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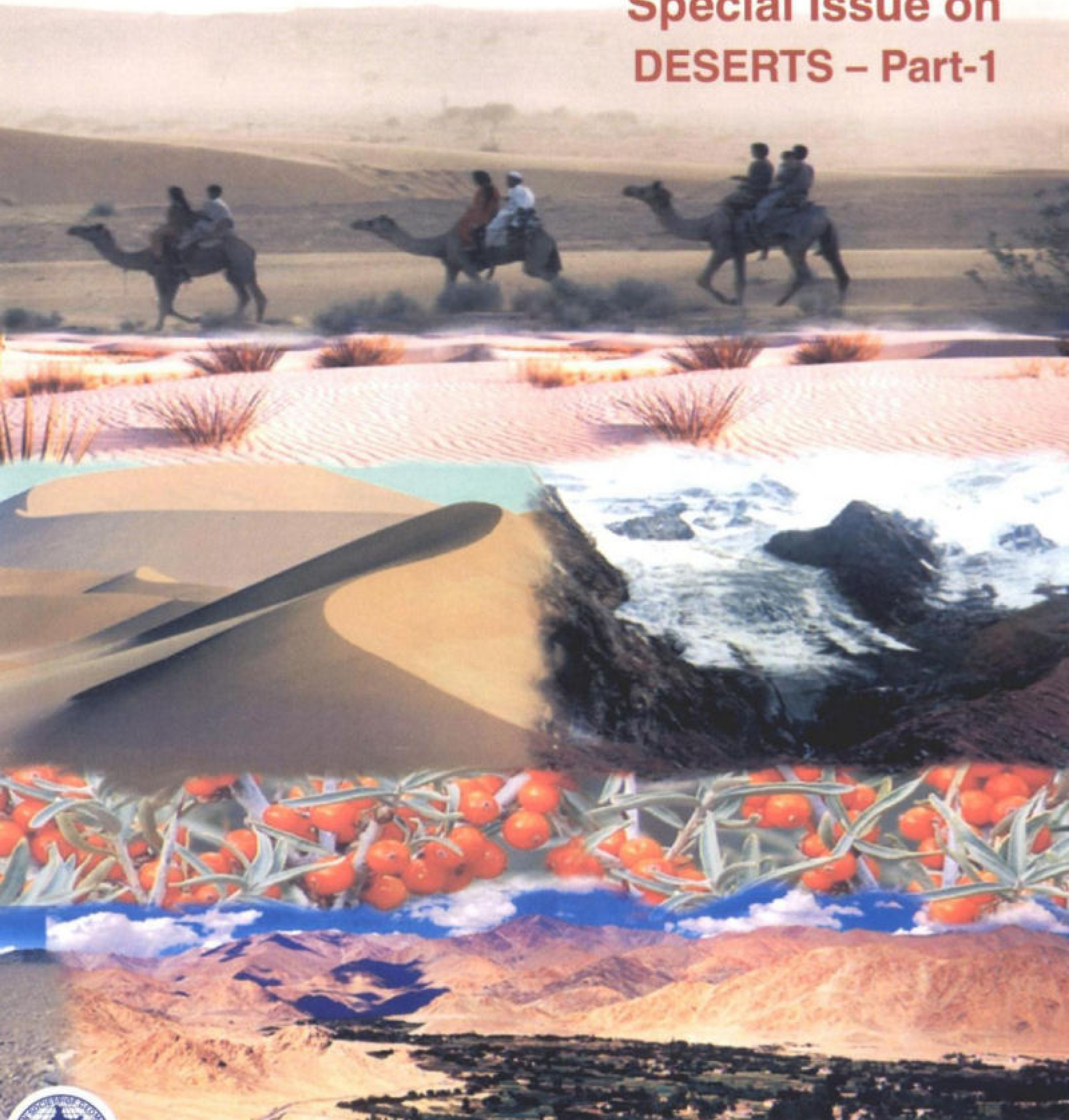

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EDITORIAL

This issue and a forthcoming one are focused on the theme of Deserts in India. In the lead article of this issue, the long history of the Thar desert is traced out by two senior authors Singhvi and Kar. The issue includes articles on both hot desert areas in Rajasthan and cold desert areas in Ladakh region of Jammu & Kashmir.

Recent floods in Rajasthan desert had led to the preparation of Catchment Atlas for the area at RRSSC Jodhpur so as to be forewarned in future. The Atlas was recently released by Chairman, ISRO, Dr. G. Madhavan Nair at a special function held at Jodhpur.

Editorial Board member C.P. Singh has designed the cover page of this issue making a collage of appropriate images from various sources including the flora and fauna of cold and hot desert regions in India. The effort is commendable.

This issue has been compiled and edited by Dr. Nandakumar, a senior member of the Editorial Board. He deserves special thanks.

Baldev Sahai
Chief Editor

Announcement

Indian Society of Geomatics is launching the first issue of a peer-reviewed *Journal of Geomatics* on May 8, 2007 with the following articles. Members are requested to send their feedback and contribute their findings from original research work.

Journal of Geomatics

(A publication of the Indian Society of Geomatics)

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1. Linking hierarchies of entities and their functions in geospatial ontologies
   Sumit Sen
2. Development of spatial decision support system for water harvesting structures using remote sensing inputs
   K.H.V. Durga Rao, V. Venkateswara Rao, and P.S. Roy
3. GIS based visualization of groundwater levels and its significance
   S. M. Ramasamy, C. J. Kumanan, S. Mahalingam and N. Nagappan
4. Comparing and optimizing land use classification in a Himalayan area using parametric and non parametric approaches
   Sameer Saran, Amit Bharti, Geert Sterk and P.L.N. Raju
5. Image fusion - a performance assessment
   M. Seetha, B.L. Malleswari, I.V. Murali Krishna and B.L. Deekshatulu
6. Hydrological parameter retrieval and validation from Cartosat-I stereo data
   Ritesh Agrawal, Anjum Mahtab, P. Jayaprasad, Nadeem Ahmad, S.K. Pathan, Ajai, D.K. Singh and A.K. Singh
7. Towards geospatial interoperability based on geo-service and geo-ontology
   Manoj Paul and S.K. Ghosh
8. Managing hazards in snow covered Himalayas
   Ashok Kaushal and Yogesh Singh

THE HISTORY OF SAND DUNES IN THE THAR DESERT

A.K. Singhvi[1] and **A. Kar**[2]
[1]Physical Research Laboratory, Ahmedabad-380009
[2]Central Arid Zone Research Institute, Jodhpur-342004

1. Introduction

The geographical location of the Thar desert (*Fig. 1*) in a transitional monsoon regime is typical of the general mid-latitude circulation. This implies that minor perturbations in this pattern influence the earth surface processes in the region, on an amplified scale. Here fossil sand dunes occur in areas with annual rainfall of 400 – 500 mm. In contrast, the current dune building activity is largely limited to regions with annual rainfall less than 250 mm. This indicates an eastward shift of dune-forming climate during the past by ~300 km. Presence of numerous pedogenic[1] horizons within the dune bodies suggests that such spatial shifts in monsoon/environmental conditions that facilitated dune accretion occurred repetitively, several times in the past. Another important aspect of the Thar dunes is the presence of a variety of dune styles that range from parabolic to transverse and from star dunes to linear dunes, (*Fig. 2*). These reflect a delicately balanced control of topography, sand supply, wind and vegetation. The lacustrine[2] records also show a considerable variation in their sedimentological character, evaporite[3] mineralogy and palynological[4] record, indicating large-amplitude climate variability in the limited time span that they represent. The fluvial record of the Luni river indicates its long antiquity. Development of new methods such as the luminescence dating *(Singhvi et al, 1982)* and electron spin resonance dating *(Kailath et al, 1999)*, and available stable isotopic and geochemistry techniques, provided the potential for building a more complete and quantitative record of landscape evolution for the region.

Much of our current understanding of the landscape history of Thar desert emanates from the multi-institutional and co-ordinated Thar Desert Programme that was initiated with the help of the Department of Science and Technology (Government of India). A survey of earlier work is provided by *Singhvi and Kar* (*1992, Eds*). This programme aimed to understand the evolution of major litho-units[5] of the Thar deserts, viz., aeolian[6], lacustrine, fluvial, and the calcretes. The main objective was to achieve a quantitative characterisation of the sedimentary record of the Thar desert, develop event chronologies, attempt paleoclimatic and paleogeographic reconstructions, and evaluate human-environment relationship.

Towards this a large range of approaches/methodologies were used, ranging from digital remote sensing to electron-microprobe analyses, cathodo-luminescence, phase constrained stable carbon and oxygen isotopic analyses, accelerator mass spectrometric and radioactive decay radiocarbon dating of pollen extracts and organic remains from lacustrine sediments, thermoluminescence (TL) and optically stimulated luminescence (OSL) and electron spin resonance dating, etc. In this contribution we provide a summary of results from aeolian records, which is abridged from *Singhvi and Kar* (*2004*). Details of overviews on other lithological units are available in *Singhvi* (*2004; Ed.*).

2. Aeolian Record

Thar desert is dominated by aeolian bedforms of different dimensions, including the sand dunes. The thickness of aeolian cover ranges from < 1 m to > 100 m. The genesis of aeolian bedforms in the Thar is the result of a delicately balanced relationship between the strength and the duration of wind vector, sediment supply, rainfall, vegetation cover and land surface conditions. These factors not only determine the bedform development but are also crucial to their sustenance though time. Research in different deserts of the world have shown that many aeolian bedforms have developed over millennial scale and more, and that the aeolian stratigraphy faithfully records the changes in climate and other related environmental parameters (see e.g. *Bateman et al., 2003*; *Glennie and Singhvi, 2002; Lancaster et al., 2002*). The major aeolian features that provide clues to paleo-environmental changes are those that accrete over a sufficiently long period of time, and have some degree of stability. Our observations of the stratigraphy of many aeolian bedforms in the Thar desert and its wetter eastern margin suggest that the deposits are not unequivocally aeolian, but contain sediments contributed by local fluvial, aeolian and even lacustrine (interdunal) processes. These imply several episodes of dune building activities, separated by periods of landscape stability.

3. Sand dunes and their climatic significance

Aeolian activity in the Thar desert is mainly restricted to the period of summer winds associated with the south-west (SW) monsoon (i.e., from March till the arrival of rains by the end of June along the eastern margin, and mid-July in the western part). The north-eastern wind of winter plays a minor role. Construction of a wind erosion index (*Kar, 1993*), helped understand the spatial pattern of sand mobility and dune formation with reference to wind erosivity. This study indicated that broadly the old dune directions mimic the modern SW wind pattern, thereby implying that dune formation in the Thar is governed largely by the strength of SW monsoon wind and this was the case in the past as well, (*Kar, 1998*).

Many different types of dunes have been mapped in the desert (*Fig. 2*), including the compound parabolic dunes, longitudinal (linear) dunes, transverse dunes, linked star dunes, a variety of network dunes, major obstacle dunes (along the hill slopes), barchans, barchanoids and megabarchanoids, and low sand streaks (*Pandey et al., 1964; Singh, 1982; Kar, 1993, 1996*), which have been grouped either under old dunes or new dunes, depending on their vegetation cover, carbonate content, stability, etc. Sand dunes in the easternmost part are usually more vegetated or cultivated almost near to their crests, and sometimes gullied. Westwards, the natural vegetation becomes sparse, cultivation on dune slopes is less frequent, and dune reactivation becomes more recurrent.

4. Chronology and the Paleoenvironment

4.1 Chronometric methods: Earlier studies on Thar aimed to develop chronology based on the radiocarbon dating of carbonate nodules, but was found inadequate on account of contamination of the radiocarbon signal. Development of luminescence dating methods of quartz and feldspar now enables a direct dating of the depositional age of the dunes and pedogenic carbonates using the measurement of cumulative amount of radiation energy received by minerals from natural radiation environment due to the decay of natural radionuclides viz. *U*, *Th* and *K* and dividing it by the annual rate of radiation energy (*Singhvi et al., 1982; Singhvi and Krbetschek, 1996; Singhvi et al, 1996*).

4.2 The Pleistocene record: The earliest known record of aeolian sedimentation in the Thar desert is about 200 ka (*ka* is the standard unit of time in dating – it refers to *kilo annum* or 1000 years). Multiple evidences such as the presence of multiple soil horizons within a dune matrix, discovery of Middle and Lower Paleolithic tools[7] at 14-16 m depth in a hill-bordering linear dune near Didwana in eastern part of the desert (*Wasson et al., 1983; Mishra and Rajaguru, 1994*) and direct dating, suggest that the dunes have long antiquity. In almost all dated deep sequences across the desert, a date of ~100-115 ka in aeolian sand at a depth of 8-15 m was encountered, where the material was brownish medium to fine sand with defused carbonate nodules and had typically segregated aeolian lumps (*Kar et al., 2001; Kar et al., 2004; Singhvi and Kar, 2004*). The data gathered so far suggests that around 100 ka, a regionally extensive more arid climate prevailed over Rajasthan and surrounding areas. Depending on the topographical situation, sand supply and other environmental factors, deposition at different sites during the period was either as sand sheets, low sandy undulations or sand dunes of different kinds. *Fig. 3* provides a typical stratigraphical succession.

Distinct lithic, flaggy calcrete[8] bands in the lower part of excavated sand profiles in >100 ka aeolian sand unit suggests that some time after the aeolian deposition, rainfall and terrain conditions were favourable enough to facilitate gradual development of lithic calcrete bands within the sand beds. On the banks of Luni river, *Jain et al.* (*1999*) found a thick deposit of channel gravel luminescence dated to ~90 ka. This suggested a high-energy fluvial regime in the region after a major dry phase. Previous to this fluvial regime, the region experienced a prolonged wetter phase at about 125 ka when a major inter-glacial climate prevailed over the earth.

From ~75 ka onwards the aeolian units are mostly characterised by extensive nodular calcrete development. Analysis of the stable isotopic composition of oxygen for such calcretes within four aeolian units of an aeolio-colluvial sequence near Shergarh revealed that during 70-60 ka and 25-30 ka when the lowermost and the uppermost calcrete bands were formed, winter rain was dominant, and the climate was more arid. In between, the other two calcrete bands witnessed summer rain, and the climate was less harsh (*Andrews et al., 1998*).

Aeolian units dated to ~75, ~55 and 25-30 ka were noticed within most of the deep sandy profiles (*Kar et al., 1998; 2001*). A prolonged wet phase in the intervening period resulted in landscape stability across the desert and its margin from north to south. *Tandon et al.* (*1999*) reported major fluvial aggradation in the Sabarmati and Mahi basins of Gujarat between 40 and 60 ka, as well as pedogenesis[9] across the plains of north Gujarat and south Rajasthan, as evidenced by a reddened paleosol on aeolian fine sand deposits. As would be expected, the pedogenesis, though contemporaneous, was intense in the Gujarat plains and less intense in south Rajasthan (*Kar et al., 2001; Juyal et al., 2003*).

A major period of aeolian sand accumulation after the depositional phase of 30 to 25 ka, was between 16 and 7 ka (*Fig. 3*). The intervening period saw a major dry phase, known as the Last Glacial Maximum (LGM), which has been dated to 24.5-18.0 ka. Contrary to the popular belief that the LGM was a period of strong dune-building activity in the desert due to lowered sea level and overall aridity that facilitated aeolian sand migration, our evidence so far suggests that the LGM wind did not have sufficient strength to build the dunes. The SW monsoon wind that built the dunes in the past was very subdued during the LGM and implied weakened/negligible aeolian aggradations. The westerly and north-westerly winds contributed somewhat higher rainfall, as revealed from isotope analysis of the carbonate nodules (*Andrews et al., 1998*). Studies at Khudala in the lower Luni plains also indicated the absence of fluvial aggradations, leading to the suggestion that during LGM, geomorphic processes, both aeolian and fluvial, were dormant to the point of being inactive due to a substantially weakened SW monsoon (*Fig. 3*) (*Kar et al., 2001*). While it can be argued that the post-LGM aeolian processes could have obliterated the LGM record, the consistency of the ages throughout the region and uniform absence of LGM ages in a large data base of ages measured by us (*Singhvi and Kar, 2004*), to an extent precludes this. It follows that large-scale aeolian dynamism did not coincide with LGM in the Thar, and implicitly suggests that the desert albedo changes on account of desert expansion were also not synchronous. Translating this from a regional to global scale, this observation implies that perhaps the desert albedo changes on account of an assumed synchronicity with glacial climate have been grossly overestimated. This observation also suggests that like any physical system, landform also has a response time to a forcing function, be it climatic or tectonic. Creation of sedimentary record anywhere needs an appropriate combination of sediment supply, transport capacity and preservation potential to provide a "*window of opportunity*" for the creation of any sedimentary record on the land.

Studies on deep oceanic cores from the Arabian sea suggest that strong monsoon circulation started in the region from ~14 ka and that periods of sustained higher rainfall lagged the inception of higher wind speed by years or centuries (*Sirocko, 1996; Zonneveld et al., 1997*). This is possibly why we get a higher sand accretion in many sites during 14-10 ka only after the LGM (*Fig. 4*). It can therefore be suggested that the aeolian processes in the Thar had a small '*window of opportunity*' in the time lag between the initiation of strong monsoon wind and the arrival of high monsoon rainfall, and exploited this opportunity for enhanced sand accumulation. This window for aeolian accretion in Thar occurred at around 13 ka.

The terminal Pleistocene that witnessed high amplitude changes in monsoon events also experienced frequent repetition of aeolian and fluvial beds in some of our aeolian sections, notably at Khudala where the beds were dated to ~11-13 ka (*Kar et al., 2001*). This period, known as the Younger Dryas event, is globally known for cooler climatic excursion and significantly higher winter rainfall. Analysis of sediments from Didwana salt lake revealed fluctuating saline to deep fresh water conditions during this period (*Singh et al., 1990*). This has been the first evidence of Younger Dryas cooling event from India.

4.3 The Holocene[10] record: There is no distinguishable change in the aeolian record that indicates initiation of the Holocene by way of a marker horizon. *Fig. 4* provides dune profiles on an east west transect across the Thar. The SW monsoon wind continued to play its role in the aeolian accumulation in the region, and continued till 7 ka, but possibly with less vigour. Between 7 and 6 ka, large parts of the region experienced extended duration of higher monsoon and winter rainfall. This stabilised the sandy landscape and facilitated formation of a weakly developed paleosol horizon, or a layer of relatively coarser sand concentration. The period around ~6 ka was most humid in the desert during the Holocene. All the major saline lakes in the desert turned at least into perennial lakes. The aeolian landscape in the western most part of the desert was, however, influenced for a shorter period of time by this wetter climate. The desert experienced another phase of higher aeolian aggradations from 5 ka onwards, and it continued till ~3.5 ka (*Kar et al., 1998; Thomas et al., 1999*). There is, however, very little trace of this event, or any other major sand accretion event subsequent to it in the dune stratigraphy to the east and south of the present eastern limit of the desert. It suggests that large-scale sand reactivation in the areas beyond the present boundary of the desert took place before the Holocene Climatic Optimum[11], and that the aeolian landscape in those areas attained relative stability since then. Small events during 5.0-3.5 ka, however, cannot be ruled out, especially in the natural corridors of sand movement through the Aravalli hill ranges. The 5.0-3.5 ka aeolian phase in the desert was that of reduced SW monsoon, but not comparable to any 'glacial' event. *Fig. 5* provides our reconstruction of the fossil extent of Thar Desert at 16 ka and 5 ka.

The period 4.5-3.8 ka witnessed the rise and fall of Pre-Harappan and Harappan cultures, especially along the Ghaggar valley where urban settlements flourished due to the availability of water (e.g. at Kalibangan). The dune records (*Thomas et al., 1999*), establish that the civilization flourished during a phase of continued aeolian activity, and not during a period of good rainfall, as is customarily believed. The Harappan settlements in the desert, therefore, appear to be more a case of human adaptation to declining rainfall than that of improved hydrological/precipitation events as is evident from their water harvesting methodologies and emphasis on the winter crops. The salt lake at Lunkaransar located north of Bikaner, had an inflow of water from ~11 ka. The lake became perennial around 7 ka and was dry by ~3.6 ka. The drier conditions were most intense around 3.7 ka. The lake partially recovered by ~1.8 ka (*Bryson, 1989*). The salt lake at Bap near Phalodi in western Thar, desiccated by ~6 ka (*Deotare et al., 1998*). By contrast the salt lake at Didwana recorded a decline in rainfall at 4.2 ka (*Singh et al., 1990*), but has continued to receive some fresh water even up to recent time. This implies a distinct spatial gradient in the century-scale SW monsoon rainfall distribution in the desert, such that the western part is visited by the rains for a shorter period and, hence, gets lesser opportunities for the stabilization of aeolian landscape. A synthesis of dune record additionally suggests a 1500-year cycle in dune accretion. Another important aspect is the presence of time lag between changes in the lake hydrology and the dune activity such that the dune accretion preceded the lake hydrological changes by a few centuries (*Fig. 6*) (*Thomas et al., 1999*).

