THE IMPERATIVE OF SAND DUNE STABILIZATION IN SEMI ARID ZONE WITH FOCUS ON JIGAWA STATE, NIGERIA

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ABSTRACT

Increasing climate variability has increased desertification process in the drylands of Nigeria which make sand dune stabilisation imperative. This study focuses on the menace of sand dune and its stabilisation process in Jigawa state. Sand dune is an accumulation of sand usually in a dry or coastal environment. The extreme Northern part of the country has been experiencing a devastating with the problems of Sand dunes. This research aimed at analysing sand dune stability in the study area. Two different methods of dune stabilisation were used for this study these are Biological and Mechanical. In the Biological three exotic, resistant and fast growing tree species were selected and sorted out for planting. These species include Azadirachta indica, Acacia senegal and Eucalyptus camaldulensis. While the in the Mechanical methods fences are erected at right angle to the prevailing wind direction and at a distance of not more than 2.5 meters on the windward side. The result shows that Biological method is more effective than the Mechanical and that Eucalyptus camaldulensis was found to have performed better than the other species with about 77.30% of survival rate. The study recommend for more studies on the other species that will tolerate the hash condition for survival and also there need for more studies using GIS and Remote sensing to deterring their movement particularly the direction.

Key words: Biological, Climate, Mechanical, Sand dunes, Stability,

INTRODUCTION

Sand dune formation through desert encroachment is one of the serious ecological disasters facing the arid and semi-arid zones of northern Nigeria, an area comprising of Borno, Yobe, Sokoto, Zamfara, Katsina, Jigawa, and Bauchi states. History revealed that present location of the sand dunes in some of this areas were formerly occupied by human settlements but had to be vacated when dunes movement become threatening. Sand dune formation in this zone is accelerated by strong wind and erosion caused mainly by Tropical continental air mass popularly known as North-east trade winds. The area has poor vegetation and the soil particles are dry and loose (Akinbami, Salami and Siyuoanbola, 2003).

Average temperature is generally higher than world average for similar latitudes during the months of April to early June. Temperature of over 43^0C in the zone is common compared to 33^0C at the peak of rainy season from July to August. Atmospheric humidity in the area is very high with an average of about 90 percent are common during the rainy season as far north as 18^0N while mid-afternoon figures of below 16^0C are frequent during the driest period of the year from November to February. Strong dry and dust add North-East winds prevail during the long dry season which lasts for four to five months (Mackenzie and Mackenzie, 1995).

Extent of Sand Dunes in Northern Nigeria

Sand dunes increased by approximately 17 % from 820 km^2 to 4,830 km^2 (FMEnv, 2008). Some villages and major access roads have been buried under sand dunes in the extreme northern parts of Bauchi, Katsina, Sokoto, Jigawa, Borno, Yobe and Zamfara states (see Fig. 1). In addition, many rivers and lakes have been silted up, leading to rapid drying up of water bodies after the rains. Gully erosion, that hitherto was not a major threat, increased, threatening about 18, 400 km^2 (compared to only 122 km^2 in 1976/78) (FMEnv, 2005, 2008).

