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Full Length Research Paper

The dynamics of pastoral mobility routes in relation to food security in semi-arid areas of Simanjiro and Handeni districts in Tanzania

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This study specifically examined the pastoral mobility routes in relation to food security in Simanjiro and Handeni districts. The pastoralists from Simanjiro district usually migrate to Handeni and other areas as a coping strategy. During the pastoral mobility the pastoralists face different problems such as food insecurity. The data were collected by using participatory geographic information system (PGIS) and the descriptive data using questionnaire survey, focus group discussion and interviews. A total of 367 respondents were asked to fill the questionnaire, eight focus discussion one from each village, each focus group discussion comprised of eight members. The focus group discussions were assigned to locate the current and former mobility routes; once these points are reached the food is always finished, and all of these were located on the satellite image. Data show that 58% of the respondents said that the dynamics of the route was because of looking for shortcut path. Most of the pastoralists about 38.9% stayed 3 to 4 months in the destination area, 61% of the respondents had no access of food on the mobility route. 39% of the respondents had food during mobility and the food available was maize flour 44.4%, beans 20.7% and milk 18.5%. Therefore, it is evident that pastoral mobility has an impact on pastoral communities especially on food security since walking long distance searching pasture and water causes the livestock to be unhealth which lead to poor production of milk. This study recommends that the pastoralists especially the Maasai pastoralists should reduce the number of their livestock so that during drought season it could be easier to handle the livestock without deciding mobility which is more problematic, as it causes challenges such as death of livestock due to long distance travel to the pastoralists themselves and the livestock.

Key words: Pastoral mobility, pastoralism, food security, semi-arid areas.

INTRODUCTION

Pastoralism is among the most vulnerable sector to climate change and variations as they depend on the resources whose availability depend on seasonality. The major impacts of climate change on livestock production

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are through changes in production of pasture and water (Kimaro and Chibinga, 2013). The pastoral livelihoods which are mainly constituted of the delicate balance among pasture availability and livestock production are believed to be highly resilient to periodic shocks of drought and rainfall variability (Thornton and Herrero, 2015). However, the recent climate variability through increased frequencies of extreme events such as drought and floods undermine pasture and water availability (ibid). The success of pastoralist livestock production depends on mobility in order to ensure the timely and reliable access to pasture (Otieno, 2016).

Mobility of pastoral communities is part of their coping strategy to climate change and variability. Mobility is one of the tradition coping strategy based on movements within and across geographical distributed grazing units (Berhanu and Beyene, 2015). The pastoralists' way of living is reliant on the keeping of livestock and often sustained through national and regional migration (Krätli et al., 2012). Mobility is important for pastoralist living in dry land areas, as they move in search of water and forage. In this way, mobility is essential in order to reach the most optimal production in times of unstable climate and drought (Flintan et al., 2013).

This mobility create serious problems to the livestock as long distance movement weaken their body which lead to low production of milk and meat as a result the pastoralists eat ugali which they do not prefer (Helen, 2010). Also moving livestock outside of pastoralists' home areas increase the risk of livestock loss by force or through the exercise of power that means local elites and government officials which also can result to food insecurity as they lose their source of food which are livestock (Turner, 2011). Generally, pastoral mobility causes food insecurity to the pastoralists as they lack food during mobility because of overdependency on livestock products such as milk and meat which are affected by climate change and variability impacts. The pastoral mobility routes are not static, they usually change with some reasons such avoiding wild animals, shortcut in reaching the destination areas, avoiding areas with diseases such as trypanosomiasis. Therefore, this paper examines the dynamics of pastoral mobility routes in relation to food security.

MATERIALS AND METHODS

Description of the study areas

Geographical location of Simanjiro and Handeni districts

The study was undertaken in Simanjiro District, Manyara Region Tanzania (Figure 1). The region is located in the northern part of Tanzania. Geographically the district is found between latitude of 04° 30' 00''S and 05° 30'00''S and longitude of 37° 00'00'' E and 38° 00' 00''E covering an area of 20,591 km^2. The district lies at an altitude between 560 m and 2,123 m above sea level. The area's topography stretches from vast plains to scattered ridges and hill valleys. Simanjiro District is one of the six districts of the Manyara Region of Tanzania. It is bordered to the north by Arusha Region, to the north east by Kilimanjaro Region, to the south east by Tanga Region, to the south by Kiteto District, to the south west by Dodoma Region and to the west by Babati Rural District, (Homewood et al., 2012). Also the study was undertaken in Handeni District which is one of the eight districts of Tanga Region in Tanzania. Geographically the district is located between latitude of 05° 00' 00''S and 05° 30' 00''S and longitude of 38° 00' 00''E. It is bordered to the west by the Kilindi District, to the north by the Korogwe District, to the east by the Pangani District, and to the south by the Pwani Region (United Republic of Tanzania (URT), 2017).

Climatic characteristics

The Simanjiro district is characterized by semi-arid climate with annual rainfall ranging between 650 mm and 700 mm. The rainfall pattern is bimodal with short rains which occur from November to December and long rains from February to May. The wettest months are March and April while the driest months are July and August. Temperature is ranging between 13 and 30°C characterized by cold months from May to July and hot months from August to February (Pittiglio et al., 2012). Handeni district experiences coastal climate with high temperatures about 27 to 30°C and high humidity while the mean annual precipitation is 800 mm to 1500 mm (United Republic of Tanzania (URT), 2017).

Data collection and analysis

The study used both primary and secondary data to ensure the study aim is addressed. Secondary data sources include both published and unpublished materials relevant to the study aims. Sources of secondary data were from University of Dar es Salaam library, internet and other sources which are relevant. Primary data sources include household (boma) survey, focus group discussions, interviews with key informants (village leaders, village elders). The sample size of the household (boma) survey was 367 which was head of households in eight villages. Simple random selection procedure was used in selecting the heads of households who were surveyed. Quantitative data collected from household survey were analysed by the use of SPSS version 20. The data was analysed to get the frequencies and percentages. The PGIS was used to locate the former and old pastoral mobility routes and all the stations whereby the pastoralists rest during mobility.

RESULTS AND DISCUSSION

Demographic characteristics of the respondents

Age of the respondents

Age is used to indicate the level of maturity of individuals. It is believed that people of different ages have different needs, thinking, understanding and sighting of issues (Grillo, 2012). The results present the categorized age groups of respondents from the collected data based on ages. The rationale for categorizing respondents into different age groups was to facilitate clear understanding on people's perceptions on the impact of pastoral mobility on food security across different age groups. Also, it enabled the study to investigate the history of pastoral mobility. The involvement of respondents of different age groups bring different perspectives to the study which

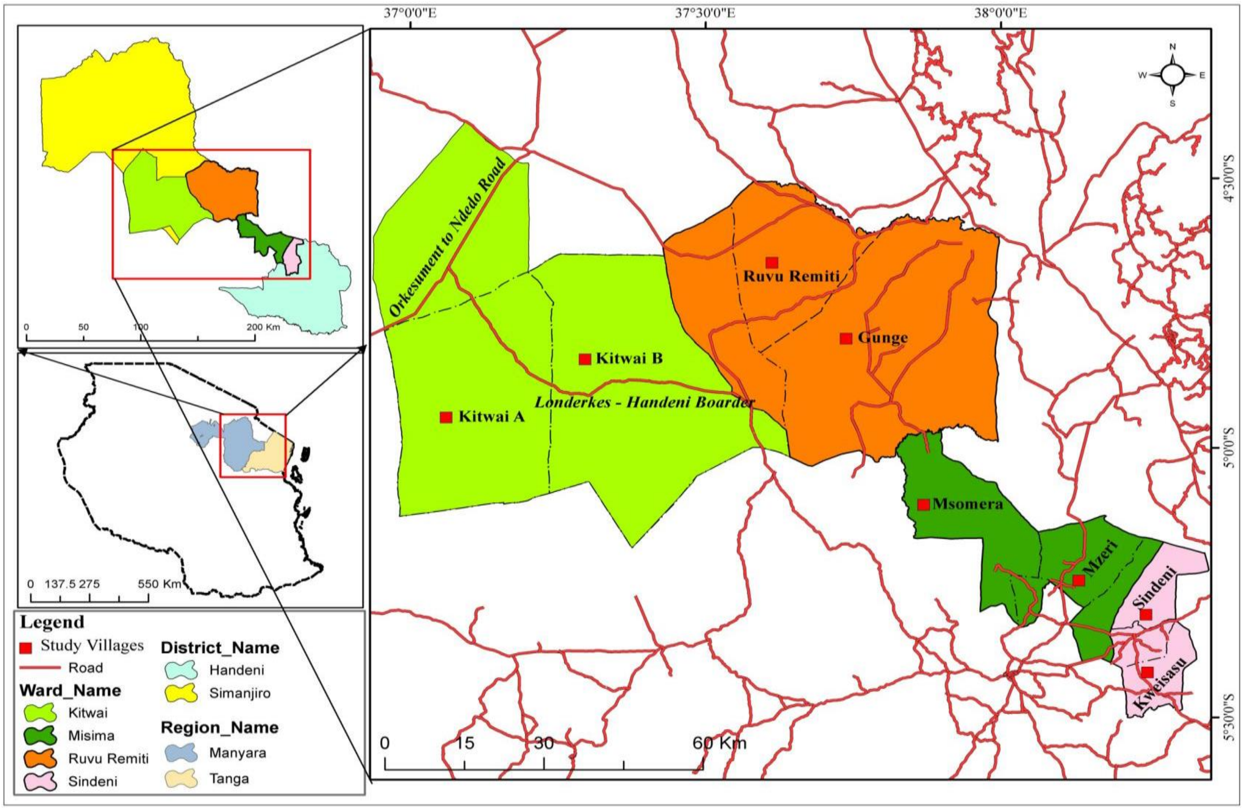

Figure 1. Location of the study area.
Source: Author generated (2018).

Table 1. The age of the respondents.

Age of respondents	Village of respondents								Sample total (n=367)
	Kitwai A (n=38)	Kitwai B (n=52)	Ruvu Remiti (n=58)	Gunge (n=26)	Msomera (n=29)	Mzeri (n=70)	Sindeni (n=52)	Kweisasu (n=42)	
Less than 25	8.5	6.5	14.5	2.4	3.1	4.5	8.3	19.2	**8.4**
25 to less than 35	25.5	16.1	35.5	22.0	31.3	24.2	27.1	26.9	**27.0**
35 to less than 45	34.0	38.7	21.1	19.5	25.0	24.2	29.2	38.5	**27.2**
45 to less than 55	6.4	22.6	17.1	29.3	25.0	22.7	12.5	11.5	**18.3**
55 to less than 65	10.6	6.5	7.9	22.0	12.5	13.6	14.6	0.0	**11.4**
65+	14.9	9.7	3.9	4.9	3.1	10.6	8.3	3.8	**7.6**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field survey (2018).

makes it more representative.

Table 1 indicates age distribution of the sampled respondents. The results indicate that on average, 8.4 and 27% of respondents reported having age of "below 25 years" and "25 to 34 years" respectively while those reported having age of "35 to 44 years" were 27.2%. Likewise, 18.3, 11.4 and 7.6% of respondents reported having age of "45 to 54 years", "55 to 64 years" and "65 years and above" respectively.

Sex of the respondents

Table 2 shows that on average, 79.6% of respondents were male while females were only 20.4%. Female's representation was higher at Kitwai A village followed by Gunge village, whereby sampled females were 46.8 and 43.9% respectively. Females were minimally sampled from Mzeri village followed by Msomera where sampled females were only 4.5 and 6.3% respectively. On average, males were most presented in the sampled results because males were the ones who travel longer distance with livestock in search of pasture and water as compared to female. Females are left home with the children and elders, and their roles were to milk the remaining cattle and prepare food for the family. Also, the females were the ones who build the huts (Inkajijiik). The main problem for Maasai women was that men in the community made all the major decisions about food. Women were left home with few choices when it came to decisions that affected their nutrition and that of their children. As in FGD the women were asked and said they were prohibited in making decisions about selling or slaughtering livestock when their husbands were away looking for pastures for their livestock. Often the men would be gone for three to four months at a time. If the family ran out of food in this time, they would have to go hungry, unless it was possible to borrow food from their neighbors. Therefore, this caused food insecurity to the members of family who left at home.

Level of education of the respondents

Education is the main key to development and is considered as a strong defense in the fight against poverty. Both developing and developed countries consider education as a strong prerequisite for development (Federico and Claudio, 2005). The study reveals that level of education of the respondents varied from no formal education to college level education. Formal education was seen as not priority in the study area, in reality formal education is the key to the development and considered as strong defence against poverty (Boopen, 2019). The significance of education level was also highlighted by Sianesi and Reenen (2003) who said that education is very important in all development perspectives because it determines the level of participation in fighting against food security.

Table 3 indicates that on average 50.4% of responses reported having no formal education, while those reported having primary and secondary education were 43.9 and 4.4% respectively. The responses reported having post-secondary education were only 1.3%. The results indicate that Msomera village had many responses (78.1%) reported being illiterate (having no formal education) followed by Gunge (75.6%) and Kitwai A (68.1%) as compared to other sampled villages. The Kweisasu village is the most educated village among all sampled villages; 92.3% of responses reported having attained education level of primary to post-secondary level.

These findings were similar to that by John (2015) which show that illiteracy is very serious problem which hinders efforts towards improving food security and it is the main cause of underdevelopment among the society. The illiteracy hinders the pastoralists to initiate the adaptation mechanisms to the problem of food insecurity that is why those who got secondary to college education had a good life, they do not suffer problems of food because they know the time to sell their livestock, the time to buy food.

Boma size of the respondents

Table 4 presents results for household size which was defined as boma size of sampled respondents. The results indicate that on average 45.8% of reported responses had boma (household) size of “0 to 9 persons” followed by 30.2 and 11.7% that reported having boma (household) size of “10 to 19 persons” and “20 to 29 persons” respectively. Those responses with boma size of “30 to 39 persons”, “40 to 49 persons” as well as “50 and above” were 6.8, 1.1 and 4.4% respectively.

Increase in boma (household) size, implies increased population of particular community which implies more mouths to feed, creating more demand and therefore, exerting higher pressure on resources (Gatiso, 2017). Most of the Maasai boma size comprising of a lot of family members which when the problem of drought come, usually are affected much because they depend much on the livestock which are easy affected by drought. Therefore, due to the nature of their family of depending one source of their income.

The nature of the pastoral mobility routes

The pastoral mobility routes are the routes whereby the pastoralists with their livestock pass when moving from their area to the destination area. Most of the pastoral mobility routes start from the area where they live. Figure 8 shows direction of the pastoral mobility routes are from Simanjiro to Handeni districts and then coming back to Simanjiro district through the same pastoral mobility routes. These pastoral mobility routes pass on the areas where the livestock can get pasture and sometimes water. Most of the pastoralists from Ruvu Remiti are moving through Lerumo village passing Kitwai B until they enter Handeni districts in the Village known as Saunyi village. The pastoralists from Gunge village divided into two groups whereby others pass through Ngiro Mountain and others passes through Larupa area, they all meet near the boundary between Simanjiro and Handeni districts and all enter Msomera village in Handeni district. The pastoralists from Kitwai A village have different mobility routes, others pass Lolongumaishi Mountain, Onyokye, Ngurret and then enter in Handeni district. Others pass Lolongumaishi Mountain then pass East of Ngurret to Saunyi village in Handeni district. Other pastoralists from Kitwai A migrate through Supaker passes Kitwai B to Saunyi village. Therefore, most of the pastoralists from Simanjiro district enter Handeni district

Table 2. Sex of the respondents.

Respondent's sex	Village of respondents								Sample total (n=367)
	Kitwai A (n=38)	Kitwai B (n=52)	R/ Remiti (n=58)	Gunge (n=26)	Msomera (n=29)	Mzeri (n=70)	Sindeni (n=52)	Kweisasu (n=42)	
Male	53.2	93.5	78.9	56.1	93.8	95.5	89.6	73.1	**79.6**
Female	46.8	6.5	21.1	43.9	6.3	4.5	10.4	26.9	**20.4**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field survey (2018).

Table 3. Level of education.

Level of education	Village of respondents								Sample total (n=367)
	Kitwai A (n=38)	Kitwai B (n=52)	Ruvu Remiti (n=58)	Gunge (n=26)	Msomera (n=29)	Mzeri (n=70)	Sindeni (n=52)	Kweisasu (n=42)	
Non formal education	68.1	45.2	48.7	75.6	78.1	37.9	39.6	7.7	**50.4**
Primary education	31.9	38.7	39.5	22.0	21.9	59.1	60.4	76.9	**43.9**
Secondary education	0.0	12.9	10.5	2.4	0.0	0.0	0.0	11.5	**4.4**
Post-secondary education	0.0	3.2	1.3	0.0	0.0	3.0	0.0	3.8	**1.3**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field survey (2018).

Table 4. Boma size of the respondents.

