Desertification/land degradation status mapping of India

Ajai[1,*], A. S. Arya[1], P. S. Dhinwa[1], S. K. Pathan[1] and K. Ganesh Raj[2]

[1]Space Applications Centre, Indian Space Research Organization, Ahmedabad 380 015, India
[2]Earth Observation System, Indian Space Research Observation, Bangalore 560 094, India

Desertification is the process of land degradation in arid, semi-arid and dry-subhumid areas. This communication describes the classification system, methodology and the results of desertification and land degradation status mapping carried out for the entire country on 1 : 500,000 scale using multi-temporal Resourcesat AWiFS data. The dominant processes of land degradation, viz. water erosion, vegetal degradation, wind erosion, salinization/alkalization, water logging, frost heaving, frost shattering, mass movement, etc. have been deciphered and mapped using satellite data. The study reveals that 105.48 mha area of the country is undergoing processes of land degradation (32.07% of the total geographic area of the country). Area undergoing desertification is 81.4 mha.

Keywords: AWiFS, desertification, dry lands, IRS-P6-resourcesat, land degradation.

DESERTIFICATION, as defined by UNEP[1] in 1992 and adopted by United Nations Convention to Combat Desertification (UNCCD), is 'land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities'. The causes of desertification are: change in frequency and amount of rainfall, reduction in vegetal cover, wrong agricultural management practices, cultivation on marginal lands, over-exploitation of the natural resources, excessive grazing, etc.

India occupies only 2.4% of the world's geographical area, yet supports about 16.7% of the world's human population; it has only 0.5% of the world's grazing land but supports 18% of the world's cattle population. Thus there is tremendous pressure on our land-based natural resources. India is endowed with a variety of soils, climate, biodiversity and ecological regions.

About 50.8 mha land area (15.8% of the country's geographical area) is arid, 123.4 mha (37.6%) is semi-arid and 54.1 mha (16.5%) area falls in the dry subhumid region[2]. All put together, about 228 mha area, i.e. 69% of the geographic area of the country is dry land (arid, semi-arid and dry subhumid). Appropriate action plan for arresting land degradation and desertification requires information on the area and the spatial distribution of the land undergoing different processes of degradation. Though the status of land degradation and desertification in the country has been assessed by several organizations, providing varied figures, the systematic spatial inventory, based on scientific method, has not been done so far[3]. Thus, there has been a long pending need for desertification/land degradation status mapping of the entire country based on scientific methods.

India is a signatory to the UNCCD, which was adopted on 17 June 1994 at Paris and came into effect from 17 March 1997. Thematic Programme Network 1 (TPN-1), on 'Desertification Monitoring and Assessment', is one of the six thematic programme areas identified as part of Asian regional action programme under UNCCD. Space Applications Centre (ISRO), Ahmedabad has been identified as the national focal organization to coordinate TPN-1 activities in the country.

One of the important tasks under TPN-1 was to prepare desertification status map at national and regional levels which could be integrated to generate the desertification status map of the world.

In view of non-availability of desertification/land degradation status map (DSM) for the country and also to fulfil India's commitment towards preparation of regional DSM under TPN-1 of UNCCD, the task of desertification/land degradation status mapping was taken up on 1 : 500,000 scale for the entire country using Indian Remote Sensing Satellite (IRS)-Resourcesat AWiFS data.

For the first time, a national level spatial inventory has been carried out for the entire country giving information on various land degradation processes and their severity. This national task has been executed by Space Applications Centre in collaboration with Central Arid Zone Research Institute (CAZRI), Jodhpur; National Bureau of

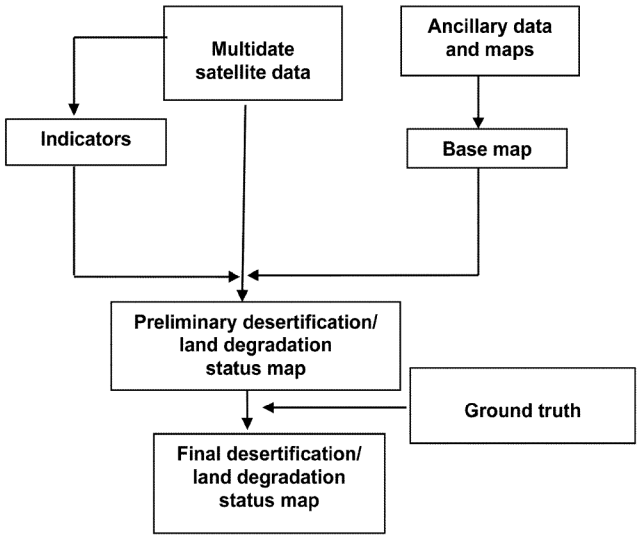

Figure 1. Methodology for preparation of desertification status map.

