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# Potency of Modified Weighted Index Analysis for Land degradation /desertification vulnerability Index: A case study on Golaghat District, Assam, India

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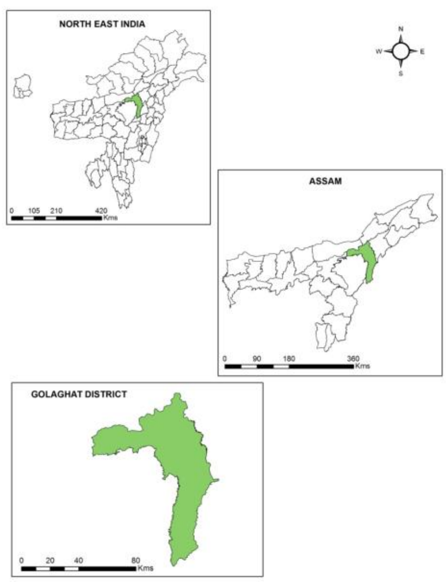
ABSTRACT

Land is primarily considered as a broad category of natural resources and degradation of land is mostly studied in terms of soil and vegetation degradation. According to UNEP (1999), land degradation is the temporary or permanent lowering of the productive capacity of land. It affects adversely the productive, physiological, cultural and ecological properties and functions of land resources. In 2016 it is estimated that, 9.14 percent of total geographical area of Assam state is under land degradation process. The most significant processes are; vegetation degradation and water logging. Topographically the state isan alluvial flood plain and falls under tropical monsoon rainforest climate, it is important to evaluate the vulnerability of landin terms of land degradation/desertification in terms of flood plain. Modified Weighted Index is a cumulative weighted indexing based on integration of Natural resource classes and socio economic classes. The methodology was developed in*Space ApplicationCentre Ahmadabad* and first tested in Kathuadistrict ofJammu Kashmir and Bellary district of Karnataka (2014) and the results were considerable. Further the methodology was adopted by number of scholars and applied in their respective areas. One of the accessible study is done byDharumarajan et.al, (2018)forAnantapur District, Andhra Pradesh, India. Thecurrent study area Golaghat district of Assam is taken as a sample site to assess the land degradation/desertification vulnerability index using Modified Weighted Index methodology.The primary focus of the current study is to examine the effectiveness of the methodology to predict the land degradation/desertification vulnerability when it comes to flood plain.

Key words: Land degradation, natural resources status, socio economic status and vulnerability index

## 1 Introduction:

Desertification is a type of land degradation through which an area becomes increasingly arid, generally losing its bodies of water as well as vegetation and wildlife (Geist 2005). Desertification vulnerability is of the degree of which a system is susceptible to or unable to cope with, adverse effects of desertification intensified by climate changes, including increased climate variability and extremes (Turkes&Akgunduz, 2011). However, this phenomenon is commonly confused with "*only the expansion of desert*". It is the extreme point of land degradation that signifies changes of physical properties of land and converted it to dry land. The primary cause of desertification is the removal of vegetation. This cause removal of nutrients from the soil, making land infertile and making unusable for arable farming. Unsustainable human activities and climate change are the two basic factors that causes desertification. But regarding the desertification due to high rate of land degradation is primarily caused by human activities as; over utilised land or over exploited land.Desertification and Land Degradation Atlas of Selected Districts of India Volume – 1, (2018) 15.8 percent(55325.40 haters) of total geographical area of Golaghat district is under the land degradation/desertification process during the period of 2011-2013. It decreased only 0.10 percent since 2003-2005. It also signifies that the study area is experiencing a continuous process of land degradation with a static severity level.Most significant process of land degradation/desertification in the district is vegetation degradation followed by water logging. It also signifies that the study area is experiencing a continuous process of land degradation with a static severity level. The current vulnerability assessment has also taken 2011-2013 as study period to validate the result with pervious estimations.



