Journal of Geosciences and Geomatics, 2017, Vol. 5, No. 6, 259-266
Available online at http://pubs.sciepub.com/jgg/5/6/1
DOI:10.12691/jgg-5-6-1

Coarse Scale Remote Sensing and GIS Evaluation of Rainfall and Anthropogenic Land Use Changes on Soil Erosion in Nasarawa State, Nigeria, West Africa

Kossi Dodzi Bissadu[1,*], Yawovi Sena Koglo[2], Dode Bendu Johnson[3], Komlavi Akpoti[4]

[1]Grantham University, Lenexa, KS 66219, United States of America
[2]Institut Togolais de Recherche Agronomique (ITRA), BP:1163 Lomé, Togo/ WASCAL Climate Change and Land Use, Department of Civil Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. University private email box, KNUST, Kumasi
[3]African Regional Institute for Geospatial Information Science and Technology (AFRIGIST), formerly Regional Centre for Training in Aerospace Surveys (RECTAS), United Nations Economic Commission for Africa (UNECA), Obafemi Awolowo University Campus, PMB. 5545, Ile-Ife, Osun State, Nigeria
[4]University of Energy and Natural Resources, Sunyani, Ghana. Land Suitability Analyst (GIS and Remote Sensing)
*Corresponding author: kbissadu@grantham.edu, bissadukossi02@gmail.com

Abstract In this study, impacts of rainfall and land use changes on soil erosion in Nasarawa State, Nigeria in changing climate, were investigated by applying remote sensing techniques, Geographical Information System (GIS) and the Revised Universal Soil Loss Equation (RUSLE). Results revealed that, changes in rainfall intensity and land cover types are the core drivers of soil erosion in Nasarawa State over 30-year (1985–2014) periods. Besides, erosion rates and magnitude were more affected by changes in soil cover than changes in rainfall amount. Therefore, agroecology agricultural systems (e.g. soil mulching, minimum tillage, agroforestry, rotational cropping systems, use of mechanical and biological anti erosive measures) could be the most efficient way of combatting soil erosion concerns while scaling-up rainfed agriculture adaptation.

Keywords: *land use change, rainfall change, soil erosion, Remote Sensing, GIS, RUSLE, Agroecology*

Cite This Article: Bissadu Kossi Dodzi, Koglo Yawovi Sena, Dode Bendu Johnson, and Akpoti Komlavi, “Coarse Scale Remote Sensing and GIS Evaluation of Rainfall and Anthropogenic Land Use Changes on Soil Erosion in Nasarawa State, Nigeria, West Africa.” *Journal of Geosciences and Geomatics*, vol. 5, no. 6 (2017): 259-266. doi: 10.12691/jgg-5-6-1.

1. Introduction

Soil erosion is a complex process that physically takes place by the movement of soil particles from a given site. Soil erosion can affect soil quality and induce soil deterioration by the loss of topsoil enriched with organic matter [1]. It is a major global environmental problem, having widespread and serious negative effects on agricultural production, infrastructure, water quality and biodiversity [2,3]. Causative factors of soil erosion include: climate, soil type, topography, vegetation and human activities. Soil and topography are non-time dependent factors of erosion by water, while rainfall and land cover or vegetation cover (which is strongly dependent on land use) vary with time and affect the degree, extent and frequency of soil erosion by water [4]. Since soil erosion generally occurs when the soil is displaced by rain and transported from the specific area, rainfall is considered as the driving factor of soil erosion. However, the factor that significantly affects the soil displacement by rain is land cover or vegetation cover change. The reduction of vegetation cover can decrease significantly soil water retention capacity and infiltration while increasing erosivity [5-10].

Nigeria in general and Nasarawa State in particular observed changes in land use land cover affecting different natural resources such as water, forest, soil and biodiversity [11,12,13]. Some land use changes lead to soil erosion, while other changes entail improvement of erosion status (e.g. soil conservation measures, agroecology systems). Moreover, Nasarawa State has been experiencing droughts spells while observed rainfall pattern appears to be increasing, and it is projected to continue associated with changes in river flow, flooding, and the distribution in the ecosystems [14]. Changes in rainfall and land use can therefore affect soil erosion status in the study area. However, in-deep approach and spatial analysis of soil erosion evolution, with regard to spatio-temporal changes in rainfall and land use, have not been explicitly conducted in Nasarawa State; resulting in poorly practiced conservation measures in most areas of the State. The objectives of this study are to (i) investigate the rainfall and land use changes and (ii) assess their impacts on soil erosion status in the past 30- year. The quantitative soil loss can be modelled by the Revised Universal Soil Loss Equation (RUSLE) [15], which is the most widely used for soil loss evaluation by taking into consideration rainfall, soil properties, topography, land cover, and conservation practice.

2. Materials and Methods

2.1. Study Area

Nasarawa State area is located in the North-central region of Nigeria between Latitude 8-9^0 North and Longitude 7-8 ° East and is bounds by Kaduna State in the North, West by the Abuja Federal Capital Territory, Kogi State and Benue States at the southern part, and by Taraba and Plateau State in the eastern part. The State covers a total landmass of 27,117km^2.

The selected study area is approximately 2,175,268 hectares and comprised ten local government areas: Akwanga, Karu, Kokona, Wamba, Keffi, Nasarawa, Nassarawa Egon, Lafia, Keana and Obi (Figure 1). It is located at an Altitude between 17 and 1309 m above sea level. The area has a tropical climate with long-term annual average precipitation of 1200mm and average mean temperature is 24°C. It has Guinea savannah as vegetation type with five soil units: Ultisols, Alfisols, Entisols, Inceptisols and Vertisols.

