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Full Length Research Paper

Environmental assessment of tropical African mahogany (Khaya)

John Frank Eshun

Department of Interior Design Engineering, School of Engineering, Takoradi Technical University, Takoradi, Ghana.

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In this study, life cycle assessment (LCIA) was used for the assessment and evaluation of the environmental performance of the Khaya lumber manufactured by three firms in Ghana. The work mainly aims to assess all possible effects to the environment, measure the carbon footprint for Ghana Khaya lumber and offer an Environmental Product Declaration (EPD) for Ghana Khaya lumber. The results show that the average environmental effect of the Khaya lumber per cubic meter in relation to GWP was 253 kg-CO_2-Eq; AP, 3.9 kg SO_2- Eq; EP, 2.6 kg Phosphate (PO_4)-Eq; POCP, 0.56 kg Ethylene-Eq. The GWP, AP, EP and POCP match very well the results of LCIA for 1 m^3 rough-sawn, kiln dried US lumber cradle to gate for 19 diverse species and the LCA results for environmental product declaration of tropical plywood production in Malaysia and Indonesia. The EPD results give useful, confirmed and equivalent information concerning the possible environment effect of Khaya lumber manufactured by three firms in Ghana. A detailed and clear LCA for the timber industry offers industry with precise areas for making physical and economic savings to benefit the wealth of the environment and industry.

Key words: Environmental assessment, tropical timber, life cycle assessment.

INTRODUCTION

Recently, the worry concerning environmental effects is now more than counting on present national regulation as global markets are placing high demand for sound environmental products (ITTO, 2005; O'Rourke, 2014).

Several international timber certification systems give consumers alternatives to select timber products obtained from forests that have good sustainability (Brundtland, 1987). Thus, life cycle thinking is highly emphasized in environmental integrated product policy and a good incorporation of this notion in the timber segment is seen as a very successful factor for a more manageable industry (Kareiva et al., 2015; Godar et al., 2015).

Ghana timber segment is very relevant in developing Ghana socially and economically via exporting of timber products (Eshun et al., 2010). Eshun et al. (2010) noted that manufacturing of timber in Ghana has a lot of environmental issues in areas of using of facilities and producing discharges and waste. There is no environmental incorporated product policy and its active incorporation in the timber industry. Hence, the aims of this work are to gather all the quantifiable inputs and products of the production process of Khaya lumber produced in Ghana, and do an evaluation of all possible

E-mail: jfeshun@yahoo.com or johneshun2014@gmail.com.

effects to the environment.

The work aims to be the benchmark for EPD of Khaya lumber manufactured in Ghana. The EPD will offer useful, confirmed and related information regarding the possible environmental effect of Khaya lumber in Ghana.

Life Cycle Assessment (LCA) is used for assessing the environmental impacts of Khaya lumber, and identifying the significant environment in a product chain. LCA is done usually for an output structure from the beginning to the end, by noting all the environmental effects from extraction of resource to the disposal of product using a series of LCA principles given by International Organization for Standardization (ISO): ISO 14040 and ISO 14044. The result can be utilized to identify avenues to better the environmental areas of a product at the different phases of its life cycle, decision making in industry and organization in selecting products to be used and marketed; example an environmental claim, eco-labeling plan or Environmental Products Declarations [EPD].

Aim of the study

The general aim of this work is to evaluate likely alternatives and plans to make better environmental impact of Khaya lumber from Ghana used as building materials with Life Cycle Assessment (LCA) based on ISO 14040/44. The primary aim of the work is to evaluate the cradle-to-gate environmental impact of Khaya lumber manufactured from Ghana and give reliable scientific proof to decide in aspects concerning possible environmental effect to facilitate its competiveness in the market.

Thus, the main aims of this work are to:

(1) Collate all quantifiable inputs and products of the production procedures of Ghana Khaya lumber.
(2) Collate and assess all possible performance of the environment.
(3) Evaluate the carbon footprint for Ghana Khaya lumber using the PAS2050 method.
(4) Profer an Environmental Product Declaration (EPD) for Ghana Khaya lumber

The work aims to be the benchmark for EPD of Khaya lumber manufactured in Ghana.

Scope of the study

The overall scope of the work to obtain the targeted goals is presented here. It entails identifying particular outputs to be evaluated, supporting product systems, and limit of the work.

MATERIALS AND METHODS

Based on the standard of ISO - 14044 (2006), an LCA is made up of four interconnected stages (Figure 1).

The first stage is 'Goal and scope definition'. This entails planning of the work in which definitions of all the detailed descriptions of the work are given such as the aim of the study, area of study; the functional unit, system boundaries, the quality of data, and the critical review process.

The second stage is the 'Life cycle inventory' involving the collation and measurement of inputs and products in all the processes. The outputs are both physical like 1 m^3 of furniture part, discharges like carbon dioxide. Here, decision is made on how to control the procedures used to produce many outputs. Inventory analysis is used to identify and quantify the resources mined and utilizations, and the environmental discharges from the processes that make up the life cycle of the products evaluated. All of these are also known as environmental interventions conveyed as measures based on units of functions. The inventory work result measures the relations between economic and environmental procedures.

The third stage is the 'life cycle impact assessment', done based on the data of the life cycle inventory. The wastes in the life cycle inventory data are categorized, meaning they are classified based on their effect. For instance, methane is a greenhouse gas and thus classified as impact category 'Global warming'. If a material donates to more than one impact group, it is allotted to all of them. After classification is characterization. Each substance is given possible impact in the impact group. A substance is given likely impact based on a dominant factor in the group; example for the global warming potential it is mainly 1 kg of CO_2 discharges. These comparative effects are then multiplied with the quantity of each release and the impact values are added up for each impact group (ISO - 14044 2006). Impact evaluation is done to have extra information for assessing a product system's LCI results to know better the environmental importance to make good decisions.

The fourth stage is interpretation. Here, the data from the inventory stage and the impact assessment stage are joined based on the aim and area of the study. Here, the decision makers draw conclusions and give recommendations; otherwise the previous stage needs to be reviewed and revised. To see more description of the LCA method, refer to ISO standard (ISO - 14044 2006).

System description

Three fundamental generic process phases consist of the cycle stage of this product.

The production stage

The production stage consists of 3 phases. Phase one entails to harvest the Khaya trees, cross-cut them into logs, extract the logs to a dumping site in the forest and transport them to sawmill. Phase two is to produce the Khaya lumber in the sawmill; phase 3 is transporting of the Khaya lumber to the manufacturers' storage before kiln drying and later to bundle or package it for shipping. The storing amenities are houses in the firm's production locations. The life cycle of the product production stage gives the greatest record for resource, power, discharge and good inflows, outflows and activities. The most environmentally consuming from the generic process stages are the extraction of the resource and production of raw materials. The usage stage and the end of life do not join the measured aspect of this Khaya lumber product life cycle assessment because it cannot be importantly conveyed by the diverse state of end use product and removal.

Use stage

The use stage of an output entails unit processes like transferring to consumers (delivery of Khaya lumber from Ghana in boats to a buyer in Europe), manufacturing of the products, and product duration. Transferring of Khaya lumber to consumers and obtaining of building cannot be conveyed as a result of the variableness of unit processes. Product unit process duration is activity that is important to preserve it and not to decrease the quality of important parameters and material durability. The durability is based on the quality of the material and manufacturing methods, for the installation and climatic impacts. The complete durability cannot be fully conveyed.

End of life (dismantling/disposal) stage

The end phase of wood product is very hard to convey. Many works like that are assumed. LCA can be done for cradle-to-grave, cradle-to-gate or gate-to-gate. The cradle-to-grave assessment of the Khaya lumber consists of the timber harvest, extraction, processing to lumber, transportation, use stage as explained in use stage and the end of life dismantling/disposal. For a primary product like Khaya lumber produced and exported from Ghana, the use phase and final product disposal phase are not fixed. Therefore in this study, the system boundary is set for cradle-to-gate, because the use phase and end of life phase cannot be relevantly expressed (Gan and Massijaya, 2014). Use and end phases are therefore excluded.

Functional unit

A functional unit of the work gives the standard for relating the environmental inputs and outputs of a product system-ISO-14044 (2006). It explains the service of the products based on the requirements of the user and is related as the unit service for a specific given time (AHEC, 2009). The functional unit of rough sawn Khaya lumber manufactured at specified moisture content and thickness is 1 m^3 of 25 to 50 mm thickness at 12% moisture content. The functional unit (FU) measures the impact of a product system used as a standard unit. The functional unit tallies with the Product Category Rules (PCR) for solid wood products.

Data quality and representativeness

The work relies on the primary data obtained from survey of three companies in Ghana as well as values obtained from the literature as shown in Table 1.

Literature values gotten from IPCC 2006 were verified using main data. From the discussion of the key quality criteria, the total quality is predicted to be very good. The data quality is the best and good enough for the specific aim and scope.

Allocation

The firms were chosen to carry one product line, kiln dried Khaya lumber and thus the level of process detail was enough to prevent many product processes. Percentages were assigned to Khaya manufactured from all the sawmills' manufacturing depending on mass (density × volume) allocation.

Field study

Company survey

Sizes of companies in Ghana are classified based on their log input. The log inputs in m^3 of the firms are utilized for their identification as large, medium and small. Yearly log input in all species of timber for big firms is 25,000 m^3 and over; medium, 15,000 m^3 but below 25,000; small size, below 15,000 m^3. Three big timber companies, called A, B, C in the study were given questionnaires to give information concerning the inputs and products of the works for resources, material utilization, power necessities, and waste produced for 2013. The terms of reference (TOR) of the work needed data from three companies. The three companies were randomly selected to make data available and reliable. Extra interview was carried out for checking of the quality of the data appropriately to help the process of the LCA. The factories manufactured Khaya kiln dried lumber and they are situated at about 50, 130 and 250 km for A, B, C from log sources. Besides lumber, company A manufactures sliced and rotary veneer and plywood; company B, sliced veneer and moldings and company C, sliced veneer, moldings and square edged lumber. The power source for the factories is the national grid, and energy mix in Ghana is 50% hydropower and 50% thermal power. Hydropower is green energy and thus the environmental problem was seen as insignificant; only the thermal energy is regarded in this work.

Exporting air-dry mahogany lumber from Ghana costs money and thus 98.6% (5,843 m^3) of African mahogany exported in 2012 was kiln dried. The major Khaya species is ivorensis. Export lumber is dried from green to 10-12% moisture content according to US schedule 56(T6-D4) for thicknesses 25, 32, and 38 mm and schedule 20(T3-D3) for thickness 50 mm. Both are in line with British schedule F. 25 mm thick lumber is dried in 14 days while 50 mm thick lumber is 20 days. Companies A, B, C are big and keep accurate data to help the process of LCA. Every firm does its logging from the forest and takes the logs for processing in their factories.

Life cycle inventory (LCI)

Compiling a detailed database of life cycle inventory (LCI) is identifying the highest environmental effects producing an output (Eshun et al., 2010). LCI value is useful to evaluate an output. Most works concentrate on the ambiguity of data in Life Cycle Assessment (LCA) database. The accurateness and worth of inventory process in LCA analysis is useful to compute LCA. Also, diverse software for analyzing LCA data can share similar data name but the assessment results effects of the data differ. Thus, a selection means has to be developed to choose best data for calculating LCA. Timber companies do not have waste data inventory in Ghana. In this work, waste factors from benchmark are used for calculating wastes based on the amounts of Khaya lumber produced using Equation 1. The aim is to make the wastes local.

All raw resources and discharges were used for each of the processes making up the life cycle of the output. Inputs consist of the utilization of materials like timber, resources like petrol. They did not treat the Khaya wood with chemical when stored as it was not preserved for long prior to sawing; the lumber made after sawing was from the heartwood that lasts and cannot be impregnated if it is to be treated. Outputs are discharges released in air, water and land, including all outputs and by-products. These processes make up the life cycle system evaluated according to the system boundary. All inputs and outputs that make up the system were totaled to accumulate the life cycle inventory (LCI).

Emissions contribute to global warming, acidification, eutrophication and smog and they are Carbon dioxide CO_2, Methane CH_4, and Nitrous oxide N_2O for global warming; Sulphur dioxide SO_2 and Oxides of Nitrogen NO_X for acidification; Nitrogen Oxides (NOx) for eutrophication; CH_4, NO_X, Non-Methane volatile organic compound NMVOC, and Carbon monoxide CO for smog. Emissions that contribute to Ozone Depletion Potential (ODP) were not considered as data were not available. The emission result is written in Equations 1 and 2 in kg/m^3 of contaminant released or

Table 1. Emission factors for the calculation of the emissions from Khaya lumber production in Ghana.

Activity area	Compound emitted	Emission factors	Unit	Reference
Forestry subsystem				
Harvesting activities (Gasoline used)	CO_2	3172.00	g/kg fuel	CORINAIR (2000)
	CO	14.07	g/kg fuel	CORINAIR (2000)
	N_2O	0.02	g/kg fuel	CORINAIR (2000)
	CH_4	7.67	g/kg fuel	CORINAIR (2000)
	NO_X	1.55	g/kg fuel	CORINAIR (2000)
	NMVOC	762.00	g/kg fuel	CORINAIR (2000)
	SO_2	0.07	g/kg fuel	CORINAIR (2000)
Harvesting activities (Diesel used)	CO_2	3150.00	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	N_2O	0.02	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	CH_4	6.91	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	NO_X	50.00	g/kg fuel	IPCC (1997)
	NMVOC	6.50	g/kg fuel	IPCC (1997)
	CO	15.00	g/kg fuel	IPCC (1997)
	SO_2	20.00	g/kg fuel	IPCC (1997)
Transportation of log to company (diesel used) + mk (Sawmill operations and internal transport diesel used)	CO_2	3180.00	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	N_2O	0.10	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	CH_4	0.20	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	NO_X	29.80	g/kg fuel	IPCC (1997)
	NMVOC	4.70	g/kg fuel	IPCC (1997)
	CO	14.00	g/kg fuel	IPCC (1997)
	SO_2	20.00	g/kg fuel	IPCC (1997)
Electricity use fossil-fuel/Thermal energy	CO_2	77.40	ton/TJ	IPCC (2010)
	CH_4	2.00	kg/TJ	IPCC (2010)
	N_2O	0.60	kg/TJ	IPCC (2010)
	NMVOC	5.00	kg/TJ	IPCC (2010)
	CO	10.00	kg/TJ	IPCC (2010)
	NO_X	200.00	kg/TJ	IPCC(2010)
	SO_2	1194	kg/TJ	IPCC(2010)

produced from an output of Khaya lumber line.

$$\text{Emission} = \text{Activity} \times \text{Emission Factor} \quad (1)$$

Impact Category Indicator = Emission (inventory data) ×

Classification Factor (2)

Selecting impact assessment categories

Assessing likely methodologies

A detailed environmental performance classes were examined. The literature review revealed that the LCIA approaches are based on the environmental issues in western nations and characterization methodologies that relate how these issues are seen in the western world (Eshun et al., 2011). Several life cycle impact assessment (LCIA) methods in life cycle assessment (LCA) are established for western nations. Their LCIA methods and characterization methodologies for diverse performance classes may not be important to African environmental situations, especially not for Ghana. LCA study on timber output does not only include foreground data on timber and production procedures; other local inputs and products are also included to fully stand for the entire output system or life cycle. The evaluation of LCIA approached and characterization factors in LCA works are shown in Table 2 and Figure 1.

Characterization method used for diverse performance classes cannot be important to African tropical environmental situations (Eshun et al., 2011). Review of LCIA and characterization methods reveal that CML-2000 is the highest utilized and most accepted internationally; it is a known impact method in LCAs of timber outputs. CML-2000 utilizes mid-point signs that are apparent in the core visible modeling. This work uses the CML-2000 method for assessing this environmental performance.

Table 2 shows that the scientifically well-known CML 2000 method to Life Cycle Inventory (LCI) was examined from which the effect classes applied in this work were selected including global warming, acidification, eutrophication, and photochemical oxidant formation.

Global warming

Greenhouse gases are the major contaminants that contribute to global warming problem, and they are conveyed as Global Warming Potentials (GWP). The GWP is an index of aggregate radiative forcing between the present and some chosen later time horizon caused by a unit mass of gas released, expressed relative to the reference gas CO_2 (1 kg CO_2) (Houghton, 1996). The burning of fuels for producing Khaya lumber is the main source of these gases.

Acidification

The process of producing of Khaya lumber leads to acidifying agents. The burning of fuel in producing Khaya is the major source of NO_x discharge. Acidification is the number of protons discharged into land/marine system. The categorization factors of acidification potential (AP) are regularly given either as moles of H^+ or kilograms of SO_2 equal (Heijungs, 1992). The latter is utilized in this work.

Eutrophication

The use of these contaminants to enrich the water and soil (Nitrogen Oxides (NOx) can result in unwanted swing in the structure of species in the ecologies, which is known as eutrophication. Many models have been used for the characterization of what life-cycle inventory data contributes to eutrophication. Heijungs et al. (1992) proposed a well-recognized model for calculating the nutrification potential (NP) of discharges based on the reference compound PO_4^{3-}.

Smog

The burning of petrol when Khaya is produced and transported lead to the discharge of VOCs, CO, CH_4 and NO_x, seen as tropospheric ozone precursors. Photochemical Ozone Creation Potentials (POCPs) help in assessing comparative contribution of diverse organic compounds to tropospheric ozone creation. The classification factor value of POCPs is from Goedkoop (2000) (PReConsultants, Amersfort, the Netherlands) that created the Eco-indicator 95.

Human toxicity

In the timber sector, the discharges of particulates, SO_2, and NO_x are important contaminants contributing to human harmfulness issue. The human toxicity potential (HTP) is an index reflecting the possible damage of a unit of chemical discharged into the environment; it is related to the natural harmfulness of a compound and its likely dosage. Classification factors in this environment are obtained from CML (2002).

RESULTS AND DISCUSSION

Analysis of life cycle inventory (LCI)

The three firms gave data about the use of their resources and power needed to operate in 2013. The data obtained were changed firstly into overall yearly mean values and then related as operational unit based on their products in capacity. Discharges for the many works were obtained from literature.

Application of the selected LCIA approach for LCA study

Here, CML 2000 is applied to the LCI results of the survey for characterizing the performance classes of Global Warming, Acidification, Eutrophication, Photochemical Oxidant Formation and Human Toxicity. Table 2 shows the CML-2000 characterization factors utilized for these performance classes. Passage for acidification, another generic acidification potential was utilized which fully measures the acidifying ability in African condition, than that in CML-2000 which selects site and is European baseline method (Hauschild and Potting, 2005). Characterizing biodiversity for the timber industry is now established and thus not used in this work.

To compare the discharges in Table 2 can be hard because of the diverse units utilized for the different performance classes. But, the mean results for all the three firms were utilized as a standard to be used to compare (Figure 1). From the results, company C had the least value of GWP due to low current constituent of generating power use in comparison to companies A and B. In general, for the other performance classes

Table 2. Evaluation of LCIA methods and characterization factors in LCA studies.

Impact category	EDIP-97 (Wenzel et al., 1997)	CML baseline-2000 (Guinée et al., 2000)	Eco-indicator-95 (Goedkoop, 1995)	Eco-indicator-99 (Goedkoop and Spriensma, 2000)
Global warming	kg CO_2 eq	kg CO_2 eq	kgCO_2	DALY
Ozone layer depletion	kg CFC 11 eq	kg CFC 11eq	kg CFC 11	DALY
Acidification	kg SO_2 eq	kg SO_2 eq	kg SO_2	PAF×m^2year
	mole of H^+ eq	-	-	-
Eutrophication	kgNO_3 eq	kg PO_4 eq	kg PO_4	PAF×m^2year
Photochemical oxidant	kg C_2H_4 eq	kg C_2H_2 eq	kg C_2H_4	kg C_2H_4
Ecotoxicity	m^3 in water	kg 1,4 DB eq	PAF×m^2year	PAF×m^2year
Human toxicity	m^3 in air	kg 1,4 DB eq	-	-
Carcinogens	-	-	kg B (a) P	DALY
Respiratory organics/inorganics	-	-	DALY	DALY
Land use	-	-	-	PDF×m^2year
Solid waste	kg	-	kg	-
Abiotic resources depletion	-	kg Sb eq	-	-
Energy Resources	-	-	MJ LHV	MJ Surplus

DALY=Disability Adjusted Life Years, PDF=Potentially Disappeared Fraction, PAF=Potentially Affected Fraction.

companies A and B had higher discharge rates of AP, EP, POCP and HTP. The environmental performance linked to producing Khaya lumber in the three firms is primarily run by using fossil fuels.

Global warming potential (GWP)

An average of 253 kg CO_2-equivalents of greenhouse gas is discharged per cubic meter in kiln dried Khaya lumber produced in Ghana (Table 2). Considering the activities that produce greenhouse gases, electricity is the first (42%). The second is diesel utilized in harvesting Khaya timber, with impact of 27% next to diesel utilized in transporting Khaya timber to sawmill (21%). According to these data, it is obvious that the global warming potential (GWP) is highly linked to using fossil fuel (Figure 1). Electricity utilized to generate current, harvest Khaya timber and transport logs over long distances, bad roads and poor haulage trucks in Ghana cause the use of high diesel. The best environment for reducing high diesel use is the use of green energy technology like solar, wind and hydropower, while re-locating factories near forest source of timber or conveying the timber by rail.

Acidification potential (AP)

The mean potential acidification impact from Khaya lumber produced in Ghana is 3.9 kg SO_2-eq for a cubic meter (Table 2). Considering the contributors of the overall acidifying discharge, diesel used to generate power contributed 46%, the largest amount next to diesel used for harvesting Khaya timber (30%) (Figure 1).

Eutrophication potential (EP)

The average eutrophying impact was up to 2.6 kg PO_4-eq for a cubic meter (Table 2). Of all the eutrophying compounds NO_X contaminants released when Khaya timber is harvested using diesel contributed 52%, next to diesel used for transporting Khaya timber to sawmill (24%) (Figure 1).