**1.2 Database:**

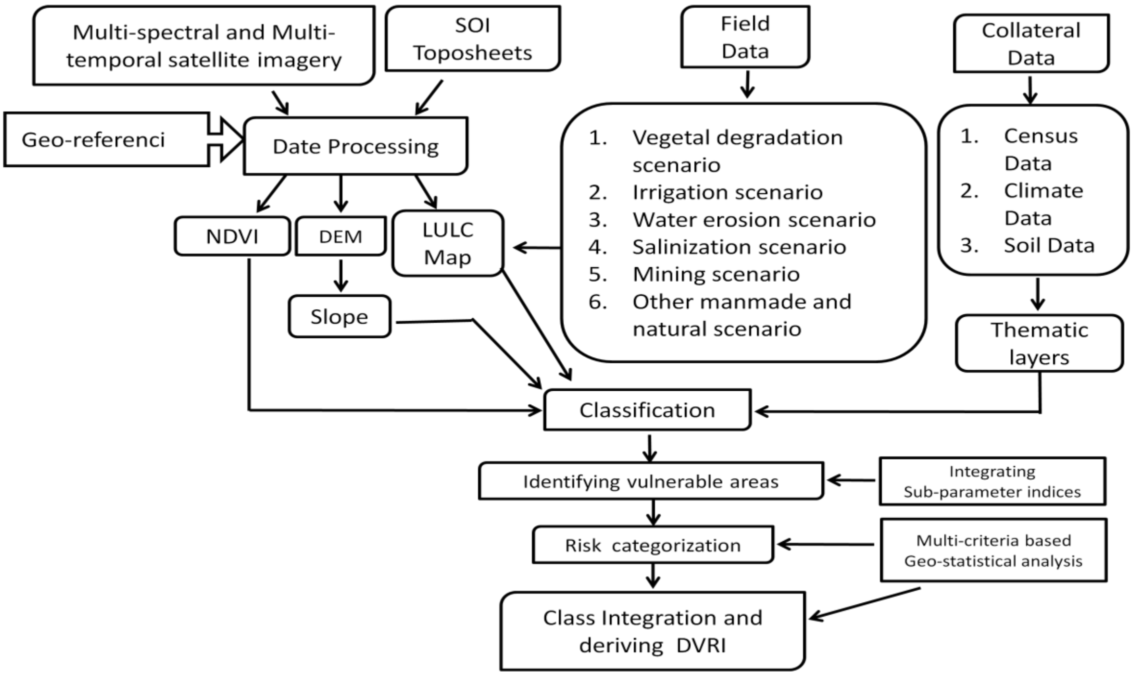
**1.** IRS LISS III, time frame 2011 -2013(NRSC)[1]. LISS III (Linear Imaging Self Scanning Sensor) is an optical sensor with 7 bits data with 141 km wide ground swath. Spatial resolution is 23.5 meters in all spectral bands. Repetitive cycle is 24 days. The satellite data has considered based on 3 agro climatic seasons as Kharif (September – November), Rabi (December – March) and Summer (April – June)

**2.** Ancillary Data ; Water body, Rivers (Natural Resources Data Base), Forest Boundary (FSI)[2] , demography & Infrastructure (Census of India, 2011), Climate (IMD)[3] and soil data (NBSS & LUP)[4].

**3.**DEM (Source SRTM). The spatial resolution is 90 meters. Further it is resample it to 30 meters using nearest neighbour.

**4.**Ground through verification (GPS points and field photograph)

**Methodology:Modified Weighted Index(MWI) (Vedas.SAC.gov.in):** It is a multi-variate Geo-statistical method, which uses for deriving the composite indices for all the spatial units separately. There are three important steps involved in the derivation of the indices i.e. Normalization of all the variables and weightages assignment, Calculation of indices at each sub-variables of Natural, Social and Economic parameters separately for deriving rate of severity and Generation Composite Index and integration with spatial polygons (KLN Sastry,2014)




**1.3 Amenity index:**The status of the settlement will be rated based on available index of all the amenities**.** This is calculated based on Modified Cumulative Weighted index Model for each class of amenity i.e. education, medical, transport and communication. The availability of the amenities are extracted from 2001 and 2011 national census by examining 1088 settlements.

$$\mathrm{Ic} = \frac{\sum \mathrm{Ai\ x\ Wi}}{\sum \mathrm{Wi}} \qquad (1)$$

i = 1 to N numbers

Where,Ic is index for a particular settlement vis-à-vis class of amenity

n = Number of amenities in a category (e.g. 8 or10 nos. in Edu.)