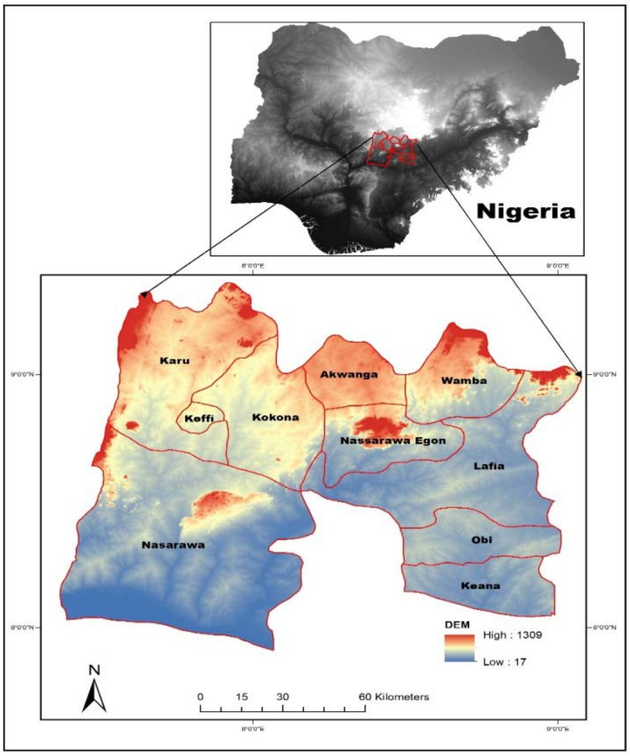

Figure 1. Location of the study area

2.2. Data and Procedures

2.2.1. Analysis of Spatio-Temporal Changes in Rainfall

Thirty-year data of annual total rainfall (1985-2014) were collected for eight meteorological stations from Lower Benue River Basin Development Authority (LBRBDA) at Makurdi, Benue State. Two 15-year average values of total rainfall for the periods 1985-1999 and 2000-2014 were produced for each station. Through ordinary kriging and were used to produce two maps of 15-year average rainfall over the study area. The subtraction of the map of the second period (2000-2014) from that of the first period (1985-1999) was performed pixel by pixel to generate the spatio-temporal change map.

2.2.2. Land Use Change Detection

Land use is “the total of all arrangements, activities and inputs that people undertake in a certain land cover type” (UNFAO, 1997); Land use change, usually couples with land cover change (LULCC) is a general term for the anthropogenic modifications of Earth's terrestrial surface. The mapping of the various Land Use Land Cover classes over the study area was carried out using the Landsat TM and OLI images of 1985 and 2014, respectively. The methodology applied involved ENVI 5.1 Maximum Likelihood classification and ArcGIS 10.3 post-processing with seven land use land cover classes identified from ground truthing. The overall accuracy was 89 % for both maps (1985, 2014) with kappa coefficient 0.8 and separability test 1.6.

2.2.3. Soil Erosion Assessment

The Revised Universal Soil Loss Equation model [15] was applied to produce the soil loss map of the years 1985 and 2014.This model (Equation 1) uses six (06) factors to estimate annual soil loss.

$$\mathbf{A} = \mathbf{R} \times \mathbf{K} \times \mathbf{L} \times \mathbf{S} \times \mathbf{C} \times \mathbf{P} \qquad (1)$$

A= Soil loss (tons/ha/year)
R= Rainfall and runoff erosivity factor
K= Soil erodibility factor
L= Slope length factor
S= Slope gradient factor
C= Soil cover management factor
P= Conservation practice factor.

R factor (Equation 2) is the coefficient of the average erosion by rain. Rain is a direct impact to the surface of soil; its kinetic energy is destroying the soil structure and brings the soil components together with runoff water. The R coefficient was computed based on the 30 –year average rainfall (H) [16]. The two maps of 15-year average rainfall were used to generate R factor maps of the two periods.

$$\mathrm{R} = 0.5 \times \mathrm{R}. \qquad (2)$$

On the other hand, the soil erodibility factor (K), represents both susceptibility of soil to erosion and the amount and rate of runoff, as measured under standard plot conditions. In this study, the soil properties required for the determination of K (equation 3) factor were collected for the five soil units identified in the study area. These properties (soil organic matter content, soil texture, structure and permeability) were collected through field survey and laboratory analysis. Then, the soil erodibility factor map K was generated using the soil map of the study area and the soil properties collected for the different soil units.

$$\begin{aligned} \mathrm{K} &= 2.8 \times 10^{-7} \times \mathrm{M} \times 1.41 (12 - \mathrm{A}) \\ &\quad + 4.3 \times 10^{-3} (\mathrm{B} - 2) + 3.3 \times 10^{-3} (\mathrm{C} - 3) \end{aligned} \qquad (3)$$

A = percentage (%) of organic matter
B = texture class
C= permeability class

$$M = \left(\left(100 - \%Clay \right) \times \left(\%very\ sand + \%Silt \right) \right).$$

The slope length and slope steepness (equation 4) can be used in a single index, which expresses the ratio of soil loss as defined by [17]. LS (Equation 4) factor map was established from 30m*30m Digital Elevation Model data. LS was generated from slope and flow accumulation in ArcGIS 10.0. The LS factor grid was determined by using the following equation (Wischmeier and Smith, 1978).

$$LS = \left(Flow\ accumulation * Cell\ value / 22.1 \right)^{m} \times \left(0.065 + 0.045S + 0.0065S^{2} \right). \quad (4)$$

Cell value is the resolution of DEM, and m ranges from 0.2-0.5 depending on the slope. Table 1 was used for determination of m-values.