*For correspondence. (e-mail: ajai@sac.isro.gov.in)

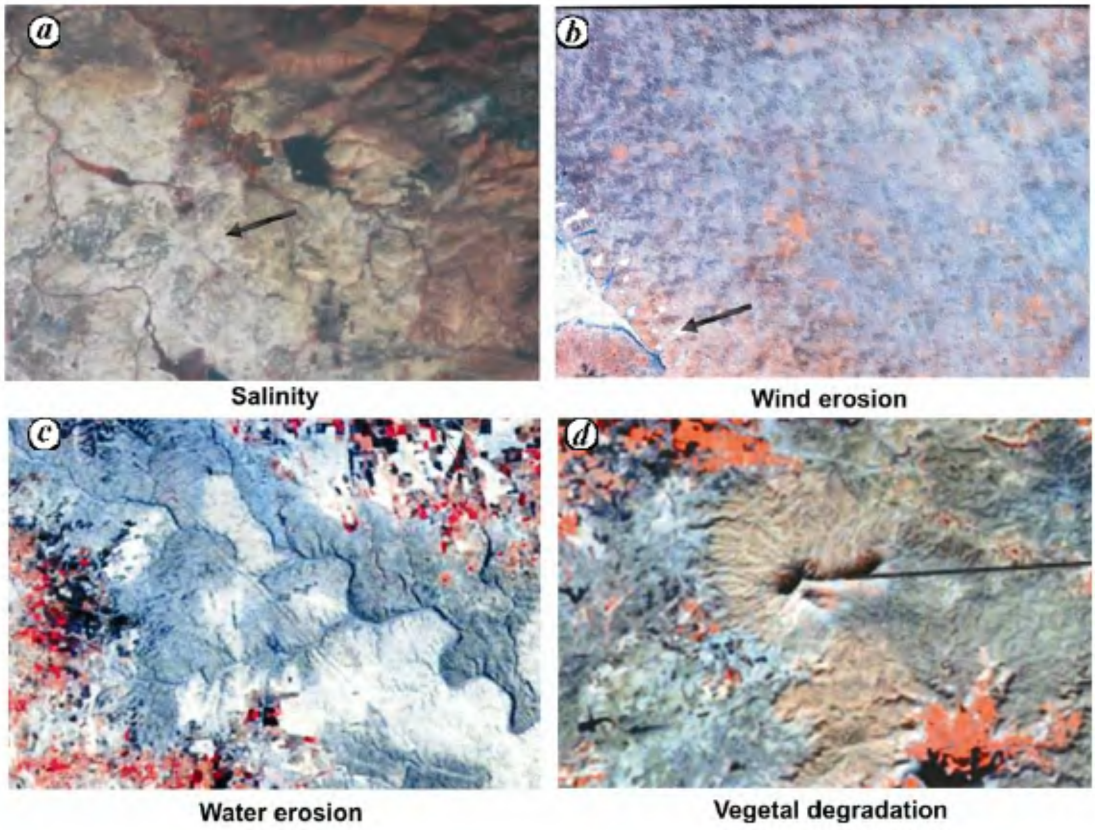

Figure 2. AWiFS image showing salinity, wind-erosion, water erosion, vegetal degradation in hot arid regions of Karnataka (***a***), Madhya Pradesh (***c***, ***d***) and Rajasthan (***b***).