Ai = 0 or 1 (0 = Not available, 1 = Available)

**Wi = Weight of the amenity with in category/class of facility, and it is defined as**

$$\mathrm{Wi} = \frac{(\mathrm{N}-\mathrm{fi})}{\mathrm{N}} \mathrm{x}\ 100 \qquad (2)$$

N = Total no. of Settlements

fi = No. of Settlements having amenity i

**1.4 Cumulative Amenities index:**

Cumulative index for a particular settlement is calculated as:

[1] National Remote Sensing Centre, Hyderabad
[2] Forest survey of India
[3] Indian Meteorological Department
[4] National Bureau of soil Survey and Land Use Planning

$$AI = \sum Ic \qquad (3)$$

c = 1 to N numbers

n = Number of amenity categories (e.g. Med. Edu. Trans. Etc.)

AI = Cumulative index for a particular settlement vis-à-vis all amenities
Ic = Index for a category of amenity (derived earlier)

**1.5 Economic Development Index:**
Economic development of a settlement is derived based on:

$$E = \sqrt{[D.W\,(W - A)]} \qquad (4)$$

Where E = Economic development status

D = Population density

W= Total proportion of employed population

A = Total proportion of unskilled workers

(I.e. unemployed + agricultural labors + marginal workers/total population)

## 2. Result & Discussion:

The desertification vulnerability index model is primary based on two basic parameters such as: biophysical index and socio economic index. Within biophysical index another five sub parameters have been consideredsuch as:climatic index, terrain index, vegetation index, soil index and land utilization index.

**2.1 Climatic Index:**The climatic index is generated based on annual average temperature, annual average rainfall and annual average relative humidity of the study area. Here the extracted results primarily represents the climatic pressure zone that indicates low temperature and suitable relative humidity and high rainfall is most acceptable. The monthly rainfall of the district ranges between 2.1 mm in the month of Decemberto 406.3 mm in the month of July. The calculated mean (µ) is 106.52 mm and Standard Deviation is (σ)[5]126.49mm. The temperature varies from 17.93º C in the month of December to 27.58º C in the month of July. The calculated mean (µ) is 23.45º C and Standard Deviation (σ) is 3.81º C. The relative humidity varies from 66.99% in the month of March to 85.74% in the month August with mean (µ) of 78.82% and Standard Deviation (σ) is 5.96%. Here the Relative Humidity is calculated with help of the following equation:
RH = (E/Es)*100 Where
RH is relative humidity in percentage
E is actual vapor pressure[6] in mill bar (mbar)
Es is saturation vapor pressure[7] in mill bar (mbar)
Depending upon the above climatic parameters the climatic index of the study area ranges from very low to high climatic pressure zone. Around 1.21% of the total geographical area comes under level-1 (very low), 35.35% is in level-2 (low), 25.21% of area is in level-3 and 38.23% of total geographical area comes under level-4 (high)

**2.2 Terrain Index:** The terrain index is based on slope, aspects and elevation of the study area. The slope is categorised as 0 to 5 degreeas first level slope, 5 – 10 degreegentle slope, 10 – 15 degreemoderate slope, and 15 – 20 degreesteep slope and above 20 degreeas very steep slope. As the district is a part of *Brahmaputra* alluvial flood plain, about 91.99% of the total geographical area comes under 0 to 5 degree first level slope, followed by gentle slope covers7.66% of total geographical area. Moderate slope is about 0.20% and steep slope is 0.14% of the total geographical area. Whereas only 0.01% of land comes under very steep slope, that is almost negligible.