There was a comparative lull in aeolian activities from ~3.7 ka to ~2.0 ka, after which another burst of intense aeolian activity took place. Almost all the excavated sections in the desert experienced this phase. At Khara in the very high wind erosion zone northeast of Jaisalmer, *Kar et al.* (*1998*) measured the growth and mobility of the paleo-crest of a transverse dune that started growing from the beginning of the Holocene. It revealed three phases of sand accumulation from ~2 ka. The first phase between 2.1 and 1.9 ka saw a vertical accretion rate of ~0.61 cm/a and a crestal advancement of ~0.87 cm/a. Between 1.8 and 0.58 ka the accretion rate declined to 0.08 cm/a and crestal advancement to 0.25 cm/a (*Fig. 7*). The latest phase since ~0.25 ka experienced vertical accretion rate of >2 cm/a and a horizontal advancement rate of 1.5-9.0 cm/a. The breaks in the periods were marked by lull in sand mobility, as well as some stability of the aeolian topography. This is reflected in grain size characteristics for the units.

By about 0.6 ka the aeolian landscape in western Thar gained some stability due to a drop in the wind strength. In the eastern part this stabilization phase started at ~0.8 ka. The time lag of ~0.2 ka for the start of a sand stabilization phase in the east and the west could be explained by the time taken by monsoon rainfall to establish itself from east to west. There is not yet any confirmatory lake record to strengthen the case for an increased rain event during the period, but a weakly developed paleosol horizon in the near-surface sediments of the dunes everywhere in the desert (*Thomas et al., 1999*). The phase also coincides with the medieval warming episode and has been documented in the slack water record of floods of river Luni during the last millennium. Thus the dune stabilization episode, paleosol formation and enhanced flooding in Luni indicated a stronger monsoon during the medieval warming.

The next phase of aeolian activity, the most recent one, started in ~0.3 ka. Globally, the period roughly between 0.6 and 0.2 ka experienced decreased rainfall, and is known as the period of Little Ice Age. During this phase of the Little Ice Age, river Luni, had possibly no significant flooding and hence a reduced rainfall can be inferred, (*Kale et al., 2000*). The limited data does not permit any inference on contemporary aeolian processes in Thar, but a lull in aeolian deposition between 0.6 and 0.3 ka could be ascribed to reduced wind.

The latest phase of sand mobility started from around 0.3 ka, but unlike in the previous phases this phase is marked by high human pressure on the sandy landscape, especially through cultivation and grazing, as well as fuel-wood collection. Mechanized ploughing of dune slopes and sandy plains during the last three decades has increased the potentials of wind erosion manifold (*Kar, 1996*).

5. Aeolian record from the southern margin of the Thar

In southern margin of the Thar aeolian sand is seen in areas where the present day annual rainfall is up to 1000 mm, and it occurs especially on the pediment plains, upland terraces and coastal plains, spanning the Sabarmati basin in the north and the Mahi basin in the south (*Juyal et al., 2003*). Most sand dunes are poorly organised (3-6 m high), while along the hills obstacle dunes (8-10 m high) have also been formed. Studies on six dune profiles along a roughly N-S transect at Dharoi, Akhaj, Dabka and Tajpura revealed that all the dunes had multiple phases of accretion, with ages ranging from 26 ka to 6 ka in the upper 6 m. Occassional ages correspond to the LGM, and could have formed despite a weak SW monsoon, due to local factors like adequate sediment supply from a large alluvial plain in the proximity of a falling sea level and a favourable sea breeze. Although older records could not be reached due to logistic problems of digging deeper, the exposed deposits also documented stability in aggradation process and human occupancy (e.g., microlith culture) during 11-8 ka when the SW monsoon was more vigorous in the region. No later aeolian aggradation was noticed in the Mahi basin sites (Tajpura, Dabka), but the sites in Sabarmati basin (Akhaj, Dharoi) experienced aeolian aggradations till 5 ka. This suggests that with the passage of time the dune-forming environment gradually shrank northward and that the southern margin did not experience any aeolian aggradations, thereafter (*Juyal et al., 2003*).

6. Conclusions

Our studies in the Thar desert and its wetter fringes provide a basis for understanding the late quaternary aeolian dynamism in the region and the nature of its relationship with climate. The following broad conclusions could be drawn from the studies:

- The aeolian activities in the region are more than 150 ka old. These occured in a cyclic fashion such that short periods of aggradations were interspaced by long periods of quiescence.
- The > 150 ka age negates the earlier concept on Thar being of anthropogenic[12] origin.
- Major phases of pre-LGM aeolian accumulation during the late Pleistocene were between 100-115 ka, ~75 ka, ~55 ka and 30-25 ka.
- The LGM was a period of high aridity, when the desert could have extended far beyond its present boundary. However, the wind strength during the period was insufficient to effect large-scale sand mobility and accumulation. Possibly all such periods of drier - cooler climates in the region experienced weaker aeolian activities.
- Maximum sand mobility and accumulation took place when the SW monsoon wind strength was sufficient during the transition period from an arid phase to a wetter phase and vice versa. These periods had sufficient winds to move sand as also moisture/vegetation to trap sand and effect aeolian aggradation.
- The transition to the peak of subsequent wet phase, the Holocene Climatic Optimum (7-6 ka), was also marked by increased aeolian activities.
- High and sustained rainfall events during the peak of strong SW monsoon during the Holocene Climatic Optimum implied reduced aeolian activities through higher vegetation cover and improved soil forming processes, leading to landscape stability.
- A northward shift in dune forming climate during the Holocene was also seen. Thus the southern margin of the mega-Thar in Gujarat did not experience any dune building activity after 10 ka, the north Gujarat plain experienced dune aggradation activity up to 5 ka, while large parts of west Rajasthan, containing the core of the Thar experienced dune activity even

after 2 ka (and up to the present in some parts). This aspect, if modelled, will provide important clues to the spatial shifts in the monsoon through time.

- Within the present desert boundary, the major phases of aeolian activities after the Holocene Climatic Optimum were between 5 and 3.5 ka, and 2 and 0.8 ka (0.6 ka in the western part). The Harappan and pre-Harappan civilizations in the northern part of the desert flourished during a waning phase of the SW monsoon, when rainfall events were more aberrant, and aeolian activities high.
- The areas to the east and south of present desert boundary did not experience any large-scale sand mobility and aeolian bedform formation after the Climatic Optimum. In most locations the activities might have stopped by the beginning of the Holocene. Younger aeolian records do not exist, suggesting either the absence for proper dune forming environment or obliteration of record. The body of evidence, so far suggests the former possibility.
- Within the desert, rates of present-day sand mobility are found to be higher than the century-scale rates of sand mobility during the past 2 ka.

We consider that we now have a first-level understanding of the climate-driven aeolian episodes within Thar desert. Many research gaps are yet to be filled. The advances in dating now permit much higher resolution and it should now be possible to estimate the duration of the 'window of opportunity' with significantly higher precision. This will be a unique case study to understand how the different aeolian landscape elements responded to the climate-driven processes in the past, especially during the transitional phases. Much of this understanding needs to be based on a proper knowledge of the present-day landscape response mechanism under identical situations. The response time of the aeolian processes to climate change needs also to be researched. We also need to understand precisely the genesis of different dune types. An understanding will in turn help tease-out information on the relative role of sediment supply and wind vector in providing a specific dune form. A finer resolution aeolian event history is to be constructed through a better dating and analytical tool to better understand the impact of climate and humans during the last 3 ka, as well as for predicting the possible future response patterns.

Acknowledgements

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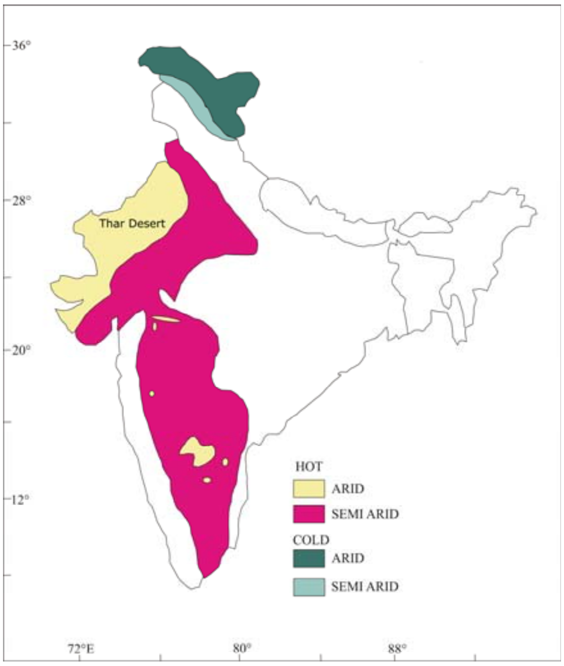

Fig. 1: Semi-arid and Arid Zones of India and the Location of Thar Desert
(International borders are not drawn accurately)

Glossary

1. *Pedogenic* – due to soil forming processes
2. *Lacustrine* – lake
3. *Evaporite*- material, sediment, resulting from evaporation of saline waters
4. *Palynological* – The study of fossil pollens and spores
5. *Litho-units* – Stratigraphic units
6. *Aeolian* - wind transported
7. *Middle and Lower Paleolithic tools* – Stone age cultures divided bases on the level of technology into Lower (earliest), middle and Upper (youngest) categories
8. *Lithic, flaggy calcretes* – Layered calcrete rock formed under lacustrine environments
9. *Pedogenesis* – soil forming process
10. *Holocene* – the last 11500 years of Earth's history
11. *Holocene Climatic Optimum* – periods when the conditions were most suitable for survival of the biota –more rain and optimum temperatures
12. *Anthropogenic* – human induced
13. *Quaternary* – The latest period in time of Earth's stratigraphical record. It is an artificial division of time to separate pre-Human and post-Human sedimentation. Broadly this reflects the past 2 million years of Earth's history

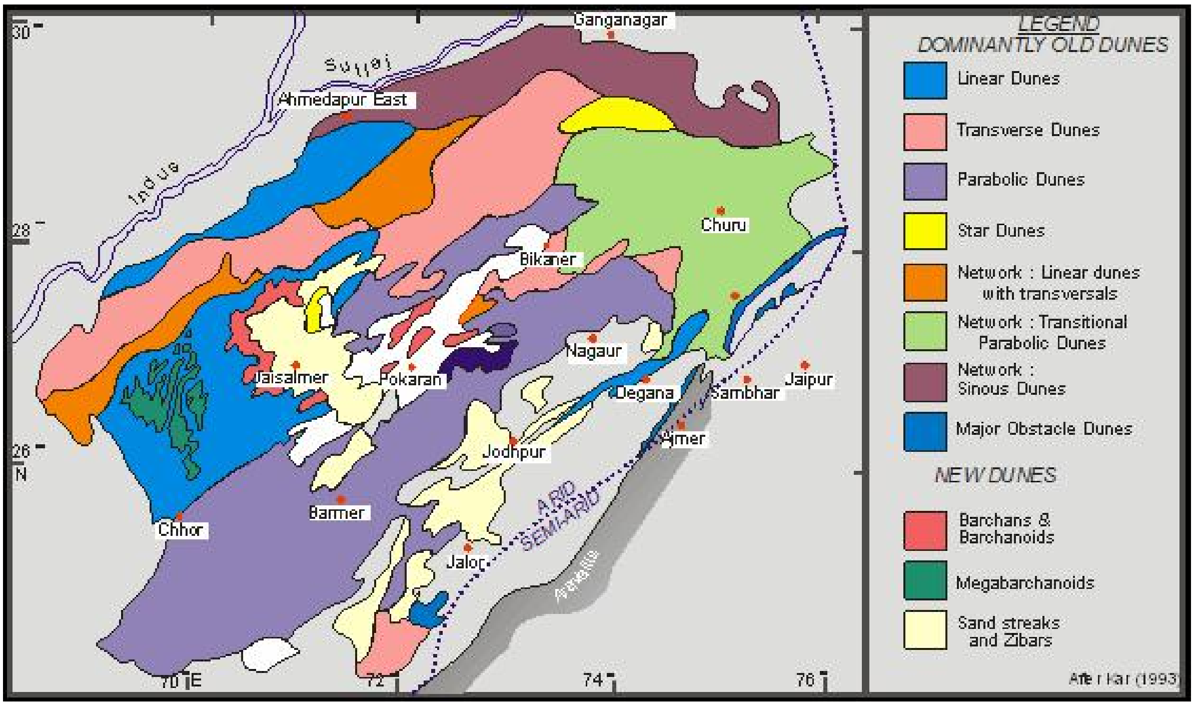

Fig. 2. Dune Types in the Thar (after *Kar 1993*)**.**

Notice that almost all the conceivable dune forms exist in this unique desert.

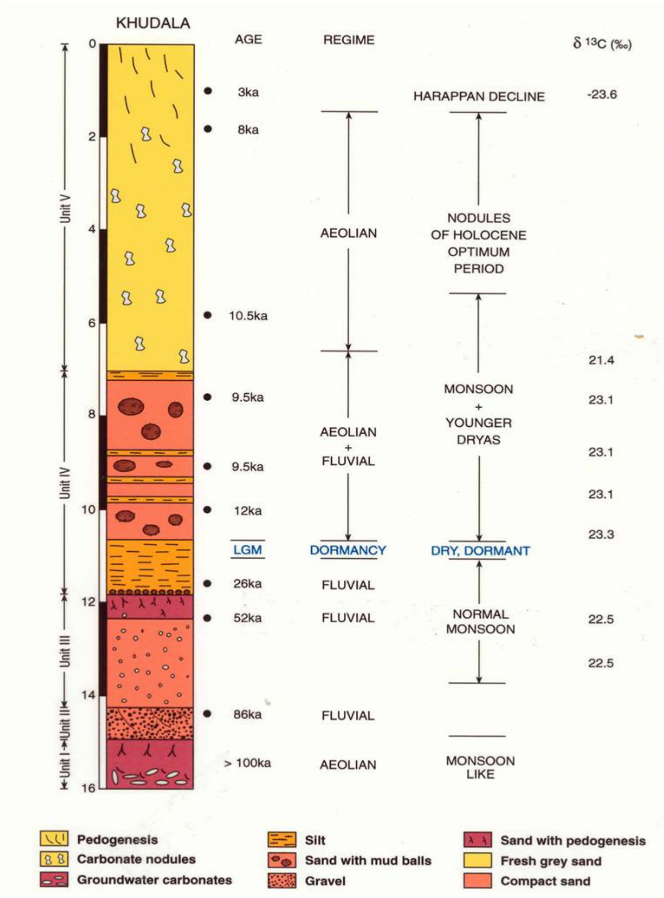

Fig. 3: Deep stratigraphic aeolian dune profile at Khudala on the banks of river Luni.

Notice the variability in sedimentation style, pedogenesis and the chronology, that indicates the antiquity, the periods of dune accretion and long periods of quiescence in the desert. Also presented are the climatic interpretations of the sequence and the suggestion of Younger Dryas period (after *Kar et al. 1999*)

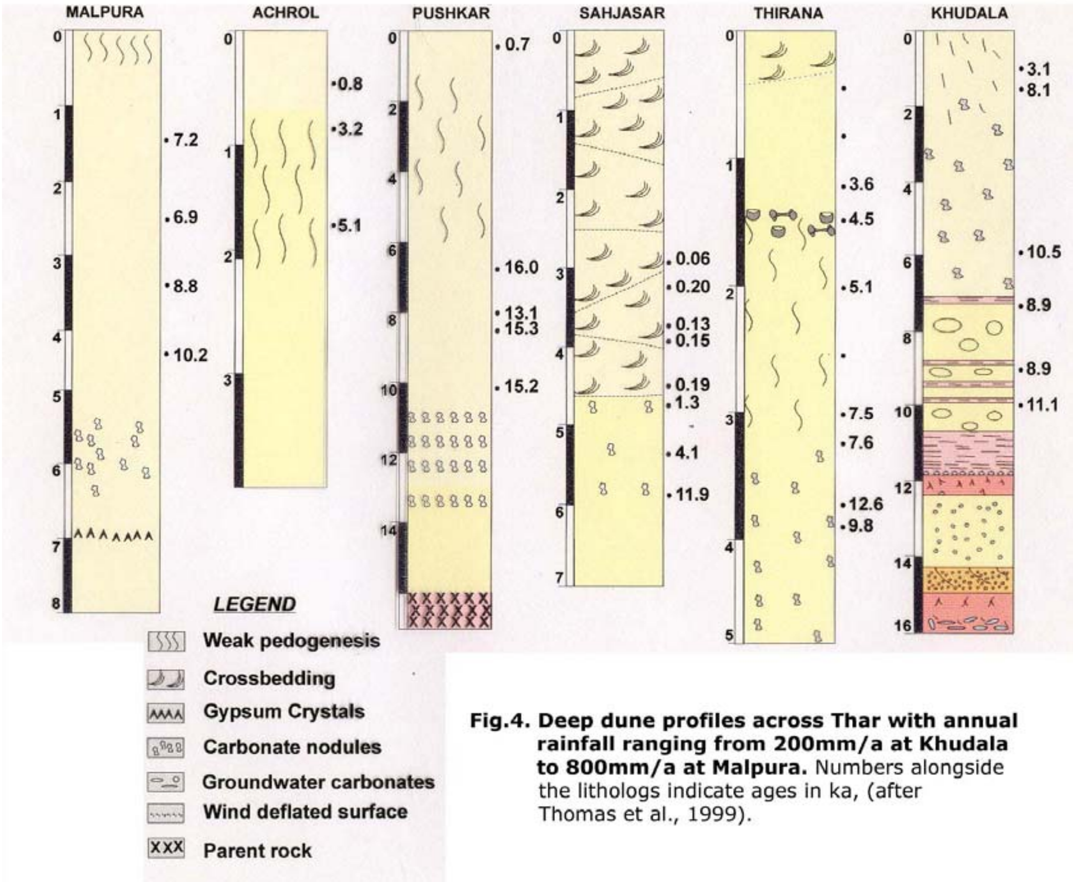

Fig.4. Deep dune profiles across Thar with annual rainfall ranging from 200mm/a at Khudala to 800mm/a at Malpura. Numbers alongside the lithologs indicate ages in ka, (after Thomas et al., 1999).

