Status of desertification in South India – assessment, mapping and change detection analysis

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Desertification is the transformation of productive land into a non-productive one due to poor resource management, and unfavourable biophysical and economical factors. Periodical assessment of desertification status is imperative for a suitable comprehensive and combating plan. In the present study, desertification status maps of Andhra Pradesh (AP), Karnataka and Telangana in South India have been prepared using remote sensing data for two time-frames (2003–2005 and 2011–2013) and change detection analysis has been carried out. The results reveal that 14.35%, 36.24% and 31.40% of the total geographical area in Andhra Pradesh, Karnataka and Telangana were affected by desertification processes respectively, in 2011–2013. Among the desertification processes, vegetal degradation contributes 7.27% of total area in AP, followed by water erosion (4.93%) and waterlogging (0.83%), whereas in Karnataka water erosion (26.29%) is dominant followed by vegetal degradation (8.93%) and salinization (0.45%). Change detection analysis shows that desertification processes of AP and Karnataka have increased by 0.19% and 0.05% respectively, whereas in Telangana it has decreased by about 0.52% from 2003 to 2005 data. The present database will help the scientists, planners and stakeholders to prepare appropriate land reclamation measures to control the increasing trend of desertification.

Keywords: Change detection analysis, desertification, salinization, vegetal degradation, waterlogging.

DESERTIFICATION is the degradation of land resources either by natural phenomenon or anthropogenic activity which adversely affects land fertility, ecological system and livelihood security in arid, semi-arid and dry subhumid regions. The major desertification process comprises of degradation of vegetative cover, soil erosion, waterlogging, salinization/alkalinization and decline of soil fertility[1]. Desertification affects one third of the world's land area especially the dry land ecosystem with aridity index less than 0.65 (ref. 2). The estimation of the United Nations Convention for Combating Desertification (UNCCD) shows that globally around 3.6 billion hectares of land is affected by desertification[3]. In addition, every year 5300 million tonnes of fertile soil is being lost along with 8 million tonnes of plant nutrients due to soil and water erosion[3], and overall about 250 million people are directly affected by land degradation[4,5]. Land resources are also degraded due to residential, road construction and mining activities[6]. The failure of resource management policies, particularly in the developing countries, has aggravated the intensity of desertification in marginal lands[7].

Periodical assessment and monitoring of desertification processes is imperative for the preparation of suitable comprehensive planning and adoption of reclamation measures. The status of desertification and its severity can be assessed using remote sensing data on both regional and global scale[8]. The present high-resolution remote sensing data and geocomputation techniques have substantially contributed to mapping the desertification processes such as vegetal degradation[9–11], water erosion[12,13], salinization[14,15], etc. Different methodologies have been used for mapping the status of desertification and its impact on land resources across the world[16–19]. The environmental sensitivity of land resources using biophysical and socio-economic parameters is common among researchers in assessing the degree of desertification[1,17,20,21].

India, the second most populus country in the world, became highly vulnerable to environmental stress due to its growing population that affects 228 million hectares (69%) of total geographical area. Further, 57% of land area which is under cultivation faces severe problem of land degradation[22]. The main factors responsible for desertification in India are extension of cultivation in marginal lands, inadequate soil water conservation measures, intensive cropping system, poor irrigation management and over-exploitation of groundwater. The process and intensity of desertification depend mostly on the type of agricultural practices employed in the agro-ecological region. According to UNCCD, it is mandatory to conduct and monitor desertification at regular intervals since it is a purely dynamic process[16,23,24]. In this present study, desertification status of Andhra Pradesh (AP), Karnataka and Telangana is assessed using remote sensing data of two time-frames (2011–2013 and 2003–2005) to analyse the change in status over the period.

The desertification assessment was carried out for the three southern states of India, viz. AP, Karnataka and Telangana at 1 : 500 K scale. Total study area is 466,836 km^2, which is 14.2% of the total geographical area (TGA) of the country, and located between 11.34°–19.54°N lat and 74.4°–84.45°E long. The area has been divided into three major physiographic divisions, viz. Deccan Plateau, Hill Ranges (Western Ghats and Eastern Ghats) and Coastal Plains. It is endowed with a wide

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Table 1. Process-wise changes in desertification status of Andhra Pradesh