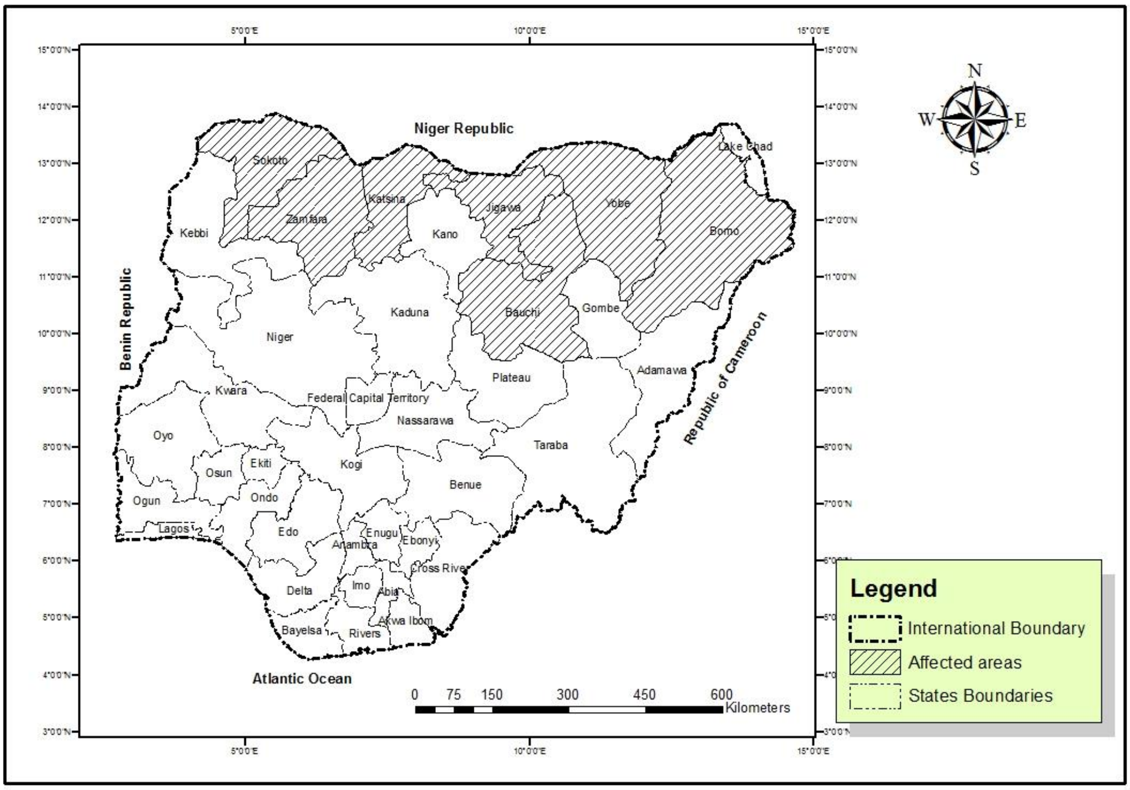

Fig. 1: Northern Nigeria Showing Areas Predisposed to Desertification

It has been estimated that between 50% and 75% of the 11 frontline states of Nigeria are under severe threat (FMEnv, 2005). These states, with a population of about 35 million people account for about 35% of the country’s total land area. The pressure of migrating human and livestock populations from these states are being absorbed by buffer states (Benue, Kaduna, Kogi, Kwara, Nasarawa, Niger, Plateau and Taraba) and FCT in the North to central part of the country, resulting in an intensive use and degradation of the fragile and marginal ecosystems of these areas (FMEnv, 2005, 2008).

Studies have shown that the length of the rainy days in the area is declining in response to climate fluctuation of normal rainfall. The pressure point buffer states are reported to have about 10% to 15% of their land areas threatened by desertification. It is estimated that the country, on the whole, is currently losing about 351,000 hectares of its landmass to desert conditions annually, and such conditions are estimated to be advancing southwards at the rate of about 0.6 km per year (Tiffen and Mortimore, 2002, FGN, 2004; Wood and Yapi, 2004).

Dune activity is typically viewed as an index of aeolian sand transport potential (Ash and Wasson, 1983; Lancaster, 1988). The term dune activity and dune mobility are often used synonymously, but a case can also be made to treat them more distinctly (Thomas, 1992; Lancaster, 1994). For instance, describing a dune as having high mobility, or simply being mobile, is inherently suggestive that the dune is demonstrating migratory movement. Not all types of dune, however, migrate. In terms of characteristic behaviour dynamic linear dunes typically extend while star dunes accumulate (Thomas, 1992; Livingstone and Thomas, 1993).

Sand dunes form some of the most spectacular and dynamic landforms on the planet. Individual sand granules (grains of sand) accumulate through water and wind (eolian) transportation, a process known as saltation. Individual saltating granules form transversely (perpendicular) to the wind's direction forming small ripples. As more granules collect, dunes form. Sand dunes can form in any landscape on Earth, not just deserts (Rudolphy, 2013).

To some extends in other places sand dunes are common features of shoreline and desert environments like the Namibian desert that is situated along the shoreline. Dunes provide habitat for highly specialized plants and animals, including rare and endangered species. (Scottish Natural Heritage, 2009).

Sand Dunes and Climate Change

According to Tsoar (2004) it is obvious that all fixed dunes were active in the past and became stabilized when their climate changed. Most scientists refer to climate change as a change in rainfall and temperature, which are the two important climate elements that affect vegetation growth (Houghton, 2001). The concept of active dunes formation under arid conditions and natural fixation during wet periods is based on the known interaction of temperature with precipitation as an important determinant of the average annual net primary biomass production (Lauenroth, 1976). For this reason, it is expected that sand dunes in hot deserts would be devoid of vegetation and active, while the dunes along the coasts of humid areas would be vegetated and stabilized. However, there are many examples of active sand dunes in humid areas (Hunter, Richmond and Alpha 1983; Jimenez *et al.*, 1999) and stabilized dunes in arid areas (Tsoar and Blumberg, 2002).

