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Detection and Analysis of Desertification Sensitive Areas in Sabarkantha District of Gujarat

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***Abstract*—Desertification can be defined as the consequence of a set of various important processes that are active in both arid and semi-arid environments, where the main limiting factor is water for land use in ecosystems, and several other factors such as climate change and human activities may cause it (GAD). It is the changes in land and its vegetation that makes land unable to support life, becoming like a desert. Small land areas degraded by human activity or/and drought can expand and connect with other areas, creating desert-like conditions. Indicators to desertification are based on the available resources including remote sensing images, topological data, climate, soils, and vegetation data. This research aims "To map the desertification status of one district of Gujarat i.e. Sabarkantha District" using LISS III data on 1:50,000 scale. The algorithm is based on the MEDALUS (Mediterranean Desertification and Land Use) model for calculating ESA (Environmentally Sensitive Areas) index to determine the situation and tendency of desertification. The general methodology is fully described by (Kosmas, 1999).The study area covers 7390 sq.km of Gujarat state. The maximum and minimum temperature of the place is 40.5 degree centigrade and 9.04 degree centigrade respectively. Research shows that most of the area falls under moderate conditions among which major area of vegetation falls between dense to very dense which decreases the probability of land degradation during Kharif season. The final Desertification Vulnerability map shows that about 5420.97 sq.km of area falls under low risk, 1910.59 Sq. Km has moderate risk while only 4.78 sq.km of area falls under high risk category. Rest is not affected. i.e. ten out of thirteen sub districts falls under low risk while other three namely Vijaynagar, Bhiloda and Bayad has moderate desertification conditions and if proper treatment is not given to these areas would lead to high damage as they concern with the desertification conditions.**

Keywords- Desertification; ESA; Vulnerability;Remote Sensing;GIS; SI; VI; SEI; TI; CI.

I. INTRODUCTION

Desertification is a serious environmental and socio-economic problem encompassing huge territories at a global, regional and local scale. The features and end results of the desertification process are devastating for the environments, economies and political stability of the countries they occur (Abbasova, 2010). These features of desertification include reductions of crop yields, perennial plant cover and rangeland's biomass productivity, woody biomass, shortages of water, water pollution, air pollution, and other drawbacks, potentially leading to societal disruption ((Nairobi)., 1991)

Desertification includes a set of important processes, which are active in the arid land due to scarcity of land and water resources. Desertification of an area proceeds if certain land components are brought beyond specific threshold, where further change produces irreversible alterations.(Tucker, 1980-1990).

Environmental systems are in a state of a dynamicequilibrium having external driving forces. Small changes in the driving forces,such as climate or imposed land use are partially accommodated by small changes in the equilibrium and partially by being absorbed or buffered bythe system. (GAD).

Besides of variety of methods of estimation, researchers proposed soil erosion from water and wind erosion but, to date, no specific method for classification of desertification intensity based on the total desertification processes has been provided.

Desertification indicators are those, which indicate the potential riskof desertification while there still time and scope for remedial action.Therefore, assessment of Regional Indicators should be considered for assessment of desertification processes. Based on available international source materials, regional indicators includes remotely sensed images, topographic data (maps or DEM(Digital Elevation Models)), climate, soils and geological data, at different scales) (Kosmas, 1999)

The key indicators such as soil quality index, vegetation index, climate index, socio economic index can be used for ESA's to desertification. These parameters can be easily extracted from reports on soil, vegetation, climate, etc.

II. METHODOLOGY:

Land degradation includes complex set of processes, which interact in space and time leadingto decrease in land productivity. Thus identification of the various indices is necessary to identify the desertification vulnerable areas. The methodology hasbeen adopted from Mediterranean Desertification and Land Use (MEDALUS) project. (Kosmas, 1999). Inthis project vegetation pattern for the years 2008, 2010 and 2011 has been computed using LANDSAT TM imagery after that all other quality indicessuch as climate index, soil index, terrain index and socio-economic index has been calculated and then combined to calculate DesertificationVulnerability Index (DVI).