Boma size	Village of respondents								Sample total (n=367)
	Kitwai A (n=38)	Kitwai B (n=52)	Ruvu Remiti (n=58)	Gunge (n=26)	Msomera (n=29)	Mzeri (n=70)	Sindeni (n=52)	Kweisasu (n=42)	
Less than 10	42.6	54.8	52.6	31.7	21.9	40.9	45.8	84.6	**45.8**
10 to less than 20	29.8	32.3	13.2	39.0	28.1	39.4	45.8	15.4	**30.2**
20 to less than 30	14.9	9.7	18.4	14.6	21.9	6.1	4.2	0.0	**11.7**
30 to less than 40	6.4	3.2	7.9	12.2	15.6	4.5	4.2	0.0	**6.8**
40 to less than 50	2.1	0.0	1.3	2.4	3.1	0.0	0.0	0.0	**1.1**
50+	4.3	0.0	6.6	0.0	9.4	9.1	0.0	0.0	**4.4**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field survey (2018).

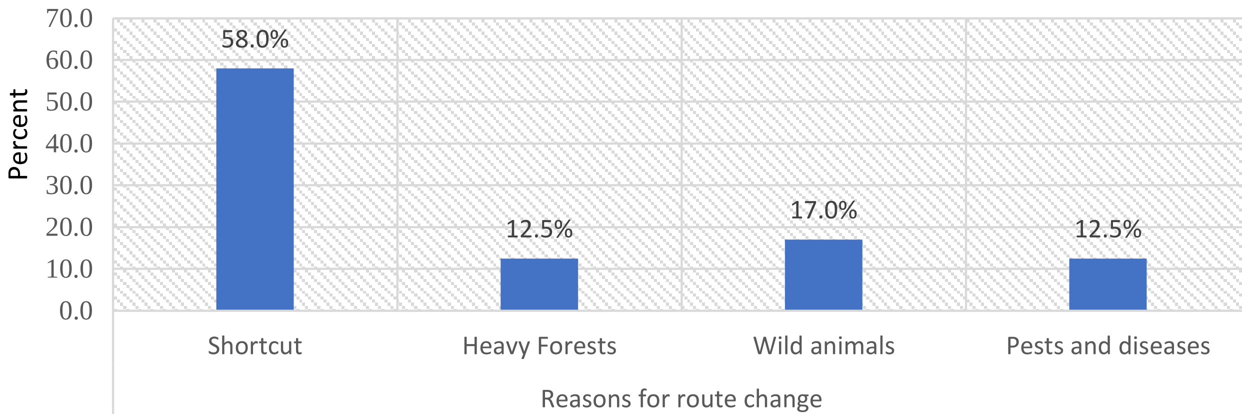

Figure 2. Reasons for route change.
Source: Field survey (2018).

through Msomera village to Mzeri village while others enter through Saunyi village to Sindeni and Kweisasu villages.

Figure 9 shows during the rainy season the pastoralists migrate from Handeni district to Simanjiro district. The Maasai pastoralists from Kweisasu village are divided into two groups, others move through Sindeni village then pass Mzeri village to Msomera village to Simanjiro district through Gunge village. Other Maasai pastoralists from Kweisasu village pass Mzeri village and then enter Simanjiro district through Gunge village. Those pastoralists who went in Msomera village also pass dry season pasture area and enter Simanjiro district through Gunge village, others from Msomera village pass Saunyi village and then enter Simanjiro district through Kitwai B village.

The former and current pastoral mobility route

The pastoral mobility routes have been changing with time, the change of the routes depends on several reasons such as shortcut of the route so as to reduce number of travelling days, heavy forests because it is not easy to pass with livestock across heavy forest, wild animals are another reason for route change this mean that in some area when passing with their livestock the wild animals like lion attack the livestock, in so doing they decide to change the route. Also, pests and diseases have been the cause of pastoral mobility route changes. The findings from Figure 2 reveal that most of the Maasai pastoralists about 58% change their mobility route because of identifying the short cut route to reach their destinations, other pastoralists reveal that about 12.5% of the respondents reveal that heavy forests, pests and diseases were the cause of them to change the mobility route, 17% of the respondents revealed that wild animals were also the cause of the pastoralists to change the pastoral mobility route. These former and current routes are shown on the maps on the Figures 8 and 9; where the reasons of change also can be seen clearly.

Also, Shem (2010) support the study as identified the routes whereby one is like that identified by the pastoralists themselves during data collection. He categorized four pastoral mobility routes as follows: pastoral mobility route from lake zone, pastoral mobility route from central zone, northern zone pastoral mobility route and new formed pastoral mobility routes. The pastoral mobility routes from the North to South East of Tanzania, whereby those pastoralists from Monduli district migrate to Simanjiro district and when reaching in Simanjiro district the routes divided into two whereby one goes to Same then to Kenya and others goes to Lushoto district and on the other hand the other route from Simanjiro district to Kiteto and Handeni districts. Therefore, this route is much used by the Maasai pastoralists whereby their movement pass at Handeni district others move to Muheza whereby others remain at Handeni until the rainy season to go back at Simanjiro district (Shem, 2010). These routes are shown on the Figure 3. All the routes are moving southward because most of the northern part of Tanzania prone to drought while in the south of the country experiencing high rainfall which make the presence of pasture and water. The other routes include from lake zone to southern part of the country (Tanzania), another pastoral mobility route is from central zone to southern part of Tanzania, each pastoral mobility route is dominated by its own pastoralists' community, for instance red pastoral mobility route is dominated by Maasai community.

The reasons for pastoral mobility

Most of the Maasai pastoralists opted for mobility as the coping strategy against the impact of climate change and

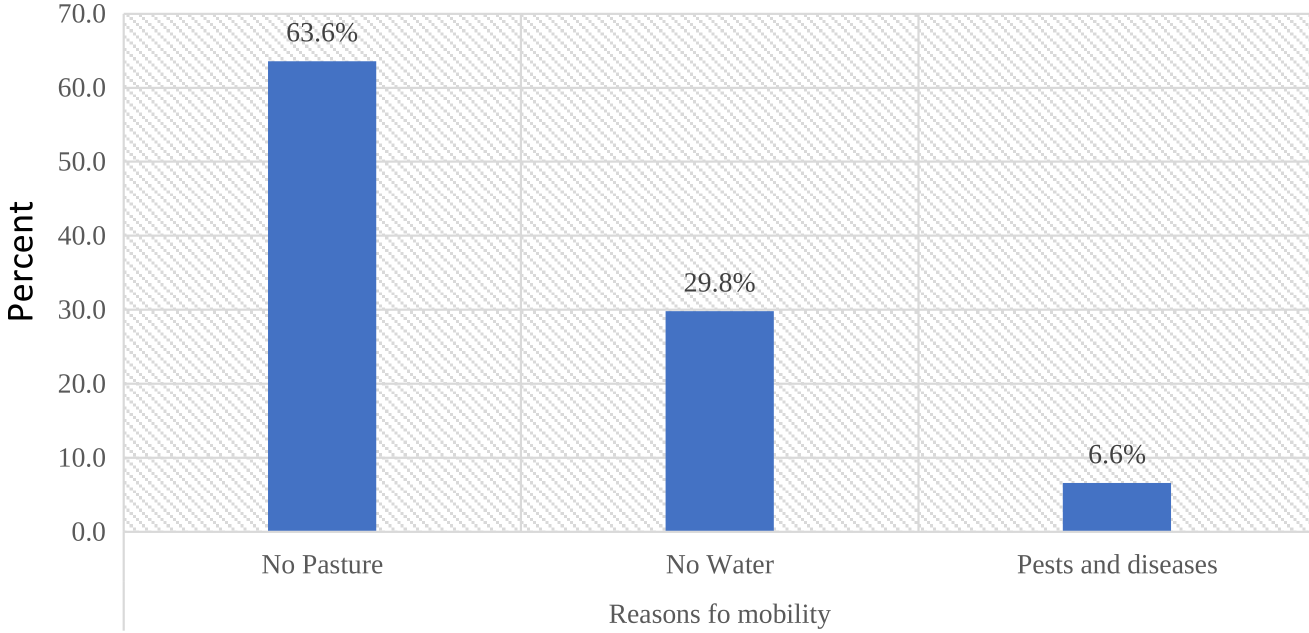

Figure 3. Reasons for mobility.
Source: Field survey (2018).

variability. Therefore, the findings on Figure 3 reveal that most of the Maasai pastoralists about 63.6% were moving with their livestock because of having no pasture in their area during the dry season, also 29.8% of the respondents revealed that water scarcity is also one of the reasons make the move with their livestock to other areas outside their district and even outside the region. Few respondents about 6.6% of the respondents revealed that pests and diseases also made them to migrate to other areas outside the district and region. Therefore, the main reason for the Maasai to migrate to other areas is insearch of pasture.

Time spent at the destination area

During the drought seasons the Maasai pastoralists move with their livestock to other areas outside their areas and when arriving at the destination area they usually stay more than a month until their area of origin gets rain. The findings as indicated on Figure 4 reveal that 38.9% of the respondents stayed 3-4 months away from their home in search of pasture and water. On the other hand 26.5% of the respondents revealed that they stayed 1-2 Months in the area which they went insearch of pasture and water. 24.8% of the respondents said that they stayed about 5-6 months far away from their villages insearch of pasture and water, and very few about 4.4% of the respondents stayed 8-9 months in the destination areas. Therefore, 3-4 months are the ones which many respondents stay while in the areas of destinations.

Food availability during migration to destination

During the pastoral mobility, most of the pastoralists face the problem of food availability since most of the areas where they pass there is no food available, therefore when the food carried is finished then there is no alternative until they send the information home so as thy should prepare food and send where the Moran and their livestock are, this causes them to remain without food for some days, but to those who have goats and sheep they just slaughter one and get food but the sufferings is for those who does not have goats and sheep. The findings from Figure 5 show that most of the respondents about 61% revealed that there was no food available when they were on the way to destination area and very few about 39% said there was food during mobility. Therefore, this shows that most of the pastoralists face the problem of food when they are on the way to destination area. Also, this was shown on the map Figure 8 which have pointed out the kilometers when reached the food carried is finished, these points are also the stations to rest for sometimes while waiting from their home or from somebody who is sent nearby village to buy the food, while waiting the Maasai pastoralists are just staying without food, sometimes eating roots, others with cattle which can produce milk they can get a little milk at that point because of long journey travelled.

Type of food available around migration route

Some of the Maasai pastoralists pass on the routes

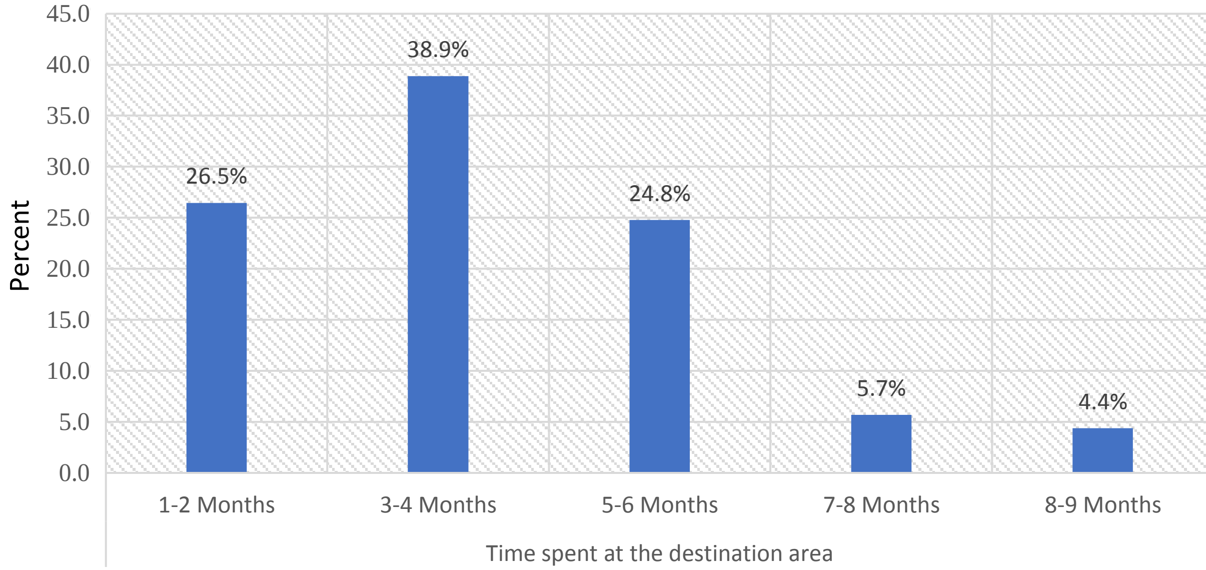

Figure 4. Time spent at the destination area.
Source: Field survey (2018).

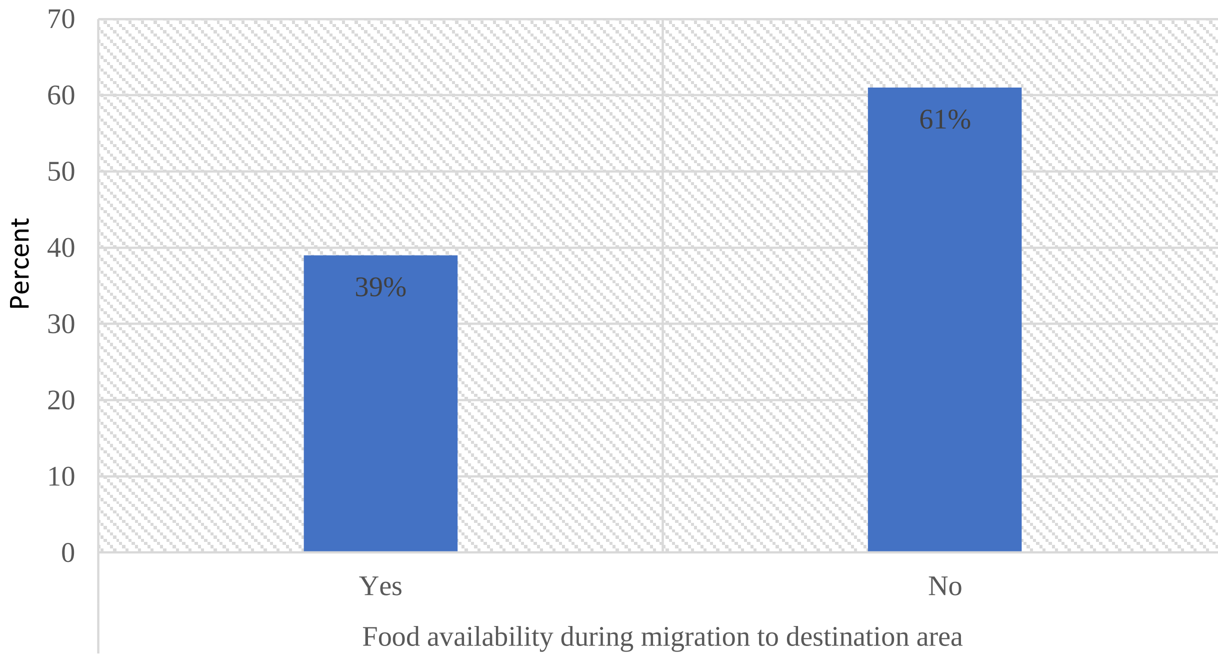

Figure 5. Food availability during migration to destination area.
Source: Field survey, (2018).

which are along the villages whereby when their carried food is finished, they can access food on those villages. The food types are maize floor, beans, meat, milk and rice. The findings from Figure 6 show that most of the respondents about 44.4% revealed that the food type which was very much available when they were on the way to destination areas was maize floor, next one was beans which about 20.7% of the respondents revealed it was the second to be found easily when they are moving with their livestock, milk also was another type of food which the pastoralists about 18.5% depend on when are travelling with the livestock in search of pasture and

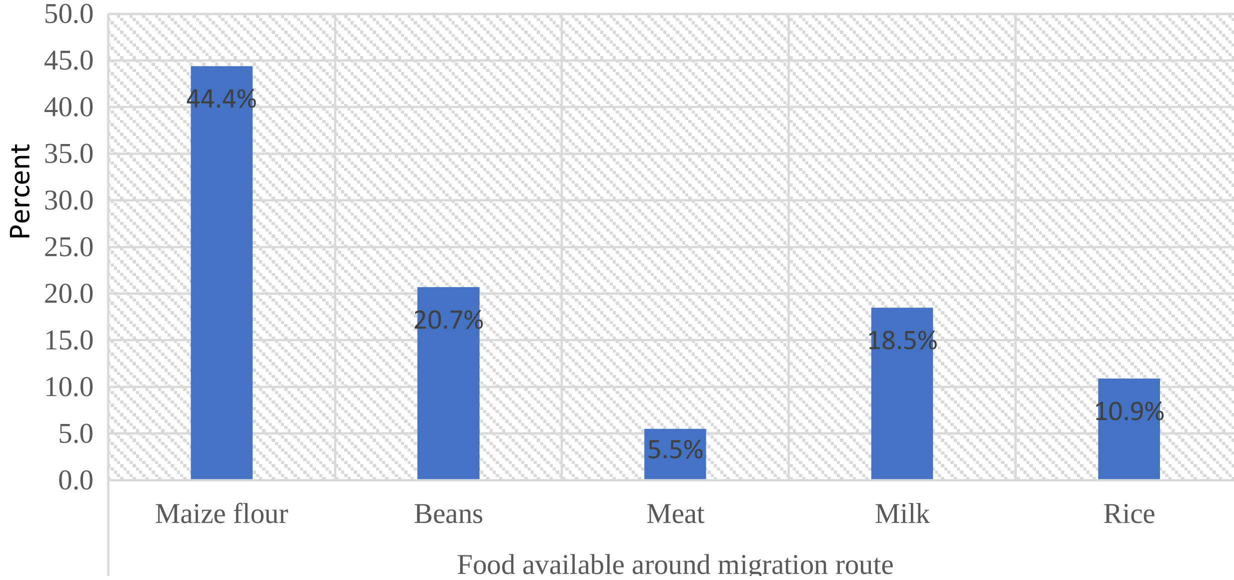

Figure 6. Type of food available around migration routes.
Source: Field survey (2018).

