Journal of Soil Science and Environmental Management Vol. 2(4), pp. 103-109, April 2011
Available online at http://www.academicjournals.org/JSSEM
ISSN 2141-2391 ©2011 Academic Journals

Full Length Research Paper

Assessment of soil and water conservation measures practiced by farmers: A case study in the Tolon-Kumbungu District of Northern Ghana

Baatuuwie B. N.*, Kwame Ochire-Boadu, Abdul-Ganiyu S[2]. and William J. Asante

Faculty of Renewable Natural Resources, University for Development Studies, P. O. Box TL 1882, Tamale, Ghana.

Accepted 8 April, 2011

This study was undertaken in three communities in Tolon-Kumbungu district of the Nothern region to determine the level of soil erosion on farmlands as well as the soil and water conservation measures adopted by farmers in the area. The results indicated that the farmlands are moderately sloppy (4%) with an estimated soil loss of 2.6 tonnes/ha. Average bulk density was found to be 1.6 g/cm^3, indicating slightly compact soil leading to low infiltration rate. Conservation measures put in place by farmers to reduce erosion, increase soil nutrients and conserve moisture include; ridging across the slope, mounding with mulching, use of chemical fertilizer and manure application. The study revealed that soil erosion is moderately high in the area but farmers have put measures in place to reduce its effects and conserve soil moisture.

Key words: Infiltration rate, infiltrometer, upstream, midstream, downstream, bulk density.

INTRODUCTION

Water supply, especially rainfall, contributes enormously to the productivity of any farming venture. However, erratic rainfall coupled with its associated setback of soil erosion leads to soil nutrient, and moisture losses (Bobobee and Bart-Plange, 2005) has been a problem to farming over the years. Nutrient loss through erosion has a severe effect on soil fertility. Most nutrients are found in the topsoil which is mostly removed by erosion. Also, less water penetrates (infiltrates) into the soil since there is increase in run-off rate as a result of erosion. Therefore, less moisture is absorbed and more soil is carried away. One major driver of soil erosion is deforestation (Stocking and Murnaghan, 2001). A sequel to the deforestation is typically large-scale erosion, loss of soil nutrients and sometimes total desertification, (Mingyuan et al., 1998). The physical structure of soil suffers when organic matter from biomass is depleted. A common result is soil surface crusting, which impedes germination and increases run-off. As a result, soils become more vulnerable to erosion.

*Corresponding author. E-mail: tuuwiebernard@yahoo.com. Tel: 0243888371.

Also, organic matter, when decomposed, produces natural ‘glue’ that binds soil particles together thereby reducing its erodibility. So, when levels of organic matter drop as a result of deforestation, the particle binding ability of the soil is reduced making it susceptible to erosion (Mingyuan et al., 1998).

Soil erosion by water and soil degradation in Ghana was noticed way back in the ‘30s and measures were taken to solve the problem (Quansah, 1990) but nevertheless in 1989, investigations done by the Soil Research Institute in Ghana revealed that at least 23% of the country was subject to very severe sheet and gully erosion, 43.3% to severe sheet and gully erosion and 29.5% to slight to moderate sheet erosion. As a result of the continued increasing pressure on the land, it is however expected that figures may be much higher (Quansah et al., 1989). Especially in the Northern part of the country, erosion problems are severe and both physical and socioeconomic factors have intensified due to a combination of characters such as population pressure, poor farming practices, high erosivity, erodibility etc (Agyepong and Kufogbe, 1994). Most researchers agree that soil erosion has a serious impact on agricultural production.

However, it is difficult to quantify the effect of the loss of a unit of soil on crop yield (Lal, 1987) because of lack of direct, clear-cut relationship between erosion and productivity. Moreover, soil is only one of the factors affecting productivity, as crop yield is a function of many variables (Perrens and Trustum, 1984). Several researchers have systematically analyzed data from field experiments relating erosion and productivity. Such studies consider the relations between soil erosion and crop yields on different types of soils along different slopes and under different tilling and fertilization conditions (Lal, 1988, 1994; Stocking and Peake, 1986). Alfsen et al. (1997) used a computable general equilibrium (CGE) model to explore the relationship between soil erosion and crop productivity in Ghana. According to Stocking and Peake (1986), an exponential relation best describes the fall in yield in most cases with cumulative erosion, with the coefficient in the exponential equation ranging from –0.002 to –0.036 depending on the crop type. The relations between erosion and the yield of maize and cowpeas grown on one soil type (Alfisols) in Southeast Nigeria have been documented by Lal (1983). In Ghana, Adama (2003) studied the relation between soil erosion and maize crop yield on another soil type (Acrisols). In another work in this area, Thao (2001) studied the effect of erosion on root crops, in particular cassava, in Vietnam.