**2.3 Vegetation Index:** For vegetation index NDVI technique has been used.Normalized Difference Vegetation Index (NDVI)technique is a simple graphical indicator that quantifies vegetation by measuring the difference between near infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). NDVI ranges between values -1 to +1.
The vegetation index is classified into five classes based on NDVI such as:dense vegetation that covers 12.95% of total geographical area of the district, open vegetation covers 47.18% of the area andsparse vegetation that covers 39.87% of the total geographical area of the district.

**2.4 Soil Index:** The soil index is based on physical and chemical properties of soil. For the study the properties of soil depth, texture, soil erosivity, soil water holding capacity and pH values are taken in to consideration. The soil index is primarily represents the land capability index of a particular area, which also represents the productive capacity of the soil. The generated land capability index shows that 0.37% of total geographical area comes under class 1 land capability class, 22.75% comes under class 2 land capability class, 49.81% comes under class 3 land capability class, 12.75% under class 4, 1.61% under class 5 and 12.71% of total geographical area comes under class 6 land capability class.

[5]High standard deviation indicates that the data points spread out over a wider rangers of values.
[6] Actual vapour pressure is a measurement of the amount of moisture in a volume of air.
[7] The saturation vapour pressure is the pressure of a vapour when it is in equilibrium with the liquid phase. It depends upon temperature; as the temperature rises the saturation vapour pressure rises as well.

Table: 2.4 Soil properties: Golaghat district (NBSS)

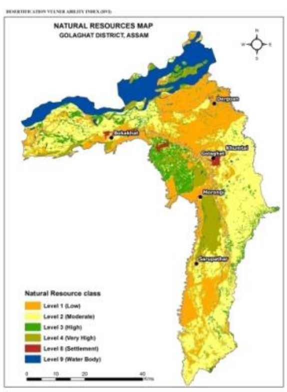
| **Soil index code** | **Description** | | | | | |
|---|---|---|---|---|---|---|
| | Depth | Texture | Permeability | Erosion intensity | pH | Soil Quality |
| 1 | >80 | Fine-silty, mixed, *hyperthermic family of typicFluvaqents* | Well drained | Very Low | 5.1-5.5 | V. good |
| 2 | 60 – 80 | Fine-silty, mixed, *hyperthermic family of typicFluvaqents* | Good to moderate drained in monsoon | Very Low to Low | 5.5 – 6.5 | Good |
| 3 | 40 - 60 | Coarse silty, fine loamy, coarse loamy | Moderate drained in monsoon, improves in post monsoon | Low to Moderate | 6.5 – 7.5 | Moderate |
| 4 | 20 - 40 | Fine silty | Poorly drained in monsoon, improves in post monsoon | Moderate to High | 7.5 – 7.7 | Poor |
| 5 | 0 - 20 | Coarse loamy | Very poorly drained in monsoon | High to Very High | > 7.7 | V. poor |

**2.4a Land Capability**:

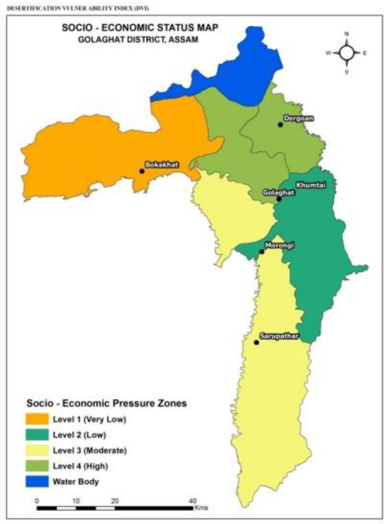
Table: 2.4a Land capability: Golaghat district (NBSS)