Table 5. Those who are involved in pastoral mobility.

Involved in Mobility	Responses		Percent of Cases
	N	Percent	
Elders	73	18.6	21.9
Morani	294	81.4	95.4
Total	367	100.0	117.2

Source: Field work (2018).

water and meat about 5.5% of the respondents reported it was another type of food which they depended on, this shows that even though the pastoralists depend their living on livestock but very rarely slaughter their livestock for food especially those without goats and sheep.

Participants in pastoral mobility

The pastoralists' communities do not involve every individual but there are people of a certain age who are involved in moving with livestock in search of pasture and water. Table 5 indicates that 81.4% of the respondents reported Morani as being most involved in travelling with livestock in search of pasture and water, while few respondents about 18.6% reported elders as being involved in traveling with livestock in search of pasture and water. Elders are involved in a situation where there is no any Morani in particular household, hence elders remain with no option but to take livestock themselves in search of pasture and water.

The seasons for pastoral mobility

Simanjiro district is in semi-arid area and it is one of the areas which is very much affected by climate change. The most impact of climate change observed was drought which led to the mobility of Maasai pastoralists to the areas where they can find pasture and water for their livestock. The findings from Figure 7 revealed that most of the respondents about 77.2% were moving during dry seasons. This is because during this season there is no pasture and water around their areas especially to the villages which they do not have borehole. The Maasai pastoralists have several pastoral mobility; during the rainy season the Maasai pastoralists do not stay with their livestock near the bomas but they stay a bit far so that to preserve the pastures which are near the bomas for dry season. During the dry season the Maasai pastoralists and their livestock return home with their livestock and use the pasture preserved during the rainy season. Then, if the dry season prolong until the pasture are finished, they plan to go far away from their district,

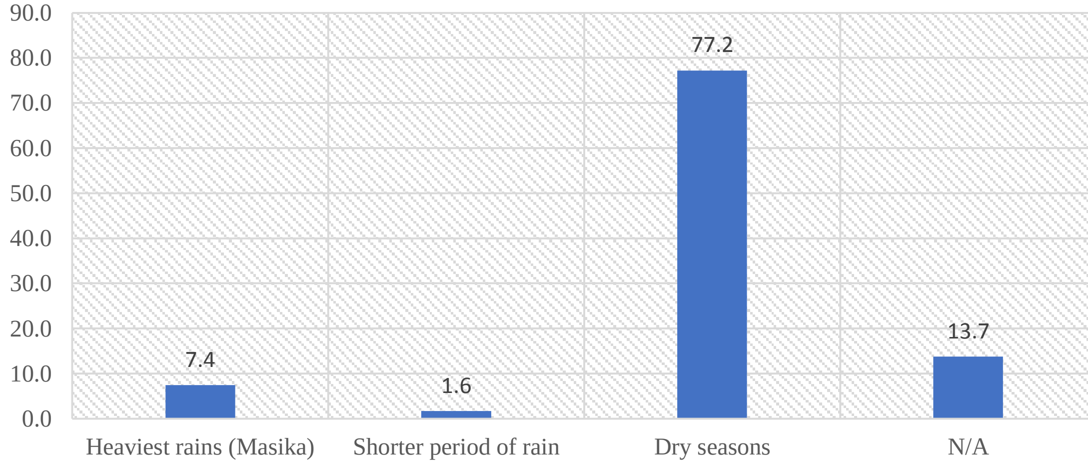

Figure 7. Seasons for pastoral mobility
Source: Field work (2018).

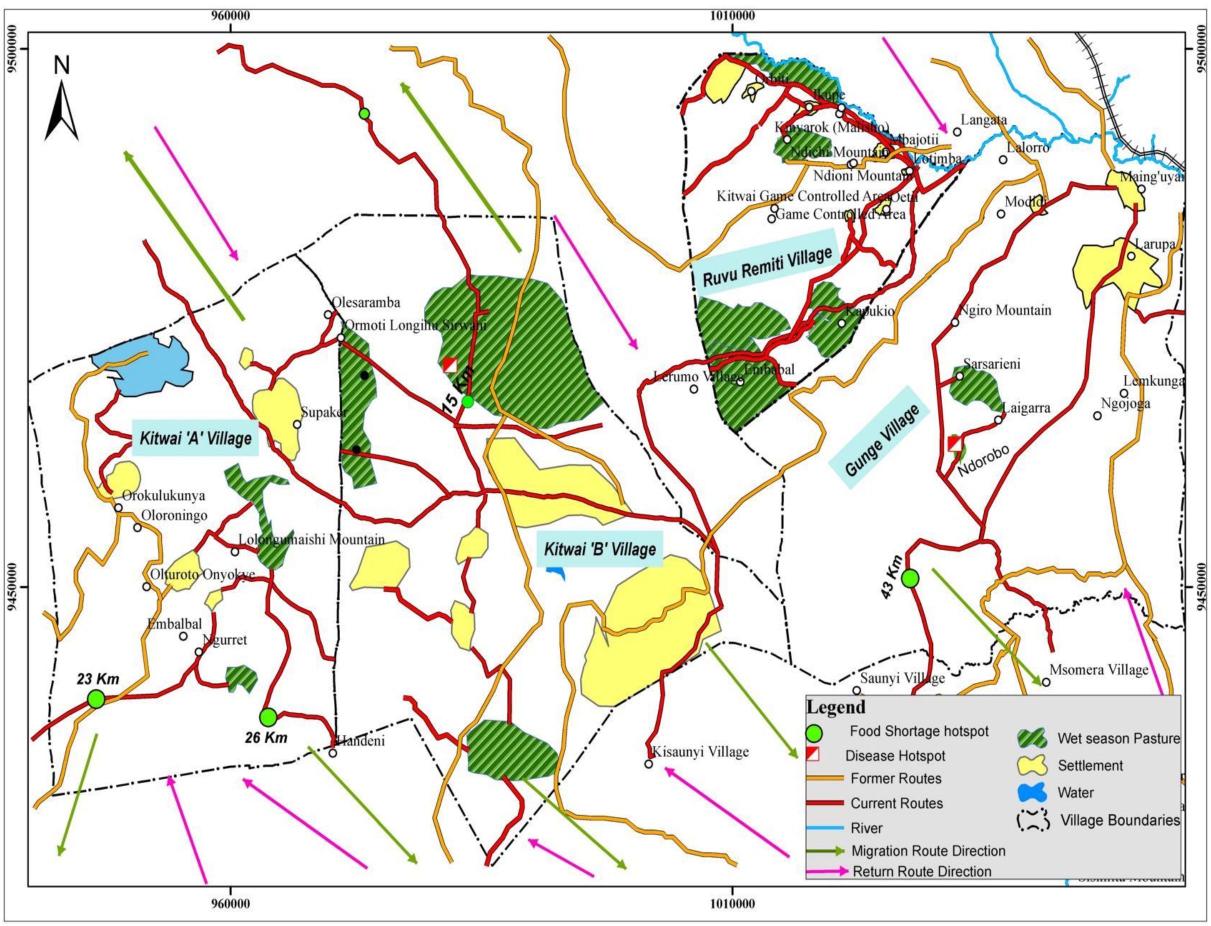

Figure 8. Map showing pastoral mobility routes in Simanjiro districts.
Source: Field survey (2018).

the Maasai pastoralists from Simanjiro districts usually go to Handeni district and Kilindi district.

This has been observed in Senegal whereby the pastoralists distinguished two main types of mobility

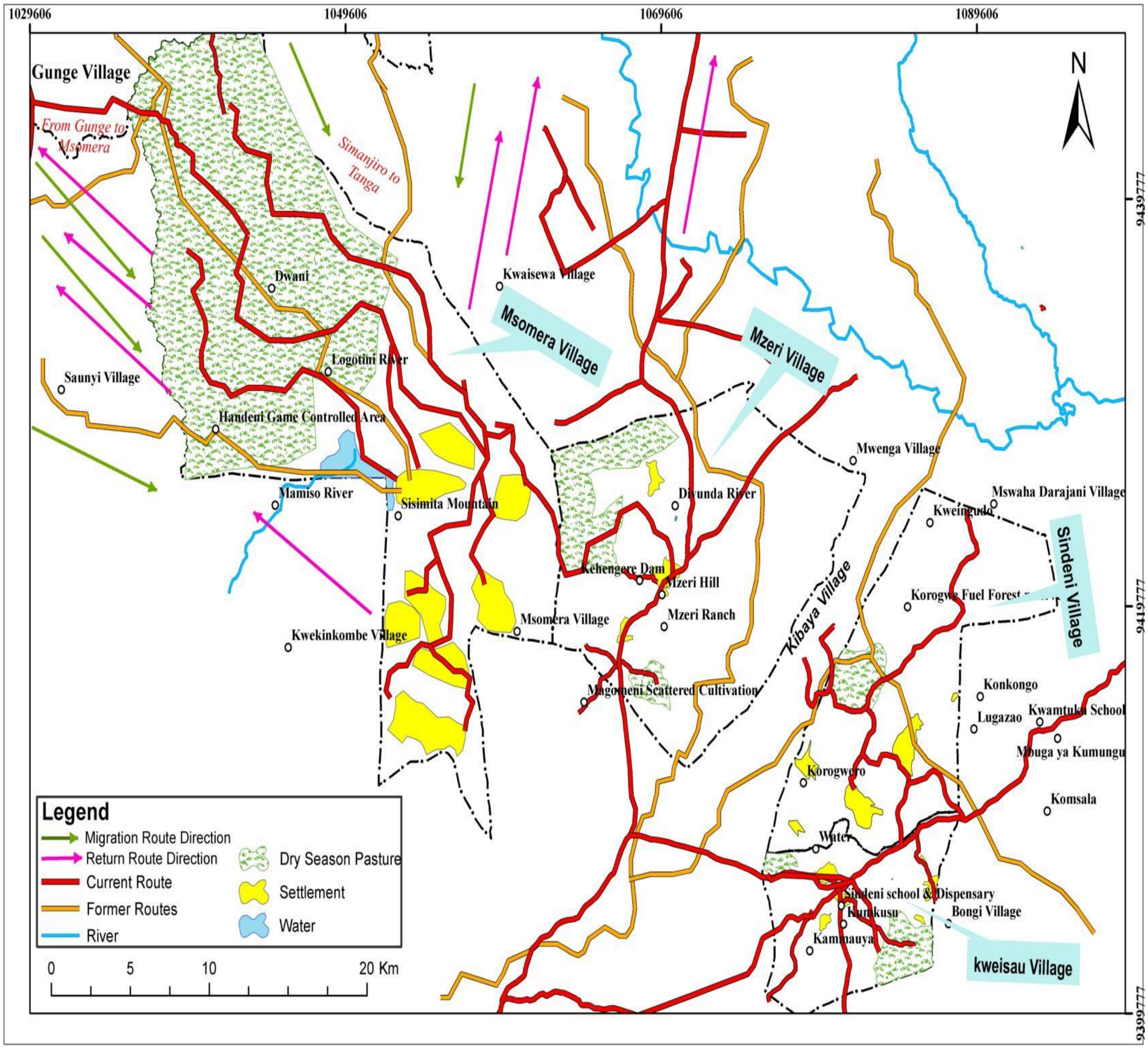

Figure 9. Map showing pastoral mobility routes in Simanjiro districts.
Source: Field work (2018).

which were daily mobility within the pastoral unit and transhumance. The latter entails leaving the pastoral unit and making a temporary camp elsewhere and it is related to different seasons which were rainy season (June-August), Cold dry season (September-January), Hot dry season (February-April), Near rainy season (May) (Adriansen, 2008). The rationale for going on transhumance was to look for pasture and water wherever they are found or when meeting the rain. The livestock taken was depending on the need of the family left, if the family left is big then the livestock left should also be proportional (Adriansen, 2008). Therefore, the months for pastoral mobility are not common in every country depending with when the different seasons occur, that is why in Simanjiro the pastoralists start moving long distance outside their compounds during dry seasons the same applied in Senegal.

Pasture preservation in Maasai communities in Simanjiro district

The Maasai communities of Simanjiro had their own way of preserving their pasture. During rainy season all the livestock except few about seven are sent far away around the village where they stayed until dry season. This is because during the rainy season the pasture and water are available everywhere in the village and around the village. During dry season the Maasai pastoralists with their livestock return to their boma and their livestock eat the pasture around their boma which was not used in the rainy season. They have traditional regulations which guide them all these, and if somebody does not respect the rules and regulations concerning pasture preserving were punished by paying fines more than 250,000 Tanzania shillings (Maleko and Koipapi, 2015). In Figure 8 shows the wet season pasture which are not very far from their bomas but when the time came, they went on those areas and stay there until dry season is when they decide to come back in their village.

Conclusion

It is evident that most of the pastoralists from Simanjiro district migrate to Handeni district in search of pasture and water. During pastoral mobility, the pastoralists face food insecurity both at home (boma) and on the way to destination areas. This is because most of the areas which they pass with their livestock are remote and sometimes cannot access food because the food is not available in those areas, the only option was to look for wild food and sometimes sending someone far to look for food. Usually, they leave few cattle about seven at their boma for food but due to drought these cattle die and lead to the suffering of food insecurity for the whole family remained at home. Therefore, in order to cope with the problem of food insecurity during pastoral mobility the pastoralists decide to sell their livestock and slaughtering some of the livestock such as goats which is not applied to all, most of them do not prefer this option. Therefore, ending up suffering from food insecurity.

RECOMMENDATION

The study recommends that, the pastoralists especially, the Maasai should reduce the number of their livestock so that during drought season, it could be easier to handle the livestock without deciding mobility as a copying strategy which is more problematic as it causes challenges to the pastoralists themselves and the livestock. Keeping large number of livestock in small areas lead to the problem of environmental degradation where in turn may lead to climate variability and change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Physicochemical quality of the groundwater perimeter of rice farms of Maga (Far North Cameroon)

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The rice-growing area of Maga is located in the floodplain of Lower Logone. It covers an irrigable area of more than 7000 ha of arable land. This area is indeed subjected to groundwater quality studies. Three campaigns of water sample studies were performed for one year in 15 points including nine boreholes and six domestic feed wells. Temperature, pH, EC, as well as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, HCO_3^{-}, NO_3^{-}, Cl^{-}, SO_4^{2-} and PO_4^{2-} were analyzed for these water samples. The results showed that these waters have a medium degree of mineralization, resulting in facies of carbonated sodium and potassium type, then bicarbonate calcium and magnesium. The levels of calcium, magnesium, sodium, potassium, bicarbonates, chlorides and sulphates are much lower than those recommended by World Health Organization (WHO) for human feed water. The contents of ammonium, nitrates and phosphates are in most waters samples above WHO prescribed level (0.5, 50 and 0.5 mg/L). These ions in high proportions have an anthropogenic origin because of the practice of rice farming. The sodium adsorption ratio (SAR) allowed us to qualify groundwater intended for irrigation.

Key words: Physicochemical, groundwater, mineralization, Maga.

INTRODUCTION

Groundwater of good quality is nowadays threatened both qualitatively and quantitatively. This threat is accentuated by human activities (Hassoune et al., 2006; El Asslouj et al., 2007; Bouderka et al., 2016) although it may have natural causes (Andre et al., 2005; El Asslouj et al., 2007; Kuldip Singh et al., 2011). Among anthropogenic sources are agricultural activities that use agrochemicals that can migrate to surface and groundwater, thus altering its quality (Fadel et al., 2007; Koné et al., 2009).

