Journal of Geomatics Vol 10 No. 2 October 2016

Monitoring and assessment of desertification using satellite remote sensing

P.S. Dhinwa[1], A. Dasgupta[2] and Ajai[3]
[1]TALEEM Research Foundation, Ahmedabad
[2]Space Applications Centre, ISRO, Ahmedabad
[3]ES-CSIR, Space Applications Centre, ISRO, Ahmedabad
Email: psdhinwa@gmail.com

(Received: Aug 13, 2016; in final form: Oct 13, 2016)

Abstract: Desertification is one of the environmental concerns globally. Desertification, the land degradation in drylands, occurs almost in all parts of the world, affecting living conditions of billions of people. In India, about one third of its geographic area is undergoing the process of land degradation. One of the basic requirements for making the mitigation plan to combat desertification is inventory of the land undergoing the process of desertification, the type of processes and their severity. Monitoring of the desertification through time is also important to know if there is any impact of the implementation of the actions towards combating the desertification. Even, the strategy for arresting desertification/ land degradation requires assessment on the increase/decrease in the area or severity of the degradation. The present study deals with the mapping, monitoring and assessment of desertification and land degradation in the Bellary district falling in the semi-arid regions of Karnataka state. Land degradation maps were prepared using IRS data of 2001 and 2011. Monitoring and assessment of changes in the desertification process and severity in Bellary district has been done during a decade (2001- 2011). Area under various processes of desertification has increased during the decade 2001- 2011.

Keywords: Desertification, Land degradation, Vegetal degradation, Water erosion, Salinity and alkalinity, Drylands

1. Introduction

Land degradation occurs all over the world. About 33 per cent of the earth's surface exhibits desert like conditions to some degree or other. Land degradation happening in drylands is called as desertification. About 70 per cent of dry lands are affected by land degradation, which support over 1 billion people in more than 110 countries. The 1977 Nairobi conference of UNCOD (United Nations Conference on Desertification) describes desertification as the diminution or destruction of the biological potential of the land, which can lead to desert like conditions.
Definitions of desertification and the evolution of the desertification concept have been reviewed by many authors (Thomas and Middleton 1994; Puigdefabregas, 2009; Eswaran et al., 2001; Reynolds et al., 2007, 2011; Brabant 2008, 2010; Safriel, 2007; Ajai et al, 2007a, 2009; DSD 2009). However, the most comprehensive and widely accepted definition of "Desertification" is from the United Nations Convention to Combat Desertification (UNCCD) which defines it as "land degradation in arid, semi-arid and dry sub-humid areas resulting from factors including climatic variations and human activities (UNCCD, 1994).

Desertification happens due to the following anthropogenic reasons; deforestation including shifting cultivation, over grazing, cultivation on marginal lands and high slopes, non-sustainable land use practices, wrong agricultural management, mining, road construction, urbanization and other activities that disturb the natural ecosystem. Socio-economic condition (poverty and illiteracy) of the local people is the major cause of land degradation and desertification. Basically, it is the increasing population (human and cattle) pressure which is responsible for disturbing the fragile ecosystem and exerts undue pressure on natural resources which activates the process of desertification. Arable land per capita is shrinking throughout the world, threatening food security, particularly in poor rural areas and triggering humanitarian and economic crises. The per capita availability of cultivable land has declined from 0.48 ha in 1951 to 0.15 ha in 2001 and is projected to decrease to 0.08ha by 2035 (Dwivedi and Sai, 2006). As per UNCCD estimates, arable land per person has declined from 0.32ha in 1961-63 to 0.21ha in 1997-1999 and is expected to drop further to 0.16ha by 2030 (Annan, 2003).

In additions to the above mentioned anthropogenic reasons, frequent droughts, extreme weather conditions, climate change etc are natural causes of land degradation and desertification. There are five types of indicators - climatic, hydrological, physical, biological and socio-economic which may be used for desertification monitoring, assessment and prediction. Spatial inventory of desertification/land degradation status and its change with time are prerequisite for preparation of any combating plan. It is important to devise strategies to reduce the adverse impacts of land degradation and the role of geomatics in identifying, mapping and prioritizing the vulnerable lands for conservation and mitigation has been amply demonstrated (Altaf et al., 2014)

Remote sensing data along with GIS has been useful for desertification mapping of India at 1:500.000 scale (Ajai et al., 2007, 2009). Multi season IRS– AWiFS data has been used in the above national level mapping. As per the above inventory, 105.48 mha. i.e., 32 per cent of the geographical area of the country is undergoing the process of land degradation (Ajai et al., 2007b, 2009).