Process of desertification	2011–13 Area (ha)	2011–13 Area (%)	2003–05 Area (ha)	2003–05 Area (%)	Change (ha) 2011–13 to 2003–05
Vegetation degradation	1,164,257	7.27	1,168,447	7.29	–4,190
Water erosion	789,433	4.93	783,830	4.89	5,603
Wind erosion	3,986	0.02	4,722	0.03	–736
Salinity	117,952	0.74	117,239	0.73	714
Waterlogging	132,334	0.83	125,755	0.78	6,579
Manmade	20,833	0.13	20,565	0.13	268
Barren/rocky	20,521	0.13	20,521	0.13	0
Settlement	49,441	0.31	26,649	0.17	22,792
Total area under desertification	2,298,758	14.35	2,267,728	14.16	31,030
No apparent degradation	13,447,078	83.94	13,476,591	84.12	–29,513
Total geographical area (ha)			16,020,500		

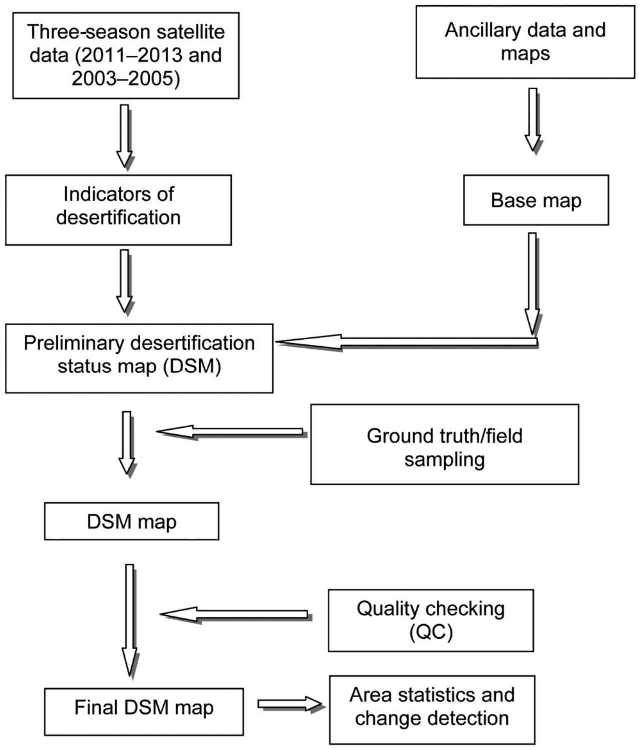

Figure 1. Methodology for desertification status mapping.

variety of soils having less fertile coastal sands to highly fertile deltaic alluvium developed from different parent materials. The major soil groups are red, laterite, black, alluvial and coastal soils. The mean maximum temperature is 42°C for Telangana and 45°C for Karnataka and AP and mean minimum temperature is 23°C, 16°C and 20°C for Telangana, Karnataka and AP respectively. The average annual rainfall is 907, 1248 and 940 mm for Telangana, Karnataka and AP respectively. The potential evaporation of the study area ranges from 700 and 2450 mm. Land-use statistics show that about 47.83% is under agriculture, 20.5% under forest, 7.9% under fallow lands and 7.16% is under non-agricultural uses.

The Resourcesat AWiFS (Advanced Wide Field Sensor) data (56 m spatial resolution) of two time-frames (2011–2013 and 2003–2005) were used for the present study. Three-season satellite imageries of *kharif* (June–September), *rabi* (October–February) and summer (March–May) were procured and used for assessment of desertification status. In addition, SOI toposheets (1 : 250 K), forest boundary (Forest Survey of India), water body, rivers, administrative boundary, road and rail network datasets were used as reference data.

Three-tier classification systems were followed for assessing different degradation processes, i.e. land-use type, process of degradation and its severity. The major land uses in the study area are agriculture – unirrigated (D), agriculture – irrigated (I), forest/plantation (F/P), land with scrub (S), barren/rocky area (B/R), dune/sandy area (E), water body/drainage (W) and others (T). The major processes are vegetal degradation (v), water erosion (w), wind erosion (e), waterlogging (l), salinization (s) and man-made degradation (m). In the third level, the processes were further classified into low (1) or high (2) based on the level of severity.

Desertification classes were identified and analysed from Geo-coded AWiFS digital data using on-screen visual interpretation techniques along with ancillary information (Figure 1). Satellite datasets were preprocessed for geometric and radiometric corrections before image interpretation. Geo-database was created in GIS using ArcGIS software package (ArcGIS 10.1) based on National Spatial Framework on 1 : 500 K with LCC projection and WGS 84 datum, and state-wise preliminary desertification status maps (DSMs) were prepared.

