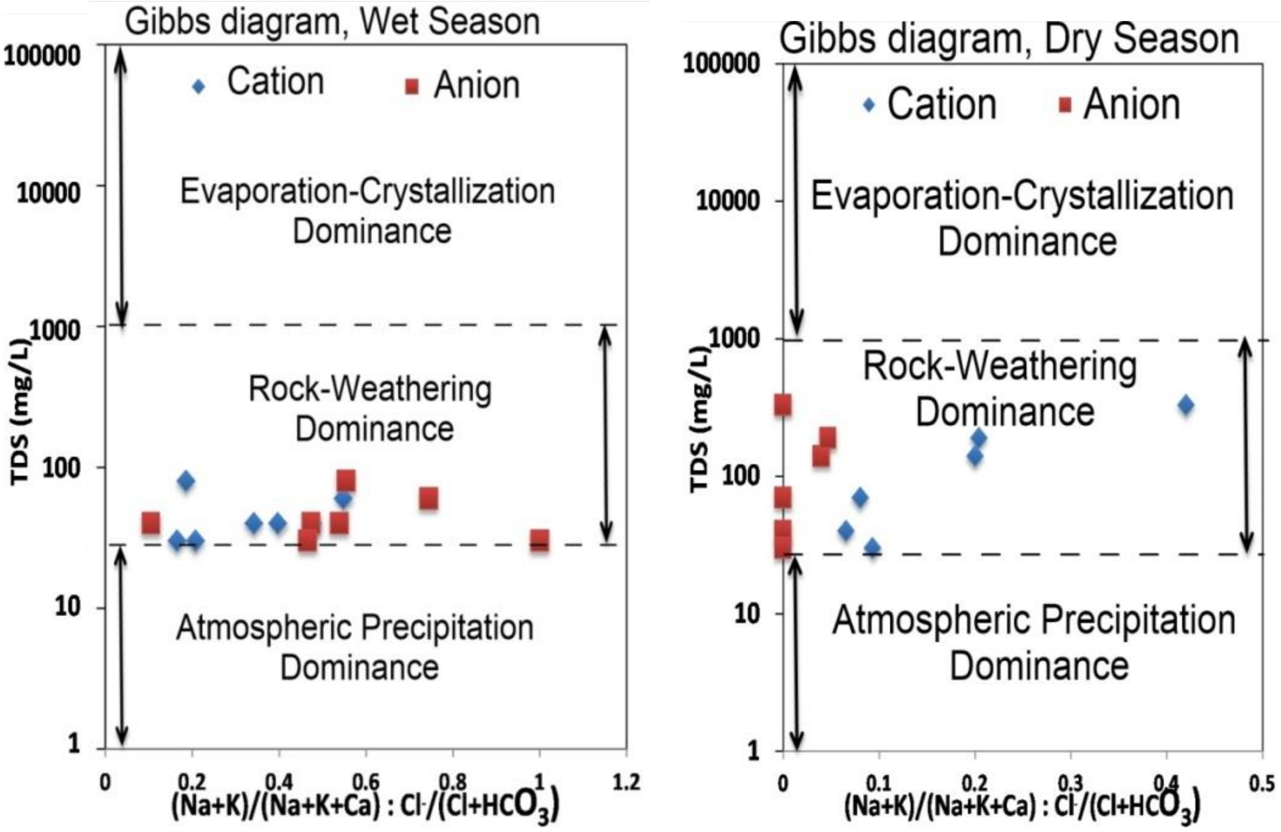

Figure 5. Gibbs diagram for sources of ionic content in Melong.

Table 3. Temporal and spatial variation of indicator bacteria in CFU/100 ml.

Sampling points / pollutant	Rainy season							Dry season						
	MW11	MW30	MW45	MS7	MS46	MS50	MT64	MW11	MW30	MW45	MS46	MS50	MT64
Enterobacteria	300	500	250	700	200	100	600	50	150	500	400	600	00
E. coli	150	300	100	500	100	50	400	10	100	300	200	400	00
Streptococcus	20	04	25	150	00	03	20	00	30	10	05	50	00
Salmonella	50	200	90	200	50	75	300	15	30	150	100	200	00
Shigella	10	15	10	50	20	00	40	00	10	50	15	00	00
Staphylococcus	00	05	00	300	05	00	120	10	20	00	05	00	00
Vibrio	01	01	02	150	00	00	30	00	10	10	00	30	00

period. The highest value of *Vibrio* was noted in the wet period from sample MS7 (150 CFU/100 ml) and the lowest (10 CFU/100 ml) from samples MW30 and MW45 was obtained during the dry period. There was no spectacular variation in indicator bacteria amongst the sampling points. High counts prevailed during the wet period whereas lower counts were noted during the dry period, with *Enterobacteria* portraying the highest counts of 700 CFU/100 ml in MS7 during the wet period. This same sampling point presented high counts of *Vibrio* (150 CFU/100 ml). On the other hand, *Streptococcus* was not detected in water samples from MS46 during the wet period but was recorded during the dry period. All species were absent in MT64 in the dry season.

Fitness of the studied water sources for domestic uses

The results obtained were assessed to appraise the potability of the analysed water for domestic use with reference to WHO (2017) guidelines. pH values of the subsurface water was slightly acidic to neutral and water samples from MW11, MW45, MS46 and MS50 had values out of the permissible limits of WHO in the rainy season. Turbidity values higher than 5 NTU were obtained from MS7, MW30 and MT64. This is an indication of exposure of the water sources to physical contaminants as a result of lack of protective measures. The values of Cl^- exceeded the recommended levels in the wet period in all the water samples whereas all the other parameters were within acceptable limits for drinking water. With respect to water hardness, the analysed samples had values fluctuating from 9.22 to 24.98 mg/L during the wet season and 6.01 to 24.96 mg/L during the dry period. Water hardness is of prime importance in appreciating water quality for domestic use and is ascribed to the occurrence of alkaline earth metals (Ca^{2+} and Mg^{2+}). Hard water may pose no impact on health but rather an aesthetic issue due to disagreeable taste. With reference to Pandian and Sanka (2007) hardness classification, all groundwater samples in Melong can be classed as soft in both seasons, thus would have no potential health risk on the users. From a bacteriological perspective, the sampling points were grossly polluted with the exception of MW11 and MT64 in the dry season in which the level of indicator bacteria could be acceptable with respect to Cheesbrough (1991) classification. All the other sampling points require basic treatment before the water can be used for domestic purposes.

Suitability of the studied groundwater for agriculture

Characterizing water for agriculture is primordial because low quality water may adversely affect the output of some plant species (Mohammad et al., 2018). Watering of crops during the dry period is a common practice in Melong. This therefore necessitates investigating the category of water employed because contaminated water would have negative consequences on the crops that are watered. Irrigation water that contains high concentration of sodium salts would cause the salts to pile up in the root zones of crops thereby impeding the flow of water in the soil by physically damaging the soil structure. The classification of the water sources based on SAR values revealed that all samples from the water sources were below permissible levels according to Mohammad et al. (2018) and thus fit for agriculture.

Vulnerability of groundwater sources to pollution in Melong

Groundwater is easily accessed in Melong through hand-dug shallow wells which are in most cases not protected from pollution from diverse sources. The area is susceptible to floods during the wet season as the flood water overflows into the wells, thereby, raising the level of contaminants of the water. The indiscriminate use of fertilizers by farmers to increase crop yield, as well as cattle rearing upland by the Bororo grazers, where cow dung is often carried by overland flow to lower altitude where the poorly constructed wells are found poses a great threat to the quality of groundwater resources. In most cases, poorly constructed latrines are not far from the hand-dug shallow wells and faecal waste could easily infiltrate and flow with groundwater to contaminate the water.

Conclusion

This current research was designed to investigate groundwater characteristics used in Melong (Littoral Cameroon) for domestic and irrigation activities. Subsurface water in Melong is acidic to neutral in nature, soft and lightly mineralized. Major water type is $CaHCO_3$ whereas the main hydrogeochemical facies present were Ca-Mg-Cl-SO_4 and Ca-Mg-HCO_3. Water chemistry is predominantly controlled by weathering of the host rock through mineral dissolution and ion exchange processes as well as anthropogenic sources. Analytical results of the water samples revealed that tap water which served as the reference sampling point was of reasonable good quality thus, healthier than the well and spring water. Chemically, groundwater sources in Melong are fit for home use as well as for agricultural activities. As concerns bacteriological quality, all analysed samples presented indicators of pollution except for the tap water sample in the dry season. The subsurface water sources may threaten human health if the water is consumed without pre-treatment. A heavy metal investigation is therefore recommended for the groundwater sources so as to establish their suitability for various activities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ako AA, Shimada J, Hosono T, Ichiyanagi K, Nkeng GE, Fantong WY, Eyong GE, Roger NN (2011). Evaluation of Groundwater quality and its suitability for drinking, domestic, and agricultural uses in the Banana Plain (Mbanga, Njombe and Penja) of the Cameroon Volcanic Line. Journal of Environmental Geochemistry and Health33:559-575.

Akoachere R, Ngwese YM (2017). Dug Well Biological Water Quality in Kumba– Cameroon: GIS Evaluation and Seasonal Variation of

Pollution – Indicator. Geoinfor Geostat: An Overview 5:3.

Akoanung A, Endene E, Enoh JF, Akoachere RA (2019). Assessment of groundwater quality in Bamenda–Cameroon for suitable applications. Springer Nature 1:1389. Alakeh NM, Njoyim EBT, Mvondo-Ze AD (2017). Quality Assessment of Some Springs in the Awing Community, North West Cameroon and their Health Implications. Journal of Chemistry pp. 1-5.

Annapoorna H, Janardhana MR (2015). Assessment of Groundwater Quality for Drinking Purpose in Rural Areas Surrounding a Defunct Copper Mine, Aquatic Procedia 4:685-692.

APHA **(**American Public Health Association) (1995). Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WEF: Washington DC, USA, ISBN 978-0-87553-235-6.

Appelo CAJ, Postma D (2005). Geochemistry, groundwater and pollution. Balkema, Netherlands 536 p.

Artimes GD, Ramin SD, Nagaraju (2011). Hydro geochemical and rock water interaction studies in East of Kurdistan, N-W of Iran. International Journal of Environmental Science and Research 1:16-22.

Cheesbrough (1991). Medical Laboratory Manual for Tropical Countries. 2nd Edition, ELBS 605 p.

Dirisu CG, Mafiana MO, Dirisu GB, Modou AR (2019). Level of pH in drinking water of an oil and gas producing community and perceived biological and health implications. European Journal of Basic and Applied Sciences 3:2059-3058.

Durov SA (1948). Classification of natural waters and graphical representation of their composition. Doklady Akademii Nauk SSSR 59:87-90.

Eneke GT, Ayonghe SN, Chandrasekharam D, Ntchancho R, Ako AA, Mouncherou OF, Thambidurai P (2011). Controls on groundwater chemistry in a highly urbanised coastal area. International Journal of Environmental Research 5(2):475-490.

