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LAND TRANSFORMATION AND THE ROLE OF REMOTE SENSING AS A TECHNIQUE FOR MAPPING AND MONITORING*

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Introduction

Land is in a continuous state of transformation as a result of various natural and manmade processes. The study of land transformation therefore requires a comprehensive understanding and monitoring of all the factors which affect these processes which cause changes in the physical, chemical, physiochemical and biological characteristics of land. These changes may be temporary or permanent and can be reversed with suitable reclamation/conservation practices. Both past and present human activities contribute to land transformation and the result could be either positive or negative. For example, reclamation of land from the sea, felling of trees, mining/quarring for minerals and rocks, agricultural practices and industrialisation have been known to cause negative effects like salanisation, alkalisation, desertification, aridisation, pollution, deterioration of physical properties of soils and modification of micro biological activities. Natural factors like climate, and vegetation influence the potential for land use and soil erosion (which is estimated to cause a loss of 6000 million tonnes of soil every year) also contribute significantly to the process of land transformation.

Theory of Remote Sensing

In remote sensing, reflected, scattered or radiated electromagnetic

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radiation from earth's surface is recorded in different wavelengths of electromagnetic spectrum. The incident radiation is provided by the Sun or by an active transmitter placed in an aircraft or a satellite. The objects on the surface of the earth show a characteristic wavelength response depending upon the nature of the object. We call it the "spectral signature". In common parlance it means "colour". Proper analysis and interpretation of the data recorded leads to identification of the objects on the earth. Modern remote sensing involves acquisition of such data through sensors placed onboard the airborne and spaceborne platforms. The data is recorded either on photographic films or magnetic tapes, the analysis and interpretation of which provides information about the resources under investigation. Various stages of data acquisition process are: an energy source, propagation of energy through the atmosphere, energy interaction with surface objects, energy reception by airborne and space borne sensors and generation of sensor data in pictorial or magnetic tape form. The data analysis process involves interpretation of pictorial data using, modern photogrametric instruments or processing magnetic tapes on interactive computer systems yielding statistical and classified thematic information of resources. Sample reference ground data is also collected and used conjunctively in order to obtain more accurate classification of the resources.

Sensors

Sensors which sense natural radiations from the earth are called passive sensors. The sensors which illuminate the targets with their own energy and then measure the scattered radiation from the target are called active sensors. Again the sensors (active or passive) could be classified as shown below.

Sensors (Active or Passive)

- Imaging (Camera, multispectral scanner, SLAR, etc.)
  - Instantaneous imaging (photographic camera, TV camera, etc.)
  - Line scan imaging (Multispectral scanners, linear imaging self scanning sensors (LISS), etc.
- Non-imaging (Radiometers scatterometers geophysical, etc.)

The important sensor parameters from the point of view of the resources survey applications are as follows :

(1) Spatial resolution: Capability of the sensor to discriminate the smallest object on the ground.
(2) Spectral resolution : The spectral bandwidth with which the image is taken; narrow bandwidth allows to observe certain features more prominently.
(3) Number of spectral bands and
(4) Dynamic range.

Remote Sensing Platforms

Remote sensing platforms may be aircraft, balloons, rockets or satellites. Aircraft and satellites constitute the two important types of present day platforms.

Aircraft remote sensing started a few decades back with the photographic cameras fitted onboard the aircraft. This technique is now well developed and refined. In recent years aircraft is flown with new types of sensors (e. g., scanners). Aircraft remote sensing offers certain advantages like flexibility of operation over any desired area at any time provides data of higher resolution. However, the technique has certain limitations compared to satellite sensing. They are : smaller area coverage and higher cost for repetitive surveys.

Significant developments in sensing from space started with the launching of first Earth Resources Technology Satellite (redesignated as Landsat-I later) in 1972 by USA.

Some of the important details regarding remote sensing satellites and the sensors are given in the Table 1 and Table 2.

Data Analysis and Interpretation

The remote sensing data is processed either through conventional photo-interpretation techniques or through man and machine combinations using high speed devices programmed for the purpose. The photographic imageries are interpreted by trained photo-interpreters using mainly are the fundamental elements of the picture, viz., tone, colour, texture, pattern, size, shape and shadow in order to detect and identify various objects. Aerial photographs are seen through stereoscopic instruments to obtain three dimensional effect. There are many photogrammetric instruments today for photo-interpretation and transferring the interpreted details to base maps. In the man-machine process, the scene is interactively analysed on the special purpose computers by comparing with the actual "signature" of the object collected through field visits. The "signature" or reference data is termed as training set. This system of classification of objects is quite accurate and depends on the area of training sets used, and on the dispersal of training sets over the area of the scene. The process of analysis, now-a-days, is carried on digital computers as they offer several advantages like quick processing of large amount of data, special signal processing possibilities (contrast stretch, edge enhancement and other feature enhancement, geometrical and other types of corrections, scale changing, band ratioing etc). Besides the standard peripherals, the digital system consists of an image recorder and a display terminal for interaction with the resource scientist. The film output is then processed in the photoprocessing laboratory, and legend and important topographical details are later added through cartographic procedures for producing the thematic maps. Computer can also extract several statistical parameters concerning the scene. Greyscale maps of a certain desired discipline covering a specific area can be obtained on larger scales. Digitisers are available for digitising the photo products and for subsequent analysis on the computer.