In Cameroon the water resource is abundant but its quality is still not good (Kengni et al., 2012; Kristin et al., 2014). Some studies carried out in the northern part of Cameroon in order to evaluate the groundwater quality

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reported several sources of pollution (Mbawala et al., 2010; Kristin et al., 2014; Moussa et al., 2014; Hambate et al., 2015; Sara et al., 2016), which is a threat because it lowers the overall water resources balance. Access to good quality water therefore remains big challenge for the government and the people.

In the Far North Region, only 13.8% of households had access to drinking water in 2011 (Djao et al., 2011). In the district of Maga, only a few families are connected to the water distribution network provided by Cameroon Water Utilities Cooperation (CAMWATER). Majority of the population in this area use well water and boreholes whose qualities is not controlled. However, with a dense rice activity and an intensification of market gardening, the underground water resources can be threatened by an uncontrolled use of agricultural inputs following liberalization of the market supply of these chemicals. Knowing that the pollution prevention of water is preferable to the treatment of the latter for the supply of drinking water (Mourey and Vernoux 2000), it is therefore appropriate to monitor the variation and evolution of the quality of water resource of the area. This study focuses on the assessment of the physicochemical quality of water captured by boreholes and wells in the irrigated rice area of Maga for its domestic and agricultural use.

MATERIALS AND METHODS

Description of the study area

The rice-growing area of Maga is located between latitude 10°21' and 10°51' N and between longitude 14°56' and 15°13' E. It is in the Department of Mayo-Danay, Region of Far North Cameroon. This area has about 7000 ha of developed arable land divided into four compartments (Maga East, Maga West, Pouss and Guirvidig) and more 2000 ha undeveloped (Figure 1). The climate that reigns there is of the Sahelo-Sudanese type, characterized by a long dry season that starts in October and ends at the beginning of May and a short rainy season, from June to September marked by episodes rainy violent. The average annual rainfall varies between 750 and 800 mm. The average annual temperature varies between 26 and 28°C with a monthly average that can reach 34°C in April. The morphology is dominated by a plain that before the development of SEMRY's (Société de Modernisation de la Riziculture de Yagoua) facilities in Maga remained flooded for 5 to 7 months the flood waters of Logone (Seignobos and Moukouri, 2000; Ngounou et al., 2007). On the plan geologic there are recent and ancient quaternary formations consisting of alluvial clay-sandy deposits generally between 50 and 70 m thick (Schneider and Wolff, 1992; Biscaldi, 1970). The soils of the area are poorly developed soils, Vertisols, and tropical ferruginous soils, hydromorphic soils and halomorphous soils (Barbery and Gavaud 1980).

METHODOLOGY

Water samples for the study were collected in October 2017, February and June 2018. 45 samples were collected during these three campaigns. These samples collected in polyethylene bottles with a capacity of 1.5 L, previously washed with 1 M nitric acid and then with distilled water. Before sampling in the field, these bottles are rinsed three times with the water to be taken. These samples are subsequently transported in a cooler at 4°C for laboratory analysis. Sampling points were located by their geographic coordinates determined by a Garmin branded GPS. pH, the electrical conductivity and temperature were measured *in situ* using a probe Hanna HI 98130 brand multi-parameters. The probe was submerged into the sampled water and readings taken when they stabilized. The complete alkalimetric title was determined by titrimetric in the field using a 0.02N H_2SO_4 solution. Sodium (Na^+) and potassium (K^+) were assayed by flame photometry. The other parameters (Ca^{2+}, Mg^{2+}, NH_4^+, NO_3^-, Cl^-, SO_4^{2-} and PO_4^{2-}) were determined using a Hanna HI 83300 photometer.

Statistical analysis of the data obtained with the XLSTAT 2018 software. The results obtained are compared to the WHO guideline values for physical and chemical parameters for the quality of drinking water (WHO, 2008). The Gibbs diagram (1970) was used to determine the origin of the mineralization of the waters, the hydro-chemical analysis was carried out using the Software Diagram 6.57 (Simler, 2007) and to assess water quality for agricultural use, we used Wilcox (1948) and Richards (1954) diagrams to perceive the risk of soil salinization and sodization.

RESULTS AND DISCUSSION

Physicochemical quality of water

The average minimum temperature value for all campaigns is 28.17°C while the average maximum value is 32.03°C (Table 1). The average standard deviation (SD) annual average (1.07) and the average coefficient of variation (CV) (0.035) of the temperature that these groundwaters are globally influenced by ambient temperature (Kelly et al., 2013). This temperature variation will have an influence on the reactions of the chemical elements and pH of water (Larive, 1997). These waters have a pH ranging from 6.65 to 8.19 (Table 1) which is in the meantime recommended by WHO (6.5 - 9.5) for the quality of drinking water. These waters have a low pH dispersion (SD equals 0.47) with values close to 7 can justify the strong presence of bicarbonate ions (Guilhem, 1976). These pH values are in the range of those obtained by Kristin et al. (2014) during the study of quality Groundwater in the Lower Logone flood plains.

Electricity conductivity (EC) measurements across all campaigns show values between 120 and 823.33 μS/cm with an average of 409.33 μS/cm (Table 1). The boreholes F04 and F08 then the wells P02, P03 and P06 have values conductivity range of 400 to 600 μS/cm illustrating that these water points have a medium mineralization (Table 2). Boreholes F05, F09 and well P05 have conductivity values between 600 and 1000 μS/cm indicating important mineralization. For the others water points (F01, F02, F03, F06, F07, P01, P04) mineralization is observed to be weak to slightly accentuated.

Total mineralization or TDS is the sum of cations and anions. Charge is between 82.67 and 759.67 mg/L. With the exception of the waters of points F06 and F07, all the other concentrations are characteristic of the groundwater which is included in the range 100-1000 mg/L (Chebotarev, 1950; Hem, 1989). Considering this

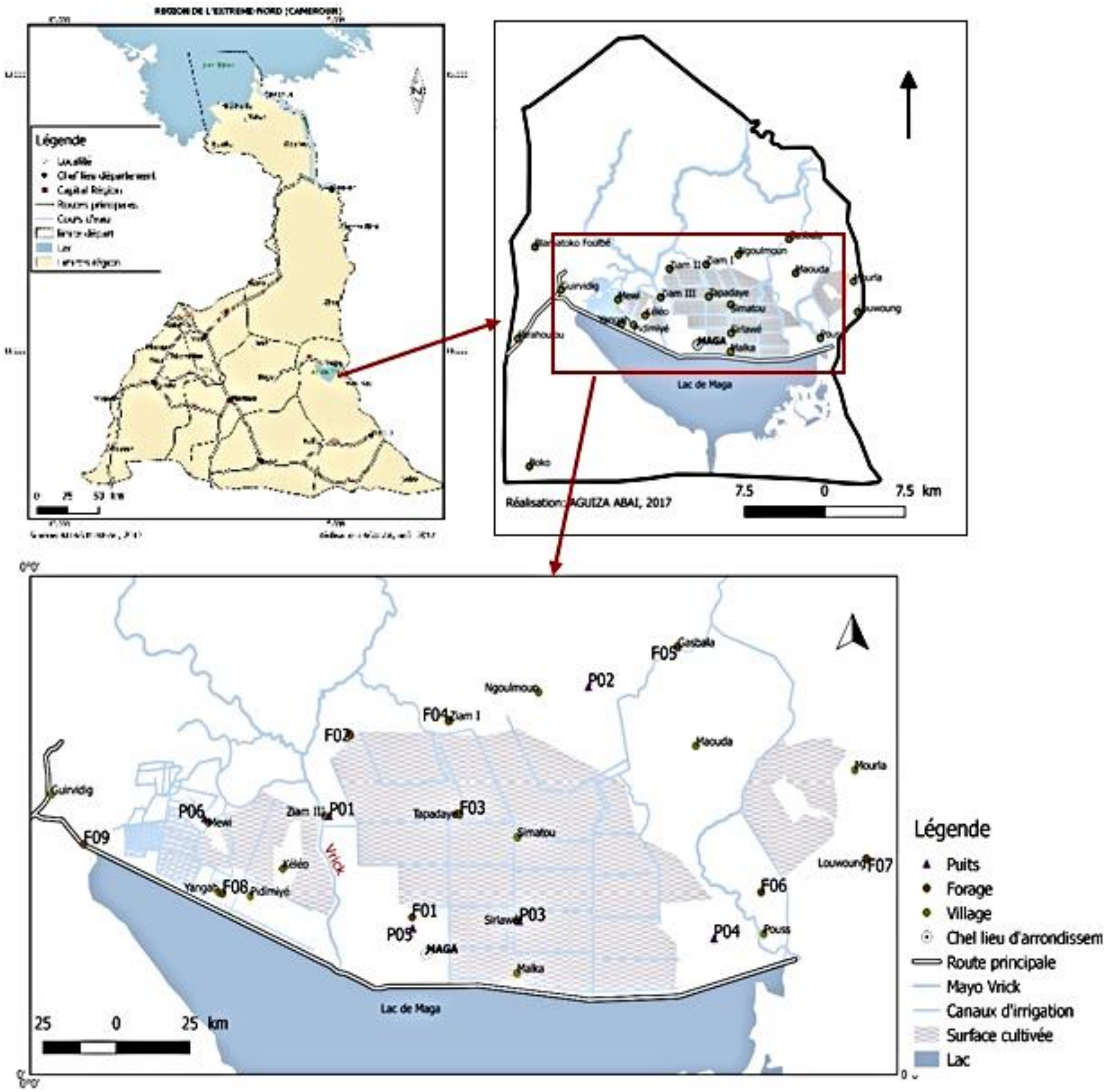


Figure 1. Location map of the study and sampling area.

mineral charge, 53% of waters are of excellent quality, 27% of good quality and 20% of fair quality (Table 3), which reflects a weak anthropic influence exerted on these waters.

Chemical quality of water

The major cations of the waters in the study area have average concentrations variables according to the chemical species sought. Of the 15 samples analyzed, the mean values are in the range 0.33 to 36.33 mg/L and then 4.33 to 19.67 mg/L for Ca^{2+} and Mg^{2+}; from 6.27 to 183.01 mg/L then 2.07 to 5.47 mg/L and finally from 1.53 to 14.87 mg/L for Na^+, K^+ and NH_4^+ respectively (Table 1). The ammonium concentration values of waters in the study area for all seasons are greater than 0.5 mg/L (Table 1), guiding value for drinking water (WHO, 2008). However, considering separately subsurface waters represented by wells and deep-lying waters represented by boreholes, we note that the average concentrations of calcium (10.06 mg/L) and magnesium (11.11 mg/L) are higher in well water than in borehole water (5.22 and 9.15 mg/L, respectively), which reflects their contribution by training from the soil in the seepage water by lixiviation and by runoff. The average concentrations of the different

Table 1. Results and statistical variables of physicochemical and chemical analyzes of water.

Sample	Physicochemical parameter				Chemical parameters									
	T°C	pH	EC (µS/cm)	TDS (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	NH_4^{+} (mg/L)	HCO_3^{-} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)	NO_3^{-} (mg/L)
F01	29.61	7.20	323.33	417.33	1.67	8.00	106.20	2.20	1.57	292.37	0.50	0.67	0.57	3.33
F02	29.14	6.87	230.00	198.00	0.67	5.33	42.52	2.07	2.07	140.72	1.20	1.33	0.20	0.00
F03	29.67	6.65	170.00	174.67	1.00	4.33	26.87	2.07	2.03	136.57	0.37	0.67	1.40	0.00
F04	30.51	7.04	413.33	292.67	1.00	11.33	56.75	2.57	2.03	216.68	0.90	0.67	0.43	0.00
F05	32.03	7.81	640.00	690.67	1.00	7.33	177.98	2.07	1.53	497.25	1.53	1.00	0.40	0.00
F06	31.97	8.18	173.33	82.67	4.33	5.33	8.29	2.07	1.57	59.11	0.40	0.67	0.20	0.00
F07	29.70	8.19	120.00	95.33	0.33	8.33	6.27	2.27	5.83	70.85	0.73	0.33	0.03	0.00
F08	31.83	7.53	540.00	425.00	0.67	12.67	81.56	2.33	1.87	323.60	0.50	0.33	0.53	0.00
F09	28.17	7.02	823.33	668.67	36.33	19.67	71.79	5.47	14.87	516.91	0.73	1.67	0.00	0.00
P01	30.35	7.10	220.00	201.00	0.33	6.33	37.01	2.17	2.27	150.99	0.43	0.67	0.57	0.00
P02	30.28	7.53	536.67	384.67	0.67	13.67	41.39	2.47	3.20	318.87	0.87	0.33	0.50	2.33
P03	29.60	6.95	220.00	212.00	10.00	7.67	33.07	2.30	2.47	144.85	1.00	9.67	0.23	0.00
P04	30.33	7.80	360.00	221.67	11.33	10.33	15.26	2.27	2.27	177.23	0.80	0.33	0.30	0.00
P05	30.07	7.71	783.33	759.67	15.33	12.33	183.01	3.37	5.73	445.12	23.37	22.00	0.03	47.93
P06	30.63	7.47	586.67	424.33	22.67	16.33	44.97	2.80	3.27	331.49	1.63	0.33	0.17	0.00
Minimum	28.17	6.65	120.00	82.67	0.33	4.33	6.27	2.07	1.53	59.11	0.37	0.33	0.00	0.00
Maximum	32.03	8.19	823.33	759.67	36.33	19.67	183.01	5.47	14.87	516.91	23.37	22.00	1.40	47.93
Average	30.26	7.40	409.33	349.89	7.16	9.93	62.20	2.56	3.50	254.84	2.33	2.71	0.37	3.57
Standard Deviation	1.07	0.47	229.84	216.04	10.54	4.39	55.10	0.87	3.42	148.63	5.83	5.82	0.34	12.31
Coefficient of Variation %	3.52	6.41	56.15	61.74	147.30	44.19	88.60	34.11	97.74	58.32	250.19	214.96	93.15	344.58
WHO (2008)		6.5 – 9.5	1300	1000	100	150	200	200	0.5	/	250	250	0.5	50

T: temperature; EC: Electrical conductivity; TDS: Total Dissolved Solid; Ca^{2+}: Calcium; Mg^{2+}: Magnesium; K^{+}: Potassium; NH_4^{+}: ammonium; HCO_3^{-}: Bicarbonates; Cl^{-}: Chlorides; SO_4^{2-}: Sulphates; PO_4^{2-}: Phosphates; NO_3^{-}: Nitrate.

Table 2. Relationship between conductivities and mineralization.

Electrical conductivity (µS/cm)	Mineralization
< 100	Very weak
100 à 200	Weak
200 à 400	Not very accentuated
400 à 600	Medium
600 à 1000	Important
> 1000	Excessive

Source: Detay (1993).

Table 3. Relationship between TDS and water quality.

TDS (mg/L)	Quality	Samples	%
< 300	Excellent	F02, F03, F04, F06, F07, P01, P03, P04	53.33
300 à 600	Good	F01, F08, P02, P06	26.66
600 à 900	Fair	F05, F09, P05	20
900 à 1200	Poor		
> 1200	Unacceptable		

Source: WHO (1984).

Table 4a. Statistical variables of physicochemical and chemical parameters of boreholes water.

Variable	Physicochemical parameters				Chemical parameters									
	T°C	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_3^-
Min	28.17	6.65	120.00	82.67	0.33	4.33	6.27	2.07	1.53	59.11	0.37	0.33	0.00	0.00
Max	32.03	8.19	823.33	690.67	36.33	19.67	177.98	5.47	14.87	516.91	1.53	1.67	1.40	3.33
Average	30.29	7.39	381.48	338.33	5.22	9.15	64.25	2.57	3.71	250.45	0.76	0.81	0.42	0.37
Std-dev	1.38	0.56	242.63	229.12	11.72	4.81	54.16	1.10	4.39	171.03	0.39	0.44	0.42	1.11
CV%	4.56	7.70	63.60	67.72	224.56	52.61	84.30	42.87	118.58	68.29	51.43	54.54	100.59	300

Table 4b. Statistical variables of physicochemical and chemical parameters of wells water.