| Class | Description |
|---|---|
| IIw | Good cultivable land, highly susceptible to flood with medium to heavy texture, suitable for cultivation with due care for flood control. |
| IIIw | Good cultivable land, highly susceptible to flood with medium to heavy texture, suitable for cultivation with due care for flood control. |
| IIIws | Good cultivable land, slightly wet and/or subjected to overflow and erosion, with light to heavy texture. suitable for cultivation with management of excess water and selection of crops adapted to wet condition |
| IIIes | Good cultivable land, slightly wet and/or subjected to overflow and erosion, with light to heavy texture. suitable for cultivation with management of excess water and selection of crops adapted to wet condition |
| IVes | Fairly good and are suitable for occasional cultivation |
| VIes | Fairly good in places for agro horticulture and mulberry plantation under intensive erosion control, whereas soils of upper reaches of these capabilities should be reserved for forestry only |
| VIIes | Fairly good in places for agro horticulture and mulberry plantation under intensive erosion control, whereas soils of upper reaches of these capabilities should be reserved for forestry only |

**2.6 Land Utilization Index:** The land utilization index is the compilation of land use/land cover, NDVI (vegetation index), terrain index and land capability index. The extracted result is divided in three basic categories as; underutilized, optimum utilized and over utilized. However settlement and water body are categorized separately and are not considered under land utilization index. Around 18.50% (546.75 sq.km) of total geographical landis underutilized category, 64.13% (1895.23 sq.km) of landis optimally utilized and 17.37% (513.46 sq.km) of landis over utilized by the locals for agriculture and other productive activities.




**2.7 Biophysical Index/Natural Resource Index:** The Biophysical Index/Natural Resource Index (NR) is the compilation of all physical parameters. The NR index of the present study is based on terrain index, land utilization index and climatic index. The NR index primarily represents the biophysical conditions or health of that particular land area. It also represents the vulnerability priority zone in terms of available land resource. The evaluated result shows that level 4 has been identified as most vulnerable in terms of desertification vulnerability index as well has taken as very high priority zone, occupying 10.92% (322.70 sq.km) of total geographical area. Followed by level 3 taken as high priority zone with 9.95% (293.94 sq.km) of geographical area. Level 2 is considered as moderate priority zone with 43.31% (1280.18 sq.km) of geographical area and level 1 is considered as low priority zone, occupying of 35.82% (1058.78 sq.km) of total geographical area.




**2.8 Socio-economic Index:** The socio-economic index is based on broadly social index and economic development index. The social index emphasises onfacility available, broadly categorised as; education, medical, transport and communication facility and it is calculated based on *equation no 1, 2 and 3*. It is evaluated separately for 6 different administrative blocks namely Bokakhat, Khumtai, Morongi, Dergoan, Golaghat and Sarupathar. Education facility includes total 6 different types of amenities (primary, middle, secondary, senior secondary schools, colleges and adult literacy centres). The amenities index (Ic) for education varies from 0 (Morongi) to .12 (Dergoan). The medical facility includes total 13 different types of amenities (allopathic dispensary, maternity and child welfare, health centre, primary health centre, family welfare centre, registered private medical centre, subsidies medical practitioner, maternity home, community health works and other medical facilities).

The amenities index for medical facility varies from 0 (Morongi) to .019 (Bokakhat). The transport facility includes total 3 different types of amenities (bus service, railway service and navigable water ways). The amenities index for transport facility varies from 0 (Morongi) to .63 (Khumtai). The communication facility includes 4 different types of amenities (post office, telegraph office, telephone connection and post and telegraph office). The amenities index for communication facility varies from 0 (Morongi) to .13 (Bokakhat).