Productive soil is one of Ghana's greatest natural resources. So maintaining land productivity and preventing environmental degradation from soil erosion are high priority national goals (Bobobee and Bart-Plange, 2005). Soil conservation is a set of management strategies for prevention of soil from being eroded from the earth's surface or becoming chemically altered by overuse, salinisation or other chemical soil conservation (Mingyuan et al., 1998; Lal, 1990). According to Morgan (1995), the main aim of soil conservation is to obtain a maximum sustained level of production from a given area of land, while maintaining soil loses below levels comparable with the rate of soil formation. Thus, it involves preserving and improving soil life support systems for a high and sustained production while reducing physical displacement of soil from one place to another (Lal, 1990).

A most effective and valuable tool to control and prevent erosion is erosion hazard/risk assessment, which according to Morgan (1986) can be defined as "an identification of areas of land where the maximum sustained productivity from a given land use is threatened by excessive soil loss". Ghana has a relatively large amount of cultivated land per capita; however, most lands are characterized by poor fertility and are subject to degradation. To sustain crop production increases and ensure food security, soil, nutrient and water resources need to be properly managed and conserved (Quansah, 1996). Hence, soil management is crucial to Ghana's economic development in several respects.

Controlling of soil erosion means protecting the soil from the destructive effects of wind and water. To achieve this, a number of conservation-oriented farming methods may be used. These include: conservation tillage, contour farming, strip cropping, grassed waterways and gully control, shelter belts and wind breaks, crop rotation. Other methods are: mulching, terracing, ridging, stone bunding, mounding, organic matter application and bed configuration (Lal, 1990). Northern Ghana has a great potential for the production of grain crops but there are constraints that prevent the realization of this. Prominent of these are periodic drought, low levels of soil nutrients, high levels of run-off and rainfall variability. Farmers in Nyankpala, Nafrang and Kukuonaayili depend mainly on rains for farming. This means that, farmers in these communities are beset with erratic rainfall, prolonged drought, degraded soil, as a result of erosion. This may lead to low productivity. Low crop yield threatens food security in the communities and ultimately aggravate the low-income levels of the people with its attendant problems such as inability to maintain wards in school, poor nutrition and migration of productive labour force. The research was therefore carried out to ascertain the conservation measures adopted by farmers to mitigate soil and moisture loss for effective crop production in the area.

METHODOLOGY

Study area

The study was carried out in Nyankpala, Nafrang and Kukuonaayili in the Tolon-Kumbungu district in the Northern Region of Ghana (Figure 1). The area is located on latitude 09° 25'N and longitude 00° 58'W and at an altitude of 183.3 m above sea level. Rainfall normally starts from May to October. Mean annual rainfall is about 1043.6 mm. Mean annual daytime relative humidity is 54%. Temperature generally fluctuates between 15 and 45°C with a mean annual temperature of 28°C. The vegetation is typically of Guinea Savanna, characterized by a large area of grassland interspersed with trees. Common trees found are *Azadiracta indica* (Neem), *Parkia biglobosa* (dawadawa) and *Vitellaria paradoxa*. The sandy nature of the soil makes it suitable for the cultivation of root and tuber crops such as yams, groundnuts, cassava and cereal crops such as maize, sorghum and millet.

Sampling techniques

Thirty farmers were interviewed, ten from each of the three communities. Simple random sampling was used to select farmers for interview on the common soil conservation practices employed in the study area. Field observation of farmer practices was also used in collection of data. To select fields for the measurement of the soil physical parameters, simple random sampling was also used.