As mentioned earlier, it is also important to study and understand if the land degradation (intensity in terms of the area and severity) is increasing or decreasing with time. This helps in making an appropriate strategy for developing action plans to arrest the processes of land degradation. Thus the study was carried out to find out the changes, in terms of extent and severity, in the status of desertification/land degradation using IRS data for the Bellary district of Karnataka during a decade.

2. Materials and methods

2.1 Study area characteristics

Bellary district is located in the central eastern part of the Karnataka state with an area of 8463 km^2 and lies between 14^0 33' and 15^0 15' N latitude and 75^0 40' and 77^0 10' E longitude. It is bounded on the north by the Raichur and Koppal districts, on the west by the Gadag and Haveri districts, on the south by the Davangere and Chitradurga districts and the east by the state of Andhra Pradesh. Tungabhadra and Hagari are the major rivers of Bellary district. River Tungabhadra flows through the west and northern side boundary of the district. The area receives an annual average rainfall of 545 mm with a wide spatial variation, ranging from 815mm in the hilly tracts of Sandur Schist belt to 243 mm in the immediate east of the belt. The temperature of the district varies from 23 to 42^{o}C. The major rock groups of Bellary district are Dharwars, Peninsular Gneisses and Granites. Granite outcrops as inselbergs are prevalent in southeastern and eastern parts, whereas knobs are present everywhere.

Red soil covers the entire peninsular gneisses granite complex where as black soil along with a minor extent of characteristic ferruginous red soils cover the Dharwars. Red soils cover about 55% and black soils about 45% of the district. Both areas have distinctly different land scrapes mainly arising out of differences in water infiltration and run off of rainwater, that often lashes the district torrentially. Since the black soils are the most productive agricultural lands, they are extensively and intensively cultivated and inhabited. Whereas the red soils with occasional rock outcrops are less extensively and intensively cultivated, except in the valleys. All the reserved forests and scrublands are seen in the red soils region of the district. Among them, the forests covering the Sandur Schist belt are still preserved, the rest of the forests are variously degraded.

2.2 Data used

IRS-1C/1D multi-date satellite data, ancillary information and collateral data has been used to prepare desertification status map and land use/ land cover map for Bellary district, Karnataka. The details of the data used in this study are given in Table 1.

Table 1: Data used

	Satellite ID	Sensor ID	Date of Acquisition
Satellite Data	IRS-1C/1D	LISS- 3 (23.5 m)	October 2001 & 11 February 2002 & 12
Ancillary Information	Topo sheets : 48M/16 48N/9, 10, 13, 14 57A/4, 7, 8, 11, 12, 13 ,14, 15, 16 57B/1, 2, 5, 6, 9, 10, 57E/1, 2, 3, 4 (1:50,000) Scale		-

3. Methodology

Details of the methodology used for mapping desertification and land degradation status, using satellite data is given in figure 1. Two season IRS LISS-III data pertaining to the years 2001/02 and 2011/12 have been used in this study aimed at monitoring the changes in the land degradation status during the period of one decade. The classification system used to map various processes and their severity for the two time frames is given in Table 2. Visual analysis techniques have been employed on the multi-season satellite data to prepare desertification status maps (DSM) for both the data sets. In addition to the DSM, land use/ land cover (LU/LC) map of the study area was prepared, basically, to understand the type and the severity of degradation processes happening vis-à-vis the land use classes in which they occur.

