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Simulating the Movement of Desertification in Sokoto and its Environs, Nigeria Using 1 km SPOT-NDVI Data

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Abstract: This study simulates desertification in Sokoto and its environs using 1 km resolution Normalized Difference Vegetation Index (NDVI) data from the SPOT instrument. The data was downloaded as ten daily composites. The extracted data of the study area was clipped using the VGTExtract Software. The ten daily composites were initially recomposed to monthly and finally to 13 annual composites (time series) using Maximum Value Composite (MVC) algorithm within the Idrisi Andes GIS environment. The Multidimensional Choice (MDCHOICE) tool of Idrisi Andes was applied on the time series for temporal vegetation dynamism assessment while 1st and 2nd order surface trend fitting were carried out to assess the direction and pattern of desertification. Desertification was categorized by 1 standard deviation to the mean and temporal profiling was also carried out to probe into NDVI values of the time series at curious points. Results show that the inter-annual vegetation vigour exhibited a diminishing trend over the time series. The direction of desertification is North-West to South-East. Site 1 is located at Illela and Bamgi in Nigeria and Site 2 around Koukadin falling in Niger Republic are the worst affected by desertification within the study area. As desertification threatens human survival intensive tree planting around these areas in form of afforestation and establishment of more shelter belts and cattle ranches to curtail indiscriminate grazing, sensitisation of people towards being friendly with the environment and provision of alternative use of energy such as kerosene and gas for domestic uses at affordable prices as well as improvement in distribution and availability as immediate measures were recommended.

Key words: Desertification, multidimensional choice, Sokoto, NDVI, shelter belts, cattle ranches

INTRODUCTION

Desertification results in the decrease of biological productivity, particularly manifesting in vegetation degradation due to climatic changes (like drought) or human activities (like overgrazing) and leads to a long lasting and possibly irreversible degraded state (Hardenberg *et al*., 2001; Mohammed, 2008). Dry-land desertification adversely affects the sustainable relationship between ecosystems and the livelihoods of people worldwide, constituting one of the major environmental challenges of the 21st century (UNCED, 1992).

The Federal Ministry of Environment of Nigeria on national action programme to combat desertification averred that a general consensus exists that desertification is by far the most pressing environmental problem in the dry-land parts of the country although, the extent and severity of this problem has not been fully established neither the rate of progression properly documented. However, between 50 and 75% of the Northern fringe is estimated to be affected by desertification.

A number of studies (Tucker *et al*., 1991; Abubakar, 1998; Fasona and Omojola, 2005; Eniolorunda, 2007; Eniolorunda *et al*., 2008; Yelwa, 2005, 2008) attempted to explain vegetation dynamics and proximate causes wholly or partly covering the study area. Such studies have shown that the extreme Northern part of Sokoto plains is vulnerable to Sahel encroachment. Consequently, the zone has been designated as fragile and hard terms such as desertification, desert encroachment, aridity among others have popularly been used to accentuate the fact that the zone is undergoing serious vegetative disappearance.

The socio-economic and ecological consequences of desertification are said to range from food insecurity, poverty, social conflict, migration to loss of habitat and natural species, among others. With increasing population and consequent increase in human activities

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on the landscape which increases the widening of degraded landmass, human survival is expectedly threatened. Therefore, for ecological sustainability in this era of climate change information on vegetation in the form of remotely sensed data that is both spatially and temporally comprehensive with appropriate resolution is very vital for effective management of the biological resources (Bino *et al*., 2008).

It is in the light of this that this research is being undertaken so as to model the movement of desertification in Sokoto and its environs using 1 km Normalized Difference Vegetation Index (NDVI) from System Pour le Observation de la Terre (SPOT) instrument. The study hopes to bridge the gap between the unknown current vegetative scenario and the existing strategy on ecosystem management.

Aim and objectives: The aim of the study is to simulate the movement of desertification in the study area using 1 km SPOT NDVI between 1998 and 2010. The following objectives are supportive of the aim:

- To assess the inter-annual trend of vegetation vigour
- To map the direction of desertification
- To assess the spatial pattern of desertification

The study area: The study area lies mostly in Sokoto State, extending partly to the North-West of Zamfara State, North East of Kebbi State and the extreme Southern part of Niger republic, covering an area within longitudes 4.0° -7.0°E and 12.0°-14.0°N (Fig. 1). It lies in the Sokoto plains which is a monotonous lowland derived from sedimentary rocks with an average height of 300 m. A large proportion of the region is characterized by sandy soil which is usually low in organic matter, nitrogen and phosphorus and may degrade rapidly under conditions of intensive rainfall (Mortimore, 1989). As a result of human activities in this generally sandy environment, denuded patches may appear when the wind-blown sand becomes mobile.