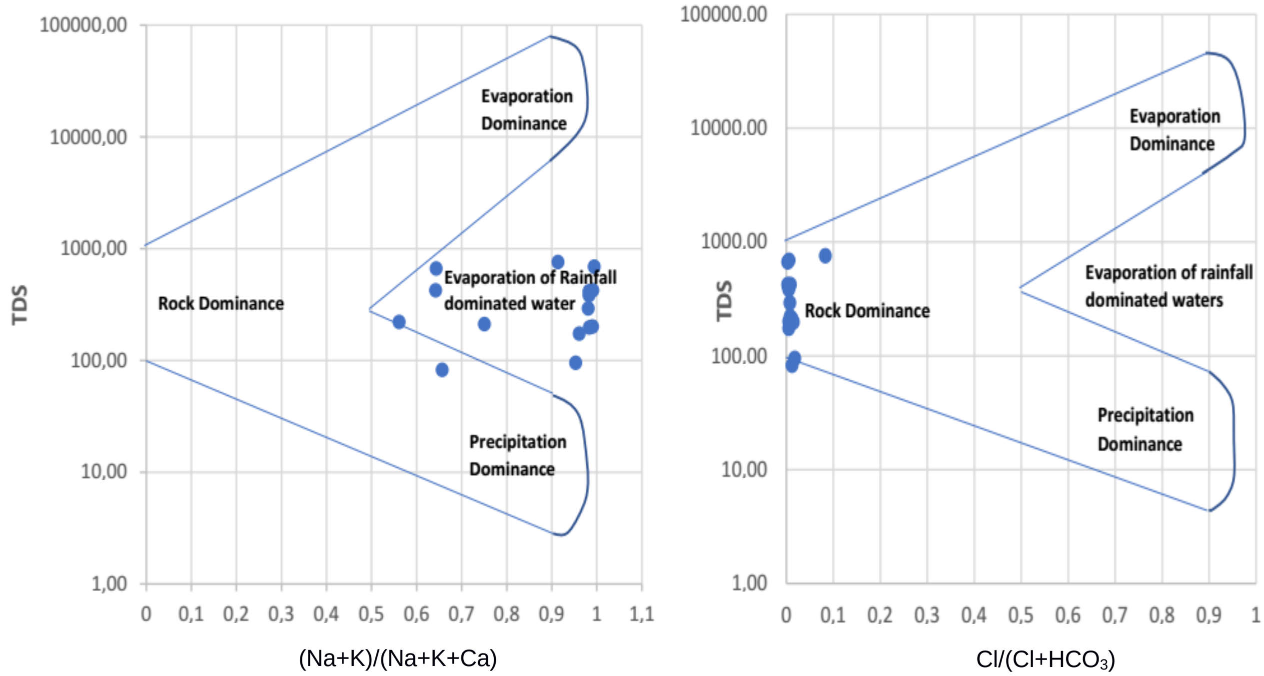
Variable	Physicochemical parameter				Chemical parameters									
	T°C	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_3^-
Min	29.60	6.95	220	201	0.33	6.33	15.26	2.17	2.27	144.85	0.43	0.33	0.03	0.00
Max	30.63	7.80	783.33	759.67	22.67	16.33	183.01	3.37	5.73	445.12	23.37	22.00	0.57	47.93
Average	30.21	7.43	451.11	367.22	10.06	11.11	59.12	2.56	3.20	261.42	4.68	5.56	0.30	8.38
Std-dev	0.34	0.33	224.13	214.70	8.61	3.75	61.56	0.45	1.31	122.33	9.16	8.86	0.20	19.40
CV%	1.15	4.52	49.68	58.46	85.67	33.81	104.14	17.68	41.22	46.79	195.61	159.58	67.40	231.57

cations are a little more homogeneous at the wells than the boreholes according the standard deviations that are higher in boreholes than wells (Table 4a and b).

Anionic concentrations in the study area are subject to important values variation between different sampling points. Bicarbonates have a average value of 254.84 mg/L with a maximum value of 516.91 mg/L and a minimum value of 59.11 mg/L with a standard deviation of up to 148.64 mg/L (Table 1). For the chlorides the average value is 2.33 mg/L with a minimum value of 0.37 mg/L and a maximum value of 23.37 mg/L. Chlorides are more concentrated in wells with average values of 4.68 mg/L than in boreholes with concentrations of 0.76 mg/L (Table 4a and b). Sulphates are weakly present with an average concentration of 2.71 mg/L with minimum and maximum values of 0.33 to 22 mg/L respectively. The phosphates and nitrates have minimum and maximum concentrations of 0.00 to 1.4 mg/L then from 0.00 to 47.93 mg/L with general averages of 0.37 and 3.57 mg/L respectively. At the sight of the standard deviations obtained, it appears that the average concentrations of the different anions are more homogeneous (low standard deviations) in boreholes than in wells (Table 4a and b).

Origin of the mineralization of water

Tracing of water can allow an evaluation of the origin of dissolved ions considering the variation of the ratio of (Na+K)/(Na+K+Ca) and Cl/(Cl+HCO_3) as a function of TDS. The projection of the different results obtained on the Gibbs diagram shows that the mineralization of our water is ensured on the one hand by the process of evaporation of rainfall (Figure 2) for the presence of alkalis (Na^+ and K^+) and on the other hand the dissolution of the minerals contained in the rock by the process of interaction water-rock for the concentration of bicarbonates. NPK elements are the main types of fertilizer used for fertilization in the area. They can



(a) (b)

Figure 2. Gibbs diagram showing the origin of the mineralization of the different water samples.

migrate from the surface to end up in the deep waters. The presence of NH_4^+ in a concentration greater than the value allowed in the water of consumption (Table 1) can be explained by the reduction of nitrates according to the equation:

$$NO_3^- \rightarrow NO_2^- \rightarrow NH_4^+$$

and also, by the fact that at the level of the upper layers of the soil, the microorganisms involved in degradation of organic ng phosphate fertilizers or pesticides (Rodier, 2009). Considering the results of the works of matter produces nitrogen compounds (Tapsoba, 1995). The phosphate levels are on average not insignificant in our waters with an average peak of 1.40 mg/L. The presence of phosphates in groundwater is linked to discharges industrial and domestic industries, or the leaching of land containi Bateman and Kelly (2007), the second hypothesis seems the most plausible in our case study.

Hydrochemical facies

The analysis of the Piper diagram (1953) of all the samples shows that: ten samples, four wells and six boreholes have facies of the sodium and potassium carbonate type and meet in the cultivated areas of the irrigated perimeter of Maga East and West; the waters of two well samples (P04 and P06) and three boreholes samples (F06, F07, F09) have a facies of calcium and magnesium bicarbonate type. They characterize the facies of on both sides of the large rice-growing area of Maga East and West.

In these two facies of water there is a dominance of weak acids with for the calcium and magnesium bicarbonate facies dominance of the alkaline earths (Figure 3, zone 5) and dominance of the alkalis on the alkaline earths (Figure 3, zone 8) for the carbonate facies sodium and potassium. Thus, the waters irrigated area are enriched with sodium and potassium, while bicarbonates remain the dominant anion. In contrast, in the area on both sides of the large perimeter facies do not present dominant ions. The order of importance of representatives of the major ions in the waters studied is as follows: $Na^+ > Mg^{2+} > Ca^{2+} > NH_4^+ > K^+$ for cations, and, $HCO_3^- > NO_3^- > SO_4^{2-} > Cl^-$ for anions.

State of groundwater quality for agricultural use

Market gardening and small-scale farming are gaining momentum in the study area where groundwaters are greatly solicited through the development of private wells and boreholes. A high concentration of sodium in the irrigation water in this case leads to absorption of these ions by the clay particles by displacing the Mg^{2+}

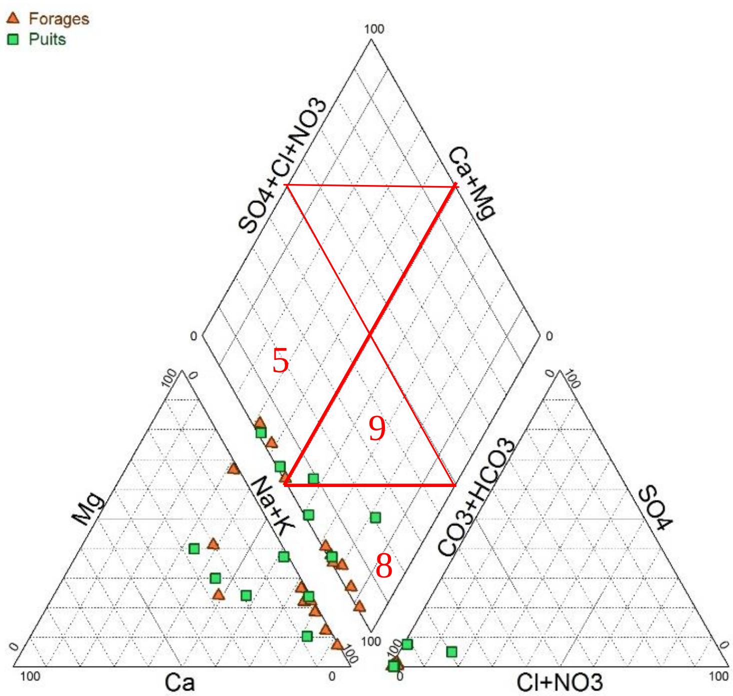


Figure 3. Hydrochemical classification of groundwater.

and Ca^{2+} ions. This process of exchange reduces the permeability of the soil and these soils become either anabolic, saline or compacted (Bauder et al., 2008; Oualid et al., 2018). The values of the conductivity (at 25°C) and those of the sodium absorption ratio (SAR) given by the equation.

$$S.A.R = \frac{[Na^+]}{\sqrt{\frac{([Ca^{2+}]+[Mg^{2+}])}{2}}}$$

are used to identify this risk in order to assess the suitability of water for irrigation. The clues SAR and values of conductivities at 25°C projected on the Richards diagram (Figure 4), show that 40% of the waters are in class S1C1, and 40% in the class S1C2 indicating that the waters are of excellent quality and good for irrigation. However, borehole F09 is in class S1C3 and borehole F05 in class S3C2 indicating water of poor quality for irrigation with a danger of sodicity and salinity (Bauder et al., 2008). The quality of groundwater for agricultural purposes can also be assessed using the Wilcox diagram (Figure 5) based on electrical conductivity and percentage of sodium (% Na^+) which is calculated as follows (Wilcox, 1955):

$$Na^+\% = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+}$$

Referring to the classification of WILCOX, the waters belong to the classes "excellent" (F02, F03, F04, F06, F07, P01, P02, P03, P04, P06), "good" (F09), "allowable" (F01, F08, P05) and for a "mediocre" sample (F05). As in the case of classification from Richards (1954), the best quality waters are those with low mineralization. For in the "allowable" class, waters may be allowed to irrigate crops that are tolerant to salt on soil with good permeability.

Conclusion

The hydrochemical study of the groundwater of the irrigated perimeter of Maga allowed us to characterize this resource. The analysis of the physical parameters shows that the water has a pH which is near the neutral with medium mineralization. Chemically these waters have facies of the carbonate, sodium and potassium types in the perimeters of Maga East and West, then bicarbonate calcium and Magnesium characteristics located on either side of Maga's large perimeter. The mineralization comes from two sources: on the one hand by the hydrolysis of ions contained in the rock by the water-rock interaction process and on the other hand by the degradation of organic matter resulting from agricultural activities giving rise to nitrogen compounds. Ammonium ions, orthophosphates and to a lesser extent Nitrates are the polluting elements of our waters. Overall, the water in our area remains acceptable for its use in

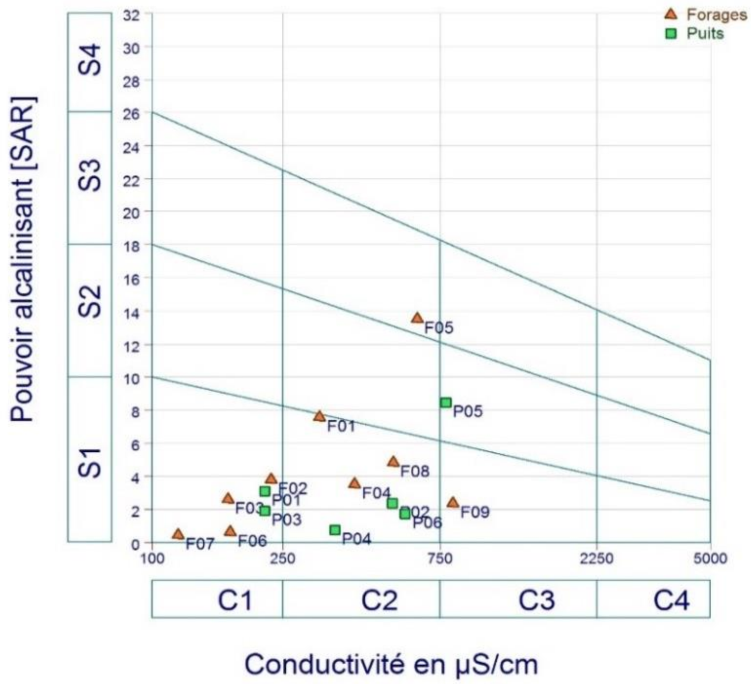


Figure 4. Diagram of Richards (1954).

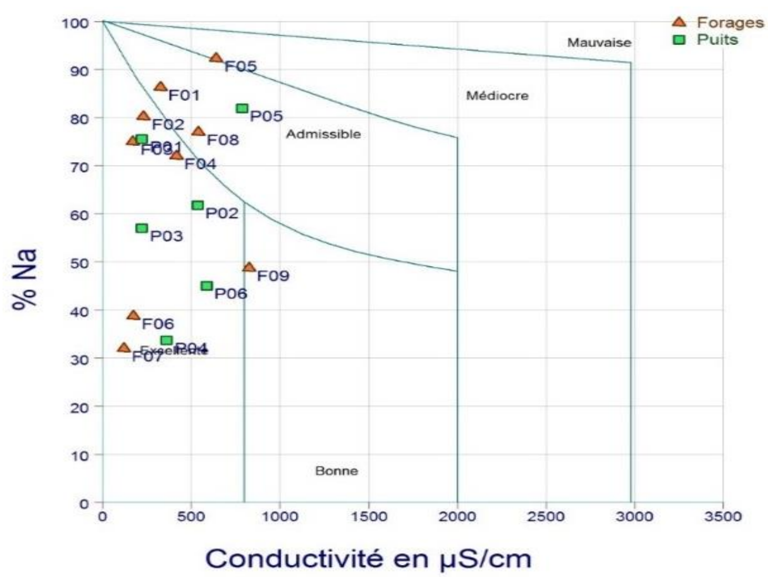


Figure 5. Wilcox diagrams (1948).

irrigation in view of the data obtained on the diagrams of Richards and Wilcox.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Crude oil polluted soil remediation using poultry dung (chicken manure)

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Remediating crude oil polluted soil in developing countries by environment-friendly approach has attracted scientific interest. Sampled crude oil and poultry dung were obtained from oil pit and farm in Warri, Delta State. 500 g/kg of crude oil polluted soil was weighed into four different containers labeled A, B, C and D; the soil was amended with the application of sundried poultry manure at various weights of 50, 75 and 100 g/kg respectively leaving sample D without amendment as control for a period of 42 days. Isolation and identification process of bacteria strains were carried out using standard spread plate method on nutrient agar. Ten bacteria isolates were obtained from the amended and control soil in this research. Genus from *pseudomonas* and *staphylococcus* has the highest representation of three species each. The rate of degradation in the sample was determined by gravimetric analysis. The total petroleum hydrocarbon (TPH) present in sample D (control) initially was 4550.08 mg/kg. Samples A, B and C after remediation period reduced to the value of 3410.61, 2664.90 and 1598.95 mg/kg, respectively. The total hydrocarbon utilizing bacteria (HUB) increased gradually in the sample A, B, C and D to 7×10^{-4}, $7.9\ 10^{-4}$, 8.0×10^{-4} and 5.0×10^{-4} respectively. The total heterotrophic bacteria count (THB) increased from 10×10^{-5} at zero week to 8.3×10^{-5}, $8.5\ 10^{-5}$, 8.6×10^{-5} and 7.3×10^{-5} in the samples respectively. Physiochemical analysis of nitrogen increased from 0.04 to 0.17 mg/kg and phosphorous also increased from 1.72 to 6.73 mg/kg after the period of 42 days. This approach showed increased remediating effect of poultry dung on crude oil polluted soil.

Key words: Crude oil pollution, remediation, chicken dung, microorganism.

INTRODUCTION

Several methods of oil degradation have been developed. These include the use of chemical, physical and biological methods (bio-remediation). Bio-remediation is a method that refers to the use of natural occurring microorganisms or genetically isolated microorganisms by man to detoxify man-made pollutants. Bioremediation relies on bacteria, plants and fungi to degrade, breakdown, transform or remove contaminants or impairments of quality from the contaminated soil and water (Ijiah and Antai, 2003). Bio-remediation techniques

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are non-invasive, cost effective, and environment friendly which does not produce toxic by-product compared to their counterparts (physical and chemical methods of remediation). In addition bioremediation conserves soil texture and characteristics (Perelo, 2010).