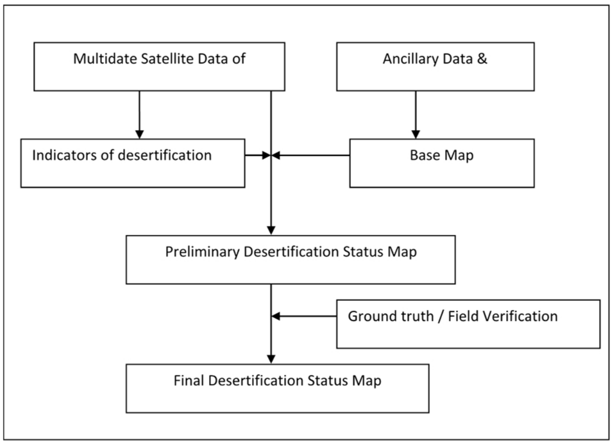


Figure 1: **Methodology for Desertification Status Mapping (DSM)**

Table 2: Classification system for Desertification Status Mapping (DSM)
LEVEL 1: Land use / Land cover

Agriculture – Unirrigated	D	
Agriculture – Irrigated	I	
Forest / Plantation	F/P	
Grassland/ Grazing land	G	
Land with scrub	S	
Barren / Rocky area	B/R	B(sc) indicating scree areas in cold deserts
Dune / Sandy area	E	
Waterbody / Drainage	W	
Glacial / Peri-glacial (In cold region)	C/L	
Others (Urban, Man-made)	OT	

- (Rocky areas within forest annotated as only V3-R in the map)
- (Vegetal degradation in Land with Scrub around periphery of notified forests delineated as Sv_)
- (Encroachment in forest area especially agricultural practices, is Fv3)
- (Barren and Rocky areas delineated separately as B or R and shown in others category of the legend)

(All settlements are hatched)

LEVEL 2: Processes of degradation

Type of processes resulting in degradation:

Vegetal Degradation	v
Water Erosion	w
Wind Erosion	e
Waterlogging	l
Salinization / Alkalinization	s/a
Mass Movement (in cold areas)	g
Frost heaving (in cold areas)	h
Frost shattering (in cold areas)	f
Man made (Mining/Quarrying, Brick Kiln, Industrial Effluents, City Waste, Urban Agglomeration etc.)	m

(Gully/ravines are shown as Xw3, where X is the Land use / cover class of surrounding area).
(Salinization or Alkalinization shown as ‘s or ‘a’ separately. Where both occur, are shown together i.e. sxay, where x and y are respective degree of severities)

LEVEL 3: Severity of degradation

This level represents the degree of severity of degradation. It is coded as ‘1’ for slight, ‘2’ for moderate and ‘3’ for severe degradation.