The increasing temperature and decreasing rainfall have led to frequent drought and desertification. The Sahara desert is observed to be expanding to all directions trying to engulf the Sahellian region of Africa with annual expansion of 1-10 km (In Gorge (2012) Odjugo and Ikhuoria 2003; Yaqub 2007). Odjugo and Ikhuoria (2003) also observe that northern Nigeria is under severe threat of desert encroachment and sand dunes are now common features of desertification in some northern states. The migrating sand dunes have buried large expanse of arable lands, thus reducing viable agricultural lands and crops' production.

Sand dunes cover vast land areas and are located primarily in arid regions (Ashkenazy, Yizhaq and Tsoar, 2009). These large areas concentrated in Africa, Australia, and Asia with about half of them exhibiting stable, fixed configurations. Most of the currently fixed dunes were active during the last glacial maximum (e.g., Hesse *et al*. 2003; Stone and Thomas 2008) when the weather was colder and drier and air turbulence was stronger (e.g., Harrison *et al.* 2001; Duller and Augustinus, 2006).

Ashkenazy *et al*, (2009) assumed that wind power (wind erosion) is the limiting factor for vegetation stability on sand dunes and that dune vegetation can exist only when precipitation is above a minimal threshold of about 50 mm/year (Danin 1996; Tsoar and Blumberg 2002; Tsoar 2005). Above this value, an increase in precipitation up to 370 mm/year (Sala *et al*. 1988) leads to denser vegetation and, therefore, to increased dune stability. When precipitation is above 400 mm/year, the extra water has only a moderate effect on dune vegetation because the plants already have sufficient water to develop.

Several studies have shown how Sand dunes are affected by climate change using aerial photos and Satellite imageries. Recent advances in image-based cross-correlation methods demonstrate the potential to derive more objective measurements of dune form movement (Vermeesch and Drake, 2008). The technique involves sub-pixel correlation of co-registered images, which yields a velocity field of dune displacements, and can also be used to derive an estimate of sand flux.

Another study show that digital topographic data was used from hardcopy aerial photographs in order to resolve three-dimensional changes associated with dune activity (e.g., Brown and Arbogast, 1999). Brown and Arbogast (1999) applied digital photogrammetric methods to scanned stereographic aerial photographs in order to quantify erosion and deposition at a dune complex along the eastern shore of Lake Michigan. Despite relatively poor accuracy in the digital elevation models produced by the photogrammetric models the data provided a reasonable estimate of coarse-scale topographic changes during the time span between photographs (1965-1987).

New technologies allow direct collection of topographic data and improved spatio- temporal resolution. LiDAR was used to resolve volumetric changes in dune fields. Woolard and Colby (2002) used LiDAR data acquired in 1996 and 1997 to calculate volumetric changes of coastal dunes at Cape Hatteras, North Carolina, USA. Mitasova *et al.* (2004) investigated short-term dune activity changes at Jockey‟s Ridge, North Carolina, USA, by combining annual LiDAR elevation data (1997-2000) with quarterly field based RTK GPS measurements. In addition to quantifying dune volumetric changes and migration, Mitasova *et al.* (2004) verified the effectiveness of dune mitigation strategies (sand fences) erected to slow dune migration and force an increase of dune height. Collectively, these investigations show the potential of monitoring dune activity changes with LiDAR. Away from coastal settings, dune form transition has been studied at White Sands Dunefield using LiDAR (Reitz *et al.*, 2010).

STUDY AREA

The area is located between latitudes $9^0$31'58" N to $9^0$42'31" N and longitudes $12^0$47'17" E to $12^0$53'11" E. Maigatari in Jigawa state is one of the commercial area that links Niger Republic and Nigeria. Maigatari is bordered to the North with Niger republic, to the East with Mallam Madori and to the South with Gumen and Gagarawa, while to the West with Sule Tankarkar LGAs (see Fig. 2).

The state has a total land area of approximately 22,410 square kilometres. Its topography is characterized by undulating land, with sand dunes of various sizes spanning several kilometres in parts of the State. Total forest cover in the State is very much below national average of 14.8% (C-GIDD, 2008). The climate of the state is semi arid, characterised by a long dry season and a short wet season. The climatic variables vary considerably over the year and are erratic. The temperature out regime is warm to hot. The mean annual temperature is about 25°C but the mean monthly values its range between 21°C in the coolest month and 31°C in the hottest month. However, the mean daily temperature could be as low as 20°C during the months of December and January when the cold dry harmattan wind blows from the Sahara Desert. Evapo-transpiration is very high and relative humidity is highest in August (up to 80 percent) and low in January through March (23 to 30 percent) when it is moderated by the harmattan. The year is characterised by well marked dry and wet of seasons.