Gibbs RJ (1990). Mechanisms Controlling World's Water Chemistry. Science 170:1088-1090.

Gift RA, Olalekan RM (2020). Access to electricity and water in Nigeria: a panacea to slow the spread of Covid-19. Open Access Journal of Science 4(2):34.

Gift RA, Olalekan RM, Owobi OE, Oluwakemi RM, Anu B, Funmilayo AA (2020). Nigerians crying for availability of electricity and water: a key driver to life coping measures for deepening stay at home inclusion to slow covid-19 spread. Open Access Journal of Science 4(3):69-80.

Gountié Dedzo M, Tsozué D, Mimba ME, Teddy F, Nembungwe RM, Linida S (2017). Importance of Rocks and Their Weathering Products on Groundwater Quality in Central-East Cameroon. Hydrology 4:1-18.

Hounslow AW (1995). Water Quality Data: Analysis and Interpretation. Lewis Publisher, New York. CRC Press 397 p.

Hussain MI, Morufu OR, Henry OS (2021a). Probabilistic Assessment of Self-Reported Symptoms on Farmers Health: A Case Study in Kano State for Kura Local Government Area of Nigeria. Research on World Agricultural Economy 2:1.

Hussain MI, Morufu OR, Henry OS (2021b). Patterns of Chemical Pesticide Use and Determinants of Self-Reported Symptoms on Farmers Health: A Case Study in Kano State for Kura Local Government Area of Nigeria. Research on World Agricultural Economy 2:1.

Isah HM, Raimi MO, Sawyerr HO, Odipe OE, Bashir BG, Suleiman H (2020a). Qualitative Adverse Health Experience Associated with Pesticides Usage among Farmers from Kura, Kano State, Nigeria. Merit Research Journal of Medicine and Medical Sciences (ISSN: 2354-323X) 8(8):432-447.

Isah HM, Sawyerr HO, Raimi MO, Bashir BG, Haladu S, Odipe OE (2020b). Assessment of Commonly Used Pesticides and Frequency of Self-Reported Symptoms on Farmers Health in Kura, Kano State, Nigeria. Journal of Education and Learning Management (JELM) 1:31-54.

Itiga Z, Chakam Tagheum PJ, Wotchoko P, Wandji P, Bardintzeff JM, Bellon H (2004). La ligne du Cameroun: Volcanologie et geochronologie de trios regions (Mont Manengouba, du Noun at Tchabal Gangdaba). Geochronique 91:13-16.

Kagou AD, Wandji P, Pouclet A, Vicat JP, Cheilletz A, Nkouathio DG, Alexandrov P, Tchoua FM (2001). Evolution volcanologique du mont Manengouba (Ligne du Cameroun) nouvelles données pétrographiques, géochimiques et géochronologique. Comptes Rendus de l'Académie des Sciences. Terre et Planètes 333:155-162.

Katte VY, Fonteh MF, Guemuh GN (2003). Domestic water quality in urban centers in Cameroon: a case study of Dschang in the West Province. African Water Journal, pp. 43-54.

Kemper KE (2004**)**. Groundwater from development to management. Hydrogeology Journal 12:3-5.

Kuitcha D, Ndjama J, Awah MT, Lienou G, Kamgang KBV, Ateba BH, Ekodeck GE (2010). Bacterial contamination of water points of the upper Mfoundi watershed, Yaounde, Cameroon. African Journal of Microbiology Research 4:568-574.

Lloyd JA, Heathcote JA (1985). Natural inorganic hydrochemistry in relation to groundwater: An introduction. Oxford University Press: Oxford, UK 296 p.

Macdonald AM, Bonsor HC, Dochartaigh BEQ, Taylor RG (2012). Quantitative Maps of Groundwater Resources in Africa.

Magha AM, Tita MA, Kouankap NGD, Wotchoko P, Ayuk MT, Kamgang VK (2015). Physico-Chemical and Bacteriological Characterization of Spring and Well Water in Bameneda III (NW, Region Cameroon). American Journal of Environmental Protection 4:163-173.

Mohammad Z, Shabbir A, Lee H (2018). Irrigation Water Quality. International Atomic Energy Agency. https://doi.org/10.1007/978-3-319-96190-3_5.

Molua EL, Lambi CM (2006). Climate, hydrology and water resources in Cameroon, Discussion Paper. CEEPA 37.

Morufu OR (2021). "Self-reported Symptoms on Farmers Health and Commonly Used Pesticides Related to Exposure in Kura, Kano State, Nigeria". Annals of Community Medicine and Public Health 1(1):1002. http://www.remedypublications.com/open-access/self-reported-symptoms-on-farmers-health-and-commonly-used-pesticides-related-6595.pdf. http://www.remedypublications.com/annals-of-community-medicine-public-health-home.php.

Morufu R, Clinton E (2017). Assessment of Trace Elements in Surface and Ground Water Quality (2017) LAP Lambert Academic Publishing. Mauritius. ISBN: 978-3-659-38813-2. www.omniscriptum.com.

Nickson RT, McArthur JM, Shrestha B, Kyaw-Nyint TO, Lowry D (2005). Arsenic and other drinking water quality issues, Muzaffargarh District, Pakistan. Applied Geochemistry 20:55-68.

Olalekan RM, Adedoyin OO, Ayibatonbira A (2019). "Digging deeper" evidence on water crisis and its solution in Nigeria for Bayelsa state: a study of current scenario. International Journal of Hydrology 3(4):244-257.

Olalekan RM, Dodeye EO, Efegbere HA, Odipe OE. Deinkuro NS, Babatunde A, Ochayi EO (2020) Leaving No One Behind? Drinking-Water Challenge on the Rise in Niger Delta Region of Nigeria: A Review. Merit Research Journal of Environmental Science and Toxicology (ISSN:2350-2266) 6(1):031-049.

Olalekan RM, Vivien OT, Adedoyin OO (2018). The sources of water supply, sanitation facilities and hygiene practices in oil producing communities in central senatorial district of Bayelsa state, Nigeria. MOJ Public Health 7(6):337-345.

Olalekan RM, Omidiji AO, Nimisngha D, Odipe OE, Olalekan AS (2018). Health Risk Assessment on Heavy Metals Ingestion through Groundwater Drinking Pathway for Residents in an Oil and Gas Producing Area of Rivers State, Nigeria. Open Journal of Yangtze Gas and Oil 3:191-206.

Pandian K, Sankar K (2007). Hydrochemistry and Groundwater Quality in the Vaippar River Basin. Journal of the Geological Society of India 69:970-982.

Piper AM (1944). A graphical interpretation of water-analysis. Transactions of the American Geophysical Union 25:914-928.

Raimi MO, Sabinus CE (2017). An Assessment of Trace Elements in Surface and Ground Water Quality in the Ebocha-Obrikom Oil and Gas Producing Area of Rivers State, Nigeria. International Journal for Scientific and Engineering Research 8(6). ISSN: 2229-5518.

Raimi MO, Abdulraheem AF, Major I, Odipe OE, Isa HM, Onyeche C (2019). The Sources of Water Supply, Sanitation Facilities and Hygiene Practices in an Island Community: Amassoma, Bayelsa State, Nigeria. Public Health Open Access 3(1):000134. ISSN: 2578-5001.

Raimi MO, Omidiji AO, Adeolu TA, Odipe OE, Babatunde A (2019). An Analysis of Bayelsa State Water Challenges on the Rise and Its Possible Solutions. Acta Scientific Agriculture 3(8):110-125.

Raimi MO, Pigha TK, Ochayi, EO (2017). Water-Related Problems and Health Conditions in the Oil Producing Communities in Central Senatorial District of Bayelsa State. Imperial Journal of Interdisciplinary Research (IJIR) 3(6):2454-1362.

Sabrina S, Palazzini D, Sieliechi JM, Ngassoum MB (2013). An Assessment of Physical-Chemical Drinking Water Quality in the Lagone Valley. Sustainability 5:3060-3076. doi:10.3390/su5073060.

Sato H, Aramaki S, Kusakabe M, Hirabayashi JI, Sano Y, Nojiri Y, Tchoua FM (1990). Geochemical difference of basalts between polygenetic and monogenetic volcanoes in the central part of the Cameroon Volcanic Line. Geochemical Journal 6:357-370.

Sudha M (2007). Ground Water Management: Need for Sustainable Approach, pp. 1-10.

Sujay RN, Paresh CD (2015). Sustainable Development and Management of Groundwater resources in Mining Affected areas: A Review. Procedia Earth and Planetary Science, ScienceDirect 11:598-604.

Tita MA, Magha AM, Kamgang KV (2013). Microbial pollution of the Mezam River System and its health impact in Bamenda (North West of Cameroon). African Journal of Microbiology Research 42:4940-4948.

Trivedy RK, Goel PK **(**1986). Chemical and biological method for water pollution studies. Environmental publication. Karad. tropical." Revue d'Hydrobiologie Tropicale 26:219-228.

World Health Organization (WHO) (2017). Guidelines for Drinking-Water Quality. Fourth Edition Incorporating the First Addendum, World Health Organization, Geneva. ISBN 978-92-4-154995-0.

Winter TC, Harve WJ, Franke OL, Alley WM (1998). Ground water and surface water: A single resource, US Geological Survey Circular 1139, Denver, Colorado 87 p. http://pubs.usgs.gov/circ/circ1139/index.html.

Yıldız D (2017). The Importance of Water in Development 1, World Water Diplomacy and Science News. Hydropolitics Academy. Ankara-Turkey pp. 1-7. https://www.researchgate.net/publication/321292650.

Zheng XD, Zhang HY, Xi YF (2004). Effects of Cryptococcuslaurentii (Kufferath) Skinner on biocontrol of post harvest decay of arbutus berries. Botanical Bulletin of Academia Sinica 45:55-60.

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The study of land use and land cover (LULC) dynamics and the perception of local people in Aykoleba, Northern Ethiopia

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It is believed that since the advent of agriculture, changes in land use and land cover (LULC) have happened. However, rates, extents and intensities of LULC changes have become more aggravated at all levels. The current study aims to examine the dynamics and perceptions of LULC change in the last four decades (1973-2013) in Aykoleba, Ethiopia using a combination of remote sensing data and the ground truth data. Focus group discussions were employed to obtain data on the status of land degradation. Remote sensing data were obtained using Landsat imageries of MSS (1973), Landsat TM, 1986 and 2000, and Landsat ETM+ (2013) with 30 m spatial resolution. ArcGIS10.2 and ERDAS Imagine13.1 were used to generate LULC classes. Accordingly, four LULC classes were identified, of which forest and bare LULC have been augmented by 8.8 and 54.9%, respectively. The escalation in forest cover is associated with plantation of eucalyptus near the home gardens, farmlands, and degraded areas. Nevertheless, open bush and grassland, and cultivated and settlement land cover classes were lessened by 27.4 and 37.8%, respectively although increase in bare land is related to abandonment of the cultivated land in hilly and sloppy areas, and overgrazing, among other factors. The local community perceived that population pressure is a top driver of LULC change in the study area. Overgrazing and lack of appropriate land use policy are also significant causes of change. Thus, the establishment of land use plan and appropriate population policy is recommended in Ethiopia.