Environmental degradation caused by exploitation and exploration of petroleum products or hydrocarbon among communities in Nigeria has been quite problematic. Organic and inorganic compounds are largely released into the environment every year, with the implication of human activities. For instance the disposal of oil spills from blow out and pipelines rupture are the most common source of Petroleum contamination (Resinger, 1995). Crude oil is a complex mixture of diverse hydrocarbons including alkanes, aromatics, branched and non-branched hydrocarbons compound including heavy metals such as hetero-atom of nitrogen, sulfur and oxygen which are polar fractions and asphaltens. The high request or demand for petroleum products in form of gas oil, engine lubricating oil, cooking gas, aviation fuel increases its production and then eventually results in oil spills and hydrocarbon pollution of the environments (Resinger, 1995). In Nigeria, the Niger Delta has witnessed several instance of oil spills in some communities like Olomoro and Uzere in Isoko South Local Government Area, Owhe-Ologbo and Erumukohwarian in Ugehil North. Mostly mangrove swamp and marsh (Eboh, 1995) have been recorded that oil contamination causes slow rate of germination in plants and reduces soil fertility. Adam and Duncan (2002) reported that this effect could be due to oil which acts as physical blamer or reducing access of the seeds to water and oxygen. It has been report that 1.7 to 8.8 million metric tons of petroleum hydrocarbon escape into the soil and water bodies every year or annually. This has caused critical environmental and health defects and increasing alternation has been paid for developing and implementing innovative technology for cleaning up this contamination. Hydrocarbon contamination of soil and fresh water especially poly-aromatic hydrocarbons (PAHs) attract public attention because PAHs are toxic, mutagenic and carcinogenic (Clemente et al., 2001). These challenges are quest for environmental sustainability that motivated researchers to search for organic substrates, which would serve as alternatives to synthetics fertilizers to enhance bio-remediation. Therefore this research has been considered because chicken dung is readily available, transportable and affordable.

MATERIALS AND METHODS

Samples collection

Crude oil contaminated soil

A known weight of 2500 g of crude oil contaminated was collected from chevron pit in Titan project Nigeria limited (TPNL) located at Ogula Forcados Terminal, Burutu L.G.A, Delta State. It was collected in a sterile polythene bag at the depth of 0 -12 cm, using a sterile spade and transported to Petroleum Training Institute Microbiology Laboratory. The chicken dung: The chicken dung was collected from poultry farm in Garki market found along Benin Sapele Road, Warri Delta State. It was collected into a Ziploc bag by packing with hand trowel and was transported to the microbiology laboratory in Petroleum Training Institute for further analysis.

Methods of sample analysis

Sample preparation, amendment and stimulation

The crude oil contaminated soil was sun dried for a period of one week and sieved through a 2 mm mesh sieve. 500 g/kg of crude oil contaminated soil was weighed using an electronic weighing balance into four clean experimental bowl respectively, labeled A, B, C and D. The chicken dung was also sun dried for a period of one week after which it was sieved to remove impurities from it. In different variations, 50, 75, and 100 g of poultry droppings were then added to the crude oil contaminated soil weighed in the experimental bowls A, B and C, respectively. While bowl D was left as the control without amendment. The set up was then left for a period of 6 weeks while the microbial analysis and the physiochemical analysis were carried out at the zero weeks and subsequently at one week intervals with proper supervision.

Microbial enumeration

A set up of six test tubes containing 9 mL of distilled water was arranged into two places in a test tubes rack then 1 g of poultry dung and the contaminated soil was weighed and introduced into the first beakers respectively. It was shaken for even distribution after which 1.0 ml of aliquot (the mixture) was aseptically transferred into the second test tube to give 10^{-1} (tenfold) dilution; further tenfold serial dilution was carried out to factor 10^{-6} dilution factor. After the serial dilution process, nutrient agar was prepared by measuring 7 g into 250 ml of volumetric flasks and shaken very well until the agar is readily dissolved. It was then autoclaved at 5000 read per minute (rpm), with temperature for some minutes when the agar was fully sterilized. It was left to cool for some minutes on a sterile working bench until when it was favorably to handle. The agar was poured into sterile Petri dishes (two plates for each sample) and was blended with Nystatin to suppress the growth of fungi growth. The plates were allowed to solidify within 24 h and also to check if it is contaminated while pouring or not. Meanwhile, after 24 h, 0.1 ml of the serial dilutions from both samples were measured using a micro pipette from factor 10^{-4} and 10^{-6} which were afterwards inoculated into the poured plate and gently swirled using the inoculums spreader. Then the plate was inverted inside the fume cupboard at room temperature (28°C) for 24 h, after which bacterial colonies that grew were counted using the standard plate counting techniques (International Pharmacopoeia, 2018).

Number of colonies population was calculated using the formula:

$$\frac{\text{No of colonies} \times \text{dilution factor}}{\text{Volume of culture plate}}$$

Isolation techniques

Discrete colonies from the primary plate were picked with the help of a sterile wire loop. They were sub-cultured into a fresh agar plate and incubated for another 48 h inside the fume cupboard. The morphological characteristics of the isolates were observed and identified after 48 h of incubation; each organism with different morphological characteristics was further plated in a slant bottle and preserved in the refrigerator at 40°C for biochemical characterization.

Determination of culturable hydrocarbon utilizing bacterial (HUB)

In determining the hydrocarbon utilizing bacteria, serial dilution and pour plate technique was adopted. Mineral salt medium (MSM) was prepared and sterilized by autoclaving at 121°C, 15 psi for 15 min and dispensed into Petri dishes. The plates were inoculated and duplicated with 0.1ml aliquot of the sample serially diluted at 10^{-4} and 10^{-6} dilution factor. The plates were incubated at 280C+/-200C for 7days and the colonies were counted from triplets; mean values were recorded in colony forming units per gram (cfu/g).

Morphological characteristics

The isolates were characterized and identified based on their cultural characteristics and biochemical procedures and reaction as follows.

Gram reaction

This was carried out to differentiate gram positive from gram-negative organisms.

Procedure: A wire loop was sterilized in Bunsen burner and allowed to cool; then a loopful of growth was collected from the agar plate and applied on a clean grease-free slide. A drop of normal saline was added, emulsified and heat fixed by passing over a flame three times. The smear was flooded with crystal violet for 30-60 s and then covered with iodine (as mordant) for 30-60 s and then washed off. It was decolorized with acetone until no color runs off the slide and rinsed immediately. The slide was covered with Safranine dye for 1 min and then washed off with clean water. The slide was kept in a track to air dry after wiping the back with cotton wool. The stand smear was then examined microscopically under oil immersion at x100 objective lens. The gram-positive bacteria appeared dark purple while gram-negative bacteria appeared red.

Motility test

Motility test was aimed at identifying motile bacteria.

Procedure: A drop of normal saline was placed on a sterile slide and colony of test organism was suspended then covered with a cover slip. The slide was examined microscopically using x10 and x40 objective lenses. Movement in different directions gave a positive test while static position gave a negative test.

Catalase test

This was carried out to differentiate those bacteria that produce enzyme catalase such as Staphylococcus aureus and *Escherichia coli* which were also used as positive and negative controls respectively.

Procedure: Three milliliters of hydrogen peroxide solution was poured into a sterile test tube. Then a sterile glass rod was used to collect several colonies of the test organisms and inoculated into the hydrogen peroxide solution. It was observed for immediate active bubbling for positive test.

Oxidase test

This was carried out to identify bacteria species that will produce the *cytochromeoxidase* enzyme, *Pseudomonas aeruginosa* and *E. coli* employed as positive and negative controls respectively.

Procedure: A piece of filer paper was placed in a clean Petri dish and 2-3 drops of fresh or nascent oxidase reagent were added. A colony of test organism was collected using a glass rod and smeared on the filter paper and observed. Blue-purple color within few seconds showed a positive test.

Citrate test

This test is based on the ability of an organism to use citrates as its source of carbon. It was used to identify the Enterobacteria.

Procedure: Simon's citrate agar medium was prepared in a slant bijou bottle. A sterile wire loop was used to inoculate the test organism onto the slant medium and incubated at 30°C for 48 h after which it was examined for color formation. A bright blue color in the medium gave a positive citrate test. *Klebsiella pneumonia* and *E. coli* were employed as positive and negative controls respectively.

Methyl red test

This was carried out to identify Enterobacteria based on the ability to produce and maintain stable acid end -product from glucose fermentation. *E. coli* was used as positive control.

Procedure: Glucose phosphate peptone was used for the inoculations of test organisms and incubated for 48 h at 37°C after which few drops of methyl red solutions were added to the culture and read immediately. Formation of red color immediately showed a positive test.

Physiochemical characterisation

Determination of pH

The pH of the crude oil contaminated soil was determined using pH meter (Jenway 3015 UK). Ten grams of sun dried soil (passed through 2 mm sieve) was weighed into a 20 ml beaker and 5 ml of distilled water was added. The suspension was shaken with the use a mechanical shaker for 25-30 min, then allowed to stand for 50 min and stirred occasionally with a glass rod. The electrode was rinsed with water and dried with a piece of tissue. The electrode was inserted into the partly settled suspension to be analyzed and the pH range of the solution was measured. The pH meter was calibrated at pH 7.0 (Manas et al., 2007).

Determination of total nitrates (NO_3)

Total Nitrogen of the soil samples was determined by the macro Kjedahl digestion method. 100 g of potassium chloride was weighed into 1000 mL volumetric flask; 800 mL of deionized water was added to it and stored thoroughly until it dissolved. Distilled water was added to make it up to 1000 ml, the volumetric flask was

Table 1. Physiochemical and microbial baseline data of crude oil contaminated soil and amended soil at zero weeks.

Parameter	Value
pH	7.5
Nitrate (%)	0.04
Phosphate (mg/kg)	1.72
TPH (mg/kg)	4550.08
THBC (cfu/g)	7.0×10^5
THUBC (cfu/g)	4.5×10^4

Table 2. Physiochemical values of total nitrogen (mg/kg) on amendment soil within 6 weeks (42days) of remediation.

Duration (days)	Sample A (mg/kg)	Sample B (mg/kg)	Sample C (mg/kg)
0	0.04	0.04	0.04
14	0.06	0.07	0.09
28	0.08	0.09	0.12
42	0.10	0.13	0.17

capped with paraffin and inverted several times to mix. 4 g of the amended soil sample was weighed and placed in a conical flask. 20 mL of the extraction solution was added to the soil sample and the flask was played in a mechanical shaker box and shaken for 1 h at a given speed. The content was filtered using a line filter paper. Filtrate was analyzed using Atomic Absorption Spectrophotometer (Manas et al., 2007).

Determination of phosphorus

50 ml of 0.5 M Hydrochloric acid solution was added to a weighed 5 g of soil sample in a conical flask. The mixture was shaken and allowed for a 50 min digestion. A filtration apparatus was set up and the mixture was filtered. The filtrate was then collected in beaker. 1.0 g of phosphate mixture was weighed and dissolved in 100 ml of 2 M Sulfuric acid which was left to stand for about 20 min. The content in the beaker was left to stand for about 30 min for full color formation. UV-Visible Spectrometer was used to determine the absorbance of the phosphate concentration of the soil sample (Carter and Gregorich, 2008).

Estimation of total petroleum hydrocarbon (TPH)

Using soil sample extraction method (ASTM D575[6]-97), 10 g of each of the amended and contaminated soil was weighed into an organic free amber glass container and 10 ml of the extractant (N-hexane, dichloromethane and acetone in ratio 2:1:1) was added, using a mechanical shaker. The mixture was gently shaken for 30 min. The sample was extracted from the solutions using a sonicator and was filtered. The final volume of the extract was stored in a dried organic free chromic acid pre-clean vial; 1.00 µl was withdrawn using an automated gas-tight syringe of the auto sampler and analyzed by direct injection into the GC-FID preset at specific condition. The analysis was allowed to run and quantify data; and at various temperatures, the hydrocarbon peaks were shown on the screen and the analysis of the results was obtained. The extract remaining was refrigerated at about 4°C for further analysis (Osuji et al., 2005).

Data processing and reporting for soil and sediment

The total petroleum hydrocarbon (TPH) concentration (mg/kg) of samples (R)

$$\frac{\text{Instrument reading (total conc. in mg/L)} \times \text{Volume of the extract}}{\text{Weight of the samples (in kg)}} \times \text{DF}$$

The actual TPH (mg/kg) = R X DF; Where DF: Dilution factor; GF: Calibration Graph Factor.

RESULTS

Tables 1 to 3 show the initial values of the physiochemical and microbial characteristics of the crude oil contaminated soil and the soil amended with chicken dung at the beginning of the practical process. The TPH available in the crude oil contaminated soil was 4550.08 mg/kg, the total hydrocarbons utilizing bacteria count (THUBC) was obtained as 4.5×10^4 cfu/g and the total heterotrophic bacterial count (THBC) was obtained to be 7.0×10^5 cfu/g; while the nitrate, phosphate and the pH values were 0.04, 1.72 and 7.5 respectively (Figure 1). Microbiological characteristics of amended soil within 42 days of bioremediation (Table 8)

DISCUSSION

The initial/baseline physiochemical and microbiological characteristics of the crude oil polluted soil and the amended soil are analyzed in Table 1. The pH, Nitrate, and Phosphate were 7.5, 0.04 and 1.72 mg/kg respectively. The result in this table shows a low value of 0.04 mg/kg for nitrogen and a higher value of 1.72 mg/kg

Table 3. Physiochemical values of total phosphorous in the amended soil within the six weeks of bioremediation.

Duration (days)	Sample A (mg/kg)	Sample B (mg/kg)	Sample C (mg/kg)
0	1.72	1.72	1.72
14	2.91	3.72	4.86
28	3.42	4.48	5.71
42	4.11	5.26	6.73

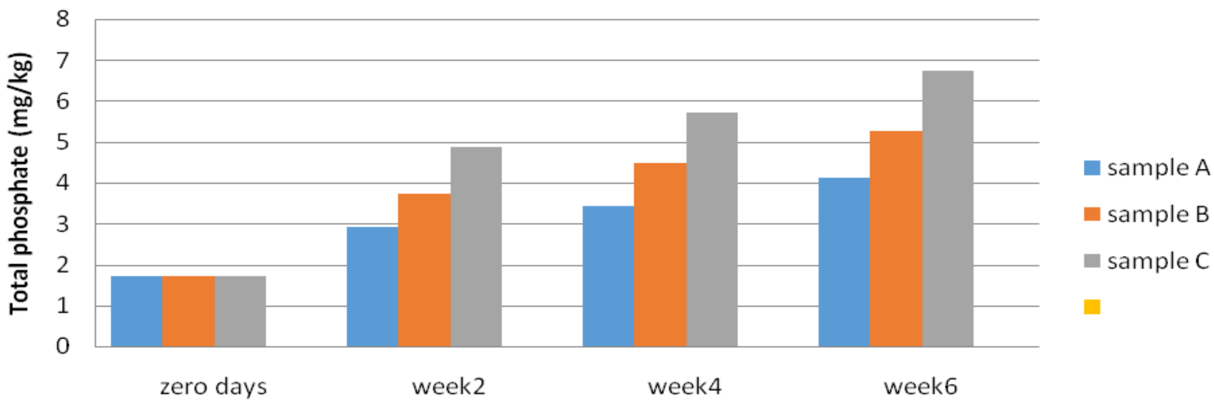

Figure 1. Effect of amendment concentration on total phosphorous. A graph showing the increase phosphorous.

for total phosphorous content with a higher content of hydrogen ion concentration (pH) of 7.5 due to the presence of hydrocarbon present in the soil. Tables 2 and 3 show the physiochemical properties of total nitrogen and phosphorous content in the amended soil for a period of six weeks (42 days). There is a progressive increase from the zero weeks to the sixth weeks of remediation in the properties of the soil with the value of 0.04-0.12 (mg/kg) in nitrogen and 1.72-6.73 (mg/kg) in phosphorous. This has been possible because the microbes present in the chicken dung found food (hydrocarbons) to feed on in the soil thereby increasing in population.

The total counts of heterotrophic bacteria populations (HBP's) are presented in Table 4 and Figures 2 to 4. The results showed that there was observed increased in the amended soil and control sample from 0 to 14days and decreased from 28 to 42 days. There are values of 8.3×10^5, 8.5×10^5 and 8.6×10^5 in sample A, B, C respectively. While a slow increase value of $7.3\text{x}10^5$ was observed in sample D (control). However, the bacteria population from soil treated with chicken manure at 100 g/kg was significantly higher while that of control was reversed. This agreed with the position of Njoku and Obi (2009) that nutrient deficiencies which arise due to petroleum hydrocarbon contamination of soil may however be offset by addition of chicken dung to the soil. The low results obtained might be attributed probably to initial inhibition of water and nutrient uptake due to the hydrophobic character of crude oil.

Table 5 showed a progressive rise in hydrocarbon utilizing bacteria population (HUBP's) observed over the course of experiment in all the contaminated soils. There was an enhanced increased growth in the HUBP's given the values of 7.9×10^4, 8.0×10^4 and 9.0×10^4 (cfu/g) and a lower decreased value of 5.0×10^4 (cfu/g) in the un-amended soil. This finding is in consistency with the report of Thieman and Palladino (2009) that addition of nutrients in the soil leads to increase in number of microorganisms, enhances their growth and increases the rate of biodegradation. It was also observed that the population increased with the increase in the weight of poultry manure. The increase in the effect of manure on population's growth of soil microorganism, according to Brandi et al. (2013), may not be unconnected with the composition of the poultry manure.