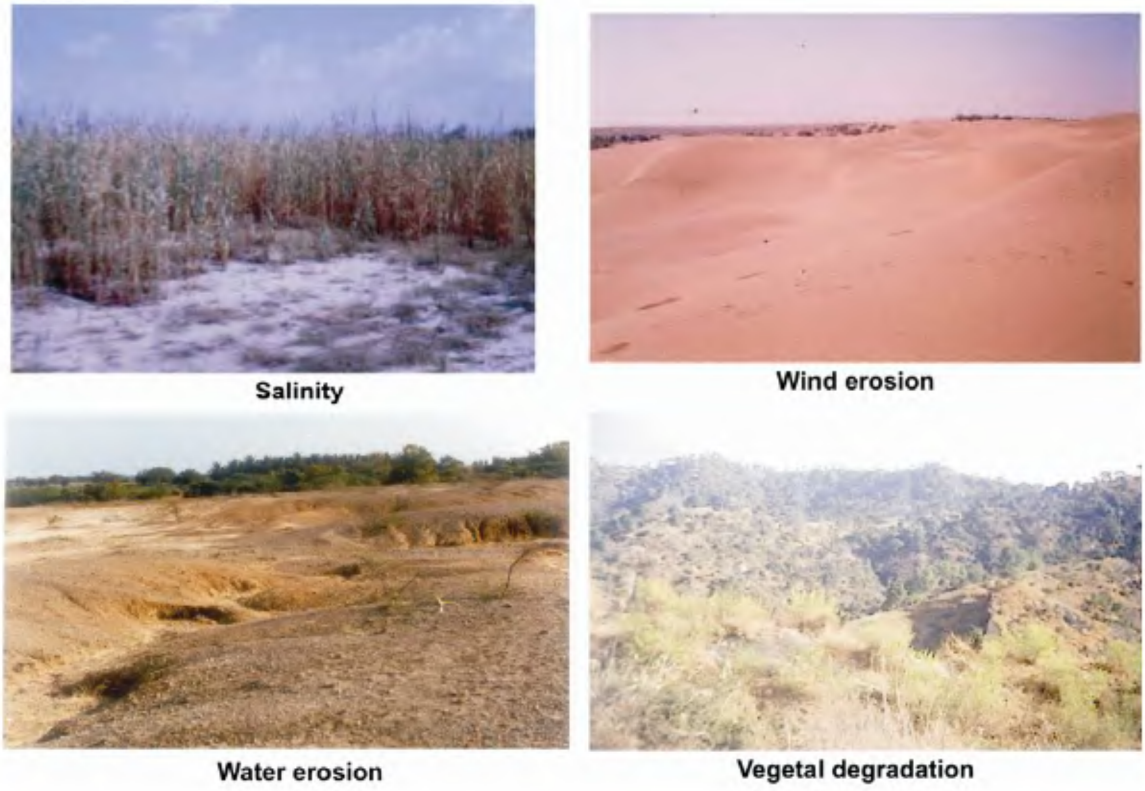

Figure 3. Field photographs showing salinity, wind erosion, water erosion and vegetal degradation in hot dry land areas of various parts of the country.

Soil Survey and Land Use Planning (NBSSLUP), Bangalore; All India Soil and Land Use Survey (AIS&LUS), Delhi; M.P. Remote Sensing Applications Centre (MPRSAC), Bhopal; U.P. Remote Sensing Applications Centre (UPRSAC), Lucknow; Jharkhand Space Applications Centre (JSAC), Ranchi; Birla Institute of Technology (BIT), Mesra, Ranchi; Orissa Remote Sensing Applications Centre (ORSAC), Bhubaneshwar; Arunachal Pradesh Remote Sensing Centre (APRSAC), Itanagar; Jammu University, Jammu; Jawaharlal Nehru University (JNU), New Delhi; Institute of Remote Sensing (IRS), Anna University, Chennai; Maharashtra Remote Sensing Applications Centre (MRSAC), Nagpur; University of Rajasthan, Jaipur; Directorate of Environment and Remote Sensing (DERS), Srinagar; Earth Observations System (EOS), ISRO, Bangalore, and Bihar State Remote Sensing Applications Centre (BIRSAC), Patna.

This communication describes the national-level classification system evolved, methodology for preparation of DSM and details of the DSM prepared for the entire country.