Measurement of slopes

The slope of farmlands was measured using the water level as a field tool. This method was adopted from Kranjac-Berisavljevic and

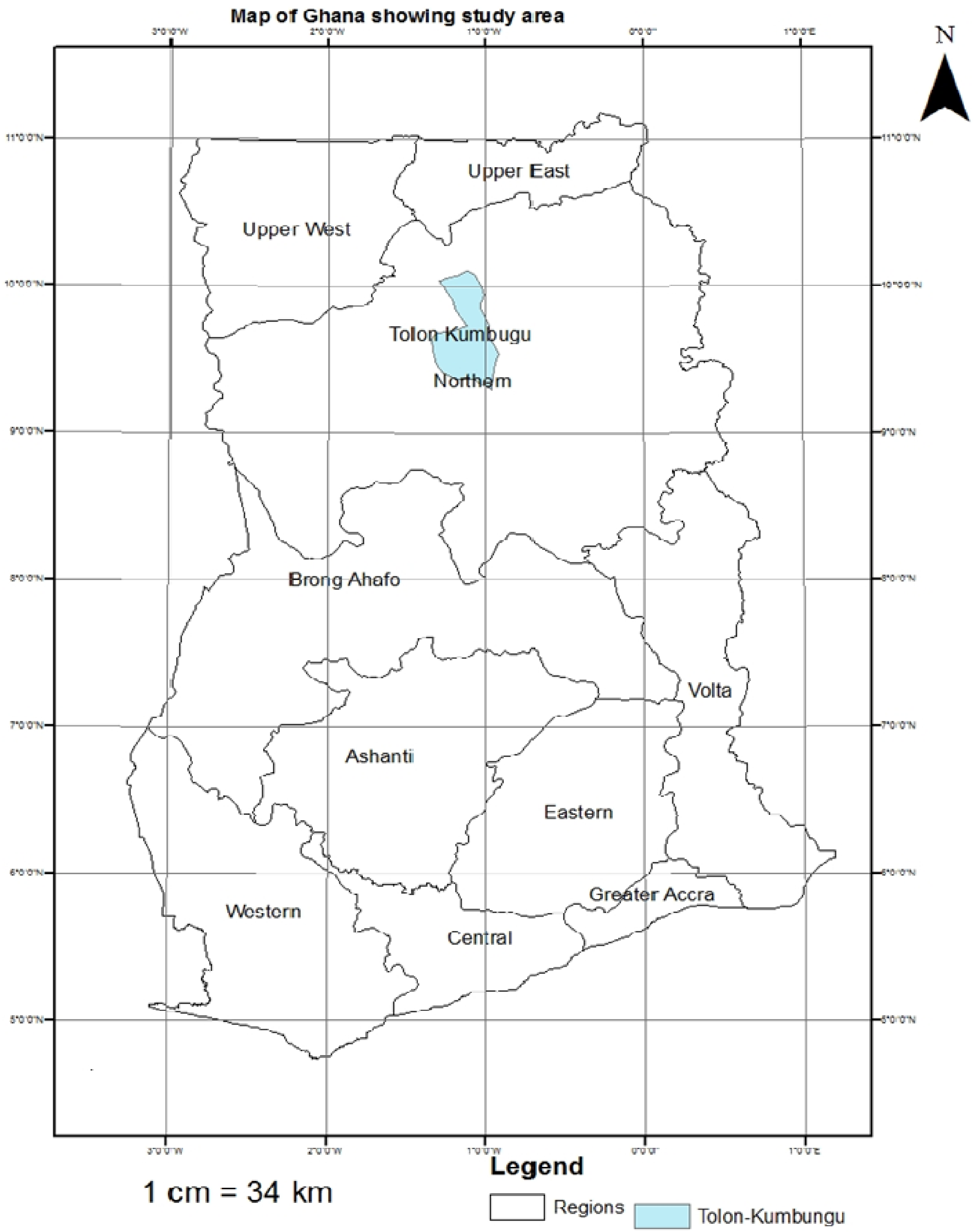

Figure 1. Map showing the study area.