Ground truth data were obtained for finalizing DSMs with more precision. Direct observations/field checks were conducted in different locations in order to associate image data to real features on the ground surface. Severity of vegetal degradation was classified based on the

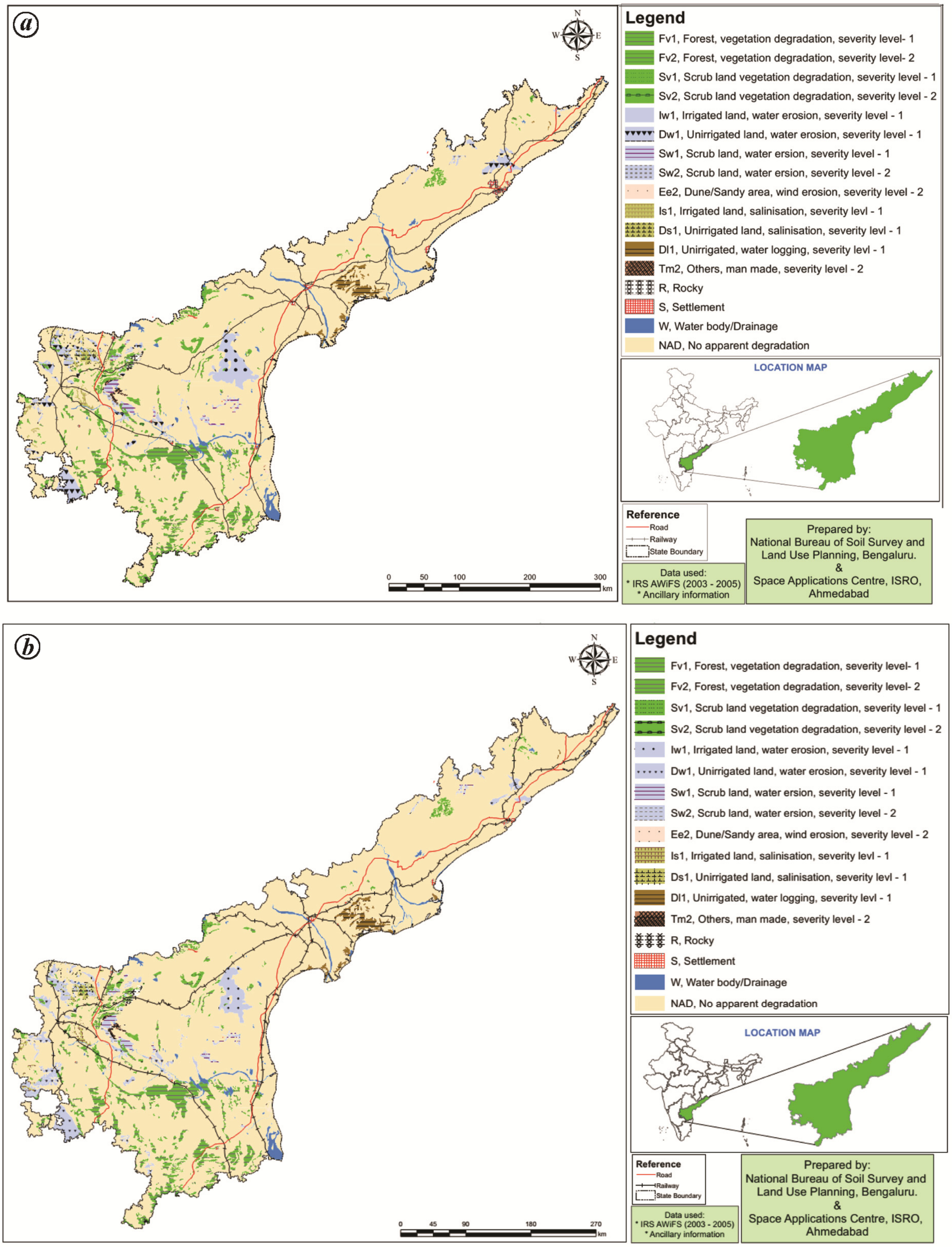

Figure 2. Desertification status map of Andhra Pradesh: ***a***, 2011–2013; ***b***, 2003–2005.