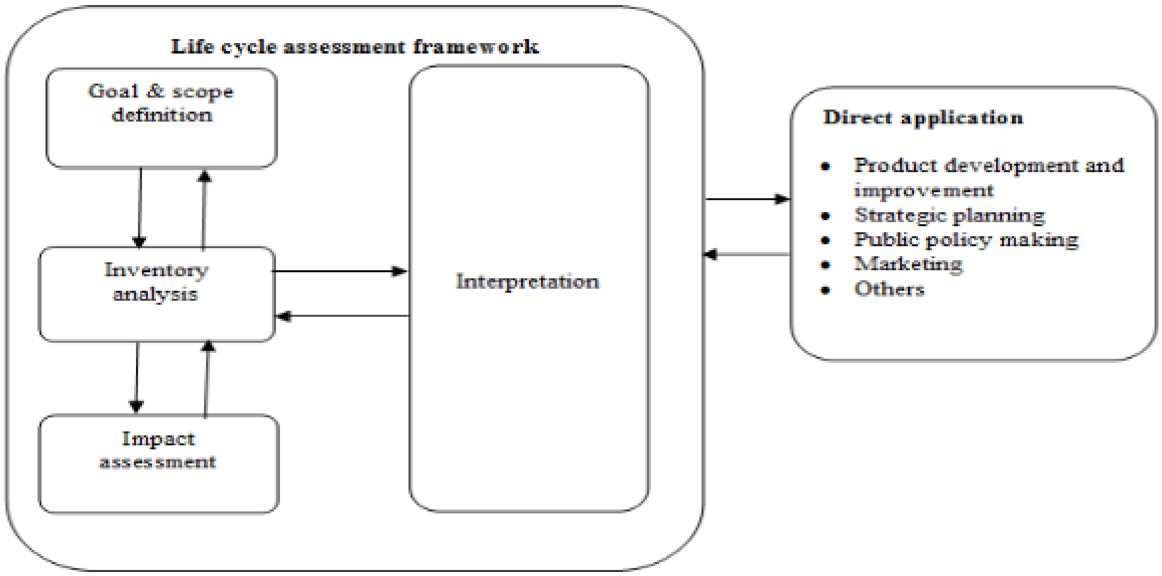

Figure 1. The phases of an LCA according to ISO 14044 (2006).

Photochemical ozone creation potential (POCP)

The potential impact of tropospheric ozone precursor compounds is 0.56 kg ethylene-eq for a cubic meter (Table 2). The smog problem had two main important sources: gasoline used to harvest Khaya timber and diesel used to harvest Khaya timber. Gasoline for harvesting Khaya timber came first (68%). The second is the diesel used to harvest Khaya timber having comparative discharge of 17%.

Human toxicity (HT)

The possible human harmfulness effect is 2.6 kg $C_6H_4Cl_2$-eq per a cubic meter. The diesel used in harvesting Khaya timber which is the main source of human toxicity compound constitutes 49%, next to diesel used to transport Khaya timber to sawmill (24%).

Assessing the carbon footprint for Ghanaian Khaya lumber in line with the PAS2050 methodology

Carbon footprint is a new concept for global warming potential and is referred to the overall greenhouse gas discharges linked to a product or service (Chaplin-Kramer et al., 2015).

Discharges of diverse separate greenhouses gases are changed to global warming potential and related in the common unit of CO_2-equivalents. The CO_2 discharge to determine the carbon footprint of product can be got from a complete LCA work. In Table 2, the mean GWP of 253 kg CO_2- equivalent can be considered as the carbon footprint for one cubic meter of Khaya lumber manufactured in Ghana.

Environmental product declaration (EPD) for Ghana Khaya lumber

Environmental product declarations are standard documents for communicating the environmental impact of a specific output using LCA. In Table 2, the mean environmental performance of Khaya lumber made in Ghana per cubic meter based on GWP was 253 kg-CO_2-Eq; AP, 3.9 kg SO_2-Eq; EP, 2.6 kg Phosphate (PO_4)-Eq; POCP, 0.56 kg Ethylene-Eq, and 2.65 kg $C_6H_4Cl_2$.Eq. GWP, AP, EP and POCP were in line with the Life Cycle Impact Assessment (LCIA) results for 1 m^3 rough-sawn, kiln dried US lumber cradle to gate for 19 different species including the LCA results for environmental product declaration of tropical plywood produced in Malaysia and Indonesia (AHEC, 2009; Gan and Massijaya, 2014).

Based on all the possible environmental signs noted in this LCA work of Khaya lumber manufactured in Ghana, it can be said that Khaya lumber output controlled from a viable tropical natural forest does better in Ghana environmentally.

Limitations

The main limitation in this work was time and budget. This assessment results are to be utilized based on the set goal and area of this work. Omitting some life cycle impact classes can lead to unfinished picture of the total performance of the products. For instance, biodiversity and potential of ozone depletion were not studied in this LCA works because there is no advanced and steady method in Africa and precisely in Ghana. Biodiversity and Ozone Depletion Potential and Biodiversity performance of hardwood production need to be studied again as novel and dependable methodologies exist. The categories factors utilized like global warming potentials (GWPs), acidifying and eutrophying potentials are not certain as these values were not created in Ghana or on Ghanaian-based data, though GWPs are mostly utilized and accepted as category factor for greenhouse gases (IPCC, 1997). The category factors utilized to calculate the PO_4-equivalents of eutrophying discharges are less utilized and depend on many suppositions (Heijungs et al., 1992). PO_4-equivalents are widely utilized in LCA work to note the gross impact of eutrophication despite the site of the discharges. Eutrophication is an environmental issue with mainly local impacts, and the eutrophication potentials can vary when eutrophication is taken as a local issue. Discharges that contribute to OPD were not looked into because there are no data in Ghana. Irrespective of the constraints, the predicted discharge and possible environmental effect shown here is the best available now and, thus served the aim of this work.

Conclusions

Life cycle assessment was utilized for the assessment and evaluation of the environmental impact of the Khaya lumber made in Ghana. Based on the results, the mean environmental performance of Khaya lumber made by three (3) firms in Ghana per cubic meter regarding GWP was 253 kg-CO_2-Eq; AP, 3.9kg SO_2-Eq; EP, 2.6 kg Phosphate (PO_4)-Eq; POCP, 0.56 kg Ethylene-Eq. The GWP, AP, EP and POCP were in line with the results of LCIA for 1 m^3 rough-sawn, kiln dried US lumber cradle to gate for 19 diverse species including the LCA results for environmental product declaration of tropical plywood produced in Malaysia and Indonesia. The results show that the environmental performance linked to Khaya lumber produced in Ghana is mostly caused by using fossil fuels. Using renewable energy sources for generating power is an alternative with good prospects against using fuel, forest activities and transporting of timber. The high return of power in timber unlike energy use in forest management makes timber a very interesting energy carrier (Lindholm and Berg, 2005). Also, to make better the environmental impact of Khaya lumber produced in Ghana, firms can decrease diesel use by trucks and improving transport systems like rail system and material flow in the production process to decrease internal transport (Kätelhön et al., 2015).

Wood drying using solar energy powered with high frequency inverter is also a better environmental improvement for kiln drying of Khaya lumber. Wood waste is a serious matter and needs fast consideration. This can be altered to Environmental Product Declaration use in terms of the selected scheme or Product Category Rules. It is concluded that Khaya lumber made in Ghana which is managed from a sustainable tropical natural forest does better environmentally. All data utilized in this work to measure the discharges and possible environmental effect is taken as the best data now and, thus served the aim of the work.

This work gave excellent primary data distinctive for LCA research in Africa. This can facilitate LCA methods in Ghana, and help to identify the core environmental stresses and their major contributing processes in the timber sector.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Assessment of drinking water quality at Dodowa in the Dangbe West district of the Greater-Accra region, Ghana

W. E. Arko[1*], I. O. A. Hodgson[1] and F. K. Nyame[2]

[1]Council for Scientific and Industrial Research, Water Research Institute (CSIR-WRI), P. O. Box M 32 Accra, Ghana.
[2]Department of Earth Science, College of Basic and Applied Science, University of Ghana, Accra, Ghana.

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Dodowa serves as a major peri-urban community close to the Accra Metropolis with increasing population, urbanization and settlements. Lack of access to basic infrastructural facilities including water and sanitation has hampered the development of the community. Dodowa has irregular access to pipe-borne water therefore the community resorts to other means of getting potable water. It is against this background that this study was conceived to assess the quality of drinking water sources in the community. Groundwater (Hand-Dug-Wells), stored water from pipes and mobile tanker water services were sampled to ascertain their quality since they were the major sources of water supply in the community. In all, 100 samples were collected for four months, 8 hand dug wells and 2 boreholes were sampled for groundwater, 10 stored water in either poly tanks or concrete tanks and then 5 mobile tanker water services were also sampled and physico-chemical and bacteriological parameters were assessed. The sources of water were also assessed to ascertain their quality. The available water sources in the Dodowa township could not be considered potable especially the groundwater which had high levels of turbidity, total dissolved solids (TDS), chloride, sodium and iron and therefore needs treatment before use. All the water sources had coliform bacteria which could cause water borne disease such as cholera, typhoid, dysentery and diarrhea thus unsafe for drinking without treatment.

Key words: Physico-chemical, microbiological, groundwater, potable water, water quality, Dodowa, coliform bacteria.

INTRODUCTION

Cairncross and Valdmanis (2006) defined access to water supply as the availability of at least 20 L/capita/day from a source within 1 km of the user's dwelling. This accessibility to an improved water supply can either be house connections and public or community sources. Globally, 1.1 billion people lacked access to improved water sources, which is 17% of the global population. Also, 2.6 billion people which is 42% of the world's population lacked access to improved sanitation. There is a link between good water and sanitation. In sub-Saharan Africa, 42% of the population is still without improved water and also sanitation coverage is a mere

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

36% (WHO, 2004).

Each human being needs to consume several litres of fresh water daily to sustain his or her life. Since life is dependent on water, quality is paramount. However, fresh water is at a premium. Over 97% of the world's water is seawater thus unsuitable for drinking and for most agricultural purposes (Baird, 2000).

The 2010 population and housing census puts Ghana's population at twenty four million, six hundred and fifty eight thousand, eight hundred and twenty three thousand people (24,658,823) with a growth rate of 2.5% (Ghana Statistical Service, 2014). It is without doubt that the population of Ghana is increasing at a rapid pace. Although most of the population growth takes place in the cities, majority of Ghana's population still live in rural areas (Schäfer et al., 2010).

According to the 2010 population and housing census, 46.5% have access to pipe borne water while 29.1% use borehole or protected well. In addition, 9.4% rely on sachet/bottled water. About 10.6% of households depend on surface water such as rivers, streams, dams, canals and ponds for drinking. Less than 1% (0.7%) depend on rainwater while 1.1% depend on tanker/ vendor services (Ghana Statistical Service, 2014).

Water supply and sanitation in Ghana faces a lot of problems. Poor access to improved water and sanitation in Ghana is attributed to a number of reasons which include weak sector policies, lack of political will, weak local government capacity and inadequate financing (Osumanu, 2010).

This study seeks to find the other sources of drinking water in the Dodowa community since that of the Ghana Water Company Limited is irregular. The quality of the other sources of drinking water will also be looked at. This research is also being conducted so that other researchers will build upon it.

Dodowa serves as a major peri-urban community close to the Accra Metropolis with increasing population, urbanization and settlements. Lack of access to basic infrastructural facilities including water and sanitation has hampered the development of the community. Dodowa has irregular access to pipe-borne water, therefore the community resorts to other means of getting potable water. Water sources available to the people include boreholes and hand dug wells. Many people in Dodowa store water in containers such as poly tanks and concrete tanks. They also patronize the services of water tankers. This research, therefore seeks to find the quality of boreholes and hand dug wells, stored water facilities and water tanker services as drinking water in the community and to provide data to help inform planning and decision making to ensure improvement in provision of water supply quality and facilities in the area. According to the Public Utilities Regulatory Commission (PURC) of Ghana, majority of urban households depend on secondary water providers like tankers, cart operators and domestic vendors, at a cost that is 12 times more than normal (paying too much for poor services). It is against this background that the study was initiated to access the quality of drinking water sources in the community. Groundwater (Boreholes and hand dug wells), stored water from pipes and mobile tanker services were sampled to ascertain their physico-chemical and bacterialogical quality since they were the major sources of water supply in the community. Sources considered as improved water are piped public water into homes, public standpipe, borehole, protected (lined) dug well, protected spring, and rainwater collection; unimproved are unprotected wells and springs, vendors, and tanker-trucks (WHO and UNICEF, 2000).

METHODOLOGY

Study area

Dodowa is the district capital of the Dangme West district. The district lies between latitudes 5°45' and 6°05' north and longitude 0°05'E and 0°20'W. It has a population of 122,836 comprising 58,806 males and 64,030 females (Ghana Statistical Service, 2014). In all, the district occupies a total land area of about 968.361 km^2 (Figure 1). The district has Dodowa as its capital. Based on Legislative Instrument, LI 2137, Dangme West district was split into two to have Ningo Prampram and Shai-Osudoku districts in June, 2012 (2010 Population and Housing census, District Analytical Report, 2014). It shares boundaries with the North Tongu district to the North-East, Yilo and Lower Manya districts to the North-West, Akwapim North district to the West, Kpone Kantamanso district to the South-West, Ningo Prampram district to the South and the Ada West district to the East (2010 Population and Housing Census, District Analytical Report, 2014). The Volta River washes the North-Eastern portions of the district (Ghana Statistical Service, 2014).

The Southeastern coastal plain of Ghana, which encompasses the Dangme West district, is one of the hottest and driest parts of the country. Temperatures are however subjected to occasional and minimal moderating influences along the coast and altitudinal influences affected by the Akwapim range in the northwest. Temperatures are appreciably high for most parts of the year with the highest during the main dry season (November - March) and lowest during the short dry season (July - August). They average a few degrees lower on the coast and close to the Akwapim range than they do over most of the plains. The absolute maximum temperature is 40°C. Mean annual rainfall increases from 762.5 ml on the coast to 1220 ml to the North and Northeast close to the foothills of Akwapim Range and on the summit (District Medium Term Development Plan 2010-2013, 2014).

The accessibility to potable water in Dodowa community is generally inadequate. The bigger and sub-urban communities like Dodowa, Prampram, Ningo, Afienya, Asutsuare, Osuwem, Ayikuma, etc., that are connected to GWCL lines from Kpong and Osudoku Water Project, in which flow of water is highly unreliable. In fact, Dodowa currently receives water from the GWCL only once in a week. To address this problem, the assembly has started the drilling of boreholes in suburbs of Dodowa so as to increase access to water supply (District Water and Sanitation Plan 2011-2014, 2014).

Water sampling

A total of 100 water samples were taken. Groundwater samples

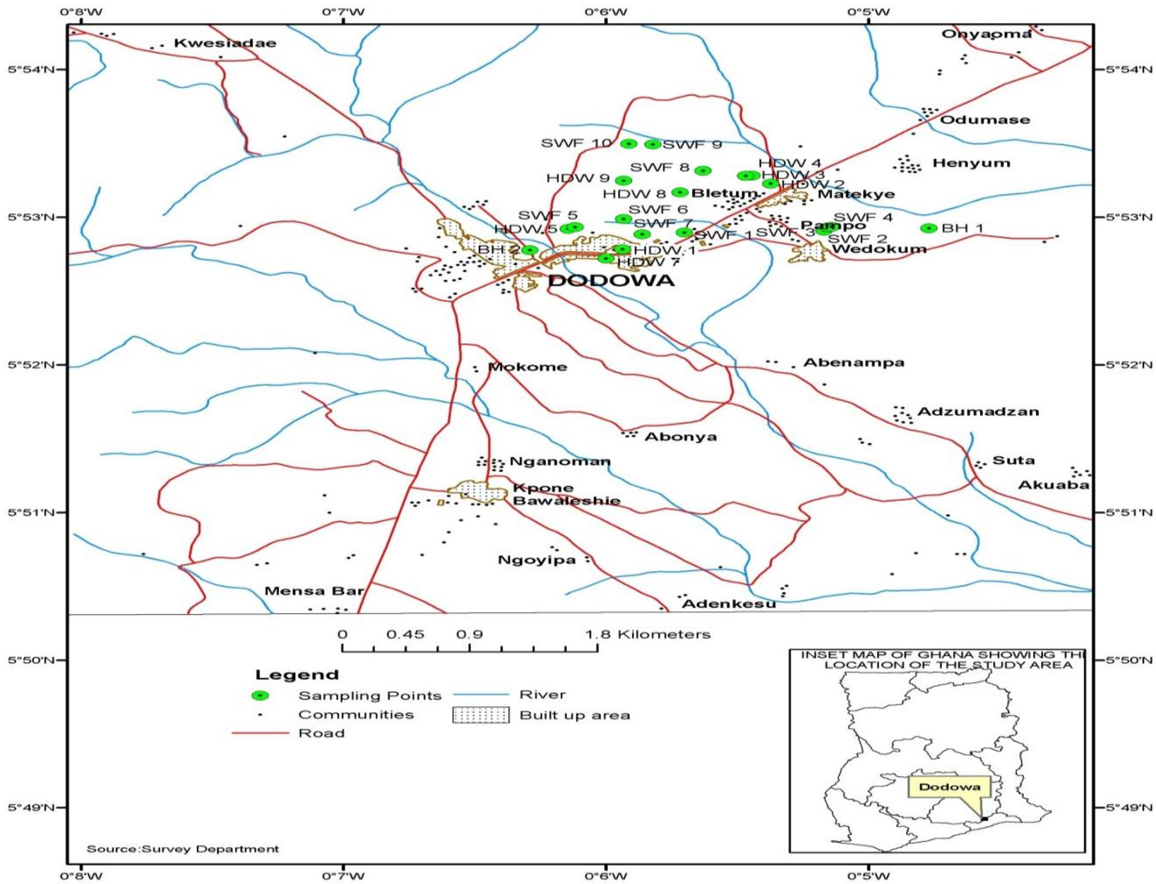

Figure 1. Map of Dodowa with sampling sites.

were collected between the periods of four months (November 2012 - February 2013). Eight hand-dug well (HDW) and two borehole (BH) water samples were collected for each month for the sampling sites. Ten stored water (SWF) samples (poly tanks and concrete tanks) were also taken during the four months. Twenty mobile tanker (MTS) services were also sampled.

One-litre plastic bottle was filled with water at each site. This was subsequently used in the laboratory for off-site analysis. Samples for bacteriological analysis were collected into 500 ml sterilized bottle and the cap covered with aluminium foil to avoid contamination during sampling. The samples were kept on ice and transported to the CSIR-WRI laboratory for the physico-chemical analysis. The bacteriological analyses were carried out immediately on arrival at the CSIR-WRI laboratory.

Physico-chemical and bacteriological analysis

The physico-chemical parameters were determined according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). Turbidity was measured with a HACH 2100 P Turbidimeter, colour by visual comparison method comparator, and pH by Suntex Model SP 701 pH Meter. Conductivity was measured with Cybersan PC 510 conductivity meter, total dissolved solids and suspended solids were measured gravimetrically after drying in an oven to a constant weight at 105°C. Sodium and potassium were measured by flame emission photometry, calcium and magnesium by the EDTA titration, sulphate by the turbidimetric method, and chloride by Argentometric method. Other analyses included alkalinity by strong acid titration. Nitrate was determined using hydrazine reduction method, Nitrite by diazotization method and Phosphate by stannous chloride method. Ammonium was determined by direct nesslerisation and spectrophotometric determination at 410 nm. Nitrate was determined at 520 nm, nitrite at 540 nm and phosphate determined at 690 nm. Fluoride was determined by SPADNS method, total iron and manganese by Atomic Absorption Spectrophotometry (AAS). Bacteriological analyses involved the determination of total and faecal coliforms by membrane filtration.

Statistical data analysis

Statistical analysis was done using SPSS version 19.0 for windows and Microsoft Office Excel 2013. ANOVA t-test was done.

RESULTS AND DISCUSSION

Table 1 shows the water quality parameters for the groundwater, stored water and tanker water.

There was no significant difference between the groundwater, stored water and tanker water for pH ($p>0.05$). The pH of the ground water sources were

Table 1. Water quality data for groundwater, stored water and mobile tanker.

Parameter	Min	Max	Mean	SD	GSA/WHO
Groundwater					
pH (pH units)	6.28	7.62	6.98	0.450	6.5 - 8.5
Turbidity (NTU)	3.52	85.2	23.0	26.5	5
EC (µS/cm)	363	6968	2038	1951	-
TDS (mg/l)	200	3833	1121	1073	1000
HCO_3 (mg/l)	55.6	496	256	145	-
NO_3 (mg/l)	0.140	0.840	0.365	0.207	10
SO_4 (mg/l)	44.8	219	91.2	52.6	250
Cl (mg/l)	68.1	2134	468	617	250
Ca (mg/l)	16.7	292	93.5	82.7	200
Na (mg/l)	52.9	1084	238	312	200
Mg (mg/l)	11.9	112	59.6	37.3	150
K (mg/l)	2.75	11.1	4.39	2.44	30
Fe (mg/l)	0.040	1.74	0.495	0.588	0.3
Fluoride (mg/l)	<0.005	<0.005	<0.005	<0.005	1.5
TC (cfu/100 ml)	0	581	122	195	0
FC (cfu/100 ml)	0	229	27.7	71.5	0
Stored water					
pH (pH units)	6.12	7.34	6.93	0.393	6.5 - 8.5
Turbidity (NTU)	2.30	9.25	4.67	2.09	5
EC (µS/cm)	192	392	301	66.8	-
TDS (mg/l)	105	214	165	35.4	1000
HCO_3 (mg/l)	38.6	67.4	54.9	10.4	-
NO_3 (mg/l)	0.270	1.46	0.506	0.398	10
SO_4 (mg/l)	14.6	64.1	40.1	13.9	250
Cl (mg/l)	18.1	62.2	29.8	16.7	250
Ca (mg/l)	11.4	22.0	14.9	3.40	200
Na (mg/l)	20.9	49.2	29.8	9.57	200
Mg (mg/l)	3.75	9.02	5.92	1.74	150
K (mg/l)	2.20	3.30	2.75	0.310	30
Fe (mg/l)	0.040	0.230	0.101	0.061	0.3
Fluoride (mg/l)	<0.005	<0.005	<0.005	<0.005	1.5
TC (cfu/100 ml)	0	115	11.5	35.9	0
FC (cfu/100 ml)	0	0	0	0	0
Mobile tanker					
pH (pH units)	5.30	7.71	6.91	0.697	6.5 - 8.5
Turbidity (NTU)	1.64	32.5	7.37	9.00	5
EC (µS/cm)	272	1824	891	553	-
TDS (mg/l)	150	1003	490	304	1000
HCO_3 (mg/l)	12.0	317	137	81.6	-
NO_3 (mg/l)	0.020	2.84	0.944	0.962	10
SO_4 (mg/l)	15.3	274	75.5	68.9	250
Cl (mg/l)	30.8	501	144	132	250
Ca (mg/l)	16.0	124	49.1	27.6	200
Na (mg/l)	5.00	269	77.3	69.5	200
Mg (mg/l)	1.90	89.8	27.6	24.4	150
K (mg/l)	1.00	7.60	3.12	1.27	30
Fe (mg/l)	0.00	0.720	0.147	0.215	0.3
Fluoride (mg/l)	<0.005	<0.005	<0.005	<0.005	1.5

Table 1. Contd.