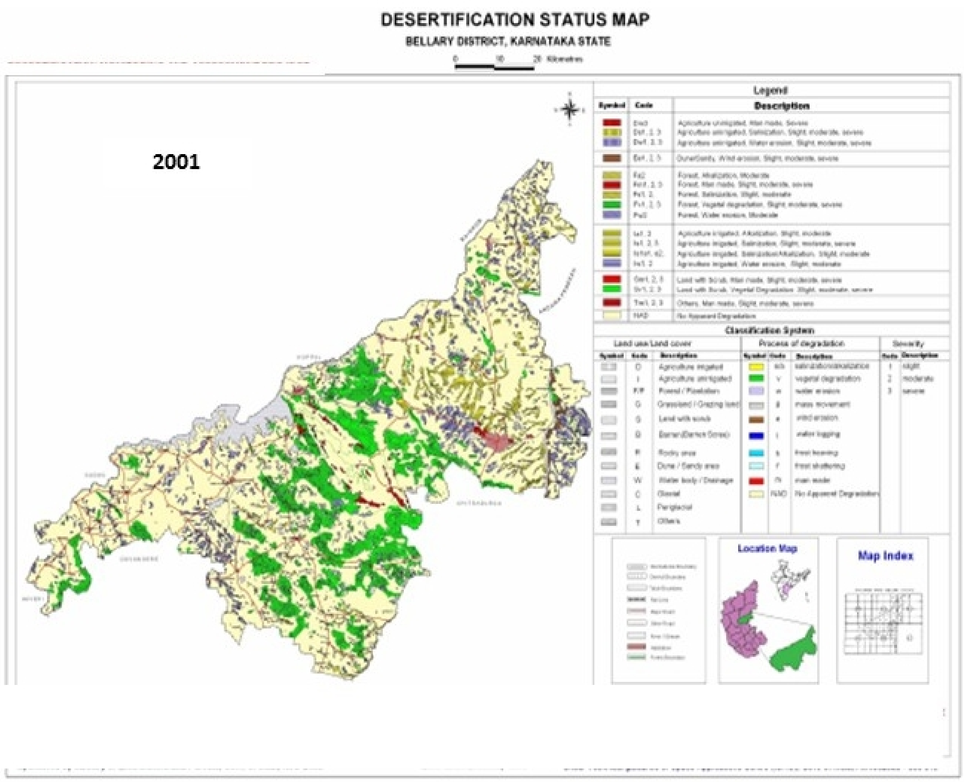
4. Land use / land cover mapping

Land use/ land cover (LULC) map of Bellary district was prepared by visual analysis of multi-date IRS LISS-3 data of 2011- 12 and through the use of ancillary information and collateral data. In Bellary district, Karnataka, there are twenty seven categories of level-III LULC types, namely, town/cities, habitation with vegetation, industrial area, villages, rabi crop, kharif crop, double crop agricultural plantation, fallow land, aquaculture pond, moist and dry deciduous open forest, degraded forest, mixed vegetation, forest plantation, prosopisjuli flora, scrub forest, tree groves, barren rocky/stony waste, sheet rock area, gullied/ravine land, land with scrub, land without scrub, mining/industrial wasteland, salt affected land, sandy area, lake/pond, lake/tank(dry), reservoir, river/stream, river island (Fig.4) . LULC map gives an account of spatial distribution and areal extent of various categories of land use/ land cover. When it is integrated with other requisite themes, e.g. ground water prospect, slope and land capability, it gives a clear picture of availability of natural resources at a particular place. Integration of the land use map with the desertification status map provide the information about the land degradation happening in a particular land use. This information is vital for preparation of desertification combating plan.

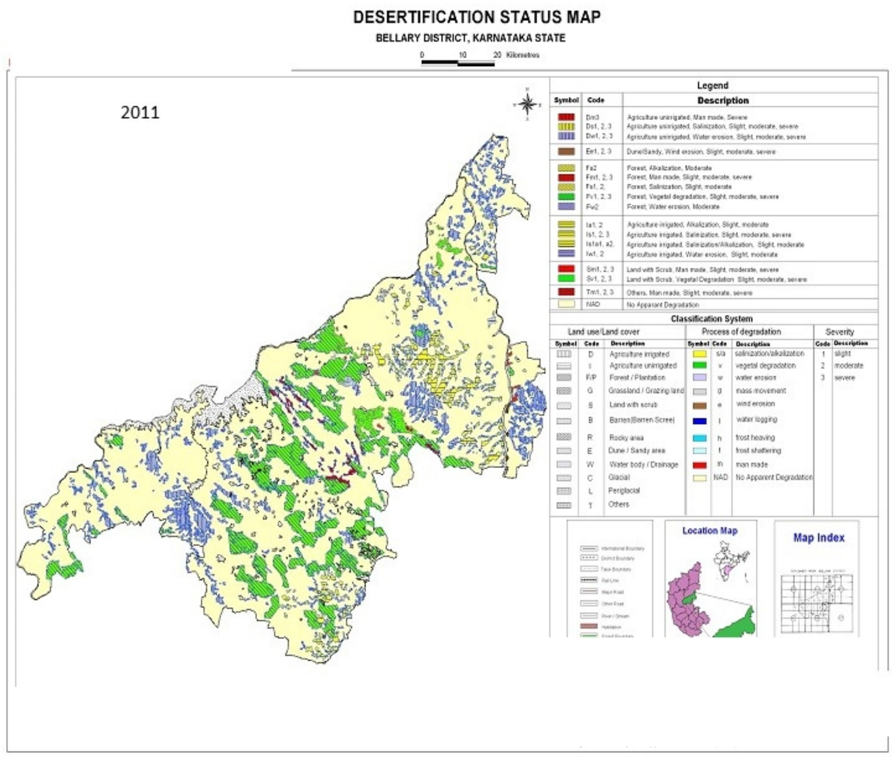
5. Results and discussion

Bellary district has a geographical area of 8463 km^2. Desertification status map of Bellary district, prepared using the IRS LISS-III, for the years 2001 and 2011 are given in Figure 2. Area under different desertification processes are presented in Fig.3. Desertification mapping for the year 2001 reveals that vegetal degradation, salinity/alkalinity, wind erosion, water erosion and mining manmade are the significant desertification processes observed in the district which covers almost 21 per cent of area of the district. Area under vegetal degradation has increased from 1101.70 ha in 2001 to 1132.22 ha in 2011. Land undergoing water erosion was 370.35 ha in 2001, which increased to 497.33 ha in 2011. Salinity in the district has increased from 298.94 ha in 2001 to 314.21 ha in 2011. Land degradation due to the human activities (manmade) has also increased from 43,41 ha in 2001 to 81.80 ha in 2011. Total area undergoing the process of land degradation in the district was 1814 ha in 2001, that has increased to 2025,56 ha (about 24% of the geographic area).