Advantages of Remote Sensing

Advantages of techniques of remote sensing for resources survey are listed below:

(1) Large area coverage enabling regional surveys of variety of themes and identification of large features.
(2) Repetitive coverage, allowing monitoring of dynamic themes like water, agriculture, etc.
(3) Data acquisition over inaccessible areas.
(4) Data acquisition at multiple heights-allowing different scales and resolution of data.
(5) Same raw remote sensing data can be analysed/interpreted for different purposes and applications.
(6) Amenability of remote sensing data to computer processing and thus making the method fast and accurate.

Land Transformation Studies Through Remote Sensing

It has been demonstrated in India and many other countries that remotely sensed data can be used to identify the problem areas, map and monitor the changes on the land surface over a period of time. As satellites with different orbits and sensors became available, users are able to acquire and compare the latest data with that obtained from various conventional sources. By geocoding the data from two or more satellites, the geometry of the products become satellite and sensor independent and can be easily overlaid, compared and combined. The strength of the satellite observation system lies in the repetitive coverage which they

TABLE —SPECTRAL DEFINITIONS AND SOME RELEVANT DETAILS OF SOME OF CURRENT AND NEAR FUTURE REMOTE SENSING SATELLITES

	Multispectral Scanner (LANDSAT 1, 2, 3, 4, 5)	*Thematic Mapper (LANDSAT-4, 5)*	*GRV (SPOT)*	*Linear Imaging Scanning Sensor (I R S)*
Organisation	NASA (USA)	NASA (USA)	CNES (France)	DOS (India)
Launch Date	1972, 75 & 78	1982, 84	1986	1988
Spectral Bands	0.5—0.6 μm 0.6—0.7 μm 0.7—0.8 μm 0.8—1.1 μm Landsat-3 Only 10.4—12.6 μm	0.45—0.52 μm 0.53—0.61 μm 0.62—0.69 μm 0.78—0.91 μm 1.55 - 1.75 μm 10.42—11.66 μm 2.08—2.35 μm	Multispectral 0.50—0.59 μm 0.61—0.68 μm 0.79—0.89 μm or Panchromatic 0.51—0.73 μm	0.45—0.52 μm 0.52—0.59 μm 0.62—0.68 μm 0.77—0.86 μm
Linear Resolution	80 M 240 M Thermal (infrared)	30 M 120 M Thermal (infrared)	20 M Multispectral 10M Panchromatic	73 M LISS-I 36.5 M LISS-II

Orbit Repeat Period	18 days	16 days	26 days (5 day revisit capability)	22 days
Mean Altitude	919 Km	705 Km	832 Km	904 Km
Swath Width (NADIR)	185 Km	185 Km	2 × 60 Km Pointable across track (+/−400 Km)	148 Km LISS-I 2 × 74 Km LISS-II
Equatorial Crossing Time	9 H 30 M	9 H 30 M	10 H 30 M	10 H

TABLE 2—SPECTRAL DEFINITION AND UTILITY OF SPECTRAL BANDS IN THE CURRENT REMOTE SENSING SATELLITES

	LANDSAT MSS			THEMATIC MAPPER			I R S (Proposed to be Launched in 1988)	
Band	*Speionl Reg*	*Utility*	*Band*	*Spectral Region*	*Utility*	*Band*	*Spectral Region*	*Utility*
4	0.5—0.6 μm	Useful in delineating areas of shallow water such as shoals, reefs etc. determination of turbidity in water.	1	0.45—0.52 μm	Bathymetry in less turbid waters, soil vegetation differences deciduous/coniferous differentiation soil type discrimination.	1	0.45—0.52 μm	Shallow water mapping, soil/vegetation differentiation forest species differentiation, geological applications.
5	0.6—0.7 μm	Useful for defining cultural & topographic features.	2	0.52—0.80 μm	to measure visible green reflectance peak of vegetation for vigour assessment.	2	0.52—0.55 μm	green reflectance of healthy vegetation.
6	0.7—0.8 μm	emphasises vegetation boundary between land and water & landforms	3	0.63—0.69 μm	chlorophyll absorption band important for vegetation discrimination.	3	0.62—0.68 μm	chlorophyll absorption for plant species differentiation.
7	0.8—1.1 μm	provides the best penetration of atmosphere haze, effective for land and water delineation	4	0.76—0.90 μm	useful for determination biomass content and for delineation of water bodies.	4	0.77—0.86 μm	Boimass survey water body delineation.