percentage decrease of plant cover. Water and wind erosion were assessed based on loss of topsoil layer. For assessing the status of salinization soil samples were collected from field and measured for pH and EC (electrical conductivity), and severity of waterlogging was identified based on the period of time water remained

Table 2. Process-wise changes in desertification status of Karnataka

	2011–13		2003–05		Change (ha)
Process of desertification	Area (ha)	Area (%)	Area (ha)	Area (%)	2011–13 to 2003–05
Vegetation degradation	1,712,386	8.93	1,704,569	8.89	7,817
Water erosion	5,043,041	26.29	5,059,629	26.38	–16,588
Wind erosion	2,159	0.01	2,159	0.01	0
Salinity	86,740	0.45	86,582	0.45	158
Manmade	20,876	0.11	18,704	0.1	2,172
Barren/rocky	3,389	0.02	2,887	0.02	502
Settlement	82,409	0.43	66,413	0.35	15,996
Total area under desertification	6,951,000	36.24	6,940,943	36.19	10,057
No apparent degradation	11,984,329	62.49	11,994,157	62.54	–9,828
Total geographical area (ha)			19,179,100		

Table 3. Process-wise changes in desertification status of Telangana

	2011–13		2003–05		Change (ha)
Process of desertification	Area (ha)	Area (%)	Area (ha)	Area (%)	2011–13 to 2003–05
Vegetation degradation	541,145	4.71	538,533	4.69	2,612
Water erosion	2,854,285	24.85	2,951,871	25.7	–97,586
Salinity	86,514	0.75	81,917	0.71	4,597
Manmade	16,982	0.15	14,592	0.13	2,390
Barren/rocky	1,979	0.02	1,979	0.02	0
Settlement	97,951	0.85	69,591	0.61	28,360
Total area under desertification	3,598,856	31.34	3,658,482	31.86	–59,626
No apparent degradation	7,689,491	66.96	7,631,019	66.45	58,472
Total geographical area (ha)			11,484,000		

stagnated in the field. According to the ground truth data the changes in desertification classes were modified.

The image analysis of 2011–2013 time-frame (Table 1 and Figure 2 *a* and *b*) showed that the dominant desertification processes in AP were vegetal degradation (7.27%) followed by water erosion (4.89%) and waterlogging (0.83%). The other processes like salinization (714 ha) and man-made degradation activities (268 ha) have also had certain impact. The main causes for vegetal degradation were biotic interference, forest fires, over-mining for minerals and metals, excessive use of firewood and severe deforestation. The percentage of area under desertification was higher in Anantapur district (11.85) followed by Kurnool (10.91), Prakasam (10.86) and Chittoor (9.35) districts. Kurnool district experienced high forest vegetal degradation (5.1%), while Anantapur district had high water erosion (7.3%). Previous studies showed that nearly 40% of TGA in AP was eroded by water[25].

In 2003–2005 time-frame, vegetal degradation contributed 7.29% of total area followed by water erosion (4.89%), waterlogging (0.78%), salinization (0.73%) and wind erosion (0.03%). Overall, the change detection analysis showed that the area under desertification had increased by about 0.19% in AP from 2003–2005 to 2011–2013. An area of about 4190 ha was recovered from vegetal degradation in 2003–2005 due to recent afforestation schemes implemented by the Government, whereas other processes like waterlogging (6579 ha), water erosion (5603 ha) and salinity (714 ha) had increased in the state.

The area under desertification in Karnataka in the 2011–2013 time-frame was 36.24% of TGA (Table 2 and Figure 3 *a* and *b*). Among the districts, Belgaum (6.93%), Gulbarga (5.66%), Tumkur (5.58%) and Bijapur (5.43%) had high area under desertification. The prominent processes were water erosion (26.29%) followed by vegetal degradation (8.93%) and salinity (0.45%). Bellary district experienced high vegetal degradation due to increased mining activities and extraction for timber[26].

Water erosion contributed 26.38% of area followed by vegetal degradation (8.89%) and salinity (0.45%) in the 2003–2005 time-frame. Overall, the change detection analysis showed that area under desertification had increased by about 0.05% in Karnataka from 2003–2005 to 2011–2013. This change is due to increased area under vegetal degradation (7817 ha), mining activities (2172 ha) and salinity (158 ha).