A. Study Area:

Sabarkantha District is an important district in North Gujarat region. It is located between 23.03^0 N and 24.30^0 N latitude and 72.43^0 E and 73.39^0 E longitudes and occupies about 7390 km^2 of Total Geographic Area (TGA) of Gujarat

State. It falls under North Gujarat agro climatic zone having [4]sandy loam to sandy type of soil.

The district has 13 talukas with 1406 villages. Out of 441103 hectares of cultivated land, 112913 ha (26%) are irrigated land, remaining land (74%) is unirrigated one. Bore well and Open well are the main source of irrigation for about 76% of irrigated land. (**Source:** Season and Crop Report, Directorate of Agriculture, (1999).

B. *Desertification Vulnerability Index:*

Since climate, soil, vegetation, terrain play a significant role in desertification of any area, this work includes all these indices.

All the indices were combined using geometric mean to form an index called Desertification Vulnerability Index (DVI) which is defined as:

$$DVI = (SQI*SEI*CI*VI*TI)^{1/4} \qquad (1)$$

Where SQI is the soil quality index, SEI is the socio economic index, VI is the vegetation index, CI is the climate index and TI is the terrain index.

TABLE 1: SOURCES OF INDICES USED

Index	Inputs	Sources
Climate	Rainfall	Directorate of Agriculture
Soil	Depth, texture, drainage, slope and erosion	Soil Survey of India
Vegetation	Normalised Difference Vegetation Index	Landsat-TM
Terrain	Slope and aspect	DEM(downloaded from BHUVAN)
Socio-economic	Population pressure, unemployment, illiteracy, poverty	Census of India

1) *Soil Quality Index (SQI):*

Soil has a great effect on biomass production and hence is a dominant member of the ecosystem that affects the productivity. Its computation includes five different parameters namely: soil depth, slope, drainage, erosion and texture. All of these parameters have been digitized from the soil map taken from Soil Survey of India at the scale of 1:250000.

$$SQI= (depth*drainage*erosion*texture*slope)^{1/5} \qquad (2)$$

2) Climate Quality Index:

For the preparation of climatology indicator seventeen existing stations namely, Badoli,Bayad, Dhandop, Gunva, Himatnagar, Idar, Kundla Campo, Maghodi, Malpur, Pal, ParsodaCampo, Posina, Prantij, Shamlaji, Vadagam, Vijaynagar, and Virpur has been used and onlythe rainfall parameter has been considered. Climate Index has been calculated using the following formula:

$$CQI = (rainfall)^{1/1} \qquad (3)$$

Average monthly seasonal rainfall for the years 2001 to 2010,(June to September) has been considered to calculatethis quality index. This rainfall data has been classified into threeclasses viz. low, moderate and high. The scores of climate & soil indices are in table 2.

TABLE 2: SOIL& CLIMATE PARAMETERS

3) *Terrain Index*

Parameter	Description	Value	Score
Drainage	Well Drained	Low	100
	Moderately Drained	Moderate	150
	Excessively / Poorly drained	High	200
Texture	Coarse Loamy, Calcareous Coarse Loamy	Coarse	200
	Loamy Skeletal	Moderate	160
	Loamy Soils	Moderately Fine	140
	Fine Loamy	Fine	120
	Fine Soils	Very Fine	100
	<135	High	200
Rainfall	135to200	Moderate	150
	>200	Low	100

Terrain refers to the up and downs of the earth surface, similarly this also referred as topography. Any kind of terrain characters can be shown in different way like, sloperepresents the terrain in relation to the inclination; aspect represents the terrain in relation tothe direction, etc.

Slope can be used to find various other geographical factors.Aspect is referred as the face of the terrain in relation to the direction. Aspect and NDVI values have been manually but empirically categorized using mean and standard deviation of the respectivevalues.