Key words: Analysis, dynamics, Ethiopia, land cover, land use.

INTRODUCTION

Land-use refers to means in which land has been utilized by humans and their territory, commonly highlighting the functional nature of land for economic activities (Rawat and Kumar, 2015). Lambin et al. (2003) also discussed

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land use as the aim for which human beings exploit the land cover whereas Rawat and Kumar (2015) viewed a land cover as the physical attribute of the earth's surface. Land cover refers to social, cultural, and economic feature that entails human beings as they influence, outline, and create the environment (Wood and Porro, 2000). According to Quentin et al. (2006), any biological, physical or chemical changes related to land management are referred to as land use change. It is believed that changes in land use and land cover (LULC) occurred since the start of agriculture but the prevailing rates and intensities of LULC modifications are far larger than ever in the history of human beings, triggered by unmatched alterations in the ecosystems and environmental processes at different geographic scales. The topic of LULC change has developed a hot research agenda on international environmental dynamics and understanding the effects of surface processes on climate (Sagan et al., 2014). Dinka (2012) explained LULC change (LULCC) as the alteration of environment by human beings, which influence climate, biogeochemical cycles, ecological circumstances, and geomorphology. Such changes are associated with deforestation, agricultural expansion, and urban expansion, among others (Liu et al., 2007). Both natural and anthropogenic land cover dynamics affect biodiversity and the ecosystem services (Haque and Basak, 2017), cease socio-cultural practices, and improve natural disasters such as flooding (Mac et al., 2004).

Land degradation in developing countries, mainly sourced from the LULC is characterized by the current agricultural land expansion and production system (Mekuria, 2005; Barana et al., 2016), which can be revealed by intensified surface runoff as well as decline in yield. Many countries of low economy have rich natural resources and depend upon them, and have contributed to environmental out migration (IPBES, 2019). According to Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services//IPBES (2018), battling land degradation in Africa and restoring the degraded land is an urgent priority to protecting the biodiversity and ecosystem services.

IPBES (2018) also indicated the expansion of agriculture into native vegetation, climate change; indefensible forestry practices, urban growth, and infrastructural development are principal direct drivers of land degradation and related biodiversity loss. The rate and intensity of the dynamics of land use modification in Ethiopian agricultural land areas has increased significantly during the last decades at the expense of natural vegetation (Kiros, 2008), and gave rise to severe degradation of the natural environment, the downturn and ultimate extinction of species and the loss of ecosystem services (IPBES, 2018). Deforestation and the consequent land degradation are global threats, and so are they in Ethiopia (Adugnaw, 2014). Land degradation is common in heavily populated highlands of Ethiopia (Aklilu et al., 2007). It is undesirable outcome of obstinate deforestation, physical and biological soil deterioration, and overgrazing of the agricultural land use types (Hurni, 1993), which consecutively caused low agricultural produce and poverty (Pender and Birhanu, 2007).

Various studies in Ethiopia depicted that increased dynamics of LULC was associated mainly with the high population pressure and the complex landscape where there is a heavy rainfall in the highlands of the country (Helden, 1987; Aklilu et al., 2007; Tadesse et al., 2017; Fikire et al., 2021), which has led to an escalation in the susceptibility of vegetation cover, land degradation and the reduction of biological resources. This in turn caused the environmental decline (Barana et al., 2016), and hostile influences the livelihood poverty (Hagos, 2014; Mohammed et al., 2017). IPBES (2018) depicted seriousness of the problem in its report that climate change and land degradation are liable to force 50 to 700 million individuals to migrate by 2050. Wubie et al. (2016) also discussed that land degradation; desertification and biodiversity loss are effects of LULC change in Ethiopia. Traditional poor agricultural systems mingled with weak policies and institutional environments along with other socioeconomic problems have given rise to LULC changes in Ethiopia (Zeleke and Hurni, 2001). Therefore, the connection between LULC change and its causal factors remain multifaceted and dynamic (Mather and Needle, 2000).

The aforementioned facts demand both national and international attention on regular tracking of the changes using the latest data on LULC with the purpose to evaluate complex causes and effects in order to plan future tendencies better at different scales (Prenzel, 2004). Change analysis and detection of features of earth's surface allow someone to comprehend the natural phenomena (Butt et al., 2015). LULC change detection is of a vital importance to realize the landscape dynamic and sustainable land use management (Rawat and Kumar, 2015). Gathering remotely sensed data permits synoptic study of the earth-system function, patterning, and changes at diverse scales over time. Such data also offer an authoritative link between localized ecological research, and conservation of biodiversity (Haque and Basak, 2017).

The assessment of the study area and development of a management plan demand appropriate quantification of the present and past LULC parameters as changes perceived to help in realizing both anthropogenic and natural processes. Accordingly, the present study area, Aykolba, was chosen for the change detection since it is exposed to land degradation, deforestation, and overgrazing among others. Therefore, the major aim of the study was to investigate LULC dynamics and perceptions of LULC change over the last four decades (1973-2013) in Aykoleba.

The study seeks to answer the following research questions:

(a) What are LULC categories and patterns of land use dynamics over the last 4 decades (from 1973 to 2013) in Aykoleba?
(b) Is there a shift in LULC categories through spatial comparison of the LULC maps produced?
(c) How do local communities perceive LULC dynamics of the study area?

MATERIALS AND METHODS

The study area

Aykoleba is located in Wogera *Woreda* (district) of Amhara Regional State, Ethiopia (Figure 1), which covers an area of 14, 424 ha. The study area lies between the geographic coordinates of 14°10'52"N to 14°36'855" N latitude, and 35°63'04" E to 36°30' 84"E longitudes. The climate of Aykoleba falls within the *Woyna Dega* (mid land) to *Dega* (high land) and the altitudinal range of 1800 and 3080 m above sea level (asl) (WWAB, 2017). The average annual mean temperature is 15.5°C whereas the annual rainfall ranges between 500 and 1600 mm with an average of 900 mm Ethiopian Meteorological Services (EMS, 2013). The *Woreda* has a total population of 244,928 (124653 males and 120275 females) with an average population density of 134.5 persons/km^2 but the total population of the study area was 3,736 Central Statistical Agency (CSA, 2007). The soil types common to the study area include vertisols and cambisols though cambisol covers > 50% of the study area (FAO, 1986). Livelihoods of the majority of the population rely on mixed crop and livestock production systems Wogera *Woreda* Agricultural Bureau (WWAB, 2017).

Methods of data collection and analysis

The primary and secondary data were collected from diverse sources. For the LULC analysis, freely accessible time series Landsat satellite images were used (earthexplorer.usgs.gov). In order to examine LULC dynamics, Landsat imageries of MSS (1973), Landsat TM of 1986 and 2000, and Landsat ETM$^+$(2013) with 30 m spatial resolution were employed for Aykoleba (Stefanov et al., 2001). ASTER, DEM, and topographic map of the study area (1:50000) were collected from the Geospatial Information Institute of Ethiopia. Images were Ortho rectified into Universal Transfer Mercator (UTM) zone 37N, WGS 1984. Image processing and GIS data analysis were performed using remote sensing and GIS software, including ERDAS Imagine 13.1 and ArcGIS 10.2, respectively. Initially, images were transformed into UTM and Geo-referenced to a datum to which Ethiopia has been chosen by WGS-84. The demarcated study area was digitized in Arc GIS 10.2 to superimpose the view on spatial databases produced from the photographs and the satellite image.

The identification and classification of LULC types on the aerial photographs were presumed by visual interpretation with mirror stereoscope whereas post-classification change detection was used for the period of 1973 to 2013 following Singh (1989). The overall research procedure for the LULC change analysis was structured in the schematic diagram (Figure 2). Google earth image, field inventory and ground control point reading were major sources of data to generate the up-to-date land cover map of the study area. The trends and dynamics of LULC change were evaluated using Landsat image that offers a multi-temporal, multi-spectral and multi-resolution range of imagery for the land cover analysis following Oettera et al. (2000) and Yuan et al. (2005).

LULC change detection and NDVI methods were employed to examine the rate of land use change and the level of degradation following previous studies (Amanuel and Mulugeta, 2014). The normalized vegetation index (NDVI) values were extracted from the Landsat satellite images for the study periods to associate the result with supervised classification of land cover classes. The empirical formula for calculating NDVI = Near infrared - Visible red/Visible red + NIR; where NIR is the near infrared band value for a cell. NDVI value ranges from "+1 to -1" Close to '+1' means denser and greener vegetation and close to '0' means less green or other colored vegetation or dry leaf. '0' means no vegetation and '0 to1' represents other land cover types whereas negative values indicate the absence of vegetation that may match with the presence of water bodies (Haque and Basak, 2017).

Socio-economic data were gathered from 130 households selected randomly through household survey from the study area. In order to engage in-depth discussions, key informant interviews, and focus group discussions (FGD) were conducted to collect data regarding the past and present circumstances, including the drivers of LULC change of the study area. The district, administration, and household participants were chosen using a three-stage sample approach that included purposive and random sampling, while the household respondents are being chosen via systematic random sampling following Wubie et al. (2016). As a result, out of 2411 households 40 households were selected from each of the 3 elevation classes namely the lower (1800-1999 m asl), middle (2000-2499 m asl), and the upper (2500-3080 m. asl) classes. Sampling for the socio-economic survey of the study area was done in two phases. The first phase required selecting sample locations, while the second involved selecting individual households from the selected community. Furthermore, the focus group discussions (FGDs) were carried on with 16 participants (4 women and 12 men) to gain supplementary information about the long-term experience of LULC exercise in the study area. The participants for FGDs comprised of 4 farmers, 5 development agents, 4 *Kebele* (the smallest administrative structure in Ethiopia) cabinet members, and 3 community elders who were chosen by the *kebele* administrative bodies and the knowledgeable community representatives. For the in-depth discussion, 9 elderly peoples (age >60 years) were purposefully chosen as they were expected to have better historical information about the trends in LULC change over the past 4 decades. The study sample size was calculated as following Kothari (2004).

$$n = \frac{Z2.p.q.N}{e2\ (N-1) + Z2.p.q}$$

where n = denotes the sample size. Z = 95 confidence limit (interval) under normal curve that would be 1.96. P = 0.1 (percentage of the population to be included in the sample that is 10%). q = none occurrence of event = 1-0.1, which means (0.9). N = Total number of household = 2411. e = margin of error or degree of precision (acceptable error term) (0.05).