TC (cfu/100 ml)	0.00	523	150	144	0
FC (cfu/100 ml)	0.00	204	33.2	64.3	0

between 6.11 and 7.75 with a mean of 6.98 and standard deviation of 0.494. The pH for the stored water and the mobile tanker was also within the WHO Guideline values with means of 6.93 and standard deviation of 0.507, and 6.91 and standard deviation of 0.697, respectively. All the three water sources were within GSA and WHO guideline value of 6.5 to 8.5. Acidity (pH) and alkalinity are the base- and acid-neutralizing capacities of water. Waters of low alkalinity (<24 mgl^{-1} as $CaCO_3$) are considered to have a low buffering capacity and can, therefore, be susceptible to alterations in pH (Chapman, 1996). The alkalinity of some waters is due only to the bicarbonates of calcium and magnesium. The pH of such water does not exceed 8.3 and its total alkalinity is practically identical with its bicarbonate alkalinity (Ballance and Bartram, 2002). pH is important in water quality assessment as it influences many biological and chemical processes within a water body (Chapman, 1996). In unpolluted waters, pH is principally controlled by the balance between the carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds such as humic and fulvic acids (Chapman, 1996).

The turbidity for the groundwater ranges from 3.52 to 85.0 NTU with a mean of 23.0 NTU and standard deviation of 26.5 NTU, that of the stored water was from 2.30 to 9.25 NTU with a mean of 4.67 and standard deviation of 2.09 NTU. The tanker water had turbidity values with a mean of 7.37 NTU and standard deviation of 9.00 NTU. Their means exceeded the Ghana Standard Authority guideline and WHO guideline of 5 NTU. This could be attributed to heavy metals and biocides and can also harbour microorganisms or have the possibility of microbiological contamination (DWAF, 1989). The high levels also in the stored and tanker water could be due to the containers/tanks not being washed for a long time. With the three water sources, the tanker water was better with respect to turbidity followed by the stored water and the groundwater. Visible turbidity reduces the aesthetic acceptability of drinking-water. Turbidity can vary in colour and appearance, ranging from milky-white clay-based particles to muddiness from sediments and soils, red-brown iron-based particles and black manganese based particles. At high levels, turbidity can lead to staining of materials, fittings and clothes exposed during washing (WHO, 2017).

The electrical conductivity for the groundwater varied from 363 to 6968 µS/cm with a mean of 2038 µS/cm and standard deviation of 1950 µS/cm. The electrical conductivity for the stored water ranged from 192 to 393 µS/cm with mean of 301 µS/cm and standard deviation of 66.8 µS/cm. And that of the tanker water ranged from 272 to 1824 µS/cm with mean of 891 µS/cm and standard deviation of 553 µS/cm. There was however a significant difference between the water sources for electrical conductivity ($p<0.05$). Conductivity is a measure of the level of mineralization (Water Resources Commission, 2003) or the ability of water to conduct an electric current (Chapman, 1996). It is sensitive to variations in dissolved solids, mostly mineral salts. The degree to which the mineral salts dissociate into ions, the amount of electrical charge on each ion, ion mobility and the temperature of the solution all have an influence on conductivity (Chapman, 1996). And therefore, the groundwater will be more mineralized or will have high levels of cations and anions compared to the stored and tanker water.

The total dissolved solids (TDS) for groundwater values ranged from 200 to 3833 mg/l with a mean of 1121 mg/l and standard deviation of 1073 mg/l. The TDS levels for the stored water ranged from 105 to 214 mg/l with mean of 165 mg/l and standard deviation of 35.4 mg/l. And that of mobile tanker was from 150 to 1003 mg/l with mean of 490 mg/l and standard deviation of 304 mg/l. TDS comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations; calcium, magnesium, sodium and potassium and the anions; carbonate, bicarbonate, chloride, sulphate; and particularly in groundwater, nitrate (www.hc-sc.gc.ca). The groundwater had TDS higher than the tanker and stored water; this could be due to the high level of mineralization of the groundwater.

There was a significant difference between the groundwater, stored water and tanker water for chloride ($p<0.05$). The chloride values for groundwater varied from 68.1 to 2134 mg/l with a mean of 468 mg/l and standard deviation of 617 mg/l. Plate A shows the geographical map of the groundwater over the sampling sites, those in red exceeded the GSA and WHO guideline values. Chloride in surface and groundwater from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas (Department of National Health and Welfare, Canada, 1978). High levels of chloride in groundwater could be as a result of weathering of the rocks underlying the area.

That of the stored water ranged from 18.1 to 62.2 mg/l with mean of 29.8 mg/l and standard deviation of 16.7 mg/l. And that of the mobile tanker chloride levels ranged

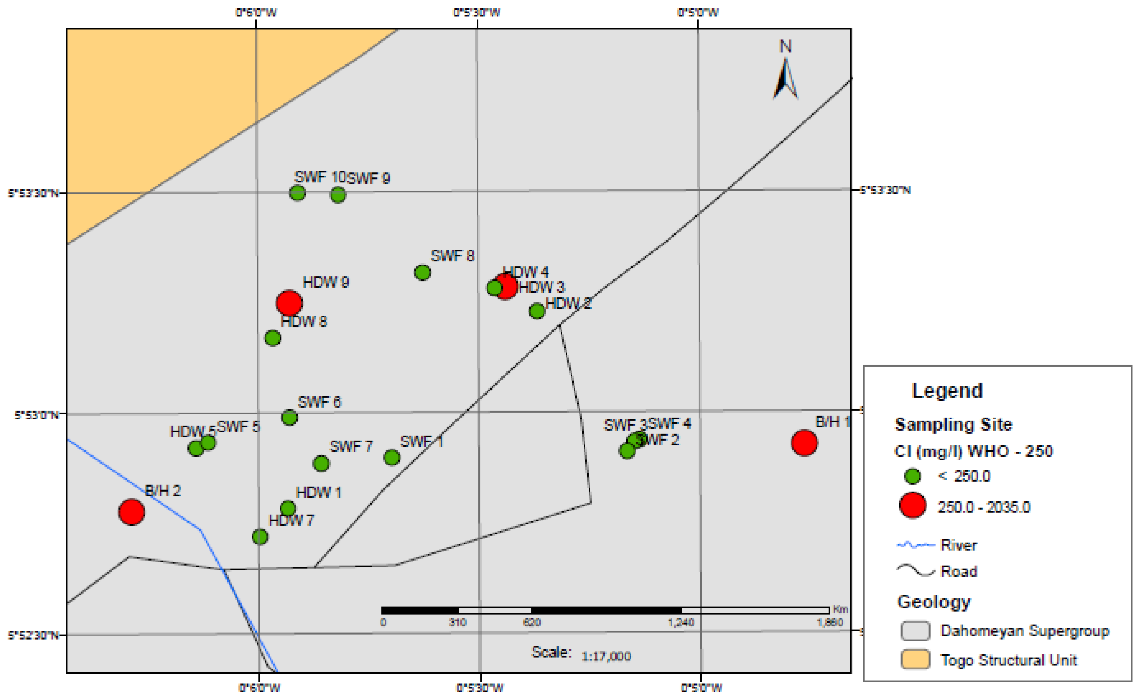

Plate A. Geographical map of chloride.

from 30.8 to 501 mg/l with a mean value of 144 mg/l and standard deviation of 132 mg/l which were within the GSA and WHO guideline value of 250 mg/l. The stored water had good quality than the mobile tanker and groundwater.

Bicarbonate values for groundwater ranged from 55.0 to 496 mg/l with a mean of 256 mg/l and standard deviation of 145 mg/l. The bicarbonate values for stored water ranged from 38.6 to 67.4 mg/l with mean of 54.9 mg/l and standard deviation of 10.4 mg/l and the bicarbonate levels for the tanker water ranged from 12.0 to 317 mg/l with mean value of 137 mg/l and standard deviation of 81.6 mg/l. The presence of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) influences the hardness and alkalinity of water. The weathering of rocks contributes carbonate and bicarbonate salts. The relative amounts of carbonates, bicarbonates and carbonic acid in pure water are related to pH. As a result of the weathering process, combined with the pH range of surface waters (~6-8.2), bicarbonate is the dominant anion in most surface waters. Carbonate is uncommon in natural surface waters because they rarely exceed pH 9, whereas groundwater can be more alkaline (Chapman, 1996). There is however, no maximum value for carbonates and bicarbonates.

The nitrate values for groundwater ranged from 0.140 to 0.840 mg/l with a mean of 0.365 mg/l and standard deviation of 0.207 mg/l. Nitrate levels for stored water ranged from 0.270 to 1.46 mg/l with mean of 0.506 mg/l and standard deviation of 0.398 mg/l and that of tanker water ranged from 0.020 to 2.84 mg/l with mean of 0.944 mg/l and standard deviation of 0.962 mg/l. The nitrate values were all within the GSA and WHO guideline values of 10 mg/l.

Sulphate levels for groundwater ranged from 44.8 to 219 mg/l with a mean of 91.2 mg/l and standard deviation of 52.6 mg/l. And that of the stored water ranged from 14.6 to 64.1 mg/l with mean of 40.1 mg/l and standard deviation of 13.9 mg/l. The sulphate levels for the tanker water ranged from 15.3 to 274 mg/l with a mean value of 75.5 mg/l and standard deviation of 68.9 mg/l. Sulphate is naturally present in surface waters as SO_4^{2-}.The values for sulphate for all the three water sources were within the GSA and WHO guideline values of 250 mg/l. The stored water was good in relation to sulphate than the tanker water and groundwater.

Sulphate arises from the atmospheric deposition of oceanic aerosols and the leaching of sulphur compounds, either sulphate minerals such as gypsum or sulphide minerals such as pyrite, from sedimentary rocks. It is the stable, oxidized form of sulphur and is readily soluble in water. High concentrations may make water unpleasant to drink (Chapman, 1996).

Calcium levels for groundwater ranged from 16.7 to 292 mg/l with a mean of 93.5 mg/l and standard deviation of 82.7 mg/l and that for the stored water between 11.4 and 22.0 mg/l with mean of 14.9 mg/l and standard deviation of 3.40 mg/l. That of the tanker water ranged from 16.0 to 124 mg/l with mean value of 49.1 mg/l and standard deviation of 27.6 mg/l. They were all within the

GSA and WHO guideline value of 250 mg/l. The stored water was better than the tanker water and groundwater.

Magnesium levels for groundwater ranged from 11.9 to 118 mg/l with a mean of 59.6 mg/l and standard deviation of 37.3 mg/l. Magnesium levels for stored water ranged from 3.75 to 9.02 mg/l with mean of 5.92 mg/l and standard deviation of 1.74 mg/l. And that of tanker water ranged from 1.90 to 89.8 mg/l with mean of 27.6 mg/l and standard deviation of 24.4 mg/l. The magnesium also followed the same trend of the stored water being better than the tanker water and the groundwater.

The salts of calcium, together with those of magnesium, are responsible for the hardness of water (APHA, 2012; Chapman, 1996; www.hc-sc.gc.ca).

Sodium levels for groundwater ranged from 52.9 to 1084 mg/l with a mean of 238 mg/l and standard deviation of 311 mg/l. Plate C shows the geographical map of sodium over the groundwater sampling sites and the sites in red exceeded the GSA and WHO guideline value. The stored water ranged from 20.9 to 49.2 mg/l with mean of 29.8 mg/l and standard deviation of 9.57 mg/l. Sodium levels for the tanker water ranged from 5.00 to 269 mg/l with mean of 77.3 mg/l and standard deviation of 69.5 mg/l. Yet again, it follows the same trend, the stored water being good, followed by the tanker water and then the groundwater.

Potassium levels for groundwater ranged from 2.75 to 11.1 mg/l with a mean of 4.39 mg/l and standard deviation of 2.44 mg/l. Potassium levels ranged from 2.20 to 3.30 mg/l with mean of 2.75 and standard deviation of 0.310 mg/l. Potassium levels ranged from 1.00 to 7.60 mg/l with a mean value of 3.12 and standard deviation of 1.27 mg/l. All the three water sources had potassium below the GSA and WHO guideline value of 30 mg/l and therefore were all of good quality in terms of potassium. The stored water was better than the tanker water and the groundwater.

Plate B shows the geographical map of iron of groundwater over the sampling sites; those in red exceeded the GSA and WHO guideline values. Iron values for groundwater ranged from 0.040 to 1.74 mg/l with a mean of 0.495 mg/l and standard deviation of 0.588 mg/l. And that of the stored water ranged from 0.040 to 0.230 mg/l with mean of 0.101 mg/l and standard deviation of 0.061 mg/l. That of the tanker water ranged from 0 to 0.720 mg/l with mean of 0.147 mg/l and standard deviation of 0.215 mg/l. The high levels of iron in groundwater and tanker water exceeded the GSA and WHO guideline values of 0.3 mg/l. This may be due to the weathering of rocks and minerals. This causes groundwater that looks clear when first brought from a well to become cloudy, and then appear orange in colour, as oxidation immediately occurs with the precipitation of ferric hydroxide, iron (II) is converted to iron (III) (Chapman, 1996).

The precipitation of excessive iron imparts an objectionable reddish-brown colour to water (WHO, 2004). These high levels of iron will impart a bitter taste to water making it have that metallic taste like that of blood, a brownish color to laundered clothing and plumbing fixtures, emergence of iron bacteria and discoloured beverages (www.usgs.gov/search) and (www.purdue.edu/envirosoft/groundwater/src/title.htm), and may also result in haemochromatosis, a condition in which normal regulatory mechanism do not operate effectively, leading to tissue damage as a result of the accumulation of iron (Watt and Merrill, 1963; Hopps, 1972; Jacobs, 1977 in www. hc-sc.gc.ca). The stored water was better in terms of quality than the tanker water and groundwater.

Total coliform (TC) bacteria counts for groundwater ranged from 0 to 581 cfu/100 ml with a mean of 122 cfu/100 ml and standard deviation of 195 cfu/100 ml and the faecal coliform (FC) bacteria counts ranged from 0 to 229 cfu/100 ml with a mean of 28 cfu/100 ml and standard deviation of 71 cfu/100 ml. Plate D shows the geographical map of total coliform over the sampling sites. The quality of water for the stored water was generally good except for the total coliform which exceeded the GSA and WHO guideline values of 0 which may be attributed to the tanks and containers used to store the water not cleaned properly and frequently.

TC counts for stored water ranged from 0 to 115 cfu/100 ml with mean of 11 cfu/100 ml and standard deviation of 40 cfu/100 ml. There are no FC in the stored water. TC and FC levels for the tanker water ranged from 0 to 523 cfu/100 ml with mean of 150 cfu/100 ml and standard deviation of 144 cfu/100 ml and 0 to 204 cfu/100 ml with mean of 33 cfu/100 ml and standard deviation of 64 cfu/100 ml, respectively.

The stored water had the best quality compared to the tanker water and groundwater. This was because the stored water is the irregular water supply from the GWCL which they have stored for use. It had a few concerns in terms of coliforms due to the way they are stored and irregularity with which the tanks are cleaned. The tanker water was from either pipe or boreholes/wells which they could not authenticate the source and the groundwater was from boreholes/wells which have not been treated, that accounts for the high levels of ions and iron.

Spatial distribution of parameters over sampling points

Plates A, B, C, and D show the spatial distribution of parameters over sampling points.

CONCLUSION AND RECOMMENDATION

The available water sources in the Dodowa township could not be considered potable especially with the groundwater which had high levels of turbidity, TDS,

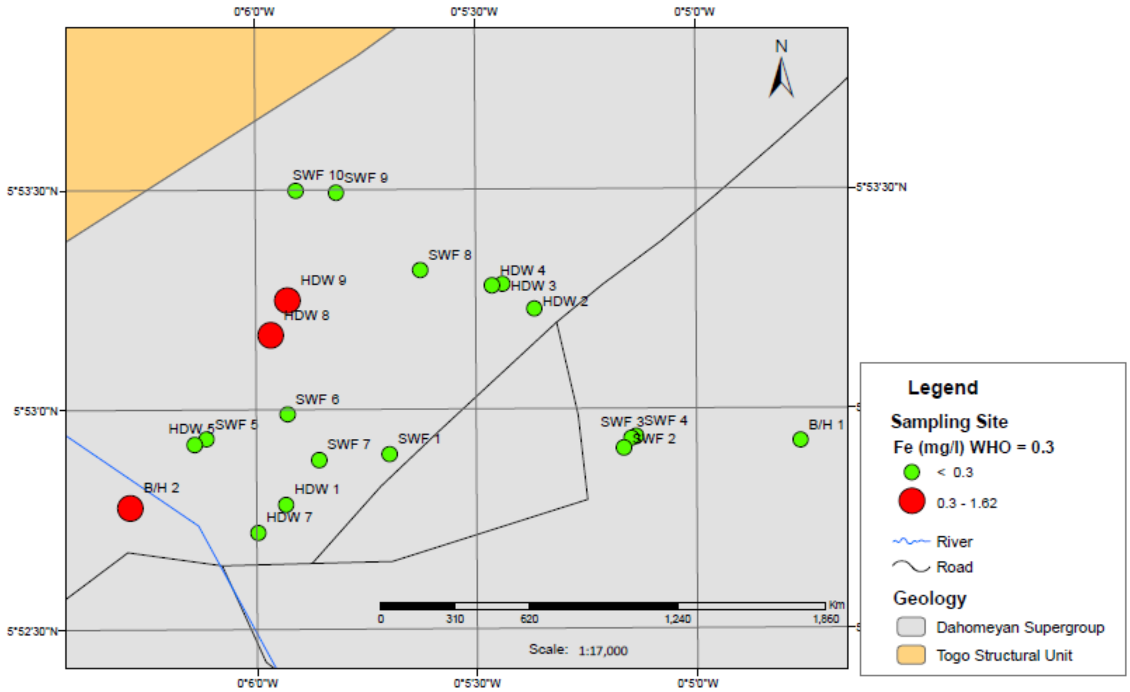

Plate B. Geographical map of iron.

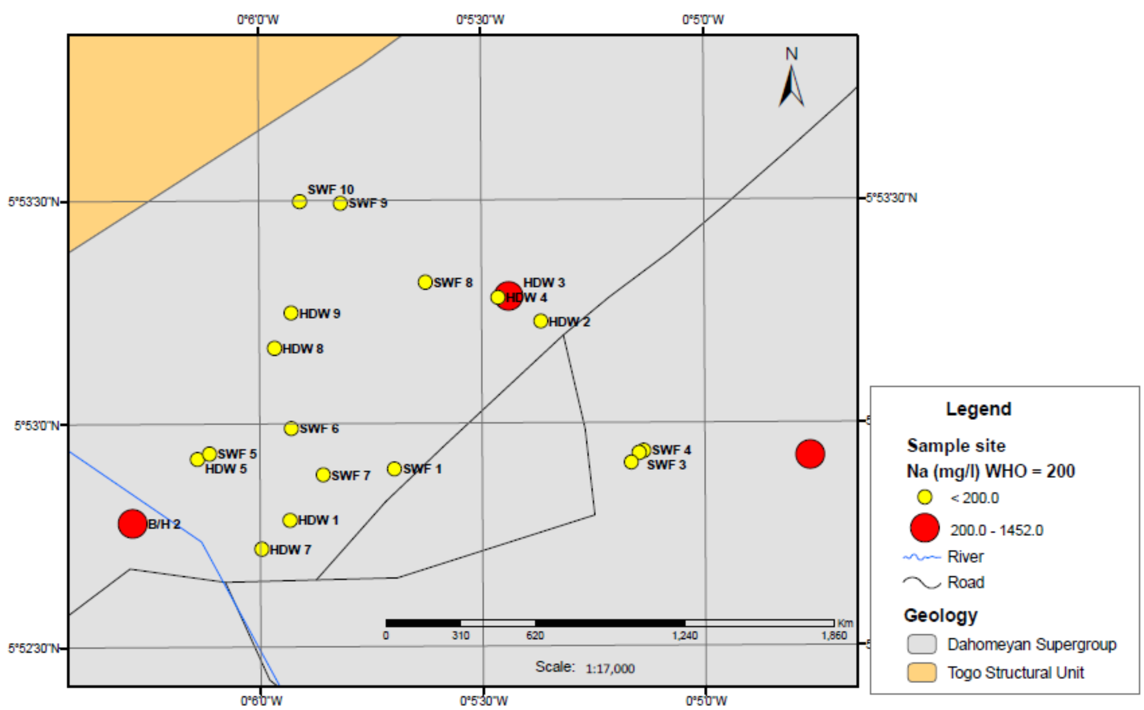

Plate C. Geographical map of sodium.

chloride, sodium and iron and therefore needs treatment before use. All the water sources had coliform bacteria which could cause cholera, typhoid, dysentery and diarrhea (Chapman, 1996). The high levels of coliform pose serious challenges to water resource management and could seriously affect public health and the socio-

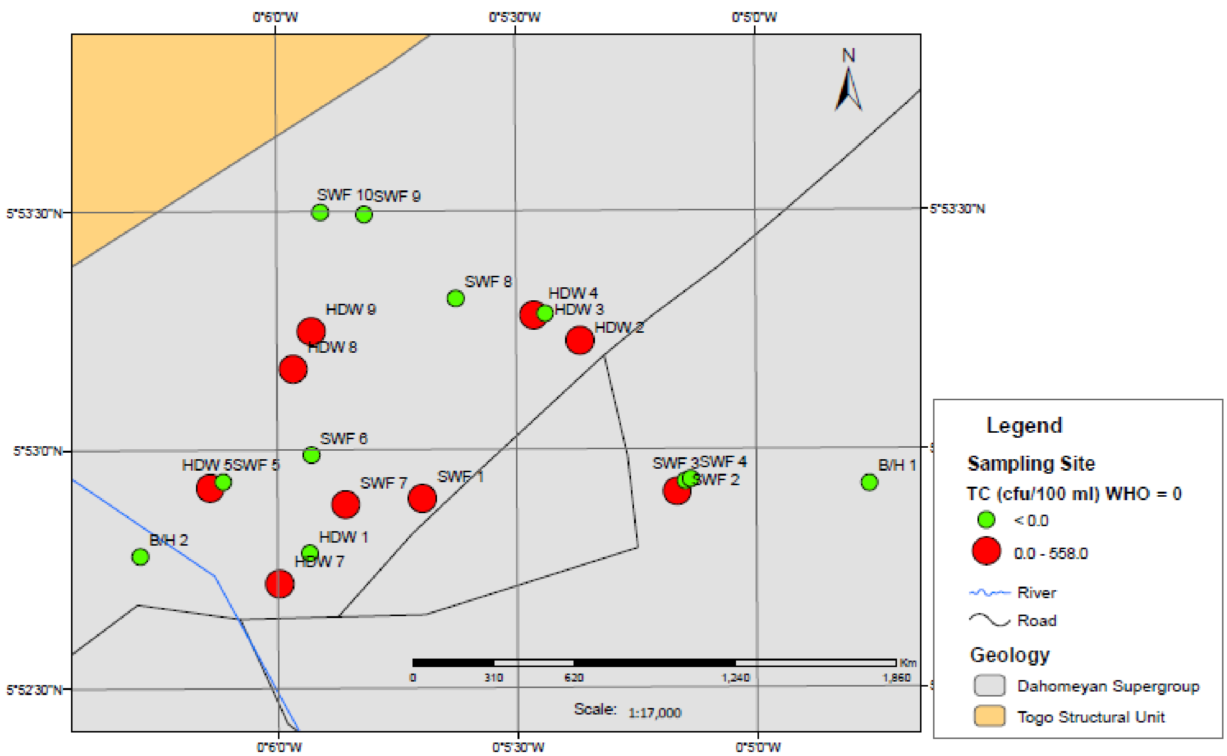

Plate D. Geographical map of total coliform.

economic effect of ingesting coliform-infested water would be disastrous (Cobbina et al., 2009).