TABLE 3:TERRAIN PARAMETERS

Parameters	Description	Value	Score
Aspect	Flat	Very Low	100
	N	Very Low	100
	NE,NW	Low	140
	S	Very high	200
	SE,SW	High	180
	W	Low	100
	E	Moderate	160
Slope	<76	Low	100
	76to88	Moderate	150
	>88	High	200

4) *Vegetation Index:*

The dominant biotic land component which is critical for desertification is the vegetationcover. Vegetation cover is very crucial for run-off generation and can be readily altereddepending on the climatic conditions. And thus NormalisedDifference Vegetation Index i.e. NDVI has been used in this project to study the vegetation pattern whichhas been generated using LANDSAT TM image for all the three

Rabi, Kharif and Zaidseasons, but only Kharif season has been considered for the purpose of vulnerabilitymodelling, since in this season the level of vegetation cover is at its maximum level[5].

Vegetation Index has been calculated using the following formula:

$$VI = (NDVI)^{1/1} \quad (4)$$

Table 4: VEGETATION INDEX PARAMETERS

Parameters	Description	Values	Score
Very Sparse	-0.08 to -0.05	Very high	200
Sparse	-0.05 to -0.03	High	180
Moderate	-0.03 to 0.15	Moderate high	160
Dense	0.15 to 0.3	Moderate Low	140
Very Dense	>0.03	Low	120
Water body	< -0.08	Very Low	100

5) Socio Economic Index:

Cultivation on marginal lands, inappropriate management practices, herding and treefelling / deforestation for fire wood gathering have all been the majorcause of desertification (Raj, 2009)[3]Thus directly or indirectly everypiece of land is influenced by the society and its economic conditions.

Population pressure, unemployment and illiteracy pose a serious threat to the environment in conjunction with the poverty. Hence to develop socio economic index all these factors hasbeen carefully analysed.Following equation had been used in this project to calculate SEI (Socio Economic Index).

$$SEI = (Population\ Pressure * Unemployment*Illiteracy*Poverty)^{1/4} \quad (5)$$

TABLE5:SOCIO ECONOMIC PARAMETERS

Parameters	Range	Value	Score
Population Pressure :	<170	Low	100
	170-285	Moderate	150
	>285	High	200
Unemployment:	0-33%	Low	100
	34-60%	Moderate	150
	61-100%	High	200
Illiteracy:	0-50%	Low	100
	51-60%	Moderate	150
	61-100%	High	200
Poverty: Fuel for Cooking	LPG	Very low	100
	Kerosene	Low	150
	Crop residue / cow dung	Moderate	175
	Fire wood / no cooking	High	200

III. RESULTS AND DISCUSSION

1) Vegetation Index Analysis:

Water body and the values representing high vegetation has the less contribution in the process of desertification and hence were reclassified in the low category while the sparse vegetation contributes maximum in the desertification process hence fell into the high to very high category. The spatial analysis yields that maximum area of about 77% (i.e. 5700 km^2) has very dense vegetation. While only 0.37% (i.e. 27.92 km^2) of the total area is under sparse vegetation.

2) Socio Economic Index Analysis:

Socio economic analysis for this study is carried for the 2001 census data at village level. (Due to unavailability of 2011 census data at village/ taluka level forcefully 2001 censusdata has been used)..

Computation of this index shows that whole Sabarkantha district falls under medium category of unemployment sincemore than 60% of the population falls under this category. More than 50% of the population has no assets and uses firewood or cow dung as the fuel for cooking and about 92630.53 sq.km of total area contributes to high poverty rate, high illiteracy rate, and has high population pressure and this area includes Khedbrahama, Bhiloda, Talod and Bayad. While Vijaynagar, Vadali, Meghraj, Dhansura and Malpur falls under moderate category and the rest falls under low category having area 2582.74 sq.km of total area

3) Soil Quality Index Analysis:

Soil Quality index has been statistically classified into three categories namely Low, Moderate and High based on their values between mean and standard deviation. The final index values have been categorized as low if the value is less than (mean-sd), as Moderate if it fall between (mean-sd) and (mean+sd) while high are those values greater than (mean+sd), where sd is the standard deviation.

