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Satellite Remote Sensing in Landuse Planning of Arid Environment

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Abstract Satellite remote sensing using IRS-1A (LISS-1) False Colour Composites (FCCs) of *kharif* and *rabi* seasons for the year 1988-89 in conjunction with ground truth enabled to identify and to map different landuse/land cover categories at levels I and II in Jodhpur district comprising an area of 22, 85,000 ha of arid northwestern Rajasthan. The extent of different landuse/land cover categories from IRS FCC products and revenue record has been computed and tabulated. It has been observed that the area mapped from IRS FCC products for all the landuse/land cover categories is less than that of revenue record due to the small scale and poor resolution of the remotely sensed data. The suitable cropping patterns, plant species and soil and water conservation measures have been suggested for the rational landuse planning of different landuse/land cover categories of the district.

Key words Satellite remote sensing, Landuse/land cover mapping, IRS-1A (LISS-1) False Colour Composites (FCCs) , National Remote Sensing Agency (NRSA), Landuse planning

Systematic information on landuse/land cover in the form of maps and statistical data is a pre-requisite for rational landuse planning on a district, regional and national level. Data available on landuse/land cover in the country are inadequate and unreliable because they were collected and complied by conventional methods which are less accurate and time consuming.

The landuse/land cover mapping of Jodhpur district in western Rajasthan was completed using IRS-1A (LISS-1) FCC imagery and landuse classification system standardised by National Remote Sensing Agency (NRSA), Hyderabad (1980). The salient features of the biophysical conditions and present status of landuse/land cover categories for rational land use planning of the district have been highlighted in this paper.

The Environment

The climate, geomorphology and soil play significant role in evaluating the present and potential use of land for rational land use planning. The rainfall variability from year to year in the district is very high with a standard deviation of 123 to 266 mm and coefficient of variation 49 to 55% (Anonymous 1982). The mean maximum and minimum temperatures during the summer season from April to June are 38^{O} to 42^{O}C and 24^{O} to 26^{O}C, respectively. In the winter season, the mean maximum and minimum temperatures remain 23^{O} to 25^{O}C and 5^{O} to 10^{O}C, respectively. The average wind speed varies from 14.8 to 16.5 kmph.

Geomorphologically the district could be divided into three broad units viz. hills and rocky/gravelly pediments, vast older alluvial plains and sand dunes and interdune plains. The hills of 60 to 150 m height above ground level comprising of rhyolite, granite, sandstone and limestone rocks are distributed throughout the district. The rocky/gravelly pediments are strewn with the rock fragments of 1.5 to 7.5 cm, 1.0 to 5.0 cm and 0.5 to 3.8 cm length, width and thickness, respectively. Flat older alluvial plains are the dominant landform features and constitute the sediments of different types and texture. Sand dunes and interdune plains, by and large, are located in the northwestern and western parts of the district (Anonymous 1982).

The soils of different types, texture and structure associated with different landforms occur in the district. Light textured sandy to loamy sand soils of sand dunes and sandy plains are highly vulnerable to wind erosion and have poor fertility status due to low carbon, low to medium P and medium K. Medium textured sandy loam to loam

Table 1 *Landuse/land cover categories statistics, Jodhpur district, Rajasthan, 1988-89*

Categories Level I and II	Category I Area (ha)	Category II Area (ha)	% of total geographical area
Built-up land	8800	8800	0.39
Agricultural land	1723358		
Kharif cropland		1057375* (61.36%)*	
Rabi cropland		48711 (2.83%)	
Kharif and rabi croplands		24289 (1.41%)	
Net area sown		1081796 (62.71%)	47.34
Fallow land		641562 (37.23%)	28.08
Forest	4336		
Degraded forest scrub land		4336	0.19
Wastelands	439452		
Salt affected land		17383	0.76
Gullied/ravinous land		7383	0.32
Land with or without scrub		168867	7.39
Sandy area (desertic)		236600	10.35
Barren rocky/stony waste/ sheet rock area		9219	0.40
Water bodies	8740		
River/stream		8350	0.37
Lake/reservoir/tank/canal		390	0.02
Others	100314		
Grassland/grazing land		99219	4.34
Mining area		1095	0.05
Total		2285000	100.00

* Figures in parenthesis indicate the percentage of total agricultural land

and clay loam soils having 70-130 mm moisture retaintion capacity are generally used for growing *kharif* and *rabi* crops. The fine textured clay loam to silty clay loam soils can retain 180 to 350 mm moiture in the profile and they are suited for *rabi* cropping on conserved moisture. Shallow gravelly sand to sandy loam soils also occur throughout the district on the rocky/gravelly and uplands. Saline soils occur in the natural and man-induced salt affected wastelands (Anonymous 1982).