In Telangana, 7.5% of the land area underwent different desertification processes (Table 3 and Figure 4 *a* and *b*), and the most significant process of desertification

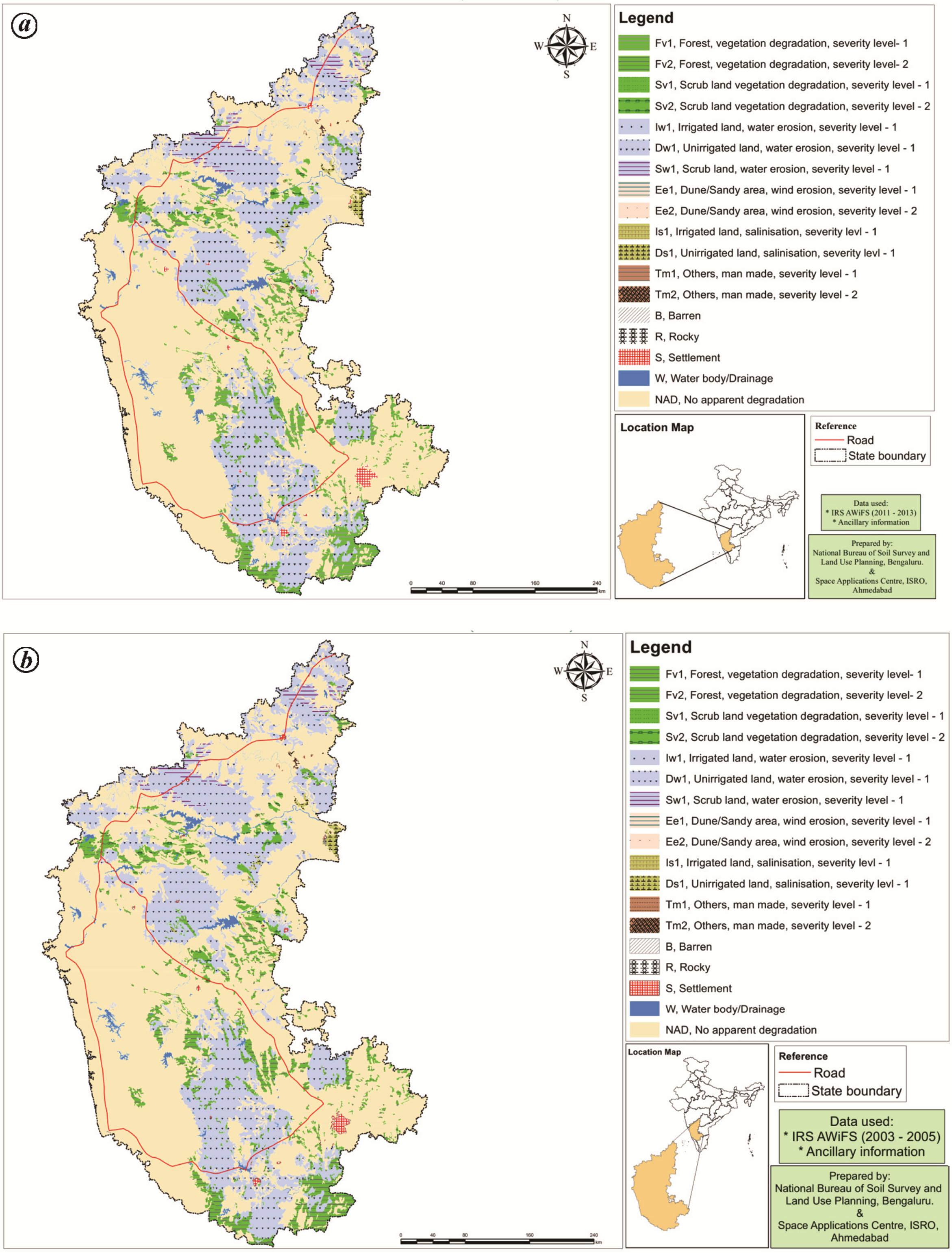

Figure 3. Desertification status map of Karnataka: ***a***, 2011–2013; ***b***, 2003–2005.

during 2011–2013 was water erosion (24.85%), followed by vegetal degradation (4.71%) and salinity (0.75%). Among the districts, Nalgonda (6.47%), Jayashankar Bhupalpally (6.40%), Bhadradri Kothagudem (6.32%) and Mahabubnagar (4.56%) experienced high desertification rate. Nagarkurnool district experienced high vegetal