The stored water had the best quality compared to the tanker water and groundwater. On that basis the following are recommended for the management of the sources of drinking water in the Dodowa community:

(1) The Dangbe West district assembly should make sure residents do not sink wells near or closer to places of convenience so as not to cause contamination of wells with faecal matter as they may be leached into the wells.
(2) There is the need to increase the effectiveness of existing legislation by making use of a community participatory model. Since the chiefs are close to the people and have significant control over the actions of individuals within their jurisdiction, collaborative enforcement of environmental regulations should be promoted between the district assembly and the local authorities.
(3) There should be environmental education by the Dangbe West district assembly and must be structured in such a way that it cuts across all spheres of society thus catering for the educated and the non-educated.
(4) Residents should be encouraged to go for rain harvesting as another source of water for potable and domestic use.
(5) Residents should be educated on how to clean and chlorinate their stored water tanks as it is their major source of drinking water.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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An assessment of the contribution of fluvial sediment discharge to coastal stability: A case study of Western Region of Ghana

Boye Borkai Cynthia[1], Boateng Isaac[2], Appeaning Addo Kwasi[3*] and Wiafe George[3]

[1]Department of Minerals Engineering, Faculty of Mineral Resources Technology, University of Mines and Technology (UMaT), Tarkwa, Ghana.
[2]School of Civil Engineering and Surveying, University of Portsmouth, Portland Building, Portland Street, Portsmouth, PO1 3AH, United Kingdom.
[3]Department of Marine and Fisheries Sciences, School of Biological Sciences, University of Ghana, P. O. Box LG. 99, Legon - Accra, Ghana.

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Fluvial sediment discharge to coastal area contributes to the stability of the coast. Deposition of fluvial sediment discharge is an important source of beach nourishment, nutrient for aquatic ecology and habitats. However, human development and interventions on rivers in the form of dams and flood alleviation schemes tend to reduce fluvial sediment supply to the coast, thus impacting on coastal stability and geomorphology. This paper assessed the contribution of fluvial sediment discharge to coastal stability for the study area. Multi-temporal topographic data acquired in 1974 and 2005; flow data on major rivers in the study area and field observations were used. Digital Shoreline Analysis System was for computation of shoreline change rates. Applying the power regression relation, sediment discharge by rivers was computed for rivers in the study area. The study revealed that rivers in the catchment supply about 1.8 × 10^5 tonnes of sediment to the shores daily, thus supporting coastal stability. Results of shoreline change showed relatively stable beach at the mouth of rivers and lagoons due to the sediment discharge. It is recommended that policies are implemented to reduce the impact of dams and beach sand mining activities along river channels to ensure the stability of Ghana's Western coastline and the coastline of neighbouring countries.

Key words: Coastal rivers, fluvial sediment, impacts of human interventions, coastal stability, Western Region of Ghana.

INTRODUCTION

Sediment supplied by rivers constitutes between 80 and 95% of total sediment deposited at the coast (Walling, 2006; Bittencourt et al., 2005). Such deposition is important for aquatic ecology and habitats (e.g. saltmarshes and tidal mudflats) (Owens, 2007). It also serves as a rich source of sediment supply for many settlements within the lower catchment of such rivers, thus high agricultural yields are often recorded.

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

Furthermore, the deposition of river load from the hinterland recharge the beach with sand materials required for normal coastal processes: sediment transport along and across the shore by the currents (Milliman et al., 1995). Segments of the shore that receive more sediment load from fluvial sources tend to record growth in beach size, whereas beach losses are observed where less fluvial sediment deposition takes place (Cooper and Pethick, 2005). This phenomenon occurs, particularly, where coastal cell boundaries clearly and distinctly exist.

Although it is estimated that global sediment supplied annually by rivers amounts to about 10 to 20 billion metric tonnes, the effect of human interventions bring considerable uncertainty in the volume of sediment load which actually reaches the coast (Darby et al., 2016). Some activities of humans (dams, alluvial mining, flood defences) frequently interfere with fluvial sediment transport by intercepting sediment upstream, before they reach shores. For instance, damming of rivers for hydroelectric power, drinking water supply and irrigation, causes sediment deficiency at the shores (Willis and Griggs, 2003; Brandt, 2000; Berkun, 2010). Fluvial sediment starvation along the shores could also cause severe erosion (Milliman et al., 1995; Walling, 2006).

Studies show significant adverse effects of river damming on many coasts worldwide. For instance, the construction of the Aswan High Dam and Akosombo Dam across the Nile River and the river Volta have led to a significant reduction of sediment supplied by the rivers to the coast and thus, resulting in serious coastal erosion along the shore (IRTCES, 2011; Pottinger, 1996; Ly, 1980; Boateng et al., 2012).

The effects of Akosombo Dam has affected the neighbouring Togo and Benin, whose coasts are now being eroded at a rate of 10 to 15 m per year (Pottinger, 1996). It is also reported that the damming of the tributary of the Mississippi River over the past 60 years has reduced sediment supplied to Louisiana's wetlands by 50% thus increasing the rate of erosion of the shores (IRTCES, 2011). Severe shoreline recession resulting from sediment deficiency to the coast is a common phenomenon from one coast to another. According to Boateng et al. (2012), most coasts are closely connected to the hinterland through the fluvial sediment input from local rivers. Therefore, development in the hinterland that alters the fluvial sediment input of local rivers could have significant effects on coastal stability.

In Ghana, the shoreline of the eastern and central zones on average are eroding between 2 and 4 m/year and 1.5 and 2.5 m/year, respectively, whiles the western zone has little pockets of erosion, on average is accreting at 0.05 m/year or stable (Ly, 1980; Wellens-Mensah et al., 2002; Appeaning-Addo, 2008; Boateng, 2012). Since fluvial sediment discharge plays a vital role in the stability of the shoreline, it is important to assess the volume of sediment supply from river sources and factors that impact on the fluvial supply to the coast in order to formulate policies to manage coastal recession in Ghana and many parts of the world.

Previous studies on fluvial discharge in Ghana and elsewhere have estimated runoff and sediment load delivery of rivers to the coast (Boateng et al., 2012; Kasim et al., 2010; Milliman and Syvitski, 1992; Yu et al., 2011). Yu et al. (2011) for instance, determined the effects of water discharge and sediment load on the evolution of modern Yellow River Delta, China, over a period (1976 to 2009). Both shoreline length and area of the Yellow River Delta were found to have increased generally over the studied period. However, the evolution of the shoreline and area of the Yellow River Delta were directly affected by the reduction of runoff and sediment load. Akasi (2011) also estimated the quantity of sediment supplied by major rivers in his study and developed a simple model to estimate suspended sediment load for the rivers in southern Ghana which could be applicable to the study area. Although within the south-western coastal basins, only rivers with large basins were considered. The large-scale analysis of the sediment load discharged makes it difficult to evaluate in detail sediment supplied by smaller basin rivers to the shores. However, rivers with relatively smaller drainage basins are as important as those with large drainage basins (Milliman and Syvitski, 1992). Smaller river basins have less area for sediment storage and therefore their sediment yield to the coast is asserted to increases as much as sevenfold for each magnitude decrease in basin area (Milliman, 1990). Small basin streams were therefore considered together with the large rivers in this study.

This paper assesses sediment discharge by rivers and uses that to determine their contribution to the stability of the coast of the study area. This study is essential as it offers policy direction to governments, particularly Ghana and decision-makers, in general, to be circumspect in their quest to implement the one-village one dam policy for power generation and irrigation.

Study area

Ghana is located in West Africa and it is bordered by Togo to the East, Cote d'Ivoire to the West, Burkina Faso to the North and the Gulf of Guinea to the South. The Western Region of Ghana lies within latitudes 4°40′ and 5°10′ North and longitudes 3°07′ and 1°40′ West (Figure 1) and covers part of the Central zone and the entire Western zones. The coastline of this region stretches to about 192 km constituting about 35% of Ghana 540 km coastline. The coast has a wide continental shelf of about 80 km off Cape Three Points. The oceanographic climate in the study area shows an average significant wave height of about 1.2 m and a significant wave period

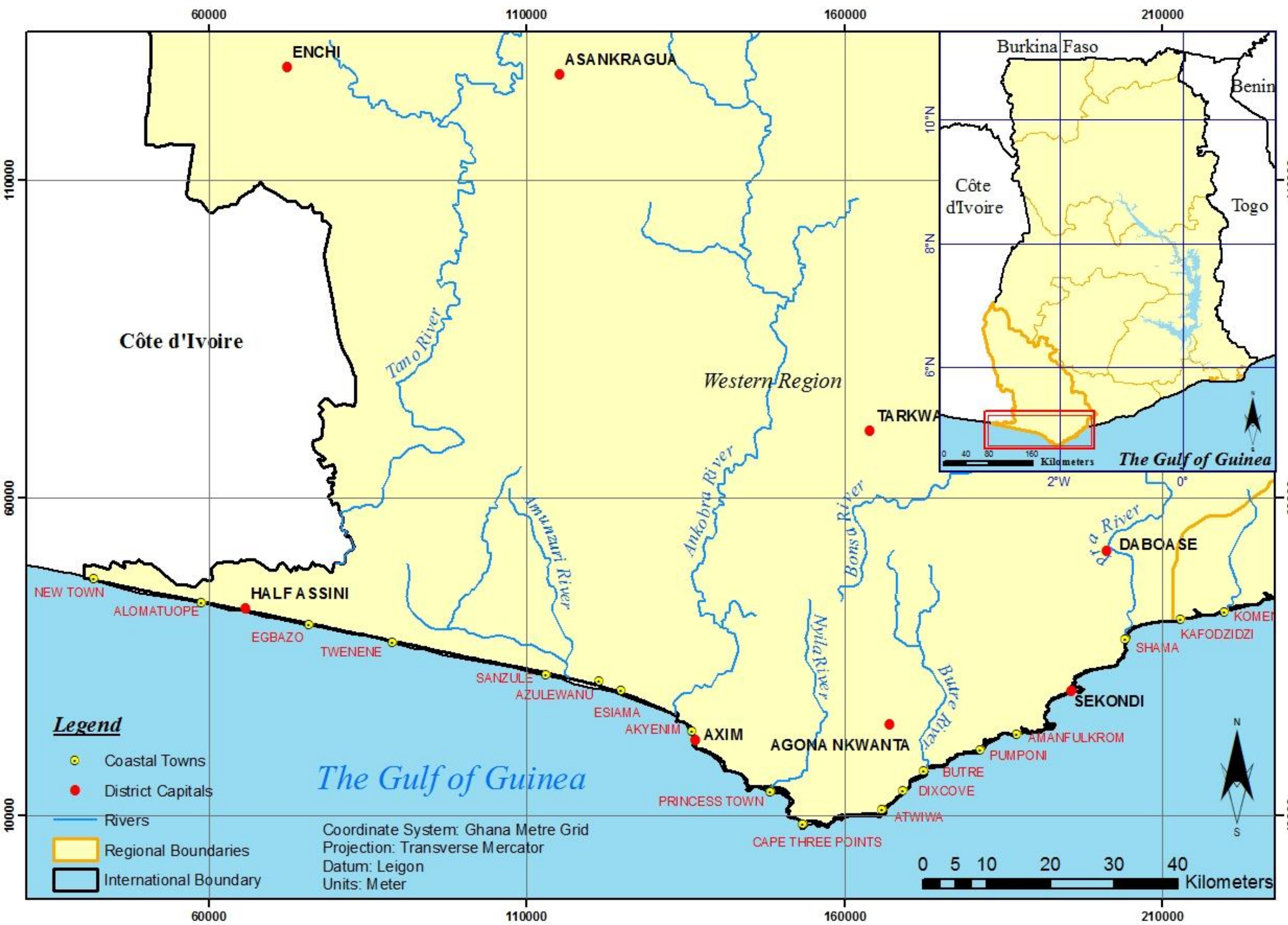

Figure 1. A map of the coast of Western Ghana.
Source: Modified from Boye, 2015.

between 10 and 12 s (Wellens-Mensah et al., 2002). Prevailing wave direction is south-southwest with a local sea level rise rate of between 2 and 3 mm/year (Boateng et al., 2017). Relatively low tides are observed in the study area with the neap and spring tidal ranges between 0.6 and 1.3 m, respectively (Wiafe et al., 2013).

The coastal material is composed of about 60% sandy beaches and 40% composite rock/sandy beaches (Boye, 2015). The coastal material properties within the study area may be described as heterogeneous with the coastal rock types ranging from granites, granitoids, through shales, sandstones to low strength soils (Kesse, 1985). Portions of the study area are bounded by high resistant rock outcrops forming promontories giving the coast the characteristic curvilinear shape of headlands intersperse with embayment along the Eastern Section (Pra River Estuary-Ankobra River Estuary) of the study area (Figure 1). The Western section of the study area has homogeneous coastal materials, which stretches to about 100 km (Ankobra River Estuary-New Town) and it is characterised by purely sandy beaches occasionally intersected by lagoons and river inlets. The shores of the study area are nourished by numerous rivers notably the Pra, Amunsuri and the Ankobra. The sediment discharge from these rivers is distributed across the shores by the strong west to east longshore drift (Boateng, 2012).

MATERIALS AND METHODS

Multi-temporal spatial shoreline dataset (1974 and 2005), hard and soft copy topographic map of the study area, river flow data, and information gathered from field reconnaissance were used for the assessment. The shoreline features were extracted from the dataset using the High Water Line (HWL) as a proxy and appended in a GIS environment. A baseline was created and orthogonal transects cast using Digital Shoreline Analysis System (Thieler et al., 2009) for the computation of the shoreline change rates for the 31 years period (that is 1974-2005). The Endpoint of Rates method (Foster and Savage, 1989; Dolan et al., 1991; Thieler et al., 2001) was adopted. Detailed discussion on the method could be found in Dean and Dalrymple (2002), Frazer et al. (2009) and Dolan et al. (1991). The Endpoint Rates and other methods such as linear regression by least square and the average of Rates methods are adopted for their accuracy since aberrations in the shoreline dataset are either excluded by the use of line of best fit (Galgano and Douglas, 2000), or checked for adherence to the minimum time criterion (Dolan et al., 1991).

From the hard and soft copies of the topographic maps of the study area, the drainage areas of the coastal rivers were digitized in a GIS environment and their catchment areas determined and validated by the manual procedure using a digital planimeter. Using available river flow data for the major rivers within the study area (Pra, Ankobra and Butre), the water discharge by the rivers were determined (Watkins and Fiddes, 1984). The peak discharge for the small basin streams was estimated from the peak stormwater runoff rates rainfall applying the Rational Method (O'Loughlin et al., 1996). The Rational Method was adopted because of its simplicity and the fact that it requires limited rainfall and drainage data. Mathematical equations for the peak flood discharge are expressed as shown in Equation 1.

Peak flood discharge $Q_{max}=0.277CAI$ (1)

where Q_{max} is the peak flood discharge (m^3/s), C the runoff coefficient of the region, A the catchment area (km^2) and I is the mean intensity of rainfall in mm/h during the time of concentration.

Assuming a total storm duration for the study area, runoff volumes were computed. Complete descriptions of the Rational method have been done by Thompson (2006), Booth et al. (2002), and Kim et al. (2003). The Rational method was used because it is widely used for computing peak discharge besides it offers a simple technique for estimating discharge of small drainage basins (Cleveland et al., 2011).

The quantity of sediment load produced by small and large basin rivers in the catchment were determined by the instantaneous sediment concentration (Cs) formula (Equation 2) adopting sediment rating coefficient and exponent values developed for coastal rivers in Ghana (Akrasi, 2011). The sediment rating coefficient and exponent were obtained using measurements of suspended sediment transport for 21 monitored stations as sample sites to collate sediment yield data in south-western and coastal basin systems. The discrete data was fed into a power regression relation (Nittrouer and Viparelli, 2014) developed using continuous data to derive a sediment rating curve, which depicts the statistical relation between suspended sediment concentration and discharge as in Equation 2.

$$C_s = aQ_w{}^b \quad (2)$$

where C_s is the instantaneous sediment concentration (mg/l), Q_w is the instantaneous water discharge (m^3/s) and *a* and *b* are the sediment rating coefficient and exponent, respectively.

The correlation between instantaneous sediment C_s and instantaneous discharge Q are statistically significant. The approach was adopted because the collections of the instantaneous daily measurement over a period are expensive (Akrasi, 2011). Suspended sediment concentration and the discharge for large river basins in Ghana are often gauged and measured by the Water Research Institute of Ghana. Using the sediment discharge of measured rivers to estimate the unmeasured one enable the sediment load to be computed for all rivers in the study area, though not the actual measured suspended sediment load, but rather a representative estimate of the rivers under consideration (Landers, 2010).

By applying the model, the sediment discharge by coastal rivers in the study area was estimated using Equation 3.

$$Q = kQ_w^n \quad (3)$$

where Q = the sediment discharge (t day¯1), Q_w = total water discharge (m^3/s), n= exponential and k=constant. The values obtained as sediment supplied by rivers were analyzed against their corresponding shoreline change rates at those sites.

It is important to note that total sediment yield from rivers comprises suspended sediment load and the bed load. Previous studies of fluvial sediment discharge have established that in most cases the bedload of fluvial sediment supply is 10% of suspended sediment load (Walling, 1984; Boateng, 2012; Turowski et al., 2010). The assumption of 10% of suspended sediment load as bedload has been applied in this paper. Furthermore, Ayibotele and Tuffour-Darko (1979) identified from samples of 129 gauging stations that 50% of suspended sediment yield from Ghana rivers are of grain sizes less than (63 μm). The fine grain size (<63 μm) may not stay on the beach but rather may be carried offshore or to estuaries and marshes down-drift (Milliman et al., 1985; Phillips and Slattery, 2006) and therefore total sediment yield considered to be significant to the beach in the case study area represents 50% of suspended sediment yield plus the bedload from each river (Table 1).

RESULTS

A total of 47 catchments were identified along the case study area. Table 1 shows the sediment contributions of all the 47 rivers and streams of all catchment size and their correspondent suspended sediment yield, bedload and total sediment significant to the beach all in tonnes per day. Figure 2 also shows the spatial location of each sediment input.

High suspended sediment load values were recorded for the three major rivers, namely: Pra, Ankobra and Amunsuri with values ranging between 1.2×10^4 and of 2.4×10^5 tonnes/day. Other rivers which supply considerable suspended sediment load are the Anankwari (149 tonnes/day), Sweni (160 tonnes/day), Hwin (300 tonnes/day), Butre (572 tonnes/day), and the Nyan (580 tonnes/day). The peak sediment load along the study area varied considerably; the portion between the Pra and Ankobra rivers, which constitute a shoreline length of about 98 km (50%) of the total study area, contained about 83% of the rivers compared with the west of Ankobra River which stretches approximately equal length of shore contains 17% of the rivers. Most of the rivers flow in the north-south direction except for the Amunsuri, which flows in a west-east direction parallel to the shore and empties its yield in a lagoon. The total sediment yield significant to the beach and thus contributing to the coastal stability of the case study area is estimated to be about 1.8×10^5 with Rivers Pra and Ankobra supplying more than 50% of the total estimate. Figures 3, 4 and 5 show plot of all the rivers and lagoon inlets and their corresponding shoreline change.