Materials and Methods

Existing available literature and information from the revenue and forest departments and resource and wasteland maps were utilised for landuse/land cover mapping of the district. The base map showing the physical and cultural features was prepared on 1:250,000 scale from Survey of India topographical maps of the same scale. IRS-1A (LISS-1) False Colour Composites of bands 2,3,4 on 1:250,000 scale of *rabi* season for the month of January 1989 and *kharif* season for the month of October 1988 were visually interpreted by using interpretation key and characteristics like tone, size, shape, pattern and texture etc. with the help of tracing table and hand glass. Different landuse categories of *kharif* and *rabi* seasons were delineated and mapped at level I and II by following the method developed by NRSA (1989) and were checked in the field. The locations were shown on the maps and necessary details were recorded. The discrepancy observed in the landuse/land cover mapping during field checks was rectified in the laboratory. The landuse/land cover maps of the *rabi* and *kharif* seasons were superimposed on each

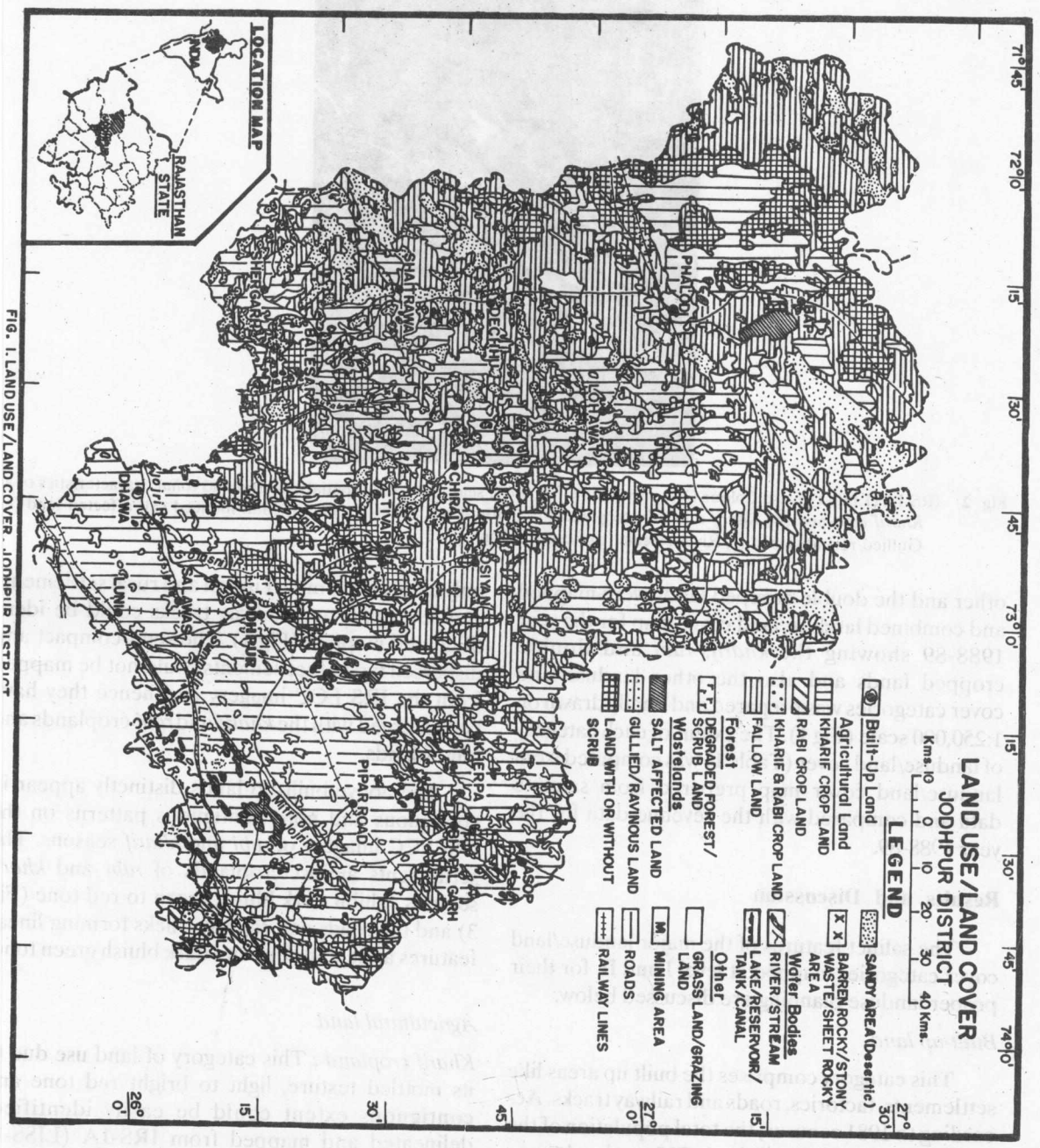

FIG. 1. LAND USE/LAND COVER, JODHPUR DISTRICT

ig 1 Land use/land cover map of Jodhpur district

Fig 2 IRS-IA (LISS-1) False Colour Composite (FCC) of *kharif* season showing spatial, spectral and tonal characteristics of a *Kharif* cropland (b) *Kharif and rabi* croplands (c) Natural salt affected land (d) Man-induced salt affected land (e Gullied/ravinous land (f) River/stream (g) Reservoir/tank