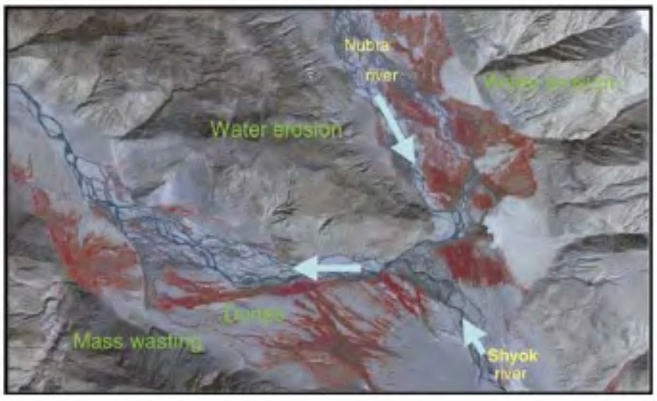

Figure 4. AWiFS image showing the water erosion/mass-wasting, etc. in cold desert area of Nubra Valley (J&K).

Figure 5. Water erosion, frost-shattering, mass-wasting, etc. in cold desert as seen in the field (Leh, J&K).

DSM on 1 : 500,000 scale was carried out using multi-date data from Advanced Wide Field Sensor (AWiFS) onboard IRS P6-Resourcesat acquired during 2003, 2004 and 2005. Ground truth data was also collected and used in preparation of DSM.

The national classification system for DSM as evolved and standardized through a pilot project[4] and adopted for the present work is given in Table 1. Level 1 comprises land use classes, Level 2 describes the land degradation process and Level 3 deals with the severity of degradations. The legends for the classification system are also given in Table 1.

IRS-P6 (Resourcesat) AWiFS geo-coded False Colour Composite (FCC) data were analysed using visual interpretation techniques to generate DSM on 1 : 500,000 scale. Details of the methodology are described in the flow diagram (Figure 1). Base maps prepared using the Survey of India topographical maps on 1 : 250,000 scale and the satellite images were used while analysing satellite data. Base features like road, rail, habitation and drainage were taken from satellite imagery whereas forest boundaries were taken from topographical maps for preparing base maps. Ground truth data collected from various places spread throughout the country were used to finalize the maps.

Table 1. National classification system for desertification status mapping

Class	Symbol
Level 1: Landuse/landcover	
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)
Water body/drainage	(W)
Glacial/peri-glacial (in cold region)	C/L
Others (urban, man-made, etc.)	(T)
Level 2: Processes of degradation	
Vegetal degradation	(v)
Water erosion	(w)
Wind erosion	(e)
Water logging	(I)
Salinization/alkalinization	(s/a)
Mass movement (in cold areas)	(g)
Frost heaving (in cold areas)	(h)
Frost shattering (in cold areas)	(f)
Manmade (mining/quarrying, brick kiln, industrial effluents, city waste, urban agg, etc.)	(m)
Level 3: Severity of degradation	

Severity	Level
Low	1
High	2

Table 2. Statewise distribution of land degradation area (ha)