5	1.55—1.75 μm	indicative of vegetation moisture, useful for differentiation of snow from clouds.	—	—
6	10.4—12.5 μm	useful in vegetation stress analysis soil moisture, discrimination thermal mapping.		
7	2.08—2.35 μm	useful for hydrothermal mapping and for discriminating rock types.	—	—

offer. This feature has not been fully exploited till now, but has great potential for mapping and also for monitoring abrupt or gradual changes in the condition or quality of land.

The detection of abrupt changes is possible using Landsat images in many cases where the changes produce an extreme visual contrast between the old and the new. Where the contrast is less or the features that have changes are small and widely distributed throughout a scene, the interpreter is liable to miss many of them using visual examination methods alone. Satellite images particularly those obtained from the present Landsat series, are useful for detection of change. Following are some of the aspects of land transformation in which satellite data can be used for detection, mapping and monitoring.

(i) Soil erosion
(ii) Soil classification and degradation
(iii) Forest degradation
(iv) Aridisation and desertification
(v) Urbanisation, industrialisation and pollution
(vi) Land use/land cover
(vii) Surface waterbodies (reservoirs/tanks, etc.)
(viii) Sedimentation of inland and estuary environments
(ix) Littoral processes/coastal erosion

A perspective of the various causes of land transformation, its effects and the application of remote sensing as a technique for mapping and monitoring of various themes of land transformation are discussed below.

Sl. No.	*Factors Causing Transformation*	*Type of land Transformation*	*Remote Sensing Theme for Study*	*Methodology o Study*
,	Heavy rains and floods	The soil is washed away and deposited elsewhere causing soil erosion due to formation of ravines and gullies	Flood plain mapping, river system and river course monitoring, mapping of drainage characteristics.	Visual and computer aided interpretation of Landsat TM data of band 3, 4 & 5 in 1 : 250,000 scale for flood plain mapping. Landsat MSS/TM data of bands 3 & 4 in 1 : 250,000 or higher scale for monitoring drainage characteristics.

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Sl. No.	*Factors Causing Transformation*	*Type of Land Transformation*	*Remote Sensing Theme for Study*	*Methodology of Study*
		Land slides and land slips occur in hilly areas	Mapping of land topography in flood prone areas.	Photogrammetric surveys using aerial photographic data.
		Water logging and submergergence of land causing soil degradation due to rise of watertable resulting in salinity/alkalinity.	Mapping of watershed areas and drainage characteristics.	Landsat TM data in 1 : 50,000 scale for field level applications.
		Silting of lakes, tanks and ponds with eroded soil. This causes overflow of water during rains.	Mapping and monitoring of characteristics of watershed and waterbodies.	Landsat TM in band 1 shows turbidity which indirectly helps to study sedimentation. Band 4 of MSS/TM in 1 : 250,000 scale can be used to monitor waterbodies.
2	Excessive heat and lack of rainfall (droughts)	Increase in aridity and degradation of soil due to lack of moisture.	Mapping of soils	Visual and computer analysis of TM data of band 2, 3 & 4 combinations in 1 : 50,000 scale. 1 : 250,000 scale can be used for regional studies.
		Destruction of vegetation cover leading to soil erosion and degradation	Mapping of vegetation cover	Visual and computer aided vegetation index analysis of MSS/TM data in 1 : 250,000 scale.

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Sl. No.	*Factors Causing Transformation*	*Type of Land Transformatian*	*Remote Sensing Theme for Study*	*Methodology of Study*
3	Overgrazing of cattle	Grass lands are converted into thornlands and aridisation of soil takes place leading to desertification and erosion.	Monitoring of vegetation cover and soil characteristics	Landsat MSS/TM data in 1 : 100,000 scale or higher scale.
		In hilly terrain overgrazing can cause landslips and landslides	Mapping of topography and vegetation cover	Aerial photographic surveys for mapping topography.
4	Excessive irrigation and repeated cultivation	Due to excess water land becomes saline/alkaline due to presence of disolved salts in water.	Mapping of soil salinity/alkalinity	Visual and computer aided analysis of TM data of band 2, 3 & 4 FCC in 1 : 50,000 scale.
		Extent of humus decreases and fertility of the soil also decreases.	Study of drainage characteristics, soil mapping.	
	Exploitation of forest resources for timber and firewood	Degradation of forest & vegetation leading to deforestation and spread of deserts Increased soil erosion because there is no vegetation to hold soil	Mapping of forest types, extent, density and changes	Visual and computer aided analysis of TM data in 1 : 50,000 or 1 : 250,000 scale.