other and the double cropped lands were mapped and combined landuse/land cover map for the year 1988-89 showing the *kharif, rabi* and double cropped lands and also the other landuse/land cover categories was prepared and finally drawn on 1:250,000 scale (Fig 1). The extent of each category of landuse/land cover (Table 1) was computed from landuse/land cover map prepared from satellite data and compared with the revenue data for the year 1988-89.

Results and Discussion

The salinet features of the major landuse/land cover categories mapped at level I and II for their proper landuse planning are discussed below.

Built-up land

This category comprises the built up areas like settlements, factories, roads and railway tracks. According to 1981 cenusus, the total population of the district was 1.67 million living in 705 rural and urban settlements which have increased manifold during the subsequent years. But due to the limitations of the resolution and scale of IRS-1A (LISS-1) FCCs only large and compact urban and rural settlement and few roads and railway tracks could be iden tified and mapped (Fig 1). The semi-compact an dispersed type of settlements could not be mappe from the IRS FCC imagery and hence they hav been merged with the *kharif* and *rabi* croplands an fallow lands.

The above built-up lands distinctly appear i contiguous and non- contiguous patterns on th IRS FCC imagery of *rabi* and *kharif* seasons. Th settlements amidst croplands of *rabi* and *khar* seasons exhibit dark bluish green to red tone (Fi 3) and the roads and railway tracks forming linea features appear in dark and dark bluish green ton

Agricultural land

Kharif cropland : This category of land use due its mottled texture, light to bright red tone ar contiguous extent could be easily identifie delineated and mapped from IRS-1A (LISS- FCC (Fig 2). The total area mapped (Table varies from revenue record which is 11,20,639 h This variation in the hectareage from two sourc