Processes → State ↓	Water erosion	Vegetal degradation	Eolian	Frost shattering	Salinity/ alkanity	Mass movement	Water logging	Rocky/ baren	Others	Total (ha)	Area % of TGA of India
Andhra Pradesh	2,084,611	2,546,819	13,054	0	136,977	0	106,543	59,552	17,236	4,964,892	4.7
Arunachal Pradesh	174,467	1,060,423	0	581,798						1,816,788	1.72
Assam	846,611	1,526,454	0	0	0	0	46,021			2,419,086	2.29
Bihar	108,490	104,812	0	0	9466	0	188,070	3646	299	414,783	0.39
Chhatisgarh	707,382	1,894,274	0	0	647	0	521	14,834	17,634	2,635,392	2.5
Goa	1172	0	0	0	0	0	0	5073		6345	0.00
Gujarat	6,790,469	2,737,866	543,322	0	3,294,079	0	0	23,521	25,951	13,415,308	12.72
Haryana/Delhi	0	0	112,304	0	72,063	0	0	50,643		235,110	0.22
Himachal Pradesh	97,232	1,918,629	259	741,783	0	4843				2,762,746	2.62
Jammu and Kashmir	207,905	313,304	618,344	7,903,008	0	4,447,429	0	0	7428	13,497,518	12.79
Jharkhand	1,160,878	641,235	0	0	0	0	3321	11,357	2095	1,818,986	1.72
Karnataka	683,450	934,861	4537	0	56,621	0		12,883	384	1,692,736	1.6
Kerala	28,775	60,691	0	0	0	0	0	411		89,977	0.01
Madhya Pradesh	1,314,276	2,083,423	0	0	2053	0	333	61,990	3283	3,465,458	3.28
Maharashtra	9,251,593	4,034,749	0	0	45,014	0	0	8371	19,450	13,359,277	12.66
Manipur	309,038	1,179,151	0				8517			1,496,806	1.42
Meghalaya	94,256	781,036	0	0	0	0	1606			876,998	0.83
Mizoram	1036	1,664,017	0							1,665,153	1.58
Nagaland		0	1,065,578	0						1,065,678	1.01
Orissa	3,206,507	2,011,038	1202				242,838	2544	5107	5,469,336	5.18
Punjab	6049	4331	0							10,380	0.009
Sikkim	20,649	152,924	0	154,776						328,449	0.31
Rajasthan	3,840,503	2,138,495	15,203,070		364,643		4108	1,383,473	31,875	22,966,267	21.77
Tamil Nadu	94,794	345,226	3090		1565				6353	451,028	4.27
Tripura	0	667,122	0				14,721			681,843	0.65
Uttar Pradesh	648,939	167,697	0		1,272,238		131,428	12,919	4282	2,237,603	2.12
Uttarakhand	82,473	2,073,049	0	827,279	811					2,983,612	2.83
West Bengal	1,789,721	618,557		275			240,480		11,634	2,660,667	2.5
Total	33,551,276	31,660,183	17,564,760	10,208,919	5,256,177	4,452,272	988,507	1,651,217	153,011	105,488,222	–