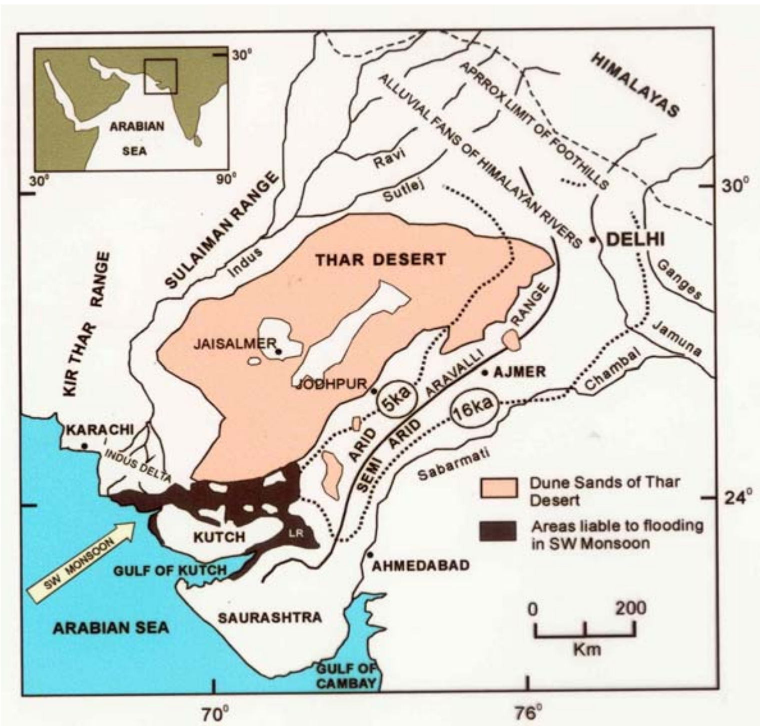

Fig. 5: Reconstruction of paleo-extent of the Thar Desert at 16 ka and 5 ka (after *Singhvi and Kar 2004*)

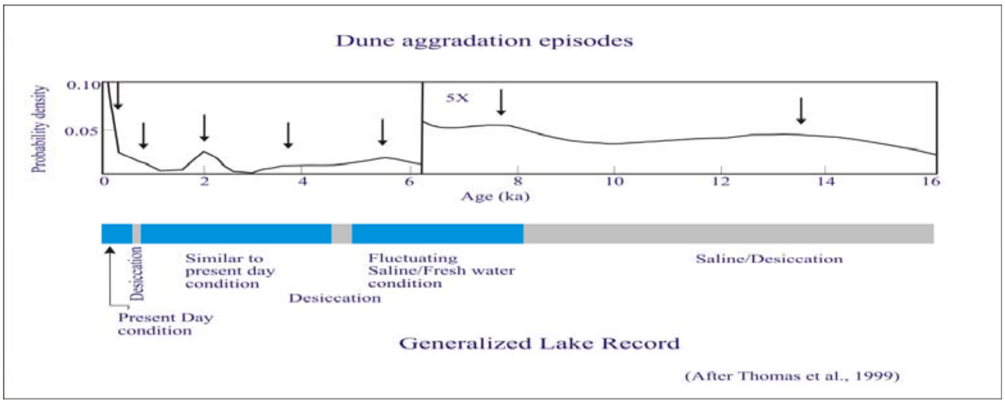

Fig. 6: Correlation of dune activity and changes in Lake Hydrology in Thar Notice that the dune accretion shows an ~1500 year periodicity and lags lake hydrology changes by a few centuries

(after *Thomas et al., 1999*)

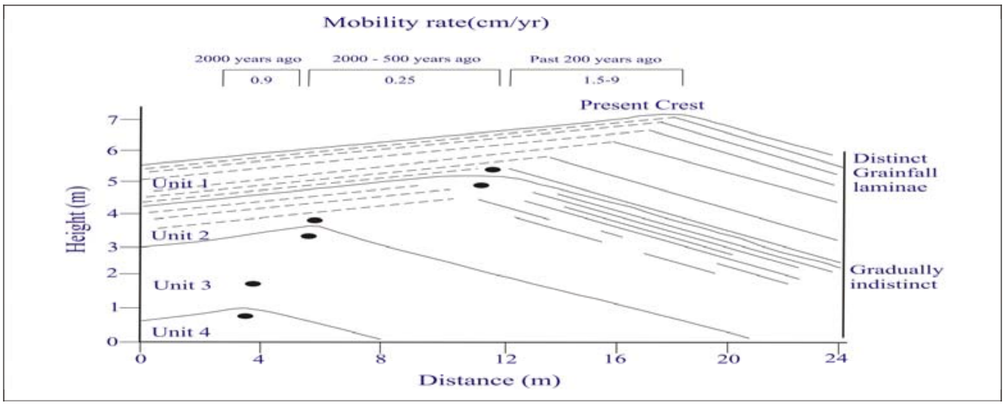

Fig. 7: Dune migration rates through time.

Notice that substantive changes due to human activity (after *Kar et. al., 1998*)

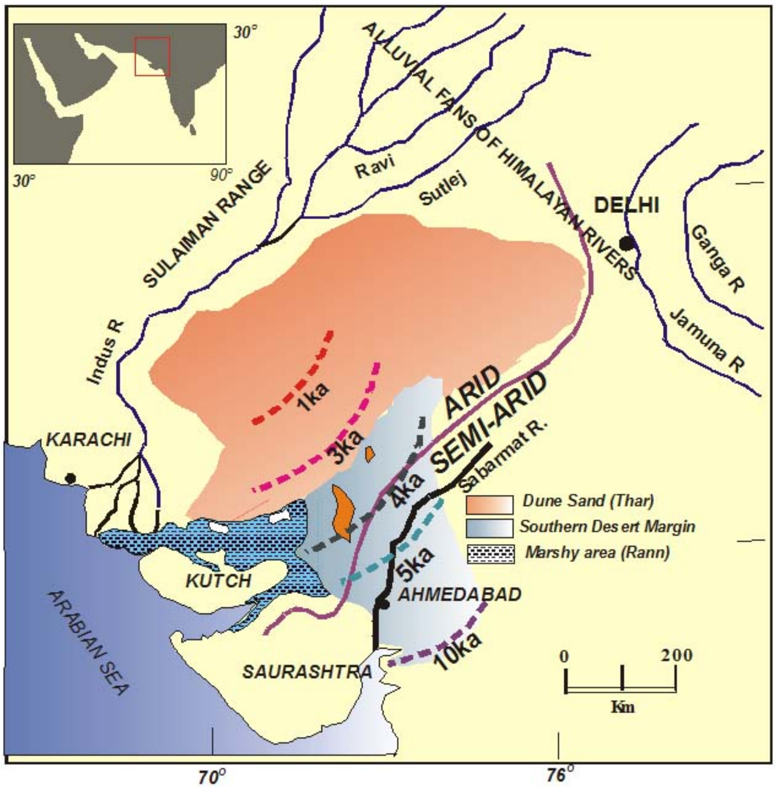

Fig. 8: Shift of active / fossil boundary of southern margin through time. The age contours indicate the upper age seen in the region, south of it (after *Juyal et al., 2003*)

USE OF GEOINFORMATICS FOR COMBATING DESERTIFICATION IN COLD DESERT REGION IN DISKIT WATERSHED, LADAKH DISTRICT (J&K)

P.S. Dhinwa*, S.K. Pathan*, Ajai* and **S.A.R. Shah****
*Space Applications Centre (ISRO), Ahmedabad-380015
**Directorate of Environment and Remote Sensing, Jammu & Kashmir Government, Srinagar
Email: *dhinwa_ps@sac.isro.gov.in*

Abstract

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. Today about 33 per cent of the earth's surface exhibits desert characteristics to some degree or other. Desertification is initiated when the vegetative cover is reduced by tree cutting, over-grazing, over-cultivation, shifting-cultivation, mining, road construction, mismanagement of land and water practices, urbanization and other activities that disturb the natural ecosystem. There are two types of parameters that contribute to the process of land degradation, socio-economic conditions of the local population (poverty and illiteracy) and pressure of population on marginal lands. Both are interrelated. Basically, it is the increasing population (human and cattle) pressure, which is solely responsible for disturbing the fragile ecosystem, which exerts undue pressure on natural resources, which in turn activates the process of desertification and thus the fertile piece of land is converted into a desert. There are five types of indicators - climatic, hydrological, physical, biological and socio-economic, which directly or indirectly contribute to desertification processes. For combating the processes of desertification in cold desert region, not much work has been reported in the literature. In this paper, an attempt has been made to evolve a decision rule and to generate action plans for combating desertification at 1:50,000 scale in cold desert region in Diskit watershed (1F3A6), Ladakh district (J&K). The multidate satellite data reveals that frost heaving, frost shattering, wind erosion, water erosion, mass wasting and vegetal degradation are the main desertification processes prominently operating in Diskit watershed. In order to arrest the processes of desertification in cold desert region in Diskit watershed various measures have been suggested. For instance, for stabilization of slopes and to arrest various desertification processes, i.e. frost shattering and mass wasting, it is advisable to do afforestation with shrubs (h*ippophae rhamnoides*) and trees (w*illow* and *poplar*) which can grow in that region. For stabilization of sand dunes it is preferred to grow grass on sand dunes since it will act as sand binder and will not allow the wind to blow fresh sand to new sites and form new dunes. *Hippophae rhamnoides*, *ephidra girardiana, myricaria rosea* and *myricaria squamosa* are important medicinal plants of very high economic value, which can grow in Ladakh district. These should be planted on gentle slopes.

1. Introduction

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. Today about 33 per cent of the earth's surface exhibits desert characteristics to some degree or other. Remote sensing data along with GIS has been useful for monitoring and assessment of desertification. The indicators of desertification amenable to remote sensing include salinity, erosion and sand sheets etc. (*Navalgund, 2006*). Desertification and drought are common features of arid and semi-arid regions. Desertification is understood as a continuous process of land degradation leading to desert like conditions. The 1977 Nairobi conference of UNCOD described desertification as the diminution or destruction of the biological potential of the land. The recent definition of United Nations is "*Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.* Recently, Regional Action Programme (RAP) to combat desertification has been formulated by UN convention to combat desertification (UNCCD) and accordingly RAP for Asian region has been initiated as a collective effort by the member countries. The aim of RAP is to strengthen the existing capacities of the member countries of the Asian region to take suitable measures for combating desertification.

More than 6.1 billion ha, 47.2 per cent of the earth's surface, is dryland. Nearly 1 billion ha of this area are naturally hyper-arid deserts, with very low biological productivity. The remaining 5.1 billion ha are made up of arid, semi-arid, and dry sub-humid areas, part of which have been degraded since the dawn of civilization, while other parts of these are still being degraded today. These lands are the habitat and source of livelihood for about a fifth of the world's population. These are the areas experiencing pressures of the environment caused by human mismanagement and problems that are accentuated by the persistent menace of recurrent drought. The term desertification was first coined in West Africa in 1949 by a French forester named *Aubreville* to describe the way in which it was perceived that the Sahara desert was expanding to engulf desert-marginal savanna grasslands. The term was raised as a major environmental issue at the United Nations conference on human environment, Stockholm, at which the United Nations Environment Programme (UNEP) was established. Desertification reached a wider audience in the 1970s when international attention was focused on the plight of drought stricken Sahel zone of Africa, south of Sahara. One outcome of this attention was the United Nations Conference on Desertification (UNCOD), held in Nairobi in 1977. A world map of land degradation by desertification and a number of case studies from all continents was prepared for the conference to illustrate the phenomenon (*UNESCO 1977, 1980*). These studies indicated that desertification was not just happening in Africa, but in drylands the world over. Following the conference, UNEP was charged with coordinating the implementation of the United Nations plan of action to combat desertification which was adopted by the conference and endorsed by the United Nations general assembly.

India occupies only 2.4 per cent of world's geographical area, yet supports about 16.2 percent of the world's human population. India has only 0.5 percent of the world's grazing area but supports 18 percent of the world's cattle population. India is endowed with a variety of soils, climate, biodiversity and ecological regions. About 228 mha (69%) of its geographical area (about 328 mha) fall within the dryland (arid, semi-arid, dry sub-humid) as per *Thornthwaite* classification. According to National Bureau of Soil Sciences and Land Use Planning (NBSSLUP), about 50.8 mha (15.8%) of the country's geographical area is arid. In addition, an area of about 15.2 mha of cold desert is located in Jammu and Kashmir and Lahul–Spiti region in Himachal Pradesh. About 123.4 mha (37.6%) of the country's geographical area consists of the semi-arid region. About 54.1 mha (16.5%) of the country's geographical area falls within the dry sub-humid region. The indicators used for desertification monitoring and assessment can be categorized into four types.

A) Pressure Indicators characterize driving forces both natural and man-made, affecting the status of natural resources and leading to desertification. Pressure indicators are used to assess desertification trends and make an early warning for desertification. Natural indicators describe natural factors, mainly climatic conditions, natural disasters, which promote the occurrence and development of desertification. Non-natural indicators describe the pressure on land leading to land degradation from human activities (*Ajai et al., 2003*).

B) State Indicators characterize the status of natural resources including land. The physical and biological features of desertified land ecosystems are the main factors to be considered. Physical indicators describe the land characteristics, physical and chemical properties of soil and hydrological features of the land ecosystem. Biological indicators are used to describe biological characteristics of the land ecosystem.

C) Impact Indicators are used to evaluate the effects of desertification on human beings and environment.

D) Implementation Indicators are used to assess the action taken for combating desertification and to assess its impact on natural resources and human beings. Such impacts refer to improvements of socio-economic and natural conditions. The positive changes in the land cover conditions owing to mitigation measures aimed at combating desertification. These are also sometimes referred to as response indicators.

The United Nations Convention to Combat Desertification (CCD) was adopted on June 17, 1994 at Paris and the World Desertification Day is also observed on June 17 every year. The convention entered into force on December 26, 1996. 172 countries have ratified the convention. India ratified the convention on 17th December 1996 and it came into force in our country from 17th March 1997. The objective of CCD is to combat desertification and mitigate the effects of drought in countries experiencing serious drought and desertification supported by international cooperation and partnership arrangements, in the framework of an integrated approach, which is in consistent with Agenda 21 of UNFCC, with a view to contributing to the achievements of sustainable development in affected areas.

2. Study Area

Diskit watershed is bounded by 34:30 – 35:00 N latitudes and 77:00 – 77:35 E longitudes. Physiographically, it is a mountainous terrain bounded on the north by Karakoram mountains range and on the south by Ladakh mountainous range of the Great Himalayas. Diskit watershed (1F3A6) which covers an area of 861 sq. km., lies in cold desert region and is situated in Ladakh district of Jammu and Kashmir (*Anon., 1990*). It is drained by Shyok river and lies on the right hand side of Shyok river. In Diskit watershed, the mean annual temperature is less than 8 degree Celsius and mean annual precipitation is less than 150 mm (*Velayutham et al*, *1999*). This watershed lies in the rain-shadow zone of Trans-Himalayan range and hence receives very scanty rainfall during monsoon season. Water erosion, frost shattering, mass movement, wind erosion and vegetal degradation are the significant desertification processes observed in this watershed.

3. Data Used

Satellite Data	IRS-1A L2A&B (Oct,1989) IRS-1D LISS- 3 (May & Oct, 2000)
Ancillary Information	52F/1,2,5,6 &10 (1:50,000) Scale
Collateral Data	1.Population 2.Climate 3.Geology 4.Soils etc.

4. Methodology

See Figure-1.

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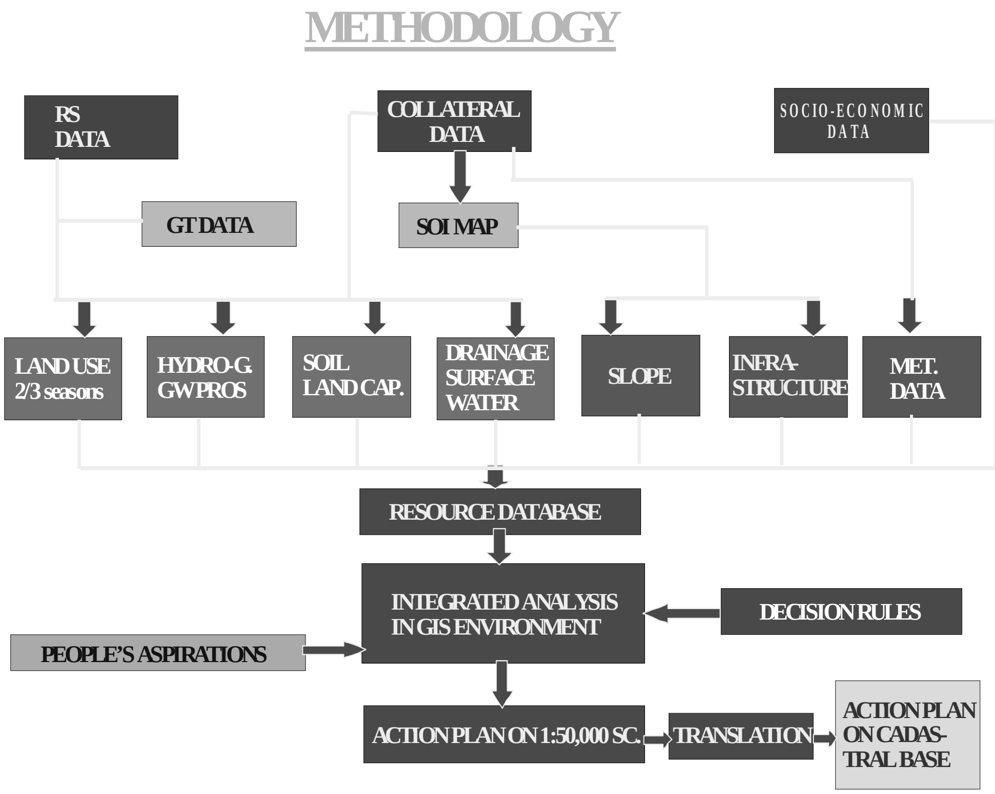

Fig.1: Flow Chart for Generation of Mitigation Plan for Combating Desertification

4. Results and Discussion

For generation of an action plan for combating desertification various thematic layers, e.g., land use/land cover, ground water prospect, land capability, slope and desertification status maps are integrated in GIS environment (*Fig.1*). As a result of it, various composite land development units (CLDUs) are formed. Based on the decision rule, various measures are suggested for arresting the process of desertification (*Table 1*). The multidate satellite data has been used for preparation of various thematic maps and desertification status map of Diskit watershed. Remote sensing data along with GIS has been useful for desertification, monitoring and assessment. The desertification status map of Diskit watershed shows that, water erosion (34 per cent), frost shattering (25 per cent), mass movement (13 per cent), wind erosion (2 per cent), and vegetal degradation (1 per cent) are the main desertification processes prominently operating in Diskit watershed (*Fig.2*) and also referred in *Table-2*. For stabilization of slopes on mountain terrain and to arrest desertification processes, such as, frost shattering and mass wasting, it is advisable to do afforestation with shrubs (hippophae rhamnoides) and trees (willow and poplar) which can grow in that region. For stabilization of sand dunes it is preferred to grow grass on sand dunes since it will act as sand binder and will not allow the wind to blow fresh sand to new sites and form new dunes. Since hippophae is a medicinal plant and is of high economic value, aerial seeding of hippophae is also recommended on highly mountainous terrain and on steep slopes (*Fig.3*). The measures suggested for combating desertification are as follows:

Table 1: Decision rule for generation of action plan for combating desertification

Sr. No.	LU/LC	Process	Severity	Slope (%)	GWP	Land Capa-bility$	Measures	Remarks
1	Sand Dune	Aeolian	Slight/ Moderate	1-3	Mode-rate.	4	• Shelter Belt Plantation • Plant hedges • Phyto-reclamation (grasses & shrub)	It helps in arresting the movement of sand sheets/ sand dunes
2	Agricul-ture Land	Water erosion	Slight	1-3	Mode-rate	4	• Agro-Horticulture • Crops (short growing period) • Vegetables (short growing period)	Growth of economy and food and fibre for sustenance of local people
3	Stony waste	Mass Wasting	Slight	3-5 / 5-10	Poor / Mod.	4/5	• Agro-Horticulture • Vegetables (short growing period)	Growth of economy and food and fibre for sustenance of local people
4	Glacio-alluvial fans	Mass Wasting	Moderate / Severe	5-10 / 10-15	Poor	5/6	• Fruit trees (Apricot, Plum etc.) • Medicinal Plants (Hippophae)	Development of natural resources and the economy of the region
5	Barren/ Rocky	Mass wasting /Weathe-ring	Severe	>35	Poor	7/8	• Medicinal Plants (Hippophae)	Growth of economy for sustenance of local people
6	Forest/ Planta-tion	Vegetal / Mining	Moderate / Severe	3-5 / 5-10	Poor / Mod.	5-6	• Afforestation (Willow, Poplar, Mercaria etc.) • Fruit trees (Apricot, Plum etc.) • Medicinal Plants (Hippophae)	Development of natural resources and increase in the economy of the region
7	Forest/ Planta-tion	Vegetal	Moderate /Severe	>35	Poor	7-8	• Medicinal Plants (Hippophae)	Growth of economy for sustenance of local people
8	Barren / Rocky / (Glacial /Peri-glacial)	Frost heaving/ Frost shattering	Severe	>35	Poor	7-8	Pasture development / Natural regeneration and aerial seeding	Restoration of biodiversity/ Biomass

Note: $ Land capability denotes arable and non arable classes in agriculture land. Classes 1 to 4 refer to arable lands and classes 5 to 8 refer to non arable lands.