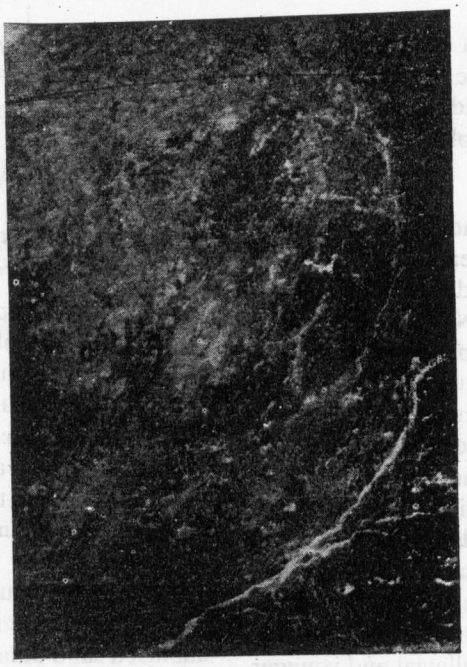

Fig 3 IRS-IA (LISS–1) False Colour Composite (FCC) of *rabi* season showing spatial, spectral and tonal characteristics of (a) Built-up land (b) *Rabi* cropland (c) Fallow land (d) Degraded forest/scrub land (e) Land with or without scrub (f) Sandy area (desertic) (g) Barren rocky/stony waste/sheet rock area (h) Grassland/grazing land (i) Mining area

of data may be due to poor resolution and small scale of the IRS FCC imagery and stunted growth of crops and their poor chlorophyll content because the cultivated area could not be properly registered and mapped.

Rabi cropland : This landuse category occurs in eastern part, due to distinct field boundaries and bright red tone, it could be easily delineated and mapped from IRS FCC imagery of cool season (Fig 3). The total area as per the revenue record could not be mapped due to small scale and poor resolution of IRS FCC imagery. Beside this , may be that the crops sown in this season have not grown well in some areas due to non-availability of water for irrigation.

Kharif and rabi croplands : This category of landuse covering 1.41% of the total agricultural land (Table 1) appears in light red tone in *kharif* season and the field boundaries in certain areas are not distinctly visible. In *rabi* season, such croplands appear in bright red to dark red tone with distinct field boundaries on IRS FCC imagery (Fig 2).

Fallow land : The current fallow lands appear in light grey to yellowish blue tone and the long fallow lands in dark grey to dark greenish tone with indistinct field boundaries in continuous patches on IRS FCC imagery (Fig 3). The area mapped and delineated (Table 1) under fallow lands varies from the revenue record (7,38,520 ha). The variation may be due to scale and resolution limitations whereby small areas could not be delineated and mapped separately from IRS FCC data. Such areas, therefore, have been merged with the croplands.

Forest

Degraded forest scrub land : This category of landuse associated with the rhyolite hills, rocky/gravelly and buried pediments and sandstone plateau appear in grey and dull red tone on IRS (LISS- 1) FCC (Fig 3). The average tree density of *Acacia sengal* is 120 plants ha^{-1} on protected site and 20-60 plants ha^{-1} on the unprotected degraded locations. The degraded forest occurring on the light to medium textured flat older alluvial plains is occupied by *Prosopis cineraria, Capparis decidua* etc. The area as per revenue record under degraded

forest (6,590 ha) is more than mapped (Table 1) area which could be due to the fact that the small areas under this category could not be delineated and were merged with the croplands.

Wastelands

Salt affected land : Natural and man-induced salt affected wastelands could be easily identified and mapped from IRS FCC data due to their distinct shape, size, tone and texture. Natural salt affected lands in the form of saline depressions and saline flats exhibit bright white to dull white tone with mottled texture on IRS FCC imagery (Fig 2). They are genetically related with the buried courses of the prior drainage channels and neotectonic activities. Such wastelands constitute sand to loamy sand and loam to clay loam soils (pH 7.8 to 8.6 and EC 1.82 to 29.30 dSm^{-1}). The salts of the commercial importance are extracted from the saline depressions. Man-induced salt affected lands are associated with the flat older alluvial and younger alluvial plains and exhibit dull white to light reddish brown tone on IRS FCC imagery (Fig 2). They have developed due to the use of saline and canal water for irrigation and rise of ground water table.

The halophytic shrubs and grasses like *Suaeda fruticosa, Sporobolus marginatus* and *Prosopis juliflora* are the dominating vegetation species of the saline flats.