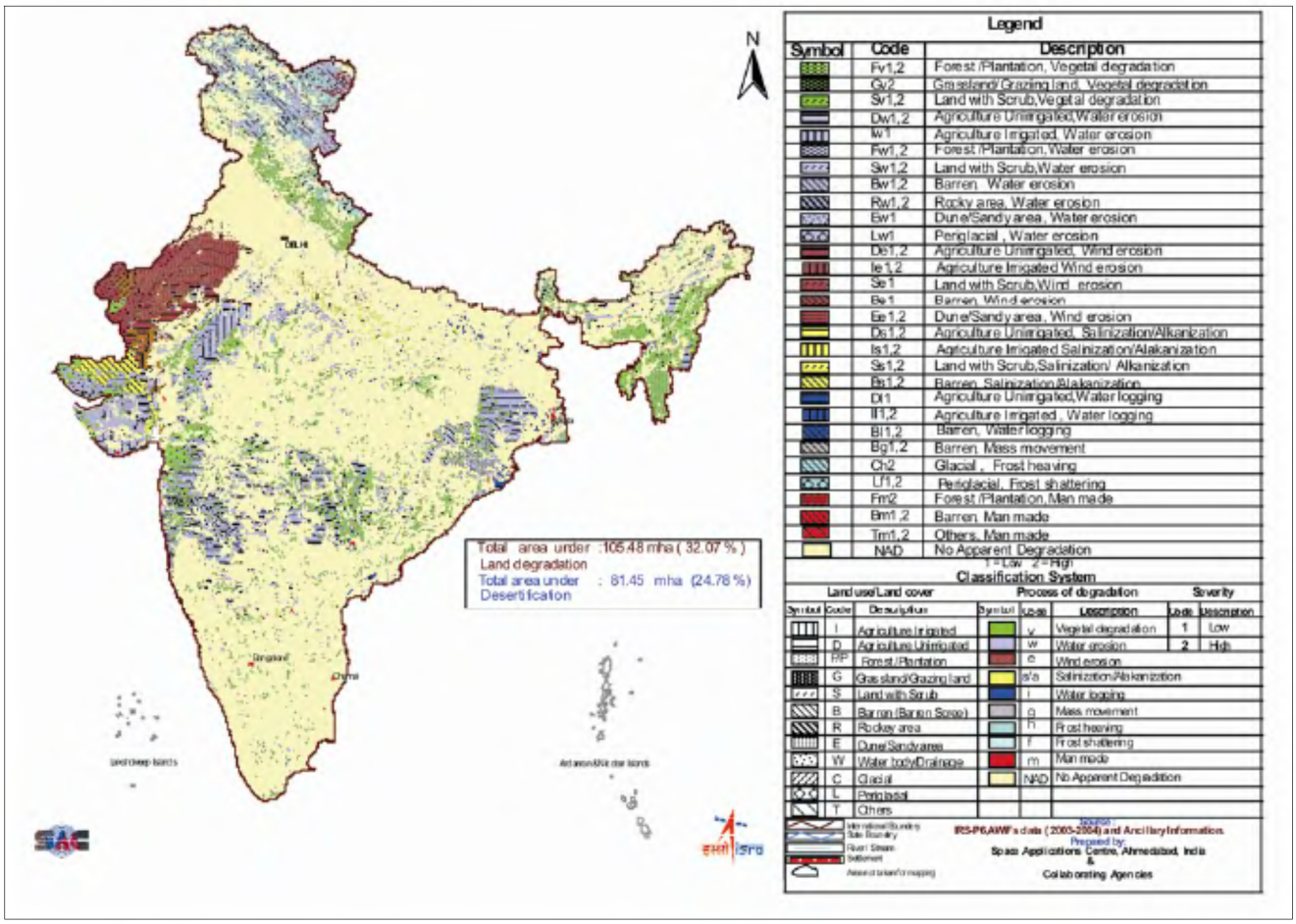

Figure 6. Desertification/land degradation status map of India.

Table 3. Processwise area (mha) under desertification

	Water erosion	Wind erosion	Vegetal degradation	Frost shattering	Mass-movement	Salinity/ alkalinity	Rocky/ barren	Water logging	Men-made	Frost heaving	Total (mha)
Arid	3.67	16.16	1.97	6.39	3.66	3.03	0	0	0	0.01	34.89
Semi-arid	17.67	1.6	8.43	1.77	0.5	0.71	1.16	0.07	0.08	0	31.99
Dry subhumid	4.87	0.01	7.23	1.31	0.3	0.23	0	0.59	0.03	0	14.57
Total	26.21	17.77	17.63	9.47	4.46	3.97	1.16	0.66	0.11	0.01	81.45

The final DSM mylars were vectorized and put on a national spatial frame work. The seams were removed between adjacent map sheets to prepare seamless map for states and finally for the country.

Various processes of land degradation/desertification appear distinctly on satellite imagery. As an example, the satellite image showing desertification/land degradation processes such as water erosion, wind erosion, vegetal degradation, salinity, etc. in the hot dry land regions are given in Figure 2.

The field photographs of these land degradation processes are given in Figure 3. Similarly, the satellite images distinctly showing frost-shattering, mass-wasting, water erosion, etc. in the cold regions are given in Figure 4. The field photographs for these processes are given in Figure 5.

DSM prepared for India is given in Figure 6. The map shows spatial distribution of land degradation along with land use/land cover classes for the entire country. The legends including the symbols and colour scheme for land use and land degradation process are also given in Figure 6. The total land area undergoing process of degradation is 105.48 mha, which is 32.07% of the total geographic area (TGA) of the country.

Processwise land degradation area in the country is given in Figure 7. Water erosion (10.21% of TGA), vegetal degradation (9.63% of TGA) and wind erosion (5.34% of TGA) are the major land degradation processes in the country.

Statewise distribution of area under land degradation is given in Table 2. Rajasthan has the largest area (21.77%

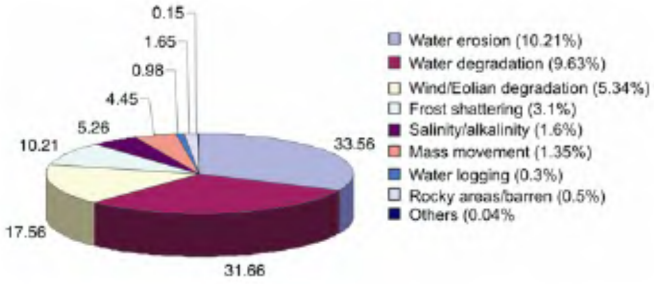

Figure 7. Processwise status of land degradation in India (mha).

of the TGA) under land degradation, followed by J&K (12.79% of TGA), Maharashtra (12.66% of TGA) and Gujarat (12.72% of TGA).

The boundaries of arid, semi-arid and dry subhumid regions of the country were superimposed on the DSM of India to find out the area under desertification. The processwise area under desertification for the country is given in Table 3.

