Journal of Geomatics Vol. 13, No. 2, October 2019

A decision based approach to develop action plans for land degradation neutrality using geospatial techniques in a semi arid region of India

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(Received: Sep 13, 2018; in final form: July 04, 2019)

Abstract: Land Degradation (LD) is one of the most serious environmental problem leading to temporary or permanent decline in the productive capacity of the land and hence affects the food security. There is a need to rehabilitate degraded lands to support sustainable food production. In the present study, an attempt has been made to develop decision based approach for action plan development aimed towards achieving regional level LD neutrality in the state of Telengana using existing Land Use/Land Cover (LU/LC), LD and slope maps prepared at 1:50,000 scale using Resourcesat-1 LISS-III and Cartosat DEM. Results of the study revealed that water erosion, salt affected soils and forest degradation were the major category of LD accounting to 87.7%, 5.3% and 3.6% respectively of the total LD area. A number of rule sets were generated for each LD class based on various land conservation practices advocated by regional and international organizations. Afforestation/ gulley plugging, contour graded bunds, grass cover establishment are the major action plans recommended to reduce the loss of land due to water erosion and forest degradation. Adoption of such activities may help restoring 76.4% of the area under LD in the study region.

Keywords: Land Degradation, Neutrality, Remote Sensing and GIS

1. Introduction

India is endowed with vast natural resources specifically land which is a vital source growing food, fibre and firewood to meet the human needs, preserving forests and biodiversity, facilitating the natural management of water system and acting as a Carbon store. India homes over 16% of world's population in an area, which is 2.42% of global spread. Per Capita arable land in India, which is around 0.15 ha at present, is expected to decrease to a meagre 0.09 ha by 2075 (Navalgund, 2006).The degradation of dry land is one of the most serious environmental problem and major reason for such projected changes in India. LD is reducing the natural resources available, making us all less resilient and more vulnerable to the impacts of climate change on food security (Gomiero, 2016). Lack of adequate information on soil resources coupled with improper land use planning have resulted in many of the present day LD problems in our country such as salinity/ alkalinity and water logging in command areas, severe erosion in catchments leading to siltation of reservoirs, decrease in productivity of crops etc. LD tends to be an irreversible process, therefore in order to establish sustainable land use system, it is important to make attempts to discover the area prone to LD as well as to monitor the progress of degradation (Uchida, 1994).

The traditional soil surveys are providing information on degraded lands which are subjective, time consuming and laborious. Geo spatial techniques have reduced field work to a considerable extent. It is due to advantages with satellite data like availability of data in multi-spectral channels, repetitive coverage of same area at regular intervals and compatibility for data analysis at faster rates on computers. Currently, remote sensing data is being regularly employed in the survey of degraded soils, because of development of operational methodologies. Synoptic coverage in narrow and discrete spectral bands provided by space borne sensors at regular interval enabled inventorying degraded land and monitoring their temporal behaviour at operational level (Dwivedi, 2001). The quantification of spatial behaviour at the specific moment is an initial step to monitor the progress of LD. The capability of wide spatial coverage of remote sensing data is its advantageous characteristic. Systematic research and development efforts in the application of satellite data in soil studies has now resulted in the development of operational methodology to map degraded lands and monitor them on routine basis at 1:50,000 or larger scale (Manchanda et al., 2002).

Several researchers in India have used remote sensing data for LD assessment to delineate the state of soil erosion, soil salinization, water logging, foliage deterioration, etc (Venkataratnam and Ravisankar, 1992; Dwivedi and Sreenivas, 1998; Dwivedi et al., 2006). Beside that efforts were also made by various agencies across the India to identify various types of degraded lands, their spatial extent and severity levels (DAC, 1994; http://www.nbsslup.in; http://bhuvan.nrsc.gov.in). Bhattacharyya et al. (2015) reported that soil degradation in India is estimated to be occurring on 147 Mha of land, including 94 Mha from water erosion, 16 Mha from acidification, 14 Mha from flooding, 9 Mha from wind erosion, 6 Mha from salinity, and 7 Mha from a combination of factors. Therefore, in recent years increasing emphasis is laid on the information on the nature, extent, spatial distribution and magnitude of LD which plays a vital role in planning the strategies for reclamation /conservation of degraded lands. Assessment of LD status in terms of water and wind erosion, salt affected and water logging is an important pre-requisite for land resources conservation planning and reclamation programmes. The water erosion in the erosion map depicts areas having soil loss greater than 10 tons/ha/year (http://bhuvan.nrsc.gov.in).Salt affected areas are one of