Table 1. m-value

Slope (%)	m-value
>5	0.5
3-5	0.4
1-3	0.3
<1	0.2

Adopted from [18].

The C factor (Soil cover management factor) is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow. Land use maps of 1985 and 2014 were used to analyse the C value. After changing the coverage to grid, a corresponding C value was assigned to each land use classes using reclass method in ArcGIS as given by İrvem and Tulucu [19]. Forest was assigned the lowest C value (0.02) whilst the highest value (1) was assigned to bare surface [20]. However, a value of zero (0) was attributed to water body with the assumption that water body does not contribute to the soil loss or its contribution could be negligible. Therefore, the C factor map of 1985 and 2014 were generated to produce the soil erosion map of 1985 and 2014, respectively. While, the P factor (Conservation practice factor) is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope culture. As the data for P value were not available for the past 30 years, it was assumed that there were no conservation practices, and then P was not incorporated into the model. After completing data input procedure and preparation of R, K, LS and C maps as data layers, they were multiplied in the GIS to provide erosion maps of 1985 and 2014. Change detection in soil erosion was then performed through the subtraction of two erosion maps of 1985 and 2014.

3. Results

3.1. Spatio-temporal Change in Rainfall

15-year average rainfall was evenly distributed over the study area for the two periods, with low values observed at the south east and high values at western part. The study area experienced increase in rainfall from the first period to the second (Figure 2), the minimum value shifted from 1234.19mm in 1985 to 1212.77mm in 2014 (6.9% of increase) whilst the maximum increase from 1287.45mm in 1985 to 1352.81mm in 2014 (5.08% increase).

The spatial distribution of the change in 15-year average rainfall over the study area. 1.14% of the total area experienced decrease in rainfall and the southern part of Nasarawa local government recorded the highest decrease in rainfall. While 0.07% of the area did not observed any change, 98.79% recorded increase in rainfall (Figure 3).

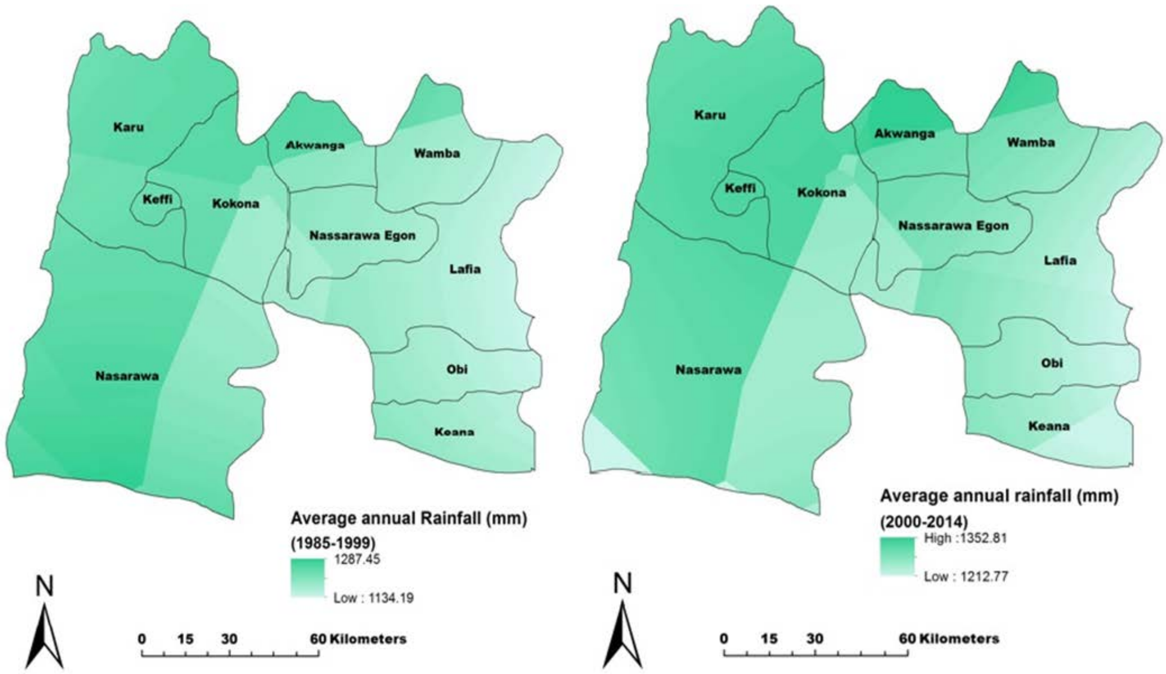

Figure 2. Spatial distribution of the average rainfall for the period 1985-1999 and 2000-2014

