British Journal of Environmental Sciences
Vol.10, No.3, pp., 16-39, 2022
ISSN 2054-6351 (print),
ISSN 2054-636X (online)

Desertification Severity in Sudan Sahel, The Medalus Model and a Peep into the Future: A Case Study of Zamfara State, Nigeria

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Citation: Felix Ezeh and Ayo Omotayo (2022) Desertification Severity in Sudan Sahel, The Medalus Model and a Peep into the Future: A Case Study of Zamfara State, Nigeria, *British Journal of Environmental Sciences*, Vol.10, No.3, pp., 16-39

ABSTRACT: *The Sudano-Sahelian Region is fast losing its status as being on the fringe of the Sahara Desert to becoming a part of the desert given the rate of the Saharan expansion in the region. The traditional method of combating desertification only after it has set in has not proven to be effective. A measure that entails the determination of desertification severity of and direction in a place seems to present a more suitable solution to the malaise. This study tends to combine the use of a regression equation and environmentally sensitive area index (ESAI) of the area to project desertification severity of the region in ten years.*

KEY WORDS: sudano-saheian region, desertification, medalus template, regression equation

INTRODUCTION

The French Botanist, Andre Aubreville, was credited with the coinage of the term desertification (Aubreville 1949). He described it as the changing of a once productive land into a desert as a result of ruination of land by man-made soil erosion. Glantz, (1994) described it as a process that has a series of incremental changes in biological productivity in arid, semi-arid and dry sub-humid ecosystems while the United Nations described it as a process of land degradation in arid, semi-arid and dry sub-humid areas caused by changes in climatic factors, human and animal activities (UNCCD 2004).

The issues of desertification have also been described, in various ways, by many authors. Ceylan, (2009), Guo *et al* (2011), Geist and Lambin, (2004), Narrallah and Ballings (1995), Wu and Long, (2002), Medugu, *et al* (2009) and Gbahobo, (2011) listed population growth, urbanization, demographic features, technology, water use trends, governmental policies, farming, social life, changes in precipitation, temperature, wind and environmental habits as causal agents and argued that the resultant effects are reduced land productivity, hunger, depressed economy and conflicts. In the face of its grave impact on the lives of the people therefore, desertification containment is of utmost importance. Enabor and Popoola, (1994) classified desertification-causing factors into Natural and Anthropogenic factors.

Natural Factors

Rainfall is related to the amount of water vapour in the atmosphere. This water vapour falls back to earth as precipitation. Water loss to the atmosphere is from the earth surface via

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Journal level DOI: https://doi.org/10.37745/bjes.2013

evaporation as well as plants via transpiration (jointly referred to as evapotranspiration). Chenery, (1974) explained that water loss to the atmosphere through evapotranspiration is returned back to the soil as precipitation and encourages further vegetation growth. Scones, (1996) noted, however, that desertification could result if there is an imbalance whereby water loss to the atmosphere is higher than precipitation. Temperature changes and wind systems are other natural causes of desertification.

Anthropogenic Factors

On the other hand, anthropogenic factors are those that result from activities of man and animals.

Man, through his activities such as over cultivation, over grazing, excessive irrigation, deforestation, and urbanization, adversely impacts the ability of land to capture and hold water. In his strive to solve his economic problems, man has continually increased the chances of desertification (Brahic, 2007). He further argued that these human attempts to exploit the resources of the semi-arid ecosystems set the stage for ecological damage that often results to desertification. UNCCD, (2004) observed that the paucity of forage, which has led to overgrazing of available grasslands beyond their carrying capacity, is a major cause of desertification. The situation has been further aggravated by the increase in human population.

Growing practices of slash-and-burn and other methods of subsistence farming, necessitated by famines in less developed countries, are other causes of desertification (Olarenwaju *et al*, 2002). Examples of this extreme outcome can be seen in most parts of Northern Nigeria where a large per-cent of the Region's total land mass has become barren, sterile land.

In some areas, nomads moving to less arid areas disrupt the local ecosystem and increase the rate of erosion of the land. Nomads, typically, try to escape the desert but, because of their land use practices, they bring the desert with them (Okorie, 2003).

Desertification Containment in Sudan Sahel

Desertification has been found to be deleterious to the very existence of man. The UNEASC (2007) reported that the impact of desertification in Nigeria is quite grave to the extent that it poses a serious threat to life. Medugu *et al*, (2007) reported the shrinkage of available land for farm and the degrading of aesthetics space. According to Bogumil, (2012), the visible sign of this phenomenon is the gradual conversion of woodland and tall grass savannah to short grass savannah.

To avert the effects of desertification, both farmers and the government have embarked on efforts to assure survival. The farmers have embarked on various agricultural systems such as shifting cultivation, crop rotation etc. Government on its part has established shelter belts along the desert fringes under the World Bank assisted afforestation programs. Regrettably, this has not been particularly effective as residents continually exploit these for firewood.

Generally, efforts at desertification containment, in the Sudano-Sahelian Region, had tended to revolve around determining the causal factors and taking steps to mitigate them. This resulted in attention been directed to the two main causal factors. Following more studies, however, we now know, for instance, that anthropogenic factors, more than natural factors, are

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responsible for desertification (Milich, 1997). Further advances have also been made that isolated organic matter and free-range farming as the anthropogenic factors that most affect the desertification process in the area (Ezeh and Omotayo, 2020).

Clearly, it is not enough to identify the causal factors and to go on to mitigate them. Perhaps more important is being able to forecast desertification occurrence in time and intensity. For instance, if the direction of the desertification process of a place is known and its intensity area coverage established, it will be possible to project where its spread will get to in a given time in future. This will ensure that appropriate solutions are applied in terms of quantity and type.

Studies on desertification in the Sudano-Sahelian Region seem to be devoid of empirically determining its severity and projecting into its future direction. Being able to situate the severity of desertification would make it possible for a correct measure of solution to be deployed in the containment process. On the other hand, projection of its direction would ensure that enough preventive measures are mobilized against occurrence/spread. Clearly, a combination of the two measures would, most likely, help to adequately deal with the problem of the advancing Sahara Desert with respect to the Sudano-Sahelin Region. Consequently, the aim of this study is to determine the future status of desertification severity of the Sudano-Sahelin region, in ten years, if the present land use methods subsist. This shall be done by:

- Determining how anthropogenic factors bring about desertification in the area.
- Establishing the desertification severity of the area at this point in time and,
- Projecting the desertification severity of the area in ten years.

MATERIALS AND METHODS

Study Area Description

The Sudano-Sahelian Zone is a term used to describe the area embeded by the Sahel and Sudan savannas. It stretches from the Atlantic Ocean in the West to the Red Sea in the east. It covers most of the southern parts of some northern African countries, Central African countries and northern parts of some West and East African countries.