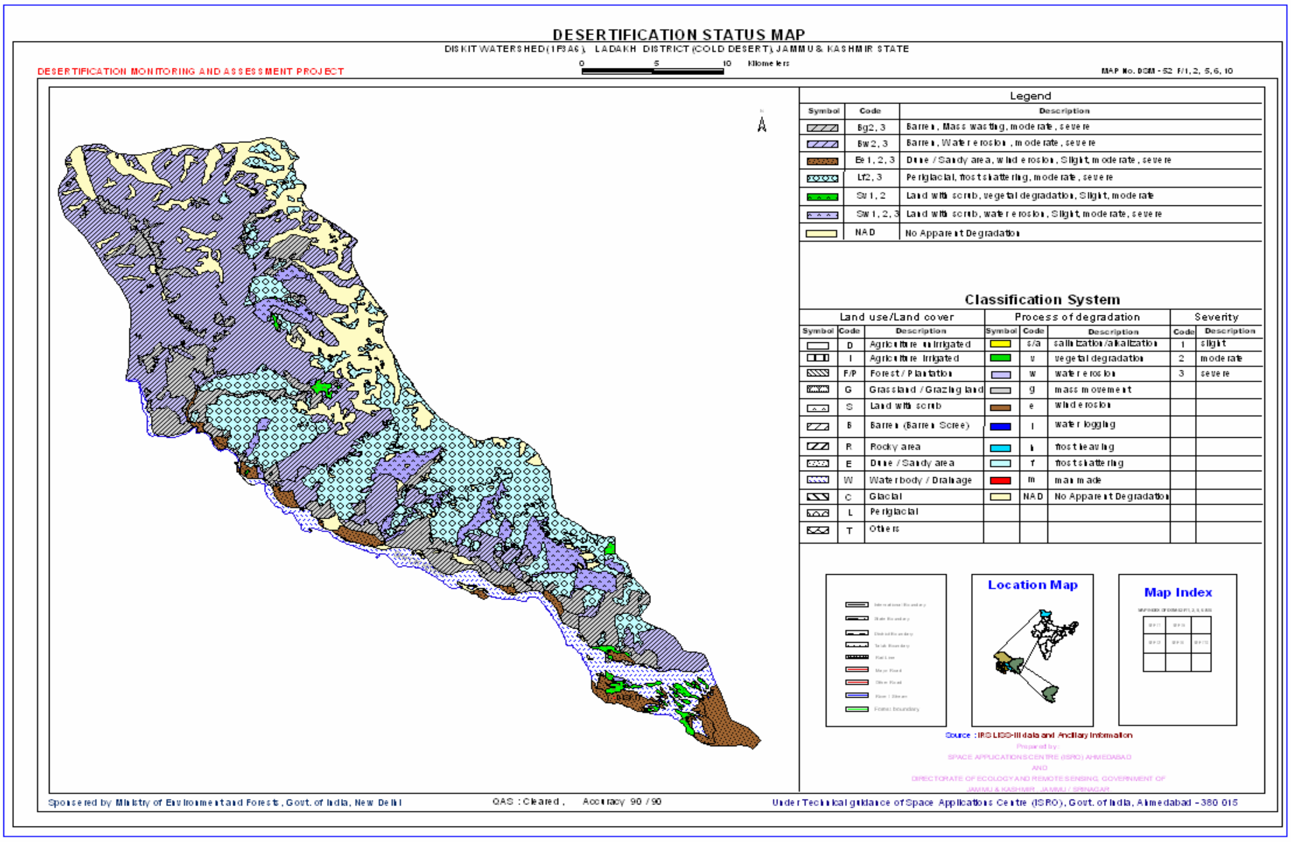

Fig.2: Desertification Status Map of Diskit Watershed(1F3A6)

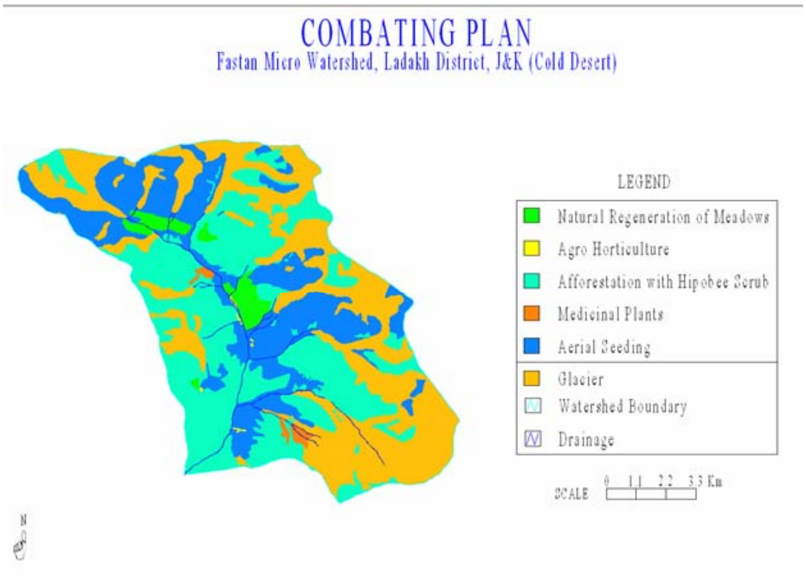

Fig. 3: Combating Plan Map of Diskit Micro Watershed(1F3A6), Ladakh District (J & K)

Table 2: Area under various processes of desertification

S. No.	Type of Land Use	Type of Degradation	Severity code	Area in hectares	Percentage of area
1.	Periglacial	Frost shattering (24.63)	Lf2	12825	14.89
			Lf3	8388	9.74
2.	Barren	Water erosion (34.17)	Bw2	4642	5.39
			Bw3	24778	28.78
3.	Land with Scrub	Vegetal degradation (1.13)	Sv1	706	0.88
			Sv2	220	0.25
4.	Land with Scrub	Water erosion (5.03)	Sw2	4311	5.00
			Sw3	25	0.03
5.	Barren	Mass movement (12.61)	Bg2	2195	2.55
			Bg3	8664	10.06
6.	Dune/Sandy area	Wind erosion (2.18)	Ee1	1375	1.59
			Ee2 Ee3	1621 266	1.88 0.30
7.		NAD	-	11081	12.87
8.	River	-	-	4990	5.79
			Total	86095	100.00

a) Natural regeneration of meadows (13775 ha covering 16% area)**:** Ladakh district is rich in pastures and supports a good population of sheep, cattle and wildlife. Natural regeneration of meadows is suggested on moderately sloping regions of Karakoram range. (*Anon, 2003*)

b) Agro-horticulture (24106 ha covering 28% area)**:** The agricultural area in gentle slopes is best suited for growth of fruit trees. Important fruit trees (apple, apricot, walnut and strawberry), which are of very high economic value should be grown on foothill regions and along the Shyok river where water is available.

c) Afforestation (24968 ha covering 29% area)**:** Afforestation with suitable tree species (willow and poplar) with adequate soil and water conservation measures (stagerred trenches) is suggested where terrain is strongly sloping.

d) Medicinal Plants (4305 ha covering 5% area)**:** The Ladakh region is rich in medicinal plants. hippophae *rhamnoides*, ephidra *girardiana,* myricaria *rosea* and myricaria *squamosa* are very important medicinal plants. If these plants are grown on very large scale on gently sloping regions, they can act as major source of income for local population.

e) Aerial Seeding (18941 ha covering 22% area)**:** Since hippophae is a medicinal plant of high economic value, aerial seeding of hippophae is recommended on highly mountainous terrain and on steep slopes.

5. Conclusion

Remote sensing data along with GIS has been useful for desertification, monitoring and assessment. Combating desertification through conservation of soil, efficient management and utilization of rain water and management of non-arable lands for fodder, fruit and fuel, stabilization of sand dunes and growing of medicinal plants are the core strategies of natural resources management in the cold desert region. Hence, it is concluded that remote sensing and GIS are very important and promising techniques helpful for preparation of an inventory of natural resources, creation of spatial database and for understanding the status of severity of processes of desertification and for generation of eco-friendly action plan for combating the processes of desertification.

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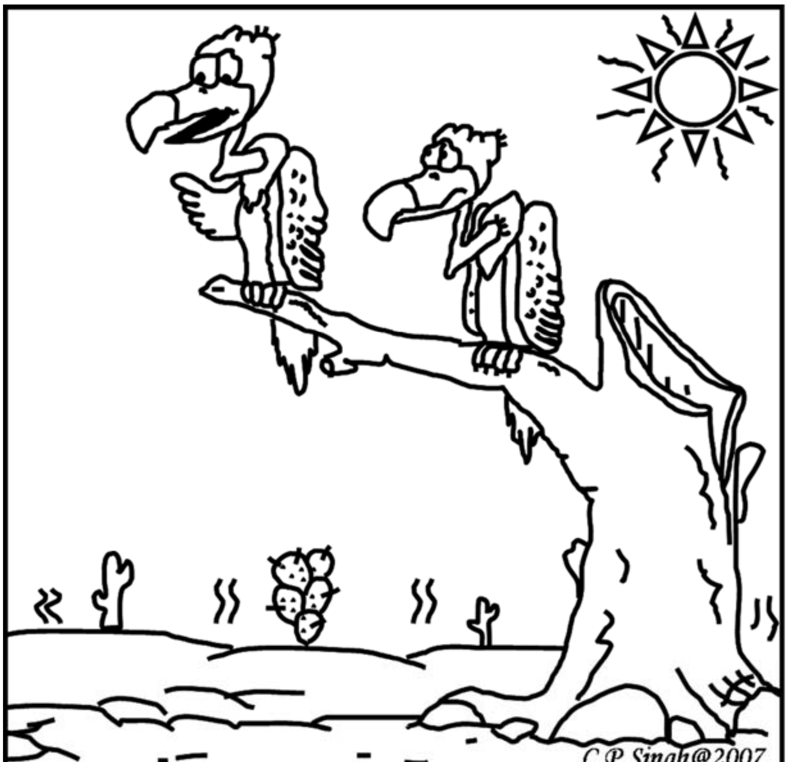


I blame it on the GPS-System :
Nobody gets lost here anymore...

CATCHMENT ATLAS FOR RAJASTHAN DESERT

Rajashree V. Bothale and **J R Sharma**
Regional Remote Sensing Service Centre, ISRO, DOS, Jodhpur – 342003

Abstract

Unprecedented floods in desert have proved that the natural disasters have no geographical barriers and a new outlook is necessary to realize the consequences of intense rain over desert, in understanding flow accumulation, catchment areas, runoff generation and flow through defined channels. Availability of an authentic drainage and watershed map is the foremost requirement for any hydrological study and will augment the planners for *apriori* decision making in near real time scenario. Digital elevation model (DEM) data along with IRS satellite data have been used for generation and validation of catchment atlas. The '*Rajasthan Desert Catchment Atlas*' has sub-district wise details with 110 total number of plates covering 12 districts of western Rajasthan namely, Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jalor, Jaisalmer, Jhunjhunun, Jodhpur, Nagaur, Pali and Sikar.

1. Introduction

Rajasthan desert which spans over 12 districts, namely Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jalor, Jaisalmer, Jhunjhunun, Jodhpur, Nagaur, Pali and Sikar receives scanty but erratic rainfall in general. Occurrences of sudden and intense rain have become more frequent in the recent past. With the recent floods need is felt to understand and realize the consequences of intense rains over desert areas.

With the development of satellite technology and availability of different types of satellite data products, it has now become possible to get digital elevation model (DEM) data for entire study area with reasonable accuracy. Hydrologic interpretation of DEM is based on the fact that it views DEM as a surface that naturally allows flow of water and directs it to flow towards channels located at relatively lower elevations in the topography. DEMs are useful for interpretation of flow paths and delineation of catchments and channel network.

Preparation of *'Rajasthan Desert - Catchment Atlas (with potential drains)'* is an endeavor to provide information on post rain water movement to all the hydrologists concerned.

All the atlas plates for catchment and potential drains are based on the interpretation of digital elevation model (DEM) from Shuttle Radar Topographic Mission (SRTM) and IRS AWiFS. LISS III false colour composites (FCCs) have been used for updating base layers and validation of potential drains for the existing channels and rivers.

2. Study Area

The Great Indian Desert is bounded by latitudes 24° 30' to 30°N and longitudes 69°30' to 76°E. It is a part of Thar desert with Aravalli hill ranges forming the eastern limits of the desert. Twelve districts with 86 sub-districts in western Rajasthan covering an area of 208751 sq km form the desert. *Figure 1* shows the index map of study area.

Desert is characterized by sparse and highly variable rainfall, extreme variations in diurnal and annual temperatures and high evapo-transpiration. Weather pattern is broadly classified into four distinct seasons, viz., winter (December–February), summer (March-June), monsoon (July-September) and post monsoon (October-November). Average annual rainfall varies significantly in the desert areas. Normal monthly temperature varies from 3 to 10°C in winter and 40 to 42°C in summer.

The present landforms of the desert are the products of a long history of *exogenic* and *endogenic* activities in the region. Hill-rocky/gravelly, pediment – flat buried pediment, older and younger alluvial plains – river bed are common landform sequence produced by fluvial processes within the desert. Spatial extent of fluvial landforms has reduced over time due to their progressive burial by the aeolian sands. Sand dunes, interdunal plains and the sandy undulating plains have been formed and these units cover about 50% area of the desert.

3. Methodology

Catchment atlas of Rajasthan desert is based on the interpretation of digital elevation model (DEM) from Satellite Radar Topographic Mission (SRTM). Hydrologic interpretation of DEM is based on the fact that it views DEM as a surface that naturally allows flow of water and directs it to flow towards channels located at relatively lower elevations in the topography. DEMs are useful for interpretation of flow paths and delineation of catchments and channel network. SRTM is a joint project between NASA and NGA (National Geospatial-Intelligence Agency) to map the world in three dimensions. SRTM global data is available at 3 arc second (90 meter) grid spacing. The product consists of seamless raster data, which is provided according to user-specified area coverage. SRTM 'finished' data meet the absolute horizontal and vertical accuracies of 20 m (circular error at 90% confidence) and 16 m (linear error at 90% confidence), respectively, as specified for the mission. The vertical accuracy is actually significantly better than 16 m. It is closer to + 10 m. Different steps to create catchment and lowest elevation potential drain are as follows:

3.1 Calculation of flow direction

Flow direction grid gives direction in which each cell in a surface drains. Direction of steepest downward descent for each cell is determined. For every 3 x 3 cell neighbourhood, the grid processor stops at the center cell and determines which neighbouring cell is lowest. The output of flow direction is an integer grid whose values range from 1 to 255. The values for each direction from the center are:

32	64	128
16		1
8	4	2

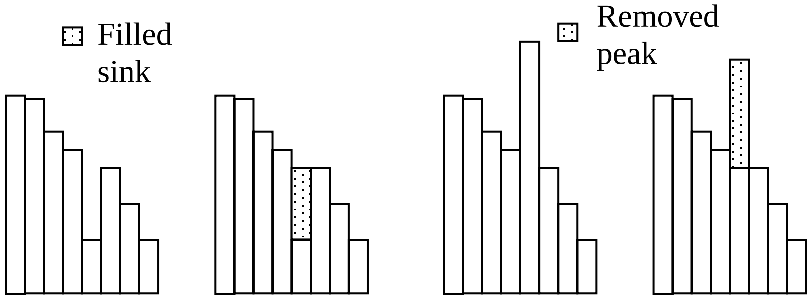
Sample input and output flow direction grids are shown here.

80	74	71	73
76	69	58	51
71	55	46	39
66	60	57	24

2	2	2	4
2	2	2	4
1	1	2	4
128	128	1	2

3.2 Creating a Depression-less DEM

Elevation grid is required to be filled for sinks, which are areas of internal drainage. Sinks and peaks are often errors in data due to resolution of the data or rounding of elevations to the nearest integer value. Sinks should be filled to ensure proper delineation of basins and streams. If the sinks are not filled, a derived drainage network may be discontinuous. Area specific threshold value is used to create depression-less DEM for the study area. The continuity of terrain is based on proper filling of sinks.



3.3 Flow accumulation calculation

Flow accumulation is the next step in hydrologic modeling. Watersheds are defined spatially by the morphological property of drainage. In order to generate drainage network, it is necessary to determine the ultimate flow path of every cell on the landscape grid. Flow accumulation creates a grid of accumulated flow to each cell, by accumulating the weight for all cells that flow into each down-slope cell.

Output cells with a high flow accumulation are areas of concentrated flow and are used to identify stream channels. Sample flow accumulation result is shown here.

0	0	0	0
0	1	1	2
0	3	7	5
0	0	0	20

3.4 Catchment delineation

By identifying ridgelines catchments are delineated. Flow direction grid is used to find all sets of connected cells that belong to same drainage basin. Catchments are created by locating the pour points at the edges of the analysis window (where water would pour out of the grid), as well as sinks, then identifying the contributing area above each pour point.

DEM for the desert area was analysed to generate catchment and potential flow drains.

3.5 Analysis and Atlas Preparation

Analysis was carried out for entire desert area by dividing it into number of overlapping regions to avoid memory overflow. Edges of each region were removed and catchments were picked up from common areas to evade boundary problem. Based on the terrain elevation and natural slope drains which have potential for water flow were delineated. Continuity of drains was obtained by eliminating small obstructions in the flow path. District wise summary of catchments delineated using satellite data is given in *Table 1*.

From *Table 1*, it is clear that Pali and Jodhpur districts have more than 75% district area under shared catchments with adjacent districts. Ganganagar district has maximum percent area under catchments lying fully within district. Construction of canals in Ganganagar district and high dunes in Bikaner, Jaisalmer and Barmer districts obstruct the natural flow resulting in small catchments.

Table 1: District wise summary of delineated catchments and shared catchments between districts

District	District area (In sq km)	Total catchments completely within district (Area > 5 sq km)	Area of catchments completely within district (In sq km)	District area covered with shared catchments (In %)	Area of biggest catchment formed within district (In sq km)
Barmer	28387	542	19756.4	30	2185.09
Bikaner	27244	581	19879	27	1547.06
Churu	16830	403	11582.2	31	562.94
Ganganagar	10978	238	8829.48	20	1260.64
Hanumangarh	9656	171	5220.95	46	331.87
Jaisalmer	38401	815	27327.7	29	4270.16
Jalor	10640	60*	7407.22	30	1913.63
Jhunjhunun	5928	39	4122.4	30	1091.84
Jodhpur	22850	87	4868.02	79	903.91
Nagaur	17718	76	8399.38	53	1968.53
Pali	12387	66	2034.4	84	424.92
Sikar	7732	67	4393.63	43	471.56

* Continuity of Jalor with Gujarat was not studied, hence only 30% area was demarcated as shared catchment

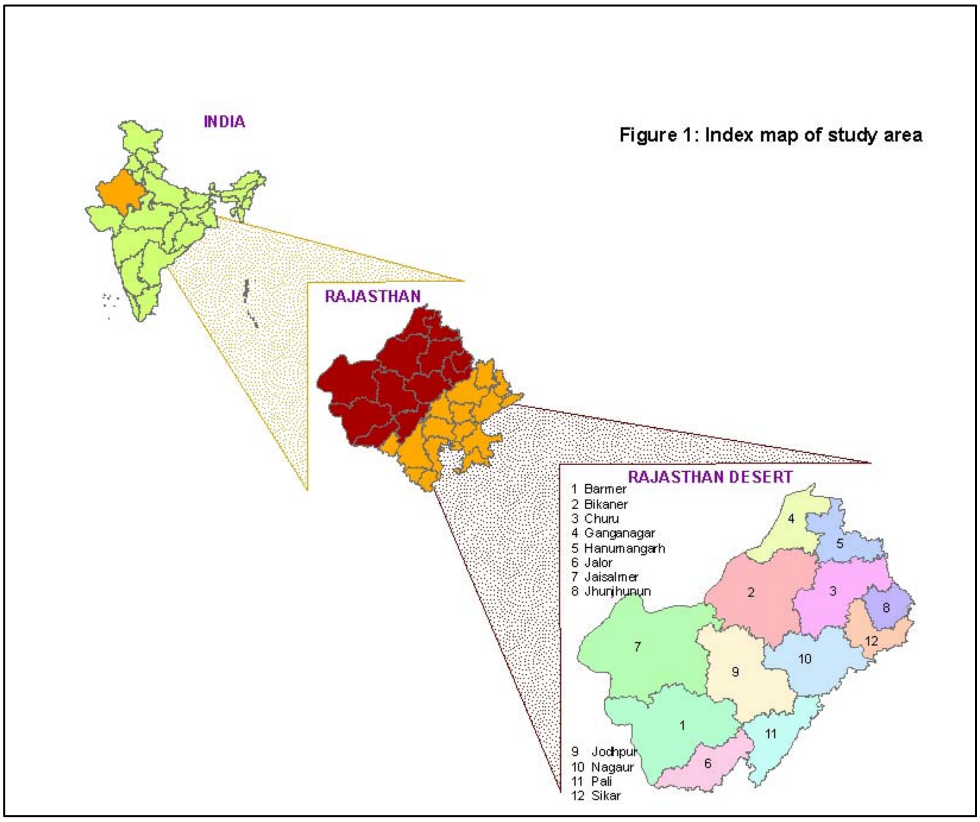


Figure 1: Index map of study area

Release of *Rajasthan Desert Catchment Atlas* by Chairman, ISRO Dr. G. Madhavan Nair to Mrs. Kiran Soni Gupta, Division Commissioner, Jodhpur

After complete analysis of data for Rajasthan desert, 'Rajasthan Desert - Catchment Atlas (with potential drains)' atlas was conceived. Sub-district wise atlas plates were prepared. There are 110 plates in the atlas. Sub-district wise plates show false colour composite (FCC), digital elevation model (DEM), catchment map, potential drains, statistics table for catchments, major road and rail network and major settlements. In addition, district wise summary shows the existing major drains, isoheights, landuse/landcover and annual rainfall over the years. District wise hillshade view map gives idea about terrain. *Figure 2* shows the input data, outputs generated and sample plate for Phalodi sub-district of Jodhpur district, Rajasthan.