Comparison of desertification status maps prepared from the satellite images of 2001 and 2011 reveals that there is an overall increase in the area under different processes of desertification. The increasing trend in the extent of land degradation processes could have adverse impacts on several land surface processes linked to hydrology and soil erosion (Rashid et al., 2011) and therefore it is important to take appropriate combative measures to minimize or arrest the processes of land degradation in the district.



2a



2b

Figure 2: Desertification status map of Bellary district (2a) for 2001 and (2b) 2011

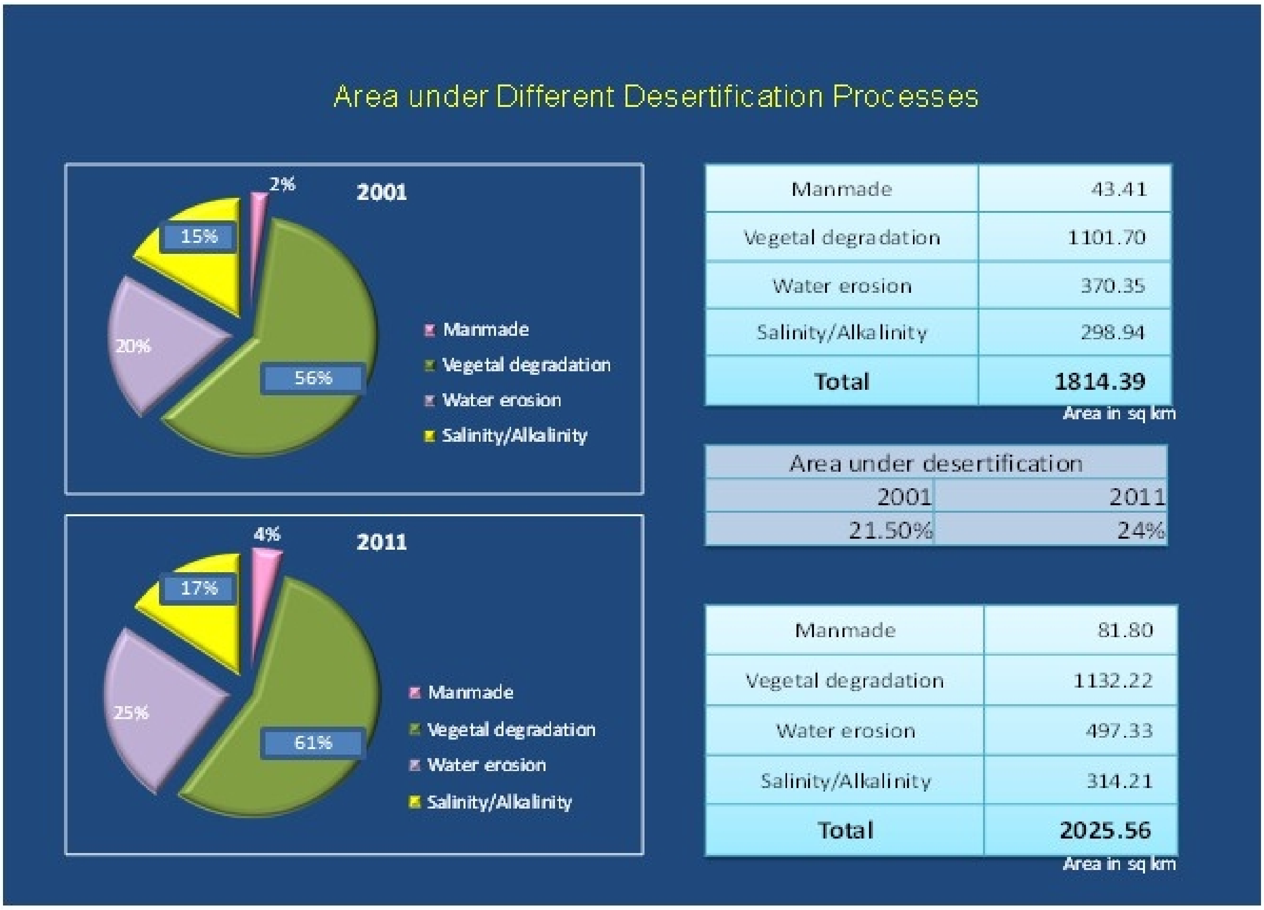


Figure 3: Area under different desertification processes during 2001 and 2011

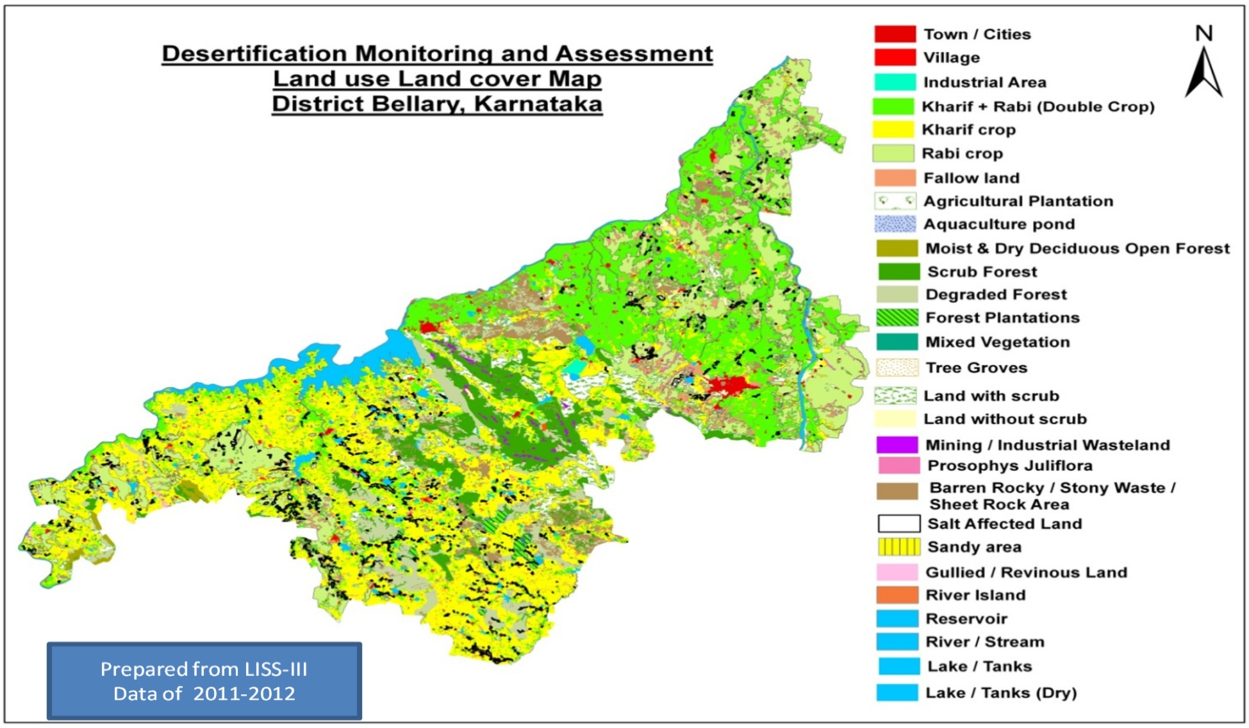


Figure 4: Land use/ land cover map of Bellary district

6. Conclusion

Earth Observation satellite data were used to prepare the desertification/land degradation status map (DSM) for Bellary district of Karnataka state for two time frames 2001 and 2011. These maps have been used to monitor and assess the process of desertification during the period of one decade. As per the DSM maps of 2001and 2011, the area under land degradation in the district has increased from 21.5 % to 24%. The main land degradation processes active in Bellary district are vegetal degradation, water erosion, salinity/alkalinity and man- made (mining). The results clearly reveal that process of desertification is showing an increasing trend. Appropriate measures need to be taken to arrest and if possible, reverse the process of desertification in the district. Land degradation, livelihoods and environmental settings are inextricably linked. It is therefore recommended that action plans for the conservation of land resources and mitigation of land degradation in the entire country be made an important ingredient of the rural development planning at the Panchayat level.