The spatiotemporal changes in shoreline at the river/stream mouths over the 31 years period of the shoreline analysis (that is 1974 – 2005) is as shown in Figure 3 to 5 have revealed minimal accretion at few sites, such as Axim (0.46 m/year) and Nfuma River mouth near Dixcove with a rate of 0.2 m/year, except for Takoradi and Sekondi harbours where expansion works

Table 1. Fluvial sediment contribution to the coast of Western Region of Ghana. (Modified from Boye, 2015)

S/N	River/Town Names	Drainage area (km^2)	Total suspended sediment (T/day) (Cs=KQw^n)	Bedload (T/day) (10% of Total suspended sediment)	Total sediment yield to the coast (T/day) (suspended sediment + bedload)	Total sediment yield significant to the beach (T/day) (50% of suspended sediment + bedload)
1	Pra (Shama)	23168	249459.2	24946.00	274405.00	149676.00
2	Amena	1	0.4	0.04	0.48	0.26
3	Amuesi	3	1.7	0.17	1.83	1.00
4	Atombaka	2	1.1	0.11	1.17	0.64
5	Anankwari	122	149.0	14.90	163.91	89.41
6	Ngyiresia	8	5.7	0.57	6.23	3.40
7	Esuekyir	20	18.7	1.87	20.56	11.22
8	Ngyamuabaka	6	4.1	0.41	4.48	2.44
9	Kansawura (New Takoradi)	22	17.8	1.78	19.56	10.67
10	Hwin	241	300.0	30.00	330.04	180.02
11	Fungo	2	1.3	0.13	1.42	0.78
12	Aladoa (Adwowa)	27	23.2	2.32	25.53	13.92
13	Obimpe	3	2.2	0.22	2.39	1.30
14	Agyingyake	19	15.8	1.58	17.36	9.47
15	Mpatano	1	0.7	0.07	0.78	0.43
16	Butre	384	571.9	57.19	629.13	343.16
17	Baiben	3	1.8	0.18	2.02	1.10
18	Busua	11	9.3	0.93	10.19	5.56
19	Nfuma (Dixcove)	3	1.8	0.18	2.00	1.09
20	Asutsintsin	2	0.9	0.09	1.03	0.56
21	Mawu	3	1.7	0.17	1.83	1.00
22	Atwiwatia	2	1.4	0.14	1.53	0.84
23	Atwiwa	1	0.7	0.07	0.74	0.40
24	Medwuapim	4	2.2	0.22	2.44	1.33
25	Sweni	131	160.6	16.06	176.62	96.34
26	Kataku	10	6.6	0.66	7.25	3.96
27	Ajukwa	7	5.0	0.50	5.46	2.98
28	Wurawura/Anuo	2	0.9	0.09	0.99	0.54
29	Aketechi Lagoon	2	1.1	0.11	1.24	0.67
30	Ehunli	3	1.7	0.17	1.84	1.00
31	Nyan (Princess Town)	385	580.0	58.00	637.97	347.98
32	Pan (Mutrakoni)	8	5.7	0.57	6.24	3.40
33	Miemia	9	5.8	0.58	6.43	3.51
34	Arasuri (Egyembra)	16	12.8	1.28	14.07	7.67
35	Ewuku	3	1.8	0.18	1.99	1.08
36	Adenchemsu	10	6.8	0.68	7.44	4.06
37	Axim	2	1.1	0.11	1.26	0.69
38	Axim Nkekan	2	1.0	0.10	1.06	0.58
39	Mpema	15	11.8	1.18	12.96	7.07
40	Ankobra river	8338	31634.2	3163.42	34797.61	18980.52
41	Biale	33	27.7	2.77	30.52	16.65
42	Kikam	12	7.7	0.77	8.44	4.60
43	Amunsuri Lagoon	873	12665.8	1266.58	13932.40	7599.49
44	Anochi	9	6.7	0.67	7.36	4.01
45	Atuabo	26	21.7	2.17	23.82	12.99
46	Beyin	31	28.4	2.84	31.19	17.01

Table 1. Contd.

47	Elonyi Lagoon	50	46.1	4.61	50.70	27.65
	Total (T/day)	34035	295833.3	29583.41	325416.49	177500.45

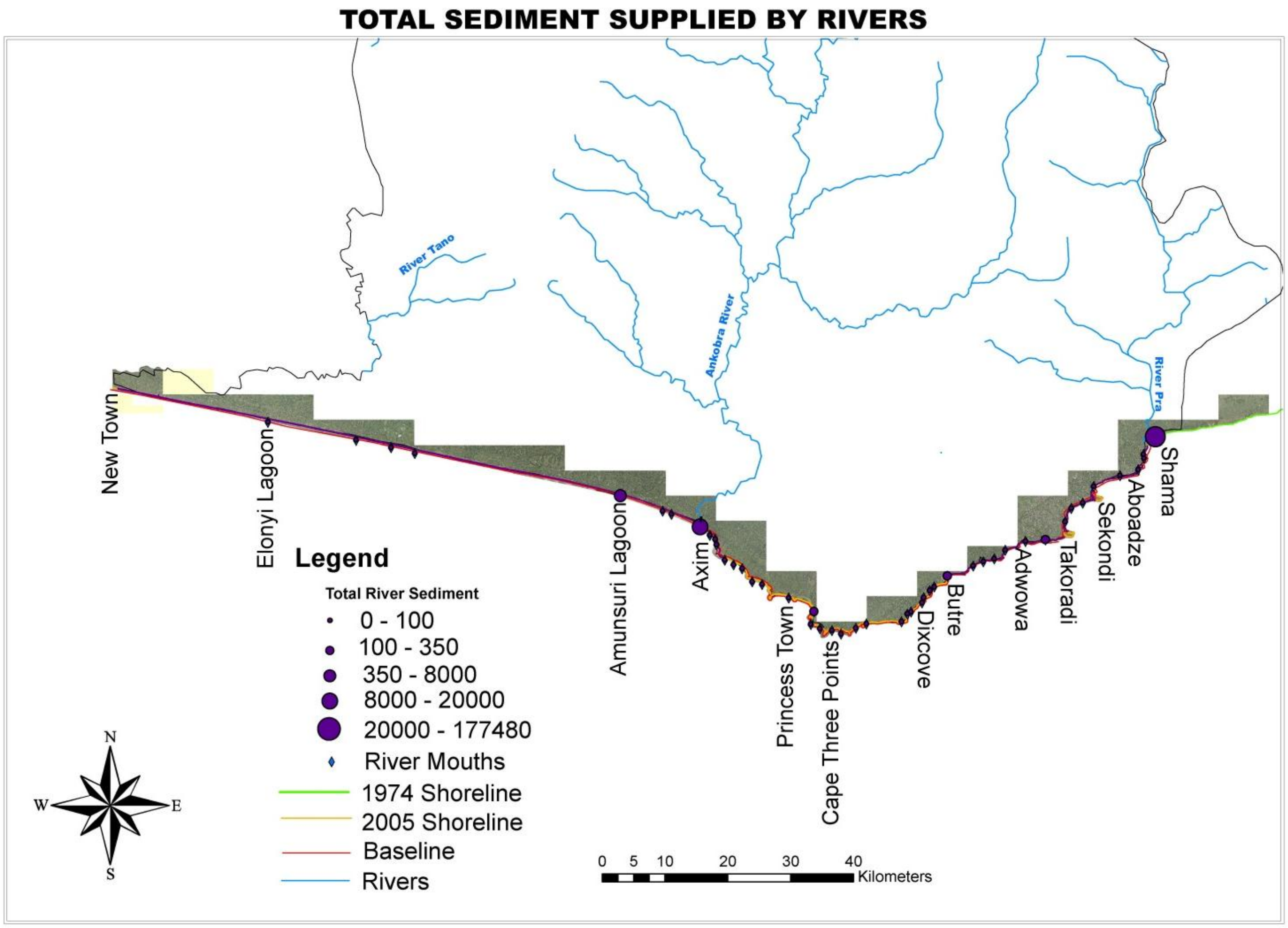

Figure 2. A map showing total sediment yield from the rivers. (Modified from Boye, 2015)

had been carried out in 2004, thus high accretion values are observed at those sites. Mean shoreline change rate of -1.13 m/year and -1.28 m/year were recorded at the eastern (Shama-Butre) and the western (Butre-Axim) sections, but a relatively high value of -2.00 m/year was registered for the third section (Axim-New Town) (Figure 2). A mean shoreline change value of -1.62 m was recorded at the entire study area over a period of 31 years. This confirms Boateng (2012) observation that the western coast of Ghana experiences less erosion than the rest of Ghana's coastline. The results from Figures 3 to 5 reveal that there is either less recession or accretion at all the coastal areas that received significant river discharge (Figure 2). This could be attributed to the significant fluvial sediment supply to the area.

DISCUSSION

The study area is adequately nourished with sediment produced by the 26 main rivers in the catchment from which about 1.8×10^5 tonnes of sediment reaches the coast daily. The variable quantities of the fluvial sediment supplied by the various rivers are shown spatially by the graduated symbols at the river mouths as shown in Figure 2, from where they are distributed along the shores (Peduzzi, 2014). It was observed from the shoreline change analysis that minimal accretion or recession was recorded at the river mouths, which gives an indication that significant amount of the sediment supplied is retained near the river mouths. This finding confirms Qiao et al. (2010) observation of high

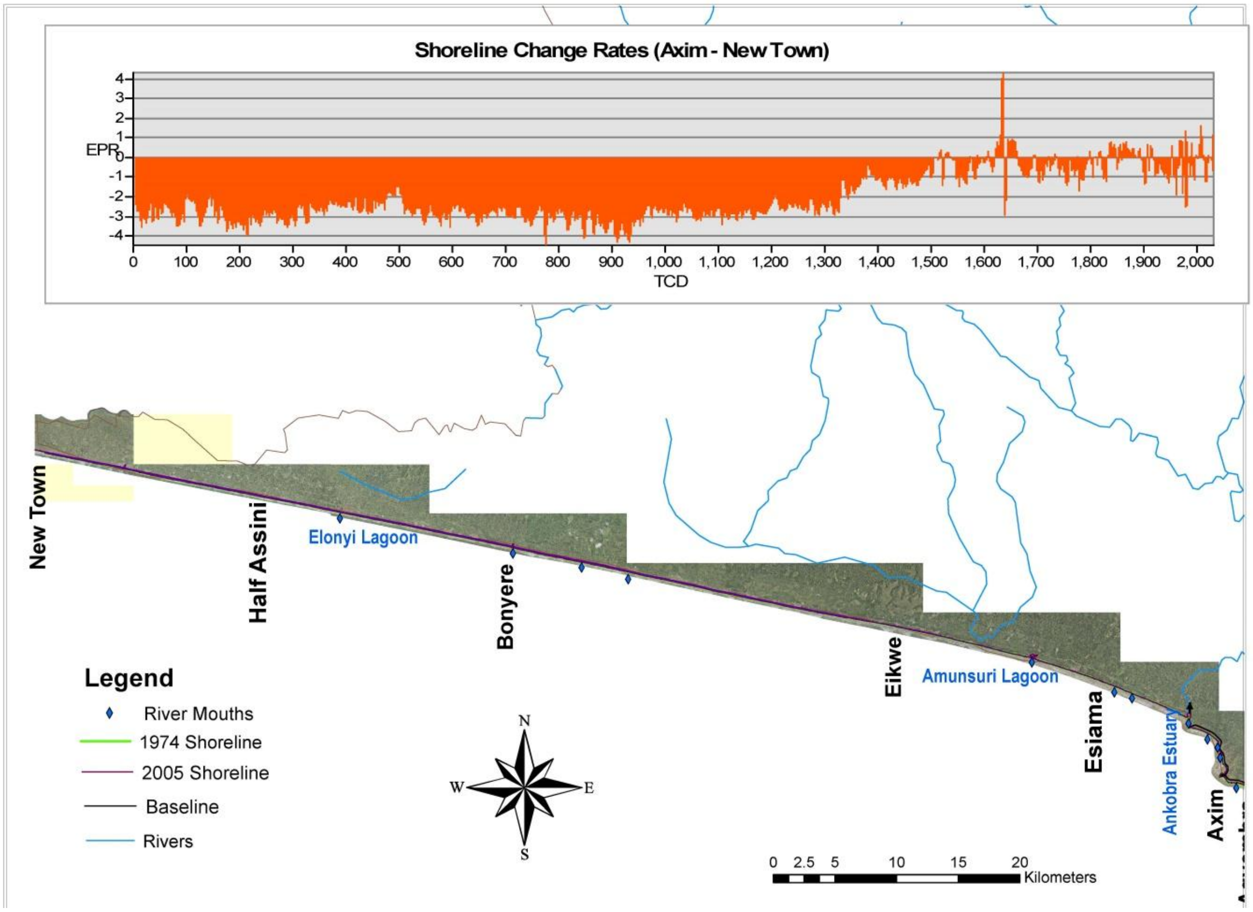

Figure 3. Shoreline change between 1974 and 2005 from Shama (East) to Butre (West).

suspended sediment concentration at the mouth of the Yellow River in their study of the distribution and transport of suspended sediment from the Yellow River. Since suspended sediment constitutes about 90% of the total fluvial sediment supplied in the study area it is reasonable to conceive that the quantity of sediment supplied at the river mouths tend to decrease as one moves farther from the river mouths. This pattern is synonymous with the shoreline change at the study site. The accumulation of sediment supplied by rivers along the beach seems to be linked with the shoreline change rates at those sites, which therefore confirms that fluvial sediment provides materials that stabilize the beaches as well as the shoreline.

The fine grain size below 63 µm may not stay on the beach because they are very fine and may be carried away in suspension to offshore or to estuaries and marshes downdrift. However, this interpretation has been challenged by Cooper and Pontee (2006) who argued that the fine suspended sediment that is deposited in saltmarshes and tidal mudflats downdrift has an important influence on the stability of the coastal environment. The rate of coastal sediment transport across the shore usually determines the actual sediment that is retained at any given section of the shore. Where the sediment supply by rivers exceed sediment transported across shore the beach grows subsequently the shoreline accretes, but where there is a deficiency in the sediment supply the beach dwindles, thus shoreline recession is recorded.

We have identified that rivers with medium catchment size (between 100 and 500 km^2) such as the Nyan, Butre, Hwin, Sweni and Anankwari supply significant quantities of sediment and tend to have wide and stable beaches compared to the larger catchments like Rivers Pra and Ankobra. This phenomenon is based on the fact that rivers with medium basins have steeper gradients, less storage capacity, less abraded materials, and greater response to episodic rainfall events, such as floods and landslides (Milliman et al., 1999).

The shoreline in the study area is changing at variable rates consistent with the variability of sediment supply by rivers. Isolated parts of the shore recorded minimal accretion; other portions are categorized as experiencing minimal, moderate, high or extreme levels of shoreline change rates according to European standards

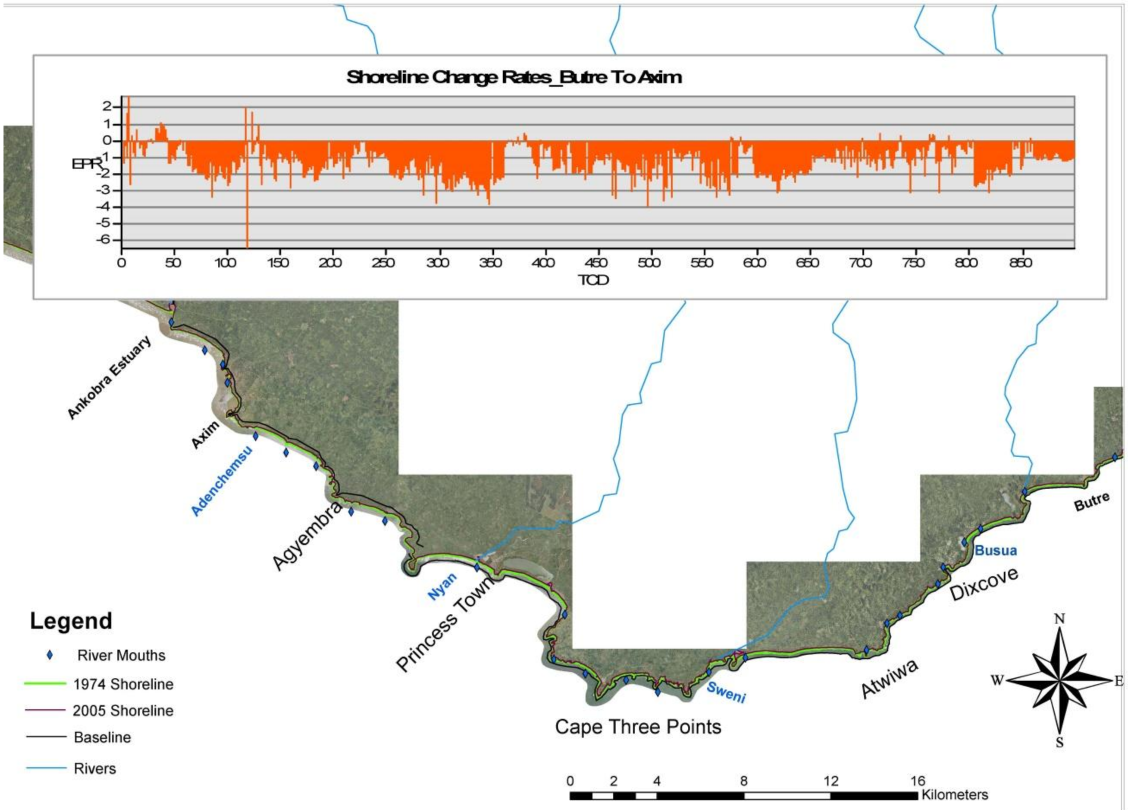

Figure 4. Shoreline change between 1974 and 2005 from Butre (East) to Axim (West).

(Kotsovinos and Georgoulas, 2008). Areas such as Ngyiresia and Nfuma (Dixcove) recorded minimal accretion of 0.16 and 0.38 m/year, respectively. This may be attributed to the fact that sediment supplied by rivers at the section exceeds those transported across the shores by the physical processes. Rivers that nourish these sections have small drainage areas and therefore supply relatively coarser particle sizes of sediment (Buffington et al., 2002) that stays on the beach. In addition, the shoreline between Axim and Shama comprises alternating bays that are enclosed by headlands. The headlands facilitate the interception of the west to east longshore drift of sediment, which is stored in the alternating bays. Hence, erosion at the bay frontages is relatively low compared to the areas outside the bays (Figures 3 to 5).

Sediment supplied by the rivers nourish the beach and maintain beach stability. However, there are two major threats (beach sand mining and Dam construction) that may have a negative impact on the relative stable shoreline if sustainable measures are not taken now. Historically, the coastline of the western region of Ghana has been rural and less developed. However, the recent oil find in the region has led to increasing development in the area. The local people have resorted to the illegal practice of excavating beach sand for construction. This practice could lead to increase in coastal erosion and shoreline recession if not checked (Jonah et al., 2017). The second factor which poses a threat to the coastal stability of Ghana's western coastline is the proposal to dam both Ankobra and Pra Rivers to develop hydroelectric power to support the growing energy demand in the region (Kufour, 2007). Hydro-power is one of the recommended clean energy strategies to reduce the effects of climate change. However, the development of the dam to generate hydro-power tends to impound and reduce fluvial sediment supply to the coast drastically (Ly, 1980; Boateng et al., 2012). Hence, the proposed development of dams on Pra and Ankobra Rivers could have a seriously deleterious effect on the coastline if appropriate interventions are not developed to compensate for the loss of sediment supply from the two rivers.

CONCLUSION AND RECOMMENDATIONS

The study has established the fact that significant quantities of sediments are discharged by rivers and streams within the study area. The sizes of the catchment areas, as well as the slope of the rivers, influence the quantity and particle size of sediment supply by a river.

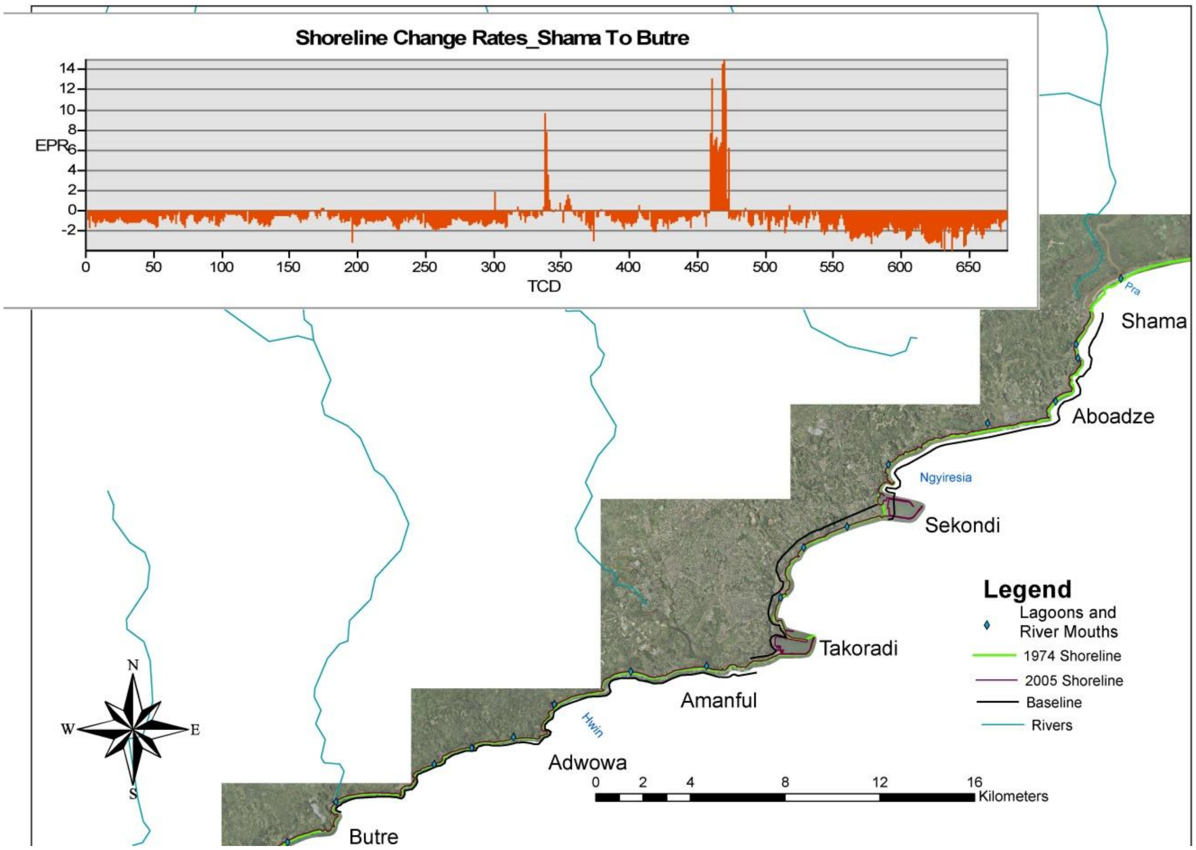

Figure 5. Shoreline change between 1974 and 2005 from Axim (East) to New Town (West).

The study has also found that fluvial sediment discharge from the coastal rivers in the study area supplies significant sediment to nourish the beaches and make immensely contribute to coastal stability. This implies that fluvial sediment plays a vital role in the sediment budget of the study area. It was also evident that the shoreline change rates along the shores of rivers/lagoons inlets and areas with embayment had less erosion than other sections of the shoreline without these features.