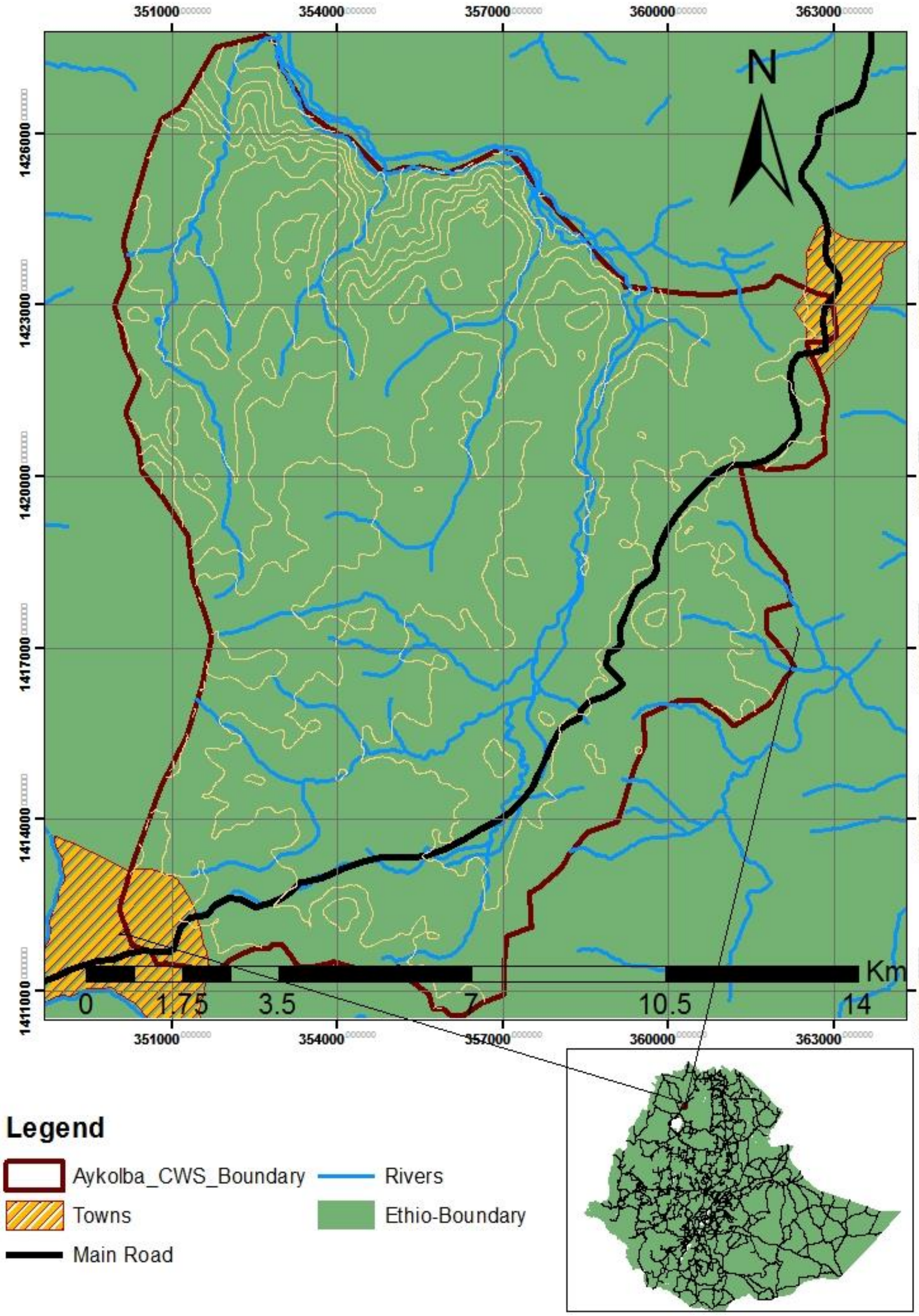

Figure 1. Location map of the study area (**Source**: WGS 1984, UTM Zone 37N, Projection: Transverse Mercator).

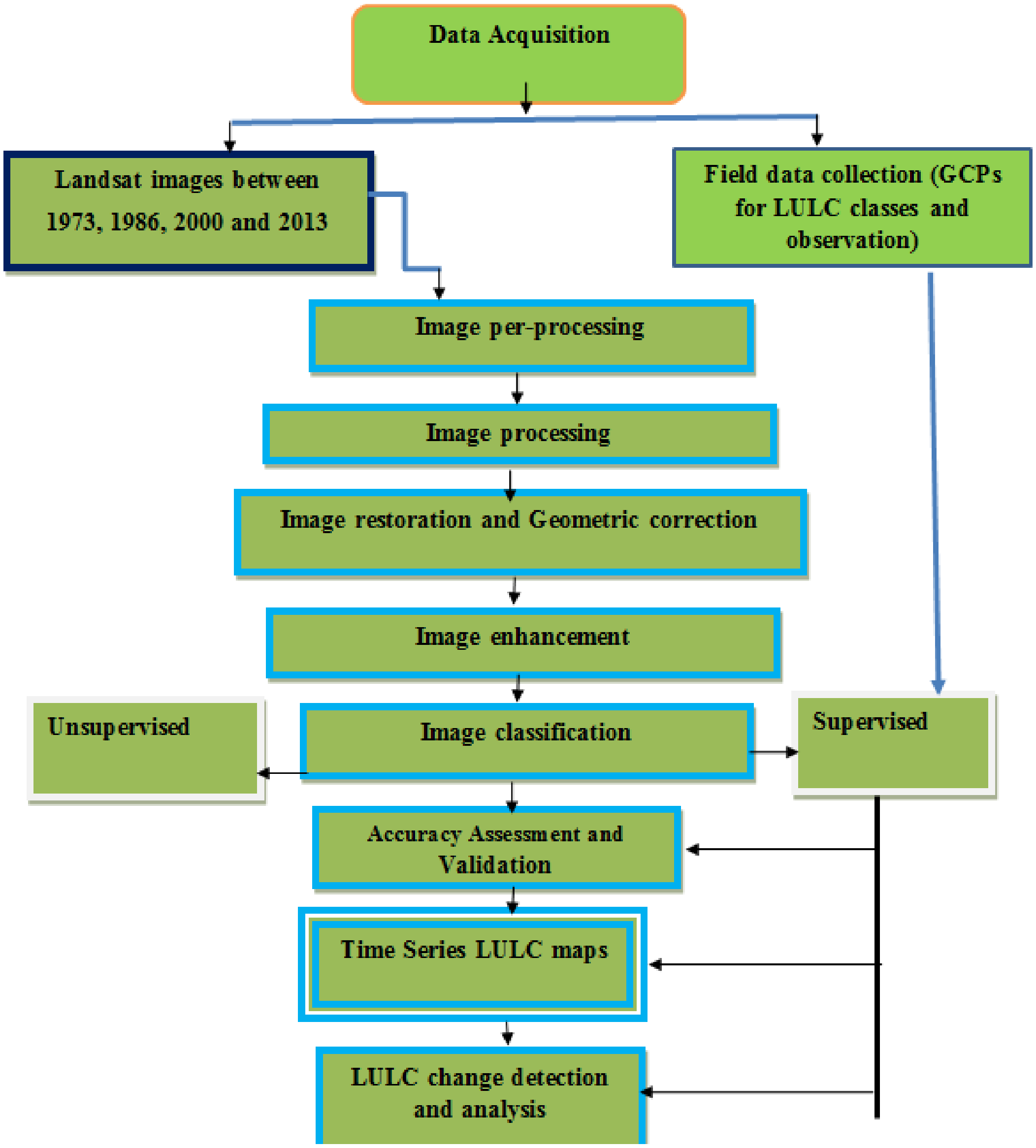

Figure 2. Schematic representation of LULC dynamics and data analysis process.

Accuracy assessment

Accuracy assessment was carried out by matching the classified image with the land cover classes on the topographic maps and the ground control points on the field. For the first comparison, accuracy evaluation based on 1973, 1986 and 2000 classified images were carried out through visual interpretation and the assistance of topographic maps. In this regard, 20 points were spread randomly across the classified image and topographic maps of the particular period. For the classified cover types, 40 random sampling points were set up and visited in the field for the validation of the actual cover type. Conversely, for the 2013 image, the ground truth data accuracy assessment was done by comparing remote sensing generated classification and the reference test data. Table 1 displays the findings of the confusion matrix generated to analyze the classification's accuracy. Overall accuracy is 89.4%, with a kappa value of 0.854. This means that 89.4% of LULC classes are correctly categorized. Individual class accuracy varies from 100% for cultivated land and settlement to 72% for forestland. The accuracy of the producers varies from 94.4% for degraded/bare land to 76.5% for open bush and grassland, respectively. Overall, kappa statistics of 0.854, indicating that there is 85% better agreement than would be expected by chance alone. According to Pontius (2000), whether the kappa statistics was much less than 0.4, between 0.4 and 0.7, or greater than 0.75, the scientifically acceptable outcome for kappa coefficient is bad, good, or excellent, respectively. Kappa represents an agreement between the classified LULC and the observed land use category. It was

Table 1. Confusion matrix of classification accuracies for Aykoleba.

Classified data	Reference data					
	OB&GL	C&SL	FL	DL	Total	User accuracy (%)
OB&GL	**26**	2	4	0	32	81.3
C&SL	0	**64**	0	0	64	100.0
FL	4	3	**27**	3	37	72.9
DL	4	0	0	**51**	55	92.7
Total	34	69	31	54	**188**	-
Producer accuracy (%)	76.5	92.8	87.1	94.4	-	-

Overall accuracy 89.4%; Kappa statistics 0.854. OB&GL= Open bush and grassland, C&SL= Cultivated and Settlement, FL= Forestland, DL= Degraded land.

evaluated following Butt et al. (2015) based on the equation:

$$\text{Kappa} = P\ (A) - P\ (E)/\ 1 - P\ (E) \qquad (1)$$

where P (A) represents the number of times the K raters agree, and P (E) represents the number of times the K raters are anticipated to agree by chance. P (A) and P (E) are computed using the following Equations 2 and 3:

$$P\ (A) = \frac{(CP+UP)}{(TP)} \qquad (2)$$

$$P\ (E) = \frac{(CP+MA)\ (CP+FA)+(FA+UP)\ (MP+UP\ )}{TP*TP} \qquad (3)$$

Here, changed pixels (CP) relate to pixels that have been detected to change, whilst unaltered pixels (UP) refers to pixels that have been identified to be unchanged. TP stands for total number of pixels, missed alarms rate (MA), and false alarms rate (FA), respectively. The sum of CP, UP, MA, and FA is TP. The higher the kappa coefficient, the more accurate the segmentation.

Change detection

It refers to the process of identifying alterations in the state of an object or phenomenon by ascertaining it at various times. Remote sensing based change detection employs assessment of a set of temporal images covering time of concern using specific change detection algorithms (ESCAP, 1996). Change detection is significant for monitoring the change of earth's surface features in order to realize interactions between human and his environment to enhance the management and use of natural resources as described by Singh (1989). With the aim of obtaining the information on LULC dynamics in terms of pattern and rate of conversion, post-classification change detection analysis was effected in ERDAS Imagine 13.1 employing classification images of 1973, 1986, 2000 and 2013. Effective use of Satellite Remote Sensing for LULC change detection relies upon appropriate knowledge of landscape topographies, imaging systems and a method engaged in association with the aim of the analysis (Yang and Lo, 2002). The change detection of LULC comprises the interpretation and analysis of multi-temporal and multi-source satellite images to categorize temporal phenomena or changes through a certain retro. There are four conditions of LULC change detection characteristics such as, detecting the changes that have occurred, classifying the nature of the change, computing the areal extent of the change, and evaluating the spatial pattern of the change as argued by Yismaw et al. (2014). Change detection methods have been grouped generally into image algebra, transformation and classification. Classification categories include post-classification comparison, spectral temporal combined analysis, expectation-maximization algorithm change detection, unsupervised change detection, and hybrid change detection and artificial neural networks (Lu et al, 2007). For detecting LULC changes, this study used post classification compassion, an integrated GIS and remote sensing method, and supervised classification. The major benefit of these techniques is their ability to offer a matrix of change information and minimize adverse impacts from atmospheric and environmental changes across multi-temporal images.