Acknowledgements

One of the authors (Ajai) is thankful to CSIR for support under ES scheme. P.S. Dhinwa is grateful to Dr. Irfan Khan, Director, TALEEM Research Foundation, Ahmedabad for his valuable guidance and moral support in preparation of this research paper.

References

Ajai, A.S. Arya and P.S. Dhinwa (2003). Desertification: The creeping disaster, NNRMS Bulletin (28), pp.52-64.

Ajai, S.K Pathan, P.S. Dhinwa, A.S. Arya and 41 others (2007a). Desertification monitoring and assessment using remote sensing and GIS: A pilot project under TPN-1, UNCCD. Scientific Report No: SAC/RESIPA/MESG/DMA/2007/01, Space Applications Centre, ISRO, Ahmedabad, India.

Ajai, A.S. Arya, P.S. Dhinwa and 49 others (2007b). Desertification/land degradation atlas of India. Space Applications Centre, Ahmedabad. ISBN No. 978-81-909978-2-9.

Ajai, A.S. Arya, P.S. Dhinwa, S.K. Pathan and K. Ganeshraj (2009). Desertification/land degradation status mapping of India. Current Science 97(10): 1478-83.

Altaf, S., G. Meraj and S.A. Romshoo (2014). Morphometry and land cover based multi-criteria analysis for assessing the soil erosion susceptibility of the Western Himalayan watershed. *Environmental Monitoring and Assessment*, 186(12): 8391-8412.

Annan, Kofi (2003). Message by UN secretary general Kofi Annan for the world day to combat desertification and drought. June 17, 2003.

Brabant, P. (2010). A land degradation assessment and mapping methodology, Standard guideline proposal, Comite' ScientifiqueFrancais De la desertification les dossiers thematiques. CSFD Issue 8, Agropolis International.

Brabant, P. (2008). Activities humaines et degradation desterres, collection Atlas Cederom, Indiateurs et methode, IRD Paris. Published under the International Year of Planet Earth (IYPE) Planet Terre label (cartographie.ird.fr/degra_PB.html)

DSD. (2009). Integrated methods for assessment and monitoring land degradation processes and drivers (land quality), White paper of the DSD working group 1, version 2. Http://dsd-consortium.jrc.ec.europa.eu/documents/wg1 white-paper draft-2 20090818.pdf

Dwivedi, R.S. and M.V.R. Sesha Sai (2006). Proc. of regional workshop on deserts and desertification, at Hyderabad during Dec. 29-30, 2006, p.31.

Eswaran H., R. Lal and P.F. Reich (2001). Land degradation: An overview. In: bridges, E.M., Hannam, I.D., Oldeman, L.R., Pening De Vries, F.W.T., Scherr, S.J., Sompatpanit, S. (Eds.), Response to land degradation. Science Publishers Inc, Enfield, NH, pp. 20–35.

Rashid, M., M. Lone and S.A. Romshoo (2011). Geospatial tools for assessing land degradation in Budgam district, Kashmir Himalaya, India. Journal of Earth System Science, 120(3), 423–433.

Puigdefabregas, Juan, Gabriel del Barrio and Joachim Hill (2009). Advances in studies on desertification. Contributions to the International Conference in memory of Prof. Johm B. Thornes. -Murcia: Universidad de Murcia, editum. Pp 77- 87 Ecosystemic Approaches To Land Degradation.

Reynolds, J.F., D.M. Stafford, E.F. Smith, B.L. Lambin, II. Turner, M. Mortimore, S.P.J. Batterbury, T.E. Downing, H. Dowlatabadi, R.J. Fernandez, J.E. Herrick, E. Huber-Sannwald, H. Jiang, R. Leemans, T.

Lynam, F.T. Maestre, M. Ayarza and B. Walker (2007). Global desertification: Building a science for dryland development. Science 316: 847–851.

Reynolds, J.F., A. Grainger, Stafford Smith, D.M. Bastin, G.L. Garcia-Barrios, R.J. Fernández, M.A. Janssen, N. Jürgens, R.J. Scholes, A. Veldkamp, M.M. Ver-straete, G. Von Maltitz and P. Zdruli (2011). Scientific concepts for an integrated analysis of desertification. Land Degradation & Development 22, 166–183.