Gullied/ravinous land : This category of wasteland includes the gullies of 3 to 20 m depth and 2.5 to 35 m width. The dominant plant species on this type of wasteland are *Capparis decidua, Acacia senegal,* and *Leptadenia pyrotechnica*. The gullied lands except small gullies due to their distinct shape, size and pattern could be easily identified and mapped from IRS FCC imagery. They distinctly appear in white to grey and light reddish brown to dark brown tone on the above imagery (Fig 2). The study on the temporal change detection in gullied areas of Jodhpur district using Survey of India topographical maps (1958) and LANDSAT TM data (1986) revealed that the areal extent of the gullied areas has increased from 198.5 to 242.0 ha (22%) over a period of 29 years (Singh *et al.* 1990).

Land with or without scrub : The rocky/gravelly flat surfaces with shallow soils in pockets and devoid of vegetation (Singh *et al.* 1989) exhibit whitish grey to grey tone on IRS FCC imagery whereas the areas with vegetation appear in light red to greenish brown and dark tone (Fig 3). The sheet and rill erosion are the major limitations of this category. The shrubs, trees and grasses occurring on this wasteland are *Euphorbia caducifolia, Zizyphus nummularia, Acacia senegal* and *D. sindicum.*

Sandy area (desertic) : The sandy areas comprising of different types of dunes due to their magnitude, form, shape and pattern could be easily identified, delineated and mapped from IRS FCC imagery. These watelands in the form of dunes in contiguous chains of clusters and with irregular pattern and smooth to mottled texture appear in light yellow to brownish and greenish blue to light red tone on the above image. The reactivated parts of the dunes due to the accumulation of fresh sand appear in white to grey tone (Fig 3). The stabilised and unstabilised sand dunes viz., obstacle, parabolic, longitudinal, transverse and barchan of 5 to 60 m height having gentle to moderate and steep to very steep slopes and structureless soils are the major constraints and largely occur in the western part of the district. The plant species like *Acacia senegal, Prosopis cineraria,* and *Calligonum polygonoides* grow on this category of wateland. The riverine sand transported by the floods of 1979 and 1990 were reworked and deposited in the form of dunes and hummocks by aeolian process on the flood plains of the Luni and the Mitri rivers resulting in the formation of new wastelands.

Barren rocky/stony waste/sheet rock area : This category of wasteland comprising of sandstone, limestone, rhyolite, granite rocks and sheet rocks is characterised by steep slope, presence of water erosion, boulders, cobbles and gravelly sand. These wastelands have been further degraded due to increasing biotic activities like cutting and lopping of plants, grazing and mining for construction of houses, roads and factories and new watelands are being formed (Singh & Kar 1988). The areas of large size of this category could be easily identified delineated and mapped from IRS FCC data but the unmappable small rock outcrops and rocky/stony areas were merged with the croplands and fallow lands. Such type of wasteland appears in dark grey

to dark and brown to dark brown and light red tone in irregular shape and contiguous and non-contiguous pattern on IRS FCC imagery (Fig 3). The comparative study of the Survey of India topographical maps (1958) and Landsat TM data (1986) have revealed that in Jodhpur district the areal extent of the uplands in the form of rock outcrops and rocky/stony areas decreased from 30 to 3973 ha in 1958 to 30 to 3375 ha in 1986 (average 20%) due to the cultivation, mining and construction of settlements (Singh *et al.* 1990).

Water bodies

River/stream : The Luni and the Mitri rivers with their numerous tributaries in the linear and contiguous pattern and mottled texture distinctly appear in the white to grey and light red to greenish blue tone on the IRS FCC imagery (Fig 2). The sand bars of different dimensions in the river beds support the pure stand of *Tamarix ereoicoides, Prosopis juliflora,* and *Leptadenia pyrotechnica.* The study using LANDSAT TM data on the temporal changes in the courses of these ephemeral rivers has revealed that over a period of 29 years, their courses have increased upto 1.8 times through bank erosion by flash floods (Singh *et al.* 1988).