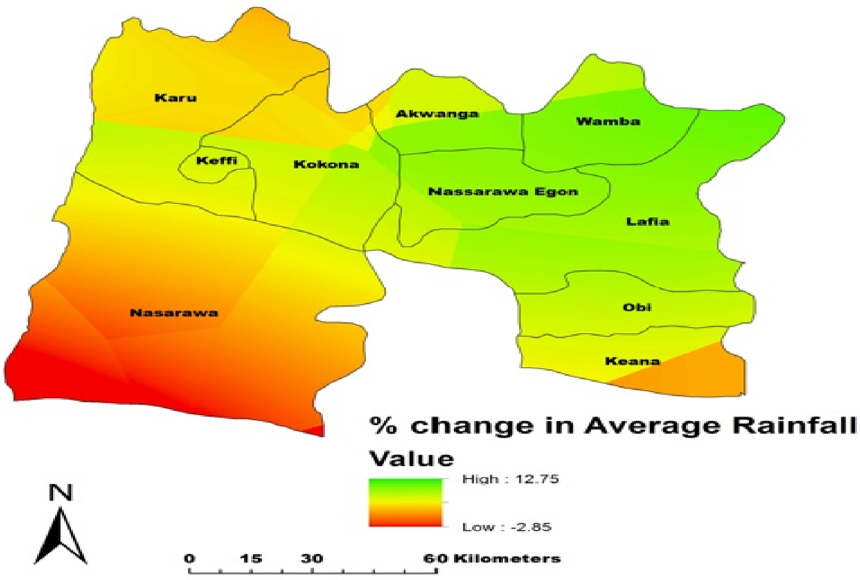

Figure 3. Spatial distribution of changes in 15-year average rainfall

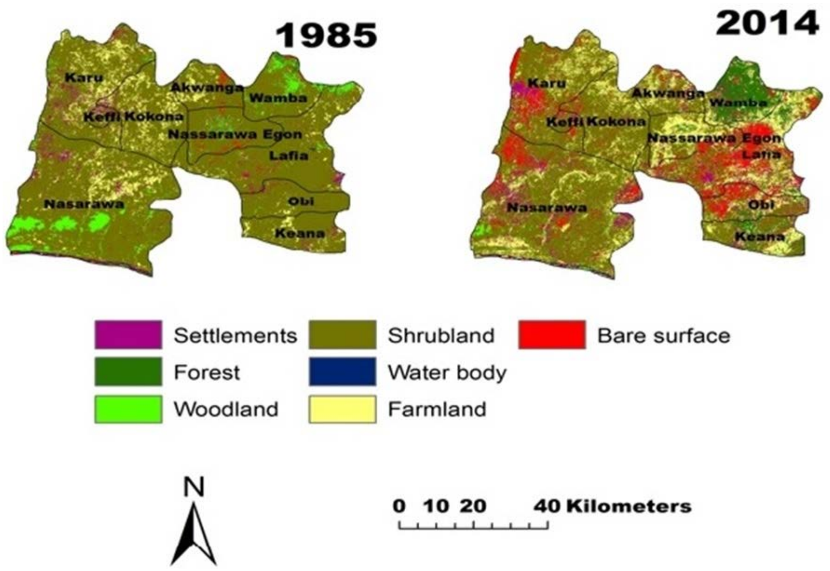

Figure 4. Land Use Land Cover Map of 1985 and 2014

3.2. Land Use Change Detection

Seven land use land cover classes were identified including settlements, forest, woodland, shrubland, farmland, water body and bare surface. Results of supervised classification for 1985 (Figure 4) shows that, majority of the area was covered by shrub land, with an area of approximately 1,702,251ha which represents 78.34% of the total landmass of the study area. Farmland, settlements, woodland, bare surface, forest and water body covered 163,606ha (7.53%), 141,366ha (6.5%), 125,438ha (5.75%), 18,765ha (0.86%), 10,777ha (0.49%) and 10,618ha (0.48%), respectively. Conversely in 2014, land use land cover has shifted in coverage (Figure 4). Shrub land was still maintaining its percentage share as the widest coverage, but reduced to 52.58% of the total landmass. Also, woodland and water body decrease in coverage from 5.77% to 0.64% and 0.49% to 0.36, respectively (Table 2). Farmland, settlements, bare surface and forest have net change of +9.11%, +8.44%, +7.18% and +6.29, respectively. Expansion of agricultural land and settlements in Nasarawa State is the main cause of reduction in shrub and woodland [21]. The destruction of woodland located along rivers increases the evapotranspiration of water surface thereby, reducing the amount and extent of water in the rivers, especially in Nasarawa local government area which hosts the biggest river basin in the State (River Benue).

Table 2. Land use land cover classes distribution in 1985 and 2014

Land use	Area 1985		Area 2014		Net change	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Settlements	141,366	6.51	324,711	14.94	183345	+8.44
Forest	10,777	0.5	147,487	6.79	136710	+6.29
Woodland	125,438	5.77	13,906	0.64	-111532	-5.13
Shrub land	1,702,251	78.34	1,142,557	52.58	-559694	-25.76
Water body	10,618	0.49	7,830	0.36	-2788	-0.13
Farmland	163,606	7.53	361,591	16.64	197985	+9.11
Bare surface	18,765	0.86	174,739	8.04	155974	+7.18
Total	**2,172,821**	100	**2,172,821**	100		