4. Conclusion

'Rajasthan Desert – Catchment Atlas (with potential drains)' is an unique effort to demarcate catchments in plain lands of Rajasthan desert. Catchment atlas is useful for scientists, academicians, planners, administrators, and all those working in the field of hydrological studies in Rajasthan desert. Some of the application areas include preparedness for floods, mitigation of droughts, identification of vulnerable areas during flash floods, identification of sites for culverts, planning for water harvesting structures and infrastructure planning.

Acknowledgements

We are grateful to scientific staff of RRSSC Jodhpur for help, support and suggestions during atlas preparation. Thanks are also due to Dr Dhir for providing valuable suggestions which helped in improvement of atlas.

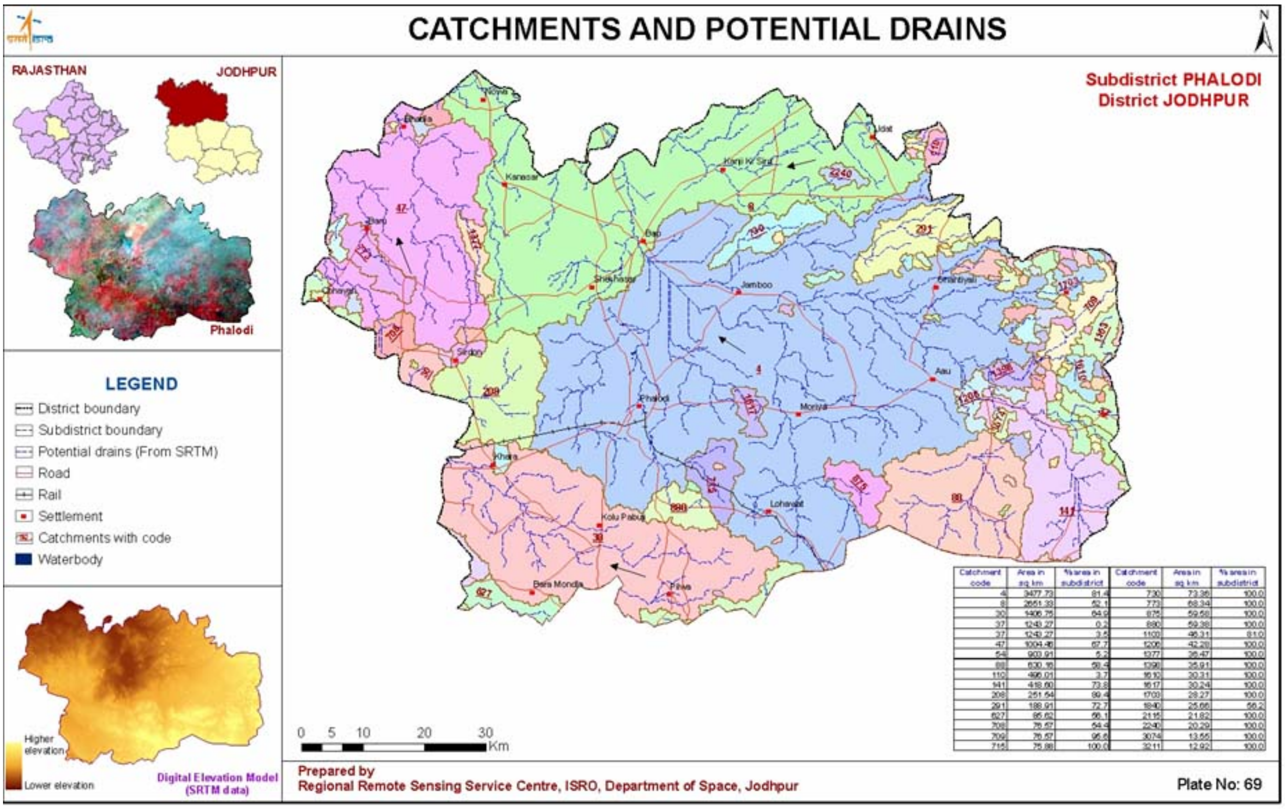


Figure 2: A Sample Plate in Atlas

INVENTORY ON DESERTIFICATION STATUS OF INDIA USING MULTI-TEMPORAL AWIFS DATA

A.S. Arya, P.S. Dhinwa, K. Ganesha Raj*, S.K. Pathan and **Ajai**
Space Applications Centre, Ahmedabad – 380015
*ISRO-HQ, Bangalore – 560094
Email: *arya_as@sac.isro.gov.in*

Abstract

Desertification is the continuous degradation of land under the influence of natural and anthropological causes in arid, semi-arid and dry-sub humid conditions. Mostly, it is a slow and creeping process except for certain events like torrential periods leading to heavy soil erosion in a short period of time, events of landslides, *jhoom* cultivation leading to forest degradation etc. There exist no substantial database on the status of desertification in India, as a whole. As such, to assess the status of desertification for entire country is a Herculean task and needs to be carried out using fast, accurate, cost effective and less exerting method like satellite remote-sensing. An attempt has been made to carry out desertification status mapping (DSM) of entire India using multi-temporal IRS-Resourcesat AWiFS data on 1:500,000 scale. This has been accomplished by involving about 16 different institutions/ agencies in the country. The DSM output reveals the land use/ cover categories affected by various processes of degradation with varying severity. The various processes of degradation observed includes water erosion, vegetal degradation, wind erosion, salinization/ alkalization, water logging, frost heaving, frost shattering, mass-wasting, man-made etc. The two main processes of degradation observed are vegetal degradation in forests and scrublands followed by water erosion in agriculture areas. This is a unique attempt to map both hot and cold regions in totality based on a comprehensive classification system developed for DSM through a pilot project in about 16 different test sites, 8 each in the hot and cold regions of India at 1:50,000 scale. The study reveals that there exists about 105.5 mha area under various processes and severity of desertification, which is nearly 32.1%. This means that nearly one-third geographical area of the country is under desertification. The present paper deals with the description of the project, indicators used, classification system, methodology adopted and the results achieved for the maiden inventory of India's status of desertification. The study clearly demonstrates end-to-end consensus approach of harmonization of the data, evolution of a comprehensive classification system, development of methodology, followed by validation of this harmonized approach by carrying out pilot studies in arid, semi-arid and dry-sub humid areas of both hot and cold desert regions and finally opeartionalising the approach for carrying out DSM for entire India on 1:500,000 scale successfully.

1. Introduction

The 1977 United Nations Conference on Desertification (UNCOD), in Nairobi, described desertification as the diminution or destruction of the biological potential of the land. United Nations Environment Programme (*UNEP, 1992*) defined desertification as "the land degradation in arid, semi-arid, and dry sub humid areas resulting mainly from adverse human impact''. The recent definition of desertification accepted by United Nations is "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities".

In India, reportedly, dryland comprises about 228 mha (69%) of the total geographic area of the country. About 50.8 mha (15.8%) of the country's geographical area is arid , about 123.4 mha (37.6%) is semi-arid region and about 54.1 mha (16.5%) falls within the dry sub-humid region (*Fig. 1*).

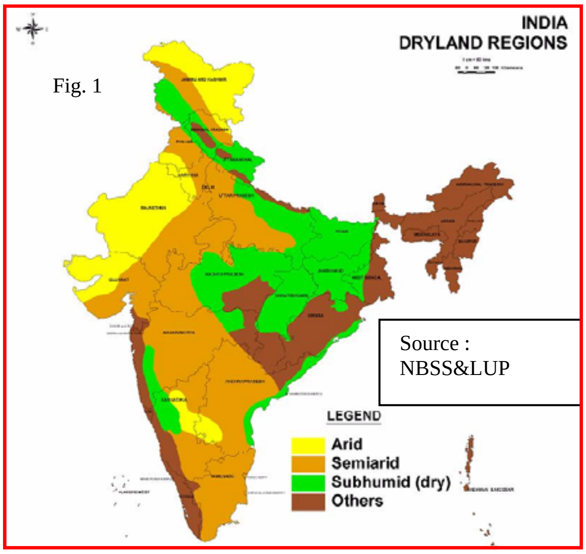


Fig. 1: Dryland Regions of India

At present no comprehensive database or information is available on status of desertification in India. Hence, an attempt was made to evolve a methodology and comprehensive classification system through a pilot project in about 16 different test sites, 8 each in the arid, semi-arid and dry-sub humid hot and cold regions of India at 1:50,000 scale for assessing the desertification status of India using multi-temporal IRS-LISS III FCC's . It is a three-tier approach. At level – I, there are mainly ten classes of land use and land cover, at level –II, there are nine different processes of desertification and at level-III, there are three categories of degree of severity were considered. (*Table 1*).

It is note-worthy that the classification system used for DSM at 1:50,000 scale has three levels of severity i.e slight, moderate and severe. However, while attempting DSM at 1:500,000 scale it was decided to keep only two categories i.e. low and high.

This work is carried out jointly by Space Applications Centre (ISRO), Ahmedabad and about 16 collaborating agencies having in-house expertise on remote sensing & desertification/land degradation.

Table – 1: Classification System

Level 1: Landuse / Landcover –
The following categories have been identified: -

Agriculture – Unirrigated	(D)
Agriculture – Irrigated	(I)
Forest/ Plantations	(F)
Grassland/Grazing land	(G)
Land with scrub	(S)
Barren / Rocky area	(B/R)
Dune / Sandy area	(E)
Waterbody / Drainage	(W)
Glacial / Peri-glacial (In cold region)	C/L
Others (Urban, Man-made etc.)	(T)

Level 2: Processes of Degradation
Types 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 Agg etc.)	(m)

Level 3: Severity of Degradation
This level represents the degree and severity of the degradation.

Low	1
High	2

To prepare a desertification status map of India in 1:500,000 scale using multi-temporal AWiFS data (2003-2004), the major land use/ land cover classes considered are agriculture-unirrigated, agriculture-irrigated, forest/plantation, grassland/grazing land, land with scrub, barren, rocky, dune/ sandy area, water body/ drainage, glacial, peri-glacial and others, delineated visually using the basic elements of interpretation.

Vegetal degradation, water erosion, wind erosion, water logging, salinisation/ alkanisation, mass movement, frost heaving, frost shattering, and man made are the main desertification processes observed in India. `High' and `low' are the two levels of `degree of severity' which are mappable at 1:500,000 scale.

It is for the first time a national level spatial inventory has been carried out for the entire country giving the information on the various desertification processes and their severity involving relevant collaborators like CAZRI, Jodhpur, NBSSLUP, Bangalore, AIS&LUS, Delhi, MAPCOST, Bhopal, UPRSAC, Lucknow, Jhar-khand RS Centre, Ranchi, BIT-Mesra, Ranchi, Orissa RS Centre, Arunachal Pradesh Remote Sensing Centre, Itanagar, Jammu Univ, Jammu, Jawahar Lal Nehru University (JNU) , Delhi, IRS – TN, Chennai, MRSAC, Nagpur, Univ. of Rajasthan, Jaipur & DERS, Srinagar. See box appearing in page 33.

To achieve this, firstly the indicators of desertification have been frozen using brain-storming sessions of experts and eventually arriving at a consensus comprehensive list of indicators as shown in *Table –2* . The same effort has been put to harmonise the data sets, the classification system and the methodology for desertification status mapping. This has been further validated through 16 pilot projects in hot and cold dryland regions on 1:50,000 scale and finally operationalised to prepare DSM of entire India in 1:500,000 scale. All those indicators, amenable to remote sensing have been taken into account while preparing the desertification status map of the country. They are further discussed as below:

Table 2: Indicators of Desertification

Table 2.1: Pressure Indicators

Physical	Rainfall, temperature, wind, humidity, potential evapotranspiration, solar radiation, cloud cover
Socio-economic	Population density, education status, livestock density, forest felling, fuel and fodder consumption/supply collection of medicinal plants, shifting cultivation, diminishing of water resources, land management practices

Table 2.2: State Indicators

Physical indicators	Erosion status of the land, salinity/alkalinity, shifting in sand sheet/sand dunes, water logging, soil moisture, soil types and properties, stone coverage/barren rocky area, number and spread of water bodies, groundwater status, turbidity of water bodies
Biological indicators	Types of vegetation species, composition of vegetation, condition and coverage of vegetation biomass and productivity of vegetation crop area and yield

Table 2.3: Impact Indicators

Land use	Land use pattern
Socio-economic	Income, migration, mortality rate, health conditions, unemployment, illiteracy, food security and malnutrition, prices of food grain, energy consumption by source infrastructure, security and development, gender specific issues, living standard
Eco-environmental indicators	Air and water quality, occurrence of dust storm and sandstorm, land pollution

Table 2.4: Implementation Indicators

Action indicators	Economic input for combating desertification, investment level, state of the development and implementation of action plan to combat desertification, state of the legislation and execution related to combating desertification, people participation, NGO involvement
Effect indicators	Proportion of desertified land rehabilitated, socio-economic standard of the people, improvement of environmental conditions

2. Methodology

The IRS-P6 (Resourcesat) AWiFS geo-coded FCC paper prints on 1:500,000 scale were visually interpreted for generation of DSM. In the absence of any map at 1:500,000 scale, base map was prepared using mostly the standard maps on 1:250,000 scale, especially for forest boundaries. The base features like road, rail, habitation etc., were incorporated in the base map. Drainage was taken from the satellite imageries due to their dynamic and shifting nature. The base map used was over laid on the AWiFS FCC paper prints and light table was used to delineate the desertification indicators, landuse/ land cover, processes of desertification, severity of desertification processes etc.

The scrub boundaries have been most challenging to delineate at this scale. However, enough caution has been taken to minimize the errors in visual interpretation. These DSM mylars were finalized after the field checks. The final DSM mylars were sheet wise vectorised and then mosaicked and subsequently clipped to generate state wise DSM maps using ARC/INFO GIS environment. Ultimately all the states were mosaicked and the final desertification status map of India was generated (*Fig. 2*). The map shows mainly the dominant processes and their respective severity acting in different land use/ land cover categories of various agro-climatic zones of the hot and cold dry-land regions of the country. This is the maiden DSM map of India ever prepared at any scale.

3. Results and Discussion

The total geographical area of India is about 328.73 mha. According to the estimates of NBSS&LUP (*2001*), the dry-lands of India constitute about 69.6 % of the total geographic area of the country.

Various departments/institutions in the country have made estimations of the land degradadtion of the country mainly between 1976 and 1994 (*Table 3*). These estimates vary from 107 mha to 188 mha, mainly due to difference in the method of data collection, scales of mapping, classification system and definition of the degraded lands. Recently, SAC, Ahmedabad has estimated the total area under desertification to be 105.48 mha (2006), the statewise statistics of the land under desertification country is given in *Table-4.*

Space Applications Centre has attempted to map the status of desertification/ land-degradation of entire drylands of India and north east region on 1:500,000 scale using IRS Resourcesat AWiFS data. The mapping work got started in 2004 and was completed in 2006.

Some areas, like parts of Jammu and Kashmir beyond the L.O.C have been mapped but no field work carried out for obvious reasons. Certain areas, which are not actually dry-lands but having fewer and smaller dimensions of degraded land, not commensurating with DSM at 1:500,000 scale, like Andaman and Nicobar islands, Lakshadweep islands etc., are not mapped as well.

It is note-worthy that NE region of India, Kerala and other areas (*Fig 1*), which are not drylands, have also been covered under this study as they do suffer from land degradation, profoundly at some places. Jhoom cultivation in north-eastern parts of the country has been covered under vegetal degradation. Forest and plantations are clubbed together for convenience of delineation. In cold desertic areas, the glacial and peri-glacial regions have been dealt as separate land cover classes due to their distinct identities. Mass movement includes the large landsilde areas and scree slopes in hilly terrain, mainly Himalayan areas.

The estimate based on the digital analysis of the mapped information in GIS suggests that the total area of desertification in India is 105.48 million hectares (mha), which constitutes 32.07 per cent of the total geographical area (TGA). There are three major processes responsible for the desertification in the country. The water erosion is the main cause of degradation in the country followed by vegetal degradation and wind erosion. *Table 4* gives the detailed break up of the estimated area (in mha) and corresponding per cent of TGA under desertification in various land use/cover, affected by different desertification processes and varying severity levels, in India. This table includes the major degradation processes in cold desert as well.

The total land area of the country is about 328.73 mha. Each state is evaluated w.r.t its proportion of area under desertification to the TGA (Total Geographic Area) of India. *Figure 3* shows the graphical representation of the DSM area (in mha) for each state and its percent contribution to the TGA of the country. Area wise (in mha) Rajasthan (22.96), has the largest area under desertification/ land-degradation, followed by J&K (13.5), Maharashtra (13.36) and Gujarat (12.86).

Table 3: Estimation of Degraded Lands by Various Organisations

S. No.	Organisation	Year	Extent of Land Degradation (in mha.)	Criteria for delineation
1	National Commission on Agriculture (NCA)	1976	175.00	Based on Secondary data only
2	Ministry of Agriculture	1985	173.64	Based on Land degradation statistics of the states
3	NBSS& LUP	1994	187.7	Mapping on 1:4.4 m scale (GLASOD guidelines)
4	Dept. of Agriculture & Cooperation, MOA	1994	107.43	Based on Land degradation statistics of the states
5	SAC (ISRO)	2006	105.48	Based on RS based mapping on 1:0.5 m scale

(Source: *Velayutham 1999* and *MoEF 2001* and *SAC 2006*)

Collaborating Agencies

- All India Soil & Land Use Survey, Delhi
- Arunachal Pradesh Remote Sensing Centre
- Birla Institute of Technology, Mesra, Ranchi
- Central Arid Zone Res. Institute, Jodhpur
- Dte.of Environment & Remote Sensing, J&K
- Institute of Remote Sensing, TN, Chennai
- Jammu University, Jammu
- Jawaharlal Nehru University, Delhi
- Jharkhand Remote Sensing Centre, Ranchi
- Madhya Pradesh Council of Science & Technology, Bhopal (MAPCOST)
- Maharashtra Remote Sensing Applications Centre, Nagpur
- National Bureau of Soil Survey & Land Use Planning, Bangalore
- Orissa Remote Sensing Centre
- University of Rajasthan, Jaipur
- UP Remote Sensing Applications Centre, Lucknow

Within each state, the status of desertification/ land-degradation is graphically shown in *Fig. 4*. It is computed in two ways, i.e the area under desertification within the state (in mha) and DSM-percent of the total area of state. Within the states, the NE-states have very high ratio of desertification/ land-degradation , as percent of total area of the state. Mizoram has the highest percent of land under desertification (80%), followed by Manipur (68%), Tripura (67%), Nagaland (65%). Outside NE-region, the other states having significant percent of desertification include Gujarat (68%), Rajasthan (67%) and J&K (59%). This indicates the ratio of area affected by desertification to the total area of the state. It is also strongly suggestive of the `land under stress'.

The results have been further analysed so as to get the distribution of various processes of desertification/ land-degradation with high and low severity. The areas with high severity is of greater importance for prioritizing the future mitigation measures to combat desertification. These have been obtained after the analysis of the integrated area statistics for various processes/ severity of desertification in each state, and subsequently calculating the statistics for the entire country. This is the maiden attempt to assess the total desertification status of India using satellite data.

4. Conclusions

1) The IRS-P6 Resourcesat AWiFS data has been successfully used to generate DSM of entire country in 1:500,000 scale
2) Nearly one third of the country (32.07%) is inflicted by desertification/ land-degradation with varying degree of severity of land degradation
3) There are about 8 major processes of degradation identified in India, of which, the water erosion is the most pronounced process, followed by vegetal degradation and aeolian processes leading to desertification.
4) Total area under desertification is 105.48 mha, which is close to the earlier estimate (107.43 mha) generated by MOA (1994) on the basis of statistics collected from various states.
5) Area wise Rajasthan, J&K, Maharashtra and Gujarat have high proportions of land under desertification.
6) Within the states, the states of NE-regions have very high ratio of desertification/ land-degradation as percent of total geographical area of the state.
7) This study provides base-line data and information for future monitoring of progression/regression of desertification by repeating the exercise every five years.