the most important degraded areas where soil productivity is reduced due to either salinization (EC > 4 dS/m) or sodicity (ESP > 15) or both(http://bhuvan.nrsc.gov.in). Water logging is considered as physical deterioration of land. It is affected by excessive ponding / logging of water for quite some period and affects the productivity of land or reduces the choice of taking crops.

The degraded lands need to be rehabilitated to support sustainable food production or, where appropriate, be restored to its natural or semi-natural state. Hence action plans are to be generated for achieving LD neutrality of our country based on existing data bases like LULC, LD, slope etc. The United Nations Convention to Combat Desertification (UNCCD) defines land degradation neutrality as "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD, 2015).

Actions to achieve Land Degradation Neutrality (LDN) include land management approaches that avoid or reduce degradation, coupled with efforts to reverse degradation through restoration or rehabilitation of land that has lost productivity. Sustainable Land Management (SLM) practices provided in the action plans, such as agro forestry and conservation agriculture, can boost yields and prevent future LD. Analysis of time series database, space based indices along with ecological and economic variables can help in identification of LD vulnerability. This information along with existing LD information will help in developing action plans in more holistic way to achieve land degradation neutrality.

Hence the current study has been conducted in the state of Telengana as a representative of semi arid region of India with the objectives, viz., 1) To develop methodology for assessing LD vulnerability 2) To develop action plan towards LD Neutrality (LDN). Achieving LDN may contribute to sustainable development efforts; it may improve food, energy and water security and build the resilience to the impacts of drought and other climate-related disasters.

2. Materials and methods

2.1 Study sites

The study was carried out in the state of Telangana which located between 17.36° and 12.97°N latitude (Figure 1). The geographical area of Telangana is 112,077 square kilometers. Telangana is situated on the Deccan Plateau in the central stretch of the eastern seaboard of the Indian peninsula.

Major soil types of Telangana include red sandy, dubbas chalkas, deep red loamy, and very deep black cotton soils (Biswas et al., 2015). Telangana lies in a semi-arid region and has a predominantly hot and dry climate. The annual rainfall is between 900 and 1500 mm in northern Telangana and 700 to 900 mm in southern Telangana. The average temperatures during summer and winter are 40-42 & 22-23 °C respectively.

Figure 1: Location of the study site

2.2 Data and software used

The existing LD and LU/LC maps at 1:50,000 scale generated by National Remote Sensing Centre (NRSC) for the year 2005-06 have been used in the present study (http://bhuvan.nrsc.gov.in). The LD mapping was carried out using Resourcesat-1 multi-temporal LISS-III data of 2005-06 on 1:50,000 using visual interpretation using the multi-temporal LISS-III data. Classification system along with visual interpretation cues were developed for LD mapping (NRSC, 2007). This was supported by adequate field checks, soil chemical analysis and internal as well as external quality checks at various stages. The land degradation processes addressed were water erosion, wind erosion, water logging, salinisation / alkalization, acidification, glacial, anthropogenic and others. Similarly, LU/LC mapping was carried out using Resourcesat-1 multi-temporal LISS-III data of 2005-06 on 1:50,000 scale using visual interpretation of the multi-temporal LISS-III data. Around 900 LISS-III images acquired during kharif, rabi and summer seasons were used. Visual interpretation of multi-season data was supported with knowledge from historic thematic bases like waste lands and LU/LC as well as Cartosat DEM. Slope map at 1:50,000 was generated from the existing 1:10,000 slope maps using resampling techniques. All the analysis has been carried out using ArcGIS version 10.2.1 and Erdas Imagine-2016 software.