Post classification change detection

It links two individually formed classified LULC maps of two dissimilar dates. Accordingly, it reduces the problem of normalizing for atmospheric and depicts the nature of the variation. The LULC change detection is based on the assumption that the two LULC maps were created appropriately (Jensen, 2002). Post classification analysis encompasses autonomously made spectral classification outcomes from each end of the time interval of interest, followed by a pixel-by-pixel or segment-by-segment evaluation to find changes in cover type. Besides, to algorithms that are employed on the classified images to fix those pixels with a variation between the two dates, statistics can be compiled to express a certain nature of changes between the two images (Lillesand et al., 2004).

RESULTS AND DISCUSSION

LULC categories and patterns of land use dynamics

Four classes of LULC of the study area were identified (Table 2), namely, forestland, open bush and grassland, cultivated land and settlement, and bare land.

However, Table 3 reveals that open bush and grassland cover class of the study periods (1973-1986) and (2000-2013) declined by 76.6% (996 ha) and 102.5% (1332.9 ha),

Table 2. Land use cover classes of Aykoleba and their description.

No.	LULC Classes	Description of land cover type
1	Forest	Areas covered with trees forming a closed canopy or nearly closed canopy (70-100%).This includes the natural forest and plantation forest dominated by eucalyptus tree.
2	Open bush and grassland	Bush land and grassland Areas covered with a mixture of grass and bush/shrubs and areas covered with permanent grass and used as a communal grazing land.
3	Cultivated land and settlement	Areas used for cultivation, including fallow plots and a complex unit, i.e., cultivated land mixed with bushes and trees, and rural and urban homesteads.
4	Bare/Degraded land	Areas with very shallow soils, covered partly with scanty grass, bush/shrub, and exposed rocks. Normally consists of abandoned cultivated land or cultivated degraded soil and with exposed rocks, sometimes with gullies; used as local grazing land.

Table 3. Land cover classification of the year (1973-2013) for Aykoleba.

LULC Classes	Land cover in each year of image							
	1973		1986		2000		2013	
	ha	%	ha	%	ha	%	ha	%
Forest	1725.9	11.9	1071	7.4	2766.4	19.2	2080	14.5
Open bush and grass land	5525.9	38.1	4530.2	31.5	5762.8	40	4429.9	30.7
Cultivated land and settlement	5354.4	37	7706.5	53.5	3658.6	25.4	3842.4	26.6
Bare/Degraded land	1876.6	13	1098.9	7.6	2218.8	15.4	4071.7	28.2
Total	14406.6	100	14406.6	100	14406.6	100	14406	100

respectively but it increased by 88% (233 ha) from 1986 to 2000. Previous researchers (Aklilu et al., 2007) also notified that areas of open bush increased between 1982 and 1998. Forestland cover showed the increasing and decreasing trend during the second to forth study periods with a net raise in forestland cover when compared with its initial period (1973). There was also an increase in forest LULC of the study area from its level of 7.4% (1071 ha) in 1986 to 19.2% (2766.4 ha) in 2000 (Table 3).

The increment might be associated with soil and water conservation actions taken by the government as one of the natural resources management methods. This was implemented country wide between 1980s and 1990s following the incidences of drought and famine in Ethiopia. The drought-induced famine of 1984/1985 was reported as one of the worst in Africa, in terms of its intensity and coverage (Woldeamlak, 2009). Between 1986 and 2000, the tendency of forest LULC was altered and it was augmented by 121.1% (1695.4 ha) (Table 4). This could be linked with tree planting assisted by sustainable land management program in Ethiopia aimed at the conservation of soil and water as explained by Barana et al. (2016).

The reduction in forest cover during the first study period (1973 to 1986) is likely associated with the increased need for the cultivated land (Figure 3). This could have been due to a speedy annual population growth in the area by 2.7% (CSA, 2007), which probably required extra agricultural land. Similar, a study from Nigeria shows that the raise in the number of human population living in the forest reserve led many of them to be employed in farming, leading to an increase in farmland at the expense of forestland (Aderele et al., 2020). The land use policy changes, mainly land reform proclamations in the country between 1975 and 1997, and the loss of land productivity due to unsustainably farming have also significantly aided for the decline in the forest cover. Similar findings were reported from Southern

Table 4. Rate of LULC dynamics (1973-2013) in the Aykoleba.

S/N	LULC classes	Rate of LC Change							
		1973 to 1986		1986 to 2000		2000 to 2013		1973 to 2013	
		Area change (ha)	Rate of change (ha/year)	Area change (ha)	Rate of change (ha/year)	Area change (ha)	Rate of change (ha/year)	Area change (ha)	Rate of change (ha/year)
1	Forest	-654.9	-50.4	1695.4	121.1	- 686.4	- 52.8	354.1	8.8
2	Open bush and grass land	-995.7	-76.6	232.6	88	1332.9	-102.5	-1096	- 27.4
3	Cultivated land and settlement	2352.1	180.9	4047.9	-289.1	183.8	14.1	-1512	- 37.8
4	Bare/Degraded land	-777.7	-59.8	1119.9	80	1852.9	142.5	2195.1	54.9

Ethiopia (Barana et al., 2016). In addition, Mengistie et al. (2013) also discussed the disappearance of a Lake due to deforestation in Ethiopia.

LULC dynamics gained from the digital imagery investigation showed that unpredictable change of trends has been observed in forest LULC (Figure 4). Between 1973 and 1986, the cultivated and settlement land cover class gained 180.9% (2352.1 ha) area from other land cover classes and practiced a positive rate of change (Table 4). As discussed by participants of the FGD, during this period, cultivable lands were abundant and the population pressure was low in most places of the study area. This explanation is well associated with pieces of evidence in LULC dynamics acquired from the digital imagery analysis. Between 1986 and 2000, the rate of change was decreased by 289.1% (4048 ha) (Table 4), and it was shrinking from 53.5% (7707 ha) in 1986 to 25.4% (3659 ha) in 2000 (Table 3). This is most likely related to the migration of people to other areas. According to explanations from FGD and informants, a large number of Bete Israel migrated from the study area. This finding is in line with the study conducted by Lambin et al. (2006) who have revealed that migration caused changes. However, another study in Wallecha Watershed by Barana et al. (2016) indicated that the cultivated land has augmented with a rate of 30.75 ha/year mostly from forests, and shrub and grasslands. Between 1986 and 2013, the cultivated and settlement LULC showed decreasing and increasing trends. But in general there has been 37.8% (1512 ha) loss of this land cover class was recorded over the last 40 years (Table 4). The result of the LULC analysis disclosed that the area coverage of the bare land has been progressively increasing starting from 1986 (7.6%) to 2013 (28.2%). This might have been connected with the cultivation of sloppy areas, unsuitable farming systems as well as climatic factors that at the end yielded degraded land. However, the study on Wallecha Watershed from 1984 to 2000 indicated a trend of successive reduction of a bare land from 4.8 to 3.2% (Barana et al., 2016).

LULC classification

The LULC classification has resulted in four major LULC classes, namely forest, open bush and grassland, bare land, and cultivated and settlement (Table 3 and Figure 5).

The largest LULC of the existing study is the open bush and grassland covering about 31% of the total land area, followed by Bare or degraded land, which covers 28.2% (Figure 5). This probably shows high land degradation in the study area that may requires ecosystem restoration to protect the biodiversity loss and ensure ecosystem functionality. IPBES (2019) showed that presently, land degradation has reduced 23% of the productivity of the global terrestrial area. Thus, local and national sustainability efforts and mainstreaming biodiversity across all productive sectors has to be aligned, as depicted by IPBES report. LULC classification could vary based on the various factors such as altitude of the area, human culture, the distribution of the rainfall, soil types, etc. The study on LULC classifications indicated that the dominant LULC was agroforestry (69%) whereas only 4.9% of the degraded land cover was reported from Gedeo Zone in Ethiopia (Birhane and Melesse, 2015). Similar study from the same country reported that the largest land cover and the degraded land area cover to be

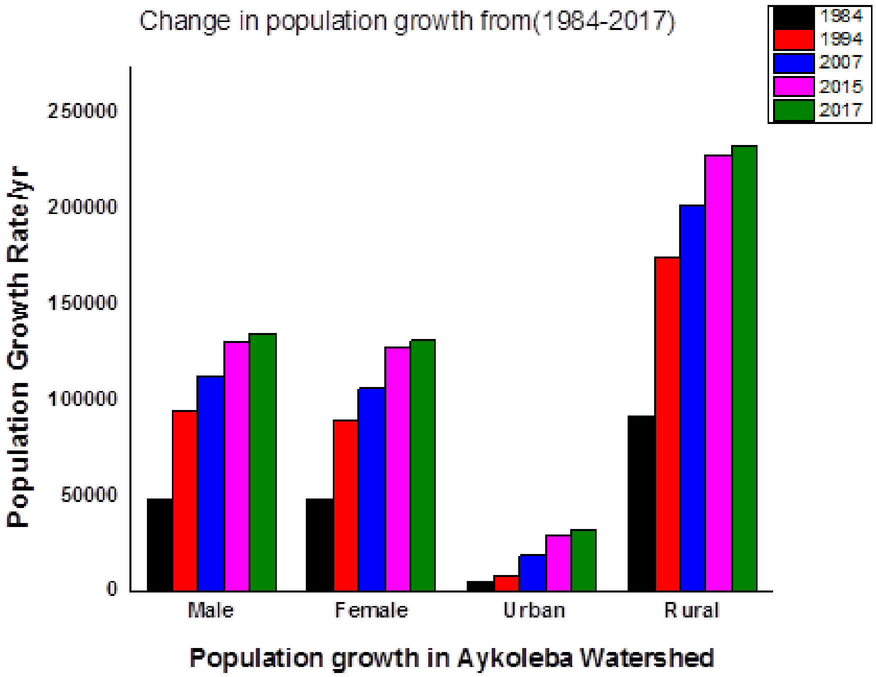

Figure 3. Population growth in Wogera *Woreda* between (1984-2017). Source: WWAB (2017).