Table 6 were obtained from Gas Chromatographic (GC) that showed a decrease in the TPH from week zero to 6 weeks (42 days) in all the samples A, B and C. The TPH content was greater in the control system (Sample D) with a value of 4550.08 mg/kg at the beginning of the experiment. This value increased gradually from week one to week six (42 days) of remediation with different rate in the samples A, B and C.

The values obtained were 2406.55, 2076.74 and 1598.95 m/kg respectively. Therefore, the rapid decrease observed was as a result of the microbes present in the chicken dung serving as organic supplement for the

Table 4. Total heterotrophic bacteria population amended non-amended crude contaminated soil with different variations of chicken dung.

Durations (days)	Sample A	Sample B	Sample C	Sample D (Control)
0	7.0	7.0	7.0	7.0
14	7.2	7.4	7.8	7.0
28	7.8	8.2	8.4	7.1
42	8.3	8.5	8.6	7.3

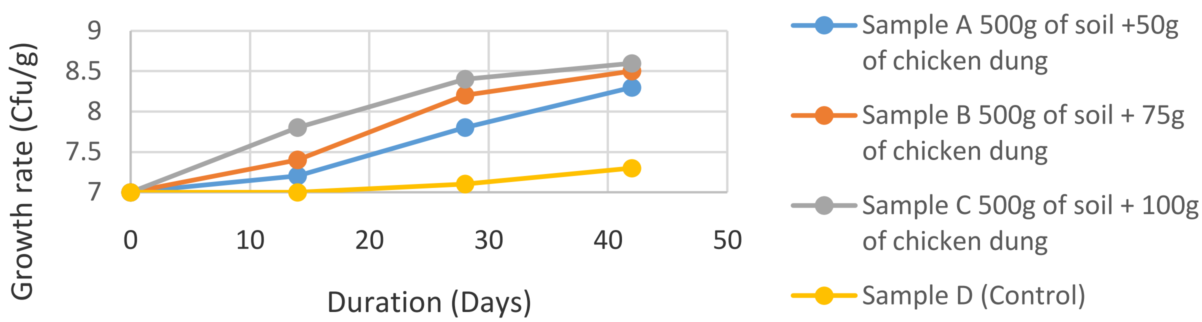

Figure 2. Total heterotrophic bacteria count.

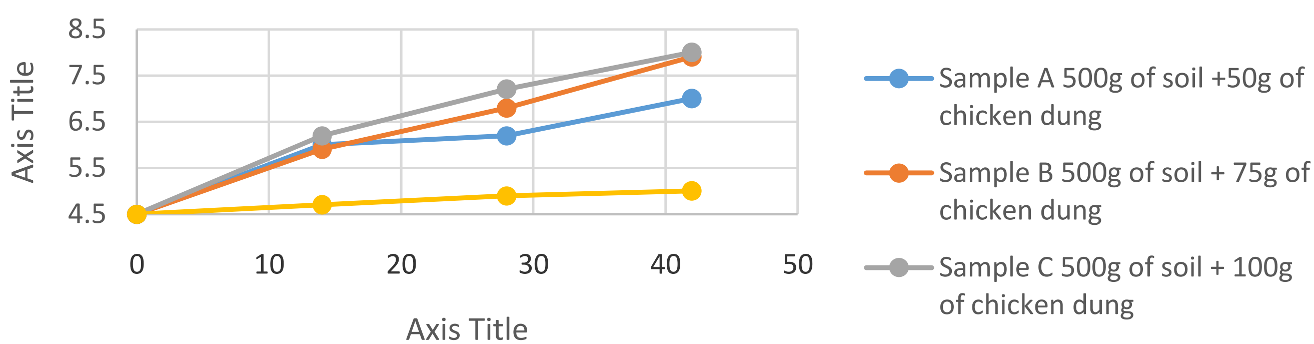

Figure 3. Total hydrocarbon utilizing bacteria. Chart showing total hydrocarbon utilizing bacteria growth.

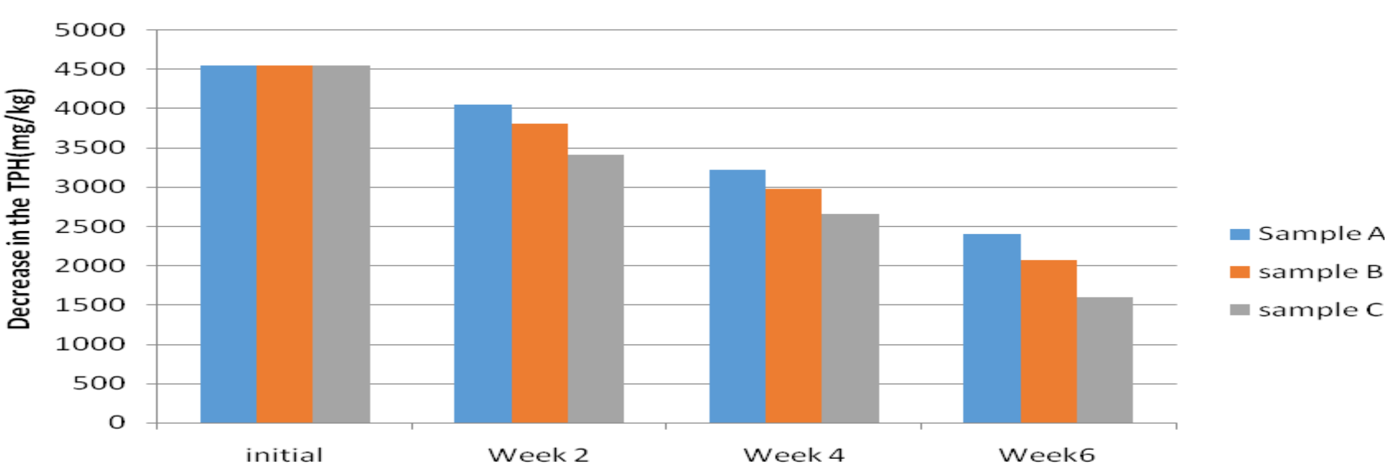

Figure 4. Effect of amendment concentration on TPH. A graph showing the decrease in total petroleum hydrocarbon.

Table 5. Total hydrocarbon utilizing bacteria count in Amended and Non-amended crude oil contaminated soil.

Duration (days)	Sample A	Sample B	Sample C	Sample D with no amendment
0	4.5	4.5	4.5	4.5
14	6.0	5.9	6.2	4.7
28	6.2	6.8	7.2	4.9
42	7.0	7.9	8.0	5.0

Table 6. The concentration of TPH after 42 days of remediation with different variations of chicken dung.

Sample g/g (%)	Initial TPH mg/kg (0 day)	TPH mg/kg after (14 days)	TPH mg/kg after (28 days)	TPH mg/kg after (42 days)	Percentage of TPH removed
10	4550.08	4053.16	3221.91	2406.55	47
15	4550.08	3811.78	29984.45	2076.74	54
20	4550.08	3410.61	2664.90	1598.95	64

Table 7. Biochemical characterization of bacteria isolated from crude oil contaminated soil.

Isolates	Gram reaction	Cellular arrangement	IND	C-T	V-P	MR	MOT	OX	UR	MAN	CAT	LAC	GLU	SUC	Probable organism
S_1	+VE	**	NR	NR	NR	-VE	-VE	-VE	-VE	D	+VE	+VE	+VE	A/G	*Staphylococcus*
S_2	+VE	Cocci in Chains	NR	NR	NR	NR	-VE	-VE	D	NR	-VE	NR	NR	NR	*Streptococcus*
S_3	-VE	*	+VE	-VE	+VE	-VE	+VE	-VE	-VE	+VE	-VE	+VE	A/G	D	*E. coli*
S_4	-VE	Rods	-VE	+VE	NR	NR	-VE	+VE	D	-VE	+VE	-VE	D	-VE	*Pseudomonas*
S_5	-VE	*	+VE	-VE	+VE	-VE	-VE	-VE	-VE	+VE	-VE	+VE	A/G	D	*E. coli*
S_6	+VE	**	NR	NR	NR	-VE	-VE	-VE	-VE	D	+VE	+VE	+VE	A/G	*Staphylococcus*
S_7	-VE	Rods	-VE	-VE	NR	NR	-VE	+VE	D	-VE	+VE	-VE	D	-VE	*Pseudomonas*
S_8	+VE	**	NR	NR	NR	-VE	-VE	-VE	-VE	D	+VE	+VE	+VE	A/G	*Staphylococcus*
S_9	-VE	Rods	+VE	+VE	NR	NR	-VE	+VE	D	-VE	+VE	-VE	D	-VE	*Pseudomonas*
S_{10}	+VE	Cocci in Chains	-VE	NR	NR	NR	-VE	-VE	D	NR	-VE	-VE	NR	NR	*Streptococcus*

IND, Indole; C-T, Citrate; V-P, Vogues Proskauer; MR, Methyl red; MOT, Motility; OX, Oxidase; UR, Urease; CAT, Catalese; LAC, Lactose; GLU, Glucose; SUC, Sucrose;+VE, Positive;-VE, Negative; NR, no reaction.

petroleum oil degrading; it aided their fast metabolic rate thereby consuming the crude oil present in the contaminated soil. Reduction was observed to increase with increased quantity of chicken dung (poultry manure) as earlier reported by Osazie et al. (2015). He reported that 90 g of cow dung fertilizer proved the best treatment option with the removal of 52.59% of crude oil from amended soil sample and this was also due the nutrient present in the chicken dung.

The isolation of diverse genera and species of bacteria from the poultry dung in this work is represented in Table 7 and is in agreement with the earlier report by Dowd et al., (2008). The hydrocarbon utilizing microorganisms isolated in

Table 8. Total heterotrophic bacteria population Amended Non-amended crude contaminated soil with different variations of chicken dung.

Durations (days)	Sample A	Sample B	Sample C	SampleD (Control)
0	7.0	7.0	7.0	7.0
14	7.2	7.4	7.8	7.0
28	7.8	8.2	8.4	7.1
42	8.3	8.5	8.6	7.3

the present study include: *Bacillus spp. Pseudomonas* spp., *Micrococcus* spp. *E. coli* spp., *Staphylococcus* spp. *and Streptococcus* spp. While the predominant genus bacteria is *Staphylococcus* spp.

Conclusion

The results in this study showed that 20% of chicken droppings supported high crude oil remediation in the polluted soil. The crude oil contaminated at the initial stage was highly degraded and a total removal of 64% of hydrocarbons was obtained. Chicken dung apart from being cost effective is also an environment friendly approach and a potential source of nutrients for microbial activity; it harbors microorganisms capable of utilizing hydrocarbons as source of carbon and energy. Thus, it is potentially useful in soil pollution response action. Therefore, crude oil polluted soil was remediated by chicken manure at 100 g/mg as bio-stimulating agent.

Recommendation

Poultry dung serves as a potential source of nutrients for microbial activity and it harbors microorganisms capable of utilizing hydrocarbons as source of carbon and energy which is potentially useful in soil pollution control. The research work has proved that chicken dung to a larger extent can biodegrade crude oil contaminated soil. It is recommended that further research should be carried out on other animal dung that are readily available in our immediate environment such as goat dung, cow dung, dog dung, pig dung etc. To know if the bacteria found in their dung would be as effective as chicken dung to degrade crude oil spilled in soil.

Authors' Contributions

This work was carried out in collaboration between all authors. Author OOE designed the study, wrote the protocol of the manuscript. Author OK performed statistical analysis. Authors SO and ODT wrote the first draft of the manuscript and managed the literature searches. All authors read and approved the final manuscript without any conflict of interest.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Ecological assessment and economic valuation of three wetlands in eastern Hararghe, Oromia Regional State Ethiopia

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Globally, wetlands are recognized as the most productive ecosystems due to sustaining a wide range of biodiversity and for providing goods and services to nearby communities. The study was carried out in three wetlands in Ethiopia; namely, Adele, Teneke and Haramaya. The data was collected from January 2016 to May 2016 in the villages which are in proximity to the wetlands to determine the degree of dependency on the wetland. Wetland physicochemical data was collected onsite using portable kits for the work. The study revealed that annual service rendered by the wetlands is 34956.62 in Ethiopian Birr. The biological oxygen demand, which is taken as an indicator for pollution was greater in all the sampling sites of Adele. The highest concentration (6.3 mg/L) was recorded at Adele 3(A3). The conservation practice designed by the local community initiative was low. From the five measures recommended, only one activity is done to conserve the wetland. The consumers' willingness to conserve services suggests that they are not willing to conserve the wetland. The study indicates that the socio-economic structure of the society is significant in their willingness to conserve and also to restore the wetlands. Educational level of the respondents is significantly affecting their willingness for conservation scheme.

Key words: Physicochemical, ecosystem, service rendered, willingness to conserve.

INTRODUCTION

Biodiversity plays a vital role in the existence of life on the earth's surface (Collings 2009). Among the most vital ecosystems of the world, wetlands provide a wide range of benefits in economical, biological, ecological, social, and cultural functions and services to human beings (Barbier et al., 1997; Fisher et al., 2008). The estimated size of wetlands is approximately 12.8 million km^2 (Finlayson et al., 1999) and wetlands generally cover about 6.4% of the surface of the earth. Reportson the status of the wetlands show that more than half of the

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wetland cover has been lost since the 1950s due to anthropogenic effect (Moser et al., 1996). America one of the developed countries, has lost 87 million hectares of wetland and in the same way, European countries like the Netherlands, Germany, Spain, Italy, Greece and Portugal have lost 55, 67, 57, 60, 66 and 63% of their total wetlands, respectively (MEA, 2005a; MEA, 2005b; Tiner, 1984) within in the last decades. In addition to these, within the past 60 years, Philippines has lost 300,000 hectares (67%) of its wetland ecosystems

In Africa due to the mismanagement of ecosystems, changes take place at an alarming rate. Land use and land cover potential changes are common due to development reasons (Jordan et al., 2003). Although in Africa, savannahs and hot deserts are common, wetlands covered a significant part of the continent. The coverage is estimated to be between 1 and 16% or 220,000 and 1,250,000 $km^2$of the total land mass of the continent (Koohafkan et al., 1998)

Economic valuation of ecosystems is defined by economists, ecologists and sociologists and other professionals in different ways. The economic value of good is defined by economists as the difference between willingness to pay for the good or service and the cost of supplying it. Economic valuation is an attempt to assign values in terms of market price for the good and service offered by the ecosystem. Communities are using the products and services provided by natural resources without incurring any cost. Therefore the value of such resources is our willingness to pay to them alone (Barbier et al., 1997).

Wetlands provide diverse economic, social, cultural, and ecological goods and services which are crucial for the livelihood of the society (Siew et al., 2015). The value of some of these functions and services could be determined by the market forces of demand and supply. However, many of them have non-market values. Therefore, the total economic values (TEV) of wetland ecosystems like other environmental resources are disaggregated into two broad categories of use and non-use values (Barbier et al., 1997; Hanley et al., 2006).

Almost all types of wetlands are found in Ethiopia except coastal and marine-related wetlands. The extensive swamp-forest complexes are found and they are estimated to cover more than 2% of the area or 22500 km^2(Deribe, 2007). In Ethiopia, wetlands such as riverine, lacustrine, alpine formations, palustrine and floodplain are common in different parts of the country. The wetlands are located in Lake Tana, Ashenge, Bale Highlands, Western Highlands, Lakes of Bishoftu, South west Rift Valley, Awash River System, Afar Depression, Western River Floodplains, Central Ethiopian Highland Wetland Complex, e.t.c (Hailu, 2003).

Although Ethiopian wetlands provide a wide range of benefits, several of them have either disappeared or are at the verge of complete drying, due to mismanagement and inappropriate utilization. In Ethiopia, the recent total drying up of Lake Haramaya and the precarious existence of Lake Abijata are clear indications for the looming danger on the ecosystem. Many of the wetland ecosystems of Africa including Ethiopia are drying up and disappearing, but it is difficult to quantify the loss due to limited research work on wetland resources. This research aims to quantify the ecosystem service rendered by the wetlands.

MATERIALS AND METHODS

Study area description

The study was carried out in three selected wetlands of eastern Hararghe (that is Teneke, Haramaya and Adele wetlands). The total area coverage of the study area is about 550sq.km. The largest ethnic groups represented in this region are Oromo (96.04%) and Amhara (3.12%), all other ethnic groups makes up to 0.84% of the population (Table 1). The dominant language spoken in the district is Afan Oromo (about 95%) while Amharic is spoken only by 4.44% of the population, and the remaining 0.56% by other languages. The majority of inhabitants are Muslims, about 95.82% and the remaining 3.71% are Orthodox Christians or followers of other religions (CSA, 2015).

Topography of the district is characterized by sloppy and gorges due to runoff water. Altitude of the district ranges from 1400 to 2340 m above sea level. The highest positions are in the districts of Dof and Jaldo. 60.1% of land is cultivatable, 2.3% is pasture land, 1.5% is forestland and 36.1% of the land is degraded or unusable (Haramaya Woreda Agriculture and Rural Development office, 2016).