Abagale (2005) who successfully used it to measure the slope of land. The slope was then calculated using the formula below:

$$\text{Slope} = \frac{\text{Differences in water level at two points}}{\text{Total distance covered}} \times 100 \quad (1)$$

Measurement of rills

Rill erosion is the major form of erosion that was observed under cultivated fields in the study. Therefore measurement was taken to determine the volume of soil that was eroded from plots of land under cultivation. The volume of soil loss from a field was calculated by measuring the depth, width and length of rills. The average width and depth of the rills were calculated, using the appropriate cross section area (that is an area of a triangle: ½ × horizontal width × depth). Volume of soil loss = cross sectional area × length of the rill.

$$\text{Soil loss } (m^3/m^2) = \frac{\text{Volume of soil loss}}{\text{Catchments area}} \quad (2)$$

$$\textbf{Soil loss (tons/ha) = Soil loss } (m^3/m^2) \times \textbf{ bulk density} \times 10{,}000 \quad (3)$$

Measurement of infiltration rate

The infiltration rate of the soil was determined for upstream, midstream and downstream of cropped fields. A double ring infiltrometer was used for the collection of the infiltration data. Depth of water that infiltrates into the soil was read at a time interval of 1 min.

Measurement of moisture content and bulk density of soils

Soil samples were collected 48 h after the first rain of the year, for the determination of moisture content and bulk density. Soil samples were taken using a soil augur at different depths of 0 to 20, 20 to 40 and 40 to 60 cm along the upstream, midstream and downstream of crop fields for moisture content determination. The soil samples were collected into transparent poly bags, air-tight and labeled. These were then sent to the laboratory and put in empty containers for oven drying. For bulk density determination, soil samples of known volumes of core samplers were collected at these same different depths, as mentioned already for moisture content.

This was done for the upstream, midstream and downstream, after which average bulk density values were then determined. The core samplers were driven into the soil vertically until its ends flushed with the soil surface inside the core at each layer thickness, and they were then covered with tight fitting lid. A knife was used to dig around the core samplers to remove them from the soil. Soil was trimmed with the knife at the ends of the core samplers and covered, which were also sent to the laboratory for oven-drying.

Laboratory analyses

The wet soil samples collected for both the moisture content and bulk density were weighed and their initial weights recorded. They were then oven-dried at a temperature of 105°C for 24 h in the laboratory. The dried samples were weighed, and empty containers were also weighed. The weight of water in the samples was obtained by finding the difference in weight between the wet samples and the oven dried samples. The moisture content and bulk density of the soil for the upstream, midstream and downstream were calculated using the formula:

$$\text{Moisture content (\%)} = \frac{\text{Weight of wet soil (Ww)} - \text{Weight of dry soil (Wd)}}{\text{Weight of dry soil (Wd)}} \times 100 \quad (4)$$

$$\textbf{Bulk density } (g/cm^3) = \frac{\textbf{Weight of dry soil (Wd)}}{\textbf{Total volume of soil}} \quad (5)$$

RESULTS

Slope of the agricultural lands and soil losses

The average slope of the cropping fields was found to be 4% and ranges between 3 and 7% with the soil loss associated with this area estimated to be 2.6 ton/ha/year.

Soil conservation practices in the area

Farmers in the study area undertake soil conservation practices in order to increase crop yields. The current conservation methods practices by the farmers are shown in Table 1. Farmers who practiced contour ploughing with tractors and manure application forms the majority of 37%, while farmers who practiced bunding and composting form the minority of 6%.

Infiltration rate on farmlands

Table 3 shows infiltration rate and their corresponding permeability at the different land levels. The initial infiltration rate for the upstream (up-slope part of the catchment), midstream (mid-slope part of the catchment), and downstream (down-slope part of the catchment) were 514.8, 540.66 and 569.76 cm/h, and the final infiltration rate, which is the terminal infiltration capacity, were 198.18, 180.99 and 343.37 cm/h, respectively. For soil to be suitable for enhanced infiltration it must, in particular be permeable and unsaturated (CIRIA, 1996). The midstream had the highest permeability index of 3.0 whilst the downstream recorded the least of 1.7. Permeability is the property of soils that allows water to pass through them at some rate. The indication of low and high permeability is based on f_o/f_c ratio as in Table 2 (Mc Quen, 1998).