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

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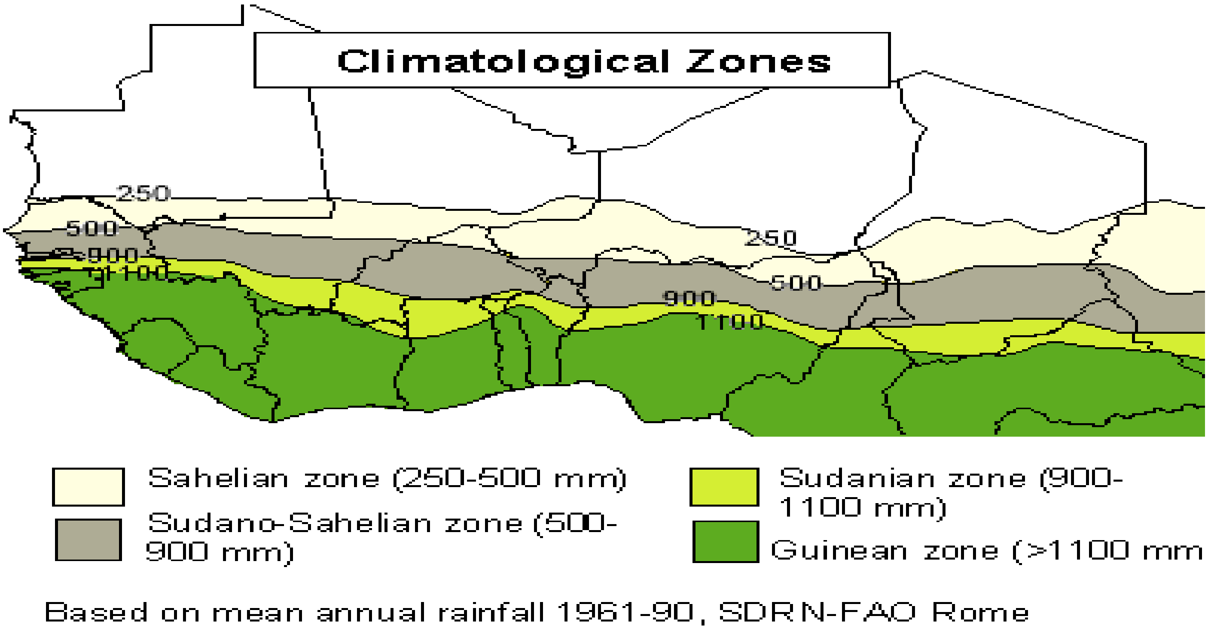

Fig 2: MAP SHOWING THE SUDANO-SAHEL BELT
Source: FAO (1999). Sahel Weather and Crop Situation. Corporate Documentary Repository

It has a tropical semi-arid climate with its lowest temperature put at about 18^{0}C and the highest at over 50^{0}C. Its annual precipitation is generally below 600mm. The rainy period is between 5 months in the Southern Sudan savannah and 3 months in the northern Sahel area while its dry season spans anywhere between 7 and 9 months (Adeaga, 2002 and Kandji *et al*, 2006). The vegetation is characterized with grass and scattered wood trees and shrubs that are deep-rooted with feathery leaves. It is also home to grazing animals and large predators. The aridity of the area is therefore so severe (Ati *et al* 2007, Kandji, *et al* 2006, Abaje et al 2013, Olatunde 2012).

Agriculture in the region features the production of grains such as cotton, maize, millet, sorghum and groundnut. These are short tenured crops, which are capable of completing their life cycles within the short rainfall regime of the area. But for the deteriorating environment, occasioned by desertification, the region was reputed as a major source of grains (Olatunde, 2013).

In Nigeria, twelve of the Nigeria's nineteen northern states are either entirely or partially embeded in the Sudano-Sahelian region and therefore share the same climatic, cultural and even religious characteristics as the Sudano-Sahelian region. The states are Kebbi, Sokoto, Zamfara, Katsina, Kano, Jigawa, Bauchi, Gombe, Yobe, Borno, Adamawa and Kaduna states. Randomly, Zamfara state was picked for the study.

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Journal level DOI: https://doi.org/10.37745/bjes.2013

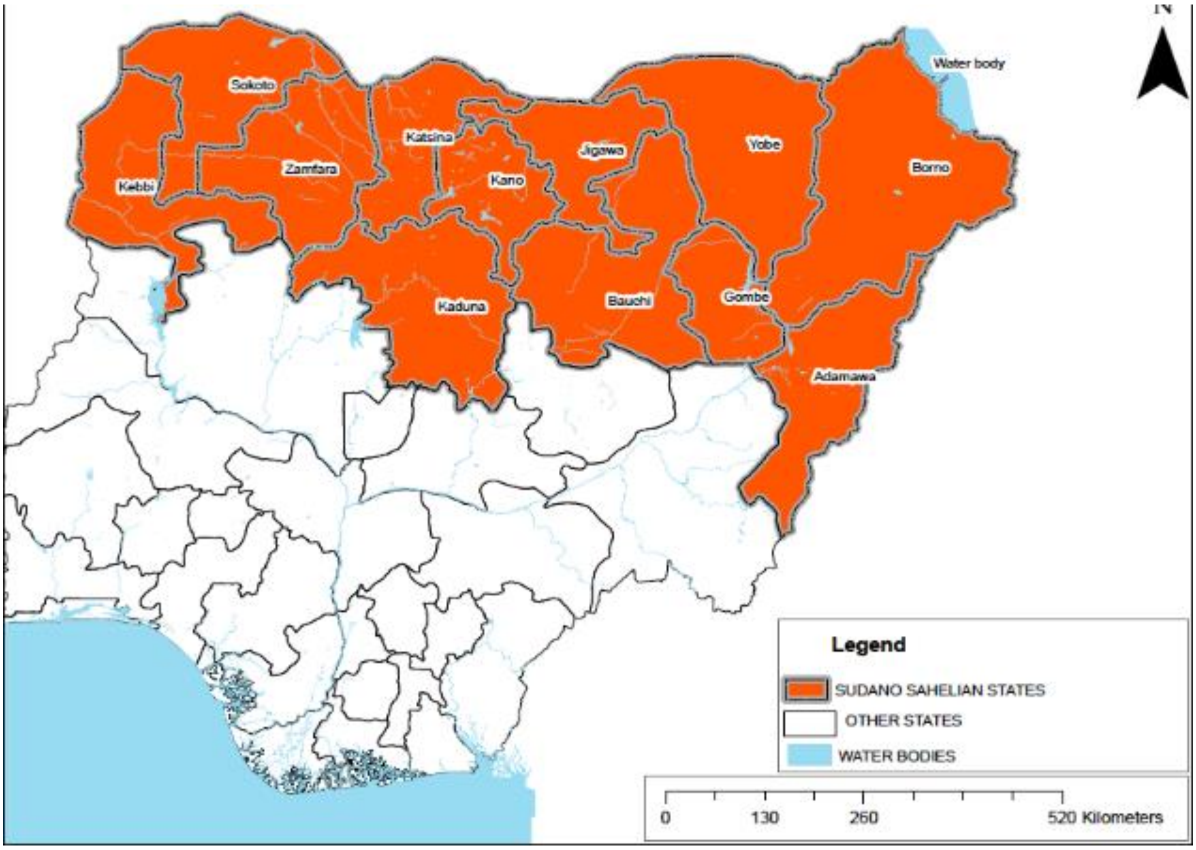

Fig 1: SUDANO-SAHELIAN NIGERIAN STATES
Source: speshworld.com (7/03/2014)

Data Collection

This study has two sections namely: the survey wherein a structured questionnaire is administered to 500 farmers (respondents) and an experiment where soil samples are collected for lab analyses and observation of the area carried out.

The Survey

Sampling

The population of the study comprises all registered farmers in Zamfara State. This includes the large and small-scale farmers. These farmers bear, directly, the effects of desertification in their everyday activities. So, they provided their assessment of perception and impact of desertification. Interaction with them and examination of their environment revealed their level of poverty, their source of energy, their preferred agricultural practices etc.