The paper has clearly demonstrated that the coast in the case study area and elsewhere may be closely connected to the hinterland through fluvial sediment discharge. Therefore, any artificial interventions (dam and flood alleviation schemes) on coastal rivers in the hinterland could have serious repercussion on coastal stability. In addition, bad practices, like beach sand mining and building of ad-hoc hard-coastal defence structures without proper consideration of the knock-on effect down-drift could have a serious effect on coastal stability. Coastal and river catchment managers should, therefore, consider the coastal rivers and the coast as a connected system, hence, coastal and river management policies must be very well evaluated and harmonized to reduce knock-on effect.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Innovative pathways for enhancing climate change and variability resilience among agro-pastoral communities in semi-arid areas of Kiteto and Kilindi Districts, Tanzania

Henry G. Mung'ong'o[1*], Milline J. Mbonile[2] and Faustin P. Maganga[3]

[1]Centre for Climate Change Studies, University of Dar es Salaam, P. O. Box 33453, Dar es Salaam, Tanzania.
[2]Institute of Resources Assessment, University of Dar es Salaam, P. O. Box 35091, Dar es Salaam, Tanzania.
[3]Department of Geography, College of Social Sciences, University of Dar es Salaam, P. O. Box 35049, Dar es Salaam, Tanzania.

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Climate change and variability threatens food security globally making life uncertain mostly for agro-pastoral communities in semi-arid areas. This has necessitated exploration of designed pathways with potentials to increase resilience among agro-pastoralists. This work investigates agro-pastoralists' innovative pathways for enhancing resilience to the impacts of climate change and variability in Kiteto and Kilindi districts. Mixed method research approach under correlation case study design was employed. Primary data were collected using household survey which sampled 384 households, Focus group discussion (n=6), in-depth interviews (key informants) and field visits. Descriptive statistics and thematic analysis were used in analyzing and presenting the findings. Majority of the respondents (81%) noted a decline and changes in seasonal rainfall and amount and increase in temperature trends (91.4%) in their areas for the past 30 years linked to reduced livestock production and cereals and pulses crop yields. These findings corroborate that from the Tanzania meteorological data (TMA). About 91.1% of the respondents said the major impacts of climate change and variability are decline in grazing/pasture lands, cultivated lands and water resources causing decreasing number of their livestock and crop productivity, ultimately food insecurity for a decade. To increase resilience, agro-pastoralists developed different innovative pathways, though most are similar. The main innovated pathways were livestock seasonal mobility, construction of traditional water points (Njoro), traditional grazing management system through traditional by-laws for pastures conservation/rotational use, growing of droughts-resistant mixed crops, Maasai traditional constructed water reservoirs (Mboutu), reducing stock numbers by selling, drought-tolerant forage species(cactus plants for Animal's fodder), keeping mixtures of herds and women transporting water by donkeys from traditional wells/Njoro. Government and other stakeholders are called upon to improve agro-pastoralists' adaptive capacity and increase households' food security status in the study areas.

Key words: Agro-pastoralist, climate change, climate variability, pathways, Njoro, Mboutu, Alalili, Iopolol, Kiteto District, Kilindi District.

INTRODUCTION

Climate change and variability is increasingly being recognized as a critical global challenge in the twenty first century especially to agro-pastoral communities living in the arid and semi-arid lands (ASAL). As stipulated by FAO (2014a) and IPCC (2007a) in the third assessment report that, changes in rainfall patterns and seasons as well as temperature increase are expected to have substantial effects to both livestock and crop production. The rate of changing climate is not uniform around the globe and the magnitude of change varies in spatial temporal (Agrawala et al., 2003). The reports also forecast that mean annual global surface temperature has risen by about 0.71°C over the last 100 years with the largest share of the increment (0.55°C) observed just in the past three decades and it will increase by 1 to 3.5°C by 2100 and the global mean sea level will rise by 15 to 95 cm. Despite substantial uncertainty about future global temperature trends the IPCC's best estimates predict temperature increase ranging between 1.8 and 4°C by 2090-2099 compared to the 1980-1999 trends with increased extreme events such as tropical cyclones, increasing rainfall intensity, droughts, floods and increased probability of dry spells. Still it is projected that if greenhouse gases emissions (GHE) remain the leading cause of climate change and variability the mean annual global temperature will increase by 1.42-5.82°C by the end of the 21thcentury (IPCC, 2007a).

Due to these reports on climatic variability, agro-pastoralists who depend on livestock keeping and rainfed agriculture production are considered as the most vulnerable group to climate change impacts because the two sectors (agriculture and livestock) are highly sensitive to climate change related extremes. Reports from World Bank (2015a) and FAO (2014b) show that there was a decline in the contribution of agriculture and livestock sub-sector to GDP from 45.1% in 2000 to 26.7% in 2007 due to changes in climatic parameters and other non-climatic stressors. Hence, semi-arid dry lands which support over 50% of the world's livestock and crop farming which contributes 20 to 30% of Africa's gross domestic product (GDP) and 55% of the total value of African exports, with 70% of the continent's population depending on the sector for their livelihood are all under stress due to global environmental climate. Therefore, due to unpredictable rainfall and changes in temperature, livestock and crop production has been severely affected resulting in decrease in food systems and security.

Africa continent has been most vulnerable to the impacts of climate change and variability because of low adaptive capacity and most people already are living in drought-prone areas and 220 million are exposed to drought each year and are highly vulnerable to food insecurity. Forexample, the noted impacts are fall in crop yield estimated at 10-20% by 2050 (Jones and Thornton, 2003), about 90% of people are prone to famine in the semiarid reside in Asia and Sub-Saharan Africa. Currently livestock keeping is a central livelihood activity to agro-pastoralists in Kiteto and Kilindi study districts that rely on it for income generation mainly from sales of milk, meat and blood consumption (Sangeda and Molel, 2014). Therefore, these semi-arid districts are among the most vulnerable districts in the country because of high dependence on this climate sensitive livelihood activity with low adaptive capacity. Climate stress affects the study districts in terms of amount, patterns and distribution of rainfall, longer dry spells and droughts and low livestock production through decreasing grazing land and water resources and damaging of crops (Sangeda et al*.,* 2013) all resulting to food shortage (Liwenga, 2003; Kangalawe and Liwenga, 2005).

Tanzania has taken several efforts to minimize the adverse effects of temperature and rainfall variations on various sectors including agriculture and livestock. The government and many non-government institutions have to some extent been supporting agro-pastoral communities through provision of weather forecast information education on good methods of farming and livestock keeping, food aids during chronic or transitory food shortages as well as improved crop seeds and livestock varieties; however the coverage of all these efforts is very limited to remote rural areas especially agro-pastoralists who dwell in very remote areas which lack accessibility/lack good infrastructures such as roads. As a response to all these effects of climate change and variability, several governments of Africa in particular have managed to introduce and establish policies, plans and programs to reduce the emerging effects across different sectors of productions including livestock and crop farming.

Building resilience has become very paramount to a great extent aiming to reduce vulnerabilities and increasing adaptive capacity, therefore enhancing resilience through various pathways to livestock and crop production means to increase the capacities of agro-pastoralists to adapt to different types of environmental shocks. Agro-pastoral communities in these semi-arid areas have been employing various traditional pathways through their indigenous knowledges systems (IKS) such as extending the cultivation of land into marginal areas, increased livestock mobility, mixed cropping, pastures conservation/rotational uses, off-farm/livestock keeping. However, the efficacy of all these innovated structures in

*****Corresponding author. E-mail: mungongo82@gmail.com.

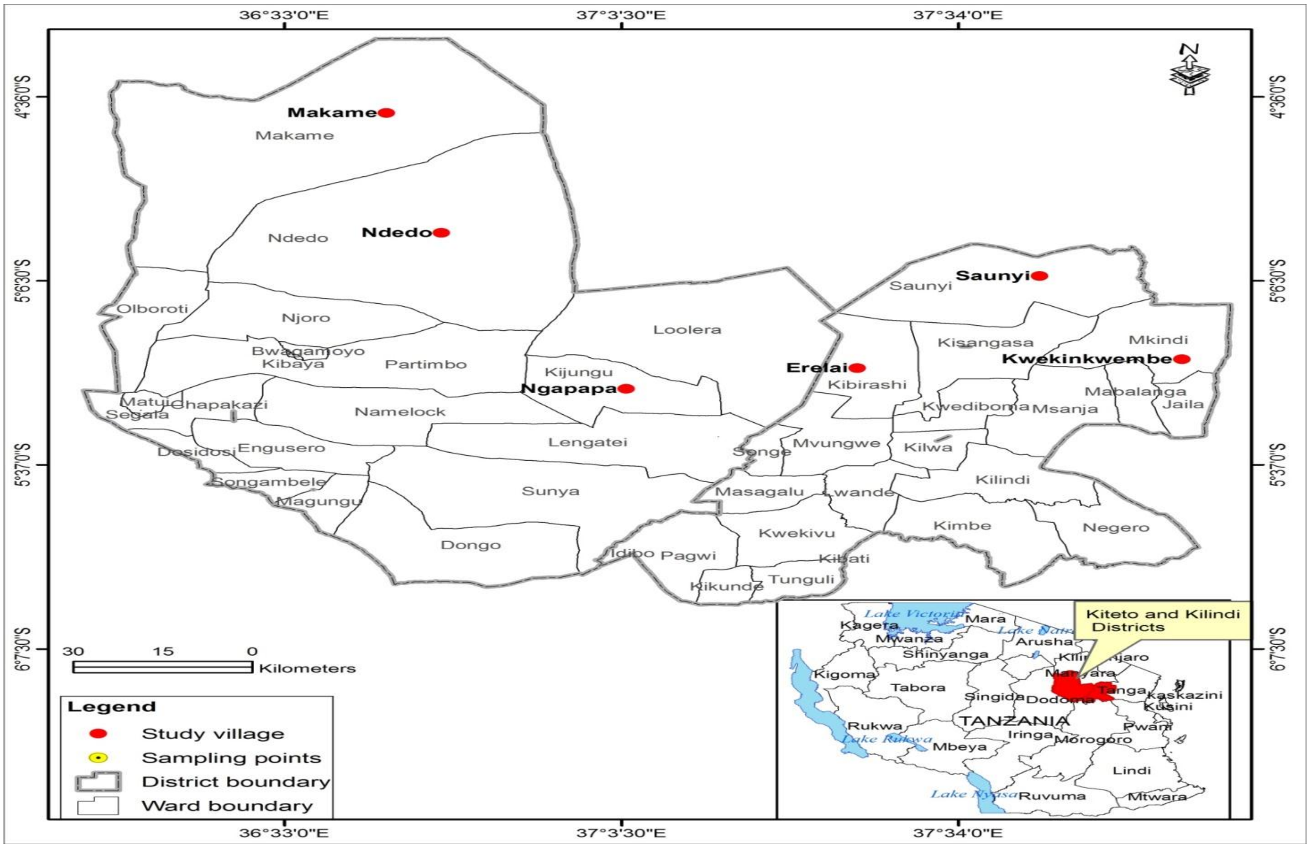

Figure 1. Kilindi and Kiteto Districts administrative areas and the sampled study villages.

guiding future adaptation strategies in accordance with the projected extreme events of climate change and variability is not well established and clearly understood. Hence, although few studies point the possibility that keeping heat-tolerant livestock is more prevalent in response to warming trends, still productivity of livestock has been down with reduced crops growing. This calls for effective and efficient pathways which will improve more livestock and crops productivity and improved food security and increasing resilience among agro-pastoral communities. Therefore, this paper aimed at investigating in detail the major traditional pathways to the impacts of climate change and variability on agro-pastoralism system at community level which are often not well documented especially in the study areas. Specifically, the paper examines the perception of agro-pastoralist on climate change and variability impacts, establishes the trends and patterns of rainfall and temperature and lastly come up with the innovated pathways to build resilience. It is anticipated that information gathered from the study will not only add knowledge to the existing literatures but it will also be used by various stakeholders like the government, policy makers and non-government organizations to address issues related to pathways for increased resilience to the impacts of climate change and variability on agro-pastoralism in ASAL as an effort to enhance household food security.

MATERIALS AND METHODS

Description of the study areas

Geographical location of Kiteto and Kilindi Districts

Kiteto District is located in northern Tanzania, Manyara region; it covers an area of 16,685 km^2 which is about 34.1% of the whole area of Manyara region whereby out of 61,770 km^2 area coverage 80% is potential for animal keeping (Pastoralism) and 20% is for crops growing and 946 km^2 area is covered by water. It lies between Latitudes 04° 36'00''and 06° 7'30'south of the Equator and Longitudes 36° 33'00'' and 37° 36'00'' East of the Greenwich (Figure 1). It lies between 1,000 – 1,5000 m above sea level and the low land areas rise from 1,100 - 1,300 m a.s.l` while the high land areas rise from 1,300- 1,500m a.s.l. Most parts of the districts are not accessible by roads especially during the rainy seasons (KDC, 2017).

Kilindi District is located in south west of Tanga region; it was re-surveyed and declared as an independent district on 2003 covering 6,129 km^2. Kilindi district is one of the eight districts of Tanga region Tanzania; it is the second largest district in the region after Handeni with an area of 6,129 square kilometers and occupies 22.9% of the total regional area. It is located in north eastern of Tanzania. It lies between Latitudes 5^0 18'00''and 6^0 48'00'' south of the Equator and

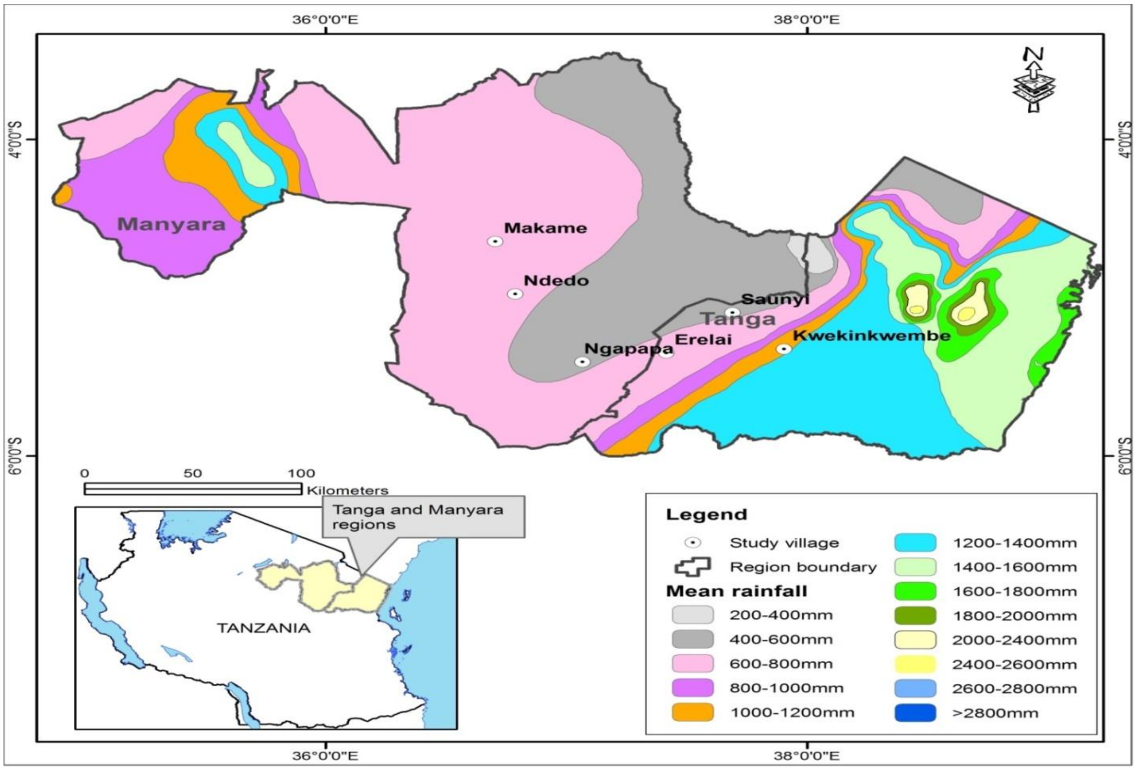

Figure 2. Mean Rainfall Distribution in Kiteto and Kilindi study districts.

Longitudes 37^0 55° 15'00'' and 38°45'00'' E degrees east of the Greenwich prime meridian (Figure 1). It is found within an altitude ranging from 300-1700 m above the sea level. Surface area is 6443.52 km^2 land coverage, of which 47% is potential for animal keeping, most is good soil for agriculture and agro-pastoralism is very dominant (KDC, 2017).

Climatic characteristics

Kiteto District is considered to be arid to semi – arid type of climate. The average day and night temperature in the district is 25°C. To a large extent the type of climate is directly related to the topography of the area. The hot months are July, August, September, October and November. The cool months are March, April, May and June. Although there are remarkable variations in the amount of precipitation; the district is receiving an average of 350-700 mm of rainfall (Figure 2).

According to KDC (2017) Kilindi District is semi-arid with total area covered by 8,919,820 km^2, average annual rainfall of 500 mm ranging from 400 to 700 mm, and temperature ranging from 13 to 30°C. It has dual periods of unreliable rain seasons comprising short rains between October to January, and long rains from February to June. The cold months are May to July while the hottest months are from August to February (Figure 2).

Data collection methods and analysis

This study employed a correlation-case study design constituting a mixed method research approach. Mixed research approach was applied in this study to provide triangulation and complementarities of the research findings (Creswell, 2013). Purposive sampling was used in the selection of the study area (Kiteto and Kilindi districts) due to its semiarid vulnerability condition, thus being more prone to climate change and variability.

Thereafter, key informants, particularly agricultural and livestock officers, livestock field officers, village leaders and elders were purposively involved in the study due to their potentiality to the research theme. Also, focus group discussions (FGD) and in-depth interviews were done in all study villages aiming to capture qualitative information. Simple random sampling was used in the selection of agro-pastoral communities. The sampling frame of this study comprised 3843 households selected from six villages, namely Saunyi, Kwekinkwembe, Erelai, Makame, Ndedo and Ngapapa. Based on the sampling frame above a total of 384 households were technically selected by using a formula proposed by Israel (2009). The formula which is based on 95% confidence level and P = 0.05 read as:

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size to be calculated, N is the total population of the study (households), and e is the level of precision or margin of error measured by probability scale of 5%. Therefore, plugging data into the formula, the following was in order;

$$n = \frac{3843}{1 + 3843(0.05)^2}$$

$$n = \frac{3843}{10}$$

$$n = 384$$

The calculated sample size was used to compute the proportion number of households in all study villages that was determined by the number of households in each village. The formula used read as;

$$n_h = \frac{N_h}{N} n$$

This resulted in a proportional sample size selected in each village where Saunyi was represented by 83 household heads, Kwekinkwembe 90, Erelai, 43, Makame, 75, Ndedo, 50 and Ngapapa, 43 making a total of 384 household heads used in the sample size. Primary data were the main source of information for this study based on qualitative and quantitative approaches and were also collected through focus group discussion (n=6 for all study village), in-depth interviews (n=10), field observation through transect walks deemed necessary to confirm some of the issues raised during in-depth interviews, focus group discussions and structured questionnaires for socio-economic survey (n=384). Both closed and open-ended questionnaires were administrated to agro-pastoral communities and government officials who were key informants. In-depth interviews, FGD and field observations were used to complete and control the quality of information collected by household socio-economic survey. Secondary information/data were obtained from published and unpublished documents and reports from different sources like rainfall and temperature data collected from Tanzania Meteorological Agency, crop yield data (maize and beans) livestock data(cattle, goats and sheeps) were collected from National Bureau of Statistics, Ministry of Agriculture, Food and Cooperatives; District Agricultural and Livestock Development Offices (DALDOs). Different publications, books, theses and journals from the libraries of University of Dar es Salaam (UDSM), Institute of Resource Assessment (IRA), government policy documents and and websites were reviewed. In all the information collected were perceived impacts/vulnerability, innovated pathways and challenges.

Quantitative data collected from the questionnaire survey were edited, to improve the quality for coding. The collected data were edited to improve the quality for coding. Analysis was carried out through the use of two software packages for data analysis namely Statistical Package for Social Sciences (IBM SPSS version 20) and Microsoft excel 2010. The software packages enabled the data to be summarized using summary statistics (frequencies and percentages) which simplified the description and presentation of the study findings as well as making patterns and trends analysis. Rainfall, temperature, livestock and crop yield data were analyzed by using Microsoft Office Excel 2007, to examine patterns and trends of the variables. Tables and figures were used to present the findings. Qualitative data from focus group discussions, in-depth interviews and field observation were analysed through thematic analysis. Simple random sampling procedure was used in the selection of the sampled households whereby about 90.7% of males and 9.3% of females were interviewed.

RESULTS AND DISCUSSION

Socio-economic profile of respondents in the study areas

Household heads education levels

Village-wise household heads education levels show that across all study villages the highest rate of illiteracy was above 60%. This implies low adaptive capacity to the effects of climate change and variability with lowest resilience status; Erelai leads by 84% followed by Saunyi (81%) (Figure 3). These findings concur with Deressa et al., (2008) who noted that, low level of education in Ethiopia represented low adaptive capacity to climate change and variability. Furthermore, Mwalukasa (2013) confirms that reasonable education levels enable agro-pastoralists to receive and transmit farming and animal keeping education at local levels.

In general the findings indicate that the majority (76%) of the agro-pastoral communities in the study districts had no formal education level, followed by holders of primary education (17.7%); those with adult education were 3.6%; secondary education were 1.8% while very few had post-secondary education (0.8%) confirmed through per village-wise in Figure 3. Also, all study villages almost have the highest rate of illiteracy above 60%, which imply low adaptive capacity to the effects of climate change and variability.

Major livelihood activities in the study areas

Livestock keeping is a primary livelihood activity carried out in Kiteto District. The economy of this district depends almost entirely on livestock and crop farming in a small scale. Animals kept are cattle, goats, sheep, donkeys and chicken which are mostly done by Maasai; major crops grown are maize, beans, sunflower, cassava, millet and finger millet. Agro-pastoralism in the district accounts for 60%; crop growing (22.8%), and pure pastoralism (17.2%) hence, agro-pastoralism is mostly dominant livelihood activity. Notably agriculture is characterized by low productivity due to unreliable rainfall (URT, 2016).