Moisture content and the bulk density of soils on farmlands

Table 4 shows the moisture content of upstream, midstream and downstream and bulk density of the agricultural fields in the area. It shows that moisture

Table 1. Current conservation practices by farmers.

Conservation practice	Number of farmers	Percentage (%)
1. Contour ploughing with tractor and manuring	11	37
2. Ridging across the slope	9	30
3. Mounding with mulch	8	27
4. Others (bunding and composting)	2	6
Total	**30**	**100**

Table 2. Permeability indication ration (Mc Quen, 1998).

Ratio (f_o/f_c)	Permeability capacity
>5	High permeability
3-5	Moderate permeability
<3	Low permeability

Table 3. Infiltration rates and the permeability of soils.

Location	Initial infiltration capacity f_o (cm/h)	Final infiltration capacity f_c(cm/h)	Permeability index (f_o/f_c)
Upstream	514.8	198.18	2.6
Midstream	540.64	180.99	3.0
Downstream	569.76	343.37	1.7

Table 4. Moisture content and bulk density of soil in the study area.

Different levels of land	Depth (cm)	Average moisture content-w/w (%)	Average bulk density (g/cm^3)
	0 to 20	6.56	
Upstream	20 to 40	8.42	1.69
	40 to 60	9.18	
	0 to 20	6.33	
Midstream	20 to 40	7.91	1.58
	40 to 60	9.13	
	0 to 20	6.44	
Downstream	20 to 40	8.89	1.53
	40 to 60	9.53	

content in the upstream and downstream is fairly high between 0 to 40 cm and decreases with depth between 40 to 60 cm. Moisture content in the midstream shows rather the reverse. Thus, it indicated that moisture content is low between 0 to 40 cm and increases with depth between 40 to 60 cm. With regards to bulk density, the upstream recorded the highest soil bulk density of 1.69 g/cm^3 while the downstream recorded the least of 1.53 g/cm^3

DISCUSSION

Soil erosion on the farmlands

From the results, the slope of the land is 4%. According to Donahue (1983), a slope between 3 to 5% is considered as moderate. Therefore, the moderately sloping nature of the land makes surface water flow to be rapid. A considerable amount of rainfall is lost from the surface, which increases the hazards of erosion and drought conditions. An estimated soil loss of the area was found to be 2.6 ton/ha/year. This indicates that, for every season, 2.6 ton/ha of the surface soil is removed by rill erosion. Therefore, the rate of erosion in the area is moderate. This is because the Potential Soil Loss (PSL) values range from less than 200 ton/ha/year in Accra, Upper West Region and Upper East Region, to close to 700 ton/ha/year in Ashanti, Northern Region, and Western Region (IFPRI, 2007).

According to Mc Quen (1998), the permeability of a soil is said to be slow when its permeability index is less than 3 and moderate when the permeability index is 3 to 5. Based on the infiltration test results (Table 2), permeability is slow in the upstream and the downstream, whiles in the midstream the soil is moderately permeable. Therefore, infiltration rate for the upstream and downstream are low whiles that of the midstream is moderate. From Table 2, the final infiltration rate for the downstream is 343.38 cm/h. This implies that the area easily becomes saturated in a short time. This may be attributed to the deposition of clay materials. According to Donahue (1983), soils with low permeability have hardpan, clayey subsoil or bedrock at the bottom of the soil (B-horizon) as it goes down the soil profile. Therefore, the area could easily become waterlogged when there is excess water or when the final infiltration capacity is exceeded. The moderate permeability of the midstream may be due to its valley nature.

Results from Table 4 indicate that, the upstream has the highest bulk density (1.69 g/cm^3); whilst the downstream recorded the least (1.53 g/cm^3). The soil has an average bulk density of 1.6 g/cm^3. Donahue (1983) reported that plants perform well when the bulk density is between 1.1 and 1.4 g/cm^3. At a bulk density of 1.6 g/cm^3 water movement and root development are curtailed. So, at an average bulk density of 1.9 g/cm^3, crop growth would be adversely affected. Donahue (1983) also stated that very compact subsoil may have bulk density as high as 2 g/cm^3 or even higher and thus have no root in them. So at bulk density of 1.6 g/cm^3, the soil may be slightly compact. The compaction could be attributed to rain drop impact on the soil, since the soil has inadequate residue cover and also the cultivation of the soil at the same depth year after year, especially when wet. The use of tillage equipment for ploughing when the soil is wet enough makes it plastic and easily compressed. The compaction of the soil impairs aeration, infiltration and root growth (Donahue, 1983).