2.3 Methodology

The existing databases on LD, LULC and slope maps were brought into a common projection system and rasterized with a cell size of 24 m resolution. The rule sets were generated for each LD classes based on the various land conservation practices advocated by regional and international organizations for action plan generation. These rules were applied on the integrated dataset in GIS environment to generate an action plans for LD neutrality. The overall methodology of the research is presented in figure 2.

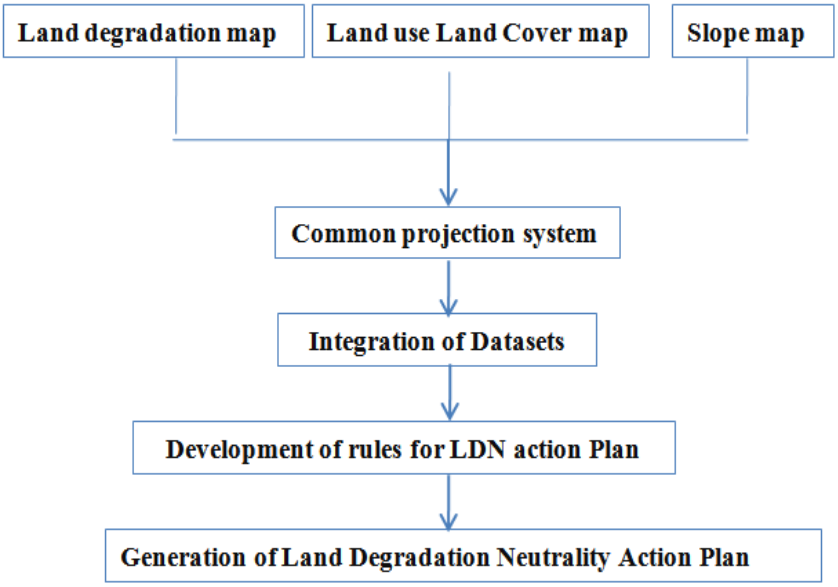

Figure 2: Flowchart of the methedology

3. Results and discussion

3.1 Variability in land use and slope

The distribution of LU/LC in Telengana state is shown in figure 3. It is observed that agricultural land is the dominant land use in the study area followed by forest and grassland. About 7.09 Mha of land is under crop cultivation, 2.63 Mha of land is under forest and grass. Wikramanayake et al., (2002) reported that over 80% of the original forest cover has been cleared for agriculture, timber harvesting, or cattle grazing. The Eastern Highlands are moist deciduous forests in the state. The slope mostly varies from very gentle to gentle (1-3%) and covers major portion of the study area. These areas comprise of pediplain with shallow weathering, sheet rock flat topped portion of hills etc. The moderately sloping area (8-15%) occur as isolated small patches at the foot hill zones. Moderately steep (15-30%) to very steep sloping zones (30-50%) are mostly observed in the hilly slopes of residual hills, denudational hills, and in the peripheral zones of the hilly terrain in the study region (Figure 3). The steeply sloping areas are also observed along isolated hills and covers very small extent.

3.2 Spatial distribution of LD processes

The overall status of LD in Telengana as per 2005-06 assessment is given in table 1. It is clear from this table that about 3322.5 thousand ha of land is under various processes of LD in the state of Telangana. The LD map of Telangana state is presented in figure 4. The water erosion is the major category of LD (2889 thousand ha) in the study area accounting to 87.7% of total LD of the state. It is mostly observed in the eastern region of the study site. It is followed by salt affected soils accounting to 5.3% of total LD in the state. The Salinization / alkalization (comprising various categories like saline, sodic and saline-sodic with varying severity) is distributed over 176 thousand ha of land. The barren rocky, mass movement and riverine sands (others category) are distributed over 120 thousand ha of land and accounts for 3.6% of total LD in the study area. The severe forest degradation (forest to non-forest) mostly occurs as isolated patches contributing 3.6% (113 thousnad ha) of total LD in the study region.