Lake/reservoir/tank/canal : In the district, there are several lakes, reservoirs, tanks and canals. Jaswantsagar is the largest water body with 52.84 mcm water storage capacity followed by Surpura, 21.65, Bisalpur 5.23, Kailana 3.54 and Balsamand 2.21 mcm etc. In addition to these water bodies, there are 1314 village ponds locally known as *nadis* of small, medium and large size used for drinking water and two springs namely Beriganga and Banganga. But due to the scale and resolution limitations of IRS FCC imagery only major lakes and reservoirs could be identified and mapped. They are distinctly visible in elongated and semi-circular shape, scattered and non-contiguous patches and in light blue to dark blue tone on the above image (Fig 2). The area of the mappable water bodies is 390 ha (0.02 %) of the total geographical area. The comparative study of the Survey of of India pographical maps (1958) and LANDSAT TM data (1986) has revealed reduction in area of water bodies and drainage basins upto 1.8 to 2.4 and 6.0 to 8.0 times, respectively over a period of 29 years (Sharma *et al.* 1989).

Others

Grassland/grazing land : The grazing lands locally known as 'Orans' and associated with hills and rocky/gravelly pediments and sandy plains are characterised by flat and undulating topography, gravelly surfaces, gravelly sand to loamy sand and sandy soils and water erosion. Major plant species of such grazing lands are *Acacia senegal, Prosopis cineraria, Capparis decidua, Calligonum polygonoides, Cenchrus biflorus* and *Eleusine compressa.* This category of landuse due to its location, shape and pattern could be easily identified and mapped from IRS FCC imagery. It appears in white to milky white and light red to brown in tone, semi-circular to circular and rectangular in shape and non-contiguous patches on the above image (Fig 3).

The total area as per the revenue record is 1,19,540 ha which is slightly more than the area computed from the landuse/land cover map (Table 1). This variation is due to the small scale of IRS FCC image and also the reduction in the areal extent of the grazing lands by increasing anthropogenic activities like cultivation and construction of houses and factories. It has been estimated fom the Survey of India topographical maps (1958) and LANDSAT TM False Colour Composite (1986) that over the period of 29 years the areal extent of the grazing lands has decreased upto 9 to 30% under different landforms of Jodhpur district. The decrease in the grazing lands associated with saline alluvial plains is lowest and it is highest in the rocky/gravelly pediments due to construction of settlements and cultivation in pockets (Sharma *et al.* 1989).

Mining area : The mining of sandstone, limestone and rhyolite has resulted into the development of this category of wasteland in the form of 'bad lands'. The major plant species of the mining areas are *Salvadora oleoides, Prosopis cineraria, Zizyphus nummularia, Eleusine compressa, Suaeda fruticosa* and *Sporobolus marginatus*. The abandoned mining