The Experiment (The Environmentally Area Sensitive Indices)

Sampling

The entire state was broken into three districts for data collection for the determination of the environmental sensitive area indices.

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

Vol.10, No.3, pp., 16-39, 2022
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Like in the survey component of the study, all fourteen local government areas in the state were covered. Three communities in each local government area were purposively chosen such that they allowed even spread across the state. In each community, multiple locations were used for sample collections, other readings (such as slope, soil depth), observations etc.

Soil auger was used in soil samples collection; core borer and a measuring tape were used for soil depth determination, theodolite for slope measurement, self-recording rain gauge was used to determine precipitation and weighing lysimeter for potential evapotranspiration.

Laboratory Analyses
The soil samples were taken to the Soil Science laboratory at the Obafemi Awolowo University for full analysis where particle analysis was used to determine the soil texture and Walkley-Black method was used to determine the organic matter content of the soil samples.

All readings/observations obtained were first standardized using the MEDALUS template and fed into the Geographic Information Services (GIS) environment, complimented with the field coordinates for the mapping process. From these the indices for soil, climate, vegetation and management qualities were computed. The environmental area sensitive indices are determined and interpreted using the MEDALUS template as shown below:

Table 1: Medalus ESAI Reading Interpretation

ESAI READING	ESAI READING INTERPRETATION
1.00 – 1.22	Absence of Desertification
1.23 – 1.30	Low Desertification
1.31 – 1.40	Moderately Severe Desertification
1.41 – 2.00	High Severe Desertification

Statistical Analysis

The Survey (Sampling)
The sample size was determined by applying Taro Yamen's formula to the population obtained from the ministry of agriculture. The formula states that, given a population N, the appropriate sample size could be determined thus:

$$n = N/1+e^2$$

Where n – sample size
N – population size
e - maximum acceptable margin of error (usually 0.05)
1 – a theoretical constant.

There are forty thousand, six hundred and forty-eight (40,648) registered farmers in Zamfara state. Out of this, there are four thousand and six (4006) large-scale farmers. Applying Taro Yamen's formula, three hundred and ninety-six (396) was obtained as appropriate sample size. But this was increased to five hundred (500). This was distributed to Local Government Areas in proportion to the number of registered farmers they have using the stratified sampling technique. All fourteen local government areas were covered.

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

ISSN 2054-6351 (print),
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The structured questionnaire, after it was validated and its reliability assured, was administered to the selected 500 respondents.

Data collected from the survey were analyzed using both descriptive and inferential test statistics. Simple/Stepwise Regression Analyses and Pearson's Product Moment Correlation Coefficient analysis were used to test stated hypothesis of the study. The regression equation used was of the following nature:

$Y = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n$

Where Y = Dependent variable (Desertification)
a = regression constant (the intercept).
b = regression coefficient.
x = Independent variables.

The Experiment (The Environmental Sensitive Area Indices)

The Mediterranean Desertification and Land Use (MEDALUS) model (sponsored by the European Union under the MEDALUS PROJECT) was used to determine the desertification severity of the place. This requires the use of geographic information system (GIS) and remote sensing. Sepehr and Ekhtesasi, (2005), applying it to Iran, reported that it identifies the parameters of factors causing desertification and then prepares maps for each factor. These maps are integrated in a GIS environment to determine the severity of desertification of the area.

Why MEDALUS

Efforts have been made to compare the outcomes of the MEDALUS model and the results of other models like the FAO-UNEP, Turkministan, GLASOD, Iranian Classification Deserts (ICD) etc. Zehtabiani *et al* (2006) noted that the medalus model "has apparent advantages …" over other models by its simplicity of determination/application and ease of adaptability. Chenchouni and Benabdarrahmane (2010), in justifying the use of medalus in Algeria, noted that it has the ability to compare with other models, such as FAO-UNEP and ICD, for assessing and mapping desertification". On the other hand, Armin and Farhad (2011) preferred MEDALUS model because of its simplicity against the FAO/UNEP and Turkministan methods.

The indices used in the MEDALUS model are climate, soil, vegetation and land management.

The data requirement for each index as well as its computation is as follows:

The Soil Quality Index (SQI) will be:
soil texture * rock fragment * soil depth * slope * drainage * organic matter content

The Climate Quality Index (CQI) will be:
Rainfall * aridity of the soil * evapotranspiration

The Vegetation Quality Index (VQI) will be:
Fire risk * erosion protection * vegetative cover

ECRTD-UK https://www.eajournals.org/
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British Journal of Environmental Sciences
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ISSN 2054-6351 (print),
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The Management Quality Index (MQI) will be:
land-use type * land use intensity * policy enforcement

From these, the Environmentally Sensitive Area Index (ESAI) of an area is computed thus:

$$\mathbf{ESAI = (SQI*CQI*VQI*MQI)^{1/4}}$$

The ESAI reading is then looked up from the MEDALUS SCALE.

RESULTS AND DISCUSSION

The Survey

From the total of forty thousand, six hundred and forty-eight registered farmers, five hundred respondents were selected for this exercise. Four hundred and fifty were selected from among small-scale farmers and fifty from large-scale farmers. Out of these, forty-nine large-scale farmers responded and four hundred and forty-eight small-scale farmers did. Table 2 shows respondents' distribution by LGAs.

TABLE 2: DISTRIBUTION OF RESPONDENTS BY LGAS

LGA	LARGE-SCALE FARMERS SAMPLE		SMALL-SCALE FARMERS SAMPLE		TOTAL SAMPLE		TOTAL FARMER POPULATION
	GIVEN	RETURNED	GIVEN	RETURNED	GIVEN	RETURNED	
ANKA	1	1	13	13	14	14	997
BAKURA	3	3	26	26	29	29	2338
B/MAGAJI	4	4	33	32	37	36	3156
BUKKUYUM	4	4	38	38	42	42	3472
BUNGUDUN	6	6	59	58	65	64	5387
GUMMI	4	4	32	32	36	36	2939
GUSAU	6	5	50	50	56	55	4656
K/NAMODA	4	4	35	35	39	39	3195
MARADUN	2	2	18	18	20	20	1495
MARU	4	4	40	40	44	44	3644
SHINKAFI	1	1	12	12	13	13	900
T/MAFARA	3	3	27	27	30	30	2390
TSAFE	6	6	50	50	56	56	4658
ZURMI	2	2	17	17	19	19	1441
TOTAL	50	49	450	448	500	497	40648

The Instrument (Survey)

The instrument is segmented into six sections namely: Assessment/determination of the extent of Desertification (from the point of view of the victims), Agricultural Practices, Incidence of Poverty, Energy Source, Farm Stability/mobility and Perception/Awareness of the causes of desertification. Largely, these, directly or indirectly, constitute the anthropogenic factors that impact the desertification process. Respondents chose from four alternative answers.

ECRTD-UK https://www.eajournals.org/
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In constructing the instrument, efforts were made to balance positive and negative items and, using the Likert-type scale, responses were converted to ratio scale. For a positive item, for instance, if he chose the third column, "disagree", as it pertains to the assessment of the impact of desertification, it means his estimation of the impact is 7.5 points. For a negative item, the same third column would mean an impact of 5 points. To reduce bias, the scores are further converted to percentages for all sections. Therefore, the scores for any section, under each local government area represent the mean (percentage) score of the scores by all the participating respondents, for that section, in that local government area expressed as a percentage of the maximum scoreable point.