Acknowledgements

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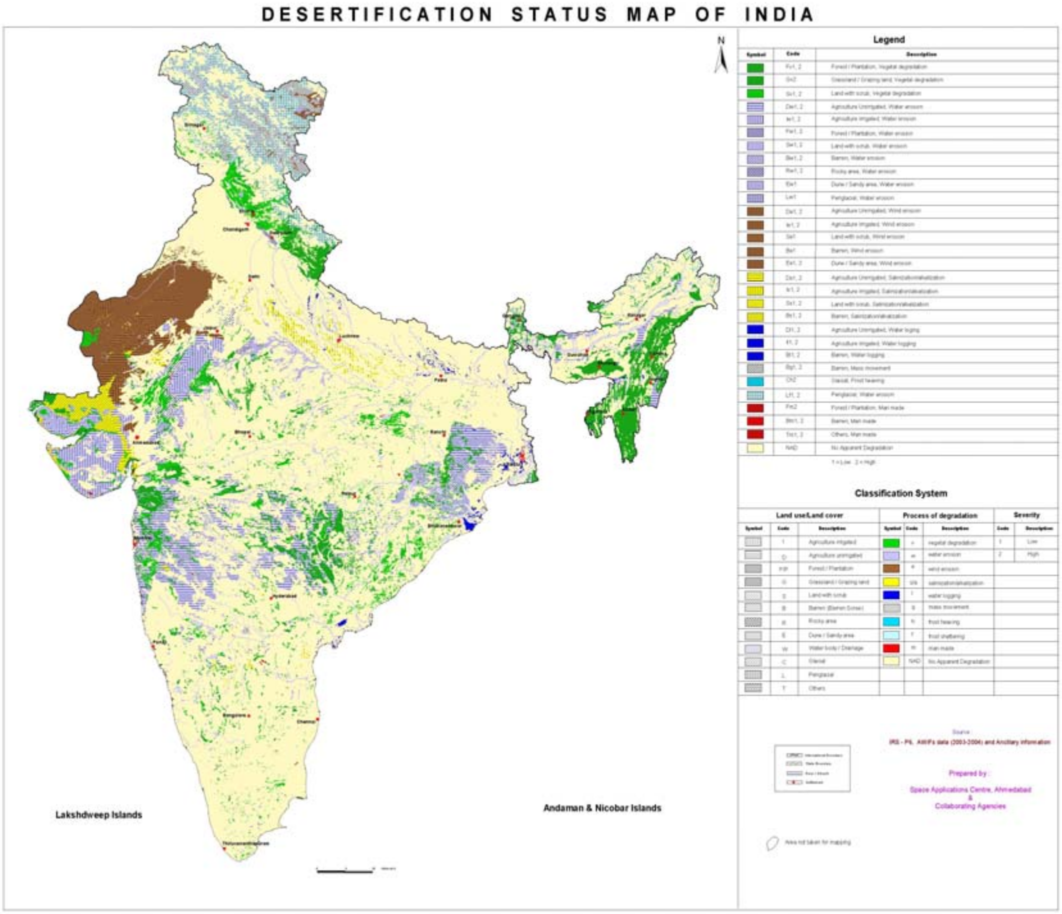

Figure 2: Desertification Status Map of India

Table 4: Estimation of the land area under desertification/ degradation in India

Processes	**SAC (2006) 1:0.5 m scale**	
	Area (mha)	**% of TGA**
Water Erosion	33.56	10.21
Vegetal Degradation	31.66	9.63
Wind/Aeolian Degradation	17.56	5.34
Frost Shattering	10.21	3.10
Salinity/Alkalinity	5.26	1.60
Mass Movement	4.45	1.35
Water logging	0.98	0.30
Rocky areas/ Barren	1.65	0.50
Others	0.15 (Man made, frost heaving etc.)	0.04
	105.48	32.07

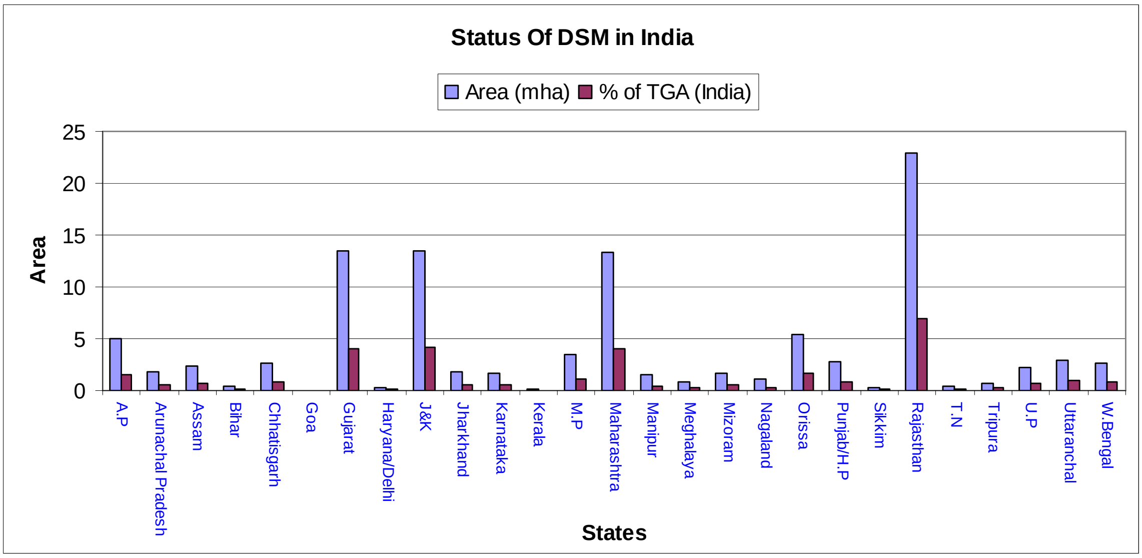

Figure 3: State-wise desertification statistics

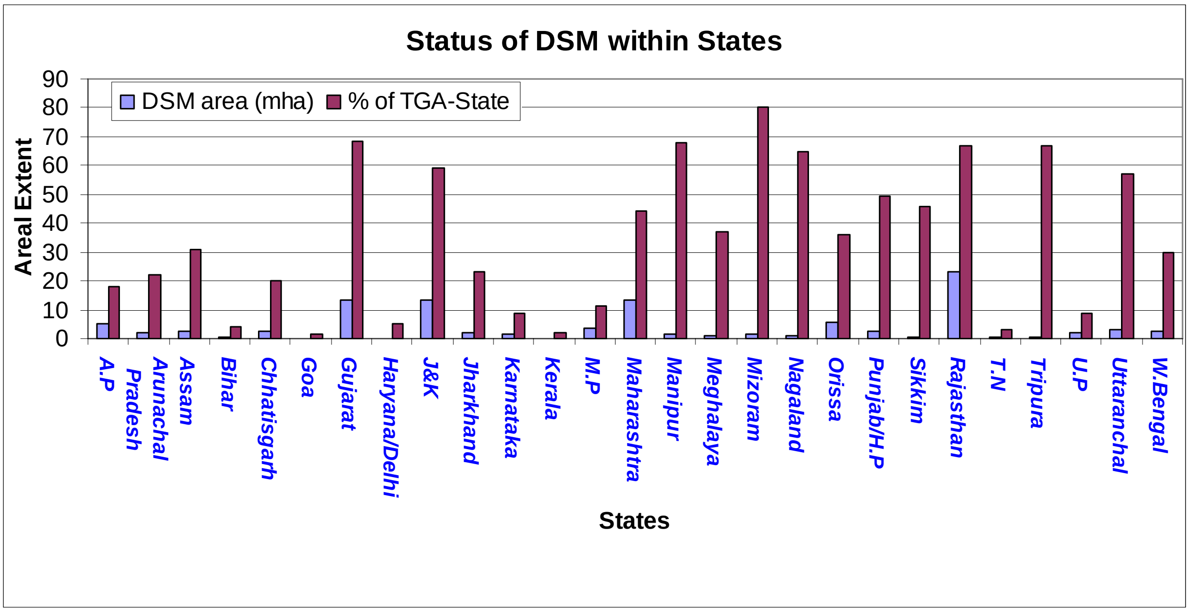

Figure 4: Desert area percentage within each state

SPATIAL AND TEMPORAL CHARACTERISATION OF THE "*THAR*" DESERT USING C-BAND WIND SCATTEROMETER

C. P. Singh[a], **D. G. Trivedi**[b], **Shiv Mohan**[a] and **Ajai**[a]
[a] Space Applications Centre, ISRO, Ahmedabad-380015
[b] St. Xaviers College, Gujarat University, Ahmedabad-380009
Email: {*cpsingh, shivmohan, ajai*}*@sac.isro.gov.in; dgtrivedi60@rediffmail.com*

Abstract

Spaceborne scatterometers have provided continuous synoptic microwave coverage of earth for nearly one and half decades. These are designed principally to measure the normalized radar cross-section backscatter from the ocean's surface for the determination of the near-surface wind speed and direction. In addition to this, scatterometers has also been investigated for land applications. The usability of scatterometer data over deserts has been investigated and presented in this article. A portion the Thar desert (falling in India) is studied in terms of its spatial and temporal backscatter response. Temporal trends of major dune types are identified and studied. The variability of backscattering coefficient is found to be of the order of 11 dB (-20.08 to -8.71 dB) in the year 2000 data of ERS-2 C-band wind scatterometer over this region. These variations are analysed in terms of scattering due to various factors like soil moisture, presence of vegetation and surface roughness. In this study, nine dune signatures over six types of sand dunes have been studied. In general, high backscattering is observed in the months of July–August and low backscattering is observed in the months of May–June. The study indicates the potential of C-band scatterometer data for monitoring temporal variability for modelling and monitoring desert ecosystems.

1. Introduction

Microwave as well as optical remote sensing data have been successfully used for monitoring and mapping of deserts all over the world. In optical bands, the desert shows higher reflectance whereas in microwave frequencies active sensor shows low backscattering coefficient values and passive sensors show high brightness temperature values (*Mishra et al, 2002*). The scatterometer from ERS-1/2 operating at C-band as well as QuikScat operating at Ku band have been investigated for land applications (*Birrer et al, 1982; Drinkwater et al, 2000 & 2001; Kennett et al, 1989; Kerr et al, 1993; Long et al, 1994, 1999; Mougin et al, 1995; Prigent et al, 2005; Wagner et al, 1999a, 1999b; Wismann, 1998*).

A scatterometer measures the normalized radar cross-section (NRCS) or backscattering coefficient of earth's surface, also termed sigma-nought (σ^o), a dimensionless quantity. For ocean, the backscatter is due to Bragg scattering of microwaves from centimetre length capillary ocean waves which is related to the wind. For land surface, the backscatter is due to the surface roughness and dielectric properties as well as volume scattering from vegetation. The scatterometer onboard ERS-1/2 operates at C-band in VV-polarization mode with 25 to 50 km spatial resolution and 500 km swath. This coarse resolution (~50 km) of the scatterometer measurements is a major drawback in studies over land surfaces. However, enhanced resolution products from Brigham Young University (BYU) are able to provide 8.9 km spatial resolution datasets, which have been generated using the scatterometer image reconstruction (SIR) resolution enhancement algorithm (*Early et al, 2001; Long et al, 1993, Long and Hicks, 2005*).

1.1 The Instruments: Scatterometers are incoherent radar that measures reflectivity over a set of different incident angles. Since single return pulses are typically noisy, averaging of the detected returns from a sequence of pulses, a process known as post-detection integration is performed to ensure more accurate measurements of the σ^o, often achieving ± 0.10 to 0.15 dB accuracy.

The Active Microwave Instrument (AMI) flown on ERS-2 operates at C-band (5.3 GHz) and uses three antennae with vertical polarization (VV) in the scatterometer mode. They are looking 45^o forwards (Fore beam), sideways (Mid beam), and 45^o backwards (Aft beam) with respect to the satellite flight direction (Fig.1). The incidence angle of the radar ranges from 18^o to 57^o, illuminating a 500 km wide swath on the right hand side of the satellite track.

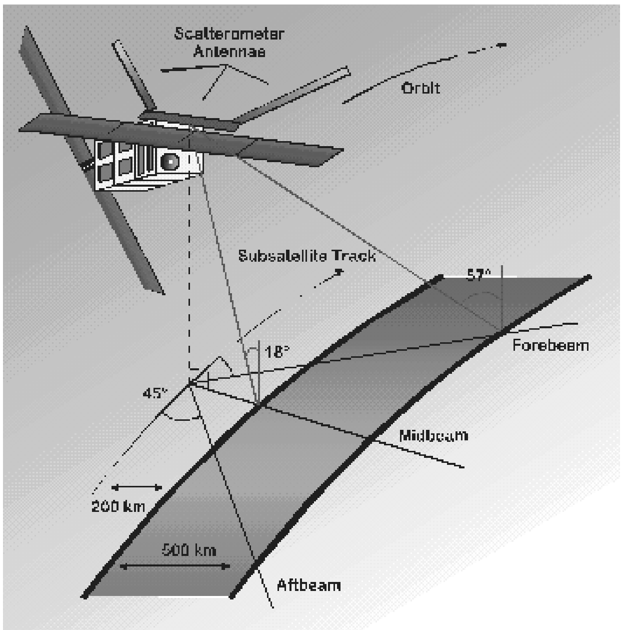

Figure 1: ERS-2 AMI Geometry

The along-track and cross-track spatial resolution are 50 km (Wismann, 1998). Enhanced resolution images from ERS-2 data use the Scatterometer Image Reconstruction (SIR) algorithm. In the processing, a linear model relating σ^o and incidence angle is assumed, i.e. $\sigma°(dB) = A + B(\theta - 40)$ where A is the "incidence angle normalized σ^o" at 40^o incidence in dB, B is the effective incidence slope of σ^o versus incidence angle in dB/deg, and θ is the incidence angle of the observation. The SIR algorithm makes images of A and B on an 8.9 km pixel grid. The effective resolution is estimated to be 20-30 km resolution, depending on region and sampling conditions. Raw ERS measurements have a quoted nominal resolution of 50 km on a 25 km sampling grid.

2. Study Area

The study area is Indian part of Thar desert, which is located between 24^o 36' – 29^o 21' N Latitude and 69^o 32' - 75^o 26' E Longitude (Fig.2). The Thar Desert (also known as the "Great Indian Desert") in India, is geographically located in the state of Rajasthan, between the foothills of the Aravalli ranges in the east and the international border with Pakistan in the west. It lies mostly in the Indian state of Rajasthan, and extends into the southern portion of Haryana and Punjab states and into northern Gujarat state. The Thar desert is bounded on the northwest by the Sutlej River, on the east by the Aravalli Range, on the south by the salt marsh known as the Rann of Kutch (parts of which are sometimes included in the Thar), and on the west by the Indus River. Depending on the areas included or excluded, the nominal size of the Thar can vary significantly. According to the WWF (World Wide Fund for Nature) definition, the Thar has an area of 238,700 km². Another source gives the area of 446,000 km² extending 805 km long and about 485 km wide, with 208,110 km² in India. Of the Indian portion, 61% falls in Rajasthan, 20% in Gujarat and 9% in Punjab and Haryana combined.

The configuration of atmospheric dynamics and sinking air masses in the region inhibit rain in this region despite the fact that considerable precipitable moisture exists in the atmosphere. Minor changes in the atmospheric circulation patterns result in amplified changes in the rainfall, the winds and the aeolian dynamism. It is an austere area where water is scarce and occurs at great depths, from 30 to 120 m below the ground level. The region is dominated by aeolian bedforms of different dimensions, including the sand dunes. The thickness of aeolian cover can range from 1m to 100m.

Westward the natural vegetation becomes gradually sparse, cultivation on dune slopes becomes less frequent, and reactivation of the high dunes are more recurrent. Aeolian activity in the Thar desert is mainly restricted to the period of summer winds associated with the south west monsoon. The north eastern wind of winter months plays only a minor role in aeolian activity and is largely limited to the northern fringe of the desert. Strong sand and dust shifting winds begin from March onwards when the surface is dry and maximum wind speed (20 km/h or more) is reached at all the meteorological stations during June. May and July are also very windy. Since this is also the period when much of the ground flora is dry, the environment is suitable for aeolian activities. The wind and the sand dynamics cease with the arrival of monsoon rains (end of June along the eastern margin of the desert, and mid-July in the western part). Although higher wind strength and lower rainfall favour erosivity of the wind (*Singhvi and Kar 2004*).

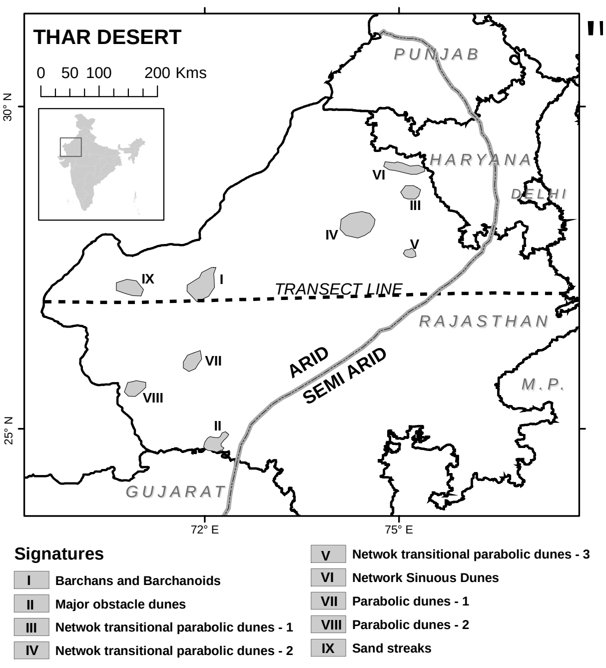

Figure 2: Study Area and Signatures (Thar desert): (Singh, *et al* 2006b)

Sand dunes of the Thar: Sand dunes are the most spectacular aeolian bedforms in the Thar desert. As in other deserts, the genesis of different types of dunes is the result of a delicately balanced relationship between the strength, direction and the duration of wind, sediment supply, rainfall, vegetation cover and land surface conditions. Commonly, dunes are classified according to their form as transverse dunes, barchan dunes, barchanoid dunes, parabolic dunes, longitudinal dunes and star dunes. Transverse dunes are long with straight crests and they migrate along the prevailing wind direction and tend to form when there is an abundant sand supply. Barchan dunes are curved like horseshoes and migrate with their arms pointing in the downwind direction. Barchan dunes form when there is limited sand available and the area between dunes is generally flat and void of sand. Sometimes they become laterally attached and form barchanoid dunes. Longitudinal dunes are dunes that elongate in the direction parallel to the prevailing winds. These dunes lack steep lee slopes and are almost symmetrical in the direction across their length. Longitudinal dunes tend to develop where the prevailing winds vary seasonally but blow from adjacent quadrants. Compound dunes can form when two or more dunes of the same type are combined by overlapping or being superimposed. Complex dunes are those in which two different dune types coalesce or overlap. Three major dune types in *Thar* are the parabolic, transverse and linear dunes. A variety of network dunes, major obstacle dunes (along the hill slopes), barchans, barchanoids and megabarchanoids, and the sand streaks and zibars are also found (*Fig 3*). Dunes of `the old system' are mostly the products of past changes in climate. These dunes are usually 10 to 40 m high, and are now naturally stabilized. Since the average silt and clay content in the dunes is 10-15% of the total sediment weight, moisture-holding capacity of the dunes is high. The dunes, therefore, can sustain a good amount of natural vegetation. In contrast, the dunes of `the new system' consist mostly of the crescentic barchans (2-8 m), the barchanoids (2-15 m) and the megabarchanoids (20-40 m), as well as some small dunes like the sand streaks etc., which are forming under the present arid condition in the western part of the desert (*Singhvi and Kar 2004*).