From the results shown in Table 4, it was realized that the moisture content of the soil for the upstream and the downstream decreased with depth. This could be attributed to the hardpan, traffic pan or bedrock at the bottom of the soil which causes the slow permeability of water through the soil. This reduced the rate of infiltration in the soil. Therefore, the soil becomes drier as the depth increases. The moisture content (%) of the soil for the midstream increased with depth even though it has a higher bulk density (1.69 g/cm^3). This could be due to the moderate permeability of the soil (permeability index of 3) at the midstream which increased the moisture content as it goes deep into the soil.

Soil and water conservation

From the study, it was realized that crop residues after harvesting were used for other purposes such as domestic fuel and feed for livestock, instead of leaving them on the field to serve as mulch. This exposes the land to heavy rain causing erosion and compaction of the soil. The low fertility of the soil according to the farmers could be as a result of erosion, which washed most of the soil nutrients away. Also, the farmers cultivate the soil usually with a mould board plough at the same depth year after year. This increases root-restricting layers such as hardpan and traffic pan to develop, as reported by Donahue (1983). Plants with restricted roots would not reach their full potential, hence low crop yield.

Due to the erratic rainfall in the study area, soil conservation practices such as cover-cropping, agroforestry practices, crop rotation and mulching are widely practiced. Other land conservation practices adopted by the farmers included contour ploughing with tractors (tillage practices), normally with a mould board plough or animal traction. The farmers plough across the slope twice before planting their crops. Ploughing across the slope increased capture of run-off water, thereby reducing soil erosion and maintaining infiltration rate as well as increasing soil macro pores after contour ploughing, as reported by Singer and Munns (2006). Manure is applied to the land after first ploughing. The second ploughing is done to mix the manure with the soil thoroughly. This helps improve the cohesiveness of the soil and increases its water retention capacity as reported by Hil (1987).

Some farmers also prefer making ridges to ploughing the land before planting. The farmers till the ground into wide parallel ridges across the slope using simple tools like hoe. According to Bonsu (1981), surface runoff is reduced as water moves across the ridges to the furrows and then down the furrows. This reduces soil erosion, since there is reduction of volume of soil loss by erosion as surface runoff moves across the ridge. Mounding is another conservation measure practiced by the farmers in the area. It is applied with mulch mostly in the cultivation of yams and sometimes cassava, where some weeds or crop residues are put on top of the mounds to serve as mulch. The mounds reduce runoff thereby reducing soil erosion. It also conserves moisture around the rooting and feeding zone of the crops, as reported by Kranjac-Bersavijevic et al. (1998). The weeds (mulch) incorporated into the mounds improved the fertility of the soil when they decompose. It also protects the soil against the impact of direct rainfall and impedes runoff, as stated by Lal (1984). This helps minimize the erosion rate in the area.

Conclusion

The results from the analysis show that, the study area has slightly compact soil (at a bulk density of 1.6 g/cm^3). The permeability of the soil is therefore low (low infiltration rate) and surface water flows rapidly causing moderate erosion on the land. This leads to low fertility of the soil, which affect crop yield. However, farmers are able to conserve the soil and control erosion to some extent through some conservational methods such as ridging across the slope, tillage practices (contour ploughing with tractors or animal traction) with organic manure or fertilizer application and mounding with mulching which enhances crop growth thus increasing yields.

REFERENCES

Adama AI (2003). The Effect of Different Tillage Practices on Soil Erosion, Water Conservation and Yield of Maize in the Semi-Deciduous Forest Zone of Ghana. Unpublished M.Sc. Thesis, Department of Crop and Soil Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Alfsen HA, Bye T, Glomsrød S, Wiig H (1997). Theory and Application: Soil degradation and Economic development in Ghana. Environment and Economic Development Economics. Cambridge University Press, 2: 119-143.