The hypothesis tested was: "there is no significant relationship between desertification and anthropogenic factors in the study area" and to test this, multiple regression and correlation analyses were conducted using SPSS and the results of the analyses are as shown in tables 3, 4, 5, 6 and 7 below.

Table 3: Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Varianc
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
DESERTIFICATION	497	44.00	43.00	87.00	69.3058	.42506	9.47615	89.79
AGRICPRACT	497	35.00	40.00	75.00	54.8330	.28611	6.37838	40.68
POVERTY	497	35.00	40.00	75.00	54.8229	.28627	6.38206	40.73
ENERGY	497	25.00	35.00	60.00	49.1187	.25274	5.63436	31.74
FARMSTABILITY	497	50.00	30.00	80.00	54.2857	.48110	10.72544	115.03
PERCEPTION	497	33.00	35.00	68.00	52.0684	.31742	7.07644	50.07
Valid N (listwise)	497							

For the results, table 3 shows the percentage mean, the maximum as well as minimum response scores for desertification assessment, agricultural practices, incidence of poverty, energy source, farm stability/mobility and people's perception of the desertification problem. The percentage mean response was highest in desertification assessment (69%). Farmers' mean response on the other variables hovered between 49%% and 55%.

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Journal level DOI: https://doi.org/10.37745/bjes.2013

Table 4: Correlation Analysis

		DESERTIFICATION	AGRICPRACT	POVERTY	ENERGY SOURCE	FARMSTABILITY	PERCEPTION
Pearson Correlation	DESERTIFICATION	1.000	.089	.087	.036	.018	-.087
	AGRICPRACT	.089	1.000	.999	-.010	-.015	-.017
	POVERTY	.087	.999	1.000	-.012	-.014	-.019
	ENERGY	.036	-.010	-.012	1.000	.095	.011
	FARMSTABILITY	.018	-.015	-.014	.095	1.000	-.050
	PERCEPTION	-.087	-.017	-.019	.011	-.050	1.000
Sig. (1-tailed)	DESERTIFICATION	.	.023	.026	.214	.343	.027
	AGRICPRACT	.023	.	.000	.416	.370	.352
	POVERTY	.026	.000	.	.398	.375	.338
	ENERGY	.214	.416	.398	.	.017	.407
	FARMSTABILITY	.343	.370	.375	.017	.	.133
	PERCEPTION	.027	.352	.338	.407	.133	.
N	DESERTIFICATION	497	497	497	497	497	497
	AGRICPRACT	497	497	497	497	497	497
	POVERTY	497	497	497	497	497	497
	ENERGY	497	497	497	497	497	497
	FARMSTABILITY	497	497	497	497	497	497
	PERCEPTION	497	497	497	497	497	497

ECRTD-UK https://www.eajournals.org/
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Vol.10, No.3, pp., 16-39, 2022
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The Pearson correlation analysis result showed that there is a significant positive correlation between desertification and agricultural practices (r= 0.089; p = 0.023), desertification and poverty (r= 0.087; p = 0.26) and significant negative correlation between desertification and perception (r = -0.087; p = 0.027). An insignificant positive correlation was found between desertification and energy source (r= 0.036; p = 0.214) and desertification and farm stability (r = 0.018; p = 0.343).

The implication of the result is that all variables impact desertification, in the same direction but at varying degrees with the exception of perception, which showed negative correlation. In other words, desertification increases as agricultural practices and incidence of poverty increased while it decreases as energy source and farm stability decreased. However, the multiple correlation coefficient is obtained as 0.089 (p < 0.05) as shown in table 5.

Table 5: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.089[a]	.008	.006	9.44770	.008	3.992	1	495	.046	2.577

a. Predictors: (Constant), AGRICPRACT

b. Dependent Variable: DESERTIFICATION

This means that, taken together, there is a positive correlation between the dependent variable (Desertification) and the independent variables with information variability given as 0.006. This implied that the independent variables accounted for 6% information about the dependent variable. The adequacy of the independent variables and the accounted information on the dependent variable is ascertained in the ANOVA table shown in table 6.

Table 6: Analysis of Variance (ANOVA[b])

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	356.300	1	356.300	3.992	.046[a]
	Residual	44183.213	495	89.259		
	Total	44539.513	496			

a. Predictors: (Constant), AGRICPRACT

b. Dependent Variable: DESERTIFICATION

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

ISSN 2054-6351 (print),
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At $F(1,495) = 3.992$; $p = 0.046$, the ANOVA shows that the model is adequate since $p < 0.05$. The implication of this is that the information accounted for by the independent variables about the dependent variable is appropriate for result utilization and further analysis. The ANOVA result also shows that there are significant differences on desertification of agricultural practices, incidence of poverty, energy source, farm stability/migration and perception of desertification by the farmers in the area. The specific effects, on desertification, of the independent variables, are further highlighted in the stepwise regression analysis coefficients in table 7

Table 7: Regression Analysis Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	62.020	3.671		16.893	.000	54.806	69.233					
AGRICPRACT	.133	.067	.089	1.998	.046	.002	.264	.089	.089	.089	1.000	1.000

a. Dependent Variable: DESERTIFICATION

The stepwise regression analysis was necessary to determine the independent variable(s) that influenced desertification, and to what extent, in the study area. Desertification is the dependent variable while agricultural practices, incidence of poverty, wood fuel consumption, farm stability/mobility and people's perception are the independent variables. The result of the analysis revealed that only agricultural practices were significant at p-value < 0.05. The Variance Inflation Factor (VIF) supported the adequacy of the results as it showed no multi-collinearity.

The resulting regression model, (which may, indeed, represent a Desertification Equation), from the analysis is therefore:

$DES = 62.02 + 13.3\ AP$

Where:

DES - Desertification
AP - Agricultural Practices

The results of the regression analysis, at $p = 0.046$, implied that agricultural practices had significant influence on the desertification of the study area. In other words, the extant land use

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Vol.10, No.3, pp., 16-39, 2022
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will result in the above regression equation. In the event that the land use method changes, the result would be a change in the regression equation.

The Experiment (The Environmentally Sensitive Area Index (ESAI))

The ESAI was conducted on senatorial district bases before consolidating to get the position for the state. The three districts are: Zamfara Central District, Zamfara East District and Zamfara West District.

In determining the ESAI, five essential steps were taken namely:

a) The raw data were collated from the field.
b) The collated field data were standardized using the MEDALUS template.
c) The four quality indices were determined for each district using the standardized data.
d) The ESAIs for the senatorial districts were calculated from their respective four quality indices.
e) These ESAIs were consolidated to get the ESAI for the state.

The Three Senatorial Districts

The three districts in Zamfara have varying numbers of local governments. All the 14 local government areas in the three districts were covered in the study. Data collated from the field was aggregated, in respect of each parameter, for each local government. These are standardized, the ESAI for each local government area determined before consolidating to get the ESAI for the respective Senatorial district. The ESAIs for the Districts are shown in tables 8, 9 and 10 below.