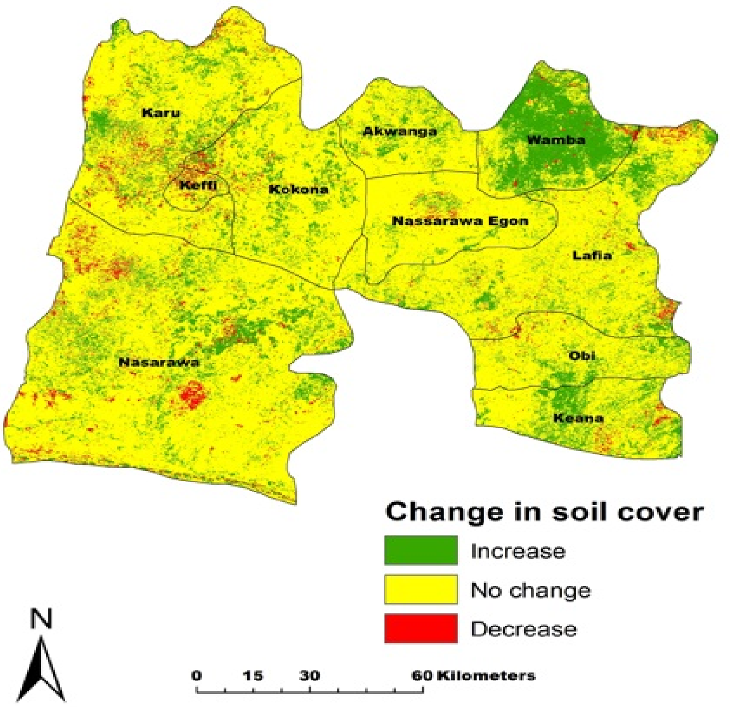

Figure 5. Spatial distribution of soil cover change from 1985 to 2014

The change of land use types can affect the C factor [1]. Therefore, changes from more covered surface to less covered surface were considered as decrease in soil cover, and the reverse was the increase. Figure 5 shows the spatio-temporal change in soil cover from 1985 to 2014. All the local government areas experienced decrease in soil cover as well as increase. Wamba recorded the highest coverage of increase; this is due to the expansion of forested area over this region. From the statistics presented in Table 3, 77.86% of the study area did not experience any change in its soil cover while 18.77% observed increase and 3.37% decrease.

3.3. Assessment of Soil Erosion Change

The assessment of soil erosion rate in the study area by applying the RUSLE revealed soil loss augmentation from 1985 to 2014 (Figure 6). The highest soil loss rate changed from 67.58 tons/ha/year in 1985 to 68.34 tons/ha/year in 2014, a change of +1.12%. The lowest value of soil erosion rate could not change because of the presence of water body, since the erosion of water body was considered negligible.

Figure 7 shows the spatial distribution of change in soil erosion. Nasarawa, Keana, Karu and Kokona were the local government areas where no change in soil erosion was observed. However, increase and decrease in soil erosion was observed in all the local government areas of the study area. Lafia was the most affected by the increase in soil erosion.

In overall, 23.16% of the study area did not observe change in soil erosion from 1985 to 2014, 32.16% and 44.68% of the area experienced increase and decrease in soil erosion, respectively (Table 3).