The maximum area i.e. 4397.86 sq.km of the district falls under moderate category and minimum of the area of about 783.5 sq.km falls under low category.

4) Climate Quality Index Analysis:

Higher the rainfall lower will be the participation to desertification thus based on statistical values, the high rainfall has been categorized into low category and low into high category of CQI and same classification had been considered for other classes.

The result shows that except Vijaynagar, Bhiloda and Bayad all the talukas fall under Moderate category i.e. vulnerable to desertification.

5) Terrain Index Analysis:

The physiographic configuration of terrain with steep slopes favours high erosion rates i.e higher the slope higher the exposer of land towards degradation leading the participation in desertification process. 62.54% of the total land falls under moderate category, 24.96% under low and rest in high category. It means only 12.5% of the total area contributes towards land degradation.

6) Environmetal Sensitive Area / Desertification Vulnerability Analysis:

All the above mentioned indices were used together for the assessment of Environmentally Sensitive Areas (ESA), on the basis of desertification vulnerability index (DVI) figure 8 shows the distribution of ESA's, while table 7 demonstrates their areas.

It is clear that most of the area falls under low risk category which exhibits 73.89% of the total area. The north eastern part of the district, i.e. Vijaynagar and Bhiloda along with Bayad in the south falls under moderate category which together exhibits 26.04% of the total area while only 0.065% of the area contributes to the high risk category and no area comes under not affected category.

ESA / DVI Classes	Area (%)
High Risk	0.065155
Low Risk	73.89202
Moderate Risk	26.04282
Not Affected	~0

IV. CONCLUSION AND RECOMMENDATIONS:

It can be concluded that the desertification vulnerability mapping and its assessment are rather important to plan combating actions and to improve the conditions and usage of natural resources. It can be realized that the merely quantitative aspect of desertification vulnerability demonstrates a clearer image of the risk state than descriptive approaches. Reliable priority actions can be planned better on basis of risk magnitude knowledge.

By analysing desertification vulnerable map for Sabarkantha district of Gujarat it can be concluded that although majority of the area has been found to be low vulnerable to desertification if they are not maintained well there may occur more damageor land degradation as it concerns to desertification process. Low risk areas have moderate soil conditions, high climate conditions; vegetation falls intovery dense to dense category, showing low socio economic conditions having flat and northdirection included in terrain conditions i.e. N, NW, NE and W conditions with less or zero slope.

Moderate DSI values indicates that moderate conditions of soil quality, moderate climate quality values, vegetation ranges from dense to sparse aspect includes E to W directions having moderate slope values.

While High risk includes low rainfall, high erosion and south aspect values and vegetation ranges from sparse to very sparse values.

At general scale remote sensing, supply valuable information concerning the soil and vegetation quality. However, for more detailedscales, conventional field observation would be essential.

We can conclude that the MEDAUS method provides a satisfactory approach for identifying desertification-prone areas while the model attempts to assess and identify factors affecting desertification, it should be noted that the final maps are based on actual data.

The Geographic Information System (GIS) is a valuable tool to store, retrieve and manipulate the data needed to compute and map various quality indices to desertification. Mathematical modelling should be developed for the operational monitoring of different elements contributing in desertification sensitivity. Multi scale mapping of ESA'sare needed to point out the risk magnitude and causes of degradation in problematic areas. Evaluation and validation of the assessment methodology are recommended, they should be a matter of scientific discussions.

Finally it could be concluded that the design and changes of original MEDAUS model based on specific conditions of each study area is necessary. In such a way the recognition ofthe important affected factors from analysis of the model is possible. Identification of effective factors can be used to present suitable policies in order to mitigate the desertification effects on the areas.