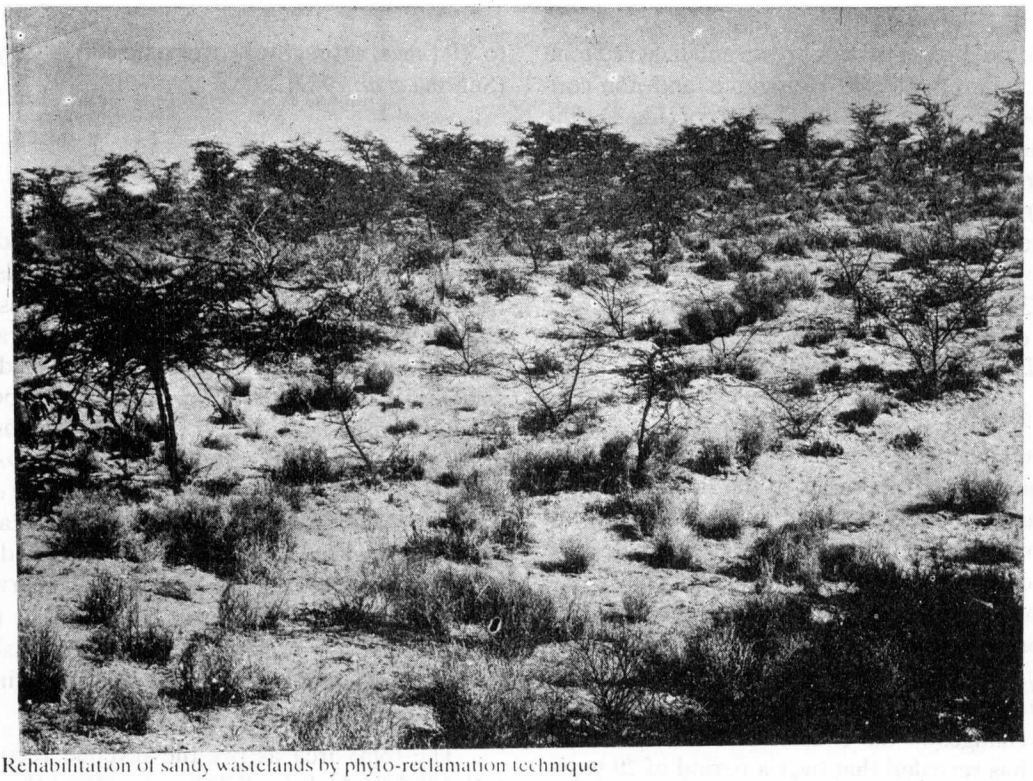

Fig 4 Rehabilitation of sandy wastelands by phyto-reclamation technique

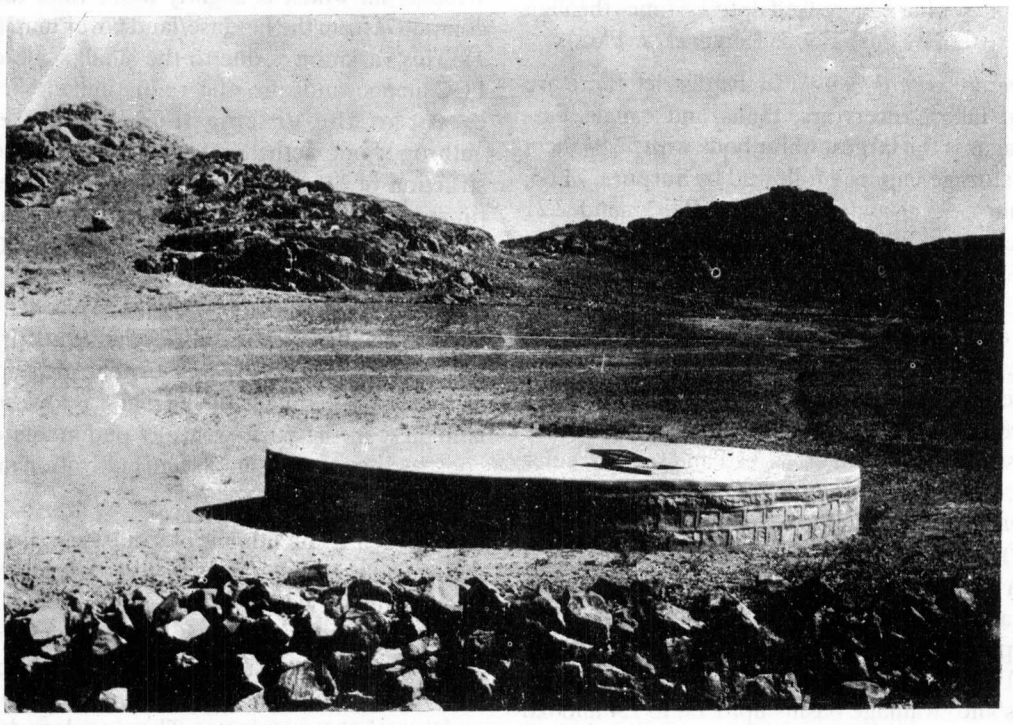

Fig 5 Harvesting of surface runoff in *tanka* (cistern) at suitable geomorphic site

pits and heaps of mine spoils are posing serious problems of waterlogging, wind and water erosion. The pits exhibits milky white to white and heaps of mine spoils appear in yellowish grey to dark grey tone with red specks on IRS FCC imagery (Fig 3).

Landuse planning

The productivity of *kharif* cropland could be upgraded by growing improved crop varieties like *bajra* (BJ 104); *moong* (S8;M8); *guar* (FS 227); *cowpea* (K 11; JC 10) and *til* (T 13) and use of 30-50 kg N ha^{-1} and 30-40 kg P_2O_5 ha^{-1}. The dry farming practices like contour bunding to minimise runoff losses, bentonite clay as sub-surface moisture barrier to reduce moisture losses, inter-plot water harvesting for improving moisture regime with proper spacing are also suggested to increase the crop yield (Singh 1976).