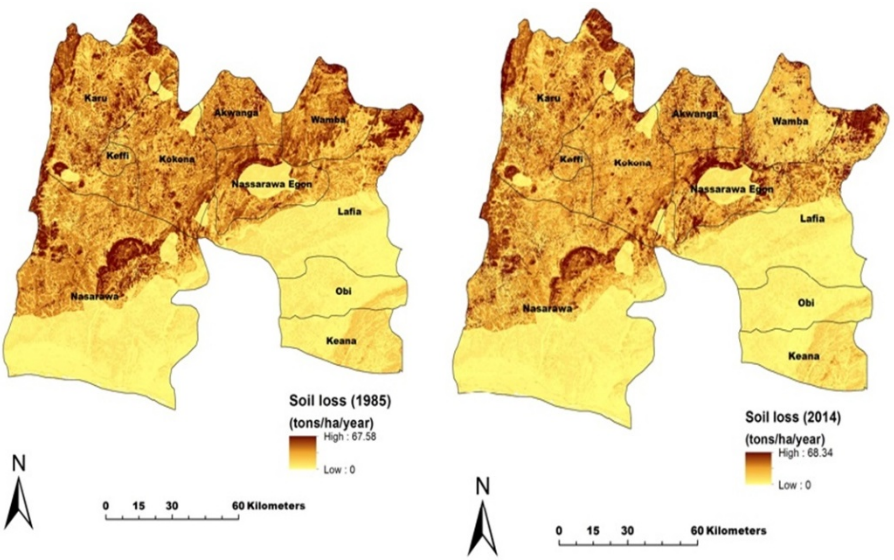

Figure 6. Soil erosion map of the years 1985 and 2014

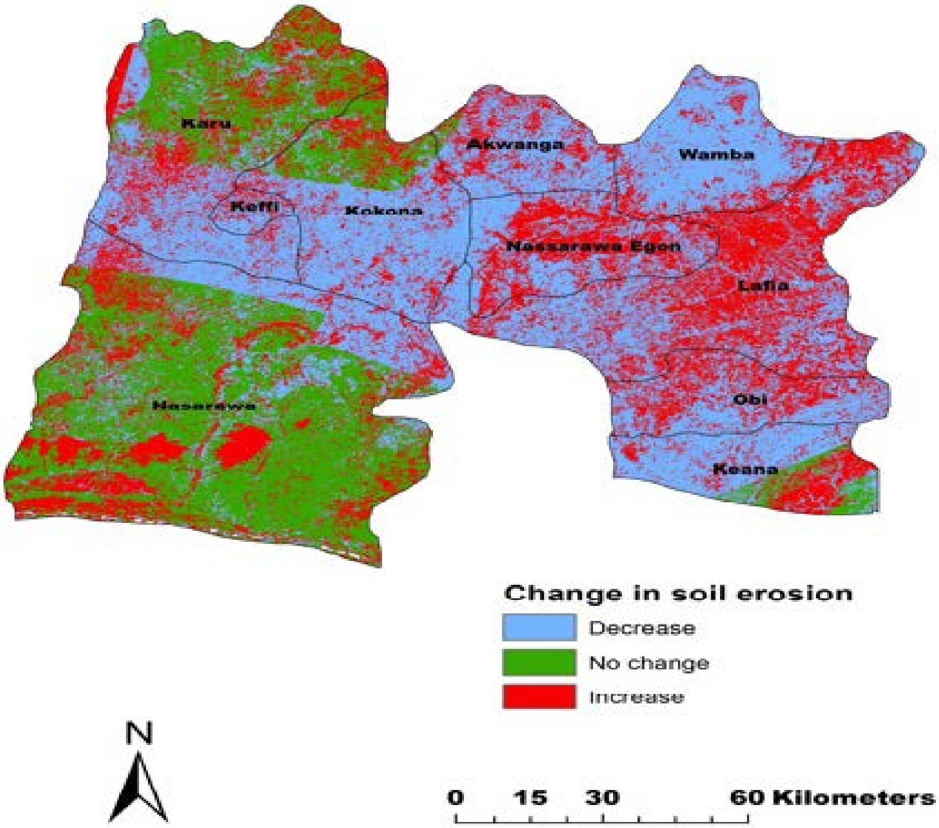

Figure 7. Spatial distribution in soil erosion change from 1985 to 2014

Table 3. Spatial change in rainfall, soil cover and soil erosion from 1985 to 2014

	Rainfall		Soil cover		Soil erosion	
	Ha	%	Ha	%	Ha	%
Increase	2149020.00	98.79	408,297.80	18.77	699566.19	32.16
No change	1489.00	0.07	1,693,663.66	77.86	503792.07	23.16
Decrease	24759.00	1.14	73,306.53	3.37	971909.74	44.68
Total	2175268.00	100	2,175,268	100	2175268	100

Table 4. Soil erosion area change due to changes in rainfall and land use from 1985 to 2014

		Change in soil erosion (%)			
		Decrease	No change	Increase	Total
Change in rainfall	Increase	44.59	22.65	31.58	98.82
	No change	0.02	0.03	0.02	0.06
	Decrease	0.07	0.47	0.58	1.12
Change in soil cover	Decrease	0.00	0.00	3.36	3.36
	No change	25.91	23.16	28.80	77.87
	Increase	18.77	0.00	0.00	18.77

3.3. Impact of Land Use and Rainfall Changes on Soil Erosion

Rainfall and land use changes are key multipliers of soil erosion (Table 4). From 98.82% of the area where rainfall increased, 31.58% observed increase in soil erosion while 44.59% observed decrease. On the other hand, 0.07% of the area of decrease in rainfall observed decrease in soil erosion while 0.58% experienced increase. Decrease of erosion in area where there was increase in rainfall could be explained by the increase in soil cover due to change in land use. Similarly, increase in soil erosion in the area of decrease in rainfall could be due to the reduction in soil cover.

In terms of land use change, all the areas of increase in soil cover observed decrease in soil erosion; however, increase in soil erosion was still observed for areas of decrease in soil cover. From the 77.87% of area of no change in soil cover, 25.91% and 28.80% experienced decrease and increase in soil erosion respectively; suggesting therefore that changes in rainfall contributed equally to soil erosion within the study area.

4. Discussion

4.1. Change in Rainfall

According to this study, increase in average rainfall was observed throughout the study area. Table 3 revealed that up to 98.79% of the area experienced increase in average rainfall against 1.12% which observed decrease. western part of the area experienced more decrease while eastern part experienced mostly increase. Both increasing and decreasing in rainfall were reported in many studies carried out in Nigeria [22,23,24,25]. Increase in rainfall observed in the northern west (Figure 3) could be a result of the expansion of forested area in the region which may probably lead to the increase in annual total rainfall, since there is a relationship between forested area and the amount and frequency of rainfall [26,27,28]. This region is equally situated at high altitude and can therefore influence positively the increase in rainfall. The southern part is located at low altitude, and additionally observed loss of vegetated area, especially woodland. This could explain the decrease of rainfall in this region of the study area. It may be concluded from the aforementioned that, changes in land use land cover associated with the altitude are major factors explaining the spatial variation of the change in rainfall in the study area.

4.2. Change in Land Use

Population growth in Nasarawa State has led to the expansion of agricultural area as well as residential areas. Figure 4 illustrates that, the population of Nasarawa State expanded their cultivated and built-up areas in the 1985 to 2014 period, thereby reducing drastically the savannah wood and shrub lands. Karu, Lafia and Nassarawa recorded the highest increase in settlements; this could be explained by the fact that, Lafia is the Capital town of the State and Karu and Nasarawa are closer to Abuja, the Capital town of Nigeria. Moreover, the reduction of deforestation associated with increase in rainfall in the northern east contributed to the expansion of forested area in that area. The decrease in water bodies was the effect of the decrease in rainfall in the southern part, where most of the river basins are located. Changes in land use over in Nasarawa State, especially increase in forested area, contributed to an overall increase in soil cover (Table 3).

