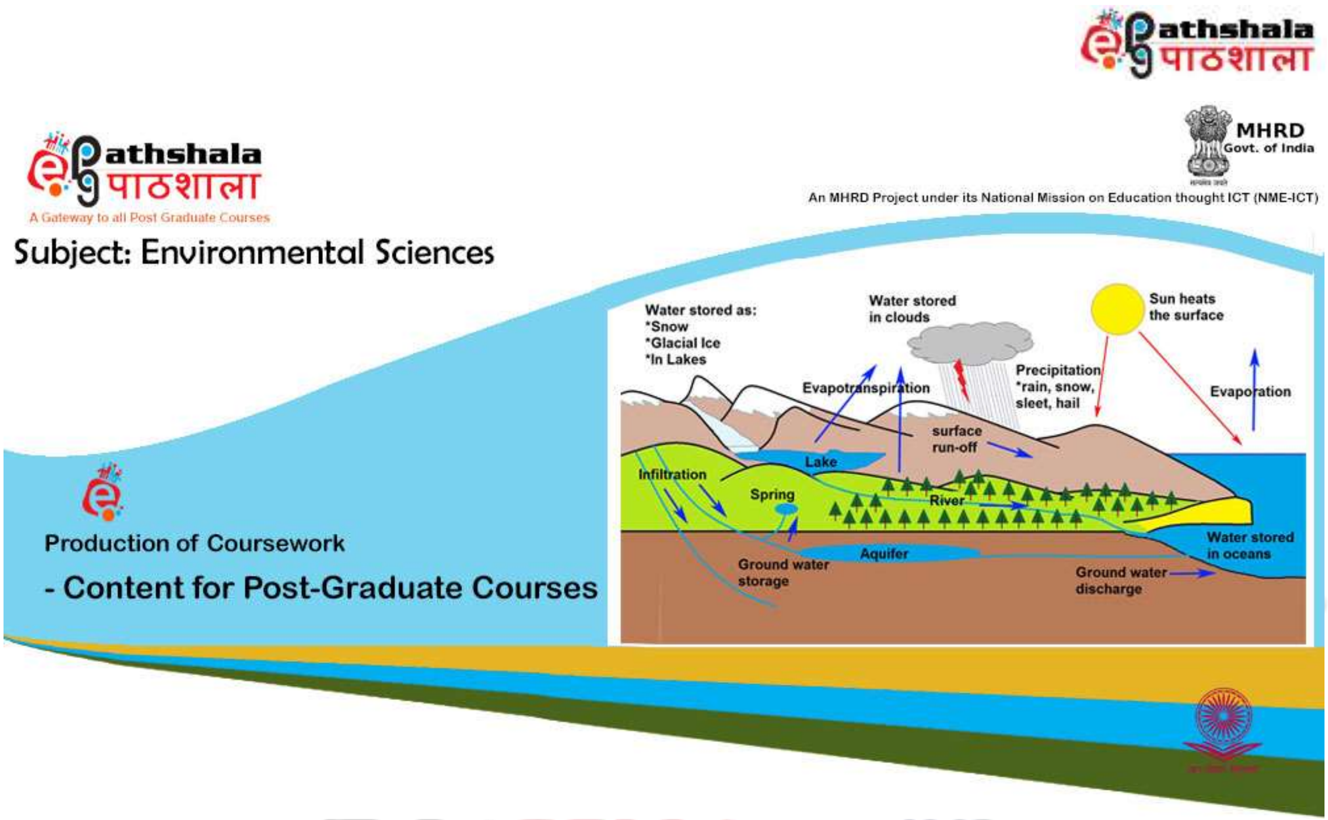

Paper No: 6 **Remote Sensing & GIS Applications in Environmental Sciences**

Module : 37 **Applications of Remote Sensing and GIS in Wasteland mapping**

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Description of Module	
Subject Name	**Environmental Sciences**
Paper Name	Remote Sensing & GIS Applications in Environmental Sciences
Module Name/Title	Applications of Remote Sensing and GIS in Wasteland Mapping
Module Id	EVS/RSGIS-EVS/37
Pre-requisites	Basic knowledge of remote sensing and GIS software
Objectives	To understand the concept of wasteland and assess the role of remote sensing and GIS in wasteland mapping.
Keywords	Remote sensing, GIS, Wasteland, Conservation, Inventory

Module 1: Applications of Remote Sensing and GIS in Wasteland Mapping

CONTENTS

1. Aim of the Module

- First, it will help understand the concept of wastelands.
- Second, it will assess the role of remote sensing and GIS in wasteland mapping.

At the end of this module, you would have obtained some idea about the wastelands, the factors leading to wasteland generation as well as reclamation of wastelands. You would also be able to understand as to how remote sensing and GIS would help in mapping of wastelands, and the advantages of these techniques over conventional methods.