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Sl. No.	*Factors Causing Transformation*	*Type of Land Transformation*	*Remote Sensing Theme for Study*	*Methodology of Study*
6	Agricultural practices	The soil changes its physical and chemical properties. The top soil is easily eroded and land becomes saline/alkaline or acidic. In the areas surrounding rural settlements natural vegetation cover is also lost due to exploitation of firewood and grasslands. Wind storms easily carry away top soil during dry season when there is no vegetation and soil is loose and dry	Mapping of landuse and land cover in agricultural areas alongwith monitoring of ecological factors.	Landsat MSS/TM data in 1 : 50,000 or higher scale.
	Industrialisation and pollution	Large amount of natural lands are converted into industrial areas destroying natural ecology. Waste materials like ash, chemicals, etc., are dumped on land causing toxification and pollution of land.	Monitoring of industrial land use patterns. pollution and its effects, ecology and vegetation. Estimation of land being converted into industrial areas.	Visual interpretation of aerial data in 1 : 50,000 or larger scale or SPOT data.
		Atmospheric pollution due to Sulphur and Nitrogen oxides causes acid rain and makes soil acidic	Monitoring of soil quality and degradation	

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Table (*contd. from page* 243)

Sl. No.	*Factors Causing Transformation*	*Type of Land Transformation*	*Remote Sensing Theme for Study*	*Methodology of Study*
8	Urbanisation	Due to increase in population urban areas are rapidly growing and encroaching agricultural and natural ecosystem is degraded.	Monitoring of urban sprawl.	Visual interpretation of aerial photographic data.
		Surface water bodies are being converted into lands and ground water is over exploited. Water content of soils is lost and vegetation destroyed leading to soil erosion.	Groundwater and surface water body mapping	Landsat TM/ SPOT data can be used as they indirectly yield information to map groundwater potential

Land Use

An important aspect of land transformation is its negative impact on land use. The study of land transformation helps us to formulate policies to improve the efficiency of land use and to prevent and reclaim those lands which have been transformed into less productive lands. The following are some of the major methods adopted to make land more productive.

(1) *Afforestation*

This prevents degradation of vegetation cover and helps in preventing soil erosion and spreading of deserts. Remote sensing techniques can be used to estimate forest cover so that we can know the extent of degradation over a period of time to take up afforestation schemes in vulnerable areas. For short term monitoring we can use TM band 2, 3 & 4 combination data in 1 : 250,000 to 1 : 50,000 scale which will bring out the problem areas/critical areas undergoing rapid changes in forest cover. This can be further studied using aerial data supported by ground data.

(2) *Wasteland Reclamation*

For identification and categorisation of wastelands Landsat TM data can be used in 1 : 50,000 scale to generate district level maps for taking policy decisions regarding utilisation/reclamation/conservation of wastelands. A major project to map the wastelands of the entire country has been taken up to enable reclamation of these wastelands to improve its productivity. Saline/Alkaline can be reclaimed through various chemical leaching processes and by providing better drainage.

(3) *Prevention of Excessive Grazing and Development of Grass Lands*

This will prevent the the aridisation and desertification of grass lands because excessive grazing causes erosion of the soil and eventual desertification. The vegetation cover and its changes over a period of time can be monitored to assess damage due to over grazing and impact of development of grass lands.

(4) *Development of Drainage Facility*

This is to make the waterlogged, swampy and flood prone areas more productive by preventing soil erosion and degradation. Mapping of waterlogged areas and comparing the same with maps prepared after creating of the drainage facilities can help us to assess the effectiveness of these schemes.

(5) *Civil Earth Works*

Civil earth works like desilting of lakes, widening of rivers, building of ridges can help to prevent soil erosion and degradation.

(6) *Improved Agricultural Practices*

Agricultural practices which are not likely to destroy the ecosystem need to be adopted to preserve the productivity of the agricultural areas. Repeated mapping and monitoring of soil quality and excessive irrigation along with the quality of irrigation water help us to formulate policies for more productive land use.

Conclusion

We have seen the fundamental causes and effects involved in land transformation and the techniques of mapping and monitoring the same using remote sensing which can also be used to effectively assess the success or failure of land reclamation and conservation practices to improve the productivity of land.