4.3. Impact of Changes in Rainfall and Land Use on Soil Erosion

In the study area, 76.84% of the total landmass observed change in soil erosion between 1985 and 2014; decreased erosion recorded the highest coverage (Table 3). Therefore, there was decrease in soil erosion over the area. Table 4 revealed that, increase in rainfall amount contributed to the increase of soil erosion in the study area with sparse or no vegetation cover. In fact, much of the increase in precipitation that has been observed worldwide has been in the form of heavy precipitation events [29,30] which increased the raindrop capacity to detach soil particles. This situation could yield in more soil loss from non-covered soil, increasing therefore soil erosion. In fact, when soils are covered and when residues are fully incorporated, soils become dense in carbon resulting in an increase of infiltration rates and soil moisture content. Therefore, soil cover is paramount in limiting soil loss and environmental damages [10,31]. The reduction in the total amount of rainfall led to the decrease in soil erosion in the area. Soil erosion responds not only to differences in rainfall intensity, but also to the total amount of rainfall [32]. However, the proportion of increased soil erosion in increased rainfall area was less than that of decreased soil erosion; suggesting that change in rainfall does not contribute a lot to the change in soil erosion in the study area.

All the areas of increase in soil cover have observed decrease in soil erosion (Table 4), and increase in soil erosion was observed in the area of decrease in soil cover. Therefore, soil cover plays an important role in soil loss in the study area. It can be concluded that, land use change impacted more soil erosion in Nasarawa State than changes in rainfall. Land use change effects erosion rates because it can significantly change the amount and character of protection offered to surface materials [33]. The protection of surface materials by specific land use on a land surface will determine the tenacity of the land to circumvent soil erosion risks. The reasons how the vegetation cover affects the soil erosion can be explained in various ways. For instance, litter production and organic matter accumulation could reduce the soil-water loss [34]. Litter not only directly protects the surface soil from splash erosion, weakens the kinetic energy of raindrops and slows runoff velocities, but also conserves surface rainwater due to its strong moisture-holding capacity (Hou *et al*, 1996 as cited in [10,34]). Meanwhile, plant roots may form a dense network in topsoil that physically binds soil particles, and the soil-root matrix has been proved to be stronger than the soil or roots separately. In addition, plant root systems also influence the properties controlling soil erodibility, e.g. soil aggregate stability, infiltration capacity, soil bulk density, soil texture, organic content and chemical composition [35]. Moreover, more complex canopy structures can intercept 10 to 20% more of the rainfall (de Jong and Jetten 2007 as cited in [36]).

5. Conclusion

In the study area, more than 75% experienced changes in soil erosion due to changes in rainfall and land use. In overall, erosion decreased for the past 30-year while rainfall and soil cover increased. Then, erosion is likely to be more affected by changes in soil cover than changes in rainfall amount. This suggests that a sustainable land use which promotes conservation of vegetation, especially trees and cover crops, can help in controlling soil erosion in Nasarawa State.

Acknowledgements

We address our profound gratitude to the German Ministry of Education and Science (BMBF), the umbrella donor through the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL).

References

[1] Wijitkosum, S. Impacts of Land Use Changes on Soil Erosion in Pa Deng Sub-district, Adjacent Area of Kaeng Krachan National Park, Thailand. *Soil and Water Resources*. 2012, 7(1): 10-17.

[2] Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair K., Kurz D., McNair, M., Crist, S., Shpritz L., Fitton L., Saffouri R., and Blair, R. Environmental and Economic Costs of Soil Erosion and Conservation Benefits. *Science*. 1995. 267, 1117-1123.

[3] Lal, R. Soil degradation by erosion. *Land Degradation & Development*. 2004, 12: 519-539.

[4] Del Mar López T., Mitchel Aide T., and Scatena, F.N. The effect of land use on soil erosion in the Guadiana watershed in Puerto Rico. *Caribbean Journal of Science*. 1998, 34: 298-307.

[5] Martínez-Casasnovas, J.A., and Sánchez-Bosch, I. Impact assessment of changes in land use/conservation practices on soil erosion in Penedès-Anoia vineyard region (NE Spain). *Soil and Tillage Research*. 2000, 57: 101-106.

[6] Cebecauer T., and Hofierka, J. The consequences of land-cover changes on soil erosion distribution in Slovakia. *Geomorphology*. 2008, 98: 187-198.

[7] Zhou, P., Luukkanen, O., Tokola, T., Nieminen, J. Effect of vegetation cover on soil erosion in a mountainous watershed. *Catena*. 2008, 75: 319-325.

[8] Mohammad A.G., and Adam, M.A. 2010. The impact of vegetation cover type on runoff and soil erosion under different land uses. Catena, 81: 97-103.

[9] Akpoti, Komlavi, Eric Ofosu Antwi, and Amos T. Kabo-bah. Impacts of rainfall variability, land use and land cover change on stream flow of the black Volta Basin, West Africa." Hydrology 3.3 (2016): 26.

[10] Koglo, Y.S., E., Abdulkadiri, A., Bissadu, K.D. and Akamah, A.K. Mitigating droughts effects on tropical agriculture systems: The role of improved soil management practices in regulating soil moisture, temperature and carbon losses. *Journal of Soil Science and Environmental Management*. 2017, 8(6), pp.104-112.

[11] Abbas, I.I, Muazu, K.M., and Ukoje, J.A. Mapping Land Use-land Cover and Change Detection in Kafur Local Government, Katsina, Nigeria (1995-2008) Using Remote Sensing and GIS. *Research Journal of Environmental and Earth Sciences*. 2010, 2(1): 6-12, 2010.