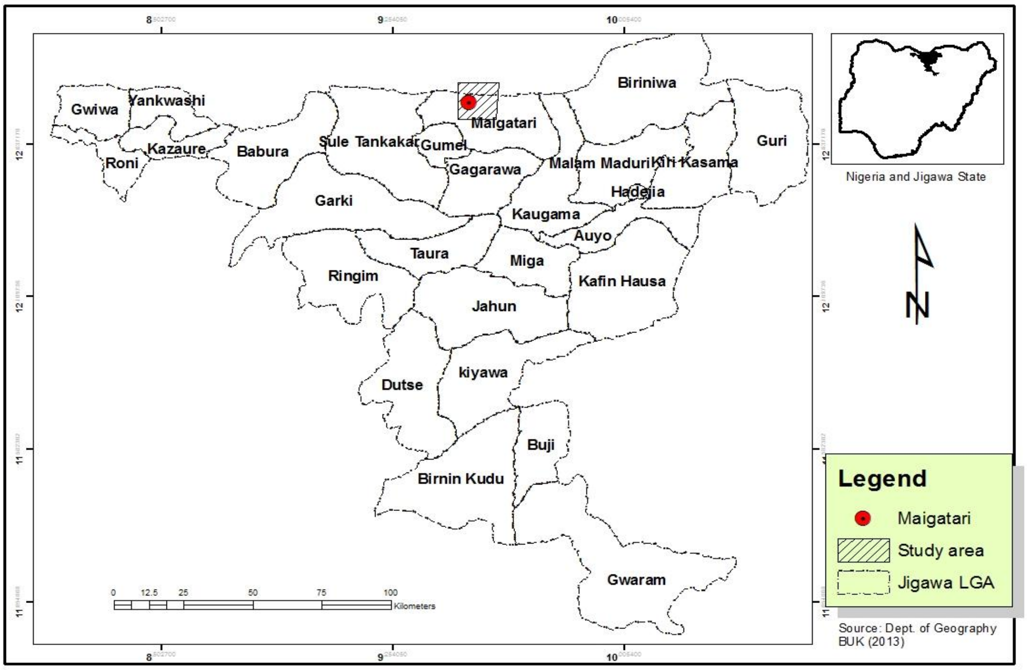

Fig. 2: Jigawa State and the study area

Wet season is roughly four months (June to September) and dry season is seven to eight he months (October to May). The rainy season may of start in May but early rains in April are not unusual. The bulk of the rainfall comes in June through September. Violent dust storms followed by tornado and lightening, usually herald the onset of the in rains in May/June and their retreat in September or early October. The total annual rainfall ranges from 600 mm in the north to 1000mm in the southern parts of the state. Great variations occur in the in annual total rainfall and may result in severe and prolonged droughts, which cause crop failures that affect livestock (www.onlinenigeria.com*)*

The migrating sand dunes have buried large expanse of arable lands, thus reducing viable agricultural lands and crops' production. This has prompted massive migration and resettlement of people to areas less threatened by desertification. Such migration has resulted in increasing spate of communal clashes among herdsmen and farmers (Yugunda, 2002; Yaqub, 2007). The major ecological problems in Jigawa state are drought, desertification and the menace of soil and wind erosion which is attributed to sand dunes movement (C-GIDD, 2008).

The area has been encountering problems caused by the sand dunes. Sand dune movement which is a serious environmental and social hazard especially in the fragile environment like the study area. These research therefore aim at examining the relevant of sand dune stabilization. Therefore there is need to control the sand dune advancement in order to minimize the disaster caused by it.

MATERIALS AND METHODS

An area occupying about 3 hectares was delineated and fenced about 49.4 meters high the fencing was to restrict grazing animals from entering the sand dune site. Although there are several methods of controlling sand dune movement, two technique of sand dune stabilization were adopted. These include biological and mechanical method.

Biological Methods

As sand dunes are known to be common in areas where the soil is dry, loose and exposed to environmental factors like, a temporary or permanent stabilization of dunes can best be achieved by the establishment of a shelter belt. This is thus the biological method.