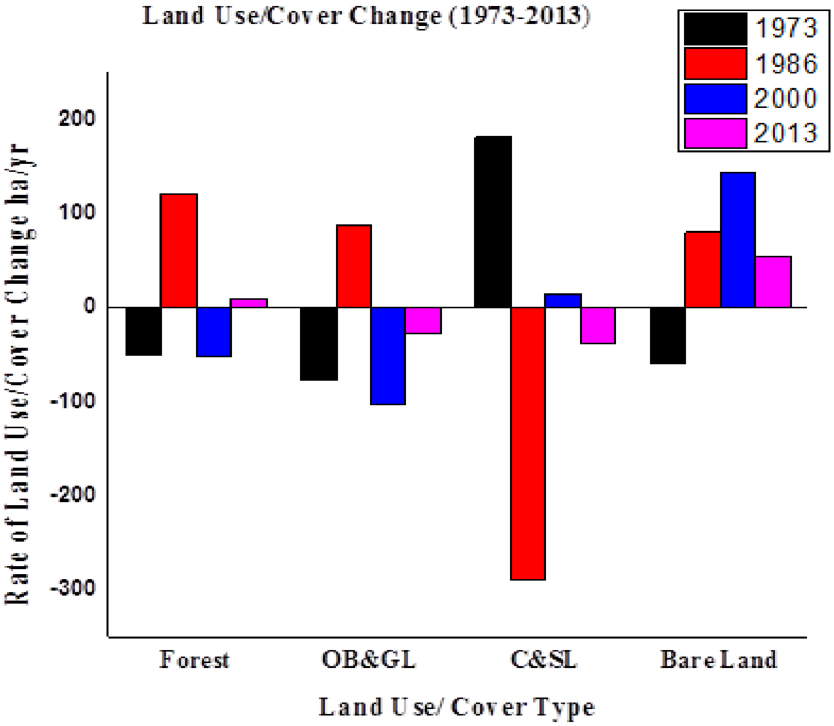

Figure 4. Percent Change in areas of LULC change in Aykoleba (1973-2013). OB = Open Bush, GL= Grazing Land, C = Cultivated land, SL= Settlement Land.

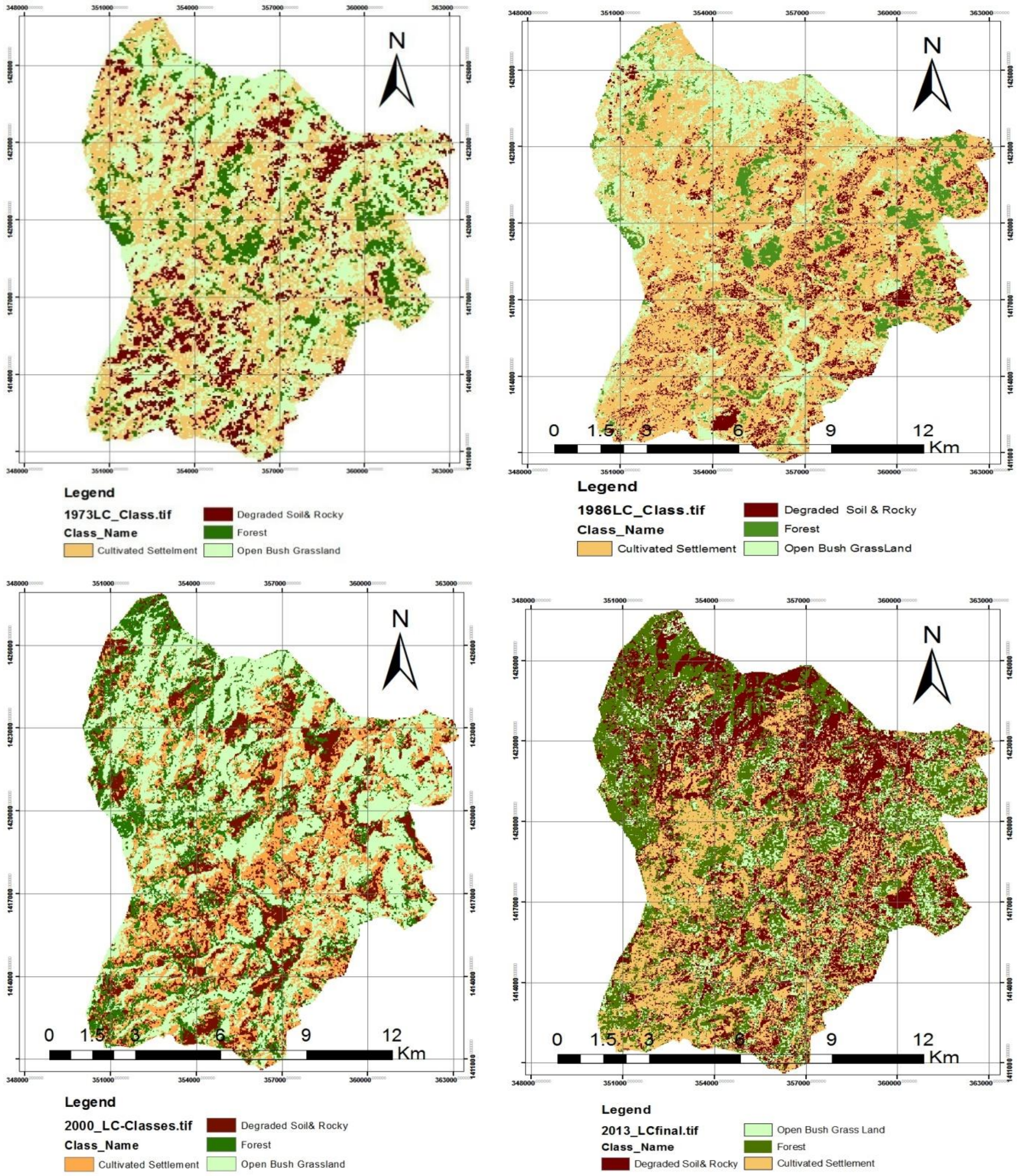

Figure 5. Classified land cover map of Aykoleba (1973-2013).

44.4 and 2.82% from Wallecha Watershed in Ethiopia, respectively (Barana et al., 2016)

The current study used bands 4, 5 or 7 from ETM+ in combination with 1, 2 or 3 to determine the vegetation condition in the Images. Different color composite red 4, green 3 and blue 2 band combinations were tested for better visual interpretation (Figures 6 and 7).

Rate and pattern of LULC

Table 4 showed the time-based variations of land cover classes and columns represent the spatial variation of land cover classes realizing the patterns of land use dynamics and its implication supports to plan an appropriate land management in the study area. Accordingly, the finding depicted that the forest and bare land increased by a rate of 8.8% and 54.9 ha/year from 1973 to 2013 whereas open bush and grassland, and cultivated and settlement lands decreased by -27.4 and -37.8 ha/year (Table 4). The increase in bare land depicts that the study area is under critical condition of conservation level. The degradation has increased from 13% in 1973 to 28.2% in 2013 (Table 3). The degradation and land use cover change of the study area is also linked with the demographic factors (population movement and increments) (Table 5). Key informant interviewees also described livestock population pressure, political instability, rainfall variability as important factors of bare land formation. They stated that the political instability during the late 1980's and early 1990's, especially a civil war between the then government (Derge) and the rebellious movement led by EPRDF, which forced the farming community internally displaced; which affected their agricultural activity specifically the crop production system and abandoning crop land to water and soil erosion. Informants maximized that climate change exacerbated by the land resource degradation particularly the soil, water and biodiversity, which was also confirmed by MoARD (2008) too. These factors probably have contributed for a dramatic change in land use and cover of the study area. A study conducted by Mohammed et al. (2017) in southeast lowland of Ethiopia reported that the cultivated land, settlement, bush land and bare land have increased by 13.8, 14.3, 12.6 and 22.3%, respectively from 1986 to 2016 whereas the woodland and grassland have fallen by 33.8 and 24.4% over the same period. A study by Barana et al. (2016) in southern part of Ethiopian showed that tree plantation and cultivated lands have increased by 31.25 and 22.2 ha/year whereas shrubs and grasslands, forest, and degraded land decreased by -35.4, -14.3, and -3.7 ha, respectively, from 1984 to 2000. The increase in forestland cover of the present study is related to the importance of eucalyptus tree for construction and fuel wood needs of the community and its significance for income generation made it become dominant plantation tree. It can be suggested that the current study area has to adopt good practices existing in the same country such as trends in reducing the degraded (Barana et al., 2016) in order to minimize the degraded areas and enhance the biodiversity and ecosystem services.

Perception on LULC dynamics

Discussants of FGD perceived that the causes for LULC were population pressure (90%), increase of agriculture (80%), the need for fuel wood and construction material (74%), and policy and institutional changes (50.4%) (Table 5). Studies in Ethiopia also showed that deforestation aimed at the expansion of agricultural activities ranging from small to large-scale commercial agricultural systems (Fikire et al., 2021), weak law enforcement (Zeleke and Hurni, 2001), and the prevalence of drought (Woldeamlak, 2009) were reported among crucial factors that drive LULC changes in Ethiopia. Informants of the current study claimed that larger population growth has driven urbanization, woodland collection, and great number of livestock that overgrazes agricultural lands.

The change in population size often considered as one of the chief factors affecting land use change (Wubie et al., 2016). Accordingly, about 90% of the respondents reported that swift population growth in the study area has put forth a pressure on the current land resources by raising the demand for food, wood for fuel and construction materials, and resulted in the expansion of croplands to hilly and sloppy areas by encroaching into uncultivated lands, including shrubs and open bush lands (Table 4). In some cases such cultivated fields were left abandoned where soil erosion and others factors have given rise to land degradation in Aykoleba. This causes environmental decline, including biodiversity loss and ecosystem disservice (Barana et al., 2016). Ayalew (2008), Tesfahun and Temesgen (2014), and Habtamu et al. (2018) also discussed that the population dynamics and its associated problems to be major drivers of LULC change. Similarly, a study from Central Malawi reported that population growth, firewood collection, charcoal production, and poverty to be main drivers of LULC changes (Munthali et al., 2019). It was recommended that reducing effects of population pressures on the remaining scarce forest resources should be a priority to be shared by rural developers, family planning advocators, supporters of free trade, and the conservationists (Carr et al., 2006). This in turn requires capacity building at local level to minimize the impact.