Agyepong GT, Kufogbe SK (1994). "Assessing the Spatial Patterns of Land Cover and Land Degradation in the Upper East Region of Ghana using satellite images", Paper presented at the inter-university seminar workshop on social science research, University of Ghana, Legon, 25th-29th July.

Bobobee EYH, Bart-Plange A (2005). Hunger without Frontiers. West African Society of Agricultural Engineering (WASAE). www.wasae.org.

Bonsu M (1981). Assessment of Erosion under Different Cultural Practices on a Savanna Soil in the Northern Region of Ghana. In: R. P. C. Morghan (ed.), Soil Conservation: Problems and prospects. Chichester, Wiley.

Donahue RL (1983). Our Soils and their Management. 5th Edition. Interstate Printers and Publishers, Inc., United States of America.

Hil H, Anne M, Edger T (1987). Erosion Control in the Tropics. Pub. By Wageningen, April 1987, English translation: Mrs. Verheij, pp. 20-25.

IFPRI (2007). Cost Implications of Agricultural Land Degradation in Ghana: An Economywide, Multimarket Model Assessment. IFPRI Discussion Paper 00698. 2033 K Street, NW Washington, DC 20006-1002 USA.

Kranjac-Bersavijevic G, Bayorbor TB, Abdulai AS, Obeng F (1998). Soil and Water Conservation in Northern Ghana. (A Review Paper Prepared by the Faculty of Agriculture, UDS Tamale, Ghana in Collaboration with Overseas Development Institutes (O.D.I) London.

Lal R (1983). Erosion caused productivity decline in soils of the humid tropics. Soil Taxonomy News, pp. 54-518.

Lal R (1990). Soil Erosion in the Tropics: Principles and Management. McGraw-Hill, Inc. United States of America.

Lal R (1988). Effect of slope length, slope, gradient, Tillage methods and cropping systems and run-off and soil erosion on a Tropical Alfisol: Preliminary results, Int. Assoc. Hydrol. Sci., 174: 79-88.

Lal R (1994). Global review of soil erosion, in, Soil and Water Science: Key to understanding our Global environment, Soil Sci. Soc. Am. Special Publication No.41: 39-52, Madison, WI USA.

Mc Quen RA (1998). Hydrological Analysis and Design. 2nd Edition, Prentice Hall, New Jersey.

Mingyuan Du, Peiming Du, Tichic M, Shigeto K (1998). 'Numerical of airflow over complex terrain concerning wind erosion". Int. Assoc. Hydrol. Sci., p. 249.

Morgan RPC (1995). Soil Erosion and Conservation. 2nd Ed. Longman group UK limited.

Morgan RPC (1986). Soil Erosion and Conservation. Longman, England.

Perrens SJ, Trustum NA (1984). Assessment and evaluation of soil conservation policy. Report, Workshop on Policies for Soil and Water Conservation, 25-27 January 1983, East West Center, Honolulu, Hawaii.

Quansah C, Baffoe-Bonne E, Aslmmah RD (1989). "Soil erosion in Ghana and strategies for conservation", A country paper presented at the African ministerial conference on environment. Regional coordination unit of the soils and fertilizers network for Africa. Seminar on soil conservation strategy for Africa, Accra, 2-30th August.

Quansah C (1990). "Soil Erosion and Conservation in the Northern and Upper Regions of Ghana". Topics Appl. Resourc. Manage., 2; 135-157.

Quansah C (1996). Soil, water and nutrient management needs for sustainable crop production. Proceedings of DSE International Seminar on Tools for Analysis and Evaluation for sustainable Land use in Rural Development, DSE, Zscortan, Germany, pp. 38-46.

Singer MJ, Munns DN (2006). Soils: An introduction. 6th Edition Published by Pearson Education, Inc. Upper Saddle River, New Jersey 07458, pp. 354-365.

Stocking M, Murnaghan N (2001). Handbook for the field assessment of land degradation.

Stocking M, Peake L (1986). Crop Yield losses from the erosion of Alfisols. Tropical Agriculture (Trinidad). January, 63(1): 41-45.

Thao TD (2001). On site Costs and Benefits of Soil Conservation in the mountainous region of northern Vietnam. EEPSEA publications www.eepsea.org.