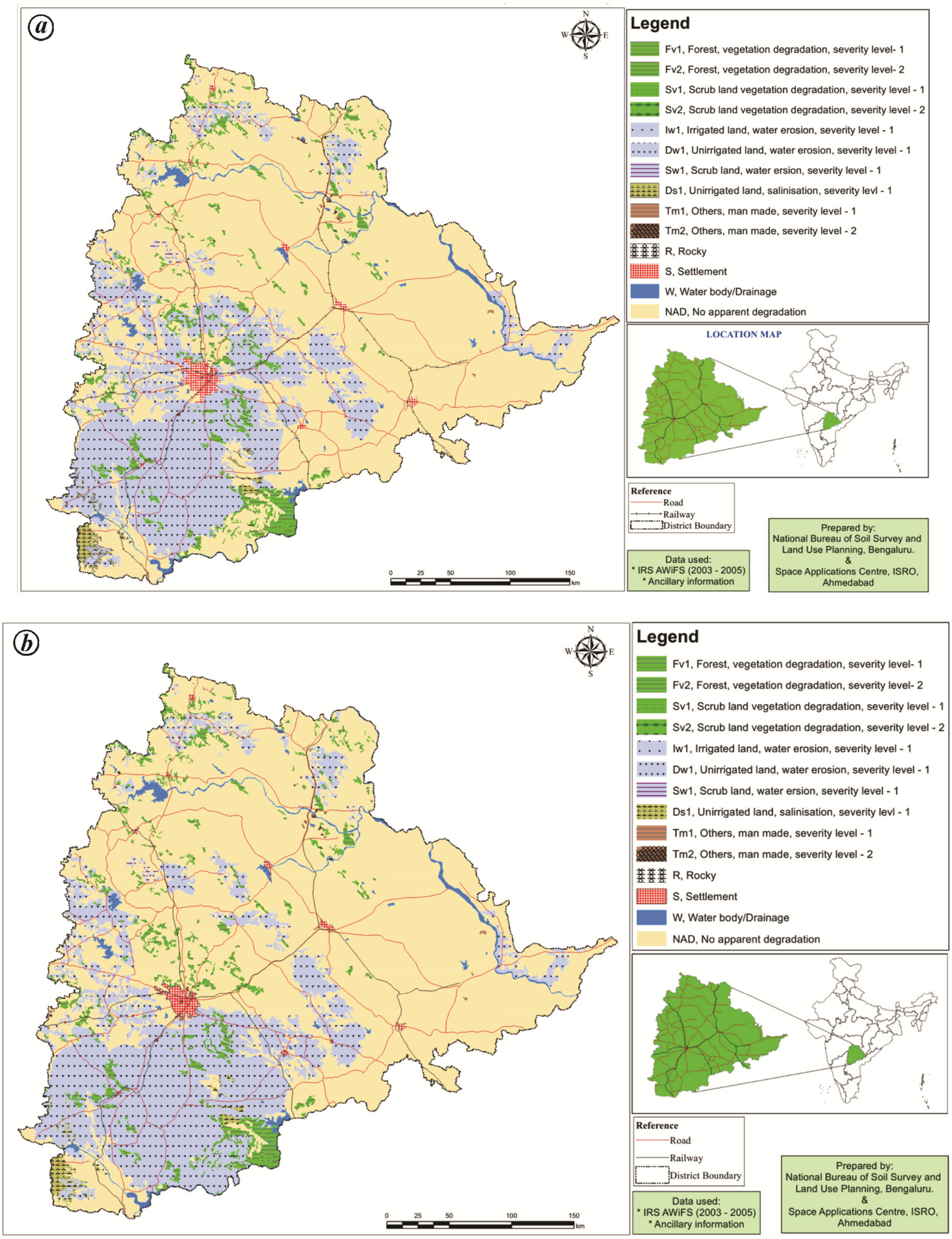

Figure 4. Desertification status map of Telangana: ***a***, 2011–2013; ***b***, 2003–2005.

degradation (0.83%), while Mahabubnagar district had high water erosion (3.84%) problem. The previous studies found that more than two-thirds of TGA of Telangana was affected by soil erosion[27].

Like 2011–2013, water erosion contributed 26.7% of total area followed by vegetal degradation (4.69%) and salinity (0.71%) in 2003–2005. Overall change detection analysis showed that desertification process had decreased by 0.52% from 2003–05 to 2011–2013. The area under water erosion low category reduced considerably and there was an increase in salinization and vegetal degradation.