TABLE 8: ESAI ZAMFARA CENTRAL

COMMUNITIES	SQI	CQI	VQI	MQI	ESAI	ESAI INTERPRETATION
GUSUA	1.69	1.44	1.65	1.59	1.59	HIGH SEVERE
WANKE	1.71	1.44	1.65	1.59	1.59	HIGH SEVERE
MARADUA	1.69	1.44	1.65	1.59	1.59	HIGH SEVERE
GUSUA LGA	1.70	1.44	1.65	1.59	1.59	HIGH SEVERE
NAHUCHE	1.69	1.44	1.53	1.59	1.56	HIGH SEVERE
YAGABA	1.57	1.44	1.53	1.59	1.53	HIGH SEVERE
KOTORKOSHI	1.57	1.44	1.53	1.59	1.53	HIGH SEVERE
KONWA	1.69	1.44	1.53	1.59	1.56	HIGH SEVERE
BUNGUDU LGA	1.63	1.44	1.53	1.59	1.54	HIGH SEVERE
KUCHERI	1.75	1.44	1.65	1.59	1.61	HIGH SEVERE
TSAFE	1.75	1.44	1.75	1.65	1.64	VERY HIGH SEVERE
FEGIN BAZA	1.61	1.44	1.53	1.59	1.54	HIGH SEVERE
TSAFE LGA	1.75	1.44	1.65	1.61	1.61	VERY HIGH SEVERE
DANMARKE	1.69	1.44	1.53	1.59	1.56	HIGH SEVERE
MARU	1.69	1.44	1.53	1.59	1.53	HIGH SEVERE
MAYANCHI	1.57	1.44	1.53	1.59	1.56	HIGH SEVERE
MARU LGA	1.65	1.44	1.53	1.59	1.55	HIGHSEVERE
Z. CENTRAL	1.65	1.44	1.58	1.59	1.56	HIGH SEVERE

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Journal level DOI: https://doi.org/10.37745/bjes.2013

Vol.10, No.3, pp., 16-39, 2022
ISSN 2054-6351 (print),
ISSN 2054-636X (online)

TABLE 9: ESAI FOR ZAMFARA EAST

COMMUNITIES	SQI	CQI	VQI	MQI	ESAI	ESAI INTERPRETATION
B/TSABA	1.64	1.44	1.53	1.59	1.55	HIGH SEVERE
B/MAGAJI	1.53	1.44	1.53	1.59	1.52	HIGH SEVERE
BILACE	1.53	1.44	1.53	1.59	1.52	HIGH SEVERE
B/MAGAJI LGA	1.57	1.44	1.53	1.59	1.53	HIGH SEVERE
KASUWANDAJI	1.57	1.44	1.53	1.59	1.53	HIGH SEVERE
K/NAMODA	1.64	1.44	1.53	1.59	1.55	HIGH SEVERE
BARKEJI	1.64	1.44	1.53	1.59	1.55	HIGH SEVERE
K/NAMODA LGA	1.61	1.44	1.53	1.59	1.55	HIGH SEVERE
ADC DAURA	1.61	1.44	1.53	1.59	1.54	HIGH SEVERE
ZURMI	1.50	1.44	1.53	1.59	1.51	HIGH SEVERE
G/BARA	1.50	1.44	1.53	1.59	1.51	HIGH SEVERE
ZURMI LGA	1.54	1.44	1.53	1.59	1.52	HIGH SEVERE
SHINKAFI	1.61	1.44	1.53	1.59	1.54	HIGH SEVERE
BULA	1.61	1.44	1.53	1.59	1.54	HIGH SEVERE
KATURU	1.61	1.44	1.53	1.59	1.54	HIGH SEVERE
SHINKAFI LGA	1.61	1.44	1.53	1.59	1.54	HIGH SEVERE
ZAMFARA EAST	1.59	1.44	1.53	1.59	1.54	HIGH SEVERE

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

British Journal of Environmental Sciences
Vol.10, No.3, pp., 16-39, 2022
ISSN 2054-6351 (print),
ISSN 2054-636X (online)

TABLE 10: QUALITY INDICES AND ESAI FOR ZAMFARA WEST

COMMUNITIES	SQI	CQI	VQI	MQI	ESAI	ESAI INTERPRETATION
TASHA KAKA	1.64	1.44	1.53	1.59	1.55	HIGH SEVERE
ANKA	1.53	1.44	1.69	1.59	1.57	HIGH SEVERE
GADAN MANYA	1.53	1.44	1.69	1.59	1.57	HIGH SEVERE
ANKA LGA	1.57	1.44	1.64	1.59	1.56	HIGH SEVERE
TASHA TAYA	1.53	1.44	1.69	1.59	1.56	HIGH SEVERE
BUKKUYUM	1.64	1.44	1.53	1.59	1.57	HIGH SEVERE
DAN ZAURA	1.53	1.44	1.69	1.59	1.56	HIGH SEVERE
BUKKUYUM LGA	1.57	1.44	1.63	1.59	1.56	HIGH SEVERE
DAKINTAKWAS	1.71	1.44	1.53	1.59	1.56	HIGH SEVERE
GUMMI	1.84	1.44	1.53	1.59	1.59	HIGH SEVERE
GIDAN BITA	1.84	1.44	1.53	1.59	1.59	HIGH SEVERE
GUMMI LGA	1.80	1.44	1.53	1.59	1.58	HIGH SEVERE
BAKOLORI	1.55	1.44	1.53	1.59	1.53	HIGH SEVERE
MARADUN	1.55	1.44	1.53	1.59	1.53	HIGH SEVERE
JIHIYA	1.55	1.44	1.53	1.59	1.53	HIGH SEVERE
MARADUN LGA	1.55	1.44	1.53	1.59	1.53	HIGH SEVERE
RUMBA ZANGO	1.70	1.44	1.53	1.59	1.56	HIGH SEVERE
SAMBO GERI	1.70	1.44	1.53	1.59	1.56	HIGH SEVERE
BAKURA	1.70	1.44	1.53	1.59	1.56	HIGH SEVERE
BAKURA LGA	1.70	1.44	1.53	1.59	1.56	HIGH SEVERE
TASHA KAIWA	1.53	1.44	1.53	1.59	1.52	HIGH SEVERE
TASHA KULURU	1.53	1.44	1.53	1.59	1.52	HIGH SEVERE
T/MAFARA	1.64	1.44	1.53	1.59	1.55	HIGH SEVERE
T/MAFARA LGA	1.57	1.44	1.53	1.59	1.53	HIGH SEVERE
ZW	1.63	1.44	1.57	1.59	1.55	HIGH SEVERE