In Kilindi District, agriculture is a primary activity carried out in the district, followed by animal keeping. It is reported that in the district agriculture accounts for more than 60% having the largest number of smallholders who also keep animals (agro-pastoralists) (40%) and is the main producer in the region as National Food Reserve Authority (NFRA) singled out the district as main collector of food crops in Tanga region (URT, 2014). This implies that the majority of the people in the area are smallholders characterized as depending on rain-fed agriculture which is so vulnerable to climate change and variability effects. Major crops grown are maize, beans, sunflower, cassava, sweet potatoes, millet and finger millet, mangoes, bananas, sugarcane. However, currently there is introduction of new crops like cashwenut, Haricot bean pigeon peas and cow pease as drought resistant crops and animals kept are cattle, goats, sheep and donkeys

The study confined to two agro-pastoral districts namely Kiteto and kilindi districts, taking three wards from each district based on different agro-ecological zones. About six study villages were selected, one village from each ward, namely Saunyi Kwekinkwembe Erelai Makame Ndedo and Ngapapa. The occupation

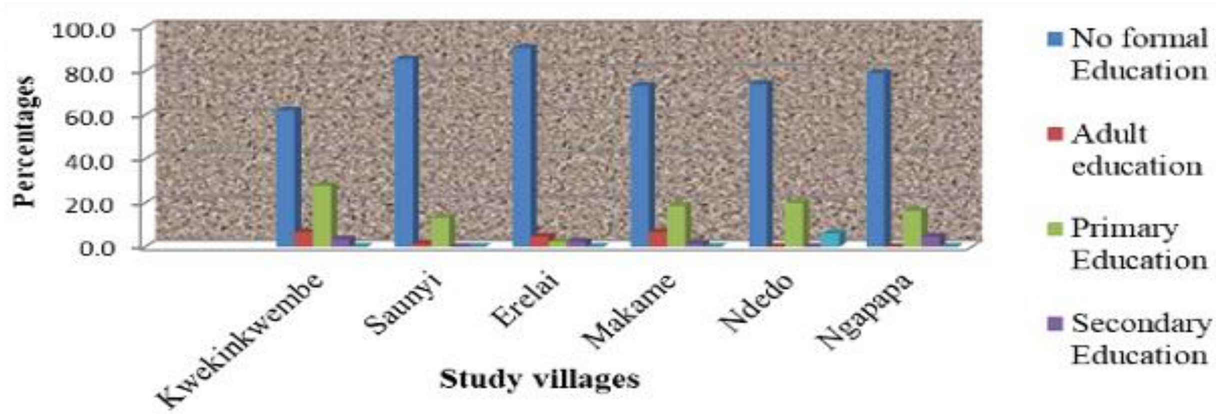

Figure 3. Village-wise household heads education levels.

performed by the household heads determines the income levels which in turn, influences vulnerability of the household to climate change and variability effects. The results indicate that, majority, about 44.4% were pure pastoralists and the remaining were the said agro-pastoralists (37.5%) and other non-farming activities. This implies that due to persistence of drought extreme, majority of agro-pastoralist have drifted to pure pastoralist. This is new observation as it is contrary to most literatures. Based on income levels in the study areas, the agro-pastoralists were wealthier than livestock keepers only thus being able to easily adapt to climate change and variability and food insecurity. The agro-pastoralists were able to sell part of their livestock to buy food in time of crop failure; the agro-pastoralists were much food secured than pure livestock keepers.

Referring to Table 1 on respondents' occupation, the results show a variety of livelihood activities that varied among and within study vilages. The findings indicate that about 44.4% of major activity was pure pastoralists who keep livestock only, and the second was agro-pastoralists (37.5%) who keep livestock and cultivate in small farms as supplement. These findings are contrary with the results from study districts report which shows more than 60% are purely crop farmers. This findings are in line with Mwakaje (2013) who found that, about 97% of the agro-pastoralists had lost at least 50% of their farm crop harvest due to drought and 44.5% had lost them due to pests and diseases which made them to drift from crop cultivation to pure pastoralism. One of the reasons for this change could be related to the limited land for cattle grazing or pastures and mobility. Starting farming could probably enhance the agro-pastoralists' livelihoods; it could also mean more pressure on natural resources in terms of clearing the bush for agriculture. It may also lead to conflicts between other land users such as investors and hunting operators in the areas.

Livelihood diversification has been one of the recommended in this era of climatic stresses as it increases resilience. The results show that, agro-pastoral communities have increased livelihoods diversification with smallest number from various activities like keeping animals only and mixing both keeping animals and cultivation, petty business (5.1), hunting (4.4%), beekeeping (4%), collecting and selling firewood (1.7%), arts and craft works (1.4), making and selling charcoal(1.2%), casual labour (0.8%), wage employment and mining (0.4%). Increased diversification among agro-pastoralist means increased resilient towards responding to stresses caused by climate change and variability in semi-arid areas. The study results show that agro-pastoralists have been increasing their diversification as a response to climatic stresses; however the extent of diversification is still low as shown in Table 1. Village-wise the findings indicate variation in major livelihood activity (livestock keeping) depending on vulnerability from climate change and variability specifically droughts such as Ndedo village (55.1%), Ngapapa (55.6%), Saunyi (65.4%) and Erelai (67.4%); other study villages like Kwekinkwembe (15.1%) had smallest number of pure livestock keepers due to less vulnerability from droughts.

Reflecting from the same (Table 1) it is interesting to see Erelai village which is most vulnerable to droughts has the lowest level of diversification than all other study villages (livestock keeping only and both keeping livestock and crop growing); this implies increased vulnerability to food insecurity. These findings also suggest that the agro- pastoralists' economy is gradually switching or drifting to expanding agriculture in marginal areas which depend on to rainfall availability in a particular year to which precaution should be provided to agro-pastoralists (Majule, 2008; Myeya et al., 2016).

Agro-pastoralists perceived impacts of climate change and variability

Field results indicated that, climate change and variability

Table 1. Respondent's occupation.

Economic activities	Districts												Total N=384	Total %
	Kiteto						Kilindi							
	Ndedo		Makame		Ngapapa		Kwekinkwembe		Saunyi		Erelai			
	N	%	N	%	N	%	N	%	N	%	N	%		
Livestock keeping only	38	55.1	33	37.1	25	55.6	19	15.1	62	65.4	29	67.4	**206**	**44**
Both livestock keeping and crops growing	11	15.9	41	46.1	17	37.8	71	56.3	20	21.4	14	32.6	**175**	**37.3**
Casual labour	0	0		0	0	0	2	1.6	2	2.2	0	0	**4**	**0.8**
Petty business	5	7.2	6	6.7	1	2.2	10	7.9	2	2.2	0	0	**24**	**5.1**
Wage employment	0	0	0	0	0	0	1	.8	1	1.1	0	0	**2**	**0.4**
Beekeeping	4	5.8	3	3.4	0	0	6	4.8	1	1.1	0	0	**14**	**3**
Mining	0	0	0	0	0	0	1	.8	1	1.1	0	0	**2**	**0.4**
Arts Craft works	1	1.4	1	1.1	0	0	4	3.2	1	1.1	0	0	**7**	**1.4**
Making and selling charcoal	2	2.9	1	1.1	1	2.2	1	.8	1	1.1	0	0	**6**	**1.2**
Collecting and Selling firewood	4	4.4	0	0	0	0	5	4.0	0	0	0	0	**8**	**1.7**
Hunting	5	7.3	4	4.5	1	2.2	8	4.7	3	3.3	0	0	**21**	**4.4**
Total	**70**	**100**	**89**	**100**	**45**	**100**	**128**	**100**	**94**	**100**	**43**	**100**	**469**	**100**

impact in the study areas were felt by agro-pastoralists in the 1980s' and still felt till date. It was also observed that all villages studied have been experiencing the impact of climate change and variability. Findings further indicate that majority of the respondents mentioned decline in number of their livestock (91.1%) to be the major indictor of climate change and variability in the study areas. Decline in the number of animals based on the extent of food insecurity has been faced for six years consecutively. This is linked to decreased rainfall amount and duration which affects pastures and water availability to animals.

Moreover, increased droughts were noted to be the second felt impact indicator mostly pointed by 89.1% of the respondents. The respondents linked increased drought that has been existing for a very long time in a repetitive way. It has great effect on water and pastures which form the basis for animals' food. Recurrent food shortage was also one among the major impact of climate change and variability in Kiteto and Kilindi districts as pointed by 87.2% of the respondents. Respondents reported that, due to prolonged droughts which result in crop failure like maize and beans as well as deaths of their animals especially cattle and goats which they depend on for food through meat, milk and blood, they have been facing food insecurity since 1990s. Apart from depending on cattle for food directly, they sell so as to buy other food sources like sugar, maize flour from shops; now they fail because of low income as the price of cattle and goats during dry season becomes very low.

Respondents further reported on the emerged new livestock diseases which were reported by 86.5% of the respondents. The agro-pastoralist emphasized that, nowadays due to changing environment. There is emergency of new animal diseases that never existed in their locality. This has caused deaths of large number of their animals. Such new diseases are rinder pests (Maasai locally known Olodwa), heart water (Maasai locally known Olmiro) Anaplasmosis (Maasai locally known as Emonywa); the old ones which have been killing their animals are lung sickness CBPP (Maasai known as Olikipei), tsetsefly/Ndorobo, Anthrax, East Coast Fever (Ndigana kali, ECF) and Foot and Mouth disease (Alerobi). Generally, livestock and crop production has been in declining trend with great variability throughout the period of study; however the decline is not similar among crops and livestock category; they all impact negatively food security of agro-pastoral communities.

Agro-pastoralists' perceptions of long-term changes in rainfall and temperature

71.1% of the respondents reported increased temperature. The agro-pastoralist emphasized that, nowadays' temperature is very high affecting growing of pastures; thus they construct traditional wells for their animals and for domestic use. The respondents lamented that dry spells have increased compared to previous years. Based on their experience, dry spells happened in February lasting for two to three weeks. Dry spells are unpredictable as they occur even in January (crops and pastures growing season), thus affecting the whole growing season and pastures. The study analysed agro-pastoralists' perceptions of temperature and rainfall variability and change for the past 30 years. The results show that the majority of the respondents (91.4%) felt that temperature was increasing. Village-wise, more than 85% of agro-pastoral communities in each village reported to have noted increased temperature rates (Figure 4). Agro-pastoralist perceived an increase in duration of hot days, indicating that generally temperature was on the increasing trends. Also, Lema and Majule (2009) reported this concern in Manyoni district.

Apart from temperature trends and patterns, majority of agro-pastoralist (81%) noted decreasing rainfall while about (3.6%) reported to have noted no changes. Decreasing in rainfall was explained based on rainfall amount, duration, distribution and intervals. They further reported that rainfall onset and cessation dates were unpredictable (seasonal changes) (Figure 5). Different studies reported similar observation from various parts of Africa. For example, studies undertaken by Deressa et al. (2011) and IPCC (2007b) indicated that there has been a decline in rainfall amount in other parts of Tanzania and Africa in general. Swai et al. (2012) also noted that, rainfall has been more erratic, more unpredictable and continues to decrease in amount in Bahi and Kondoa districts, Tanzania. The findings of this study were also supported during interview with key informants in Ngapapa village as narrated:

"………Really, there is an increase in temperature and reduced rainfall in Kiteto district especially in Ndedo village. Increased temperature and reduced rainfall have caused water decrease in our wells locally known as Njoro for every year in a very short period of time. Actually, water from the mentioned wells was used for 6 months after the rainfall cessation for animals drinking and domestic uses, but nowadays it takes only 2 to three months for our wells to dry off"…Female 53 years in Ngapapa village.

Statistical analysis of rainfall and temperature patterns and trends as scientific evidences of climate change and variability in the study areas

Temperature and rainfall data were obtained from TMA Offices and covered two weather stations one from each study district, namely, Kibaya weather station for Kiteto district and Kwediboma weather station for Kilindi District of which all covered over a period of 30 years (1986-2016). Scientific analysis of rainfall and temperature data was done in order to determine if there was consistency between these data with the agro-pastoralist's perceptions on changes in rainfall and temperature collected during the household survey.

Temperature trends

Figures 6 shows the trends in temperature change in the period of 1986 to 2016, of Kibaya weather station(Kiteto district) whereby the fitted linear trends in the Maximum temperature (Tmax) is statistically significant at the 5% level of significant (P=0.0124) with R^2=0.0575. This is presented by higher percentages (5.7%) of observed variance throughout the study period. Based on the minimum temperature for Kibaya weather station/Kiteto District, it shows statistically significance at 5% level with slop increasing faster (slope 0.0393°C y^{-1}) than the maximum (0.0124°C y^{-1}). This is presented by higher percentages (61.6%) of observed variance in the minimum (R^2=0.6161) than that observed, 5.7% in the maximum (R^2=0.0575) throughout the study period 1986 to 2016.Again, the maximum temperature trends for Kwediboma weather station for the period of 30 years from 1986 to 2016 in Kilindi district, the fitted linear trends is statistically significant at the 5% level of significance (P=0.0161) with R^2=0.2239. Also for the minimum temperature trends increased very faster (slope 0.0758°C y^{-1}) than the maximum (0.0161°C y^{-1}). This is presented by a higher percentages (74.02%) of observed variance in the minimum (R^2=0.7402) than that observed, 22.3% in the maximum (R^2=0.2239) throughout the study period 1986 to 2016 (Figure 7).

Generally, from the meteorological data analysis, it is evident that the minimum temperatures increased at a higher rate than the maximum at both weather stations. These results concur with previous studies done in semi-arid areas worldwide by Owusu-Sekyere et al. (2011), Kangalawe and Lyimo (2013). The increase in both the minimum and maximum temperature implies the increase of more frequent warmer days and nights and decreased cold days and nights. Also looking for seasonal mean for minimum and maximum temperature for the two study districts it shows increasing temperature in the rain seasons which are all significant. Therefore, changes in either minimum or maximum temperature have negative effects on the grown crops, water and pastures for livestock especially when the change amount exceeds the optimum value for particular crop and animal species.

Rainfall patterns and trends

Rainfall patterns and trends are important guides to agro-

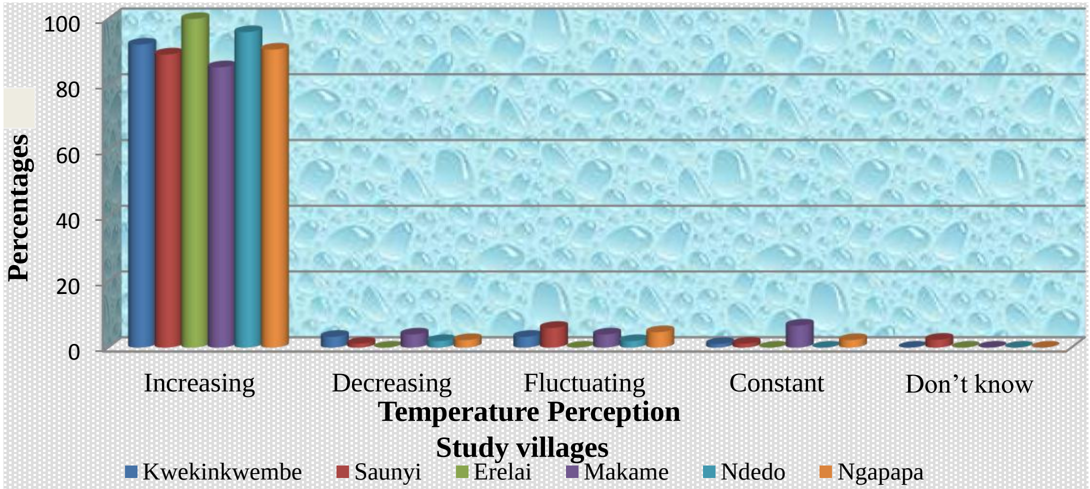

Figure 4. Agro-pastoralist perception on temperature variability.

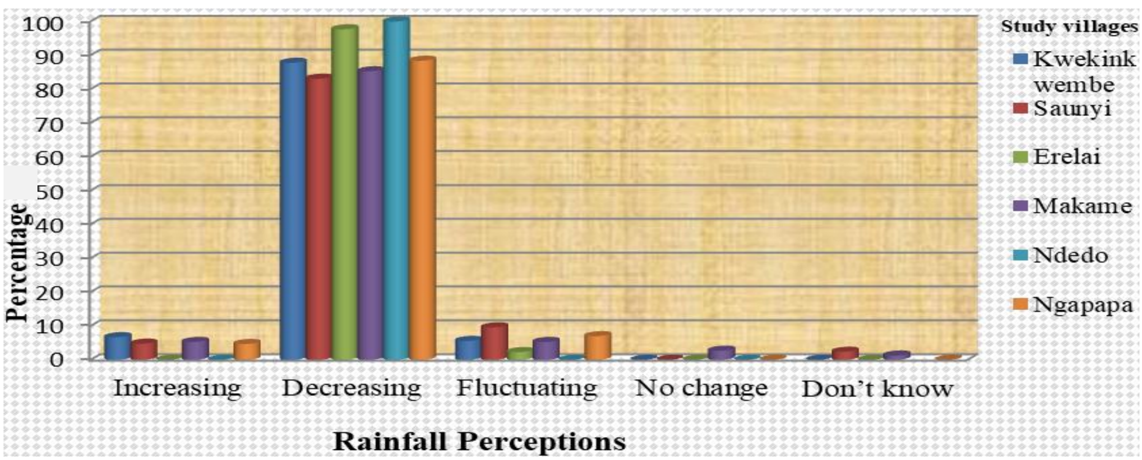

Figure 5. Agro-pastoralist perception on rainfall variability.

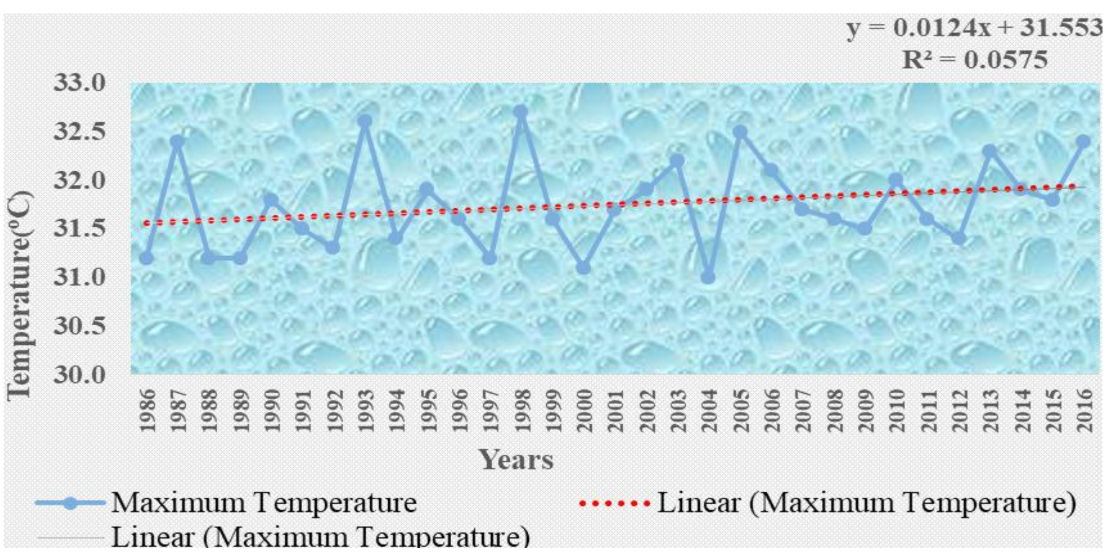

Figure 6. Kibaya weather station annual mean maximum temperature 1986 to 2016.

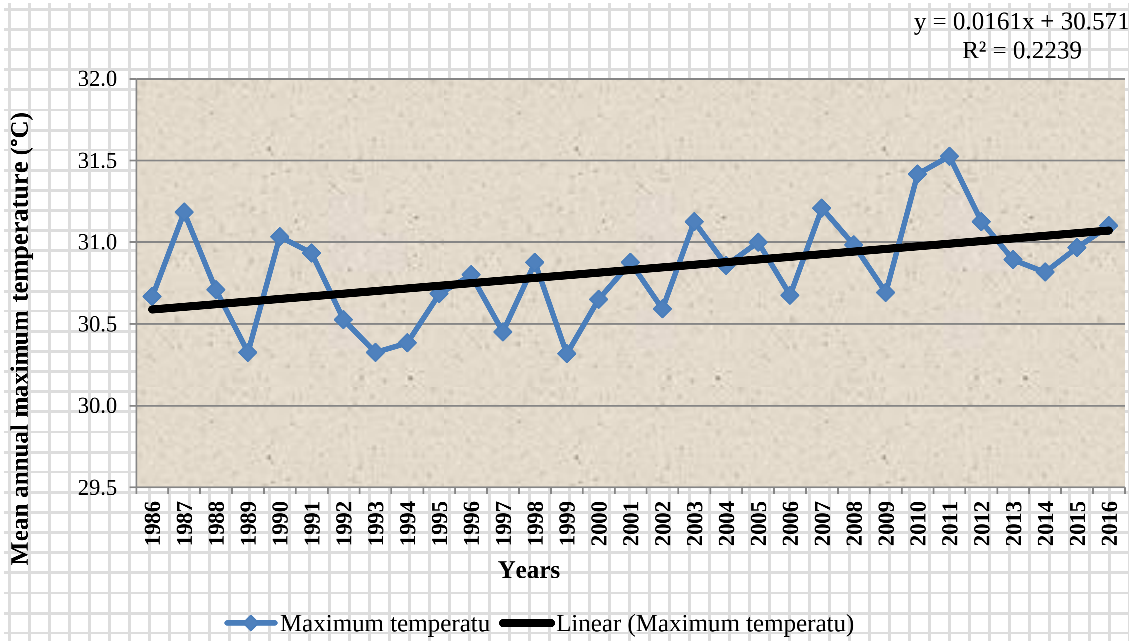

Figure 7. Kwediboma Village Annual Mean Maximum Temperature 1986 to 2016.

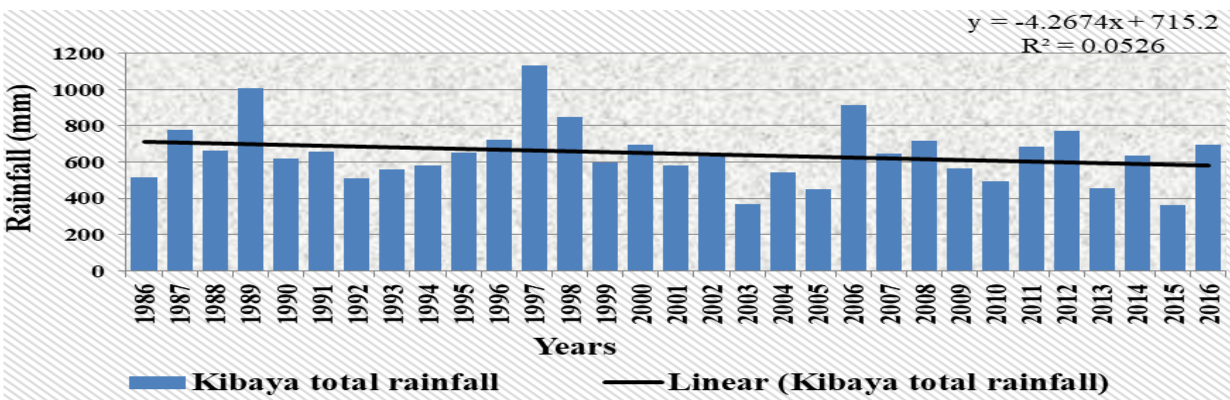

Figure 8. Annual rainfall for Kibaya weather station, 1986 to 2016.

pastoralists because they determine timing of different farming and animal keeping activities like pastures and water conservation and use, farm preparation, planting, weeding and harvesting. This study focused on quantity (amount) and distribution of rainfall, that is the total amount and their distribution. Analysis of meteorological data shows a non-significant decline in the trends of total annual rainfall in both weather stations. Using simple regression model, the analysis showed a slight decreasing trend in the pattern of annual rainfall. In Kibaya weather station (Kiteto District) the decrease was more noticeable as it shows a decline trend of R^2= 0.005 (y = -4.2674 + 715.2) (Figure 8).