In the study area, three exotic, resistant and fast growing tree species were selected and sorted out for planting. These species include *Azadirachta indica*, *Acacia senegal* and *Eucalyptus camaldulensis.* The three species were planted round the horns and on top of the dune in April, 2009 during field work. Supplementary watering was done for two months before the on-set of rainfall and during the dry season in the following year 2010 by some members of the local population.

At the horns of the dune, a kind of green belts, were established at an angle perpendicular to the prevailing wind direction that is tropical continental air mass or north-east trade wind. This was aimed at reducing the effects of the wind thus minimizing sand movement. The green belt was also designed as wind break to protect the village around.

The second biological method involves the stationing of cattle in a place for two or more weeks. The accumulated cow dung act as root-binding system and encourage the growth of organism and grasses. This also helps in tackling the effect of drifting and accumulation of sand. Complete sand dune stabilization could hardly be achieved by the use of biological method alone. This is because some seedlings may not survive and cannot alone prevent the movement of sand. The young seedlings therefore need to be protected against deflation of sand from the root and accretion (the drifting and accumulation of sand in different places). This therefore brought about the need for the third method, thus, mechanical technique.

Mechanical Method

This method involves the use of bags of sand fences which serve as an obstacle which when placed in the direction and or track of a sand-laden wind will influence the channels of flow by either increasing wind speed or reducing it. The fences are usually erected at right angle to the prevailing wind direction and at a distance of not more than 2.5 meters on the windward side of the young seedlings that are being protected. The fencing materials are cut at different heights depending on the location and need. Compression of wind flow will take place in the existing gaps between the obstacles or at the side of an obstacle resulting in an increase in wind velocity. Little or no sand will therefore be deposited in those gaps, except for a few distances down wind. This approach can be employed deliberately to keep some specific places free of sand.

More so, sands are deposited around an obstacle sometimes due to turbulence which reduces wind speed and its carrying capacity. Two types of fencing materials have so far being used. These include pre-fabricated and twigs fencing materials; they were arranged at right angles to the prevailing wind direction and firmly fixed to the ground by digging.

In the case of pre-fabricated, they are made up of guinea corn stalks woven together by binding wire or rope cut to a height of 1.9m. There are normally fixed by the ground at right angle to the prevailing wind direction and firmly trapped to the ground. Sand is largely deposited at the sides of the fence to due to reduction of wind speed.

Twigs fencing materials were improvised by cutting the floral part of twigs or shrubs up to 20 meters high or more. They are also arranged at right angles to the prevailing wind direction and appropriately trapped to the ground by digging and trapping. This type of fencing would have been the most ideal technique had it not been for the fact that its construction leads to the depletion of the eco-system of the affected areas especially in a fragile environment. Sand dune movements are known to be influenced by the nature of soil stabilization of dunes can best be achieve by establishing of negotiation cover of the affected area.

RESULTS AND DISCUSSION

Establishment of shelter belts and other wind-break mechanisms were found to have contributed significantly to the management of sand movement. They greatly reduce the speed and force of the prevailing wind by acting as barriers or wind break, hence minimizing the sand carrying capacity of the prevailing wind.

Even though three different types of tree species were used in addition to mechanical method for the prevention of further sand dunes movement, *Eucalyptus camaldulensis* was found to have performed better than other species. It has a great chance of survival percentage of 77.3% and a height growth of 2.9m when compared with *Acacia senegal* and *Azadirachta indica* which have 43.5 and 39.8% survival and mean height growth of 2.08 and 1.3m after 3 ½ years.

Sand fencing was found to be effective for the growth and protection of seedlings planted around sand dune site. Preliminary assessment revealed that the village houses were to some extent protected and agricultural planted crops were found to be performing.

CONCLUSION

Studies have shown that rainfall in the area is declining due to the climate change and poor vegetation covers in the area. Sand dune activities are serious issues in the extreme Northern part of the country. The study concludes that the use of mechanical and biological methods help in restoring some areas of the land. However, the biological method is more protective than the other especially using the tree species that can adopt the harsh condition of the area. Species that were used in the area includes; *Eucalyptus camaldulensis, Acacia Senegal* and *Azardirachta indica*. Nevertheless, *Eucalyptus camaldulensis* was found to be more protective than the other species.

Therefore, the study recommend for;

i. More studies should be carried out using other species of trees that will be used in the area which can adopt the harsh condition.

ii. There is need for more studies in the area using remotely sensed data like the Satellite images which will be analysed temporally in order to find out the nature of their movement (sand dunes).

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