The LULC dynamic analysis clearly depicted that areas under cultivation and settlement land have increased in the Aykoleba over the four decades periods (1973-2013). The respondents (80%) showed that expansion of crop production was a key driving force of the LULC dynamics in the study area (Table 5). This is because since 1980s the Ethiopian government has introduced a high yielding rice crop in the area. Consequently, a large portion of the

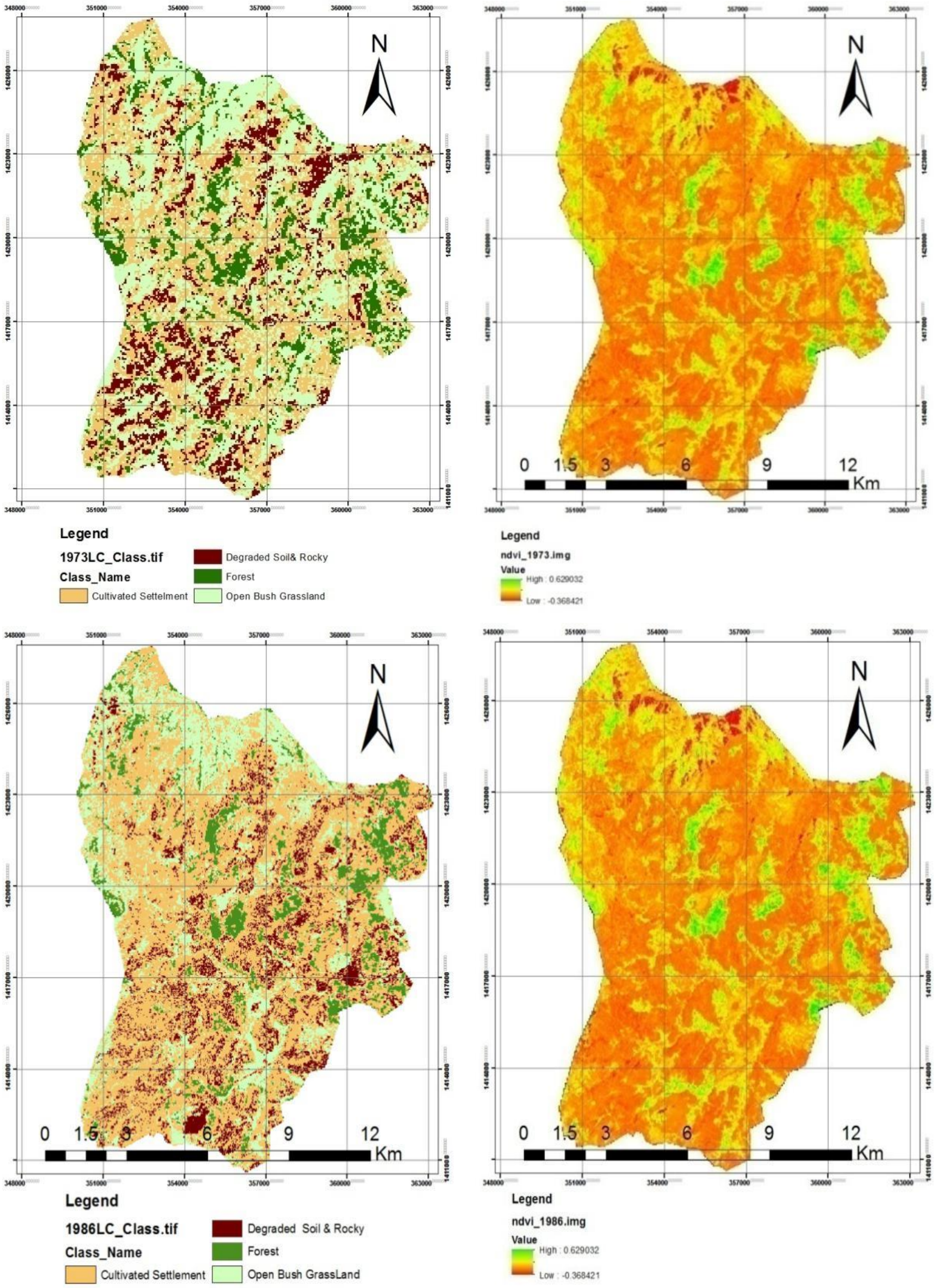

Figure 6. Comparison of LULC class and NDVI analysis (1973-1986).

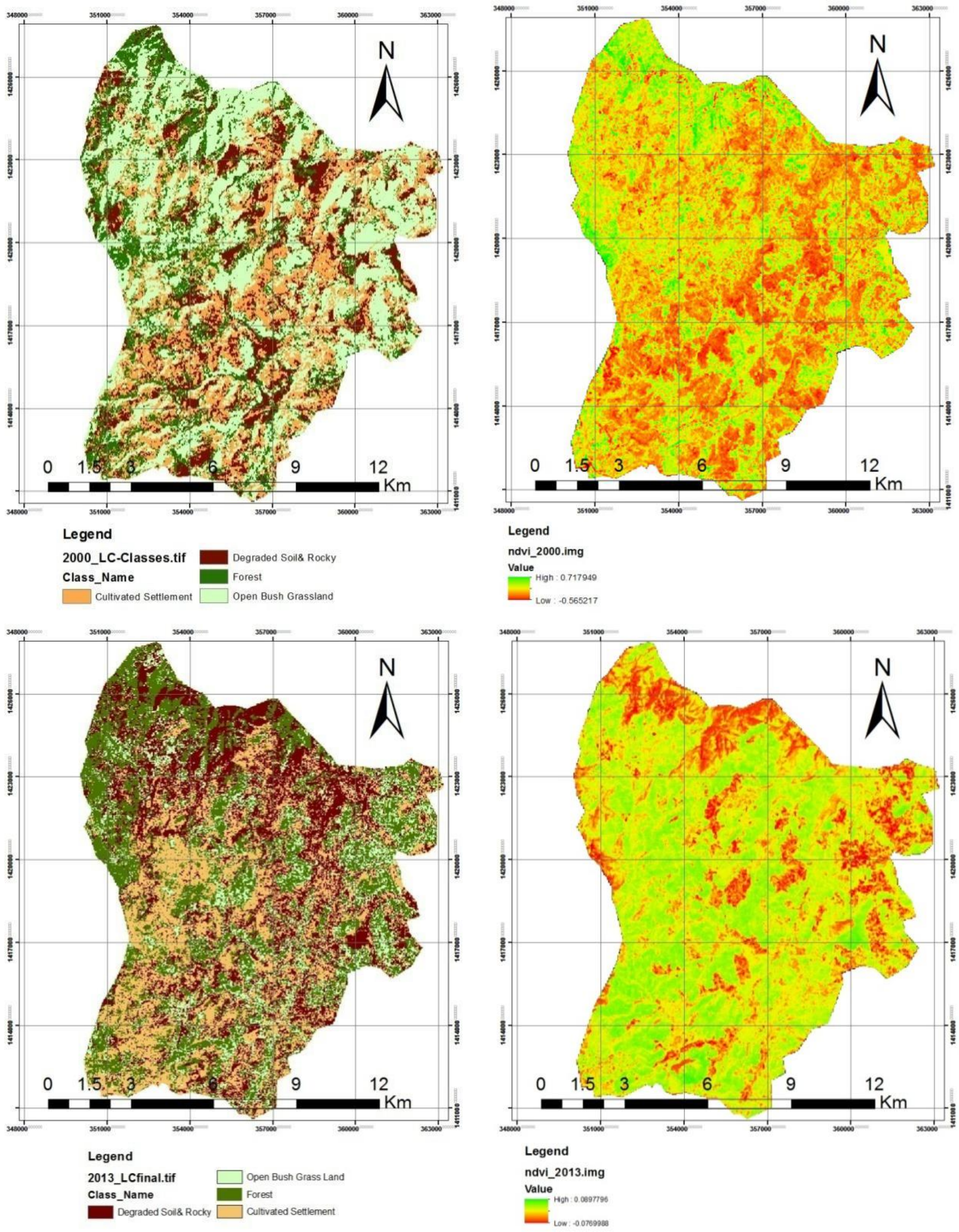

Figure 7. Comparison of LULC covers class and NDVI analysis (2000-2013).

Table 5. Perceptions of local people on the causes of LULC in the Aykoleba.

Causes of LULC	Frequency	%
Population pressure	95	90
Poverty	64	61
Expansion of agriculture	84	80
Policy and institutional problems	53	50.4
Demand for fuel and construction material	78	74

open bush and grassland was converted into cultivated land. Similarly, Barana et al. (2016) discussed that conversion of forests and woodlands into cultivated land is chiefly due to the desire of land for crop production in order to satisfy the food demand to the ever growing human population, which terminated with the loss of land productivity and land degradation. Habtamu et al. (2018) showed that the expansion of cropland in the Borana rangeland has meaningfully contributed to the change of grassland management practice into the cultivated land. The rapid population growth resulted in land fragmentation and small farm size, which in turn caused land use change (Birhane and Melesse, 2015).

Aykoleba is not only providing ecosystem services such as materials for energy demand but also serves as a means of supplementary income generation as confirmed by the respondents 74% (Table 4). The rural poor households relied on firewood sale and charcoal to generate extra income, which has also contributed to obliteration of forest and scrubland. A study by Wubie et al. (2016) reported that increased demand for fuel wood in the absence of alternative sources of energy has led to devastation of forests. Similarly, persistent logging activities in the forest reserve resulted in its loss in Nigeria (Aderele et al., 2020). Deforestation by the local people for different purposes caused land use change in southern part of the country (Mathewos, 2019). In contrast, increasing demand for firewood and house construction material, especially eucalyptus plantation caused increase in forest cover in Koga water shade (Moges et al., 2015), which is also similar to the finding of the present study.

More than 42% of the discussants showed that between 1980s and 1990s, the cultivated land cover has declined. It was noted that portion of cultivated land has been set aside and converted into degraded land. This description well corroborates LULC dynamics obtained from the digital image analysis of 1986-2000 of the cultivated land. This might have happened due to political change events that occurred in Ethiopia, and the land reform, which had seized all rural lands and distributed to the rural poors. Wubie et al. (2016) also reported the land tenure insecurity and policy to be the main driving forces behind the LULC change in Ethiopia. Furthermore, they have stated that the change in agricultural land policy along with the introduction of rice farming triggered the expansion of agricultural land at the cost of other land use types. Pastoralists in Borana range land of the Southern Ethiopia perceived that government policy is the second major among drivers of LULC changes, preventing the movement of pastoralists was a government rural development strategy that brought a large number of human and livestock population in the area, and caused change in the rangeland conditions (Habtamu et al., 2018).

Conclusion

The current study evaluated the LULC dynamics, and explored drivers of the LULC change in Aykolba, Northern Ethiopia. Over the past 40 years (1973-2013). The study of the LULC dynamics using remote sensing and GIS tools has resulted in four LULC classes. Four LULC classes were identified in this study, namely forest, open bush and grassland, cultivated land and settlement, and Bare land or degraded land. Within the four decades, the forest and bare land showed increasing trend whereas cultivated and settlement land and open bush and grassland classes were declined, which is associated with conversion of the land cover into other land uses types, especially into forest and degraded land. During the four study periods, the trend of LULC change in different classes was varied. The study showed an increase in the forestland and bare land. Large proportion of the study areas is covered by open bush and grassland, which also experienced the greatest dynamics in LULC change where this land use is changed progressively into other classes. The dynamics of population growth, which is directly dependent on natural resources, has become the primary driver of LULC change in the study area. This has led into an increase in cultivated land in order to provide subsistence food for households at the expense of existing natural resources, such as open bush and grassland. The movement of local community due to internal displacement caused abandoning of the cultivated land in hilly and sloppy areas, and overgrazing shifted the land into bare or degraded land. Accordingly, degraded land became one of the most dominant LULC class in the study area. This in turn has resulted in land degradation. Forestland use depicted increasing trend, which is related to plantation of economically useful trees such as eucalyptus. Eucalyptus also helps households to get wood for construction as well as firewood. They also generate income from eucalyptus sale. In general, increase in bare land in the study area shows a great threat to biodiversity and ecosystem service. Accordingly, the study district particularly, the office for forest and climate change has to work a lot to restore such degraded areas. Furthermore, appropriate land use policy as well as population policy need to be implemented to prevent further land degradation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aderele MO, Bola TS, Oke DO (2020). Land Use/Land Cover Changes of Ago-Owu Forest Reserve, Osun State, Nigeria Using Remote Sensing Techniques. Open Journal of Forestry 10(4):401-411. https://doi.org/10.4236/ojf.2020.104025

Adugnaw B (2014). Environmental Degradation and Management in Ethiopian Highlands: Review of Lessons Learned. International Journal of Environmental Protection and Policy 2(1):24-34.