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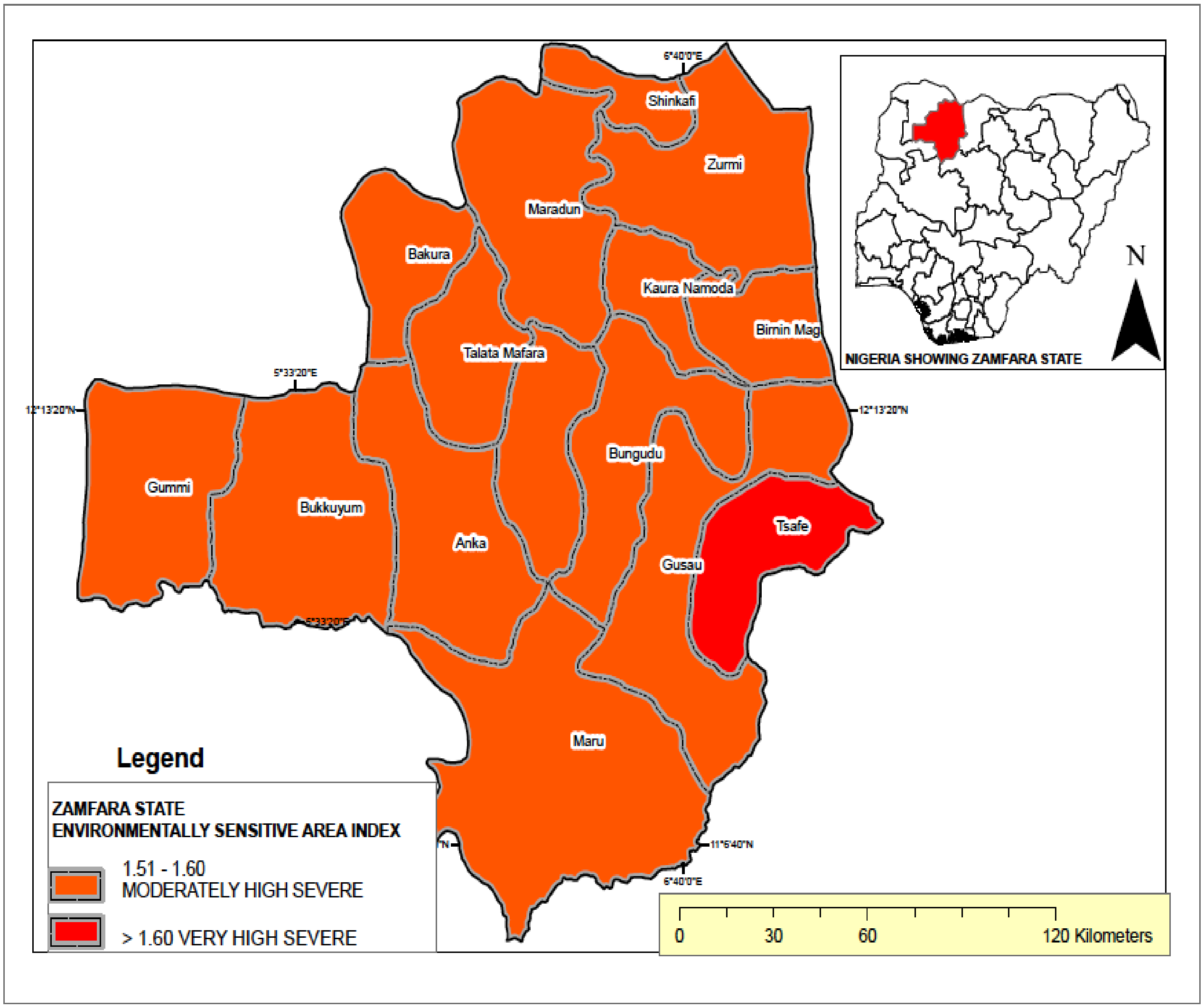

Fig 4: Environmentally Sensitive Area Index for Zamfara State

The MEDALUS measurement ranges from 1 to 2. The severity of desertification increases with the number. As a matter of fact, the model classifies anything above 1.40 as severe. The three senatorial districts all crossed that red mark. Zamfara Central District has a mean value of 1.56. Indeed, Tsafe town posted 1.64. Zamfara East and West Districts each has 1.55. By implication, desertification is severe in the entire state with a mean value of 1.55.

For ease of environmental management, (given that government may not have the resources to take on the entire state at once) this study has classified the severity band into Very High Severe (> 1.60), Moderately High Severe (1.51 – 1.60) and just High Severe (1.41 – 1.50) as shown in fig

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Journal level DOI: https://doi.org/10.37745/bjes.2013

4. Tsafe stands out as the most threatened by the desertification process. The rest parts of the state are moderately high severe by desertification.

However, although the rest parts of the state posted a Moderately High Severity by desertification threat, within them are still variations in levels of threat. Again, to guide in policy formulation for tackling desertification and managing it, the Moderately High Severely threatened areas could further be broken down to Low Moderately High Severity (1.51 – 1.55) and Moderately High Severity (1.56 – 1.59). When so done, we would have Shinkafi (1.51), Maradun and Talata Mafara (1.53) and, Bungudu, Maru and Kaura Namoda (1.55) all falling within the Low Moderately High Severity while Anka, Bukkuyum and Bakura (1.56), Gummi (1.58) and Gusau and Zurmi (1.59) are all within the Moderately High Severity band. Tsafe (1.61) stands out in the Very High Severity band. These are displayed in fig 5.

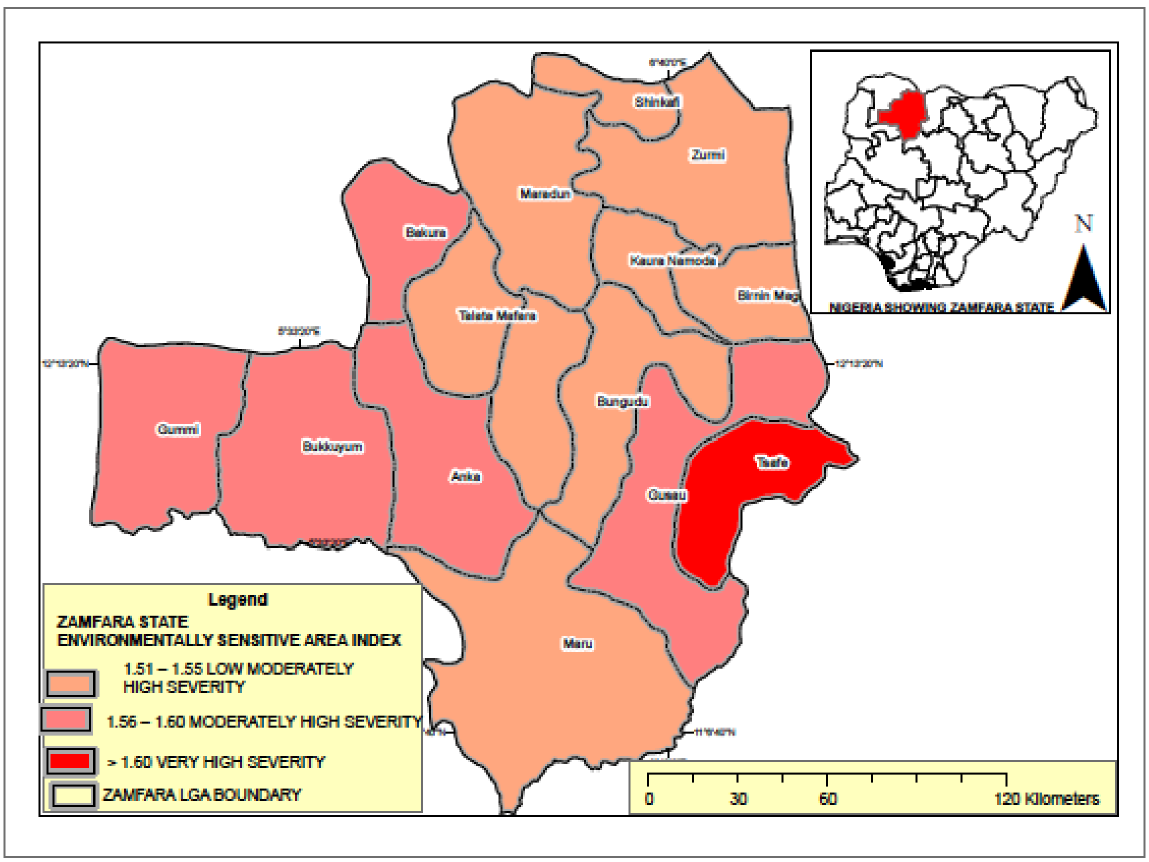

Fig 5 Environmentally Sensitive Area Index (using expanded legend) for Zamfara State

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

What the map does is to group the local government areas in order of priorities for combating desertification. In other words, clearly, Tsafe is the most urgent. This is followed by the LGAs classified as moderately high severe and finally, by those grouped as low moderately high severe.