The average annual rainfall recorded ranges between 400 mm in the North and around 650 mm in the South. Both spatially and temporally, rainfall is unpredictable and unreliable as inter-annual variability measures between 15 and 20% around this area and the temperature locally follows seasonal variation. The highest temperature is usually recorded in April or May, measuring up to 45°C while it can be as low as 20°C in December/January.

Except for forest reserves which comprise trees of 10 m average height, vegetation is mainly of short and unhealthy shrubs and grasses with the grasses measuring <1 m. The study area is drained by the Sokoto-Rima

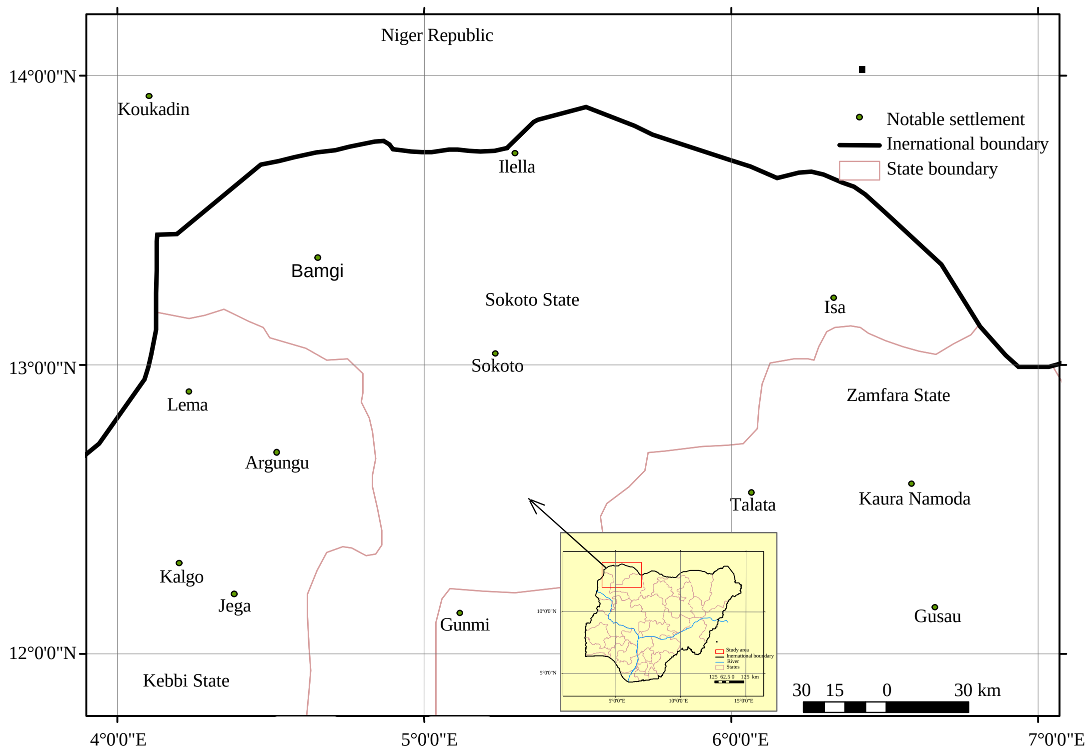

Fig. 1: Map of the study area

river system and it is underlain by sedimentary formation. The flood plain of the Sokoto-Rima river system rich in alluvial soil is cultivated all the year round mainly for vegetables. However, the general dryness of the region allows for cultivation of grains. Livestock production in this area ranks second to that obtained in the North-Eastern Nigeria. Human activities in this area coupled with the climatic oscillation are responsible for the residual vegetation (Yelwa, 2008).