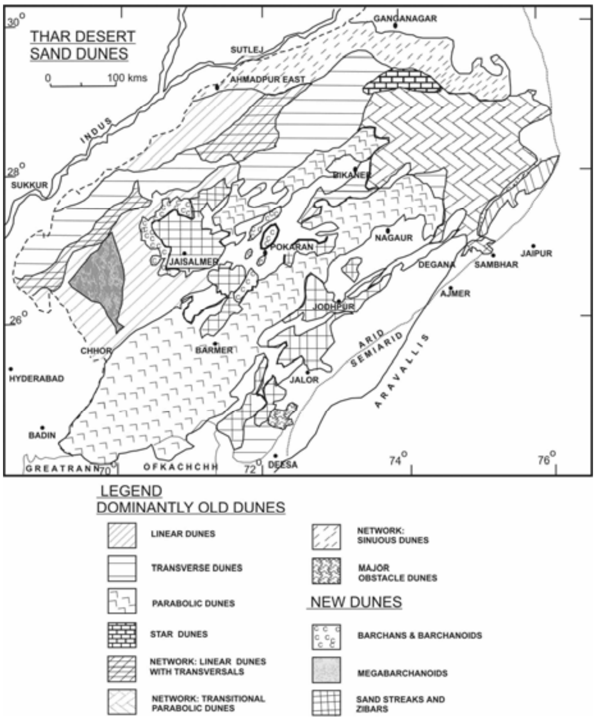

Figure 3: Dune types in Thar (after *Kar 1996*)

The soils of the arid zone are generally sandy to sandy-loam in texture. The desert soils occupy the districts of Jodhpur, Bikaner, Churu, Ganganagar, Barmer, Jaisalmer, and Jalore. The *Thar* consists mainly of the wind-blown sand. The area is covered not only by sheet of sand but also of rocky projections of low elevations which constitute the older rocks of the country.

3. Materials and Methods

The South Asia data chips available from ERS-2 Scatterometer for year 2000 are used to generate the backscattering images of India. The scatterometer data available in "sir" format was converted to Geotiff using IDL (the Interactive Data Language) script. The data are available in the form of radar σ^o image (values in dB at 40^o incidence angle). From the imported data the *Thar* region are extracted from each image and co-registered with SPOT-4 (VEGETATION) NDVI data. In addition, digital elevation model, temperature and rainfall data are also used for interpretation of the σ^o variation.

For, identifying the major dune types in this desert region, collateral dataset like, corresponding dune map (*Singhvi and Kar 2004*) was also used. For identifying the presence of vegetation, the Landsat data (ETM+) was visually interpreted. The SRTM DEM (90 m resolution) was also used to measure the height variation in the area

Subsequently, nine signatures over six types of sand dunes with or without vegetation were identified and signatures statistics were extracted and analysed. The results of some signatures are presented in this article. The methodology adopted is shown in *Figure.4*. A transect profile was also generated from Shahgarh in Western portion to Aravallis (Near Jaipur) in the Eastern portion.

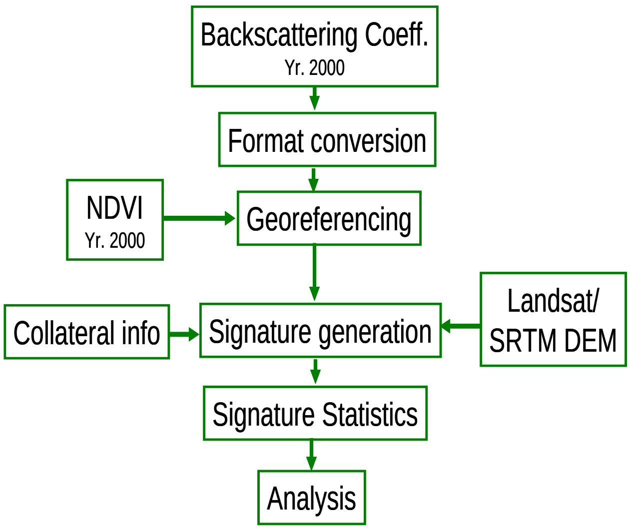

Figure 4: Methodology flowchart

4. Results and Discussion

The Thar desert presents picture of contrast in backscatter image in comparison to other land covers in India (*Fig.5*). However variation in desertic terrain is assigned due to changes in dunes roughness (*Singh, et al 2006a*). The data in year 2000 over this region shows the variability of σ^o of the order of 11 dB (-20.08 to -8.71 dB). These variations can be explained in terms of scattering due to various factors like soil moisture, vegetation, rainfall, and surface roughness due to wind. In general, high backscattering is observed in the months of July–August and low backscattering is observed in the months of May–June (*Fig.6*).

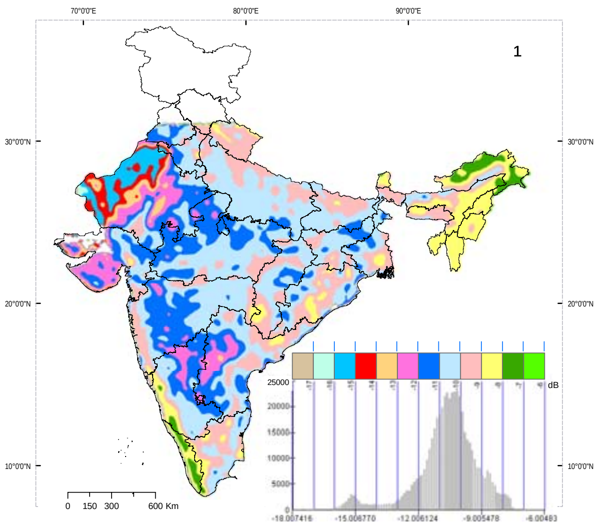

Figure 5: A sliced image map of January 2000 of ERS-2, C – band σ^o at 40^o of incidence angle (reproduced from *Singh et al, 2005*)

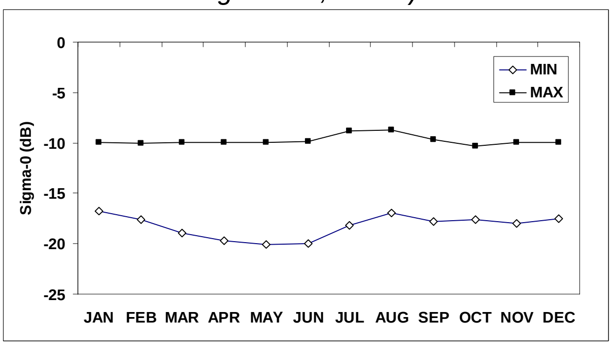

Figure 6: Variability of σ^o over the year 2000 (*Singh, et al 2006b*)

Spatial and temporal variation: In general, the minimum σ^o is observed in the June end, which is attributed due to dry soil moisture conditions. During this period the NDVI value is also found at the lowest order. The maximum σ^o observed, attributed mostly due to presence of vegetation in the mid of September.

In areas of sand dunes with-vegetation the minimum σ^o observed is in the May end, that is around -19.5 dB, which is attributed due to no soil moisture (rainfall – nil) and high mean temperature (around 36.8^o C). During this period the NDVI value is also found at the lowest order (0.16). The maximum σ^o observed in this area is -12.7 dB mostly due to comparatively less temperature (31.6^o C) followed by increased NDVI (0.27).

The σ^o shows a gradual decrease until last week of June, afterwards a sudden increase in σ^o is found up to July – August, as the moisture level increases due to arrival of monsoon (*Fig.7–Fig.11*). Onset of monsoon suddenly increases the soil moisture content, which leads to less transmission of energy through the medium and increase in surface scattering. From September onward σ^o decreases due to decrease in soil moisture attributed to percolation of water and high evaporation rate.

The monthly averaged σ^o images over Thar desert and surrounding arid region are shown in *Figure 7*. The Thar desert is characterized by low σ^o value (-25 to -13 dB), surrounded by (arid region) comparatively high σ^o value (-13 to -9 dB). The high σ^o value (-10 to -9 dB) has also been found linked to altitudinal variation in the topography (*Fig. 8*). The low σ^o value is surrounded by high σ^o value, which shows sparse vegetation cover surrounded by the desert. During summer season the areal extent of low σ^o value is found to be more than other months for the year 2000.

The increase in σ^o values continue subsequently by the growth in vegetation and corresponding increase in surface roughness. Good correlation has been observed with σ^o and NDVI (*Fig 9*). In summer months from the beginning of March, moisture content in desert region decreases significantly resulting in lower σ^o

From *Figure 10* it is evident that the overall range of σ^o follows a cyclic pattern in almost all signatures under study. Due to physical scattering mechanism (surface roughness and dielectric properties as well as volume scattering from vegetation) with dunes surfaces (attributing to variability in σ^o), it is possible to discriminate dune types. The discrimination of different sand dunes is best possible in the month of June (*Fig 11*).

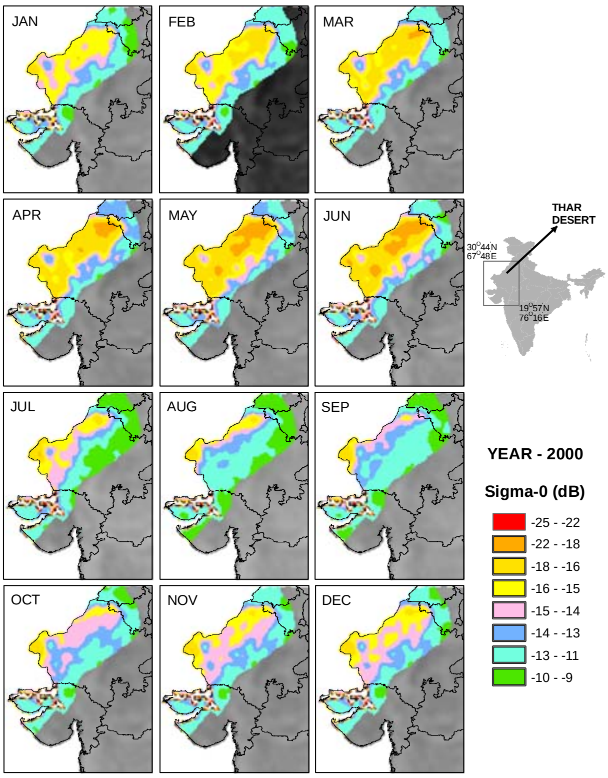

Figure 7: Monthly averaged σ^o over arid area including the *Thar* desert in the year 2000 (reproduced from *Singh, et al 2006b*).

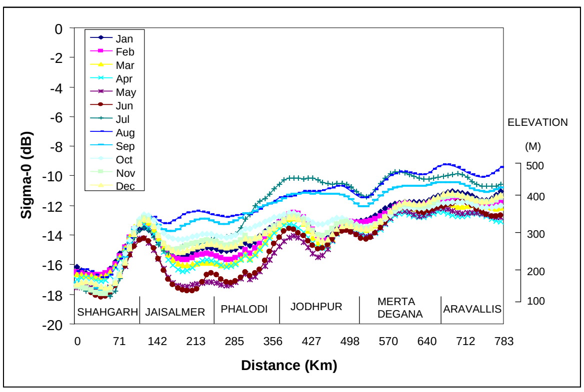

Figure 8: Transect Profile of σ^o values (*Singh, et al 2006b*)

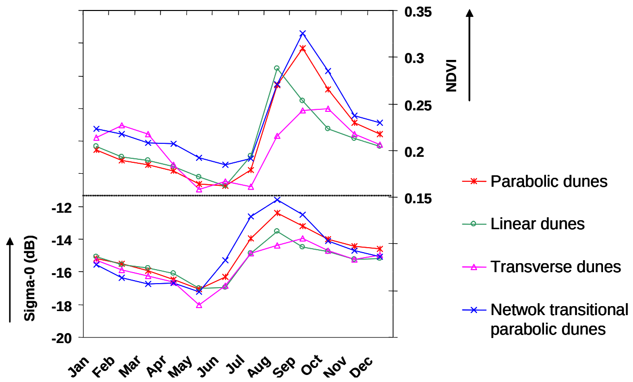

Figure 9: σ^o and NDVI response for dunes with vegetation.

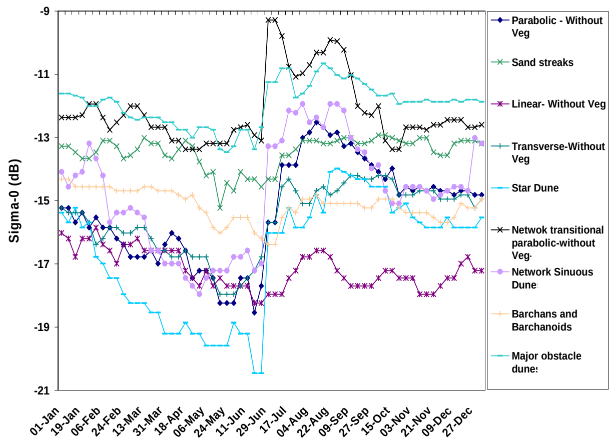

Figure 10: Backscatter response for different dune types in Thar (*Singh, et al 2006b*)

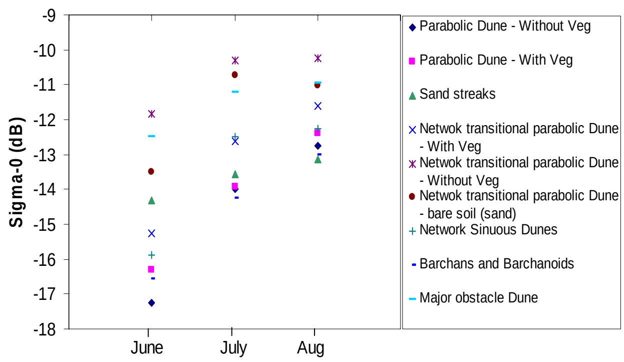

Figure 11: Separability of different dune types in the months of June, July and August

Backscatter response to dunes types: A cyclic pattern in the Thar (*Fig.7*) in general and all dune types studied (*Fig. 10*), in particular, has been observed. This pattern is mostly governed by the presence of moisture during rainy season and subsequently due to volume scattering by vegetation cover and then increase in temperature.

The order of σ^o of different dune types studied (in increasing order) is as under:
network transitional parabolic > major obstacle > network sinuous > parabolic > barchans and barchanoids > sand streaks > linear > transverse > star > megabarchanoids.

5. Conclusion

The scatterometer data shows variability of σ^o of the order of 11 dB (-20.08 to -8.71 dB). In general, high backscattering is observed in the months of July–August and low backscattering is observed in the months of May–June.

Over Thar desert region σ^o values are very low and vary gradually from summer season to rainy and winter seasons. The sharp change in moisture level in desert region is also reflected clearly from σ^o. It can also be concluded that the dune type separation using σ^o is best possible in the month of June. Time series analysis using scatterometer data over many years (decades) may give better insight on the formation of the dunes, “dune shift” and spread of desertification.

The study indicates the potential of C-band scatterometer data for monitoring temporal variability for modelling and monitoring desert ecosystem. Further attempts can be made to see the feasibility of Ku-band scatterometer datasets in such studies and potential of such datasets for monitoring the aerodynamic roughness length (Z_0) over arid regions. The dune spacing using SRTM-DEM and its relation with σ^o in the Thar can also be attempted in future.

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Apr. 11-13, 2007	Paris, France	4th IEEE GRSS / WG III/2+5, VIII/1, VII/4 Joint Workshop on Remote Sensing & Data Fusion over Urban Areas and 6th International Symposium on Remote Sensing of Urban Areas	tlc.unipv.it/urban-remote-sensing-2007/
Apr. 18-20, 2007	Moscow, Russia	International Conference on “Remote Sensing – the Synergy of High Technologies”	conference@sovzond.ru http://www.sovzondconference.ru/eng/invitation.html
Apr. 25-27, 2007	Novosibirsk, Russia	Geo-Siberia 2007 The Third International Exhibition and Scientific Congress	geo-sib@ssga.ru
May 7-17, 2007	Tampa, Florida, USA	ASPRS 2007 Annual Conference "Identifying Geospatial Solutions"	asprs@asprs.org http://www.asprs.org/tampa2007/
May 15-18, 2007	Taipei, Taiwan	5th Taipei International Digital Earth Symposium - TIDES 2007	derc@mail.pccu.edu.tw
May 16-18, 2007	Istanbul, Turkey	ISPRS Comm. VII Conference on Information Extraction from SAR and Optical Data, with Emphasis on Developing Countries	isprs2007ist@itu.edu.tr
May 23-25, 2007	Toronto, Canada	3rd International Symposium on Geoinformation for Disaster Management (Gi4DM2007)	https://www.cig-acsg.ca/cig2007/english/home.htm junli@ryerson.ca.
May 27-29, 2007	St. Petersburg, Russia	International Workshop on Information Fusion and Geographical Information Systems (IF&GIS07)	The research group of object-oriented geoinformation systems.
May 28-30, 2007	St. Petersburg, Russia	14th Saint Petersburg International Conference on Integrated Navigation System	elprib-onti@telros.net
May 28-31, 2007	Padova, Italy	5th International Symposium on Mobile Mapping Technology	naser@geomatics.ucalgary.ca www.cirgeo.unipd.it/cirgeo/convegni/mmt2007/

May 29 - Jun 1, 2007	Hannover, Germany	ISPRS Workshop on High-Resolution Earth Imaging for Geospatial Information	karsten@ipi.uni-hannover.de heipke@ipi.uni-hannover.de http://www.ipi.uni-hannover.de/ISPRS_workshop_07
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Jun. 13-15, 2007	Enschede, Netherlands	ISPRS WG II/7 Workshop 5th International Symposium on Spatial Data Quality	lswzshi@polyu.edu.hk http://www.itc.nl/issdq2007
Jun. 27-29, 2007	Stuttgart, Germany	ISPRS WG II/3+5, IV/4+6 Workshop on "Visualization & Exploration of Geospatial Data"	jschiewe@igf.uni-osnabrueck.de http://www.igf.uni-osnabrueck.de/isprs07/
Jul. 3-7, 2007	Salzburg, Austria	Geoinformatics Forum Salzburg "International Symposium & Exhibit on Applied Geoinformatics"	office@gi-forum.org http://www.gi-forum.org/
Jul. 23-27, 2007	Barcelona, Spain	IEEE/IGARSS 2007 with ISPRS WG VII/4 joint session	igarss07@cimne.upc.es http://www.igarss07.org
Jul. 30 - Aug. 4, 2007	Bangkok, Thailand	Asia Oceania Geosciences Society 4th Annual Meeting	info@asiaoceania.org
Aug. 1-3, 2007	Beijing, China	7th International Workshop of Geographical Information System	iwgis@lreis.ac.cn
Aug. 4-10, 2007	Moscow, Russia	XXIII ICA International Cartographic Conference	info@icc2007.com http://www.icc2007.com/
Aug. 20-24, 2007	Yellowknife, N.W.T., Canada	1st International Circumpolar Conference on Geospatial Sciences & Applications "IPY GeoNorth 2007"	ipygeonorth2007@NRCan.gc.ca http://ess.nrcan.gc.ca/ipygeonorth/
Aug. 28-29, 2007	Urumchi, Xinjiang, China	ISPRS Workshop on Updating Geo-spatial Databases with Imagery & 5th ISPRS Workshop on DMGIS	Dr. Jie JIANG, jjie@nsdi.gov.cn, jiangjie_263@263.net http://isprs-wg41.nsdi.gov.cn

Aug. 29 - Sep. 01, 2007	Jakarta, Indonesia	The 2nd Indonesian Geospatial Technology Exhibition	info@ptmediatama.com http://www.geospatial-exh.com
Sep. 3-7, 2007	Stuttgart, Germany	51st Photogrammetric Week	martina.kroma@ifp.uni-stuttgart.de http://www.ifp.uni-stuttgart.de
Sep. 5-6, 2007	Shangri-la, Hong Kong	Location Asia 2007	info@location.net.in
Sep. 12-14, 2007	Newcastle upon Tyne, UK	ISPRS WG I/4, IV/9 Workshop & Annual Conference of the Remote Sensing and Photogrammetry Society (RSPSoc) 2007 "Challenges for earth observation - scientific, technical and commercial"	david.holland@ordnancesurvey.co.uk http://www.rspsoc2007.org/
Sep. 17-23, 2007	Guangzhou and Three Gorges, China	2nd International Conference of GIS/RS in Hydrology, Water Resources and Environment (ICGRHWE'07) & 2nd International Symposium on Flood Forecasting and Management with GIS and Remote Sensing (FM2S'07)	hydrolab@zsu.edu.cn
Sep. 19-21, 2007	Munich, Germany	Photogrammetric Image Analysis (PIA) 2007	http://www.ipk.bv.tum.de/isprs/pia07
Sep. 21-24, 2007	Nanjing, China	APAC 2007: The Fourth International Conference on Asian and Pacific Coasts	jfge@nhri.cn.
Sep. 24-27, 2007	Victoria, Canada	2007 Free Open Source Software For Geospatial (FOSS4G) Conference	
Sep. 24-28, 2007	Budapest, Hungary	XIII ISM Congress	kalman_baratosi@mbh.hu http://www.ism.rwth-aachen.de
Sep. 25-27, 2007	Chengdu, China	ISPRS WG VII/6+7 Joint Conference on Techniques & Applications of Optical & SAR Imagery Fusion 'Mapping without the Sun'	Jixian Zhang, zhangjx@casm.ac.cn.
Oct. 28 - Nov. 2, 2007	**Jaipur**	12th World Lakes Conference	dalwani@taal2007.org, info@taal2007.org
Nov. 12-16, 2007	Kaula Lumpur, Malaysia	28th Asian Conference on Remote Sensing (ACRS 2007)	acrs2007@macres.gov.my