Ordinarily perhaps, a contiguous result would have been expected wherein the northern part of the state, on account of proximity to the Sahara, would be most severely threatened by desertification and then followed by less threatened mid zone part of the state and finally by a least threatened southern part. Unfortunately, desertification does not follow a homogenous pattern. Dregne (1986) explains that the desert "loops". He cited the green rectangle (the Ekrafane ranch) in the Eastern part of the Niger Republic that is surrounded by a totally degraded land. He argued that rather than the notion that the Sahara expands, it is man's activities that bring the desert about. That explains why Shinkafi that is the most northern and nearest to the Sahara is not the most threatened by desertification but rather Tsafe, a more southern community, is.

A PEEP INTO THE FUTURE

The regression equation and the ESAI readings combine to give the future direction of desertification in the Sudano-Sahelian region. From the linear equation, it could be established that, in ten years, desertification would have increased by 2.1% of what it is today if the current land use pattern is maintained. This means that it would have nudged up the medalus scale by 0.021. The implication of this is that, in ten years, 21.4% of Zamfara State (as against Tsafe alone, currently) would be in the very high desertification severity band.

Tables 11, 12 and 13 show the projected changes in ESAI in the three districts if the current land use pattern subsists. Table 14 shows the summary of the ESAI changes on Local Government Area bases.

Table 11: ESAI FOR ZAMFARA CENTRAL IN TEN YEARS

COMMUNITIES	ESAI NOW	ESAI IN TEN YEARS	INTERPRETATIONS
GUSUA	**1.59**	**1.61**	**VERY HIGH SEVERITY**
WANKE	**1.59**	**1.61**	**VERY HIGH SEVERITY**
MARADUN	**1.59**	**1.61**	**VERY HIGH SEVERITY**
GUSUA L.G.A	**1.59**	**1.61**	**VERY HIGH SEVERITY**
NAHUCHE	**1.56**	**1.58**	**MODERATELY HIGH SEVERITY**
YAGABA	**1.53**	**1.55**	**MODERATELY HIGH SEVERITY**
KOTORKOSHI	**1.53**	**1.55**	**MODERATELY HIGH SEVERITY**
KONWA	**1.56**	**1.68**	**VERY HIGH SEVERITY**
BUNGUDU L.G.A.	**1.54**	**1.56**	**MODERATELY HIGH SEVERITY**
KUCHERI	**1.61**	**1.63**	**VERY HIGH SEVERITY**
TSAFE	**1.64**	**1.66**	**VERY HIGH SEVERITY**
FEGINBAZA	**1.54**	**1.56**	**MODERATELY HIGH SEVERITY**

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

TSAFE L.G.A.	**1.61**	**1.63**	**VERY HIGH SEVERITY**
DANMARKE	**1.56**	**1.58**	**MODERATELY HIGH SEVERITY**
MARU	**1.53**	**1.55**	**MODERATELY HIGH SEVERITY**
MAYANCHI	**1.56**	**1.58**	**MODERATELY HIGH SEVERITY**
MARU L.G.A.	**1.55**	**1.58**	**MODERATELY HIGH SEVERITY**
ZAMFARA CENTRAL	**1.55**	**1.57**	**MODERATELY HIGH SEVERITY**

Table 12: ESAI FOR ZAMFARA EAST IN TEN YEARS

COMMUNITIES	ESAI NOW	ESAI IN TEN YEARS	INTERPRETATION
B/TSABA	1.55	1.57	MODERATELY HIGH SEVERITY
B/MAGAJI	1.52	1.54	LOW MODERATELY HIGH SEVERITY
BILAGE	1.52	1.54	LOW MODERATELY HIGH SEVERITY
B/MAGAJI	1.53	1.55	LOW MODERATELY HIGH SEVERITY
KASUAWANDAJI	1.53	1.55	LOW MODRRATELY HIGH SEVERITY
K/NAMODA	1.55	1.57	MODERATELY HIGH SEVERITY
BARKEJI	1.55	1.57	MODERATELY HIGH SEVERITY
K/NAMODA	1.55	1.57	MODERATELY HIGH SEVERITY
ADC DAURA	1.54	1.56	MODERATELY HIGH SEVERITY
ZURMI	1.51	1.53	LOW MODERATELY HIGH SEVERITY
G/BARA	1.51	1.53	LOW MODERATELY HIGH SEVERITY
ZURMI	1.52	1.54	LOW MODERATELY HIGH SEVERITY
SHIKAFI	1.54	1.56	MODERATELY HIGH SEVERITY
BULA	1.54	1.56	MODERATELY HIGH SEVERITY
KATURU	1.54	1.56	MODERATELY HIGH SEVERITY
SHINKAFI	1.54	1.56	MODERATELY HIGH SEVERITY
ZAMFARA EAST	1.54	1.58	MODERATELY HIGH SEVERITY

British Journal of Environmental Sciences
Vol.10, No.3, pp., 16-39, 2022
ISSN 2054-6351 (print),
ISSN 2054-636X (online)

COMMUNITIES	ESAI NOW	ESAI IN TEN YEARS	INTERPRETATION
TASHA KAKA	1.55	1.57	MODERATELY HIGH SEVERITY
ANKA	1.57	1.59	MODERATELY HIGH SEVERITY
GIDAN MANYA	1.57	1.59	MODERATELY HIGH SEVERITY
ANKA LGA	**1.56**	**1.58**	**MODERATELY HIGH SEVERITY**
TASHA TAYA	1.56	1.58	MODERATELY HIGH SEVERITY
BUKKUYUM	1.57	1.59	MODERATELY HIGH SEVERITY
DAN ZAURA	1.56	1.58	MODERATELY HIGH SEVERITY
BUKKUYUM LGA	**1.56**	**1.58**	**MODERATELY HIGH SEVERITY**
DAKIN TAKWAS	1.56	1.58	MODERATELY HIGH SEVERITY
GUMMI	1.59	1.61	VERY HIGH SEVERITY
GIDAN BITA	1.59	1.61	VERY HIGH SEVERITY
GUMMI LGA	**1.58**	**1.61**	**VERY HIGH SEVERITY**
BAKOLORI	1.53	1.55	LOW MODERATELY HIGH SEVERITY
MARADUN	1.53	1.55	LOW MODERATELY HIGH SEVERITY
JIHIYA	1.53	1.55	LOW MODERATELY HIGH SEVERITY
MARADUN LGA	**1.53**	**1.55**	**LOW MODERATELY HIGH SEVERITY**
RUMBA ZANGO	1.56	1.58	MODERATELY HIGH SEVERITY
SAMBO GERI	1,56	1.58	MODERATELY HIGH SEVERITY
BAKURA	1.56	1.58	MODERATELY HIGH SEVERITY
BAKURA LGA	**1.56**	**1.58**	**MODERATELY HIGH SEVERITY**
TASHA KAIWA	1.52	1.54	LOW MODERATELY HIGH SEVERITY
TASHA KULURU	1.52	1.54	LOW MODERATELY HIGH SEVERITY
T/MAFARA	1.55	1.57	MODERATELY HIGH SEVERITY
T/MAFARA LGA	**1.53**	**1.56**	**MODERATELY HIGH SEVERITY**
Z. WEST	**1.55**	**1.56**	**MODERATELY HIGH SEVERITY**