MATERIALS AND METHODS

Figure 2 shows the materials and methods used in this study. About 1 km resolution NDVI derived from SPOT-Vegetation Programme (2001) was downloaded via www.spot-vegetation.com/ as ten daily synthesis sets, dating from the month of April 1998 to December 2010. The VGTExtract Software was also downloaded from the same website so as to extract the whole dataset and to clip the study area. The extracted data sets were recomposed initially into monthly composites and later into annual composites within the Idrisi Andes GIS environment. Hence, the time series used for the study contained 13 annual composites. The Maximum Value Composite (MVC) algorithm however was used to recompose the data sets in order to take care of atmospheric effects that might be intrinsic in the data (Holben, 1986; Bijay *et al*., 2009). The Multidimensional Choice (MDCHOICE) tool of Idrisi Andes was later applied on the time series.

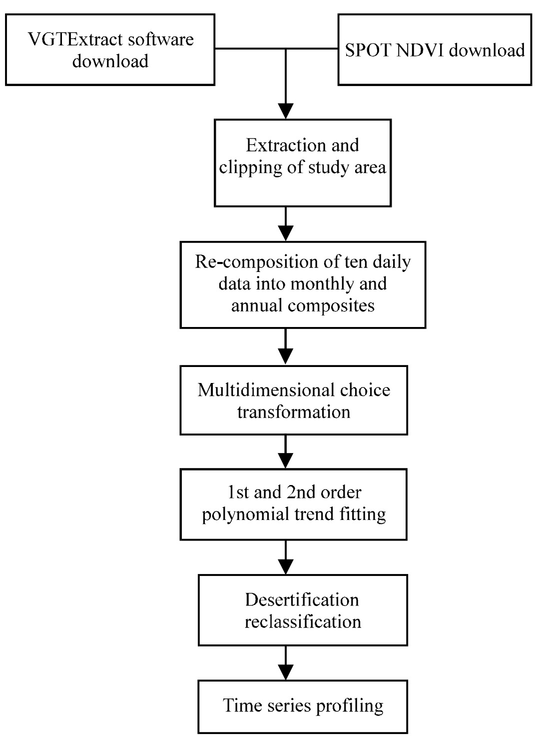

Fig. 2: Materials and methods

MDCHOICE is a procedure that produces an output map indicating which of a series of input maps has the highest value for each cell. In each year, one of the images must show the areas with the maximum vegetation vigour (highest value pixels). Thus, the output map and an attendant graph show the temporal vegetation dynamism in the study area between both dates. To model the direction of desertification, the time series was subjected to the 1st order trend surface analysis. The 2nd order however, simulates the pattern of desertification over space. Trend calculates the best-fit trend surface between pixel values and their positions within the image.

RESULTS AND DISCUSSION

Figure 3 shows the output of the multidimensional choice applied on the NDVI time series. The map shows for each year where the vegetation was most vigorous. The vegetation was most vigorous in the areas of red colour in 1998 (areas of highest NDVI values for 1998) whereas in 1999, vegetation vigour was limited mostly to the top-left corner (light yellow colour area). This inconsistent pattern of vegetation vigour confirms the sensitivity of NDVI to spatio-temporal rainfall variation. The areas of the classes in Fig. 3 were plotted in Fig. 4 to demonstrate the inter-annual variation in vegetation vigour. The result shows a downward trend of vegetation vigour. The implication of this trend is that with time, vegetation vigour will continue to diminish. The direction of vegetation degradation as generated by the first-order polynomial is shown in Fig. 5. The result shows that degradation maintains a North-West to South-East directional movement.

Figure 6 shows the result of the second-order polynomial trend fitting. The output shows the spatial pattern of desertification, thus demonstrating the spread of desertification. Most affected places are located North-East of latitude 13.0 N. More than half of Sokoto State is affected while Kebbi and Zamfara States experience relatively lower measure of desertification. Figure 6 was classified over space using 1 standard deviation from the mean. The standard deviation and the mean were generated from Fig. 7 which is the histogram of Fig. 6. These descriptive statistical values were used for classifying Fig. 6 to produce Fig. 8 using the following equation:

$$\bar{X} \pm \sigma$$

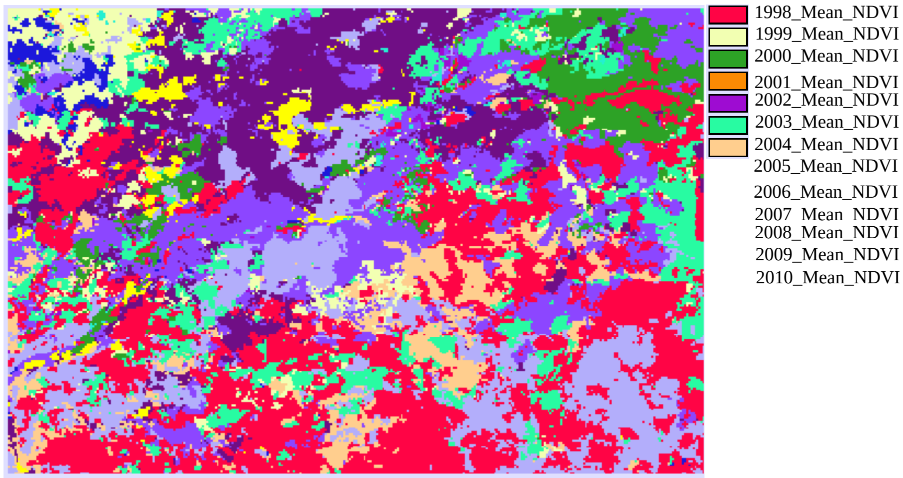

Fig. 3: Spatio-temporal vegetation variation

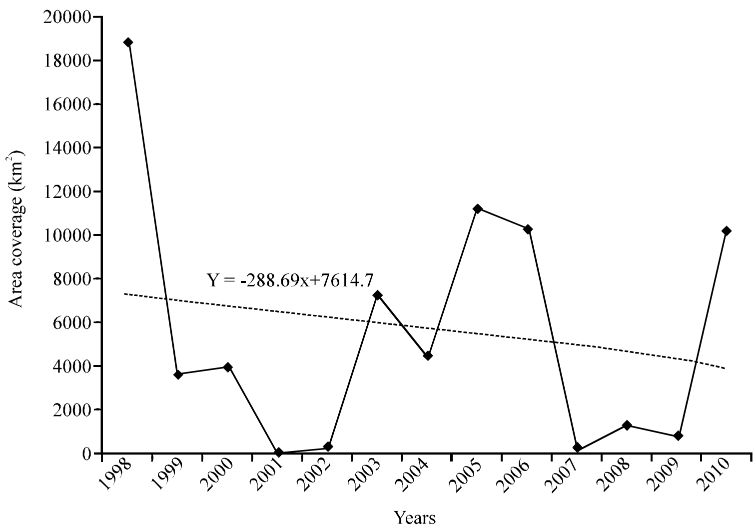

Fig. 4: Vegetation temporal trend

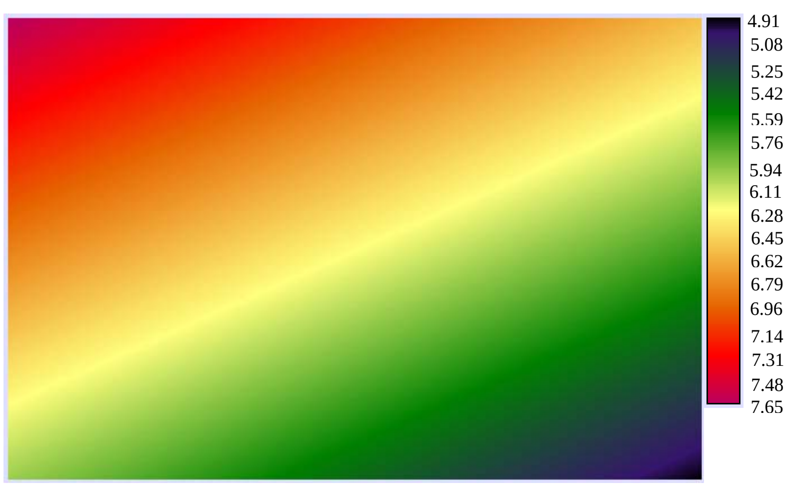

Fig. 5: Direction of desertification generated by 1st order trend

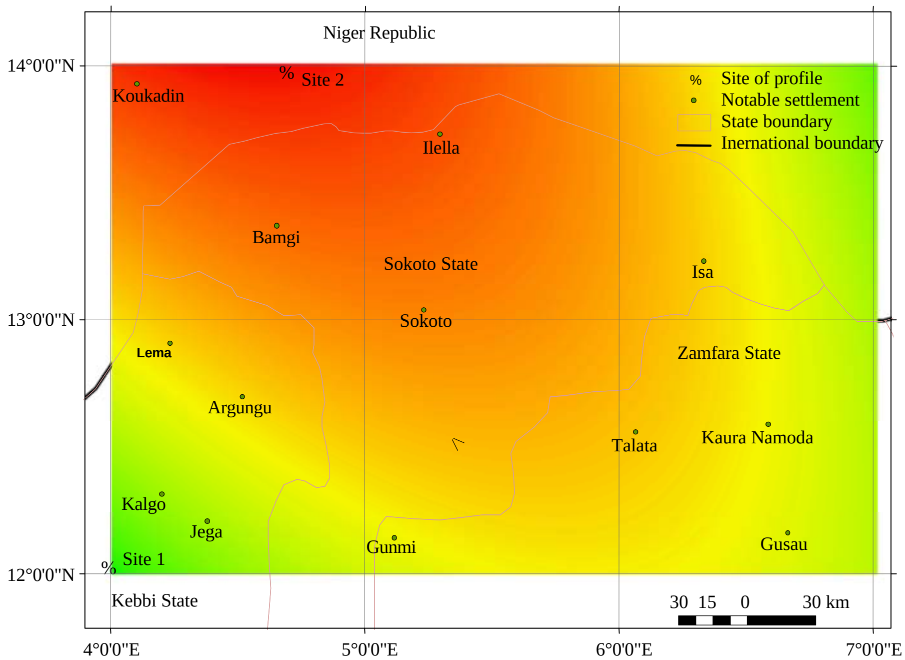

Fig. 6: Spatial pattern of desertification generated by 2nd order trend

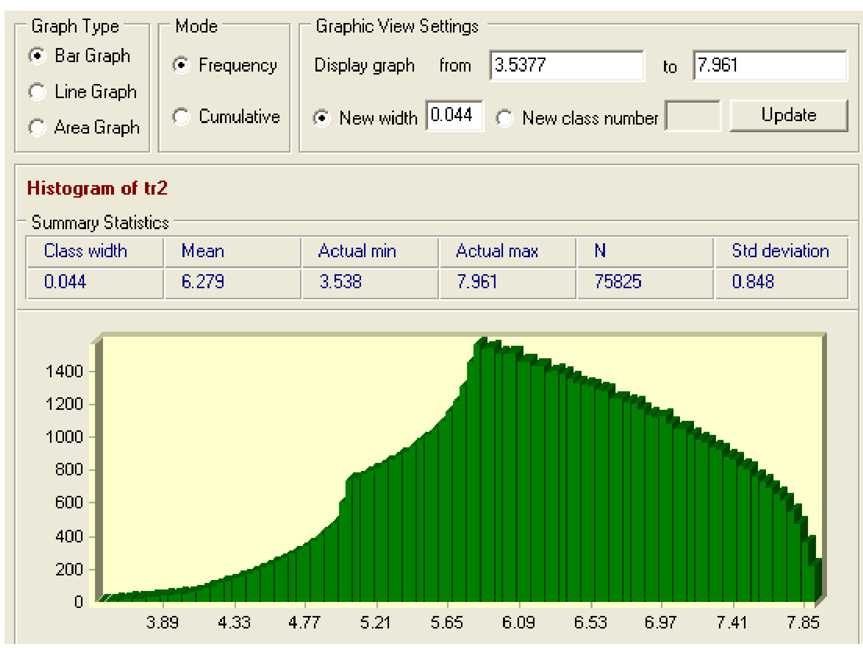

Fig. 7: Histogram of pixels in the 2nd order trend output

Where:

$\overline{x}$ = The mean

σ = The standard deviation

For this study, the mean and standard deviation values are 6.279 and 0.848, respectively. The computation using the equation yields 5.431 and 7.127. Thus, pixels with <5.431 were classified as low. Such areas are Kalgo, Jega, Site 1 and area East of Kaura Namoda and Gusau. Those with values between 5.431 and 7.127 were classified as moderate. Such places are Sokoto, Lema, Gummi, Gusau, Kaura Namoda, Argungu, Talata Mafara