Dec. 4-6, 2007	Moscow, Russia	3rd International conference "Earth from space – the Most Effective Solutions"	conference@scanex.ru http://www.transparentworld.ru/conference
Dec. 12-14, 2007	Delft, Netherlands	ISPRS WG IV/8 International Workshop on 3D Geo-Information: Requirements, Acquisition, Modelling, Analysis, Visualisation "3D GeoInfo07"	S.Zlatanova@tudelft.nl 3Dgeoinfo07@tudelft.nl http://www.3d-geoinfo-07.nl/
Dec. 17-19, 2007	**Thiruva-nantha-puram**	Trans Asiatic GIS Society Conference on GIS	bgisasia.info@tagsasia.org bgisasia.info@tagsasia.org http://www.tagsasia.org/bgisasia/
Feb. 5-8, 2008	Sydney, Australia	Global Workshop on High Resolution Digital Soil Sensing & Mapping	viscarra-rossel@usyd.edu.au.
Mar. 10-14, 2008	Perth, Australia	WALIS International Forum 2008 - Management of Geographic Information	David Lee Steere, davidls@walis.wa.gov.au
Jul. 1-5, 2008	Beijing, China	Spatial Accuracy 2008	accuracy2008@spatial-accuracy.org.
Jul. 3-11, 2008	Beijing, China	XXI ISPRS Congress	Chen Jun, congressdirector@isprs2008-beijing.org http://www.isprs2008-beijing.org/
Jul. 3-11, 2008	Beijing, China	4th International Symposium on Geospatial Information for Disaster Management (Gi4DM 2008)	Sisi Zlatanova, s.zlatanova@otb.tudelft.nl.
Sep. 29 - Oct. 3, 2008	Darwin, Australia	14th Australasian Remote Sensing & Photogrammetry Conference (ARSPC)	

ISG participated in the **Asia 2006 Remote Sensing Study** conducted by National Oceanic and Atmospheric Administration(**NOAA**)'s Satellite and Information Service on
Survey and Analysis of the Asian Remote Sensing Market - Aerial and Spaceborne *(for the period 2006 – 2016).*

The study report may be accessed at the

NOAA website **http://www.licensing.noaa.gov**

FROM ISG SECRETARIAT

i) Change of Address of Members

Members are kindly requested to inform their changed mailing address as well as current email address to update our database. This information may be mailed to isg@isgindia.org and/or to the Secretary at mhkalubarme@sac.isro.gov.in

ii) National Geomatics Awards

The details of these awards are appearing in this Issue of *ISG Newsletter* elsewhere. Members are requested to send their applications for awards for the year 2006-07 if they have any outstanding contributions in the field of Geomatics.

iii) Chapter activities and related issues

a) Active Chapter of Year Award (2006-07)

Each chapter Chairperson/Secretary is requested to send the applications for this award in the prescribed format to the President/Secretary, ISG. The prescribed format for this award is available on ISG website.

b) Chapter Reports and Audit Statements

Each chapter Chairperson/Secretary is requested to send the report on the activities of the chapter during FY 2006-2007 for publication in the ISG newsletter. They are also requested to get their accounts audited by end of May-2007 and send it ISG HQ to include in the audited report of the Society.

c) New Chapters

i) Ajmer Chapter:

The Ajmer Chapter was inaugurated by Hon'ble Vice Chancellor Prof. M.L. Chippa , M.D.S. University, Ajmer, in the presence Dr. Baldev Sahai, Chief Editor, ISG-Newsletter, on 25th January 2007. The registered office of the chapter is in the Department of Remote Sensing and Geoinformatics, M.D.S. University, Ajmer. The elected executive council members for the current session 2005-2008 are as under:

1. Chairman: Dr. Sarvesh Palria
2. Vice Chairman: Dr. Reepunjaya Singh
3. Secretary: Dr. Manisha Saini
4. Joint Secretary: Dr. Akhilesh Palria
5. Treasurer: Ms. Pratima Tak

ii) Vadodara Chapter:

The Vadodara Chapter was inaugurated by Prof. A.V. Ramachandran, Dean, Faculty of Science, along with opening of Ecophysiology and RSGIS Lab in the Dept. of Botany, M.S. University, Vadodara on 19th February 2007. A half-day workshop was also organized to familiarize the students and faculty members about the activities of ISG. On this occasion Prof M. Daniel, Head, Department of Botany, gave his blessing to the following newly elected office bearers of the chapter:

1. Chairperson: Dr. (Mrs.) G. Sandhya Kiran, Reader, Dept. of Botany, M.S. University, Vadodara
2. Vice-Chairman: Mr. Prashant C Shah, Scientist, G.E.R.I., Vadodara
3. Vice-Chairman: Prof. K C Tiwari, Dept. of Geology, M.S. University, Vadodara
4. Secretary: Shri R D Kamboj. IFS, General Manager, G.S.F.D.C. Ltd.
5. Jt. Secretary: Dr. (Mrs.) Aruna G. Joshi, Sr. Lecturer, Dept. of Botany, M.S. University, Vadodara
6. Treasurer: Mr. Satish V Joshi, Consultant, Energy Auditor, Vadodara

ISG FELLOWS

ISG-F-1 Shri Pramod P. Kale, Pune

ISG-F-2 Dr. George Joseph, Ahmedabad

ISG-F-3 Dr. A.K.S. Gopalan, Secunderabad

ISG PATRON MEMBERS

P-1 Director, Space Applications Centre (ISRO), Jodhpur Tekra, AHMEDABAD 380015

P-2 Settlement Commissioner, Gujarat, Multi-story Building, Lal Darwaja, AHMEDABAD 380001

P-3 Commissioner, Mumbai Metropolitan Region Development Authority, Bandra-Kurla Complex, Bandra East, MUMBAI 400051

P-4 Commissioner, Land Records & Settlements Office, MP, GWALIOR 474 007

P-5 Director General, Centre for Development of Advanced Computing (C-DAC), 12, Thube Park, Shivajinagar, PUNE 411005

P-6 Chairman, Indian Space Research Organization (ISRO), Antariksha Bhavan, New BEL Road, BANGALORE 560094

P-7 Director General, Forest Survey of India, Kaulagarh Road, P.O. I.P.E., DEHRA DUN 248195

P-8 Commissioner, Vadodara Municipal Corporation, VADODARA 390001

P-9 Centre for Environmental Planning and Technology (CEPT), Navarangpura, AHMEDABAD 380009

P-10 ESRI INDIA, NIIT GIS Ltd., 8, Balaji Estate, Sudarshan Munjal Marg, Kalkaji, NEW DELHI 110009

P-11 Gujarat Water Supply and Sewerage Board (GWSSB), Jalseva Bhavan, Sector – 10A, GANDHINAGAR 382010

P-12 Director, National Atlas & Thematic Mapping Organization (NATMO), Salt Lake, KOLKATA 700064

P-13 Director of Operations, GIS Services, Genesys International Corporation Ltd., 73 A, SDF-III, SEEPZ, MUMBAI 400096

P-14 Managing Director, Speck Systems Limited, B-49, Electronics Complex, Kushiaguda, HYDERABAD 500062

P-15 Director, Institute of Remote Sensing (IRS), Anna University, Sardar Patel Road, CHENNAI 600025

P-16 Managing Director, Tri-Geo Image Systems Ltd., 813 Nagarjuna Hill, PunjaGutta, HYDERABAD 500082

P-17 Managing Director, Scanpoint Graphics Ltd., B/h Town Hall, Ashram Road, AHMEDABAD 380006

P-18 Institute for Sustainable Development Research Studies (ISDRS), 7, Manav Ashram Colony, Goplapura Mod, Tonk Road, JAIPUR 302018

P-19 Defence institute for GeoSpatial Information & Training (DIGIT), C/O CAMS, Rao Tula Ram Marg, Cantt. NEW DELHI 110010

P-20 Rolta India Ltd., Rolta Bhavan, 22nd Street, MIDC-Marol, Andheri East, MUMBAI 400093

P-21 National Remote Sensing Agency (NRSA), Deptt. Of Space, Govt. of India, Balanagar, HYDERABAD 500037

P-22 ERDAS India Ltd., Plot No. 7, Type-I, IE Kukatpalli, HYDERABAD 500072

P-23 Senior Manager, Library and Documentation, Larsen & Toubro Limited, P.B. No. 979, Mount Poonamallee Road, Manapakkam, CHENNAI – 600089. Email: sv@lntecc.com

P-24 Director, North Eastern Space Applications Centre (NE-SAC), Department of Space, UMIAM, Meghalaya 793103. Email: nesac-director@rediffmail.com

New ISG Members who joined during Jan. – Mar. 2007

Name	Mailing Address	Number
Mr. S. Vasantha Kumar	GIS Engineer, Centre for Disaster Mitigation and Management (CDMM), VIT University, Vellore, PIN 632014 email: vasanth_research@yahoo.co.in	L – 846
Mr. Hangekar Chandramohan Narayan	Superintending Engineer, B/6, Snehal Classique, Bhavkar Bhavan Lane, Shivajinagar, PUNE 411005 Email: chmohan@gmail.com	L - 847
Dr. A.P. Pradeep Kumar	Lecturer, Department of Geology, University College, Trivendrum, KERALA 695034 Email: geo_pradeep@yahoo.com	L – 848
Dr. Sarvesh Palria	Head, Dept. of Remote Sensing & Geoinformatics, M.D.S. University, Ajmer 305009 Email: spalria@rediffmail.com	L – 849
Dr. Akhilesh Palria	Medical Officer, P.H.C., Fatehgarh, Dist Ajmer 305412.	L – 850
Dr. Reepunjaya Singh	Lecturer, M-7, Anna Sagar Link Road, Ajmer 305006 Email: drreepun@rediffmail.com	L – 851
Dr. Sunita Pachouri	Lecturer, H.No. 189/29, Gulab Bari, Mali Mohalla, Ajmer 305001.	L – 852
Dr. Manisha Sainin	Lecturer, Remote Sensing & Geoinformatics Department, MDS University, Ajmer 305009. Email: msaini_k6@rediffmail.com	L – 853
Mr. Mukesh Singh Boori	Remote Sensing & Geoinformatics Department, MDS University, Ajmer 305009. email: msboori@rediffmail.com	L – 854
Mr. Balram Kumar Arora	C/O Ramsingh Raj Purohit, Bank Colony, Near MDS University, Ajmer 305009.	L – 855

Mr. Rakeh Ranjan Thakur	C/O Ramsingh Raj Purohit, Bank Colony, Near MDS University, Ajmer 305009.	L – 856
Ms. Pratima Tak	Old Tagore Children AcademyLohakhan Police Line, Ajmer 305001	L – 857
Mr. Nitin Chauhan	172/27, Chauhan Bhawan, Gaddi Mailyan Jones Ganj, Ajmer 305001. email: chauhan-k2@yahoo.com	L – 858
Ms. Megha Bakshi	C/O Mrs. Mukta Diwedi, Plot No. 3, Parshuram Colony, Kayad Road, Ajmer 305001. email: meghazone@yahoo.co.in	L – 859
Ms. Nisha Rathore	7, Saraswati Nagar, Kayad Road, Ajmer 305023. Email: Nishu_singh_rathore@yahoo.com	L – 860
Mr. Devendra Singh Ranawat	S/O Shri Deeendayal Singh Ranawat, Village: Sena, Via: Sewari, Teh: Bali, Dist: Pali (Rajasthan) Email: dsr_sena@yahoo.co.in	L – 861
Mr. Shiv Prakash Panchal	Indra Colony, Nainwa Road, In front of Rajat Grah Gate No.2, BUNDI (Rajasthan) 323001.	L – 862
Mr. Vikram Tak	Shreeji Bartan Bhandar, Maliyan Subjimandi Didwana, Nagaur (Rajasthan) 341303. email: sainiv82@rediffmail.com	L – 863
Mr. Akhilesh Porwal	S/O Girdhar Gopal Porwal, Opp. Post office Chhabra, Dist: Baran, Kota, Rajasthan 325220. Email: blue_sky_200578@yahoo.com	L – 864
Mr. Avadhesh Kumar Sharma	S/O Om Prakash Sharma, Nainawan Road, Indira Colony, in front of Rajat Grah Gate No. 5 Bundi, Rajasthan 323001	L – 865
Mr. Radheysham Saini	S/O Shri Chhitarmal Saini, Near Tata Indicom Tower, Tehsil: Shrimadhopur, Dist: Sikar, Rajasthan 332715. Email: radhey_saini@yahoo.com	L – 866
Mr. R.B. Upadhyay	Sci/Engr. 23 / 22, DAPF-MEF-ESSG, Space Applications Centre (ISRO), Ahmedabad 380015 Email: raju_nup@sac.isro.gov.in	L – 867
Mr. M. Manikandan	Lecturer, C2, Aiswarya Apartments, 5/11 Vada Agaram Road, Metha Nagar, CHENNAI – 600029 Email: maniiz@yahoo.com	L – 868
Mr. Sakthivel	Senior Lecturer, Ramanujan Computing Centre, Anna University, CHENNAI – 600025 Email: psv@annauniv.edu	L – 869
Ms. Kalpana R. Patel	21, Madhukunj Society, Harinagar-Vasna Road, Near Tribhovan Park Bus stop, Vadodara 390015 email: kapoopatel@yahoo.com	L – 870
Mr. Mandar V. Mehta	16-A, Ajay Colony, Opp. Jain Derasar, Nizampura, Vadodara 390002. email: mandarmehta@dtpt.com	L – 871
Dr. K.F. Patel	D-238, Devdeep Nagar Society, Opp. Adani Super Market, Old Padra Road, Vadodara 390002.	L – 872
Mr. Ajith Kaliyath	Programme, Coordinator, D-11, Vardhaman Apartments, Mayur Vihar Phase-I, NEW DELHI 110091 Email: ajithkaliyath@yahoo.co.in	L – 873
Mrs. Devanu Bhatnagar	Centre for Remote Sensing and GIS, Maulana Azad National Institute of Technology (MANIT), BHOPAL 462007. email: devanu_t@rediffmail.com	L – 874
Ms. Anshu Gupta	Centre for Remote Sensing and GIS, Maulana Azad National Institute of Technology (MANIT), BHOPAL 462007. email: anshugupta20002001@gmail.com	L – 875

Mr. Ashwani Kumar	Asst. Prof., Faculty of Planning & Public Policy, CEPT University, Navrangpura, Ahmedabad 380009. email: ashwani@cept.ac.in	L – 876
	ANNUAL MEMBERS	
Mr. Amit Mukherjee	Office of Dept. of Defence & Strategic Studies, University of Pune, PUNE – 411007 amitmcs@hotmail.com	A-25
Mr. Panchal, Hemant. B.	19, Ajitmnath Society, Near Water tank, Karelibaug, Vadodara 390018. email:	A-26

National Geomatics Awards

Indian Society of Geomatics has instituted two National Geomatics Awards to be given each year a) for original and significant contribution, b) for innovative application(s) in the field of Geomatics. Each award comprises a medal, a citation and a sum of Rs. 25,000.

The guidelines for the award are as under:

❖ **Areas of contribution considered for the award:**

1. Geographical Information System
2. Global Positioning System
3. Photogrammetry
4. Digital Cartography

❖ **Eligibility**

Any citizen of India engaged in scientific work in any of the above-mentioned areas of research is eligible for the award.

- The awards are to be given for the work largely carried out in India.
- First award will be given for original contribution in the field of Geomatics supported by publications in a refereed journal of repute.
- Second award will be given for carrying out innovative application(s).
- The contribution for the first award should have been accepted by peers through citation of the work.
- Work based on the applications of existing technologies will not be considered for the first award.
- The work should have made impact on the overall development of Geomatics.

❖ **How to Send Nomination**

Nominations should be sent in the prescribed format, completed in all aspects to the Secretary, Indian Society of Geomatics, Space Applications Centre Campus, Ahmedabad 380015 by **August 31, 2007**.

Nominations should be signed by two Life Members of the Society and sent by Registered / Speed Post.

❖ **Selection Process**

An expert committee, consisting of at least three members, constituted by the Executive Council of the Indian Society of Geomatics, will scrutinize the nominations and recommend the awardees' names to the Executive Council. The Council will decide on the award based on the recommendations.

. FORMAT FOR NOMINATION FOR NATIONAL GEOMATICS AWARDS

1. Name of the Candidate:
2. Present Position:
3. Positions held earlier (chronological order):
4. Academic qualifications (Bachelor's degree onwards):
5. Names of at least three Indian Scientists / Technologist in the area as possible referees*:
6. Brief write up on the work (500 words) for which award is claimed:
7. Publication(s) on the above work (reprint(s) to be enclosed):
8. List of other publications of the candidate:
9. Citation of the work for which award is claimed:
10. Impact of the work (for which award is claimed) on the development in the field of Geomatics (500 words):
11. Whether the work has already won any award? If so, give details:

The Applications in the above format (five copies) should be submitted (by Registered Post or Speed Post) to The Secretary, Indian Society of Geomatics, Space Applications Centre Campus, Ahmedabad 380 015 so as to reach by **August 31, 2007**.

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* ISG is, however, not bound to accept these names and can refer the nomination to other experts/peers.

INDIAN SOCIETY OF GEOMATICS (ISG)
(www.isgindia.org)

MEMBERSHIP APPLICATION FORM

To: The Secretary, Indian Society of Geomatics
Building No. 40, Room No. 36,
Space Applications Centre (SAC) Campus
Jodhpur Tekra, Ambawadi PO, AHMEDABAD – 380015

Sir,

I want to become a Life Member/ Sustaining Member/ Patron Member/Annual Member of the Indian Society of Geomatics, Ahmedabad from _________month of _______year.

Membership fee of Rs./US$ _____ /- is being sent to you by Cash/ DD/ Cheque (In case of DD/Cheque: No.__________, drawn on Bank __________________________________ payable at Ahmedabad. For outstation cheques add clearing charges Rs. 65.00/US$ 10.00).
I agree to abide by the constitution of the Society.

Date:

Place: *Signature*

1. Name :_______________________________________
2. Address :_______________________________________
   ____
   _______________________________________ PIN:__________
   Phone: ______________Fax: ______________ Email: ____________________
3. Date of Birth : __________
4. Sex (Male/Female): ______
5. Qualification : ___________
6. Specialisation: ___________________________
7. Designation : _____________
8. Membership in other Societies: _______________________________________
   ____
9. Mailing Address: _________________________________
   ____
   _________________________________ PIN: _______

Proposed by:

(Member's Name and No) Signature of Proposer

For Office Use

ISG Membership No: ISG- -
Receipt No.: Date:

MEMBERSHIP SUBSCRIPTION				
Sr. No.	Membership Category	Admission Fee		Annual Subscription
		Rs. (Indian)	US $ (Foreign)	Rs. (Indian)
1.	Annual Member	10.00		200.00
2.	Life Member a) Admitted before 45 years of age	1000.00	250.00	
	b) Admitted after 45 years of age	750.00	200.00	
3.	Sustaining Member	---	----	2000.00
4.	Patron Member	15000.00	2500.00	----
5.	Student Member	10.00	---	50.00

MEMBERSHIP GUIDELINES

1. Subscription for Life Membership is also accepted in two equal instalments payable within a duration of three months, if so desired by the applicant. In such a case, please specify that payment will be in instalments and also the probable date for the second instalment (within three months of the first instalment).

2. A Member of the Society should countersign application of membership.

3. Subscription in DD or Cheque should be made out in the name of '**INDIAN SOCIETY OF GEOMATICS'** and payable at Ahmedabad.

4. Outstation cheques must include bank-clearing charges of Rs. 65.00/US$ 10.00.

5. For further details, contact Secretary, Indian Society of Geomatics at the address given above.

6. Financial year of the Society is from April 1 to March 31.

7. ISG has Chapters already established at the following places: Ahmedabad, Ajmer, Chennai, Hyderabad, Indore, Mangalore, Mumbai, New Delhi, Pune, Tiruchirappalli and Vadodara. Applicants for membership have the option to contact Secretary/Chairman of the local chapter for enrolment. Details can be found at the website of the Society: www.isgindia.org

8. Journal of the Society will be sent only to Patron Members, Sustaining Members and Life Members.