Aklilu A, Stroosnijder L, Graaf JD (2007). Long-Term Dynamics in Land Resource Use and the Driving Forces in Beressa Watershed, Highlands of Ethiopia. Journal of Environmental Management 83(4):448-459.

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

Barana B, Senbetie T, Aklilu B (2016). Land use/Land Cover Dynamics and its Implication on Sustainable Land Management in Wallecha Watershed, Southern Ethiopia. Global Journal of Science Frontier Research 16(4):49-63.

Birhane G, Melesse M (2015). Evaluation of Land Use Patterns across Agro-Ecological and Slope Classes using GIS and Remote Sensing: The Case of Gedeo Zone, Southern Ethiopia. International Journal of Advanced Remote Sensing and GIS 4(1):1385-1399.

Butt A, Shabbir R, Ahmad SS, Aziz N (2015). Land Use Change Mapping and Analysis using Remote Sensing and GIS. A Case Study of Simly Watershed, Islamabad, Pakistan. The Egyptian Journal of Remote Sensing and Space Sciences 18:251-259.

Central Statistical Agency (CSA) (2007). Summary and statistical report of population and housing census of Ethiopia. Central Statistical Agency, Addis Ababa.

Dinka MO (2012). Analysing decadal land use⁄cover dynamics of the Lake Basaka catchment (Main Ethiopian Rift) using LANDSAT imagery and GIS. Research and Management 17:11-24.

Ethiopian Meteorological Service (EMS). (2013). Ethiopian Meteorological Service database (1973–2005). Ethiopian Meteorological Service, Addis Ababa.

ESCAP (1996). Manual on geographic information System, for Planners and Decision makers. United Nation.

Food and Agricultural Organization (FAO). (1986). Ethiopian Highlands Reclamation Study, Ethiopia. Final Report, of FAO, Vol 1 Rome.www.fao.org/docrep/pdf.

Fikire B, Melesse M, Alemtshay T (2021). Land use/land cover dynamics and perception of the local communities in bita district, south western Ethiopia. International Journal of River Basin Management. DOI: 10.1080/15715124.2021.1938092.

Habtamu TM, Casper IB, Joel O, Abubeker H, Ayana A, Yared M (2018). Evaluation of land use land cover changes using mremote sensing landsat images and pastoralists' perceptions on range cover changes in borana rangelands, southern Ethiopia. International Journal of Biodiversity and Conservation 10(1):1-11.

Hagos G (2014). Land Use Land Cover Dynamics of Huluka Watershed, Central Rift Valley, Ethiopia. International Soil and Water Conservation Research 2(4):25-33.

Haque IM, Basak R (2017). Land Cover Change Detection using GIS and Remote Sensing Techniques: A Spatio-temporal Study on Tanguar Haor, Sunamganj, Bangladesh. The Egyptian Journal of Remote Sensing and Space Sciences 20(2):251-263.

Hurni H (1993). Land Degradation, Famine, and Land Resource Scenarios in Ethiopia. In: Pimentel D. World Soil Erosion and Conservation. Cambridge pp. 27-61.

IPBES (2018). Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services. R. Scholes, et al (eds.). IPBES secretariat, Bonn, Germany P 44.

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, et al (eds.). IPBES secretariat, Bonn, Germany P 56.

Kiros M (2008). Temporal and Spatial Changes in Land Use Patterns and Biodiversity in Relation to Farm Productivity at Multiple Scales in Tigray, Ethiopia (Unpublished).

Kothari CR (2004). Research Methodology Methods & Techniques, 2nd edition. New Age International (P) Limited, New Delhi, India.

Lambin EF, Geist HJ, Lepers E (2003). Dynamics of land-use and land-cover change in tropical regions. Annual Review of environment and Resources 28(1):205-241.

Lambin EF, Geist H, Rindfuss RR (2006). Introduction: Local Processes with Global Impacts. In: Lambin EF, Geist H (eds) Land-Use and Land-Cover Change. Global Change - The IGBP Series. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-32202-7_1

Lillesand TM, Kiefer R, Chipman JW (2004). Remote Sensing and Image Interpretation (5th edition). John Wiley & sons, Inc. New York.

Liu J, Dietz T, Carpenter S, Alberti M, Folke C, Moran E, Taylor W (2007). Complexity of Coupled Human and Natural Systems. Science 317(5844):1513-1516.

Mac JF, Velázquez A, Díaz-Gallegos JR Mayorga-Saucedo R, Alcántara C, Bocco G, Castro R, Fernández T, Pérez-Vega (2004). Assessing land use/cover changes: A nationwide multidate spatial database for Mexico. International Journal of Applied Earth Observation and Geoinformation 5(4):249-261.

Mather AS, Needle CL (2000). The relationship of population and forest trends. Geographical Journal 166(1):2-13.

Mathewos M (2019). Reported driving factors of land-use/cover changes and its mounting consequences in Ethiopia: A Review. African Journal of Environmental Science and Technology 13(7):273-280.

Mekuria A (2005). Forest Conversion-Soil Degradation-Farmers Perception Nexus: Implication for Sustainable Land Use in Southwest of Ethiopia. In WECD, Our Common Future. Oxford University Press, UK.

Mengistie KT, Schneider, Demel T, Knoke T (2013). Land Use/Land Cover Change Analysis Using Object-Based Classification Approach in Munessa-Shashemene Landscape of the Ethiopian Highlands. Review of Remote Sensing 5:2411-35. doi: doi:10.3390/rs505241

Ministry of Agriculture and Rural Development (MoARD) (2008). Ethiopian Strategic Investment Framework for Sustainable Land Management. MoARD, Addis Ababa, Ethiopia (Unpublished Project Document).

Moges K, Amare S, Alemu B (2015). Multi temporal Land use and land cover change and dynamics of Bule Nile Basin by using GIS and remote sensing techniques, NW Ethiopia. International Journal of Environmental Sciences 4:81-88.

Mohammed M, Habtamu T, Yared M (2017). Land use/Land cover change analysis and local community perception towards land cover change in the lowland of Bale range lands, SE Ethiopia. International Journal of Biodiversity and Conservation 9:363-372.

Munthali MG, Davis N, Adeola AM, Botai JO, Kamwi JM, Chisale HL, Oluwagbenga OI, Orimoogunje OOI (2019). Local Perception of Drivers of Land-Use and Land-Cover Change Dynamics across Dedza District, Central Malawi Region. Sustainability 11:832. doi: 10.3390/su11030832

Oettera DR, Cohenb WB, Berterretchea M, Maierspergera TK, Kennedy RE (2000). Land Cover Mapping in an Agricultural Setting Using Multi-Seasonal Thematic Mapper Data. Remote Sensing of Environment 76(2):139-155.

Pender J, Berhanu G (2007). Determinants of Agricultural and Land Management Practices and Impacts on Crop Production and Household Income in the Highlands of Tigray, African. Economies 17:395-450.

Pontius RG (2000). Quantification error versus location error in comparison of categorical maps. Photogrametric Engineering and Remote Sensing 66(8):1011-1016.

Prenzel B (2004). Remote sensing-based quantification of land-cover and land-use change for planning. Progress in planning 61:281-299.

Quentin FB, Jim C, Julia C, Carole H, Andrew S (2006). Drivers of Land use Change, Final report; matching opportunity to Motivation, ESAI Project 05116, Department of Sustainability and Environment and Primary Industries, Royal Melbouren Institute of Technology, Australia".

Rawat SJ, Kumar M (2015). Monitoring Land Use Cover Change using Remote Sensing and GIS techniques: A Case Study of Hawalbagh Block, District Almora, Uttarakhand, India". The Egyptian Journal of Remote Sensing and Space Sciences 18(1):77-84.

Sagan C, Toon OB, Pollack JB (1979). Anthropogenic albedo changes and the earth's climate. Science 206(4425):1363-1368.

Singh A (1989). Digital Change Detection Techniques using Remotely Sensed Data". International Journal of Remote Sensing 10:989-1003.

Stefanov WL, Ramsey MS, Christensen PR (2001). Monitoring Urban Land Cover Change: An Expert System Approach to Land Cover Classification of Semiarid to arid urban centers. Remote Sensing of Environment 77(2):173-185.

Tadesse L, Suryabhagavan KV, Sridhar G, Legesse G (2017). Land use and land cover changes and soil erosion in Yezat watershed, North Western Ethiopia. International Soil and Water Conservation Research 5(2):85-94.

Tesfahun F, Temesgen G (2014). Evaluation of land use/land cover changes of Bantneka Watershed, Ethiopia. Civil and Environmental Research 6(7):90-93.

Woldeamlak B (2009). Rainwater Harvesting as a Livelihood Strategy in the Drought-Prone Areas of the Amhara Regions of Ethiopia. Addis Ababa: Organization for Social Science Research in Southern and Eastern and Southern Africa.

Wood CH, Porro R (Eds.) (2000). Deforestation and Land Use in the Amazon. Korea: University Press of Florida.

Wubie AM, Assen M, Nicolau DM (2016). Patterns, Causes, and Consequences of Land Use/Cover Dynamics in the Gumara Watershed of Lake Tana Basin, North Western Ethiopia. Environmental Systems Research 5:8.

Wogera Woreda Agricultural Bureau, WWAB (2017). Information on Socioeconomic Activities (unpublished).

Yang X, Lo CP (2002). Using a time series of satellite imagery to detect land use and land cover changes in the Atlanta, Georgia metropolitan area. International Journal of Remote Sensing 23(9):1775-1798.

Yismaw A, Gedif B, Addisu S, Zewudu F (2014). Forest Cover Change Detection Using Remote Sensing and GIS in Banja District, Amhara Region, Ethiopia. International Journal of Environmental Monitoring and Analysis 2(6):354-360. doi: 10.11648/j.ijema.20140206.19

Yuan F, Bauer ME, Heinert NJ, Holden GR (2005). Multi-Level Land Cover mapping of the Twin Cities (Minnesota) Metropolitan Area with Multi-Seasonal Landsat TM/ETM+ data". Geocarto International 20(2):5-14.

Zeleke G, Hurni H (2001). Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the North-western Ethiopian Highlands. Mountain Research and Development 21(2):184-191.

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