3.3. Rule-sets for generating LD neutrality action plan

The rule sets were generated (Table 2) for each LD classes based on the various land conservation practices advocated by regional and international organizations. The specific rule set has been formulated by referring the slope and type of land use to generate LD neutrality action plan for a particular LD process. There are number of practices, which can reduce the loss due to water erosion from agricultural land at different slope levels namely at 0-1 % slope: levelling & field bund; 1-3 % slope: contour farming (http://nass.usda.gov) & avoiding ploughing along slopes; 3-8 % slope: contour bunding/contour trenching; 8-15 % slope: contour terracing/bench terracing; 15-30 % slope: bench terracing with stone retaining walls etc. Similar combinations are also followed for forest and grassland to protect loss from water erosion. Whereas shelter belt is found to be more suitable measure to protect loss of top soil due to wind erosion stabilized-unstabilized dunes from agricultural, forest and waste land.

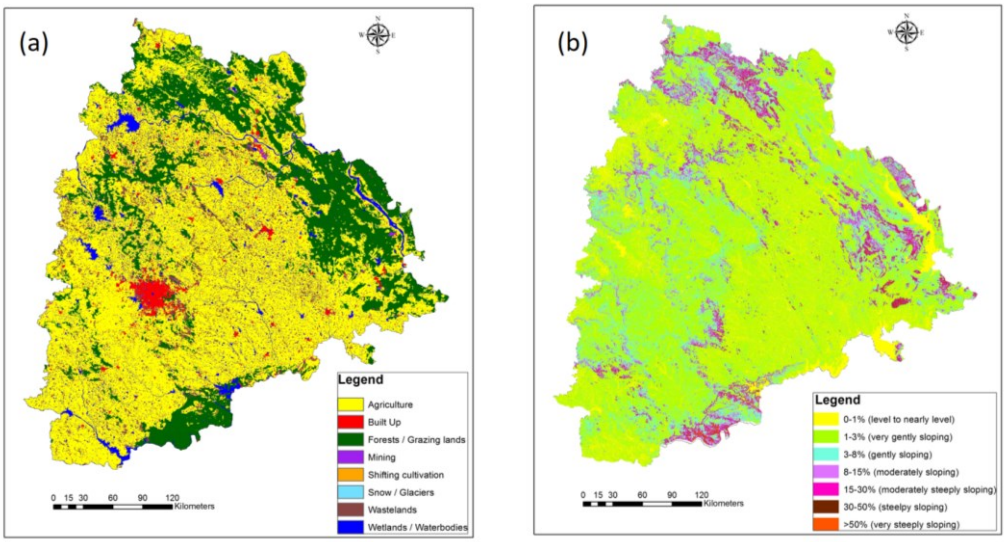

Figure 3: Land Use/Land Cover (a) and Slope map of the study area (b)

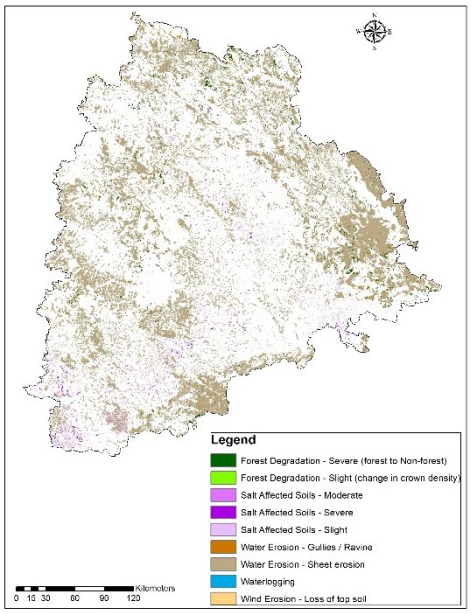

Figure 4: Spatial distribution of the Land degradation processes in the study area