The productivity of *rabi* cropland could be increased by increasing moisture and soil fertility status by mixing tank silt, clay and organic manure, optimum use of water through drip and sprinkler irrigation method, lining of water courses to check the percolation losses and use of fertilizers, 70 to 100 kg N ha^{-1} and 30 to 40 kg P_2O_5 ha^{-1}. In the areas where saline water is available for irrigation should be judiciously used and salt tolerant crops like *Kharchia* wheat and use of gypsum are suggested (Anonymous 1982).

Natural and man-induced salt affected lands may be developed into pastures by raising halophytic plant species like *Haloxylon salicornicum, Suaeda fruticosa,* and *Prosopis julifora*. To develop silvipastoral system pelleted seeds of grasses like *Sporobolous marginatus,* and *Cenchrus setigerus* or their root slips or polythene raised seedlings may be transplanted.

The headward increase of gullied lands may be stopped by gully plugging and suitable plantation. The side erosion of the gullies to protect the cultivated interfluve areas should be checked by growing grasses and shrubs like *Panicum turgidum, Colligonum polygonoides, and Leptadenia pyrotechnica.*

The land with or without scrub could be rehabilitated by enhancing the process of succession, reseseding with suitable grasses like *Cenchrus ciliaris* and *Cenchrus setigerus* through pellets or roots slips may be done during the rainy season. The saplings of trees and shrubs like *Acacia senegal* and *capparis decidua*, may be transplanted on this category of wasteland (Anonymous 1982).

The sandy area comprising of reactivated stabilished sand dunes should be properly protected by rotational grazing and seeding and planting with grass species of high sand binding capacity like *Cenchrus ciliaris* and *Lasiurus sindicus*. The sandy area consisting of unstabilised dunes could be stabilised by phyto-reclamation techniques through fencing, mulching and plantation (Fig. 4). The indigenous plant species such as *Acacia senegal, Calligonum polygonoides, Lasiurus sindicus and Cenchrus ciliaris* are suitable for rehabilitation of unstabilised dunes (Saxena & Singh 1976).

Barren rocky/stony waste/sheet rock area could be developed into pastures and small watersheds for harvesting surface runoff (Fig.5). The hill slopes and rocky surfaces covered with thin coarse sediments could be transplanted with the saplings of *Acacia senegal* and *Cenchrus setigerus* by adopting soil and water conservation measures like gully plugging, contour furrows and contour bundings.

Degraded forest may be developed by reseeding and transplanting suitable plant species like *Acacia senegal, Prosopis cineraria, Capparis decidua* and *Lasiurus sindicus* species using soil conservation measures such as trenching and contour furrowing. The grazing lands after providing suitable exclosures may be reseeded with *Lasiurus sindicus* and *Cenchrus setigerus* and transplanted with top feed species like *Prosopis cineraria, Zizyphus nummularia* and *Calligonum polygonoides* (Anonymous 1982).

Conclusions

Satellite remote sensing technique using IRS–1 A (LISS-1) False Colour Compsites (1:250,000 scale) of *rabi* and *kharif* seasons has been found useful in conjunction with ground truth for mapping level I and II landuse/land cover categories of Jodhpur district. However, due to the sacle and resolution limitations of the aobve IRS data, the

small area of different landuse/land cover categories, particularly the built-up land, water bodies, rock outcrops, grazing lands and mining areas could not be identified and mapped. As a result, there is a variation in the area of different landuse/land cover categories computed and tabulated from the map prepared from the IRS FCC imagery of October, 1988 and January, 1989 than that obtained from the revenue record. The cloud cover, particularly in the IRS FCC imagery of *kharif* season is also a limitation but it could be avoided by selecting the imagery of could free date. Based on the findings of this study, it could be concluded that the above technique through random field checks could be successfully used for the mapping of landuse/land cover categories of the other districts located under different morphoclimatic conditions.

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