The same finding was observed in kwediboma weather station (Kilindi District), whereby the patterns and trend were R^2= 0.1383 (y = -6.873 + 660.49) (Figure 9). As a comparison of the rainfall patterns in the two recorded rainfall stations, each station indicates that rainfall started from higher at the beginning of the study periods through varying levels, Kwediboma weather station for Kilindi District was leading to Kibaya weather station in Kiteto District. Rainfall decreased much from 2002 (356 mm) and 2016 (333 mm) for kwediboma weather station and 2003 (367 mm) and 2015 (363 mm) for Kibaya weather station, but a higher decline was observed in Kibaya weather station because it is purely located in semi-arid climate whereby rainfall is below 700 to 350 mm. However, Kibaya weather station received higher rainfall

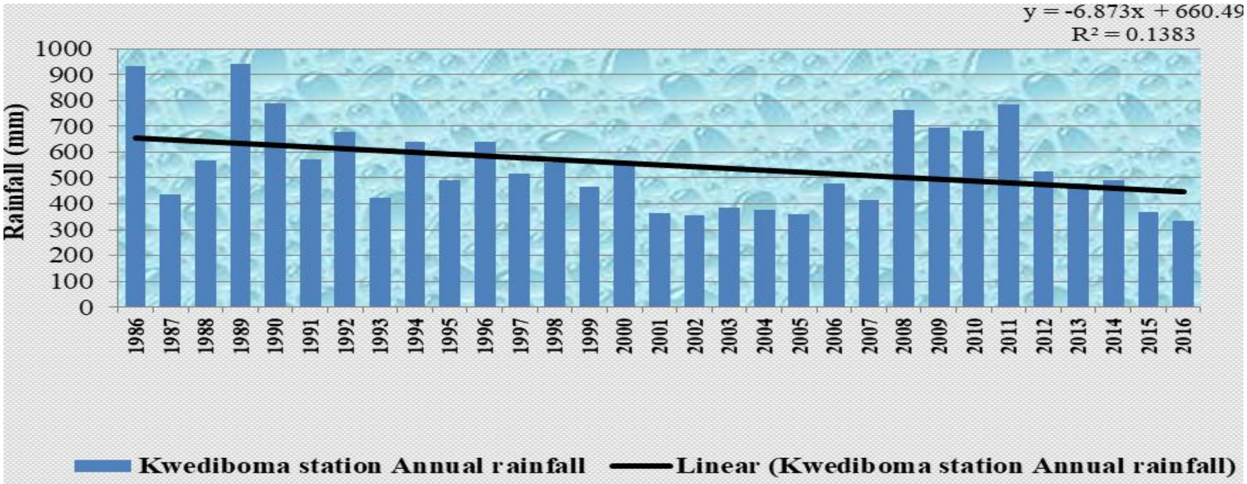

Figure 9. Annual Rainfall for Kwediboma Weather Station, 1986 to 2016.

in 1997/1998 years which was termed as Elnino years as well as Kwediboma which shows an increased rainfall amount. Kilindi District is located in different climatic zones which receive highest rainfall of 941 mm yearly, but also within Kilindi District northern part of the district receives total rainfall of 400 to 600 mm than the southern part which receives total rainfall of between 800 to 1200 mm; and it is this part where agro-pastoralism is practiced and the northern being pure Maasai pastoralist as minimal total rainfall limit crop growing (Figure 2). Kiteto District northern part of the district receives total rainfall of below 600 mm where pure Maasai pastoralists are dwelling and southern part receives total rainfall of between 650 to 800mm which allows agro-pastoralist dwellings. Generally, the two study districts experience great variability in rainfall amount and distribution which are typically indicators of climate change and variability as geographically all are found in semi-arid climates, the situation which has historically caused transitional food insecurity in the study areas.

Innovated pathways for enhancing climate change and variability resilience among Agro-pastoralist in Kiteto and Kilindi Semi-arid areas

The agro-pastoral communities have been described as "masters of innovative traditional adaptation strategies in dry lands", actively relying on variability to maximize animals productivity during periods of plenty and scarcity and carefully managing rangelands during periods of food shortage (Lyimo and Kangalawe 2010; Msangi et al., 2014). The findings from the study revealed that agro-pastoralists in the study areas employ a number of highly specific risk spreading strategies to safeguard their herds and family food security in the face of unpredictable and sometimes extreme climatic change and variability events such as drought, temperature rise, emerged livestock disease and shortage of water and pastures. Increased sustainable innovative pathways as to develop resilience upon climate change and variability for ensuring the rational use of the natural resource base on which the herds depend and also build strong social networks and food security. Overall, the main innovated pathways in order of importance were seasonal livestock mobility, construction of traditional wells/points, use of traditional by-laws for pastures conservation/rotational use, reducing stock number by selling and transporting water by donkeys from traditional wells (Figure 10).

Like in other parts of semi-arid areas of the world, agro-pastoralists in study villages areas have implemented various measures in adapting to climate change and variability impacts. Village-wise as shown in Figure 10, seasonal migration/mobility with livestock was one of the most practiced by 90%; however, Saunyi, Erelai and Ndedo use seasonal migration for 100% as adaptation to the impacts of climate change and variability due to adverse effects of droughts in these villages (Figure 10).

Seasonal migration with livestock to distant areas (livestock mobility)

Results from households, focus group discussion and key informants indicated that agro-pastoralists migrate to distant areas for search of water and pastures during dry seasons when water sources have been depleted and pastures dry up or are not enough to sustain their livestock in the areas. The findings indicate that about 95% of respondents mentioned agro-pastoral mobility as main resilient strategy against droughts. Village-wise, about 100% of respondents from Saunyi, Erelai and Ndedo practice mobility as main adaptation strategy especially during dry season. These villages are found in

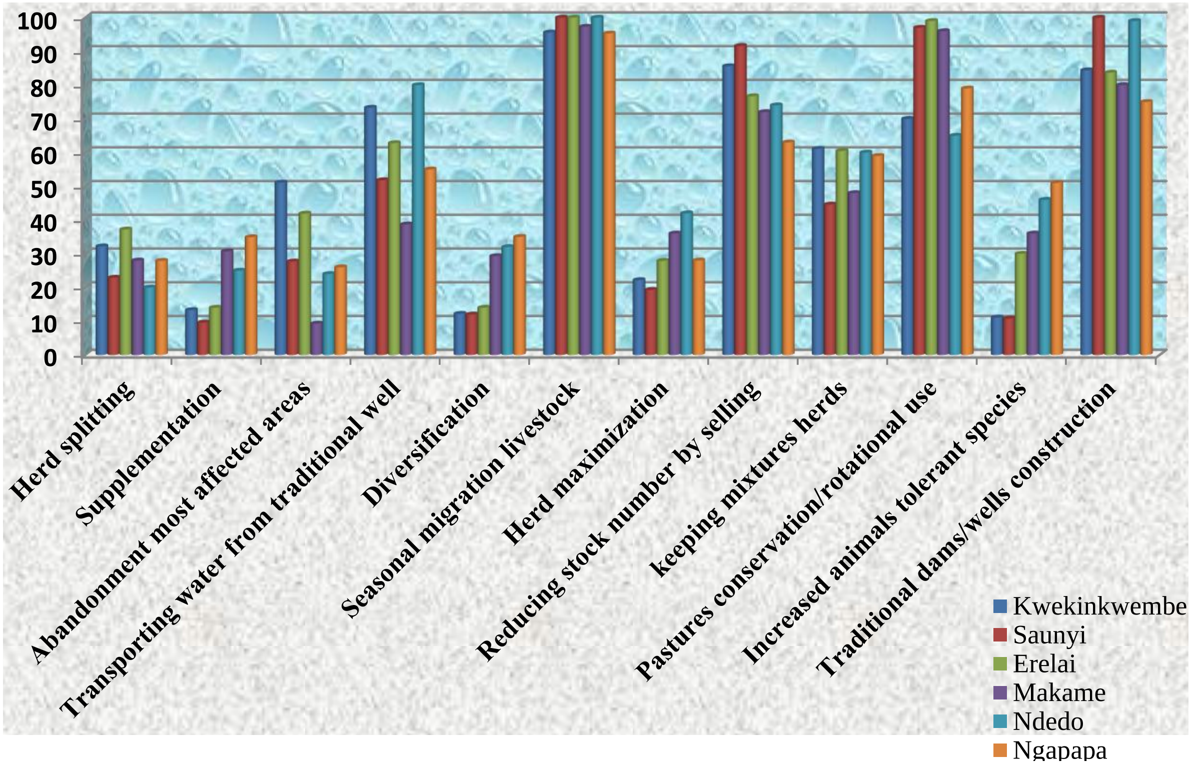

Figure 10. Village-wise agro-pastoralist perceived innovated pathways among study villages.

areas with rainfall between (400- 700 mm) (Figure 2), other villages were less because droughts were not much bigger as it was in other study villages. Through ArcGIS, there is great change in land cover due to increase of settlements, farming lands caused by population increase and urbanization making decline of both pastures and water sources, resulting to changes in livestock routes in response to changes in grazing land and water resources.

Generally, the assessment of spatial data changes over livestock routes in response to water resources and pasture lands availability revealed that about 7% of stock routes have been lost, 2% have been narrowed, and 91% are now used as roads within villages. These changes are attributed to the increase of settlements and cultivated lands. These findings concur with the study of Ernest et al. (2015) who found anthropogenic activities (settlements and cultivated areas) increased between 1980 and 2010 causing greater changes in land cover. Therefore under these changes, agro-pastoral mobility has been increasing in different parts of the country.

For example during FGD it was observed that since 1980s agro-pastoralists' mobility in search of water and pastures was on the increasing trend when compared to previous years back to 1970s. The agro-pastoralists' migration for search of pasture and water was classified into two categories: internal migration (within the country moving in short distances) and external (beyond country's borders long distances); it was practiced by group of agro-pastoralists. Internally, agro-pastoralists migrated to new emerging routes in different regions and districts of Morogoro, Tanga, Coast, Dodoma, Iringa and Kilimanjaro regions and externally the destination is Kenya and few to Uganda. In the process of migration on the way crashes with smallholder farmers happened which involved fighting and sometimes deaths. Saringe (2011) observed that mobility remains the most important agro-pastoralists' adaptation to spatial and temporal variations in rainfall and during drought years. Martin (2012) also observed that agro-pastoral season mobility is one of the best adapted and useful means of obtaining what livestock need in an ever-variable environment.

Since agro-pastoralism is adapted to variable forage supplies and water distribution, the ability of agro-pastoralists to survive in these marginal lands is attributed to their opportunistic mobility and diversified livestock husbandry. Rainfall unpredictability, both in space and time causes uneven and unpredictable levels of productivity. Also according to Meena et al. (2006), agro-pastoral seasonal mobility has proven to be the best form of land use of highly variable and heterogeneous pastoral lands in the arid and semi-arid regions as well as in the mountainous regions due to the fact that it enables the livestock to grade the diffuse and scattered vegetation of the regions rangelands or take refuge to more favorable sites during drought. However despite mobility being the most practiced among agro-pastoral communities (Maasai) there is a need to design better ways of seasonal mobility especially planning special areas for animal keeping with specified animal routes as well to review current multi-sectoral policies and laws.

The use of traditional by-laws for pastures conservation/rotational use

The establishment and enactment of traditional by-laws for pastures conservation in Maasai land that regulate livestock grazing was revealed by household respondents as one of resilience and adaptive system that has been used by agro-pastoralists against the impacts of climate change and variability. This was pointed out by 65% of respondents in both study villages/sites; however the practice was not similar among villages; the technique was mostly applied by Erelai (99%), Saunyi (97%) and Makame (96%). It was noted that agro-pastoralists had traditional knowledge on how to preserve their pasture/forage for reducing forage shortage during pasture stress times especially during dry season in almost all study villages (Figure 10). Examples of the by-laws are those related to pasture conservation and water conservation. As for pastures, grazing areas are divided into restricted and non-restricted zones (*lopolol*). In each zone there are by laws guarding the utilization of each zone. Defaulters of the by-laws are normally fined for Tsh 200,000 when one grazes animals to restricted pastures for dry season. Regarding water conservation, constructions of traditional water points (Njoro) are common in the study area especially was observed in Saunyi, Ndedo, Makame and Erelai. In the study areas, some local excavated dams are restricted to use until dry season (*Serenge*) and others are not restricted and these are used during the rainy season. Defaulters are normally fined. This is supported by Mahonge et al. (2014) who assert that some strategies like excavation of small dams are the initiatives of the pastoralists themselves based on their long-term interaction and experience with the environment. These are meant to avoid walking long distances in search of water. Therefore, despite having modern day by-laws, the agro-pastoralists have their own designed innovative adaptation structures which have been existing for time immemorial, and should be integrated with modern-one to increase environmental sustainability (Figure 11a-d).

Traditional water points (wells) construction (locally known as Njoro)

During this study, it was revealed that the constructed wells/water points (varying in size and depth) were used only by the agro-pastoral community members in all study villages. For outsiders, they must seek permission from the village leaders who would provide permission, however these wells mostly are under particular clan, hence sometimes one to get water needs permission from the clan which constructed such well. It was revealed that, about 75% mentioned this pathway as potential strategy during dry season as majority used these water points for livestock sometimes even domestic uses. It was found that most of these villages have wells which differ in terms of size and depth. Construction of wells are ways of ensuring a year round supply of water for the community domestic use and livestock as have been one of the strategies to adapt water availability problems especially during dry season. Village-wise, Saunyi (100%), Ndedo (99%), Kwekinkwembe (84.4%) and Makame (96%) had more than 45 constructed wells under different clans.

These wells are usually constructed by the agro-pastoralists themselves sometimes in collaboration with NGO's like RED CROSS in Ndedo village. The most water points were constructed locally without being built by concrete walls as they are dug deepward until it reaches the water table (Figure 12a-d). This technology is very material as it assures water availability all the time from rainy season to dry season. But things to note is that, during rainy season these wells are closed since livestock use other natural sources of water like natural streams and ponds. Normally the management of these wells is under traditional by-laws guided by Maasai believes because they are closed and opened through traditional cerebrations involving traditional prays. It is a new and preferred strategy due to several reasons: it protects water from extensive evaporation as trees are planted around the wells; acts as a slow filter for water resulting in potable water; water becomes clean for domestic use.

Reducing stock number by selling during dry season to buy food

Food insecurity has been one of the push factors for the most of agro-pastoral communities in study villages to sell their livestock especially during dry season as it was mostly observed in Erelai, Ngapapa, Makame and Saunyi villages. About 60% of respondents mentioned reducing livestock numbers to be an alternative way especially during dry season. Based on village-wise analysis the practice varied among study villages: Saunyi (91.6%), Kwekinkwembe (85.6%), Erelai (76.7%) and Ndedo (74%). However, agro-pastoralists in Tanzania have been reluctant to reduce the number of their livestock until the dry season whereby the prices of cattle fall down due to poor health as a result of poor pastures and water shortage. District livestock and fisheries officer in Kilindi district said that, droughts which hit 2009, 2014 and 2016 caused prices of cattle to be very low, from TSH 80000-120000 per cattle. However reduction in livestock

Figure 11. Pastures rotational use for conservation basing to livestock category.

Figure 12. Innovated traditional water points (Njoro) at Ndedo and Makame villages.

numbers requires alternative sources of food for agro-pastoralist in Tanzanian and thus may lead to changes in national food policy and laws.

Maasai women transporting water with donkeys from innovated traditional water points (locally known as Njoro) for domestic use

Water resources availability for domestic use in study villages has been a problem in semi-arid climates and it is influenced by variable factors, including climate change and variability through droughts and other livelihood activities. Therefore, being the problem, respondents in study villages had to move for long distance searching water for domestic uses; it was revealed by 52% being practiced by women Maasai. Hence because vulnerability to drought was not similar, the use of this strategy varied such that Ndedo (80%), Kwekinkwembe (73.3%), Erelai (63%) and Ngapapa (55%). Agro-pastoral districts such as Kilindi, Monduli, Kiteto, Simanjiro and Ngorongoro receive below 700 mm of rainfall. The impact is felt non-linearly and drier areas within this range experience significantly greater loss in surface drainage with a decrease in rainfall than wetter areas. Experience has shown that communities in Kiteto and Kilindi (rangeland areas) are experiencing decline in ground water level due to drying of water in wells, river streams that used to give water throughout the year. The drying has affected both people and livestock including wild animals.

Agro-pastoral women move very long distances with donkeys fetching water in constructed wells for more than 6 h. A village executive officer at Ndedo village (40 years old) said most nearby wells which were used previously now do not exist due to prolonged dry lands (Figure 13). Modern wells are needed in these communities especially in this era of global environmental change which will reduce distance for fetching water which affects Maasai women.

Traditional Maasai constructed water reservoirs for Livestock (locally known as Mboutu)

The influence of water availability on livestock productivity within rangelands/grazing lands has been reported to be of paramount importance. Volume of water in natural sources nowadays goes down due to prolonged droughts affecting livestock and crop farming. Therefore, because of persisting droughts which have resulted in shortage of water, agro-pastoralists through their own indigenous knowledge systems (IKS) have developed their own new water reservoirs for their livestock adaptation practices locally known as Mboutu. Mboutu has been serving agro-pastoralist for a very long time especially during dry season when water becomes very scarce resource in semi-arid areas.

Previously, Mboutu was built with natural vegetation/ small sticks with the help of mud, then pouring water from water points to Mboutu where livestock used to drink. However due to increased environmental change because of the current climate change and variability, agro-pastoralists have been required to improve much their traditional knowledge system as to go with the prevailing environment as the old water reservoirs/ Mboutu currently are not effective and efficient. Therefore they have improved much this water reservoir/Mboutu which nowadays is built using concrete and cement preventing water loss (Figure 14a). The old Mboutu has been abandoned by majority nowadays due to loss of water and inability to serve large number of livestock, hence the agro-pastoralists have innovated the new/ modern Mboutu using improved building materials like cement and concrete (Figure 14b).

Drought-tolerant forage species, cactus plants for animal's fodder

Agro-pastoralism under semi-arid conditions faces poor quality and inadequate supply of feed and shortage of water to livestock production. Therefore, spineless cactus plants (*Opuntia fícus-indica*) provide important feed materials for ruminants in drought regions especially, during the dry season due to forage shortage (Dubeux et al., 2006).

Cactus plants (Opuntia ficus-indica) are used as modern method of animal feeds because they are easy, cheap to grow, palatable and can withstand prolonged droughts (Taasoli et al., 2007). Such characteristics make these species a potential alternative important feed supplement for livestock keepers in semi-arid climates, particularly during periods of drought and seasons of low feed availability. According to district livestock officer in Kiteto district, due to persisting droughts in the district specifically in the study villages, they have adopted this new technique of making animal folder from cactus plant which normally grows well in arid and semi-arid climate/areas (Figure 15). Findings from respondents revealed that 89.3% are not aware of this technology and 10.7% are aware of this technology. The reason why few have been educated and the majority are not yet educated is due to shortage of experts from the district. Livestock officers went for training in Morocco two years ago. Ndedo and Saunyi villages were selected as pilot study village.

CONCLUSION AND RECOMMENDATION

Kiteto and Kilindi districts currently are highly dominated by pure pastoral Maasai communities than agro-pastoral as most of them have drifted from growing crops due to persistence of droughts becoming pure pastoral

Figure 13. Maasai women fetching and transporting water with donkeys from innovated traditional water points (Njoro) at Ndedo, Saunyi and Makame villages.

Figure 14a. The old Water Reservoir/Mboutu at Makame, Ndedo and Saunyi villages.

communities; hence they have been experiencing climate change and variability impacts for nearly three decades now.

The study concludes that majority of the agro-

Figure 14b. The modern water reservoir/Mboutu at Makame, Ngapapa, Erelai and Saunyi villages.

Figure 15. Spineless cactus plants for making livestock folder.

pastoralists perceived climate change and variability through observed decrease in rainfall with changes in rain seasons, increase in temperature and increase in incidences of droughts and dry spells. Furthermore the study has established the patterns and trends of rainfall and temperature in the study areas by using data accessed from the Tanzania Meteorological Agency in Dar es Salaam for Kilindi and Kiteto Districts. The data have generally shown a decrease in rainfall amounts and distribution as well as an increase in temperature, which concur with the findings from the agro-pastoralists' perceptions. Moreover, the study has presented various perceived impacts of climate change and variability on agro-pastoralism systems in the study villages. Drought stress has been pointed as a major challenge in the study districts and it has negatively affected grazing resources and agro-pastoralists livelihoods in various ways such as drying of water points (Njoro), drying of livestock pastures emergency of new livestock diseases, and increased livestock mobility as to escape from droughts and searching for water and pastures. All these have led to reduced livestock and crops production and yields differently. Therefore, impacts of climate change and variability are real and negatively affect livestock and crops production which results in frequently food insecurity hence, innovated pathways have been serving them or working well, but not effectively and efficiently as per their indigenous knowledge system (IKS). What is missing in this communities is integration of scientific knowledge in adaptation to harsh environment which has caused frequently food insecurity. Therefore, the study recommends a more integrated scientific pathway practices which involve building capacity on diversification of their sources of livelihoods like engaging with crop growing through droughts resistant crops; also integrating multi-sectoral through interventions that target agro-pastoralists' resilience by integrating academic research and other developmental activities through civil society and community based organizations which could be the most important pushing pathways for increased resilience upon climate change and variability impacts in arid and semi-arid lands (ASALs).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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