Table 1: Area statistics of various LD processes in Telangana State

LD_Processess	Area ('000 ha)	% of Total LD of the study area
Water Erosion - Sheet erosion	2889	87.12
Water Erosion - Gullies / Ravine	19.0	0.56
Forest Degradation - Slight (change in crown density)	1.00	0.03
Forest Degradation - Severe (forest to Non-forest)	113.0	3.40
Salt Affected Soils - Slight	120.0	3.60
Salt Affected Soils - Moderate	38.0	1.139
Salt Affected Soils - Severe	18.0	0.55
Water logging	0.2	0.008
Barren Rocky Areas	76.0	2.29
Anthropogenic	42.0	1.26
Others (Riverine Sand)	3.00	0.005
Total	3322.5	100.0

Afforestation is considered as one of the most beneficial process of natural regeneration of a forest, where the area is under forest and suffering from the loss of topsoil (Veldman et al., 2015). The suitable reclamation practices; adoption of salt tolerant crops /varities and proper drainage are the criteria (www.fao.org) has been considered to reduce various intensity of salt affected soils in the current study. Subsurface drainage is an effective tool to combat the problem of water logging has also incorporated in the rulsets (Ritzema et al., 2008).

3.4 LD neutrality action plan

The regional level LD neutrality action plans were developed based on the above mentioned rule sets for Telangana state which is shown in the figure 5. The area under different action plans is presented in table 3. Afforestation/ gulley plugging, contour graded bunds, grass cover establishment,and other vegetative measures are the major options to reduce water erosion, forest degradation/desertification in the study region. These action plans could be employed over 2520 thousand ha of land under water erosion and forest degradation. Adoption of such activities may help restore 76.4% of the area under total LD of the study region. The various intensity of salt affected soil can be reclaimed with different management practices, growing of salt and tolerant crops and with proper drainage. An area of 130 thousand ha may be brought to normal condition with adaption of such measures. In addition, well defined land use policies or strict legislation policies are also required to rehabilitate the degraded land.

Table 2: Rule sets for generating LD neutrality action plan

Sl No	LD process	LULC	Slope (%)	Measures
1.	Water erosion-Sheet Erosion	Agriculture	1-3	Levelling & field bund , Contour farming & avoiding ploughing along slopes
			3-8	Contour bunding/Contour Trenching
			8-15	Contour terracing/Bench terracing
			15-30	Bench terracing with stone retaining walls
2	Water erosion-Sheet Erosion	Forest	3-8	Contour Trenching
			8-15	Contour terracing
			15-30	Stone retaining walls
			30-50	Retaining walls and grass seeding
			50	Grass seeding
3	Water erosion-Sheet Erosion	Wasteland	<8	Agro-forestry; Silviculture
4	Water erosion Gullies/ravines	Agriculture		Contour graded bunds/ Gulley plugging/Soil moisture conservation measures/ Ravine side slope stabilisation with grasses
5.	Water erosion Gullies/ravines	Forest and Grassland		Afforestation/Gulley plugging
6	Water erosion Gullies/ravines	Wasteland		Gulley plugging; soil moisture conservation measures;
7	Wind erosion- Loss of Top soil/ Stabilised/Unstabilized dunes	Agriculture		Shelter belts; wind barriers; trap crops
8	Wind erosion- Loss of Top soil	Forest and Grassland/Wasteland		Shelter belts
9	Forest Degradation	Forest		Afforestation
10	Forest Degradation	Wasteland		Protected Afforestation; landscape restoration
11	Forest Degradation	Wetlands		Land rehabilitation and ecosystem restoration
12	Forest Degradation- Land Transformations	Forest		Protected Afforestation; landscape restoration
13	Forest Degradation- Land Transformations	Wasteland		Agro-forestry; Silvipasture
14	Salt affected soils	Agriculture		Reclamation; salt tolerant crops; proper drainage
15	Salt affected soils	Wasteland		Reclamation and Agroforestry, Salt tolerant trees and grasses
16.	Water logging	Agriculture		Surface and Sub surface drainage
17	Water logging	Wetlands		Land rehabilitation and ecosystem restoration