Table 13: ESAI FOR ZAMFARA WEST IN TEN YEARS

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

British Journal of Environmental Sciences
Vol.10, No.3, pp., 16-39, 2022
ISSN 2054-6351 (print),
ISSN 2054-636X (online)

Table 14: ESAI SUMMARY (LGAs) IN TEN YEARS

LGA	ESAI NOW	ESAI IN TEN YEARS	INTERPRETATION
GUSUA	1.59	1.61	VERY HIGH SEVERITY
BUNGUDU	1.54	1.58	MODERATELY HIGH SEVERITY
TSAFE	1.61	1.63	VERY HIGH SEVERITY
MARU	1.55	1.57	MODERATELY HIGH SEVERITY
B/MAGAJI	1.53	1.55	LOW MODERATELY HIGH SEVERITY
K/NAMODA	1.55	1.57	MODERATELY HIGH SEVERITY
ZURMI	1.52	1.54	LOW MODERATELY HIGH SEVERITY
SHINKAFI	1.54	1.58	MODERATELY HIGH SEVERITY
ANKA	1.56	1.58	MODERATELY HIGH SEVERITY
BUKKUYUM	1.56	1.58	MODERATELY HIGH SEVERITY
GUMMI	1.58	1.61	VERY HIGH SEVERITY
MARADUN	1.53	1.55	LOW MODERATELY HIGH SEVERITY
BAKURA	1.56	1.58	MODERATELY HIGH SEVERITY
T/MAFARA	1.53	1.56	MODERATELY HIGH SEVERITY

Clearly, table 14 shows that, of the 14 LGAs, two additional LGAs (Gusau and Gummi) would cross into the very high severity band. Eleven would be in the moderately high severity band up from five. These are further displayed in figure 6. Only three LGAs (as against 8 currently) would remain in the low moderately high severity band.

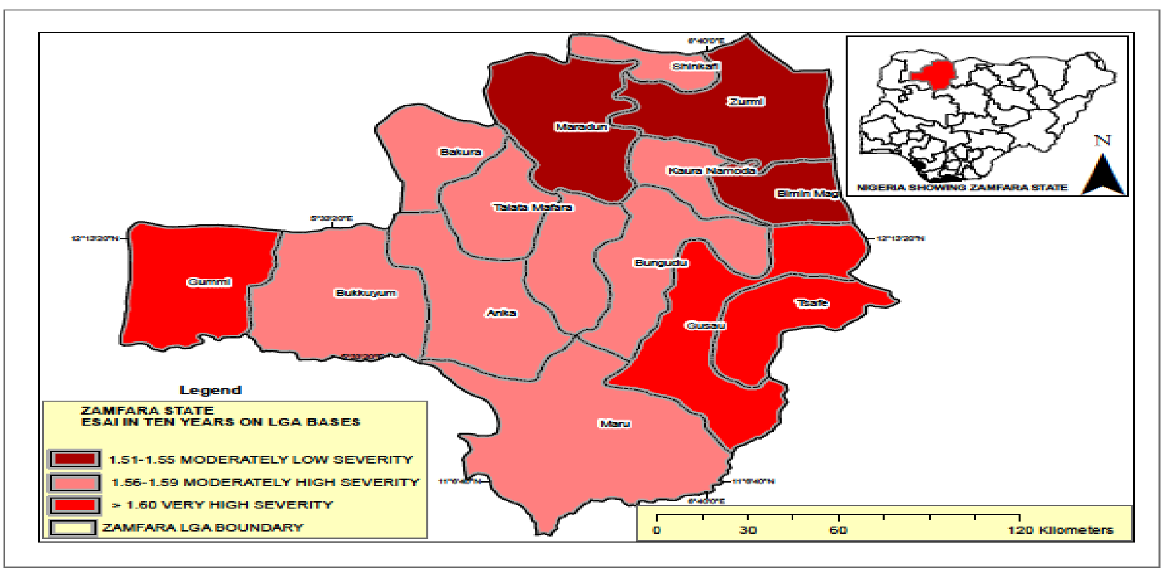

Fig 6: Environmental Sensitive Area Indices in Ten Years

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CONCLUSION AND RECOMMENDATION

The results of the Environmentally Sensitive Area Indices (ESAIs) show that all senatorial districts are severely affected by desertification having each crossed the threshold/red mark of 1.40. The reading recorded ranged from 1.52 in Zurmi to 1.64 in Tsafe. For ease of environmental management, this severity is further classified into Low High Severe (1.41 – 1.50), Moderately High Low Severe (1.51 – 1.60) and Very High Severe (> 1.60). The result showed that clearly Tsafe suffers the most as it is the only local government area in the highly severe band. All the others are in the moderately high severe classification. If the Moderately High Severe is further broken into Low Moderately High (1.50 – 1.55) and Moderately High (1.56 – 1.60), then we would have, after Tsafe which stands alone in the Highly Severe class, Gusau, Gummi, Kaura Namoda, Bukkuyum, Anka, Zurmi and Bakura in the Moderately High Severe band. All the others would be in the Low Moderately High Severe class.

On the severity of desertification in the region, the result of the environmentally sensitive area index (ESAI) showed that the severity of desertification in the study area is high. In relative terms, it further showed that while the study area was generally high in desertification severity, variations were observed from place to place and that desertification spread is not contiguous. Indeed, desertification "loops".

When the ESAI readings are taken together with the resultant regression equation from the survey exercise, the result projected that, in ten years, desertification severity would increase by 2.1%. This would nudge up the reading on the medalus scale by 0.021. Currently, Tsafe LGA is the only one in the Very High Desertification Severity band. With the resultant increase on the medalus scale, it emerges that 21.4% of Zamfara State would be in the very high desertification severity band in ten years up from 7.1%. The implication of this is that, in the Sudano-Sahel region, any area with the same characteristic as Zamfara State, will suffer the same cruel fate.

But, perhaps one of the most disturbing outcomes of the study is the revelation that unless land use pattern is improved, the desertification of the region would have worsened by as much as 2.1% in ten years leaving about 21.4% of the area in a very high severe desertification state. This therefore means that all areas, within the Sudano-Sahelian region, that have the same characteristics as Zamfara State would incline towards the same tendency.

The findings of this study give cause for great concern. The threat of desertification is real and needs to be tackled head on given its impact on food security and general wellbeing of the people. The following is recommended therefore:

1) The issue of agricultural extension services needs to be taken very seriously. The people must be sufficiently educated on the role they play in exacerbating the spread and impact of desertification and what can be done to ameliorate it.

ECRTD-UK https://www.eajournals.org/
Journal level DOI: https://doi.org/10.37745/bjes.2013

2) It is recommended that Environmentally Sensitive Area Indices (using the expanded MEDALUS scale) be conducted along the length and breadth of the Sudano-Sahelian Region with a view to tackling the problem before desertification overwhelms the region.

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