In India, the total area under desertification is 81.45 mha. Water erosion (26.21 mha), wind erosion (17.77 mha), vegetal degradation (17.63 mha) and frost shattering (9.47 mha) are the major processes of desertification.

Nearly one third of the country's land area (32.07%) is undergoing processes of land degradation. There are about eight major processes of land degradation active in the country. Water erosion is the most pronounced process, followed by vegetal degradation and eolian processes. Total area under land degradation is 105.48 mha. Area-wise Rajasthan, J&K, Gujarat and Maharashtra have high proportions of land undergoing degradation. 81.45 mha land area of the country is undergoing the process of desertification. This study provides baseline data on desertification/land degradation for the country and will be useful for future monitoring of desertification.

1. UNEP, A Status of Desertification and Implementation of the United Nations Plan of Action to Combat Desertification. Report of the Executive Director, Nairobi, United Nations Environment Programme, 1992.
2. NBSS&LUP, Agro-ecological subregions of India for planning and development, NBSS&LUP Publication, ICAR, Nagpur, 2001.
3. MoEF, National Action Programme to Combat Desertification. Status of Desertification, Ministry of Environment and Forests, Govt of India, September 2001, vol. 1, p. 293.
4. Ajai *et al.*, Desertification Monitoring and Assessment using Remote Sensing and GIS: A Pilot Project under TPN-1 UNCCD SAC/RESIPA/MESG/DMA/2007/01, 2007.

ACKNOWLEDGEMENTS. We thank Dr R. R. Navalgund, Director, Space Applications Centre (SAC) for his encouragement and guidance. We are grateful to Dr V. S. Hegde, Director, EOS and Dr J. S. Parihar, Mission Director, EOAM, SAC for providing all support and guidance. We thank all the collaborating agencies for their necessary support and help. We also thank Mr Rui Zheng, UNCCD, Bonn for providing all necessary information and support from time to time.

Received 24 March 2009; revised accepted 14 October 2009

Broodstock development, spawning and larval rearing of the false clown fish, *Amphiprion ocellaris* in captivity using estuarine water

T. T. Ajith Kumar* and T. Balasubramanian

Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502, India

Broodstock development, spawning and larval rearing of the false clown fish, *Amphiprion ocellaris* is studied under captive condition. *A. ocellaris* spawns in seawater and has also been bred in captivity using estuarine water. Continuous aeration and 10–20% water exchange was provided on alternate days. Temperature, salinity, pH, dissolved oxygen and ammonia were maintained at optimum levels. The fish were fed twice a day with various feed combinations like prawn/mussel/squid meat and live *Acetes* spp. At the age of six months in the hatchery, the fish attained 6.5–8 cm length and 14.6–15 g weight at the time of first spawning and laid eggs. The newly laid eggs were orange in colour, translucent and capsule shaped. The parents were allowed to remain in the spawning tank till hatching, which took place after 6–8 days and the hatching success rate was 90–95%. The newly hatched larvae measured 3–4 mm in length and were transferred into separate rearing tanks. They were fed with rotifers and *Artemia* nauplii and 21 days after hatching, the juveniles shifted from pelagic to epibenthic mode of life. The young ones were fed with different wet feed and they attained marketable size within three months. This is the first report on hatchery production of false clown fish, *A. ocellaris* both in India and elsewhere using estuarine water.

Keywords: *Amphiprion ocellaris*, broodstock maintenance, estuarine water, juvenile production, larval rearing.

IN recent years, there has been a surge in the trade of tropical ornamental fishes and at the same time indiscriminate exploitation has also led to negative repercussions on coral reef ecosystem. For the last two decades, the marine aquarium fish trade has witnessed steady growth[1,2]. At present, the wholesale value of the global ornamental fish trade is estimated at around 6 billion US$. According to the Global Marine Aquarium Database (GMAD), the annual global trade varies between 20 and 24 million fishes, and 9 and 10 million for other invertebrates[3]. About 90% of the freshwater fishes are farmed and the rest are collected from the wild. But in the case of marine ornamental fishes, about 95% are from the wild, whereas 5% are captive-bred[4].

*For correspondence. (e-mail: tt_ajith@yahoo.co.in)