Desertification status varies with land use, soil properties, cultivation practices, industrialization, climatic and other environmental factors. Severity of desertification process can be reduced by adoption of proper and regular management practices. Erosion and tree-felling are the two major issues in biomass productivity of forest ecosystem. Based on forest cover, soil and climate, potential areas can be identified for afforestation with suitable climate-resilient multipurpose tree species, perennial forage and fodder species[28]. Soil erosion can be managed by appropriate technical backstopping with location-specific soil and water conservation practices. Soil salinity/alkalinity in agricultural lands can be reclaimed by proper irrigation water management, development and maintenance of surface and subsurface drainage system and addition of amendments[26]. These activities may be converged with on-going National/State Government programmes like Joint Forest Management, Integrated Watershed Management Programme and Mahatma Gandhi National Rural Employment Guarantee Act, etc. to combat desertification process in the long run.

The present study indicates that remote sensing and GIS techniques along with other ancillary data could result in effective mapping and monitoring of desertification areas. Desertification analysis shows that 14.35%, 36.24% and 31.40% of TGA of AP, Karnataka and Telangana respectively, are affected by different desertification processes. The severity of desertification can be reduced by adopting proper agriculture and land-management practices. The vulnerability area identified in AP, Karnataka and Telangana provides key information for setting up sustainable development strategies. Future work can be focused on the area which is highly exposed to desertification for periodical monitoring and preparation of suitable action plans.

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Integrated assessment of drought vulnerability using indicators for Dhasan basin in Bundelkhand region, Madhya Pradesh, India

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The present study has integrated both spatially and temporally varying drought vulnerability factors to develop an integrated drought vulnerability map for Dhasan basin. A drought vulnerability index is used to classify the study area into different vulnerability zones. From the drought vulnerability assessment for the study area during July 2002, it was observed that the northeast, northwest and extreme southern part of the basin (20% area) was under critical vulnerability condition whereas the southwest and central part of the basin (79.9% area) was under high vulnerability condition. The critical drought vulnerability condition existed in Dhamoni, Pidaruwa, Sagar, Patharia Hat, Chhapri, Baroda Sagar and Singtoni region, whereas high vulnerability condition existed in the remaining parts of the study area. The integrated drought vulnerability approach gives superior result for drought assessment as compared to vulnerability assessment by considering the individual factors for the study area.

Keywords: Drought characteristics, drought indicators, drought vulnerability.

DROUGHT is a climatic hazard and a major threat among the natural climatic hazards to livelihood and socioeconomic development of people. Drought may be defined as the scanty availability of water resulting due to subnormal or erratic rainfall distribution, or a combination of both factors for a long period[1]. However, it affects a wide region for a season or for consecutive years. The arid areas are more vulnerable to drought as their source of rainfall depends on few rainfall events[2]. The ascent of drought is due to late arrival of rains, early withdrawal of monsoon, light rainfall, lack of sufficient soil moisture leading to crop failure and migration of local population. Water shortages due to the failure of the southwest monsoon lead to several situations like crop loss, less crop yields or agricultural drought. The areas under severe drought advance gradually and regions under maximum drought intensity vary from season to season[3]. The parameters indicating drought impacts comprise soil moisture depletion, reduction in streamflow, reservoir storage, lake levels and groundwater level[1]. Several methodologies have been recommended for studying the characteristics of drought to support policy makers in addressing this complex event. However, drought severity is the key factor to decide characteristics of drought. Drought severity is assessed by drought indices, which are indicator based and useful for identifying and monitoring drought precisely[4]. The drought period has considerable environmental, agricultural, health, economic and social consequences which vary according to susceptibility. Marginal farmers are more affected and drift during drought as they do not have substitute food sources.

Vulnerability assessment is the most significant aspect of drought hazard assessment and in development of drought management plans. Assessment of climate change vulnerable regions will help in the scientific understanding of climate sensitive parameters and aid in developing policies to reduce risks and prioritize research efforts in vulnerable regions to develop mitigation and adaptation strategies[5]. The drought vulnerability of wheat farmers was studied using Me-Bar and Valdez's vulnerability formula which revealed that vulnerability is a function of economic, socio-cultural, psychological, technical and infrastructural factors and there is a significant relationship between the agricultural income of the farmer and drought vulnerability[6]. Agricultural drought vulnerability for Nebraska state of central United States was studied based on factors such as climate, soils, land use and

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