Climatically, the district falls within medium altitude and lowland agro ecological zones. The mean annual temperature is about 22°C with maximum temperature of 31°C and minimum temperature of 12°C. The mean annual rainfall ranges between 700-1350 mm.

Method of data collection

A contingency valuation technique was applied for the economic survey of wetlands. Participatory approach was carried out to collect data through questionnaire from the villages.

The selected households were subjected to standardized questionnaire. The questionnaire requested to quantify the use values including fishing, water use for domestic purpose and irrigation. The dependency on the water was also surveyed through the questionnaire. The indirect usage of the water was also surveyed by associating the questions with the usage of ground water and manmade ponds.

Survey was carried out from January 2016 to May 2016 in the villages which are in proximity to the wetlands of Adele, Teneke and Haramaya to determine the degree of dependency on the wetlands. Samples were selected from the total households in the villages and they were randomly selected for the household questionnaire. For the structured questionnaire a total of 250 wetland dependent households were surveyed in these villages. Seventy five to ninety questionnaires were distributed per village and 223 questionnaires were returned. Pre-test was conducted to check the instruments understandability by respondents.

The physicochemical parameters were determined by using on-site examinations and subsequently a few of them were measured under laboratory conditions. Parameters like temperature, conductivity (Knick Portamess® 911 conductivity meter), pH (Knick

Table 1. Population of the study area.

Population based on sex		Settlement	
Male	138,282	Urban dwellers	50,032
Female	132,736	Rural dwellers	220,986
Total	271,018	Total population	271,018

Source: CSA 2015.

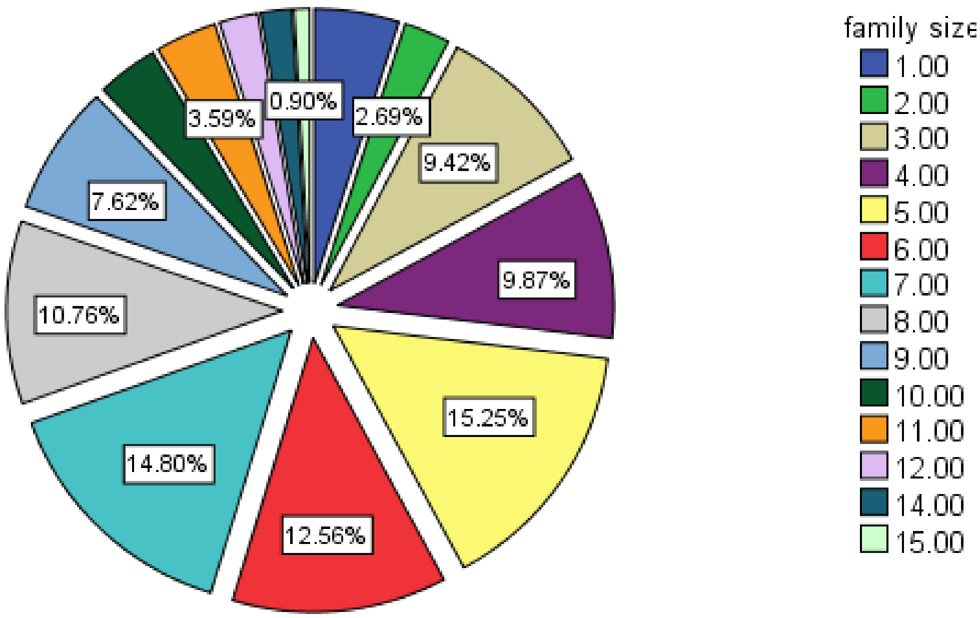

Figure 1. Family size of respondents.

Portamess® 911 pH meter) and oxygen saturation (Knick Portamess® 911 oxygen probe), were measured on-site at each sampling site.

Contingent valuation technique was used which is regarded as superior to the others interms of its validity and reliability for valuation of the environment as in Birol et al. (2005).The technique directly assesses WTP (willingness to pay) or WTA (willingness to accept) for a particular environmental outcome. The technique measures both the use and the non-use values of a given environmental resource (Cameron, 1988). The responses were regressed against the number of socio-economic and attitudinal characteristics of respondents, the availability of substitutes as well as price in cases where a discrete choice format is used.

RESULTS

The family structure of the respondents indicates that among the total of 223 respondents, 34 (15.25%) had 5 family members followed by 33 (14.08%), 28 (12.56%) and 24 (10.67%) respondents having 7, 6 and 8 family members, respectively. The highest family size recorded was 15 members of 2 families (Figure 1). The total respondents' family size ranged from 1 to 15 family sizes. The average family size was 6.

Socio economic survey

A total of 223 respondents from the villages surrounding the wetlands were identified to evaluate the level of dependency for the goods and services rendered by the Adele Haramaya and Teneke wetlands. The goods and services delivered by the wetlands are listed in Table 2. The direct uses of the wetlands are for domestic use, agriculture, household and fodder for domesticated animals.

Domestic use

The society living around the wetlands are dependent on the wetland. Due to the wetland shortage of water in the wetlands, the society gets their water supply from groundwater and manmade ponds. Among the respondents, 158 of them use manmade ponds while 45

Table 2. List of wetland resources and their economic value.

Use value	Quantity of resource	Wetland value in ETH Birr
Agriculture (irrigation)	24000/lit/month X12	30796.87
Domestic use (bath, cooking and other domestic use)	20-25 lit/person/day X365	205.31
Fisheries	3kg fish/person /year	1250.00
Domesticated animals	15-25 lit/livestock/day X365	205.31
Fire wood	750kg/year	2500.00
Total		34956.62/138.22ha/year

During the study period 1USD =22.15 ETH Birr.

of them use underground water and 20 use both underground water and their pond for drinking, irrigation, washing cloth and other activities. On average individuals in the family utilize 150 liter of water per day. The average cost for a litter of water is 0.25 cent in Ethiopia. The dependency value is 3.75ETH birr per day, which annually amounts to1368.75 cent in Ethiopian currency (1 Birr is equal to 100 cents). The drinking water if bottled, could amount to 109500.00 ETH Birr per household per year.

Agriculture

In the wetland villages, the farmers obtain their cash income largely from farming a cash crop known as chat (*Chata edulis*). Among the respondents, 145 (65 %) were dependent on agriculture, the rest of the respondents 78 (35%) are employed in different governmental and non-governmental organizations but also do have farm yards. Wetland water is utilized for irrigation of farm yards. The dependency of farmers in the wetlands is direct and indirect. The direct dependence is from using the wetland water for irrigation while the indirect is from using the underground water. The total land mass of 138.22 ha is dedicated for growing mainly chat (*Chata edulis*). The dependency for water for agriculture amounts to 1,231,875 birr per year on average.

Livestock

On average, 5 animals which includes cattle, sheep, goats, donkeys and hen were reared in each house. Farmers rely on the sale and direct consumption of the livestock products as part of their income. The dependency for livestock consumption (drinking water and fodder production) and for washing purpose accounts for 1097.25 and 13680.75 L per three cows respectively. On average there are 3 cows in each household.

Residents of the area have been living in the area for nearly 20 to 73 years, among which75.7 % of the families lived for over 20 years in the area. The wetlands provided services for the last 50years without interruption. The agricultural expansion and the introduction of agrochemicals to the area resulted in the contamination of the water. The service is decreasing from time to time due to the anthropogenic activities in the surrounding. This is manifested in the recorded BOD and DO of the wetlands. The BOD which is taken as an indicator for pollution was greater in all the sampling sites of Adele. The highest concentration (6.3 mg/L) was recorded at site A^3 at Adele (Table 3).

Causes for the depreciation of the wetlands

The major problems listed were dumping garbage and non-degradable materials to the wetlands especially plastic materials 178 (79.82%), and open area defecation 151 (67.71%); the two being the top prioritized problems. The agrochemicals used in the area 143 (64.12%) do have double effect on both inland water and underground water due to the fact that the water table of the area is near that it affects the underground water. These problems have adverse effects on the services of the wetlands by reducing water quality.

Utilization of inflow of water for irrigation is also mentioned by 125 (56.05%) respondents as one of the problems. Utilization of inflow of water has effect on the water budget of the wetlands and will lead the ecosystems to completely dry conditions.

Conservation and people’s perception

The community’s perception towards designing conservation scheme by itself is low (Table 4). Among the five questions prepared only one positive response was recorded. 169 (75.8%) of the respondents agree that they are doing conservation work to reduce silt deposition, while the rest, 48 (21.5 %) and 6 (2.7%) responded that they are not doing conservation or had no clue of the program, respectively. The next question was regarding preparation of buffer zones. Only 11 (4.9%) responded that they are demarking buffer zone; while 137 (61.4%) did not leave buffer zone and 75 (33.6%) do

Table 3. physico-chemical states of the wetlands.

Physicochemical characteristics	Haramaya wetland			Adele wetland			Teneke wetland		
	H^1	H^2	H^3	A^1	A^2	A^3	T^1	T^2	T^3
Temperature (°C)	22.5	23.26	22.3	23	22.35	24.4	24.9	23.067	25.26
DO mg/l	7.1	7.6	8.8	8.1	8.22	9.1	12.3	9.95	9.2
BOD	3.01	3.1	3.22	4.1	5.0	6.3	5.9	3.4	3.11

not even know what buffer zone was.

The third question was about their attempt to avoid agrochemicals. 192 (86.1%) of the farmers were still using pesticides and insecticides; while 5 (2.2%) respondents do not even know what agrochemicals were. The forth question was related to the intervention of government bodies in waste disposal. 127 (57%) responded that the government bodies did not allow them dumping wastes in to the wetlands; while the rest 77 responded that they allow them dumping wastes and 19(8.5%) were not aware at all. The last question was about conservation practices applied on the wetlands. 166 (74.4%) were not undertaking any kind of conservation activity for the wetland restoration and conservation while 49 (22%) responded that they are undertaking conservation activities and the rest 8(3.6%) do not know the condition.

Economic valuation on WTP or WTA

The logit regression analysis shows that the gender, age, education, marital status, family size (FM size), residence and years of stay in the area are significant. The result also indicates that education has effect in their willingness to conserve and also to restore the wetlands to their former status (Table 5). The other variables also play role in their willingness for conservation scheme of the wetlands.

DISCUSSION

As discussed in and George and Koshy (2008), if the concentration of BOD is below 5 mg/L, it has an adverse effect on the functioning and survival of biological communities and also if it is below 2 mg/L it may lead to the death of most fish. In similar manner all the sampling sites in Adele showed higher BOD values compared to Teneke and Haramaya (Table 3). This reveals clearly that Adele wetland was not experiencing pollution problems than Teneke and Haramaya wetlands. The causes for the pollution of wetlands might be due to the introduction of inorganic pollution via the use of inorganic fertilizers, insecticides and other agro chemicals which are similarly stated in Afework, 2005 and Zinabu et. al., 2002 in their survey of Ethiopian wetlands and their future fate. Similar reports were made by George and Koshy (2008) in Sasthamkotta Lake in India.

Wetlands are at the verge of extinction due to unplanned urbanization, land use changes, diversion of water for irrigation purpose, tourism industries (expansion of Hotels around water bodies), disposal of both household and industrial wastes, and intoxication via agrochemicals. Similar situations are accounted for in Finlayson et al., (2005), Legesse et al (2005) and Legesse et al (2002) in Malaysian wetlands and Abijata Lake Ethiopia, respectively. Wetlands in eastern Hararghe are also facing similar fate as of other wetlands in different parts of the country according to Abebe and Gheb (2003), Ayenew (2002), and Abebe and Gheb (2003) due to lack of orientation and mismanagement of wetlands. Lake Abijata is now at the verge of extinction and more than 50% of the area has changed to bare land. The same is true for Haramaya and Adele wetlands, if situations continue unabated.

Different wetlands in different countries have been degraded and were lost as a result of lack of understanding of proper wetland management (Bowers, 1983). According to Emerton (1998) the presence of lack of interrelated market and intervention failures, become major drivers for degradation. According to Birol et al., (2005), the major problem arises from a fundamental failure of information, or lack of understanding of the services and economic values that are associated with wetlands.

Different human activities result in bringing different side effects, such as pollution from industry from both service and product industryalso from agriculture, which have an adverse impact on sites elsewhere but for which, due to lackof enforceable rights, no compensation is paid to those affected (Turner et al., 2000; Ojeda et al., 2008).

The income from the water shows peoples' dependency in the wetlands. Similar studies in India by Ramachandra et al., (2011) and in Ethiopian lowland lakes by Legesse et al., (2004), and Ayenew 2002 show similar results. The income dependency and the farmers' awareness has impact on the conservation and restoration of the wetlands. Even if the wetlands are sources of income for number of farmers these resources are characterized by serious degradation and exploitation Because of rapid agricultural expansion, overgrazing, resettlement and excessive soil erosion etc. which call for wetland conservation, improvement and management

Table 4. Description of conservation scheme. (the position of tables 4 and 5 looks inappropriate)

Item	Response	Frequency	Percent	Mean	S.D
Have you carried out activities to reducing soil erosion and preventing silt deposition?	Yes	169	75.8	0.27	0.502
	No	48	21.5		
	I do not know	6	2.7		
Have you left a buffer zone for preventing water fromaccumulation of silt and wastes/pollutions?	Yes	11	4.9	0.71	0.552
	No	137	61.4		
	I do not know	75	33.6		
Have you avoided using pesticides and fertilizers from polluting water?	Yes	26	26	0.91	0.362
	No	192	86.1		
	I do not know	5	2.2		
Does the municipality prevent you from dumping wastes or sewage disposal?	Yes	77	34.5	0.74	0.604
	No	127	57		
	I do not know	19	8.5		
Have you undertaken any natural conservation activities for the wetlands?	Yes	49	22	0.82	0.472
	No	166	74.4		
	I do not know	8	3.6		

Table 5. Regression result of respondents.

Willingness	Coef	Std. Err	z P>|z| |		[95% Conf. Interval]	
Gender[a]	-1.916028	0.4696698	-4.08	0.000	-2.836564	-0.9954919
Age	-.0442284	0.0219018	-2.02	0.043	-.0871551	-0.0013017
Education[b]	-1.449585	0.2675359	-5.42	0.000	-1.973946	-0.9252246
Marital[c]	-.7233648	0.5284765	-1.37	0.171	-1.75916	0.3124302
FMsize|	.3248514	0.1070358	3.03	0.002	0.115065	0.5346377
residence[d]	.7771183	0.4213671	1.84	0.065	-.0487461	1.602983
years of stay	.0817197	0.0209075	3.91	0.000	0.0407417	0.1226977
_cons[e]	-.2616141	0.7782745	-0.34	0.737	-1.787004	1.263776

[a].1=female and 0=male; [b] 0=illiterate, 1=can read and write, 2=primary school, 3=secondary school, 4= college/university; [c] 0=single, 1=married, 2=divorced, 3=widowed; [d] 0= urban, 1= rural; [e] = conservation measures to be taken.

efforts Ayenew, 2002, Birol et.al., 2005 and Horton et.al., 2003.

Using contaminated water for irrigation purpose has also effect on both the quality and quantity of agricultural products produced for market for example on chat (*Chata edulis*) which is commonly grown in this area.

Conclusion

The socio economic survey, the water quality analysis and the willingness to pay results show that there is a decrease in the trend of ecosystem services with decrease in water quality. The decrease in water quality has adverse effect on the livelihood of the local community who are dependent on the wetland ecosystem services. The accumulation of nutrients or eutriphication was due to inflow of agrochemicals with runoff water and waste materials disposed in the wetland. The land use change also is one problem exhibited due to the flatness of the wetland areas and the un-favorability of the farm yards. This made the local communities to encroach to the wetland margins for farming and this decreased the buffer zone. Commercial fertilizers and other agrochemicals are polluting both the soil and the water. The underground water is near and hence is easily affected by the pollutants. Commercial fertilizers have to be replaced with animal manure and compost or other means with proper management underway. To retain the existing reserve and bring back the lost resources, efforts should be made to restore through processes including increasing awareness of the society, community based conservation schemes, wastewater treatments, wetland management and proclamation for wetland conservation and proper usage. Increasing the society's awareness will bring effective utilization and ownership of resources which enable the society to develop its own means of conservation.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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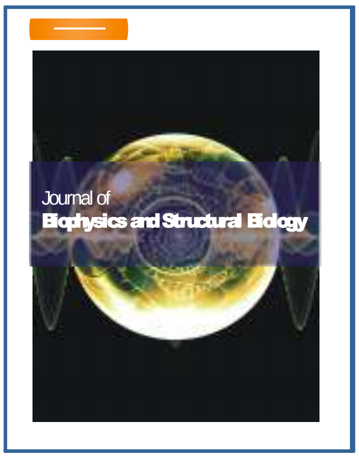

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