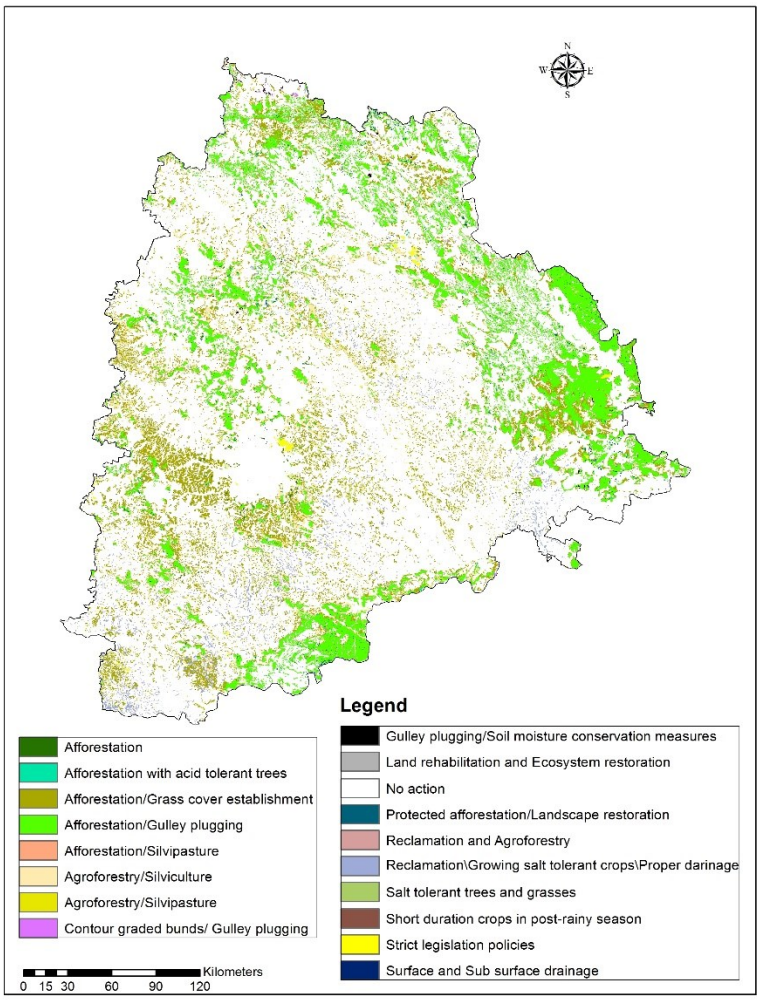

Figure 5: Land degradadtion neutrality action plan of Telangana State, India

Table 3: Area under various LD neutrality action plan in Telangana State

Action Plan	**Area (000 ha)**
Afforestation/Silvipasture	0.004
Land rehabilitation and ecosystem restoration	0.02
Short duration crops in post-rainy season	0.10
Surface and sub surface drainage	0.20
Reclamation and agroforestry	4.0
Salt tolerant trees and grasses	5.0
Gulley plugging/soil moisture conservation measures	5.0
Contour graded bunds/ Gulley plugging/soil moisture conservation measures/ ravine side slope stability	6.0
Afforestation with acid tolerant trees	10.0
Afforestation	20.0
Strict legislation policies	40.0
Agroforestry/silvipasture	50.0
Protected afforestation/landscape restoration	50.0
Reclamation/growing salt tolerant crops\providing proper drainage	130.0
No action	140.0
Agroforestry/silviculture	280.0
Afforestation/grass cover establishment &other vegetative measures	1090.0
Afforestation/gulley plugging	1420

4. Conclusions

In the present study, a decision based approach was developed to generate regional level LD neutrality action plan using geo-spatial techniques. Around 3322.5 thousand ha of land is under various processes of LD in the state of Telangana. Water erosion, salt affected soils and forest degradation were the major category of LD accounting to 87.7%, 5.3% and 3.6% respectively of the total LD area. Afforestation/ gulley plugging, contour graded bunds, grass cover establishment are the major action plans recommended to reduce the loss of land due to water erosion and forest degradation. Adoption of such activities may help restoring 76.4% of the area under LD in the study region. The future scope of work requires generation of action plans at 1:10, 000 scale or larger for effective utilisation by the users.

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