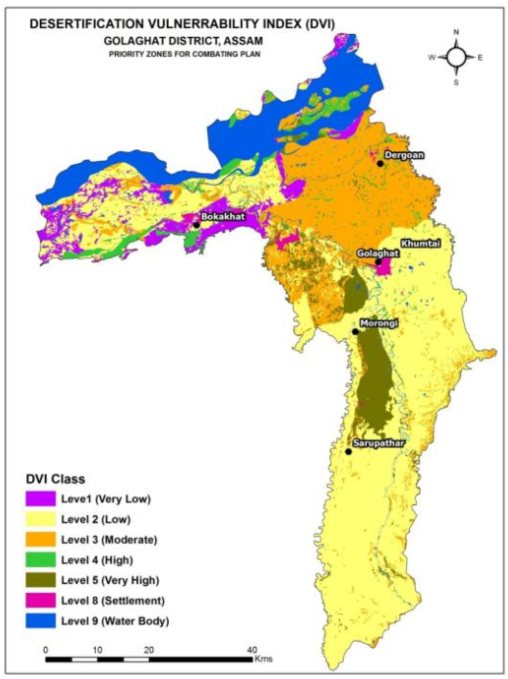
The economic development index is emphasising on population density, proportion of employed population and unskilled workers. The economic development index iscalculated differently for all 6 different administrative blocks applying *equation no. 4*. The economic development index varies from 0.59 (Khumtai) to 3.08 (Golaghat). Further compiling social index and economic development index the final output of socio-economic index is evaluated. The extracted result shows that Bokakhatadministrative blockis most developed in terms of socio-economic condition, showing very low socio-economic pressure. Followed by Golaghat administrative block, which has low socio- economic pressure. Sarupathar and Morongi blocks are categorised moderate socio-economic pressure zone. Whereas Khumtai and Dergoanare the least developed administrative blocks in terms of socio-economic condition and categorised as high socio-economic pressure zone.

## 3. Desertification Vulnerability Index:

The desertification vulnerability index is the compilation of biophysical index and socio-economic index. The estimated values of desertification vulnerability shows that 6.23% of land area falls under very low vulnerability, 55.16% of land is low vulnerability and 26.96% of land falls under moderate vulnerability. On the other hand only 4.06% of land falls under high vulnerability and 7. 59% of land area falls under very high vulnerability.

Table: 3 Desertification vulnerability Index: Golaghat District

| Index Code | Desertification Vulnerability | Area in sq. km | Area in % |
|---|---|---|---|
| **1** | Very Low | 183.89 | 6.23 |
| **2** | Low | 1627.75 | 55.16 |
| **3** | Moderate | 795.41 | 26.96 |
| **4** | High | 119.83 | 4.06 |
| **5** | Very High | 223.99 | 7.59 |



## 4. Conclusion:

The present study shows that 1139.23 sq.km of land areais under the process of moderate to very high desertification vulnerability, whereas 1811.64 sq.km of land area falls under low to very low desertification vulnerability. However comparing to other parts of the country, the rate of severity belongs to low category. In this study settlement and water bodies are not taken as a part of vulnerable areas. While comparing the desertification vulnerability index with desertification/land degradation status map of Golaghat district for the year 2011-2013, it is found that most of the moderate to very high vulnerable areas covered by agricultural land classified as no apparent degradation. Some patches of vegetation degradation level 3 are also falling under moderate vulnerability index. Another important finding is that the areas of water logging within Kaziranga National park is falling under low vulnerability index, whereas water logging is a prevailing issue within the national park, mostly during monsoon and retreating monsoon.

Here it is important to note that this comparison between land degradation vulnerability index and desertification/land degradation status map somehow shows a contradictory result. The desertification/land degradation status maps shows the current scenario of land, on the other hand desertification/land degradation vulnerability index using modified weighted index methodology shows a more probabilistic scenario. It is sometimes may not relate to the current status. It has also observed that the methodology is mostly based on analysis, in some situation it can over weighted the socio economic index then the biophysical conditions based on the prospective of the researcher. The methodology takes areas those are developed as low socio economic pressure and as follows it, primarily miss justify the current situation. Regarding the efficiency of the methodology, it is able to give a vulnerability analysis but it is more probabilistic rather than current.

Further to mention that the study shows a periodic result of a continuous monitoring process that is for the year 2011-2013. It needs further periodic observation and analysis to evaluate the severity of the degradation processes to establishwhether the land is actually converting to dry land and losing its original productivity.Further the study will also attempt to prepare best fitted combating plans for by selecting the most vulnerable areas as micro watersheds to restore the natural resource that can sustain in a distant future. *In this study settlement and water bodies are not taken as a part of vulnerable areas and labelled as level 8 (settlement) and level 9 (water body)*

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