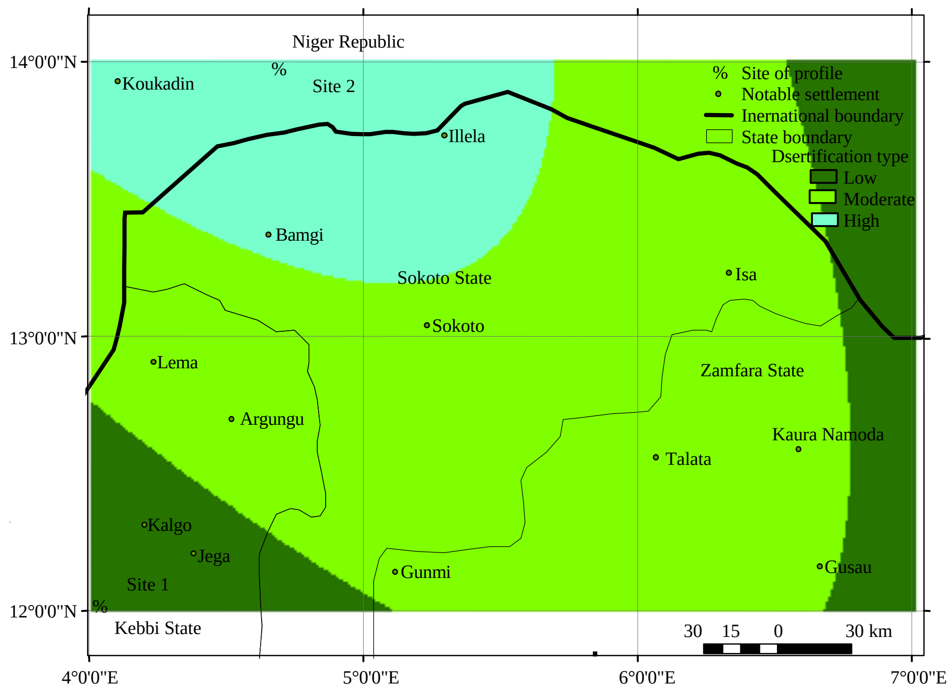

Fig. 8: Reclassified desertified area using 1 standard deviation from the mean

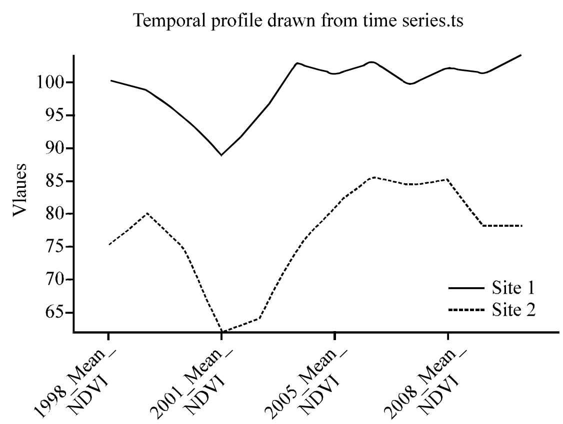

Fig. 9: NDVI Time series profile for Sites 1 and 2

and Isa. Areas with values >7.127 were rated high. This include areas around Illela and Bamgi in Nigeria and Site 2 around Koukadin falling in Niger Republic. Although, Eniolorunda and Bello were of the view that the areas North of 4.58° and 4.97°E and latitudes 13.31° and 13.52°N are either bare or rendered bare due to the combined effects of climate and anthprogenic activities such as cultivation, animal rearing, fuel wood extraction, bush burning among others.

The study by Eniolorunda (2010) and the ground truthing carried out also attested to the fact that it is really a very dry zone with exposed soil surfaces with some shrubs and grasses in some areas. Figure 9 shows the result of temporal profiles of the NDVI time series at Sites 1 and 2 of Fig. 6. Site 1 shows greener vegetation status than Site 2.

CONCLUSION

This study revealed that the study area is plagued by desertification which creeps in a North/West-South/East direction. Desertification has serious consequences that threaten human survival. It is therefore recommended that massive tree planting afforestation programme should be embarked upon in affected areas with more shelter belts. Communities around these areas should also be educated towards becoming more environment friendly as the effects of desertification normally have very enormous negative consequences.

The government should provide kerosene and gas for domestic uses at affordable prices as well as improvement in their distribution and constant supply. This should be matched with establishment of cattle ranches to curtail indiscriminate grazing which results in vegetation degradation and eventual loss in soil fertility. As the major consumers of vegetal resources are in the towns and cities of the study area, appropriate laws should be enacted and should be enforced by relevant authorities.

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