The same project can be conducted at taluka/ village level also; it all depends on the availability of the data. For the validation of the values so obtained Principal Component Analysis can be performedwhich indicate the correlation between all the parameters that are used in this project.

1) Possible Solutions to desertification:

a) Deforestation i.e. Afforestation is the re-plantation of trees, which helpsto stabilize the soil and cut down on erosion by wind and rain.
b) Using good farming practices such as proper crop rotation.
c) Overgrazing – In order to prevent grazing by animalsit is important to fence off young trees.
d) Terracing the land to slow down the water running off will make better use of therein that does fall.
e) Most of all desertification can be controlled by human activity.
f) Encouragement of sustainable farming practices (i.e. to use locally-made tools, not tractors).
g) To conserve water in local small-scale schemes such as "magic stones" in Burkino Faso.
h) Improve water supplies by building large reservoirs and drilling deeper wells.
i) Provide drought-resistant seed such as millet(northern Nigeria). GM crops.
j) Tree planting schemes such as in Mauritania to reduce soil erosion.

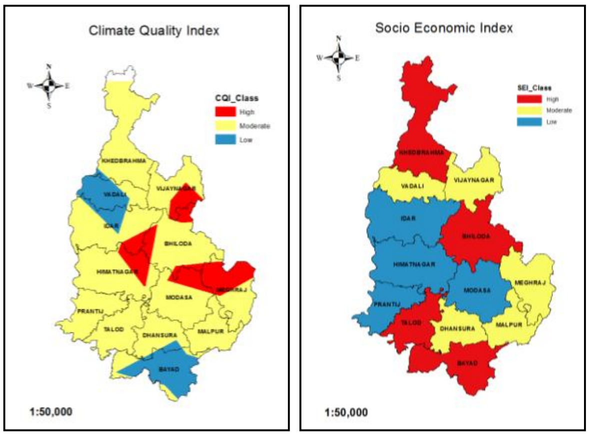

Fig1: Map of Climate quality and
Socio economic quality indices

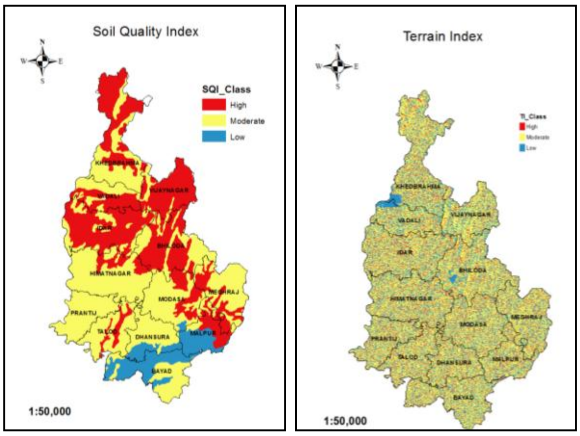

Fig2: Map of Soil quality and Terrain Indices

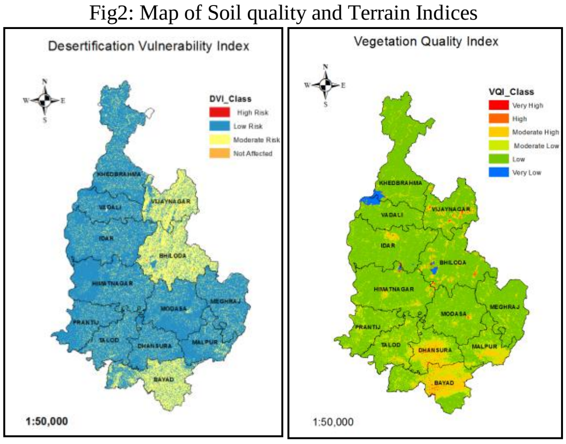

Fig3: Map of Desertification Vulnerability index and Vegetation quality Index

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