[12] Eludoyin, O.S., Wokocha, C.C. and Ayolagha, G. GIS Assessment of Land Use and Land Cover Changes in OBIO/AKPOR L.G.A., Rivers State, Nigeria. *Research Journal of Environmental and Earth Sciences*. 2011, 3(4): 307-313.

[13] Sunday, P.E and Umar, A. Spatiotemporal Analyses of Land Use and Land Cover Changes in Suleja Local Government Area, Niger State, Nigeria. *Journal of Environment and Earth Science*. 2013, 3(.9).

[14] Adefolalu, D. O. An Introduction to the challenges of Climate Change and its impacts in Nigeria. A workshop on Climate Change and Natural Disaster in Nigeria held at FUT, Minna on 3rd April, 2000.

[15] Renard, K. G., Foster, G. R., Weesies, G. A., Mccool, D. K., and Yoder, D. C. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agriculture Handbook No. 703, 1997.

[16] Roose, E.J. Application of the universal Soil Loss equation of Wischmeier and Smith in West Africa. In Greenland, D.J. and Lal, R. (eds.) Soil Conservation and Management in the Humid Tropics. John Wiley and Sons, Chichester, West Sussex, UK, 1977.

[17] Wischmeier, W.H., and Smith D.D. Predicting rainfall erosion losses: a guide to conservation planning. Agriculture Handbook No. 537, US Department of Agriculture, Washington DC, 1978.

[18] Yılman, A. and Ebru, F. “Predicting Soil Loss in the Catchments of Eldivan Sarayköy-II Dam (Çankırı), By the RUSLE Methodology”, M. Sc. thesis, Ankara University, Turkey, 2009.

[19] İrvem, A. and Tülücü, K. Coğrafi Bilgi Sistemi ile Toprak Kaybı ve Sediment Verimi Tahmin Modelinin (EST) Olusturulması ve Seyhan-Körkün Alt Havzasına Uygulanması. http://fbe.cukurova.edu.tr/makale/ cografibilgisistemi.pdf. 2004. (Accessed: 10.08.2006).

[20] Park S., Oh C., Jeon S., Jung H., Choi C. Soil erosion risk in Korean watersheds, assessed using the revised universal soil loss equation. *Journal of Hydrology*. 2011, 399: 263-273.

[21] Bruinsma, J. World Agriculture: Towards 2015/2030, an FAO Perspective. Earthscan Publications, London, 2003.

[22] Olaniran, O. J. Rainfall anomalies in Nigeria. The contemporary understanding. Paper presented at 55th Inaugural Lecture. University of Ilorin, Nigeria. 2002. (Accessed: 15:10:2016).

[23] Ayaode, J. O. Climate Change. Ibadan: Vantage Publishers, 2003.

[24] Odjugo, P. A. O. An analysis of rainfall pattern in Nigeria. *Global Journal of Environmental Sciences*. 2005, 4(2), 139-145.

[25] Adefolalu, D. O. Climate change and economic sustainability in Nigeria. Paper presented at the International Conference on Climate Change and Economic sustainablility held at Nnamdi Azikwe University, Awka, Nigeria. 12-14 June 2007.

[26] Otterman, J., Manes, A., Rubin, S., Alpert, P. and O'C Starr, O’C. An increase of early rains in Southern Israel following land-use change? *Boundary Layer Meteorology*. 1990. 53, 333-351.

[27] Hayden, B.P. Personal communication, University of Virginia, Department of Environmental Sciences, January, 2002.

[28] Pielke, R.A., Adegoke, J., Beltran-Przekurat, A., Hiemstra, C.A., Lin, J., Nair, U.S., Niyogi, D. and Nobis, T.E. An overview of regional land-use and land cover impacts on rainfall. *Tellus*, 2007, 59, 587-601.

[29] Intergovernmental Panel on Climate Change, Working Group I, 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the IPPC. Cambridge University Press.

[30] Easterling, D.R., Karl, T.R., Gallo, K.P., Robinson, D.A., Trenberth, K.E., and Dai, A. Observed climate variability and change of relevance to the biosphere. *Journal of Geophysical Research*. 2000, 101-114.

[31] Koglo, Y. S., Abdulkadir, A., Feliciano, D. and Okhimamhe, A. A. Efficacy of Integrated Straw Formulations on Lowland Rice Field Organic Carbon and Greenhouse Gas Emissions Using CCAFS-MOT Model in Niger State, Nigeria. *American Journal of Experimental Agriculture*. 2016.

[32] Nearing, M.A., Jetten, V., Baffaut, C., Cerdan, O., Couturier, A., Hernandez, M., Le Bissonnais, Y., Nichols, M.H., Nunes, J.P., Renschler, C.S., Souchère, V., and Van Oost, K. Modeling response of soil erosion and runoff to changes in precipitation and cover. *Catena*. 61, 2005. 131-154.

[33] Park, C.C. The environment: Principles and applications, 2nd edn, Routledge, London. 2001.

[34] Wei W., Chen L., Fu B., Huang Z., Wu D., Gui L. The effect of land uses and rainfall regimes on runoff and soil erosion in semi-arid loess hilly area, China. *Journal of Hydrology*. 2007, 335: 247-258.

[35] Gyssels G., Poesen J., Bochet E., and Li, Y. Impact of plant roots on the resistance of soils to erosion by water: a review. *Progress in Physical Geography*, 2005, 29: 189-217.

[36] Zhongming, W., Lees, B.G., Feng, J., Wanning, L., and Haijing, S. Stratified vegetation cover index: A new way to assess vegetation impact on soil erosion. *Catena*. 2010, 83: 87-93.