2. Introduction

Wastelands are those lands which are presently not being used to their optimum potential due to some constraints. National Wastelands Development Board, Ministry of Environment and Forests, Government of India describes wasteland as, "degraded land which can be brought under vegetative cover, with reasonable effort, and which is currently under-utilized, and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes" (Rao, et. al., 1991). Wastelands are known to result from inherent or imposed disabilities related to location, environment, or soil, as well as financial and management constraints. With increasing human and animal pressure on land, the production of vegetation for food and other uses has extended to areas under great ecological stress and less favorable environment, leading to accelerated soil erosion and excessive land degradation. Vast stretches of land have thus been transformed into wasteland owing to desertification, soil salinity, waterlogging, excessive soil erosion etc. Ecologically the value of wastelands is so precious that it cannot be measured by any monetary price. Desired one third of geographical area under forest, climate & soil protection, secure and economically and ecologically viable energy supply, biological diversity, increasing biomass can be achieved by reclaiming wastelands. It will also help in creation of rural employment, strengthening of rural infrastructure and social development & equity. It is very necessary to bring all the wastelands under productive and sustainable use through the programs like afforestation, pasture development, cropping pattern and other economic use. For this purpose reliable database on type, extent, location, morphogenesis, ownership of wastelands are required and it is also necessary to categorize the wastelands in accordance with their intrinsic characteristics and causative factors.

3. Wasteland generation process

Wasteland generation is a complex ensemble of surface processes. The problems of land degradation are on the rise. Land degradation due to desertification, soil salinity, water logging, flooding, droughts, excessive soil erosion due to deforestation and unscientific agricultural practices have resulted in the creation of wastelands. Therefore, management of land resources is essential for both continued agricultural productivity and protection for the environment. This requires an inventory of degraded lands to initiate appropriate reclamation / treatment plans. The information on the extent and spatial distribution of various kinds of wastelands is thus essential for strategic planning of development. Some possible reasons for generation of wasteland in the country are as follows:

4.1 Water Erosion: Water erosion is the most widespread cause of land degradation and occurs widely in all agro-climatic zones. The displacement of soil material by water can result in either loss of topsoil or terrain deformation or both. This category includes processes such as splash erosion, sheet erosion, rill and gully erosion. The result is more loss of fertile topsoil and plant nutrients. In some cases where subsoil has *kankars*, lime nodules, etc will get exposed on the top thereby altering the pH regime of the surface soil and subsequent nutrient holding capacity and their availability to plants. In wind erosion too, the surface soil is lost and gets deposited in other fertile areas, thereby altering the fertility and nutrient as well as water holding capacities.

4.2 Wind Erosion: It implies uniform displacement of topsoil by wind action. It can result in loss of topsoil and the deposition of the eroded material elsewhere leads to formation of dunes. The uniform displacement of topsoil by wind action occurs in thin layers / sheets. The uneven displacement of soil material by wind action leads to deflation hollows and the dunes. The lifted medium to coarse soil particles may reduce the productivity of adjacent fertile land when they are deposited in the form of sand castings.

4.3 Water logging: Water logging is considered as physical deterioration of land. It is affected by excessive ponding / logging of water for quite some period and affects the productivity of land or reduces the choice of taking crops. Either because of topography, flooding or poor drainage condition, and water logging occurs in some areas.

4.4 Salinization / Alkalization: Salinization and alkalization are problems of semiarid and arid areas. They could be of natural or man-made. This is a major problem resulting in the desiccation of plants due to high osmotic potential exerted on plant because of high concentration of salts. While, salinization is mostly associated with the coastal areas and younger alluvial plains, alkalization happens mostly in inlands and older alluvial plains. Generally, alkalization is associated with water logging due to poor permeability of soil by the presence of sodium. Salinization can result from improper management of canal irrigation water, resulting in the rise of the water table.

4.5 Acidification: Any soil process or management practices which lead to the buildup of hydrogen cations (also called protons) in the soil will result in soil acidification. It also occurs when base cations such as Calcium, Magnesium, Potassium and Sodium are lost from the soil leading to high hydrogen ion concentration. This results in decrease of soil pH below 6.5. Increasing acidity through selective removal of calcium cations on the exchange complex affects the balance in nutrient availability. It generally occurs in regions of very high rainfall.

4.6 Glacial: These are the areas under perpetual snow covered areas. It degrades an area by two processes, namely frost heaving and frost shattering. Frost heaving is defined as a process in glacial and periglacial environment where intense frost action and freezing of water evolves peculiar forms of rock, regolith and soil. The water crystallizes to ice below the surface horizon leading to micro-relief variations on the surface. This process affects the germination and root growth of several crops thereby limiting the productivity of land. Generally, these regions remain fallow during winters.

4.7 Anthropogenic**:** Human economic activities like mining, industries, etc., have also contributed to decreased biological productivity, diversity and resilience of the land. Mining, brick kiln activities and industrial effluent affected areas are included under this type of degradation. Nutrient depletion or nutrient mining from fertile agricultural fields, without replacement through manure or fertilizer, results in nutrient deficiencies. Hence, the top fertile soil is almost permanently lost, if not properly conserved. Chemical toxicity from industrial effluents and soil contaminated with poisonous chemicals affects the plant growth significantly.

4.8 Others: Some of the degraded lands, which could not be included in the above type of land degradation, are included here. They are mass movement/ mass wastage, barren, rocky / stony waste areas, riverine sand areas, sea ingression areas. According to Food and Agriculture Organization (FAO) of the United Nations (FAO, 1992), the various forms of land degradation such as soil erosion, chemical poisoning, stalinization and loss through building or mining is about 5 to 7 Mha from good cultivable lands.

4. Distribution of wasteland in India

The problem of wasteland has become a serious issue in India and it has increased with the development of technology for increasing the agricultural production. According to Indian Wasteland Atlas (2010) the wasteland area is now increased to 24% of the total geographical area. Although several agencies have estimated the total extent of wastelands, the figures as well as their definitions vary considerably. Reliable information on location, nature and extent of different wastelands on a large scale is essential for launching a programme on wasteland development.

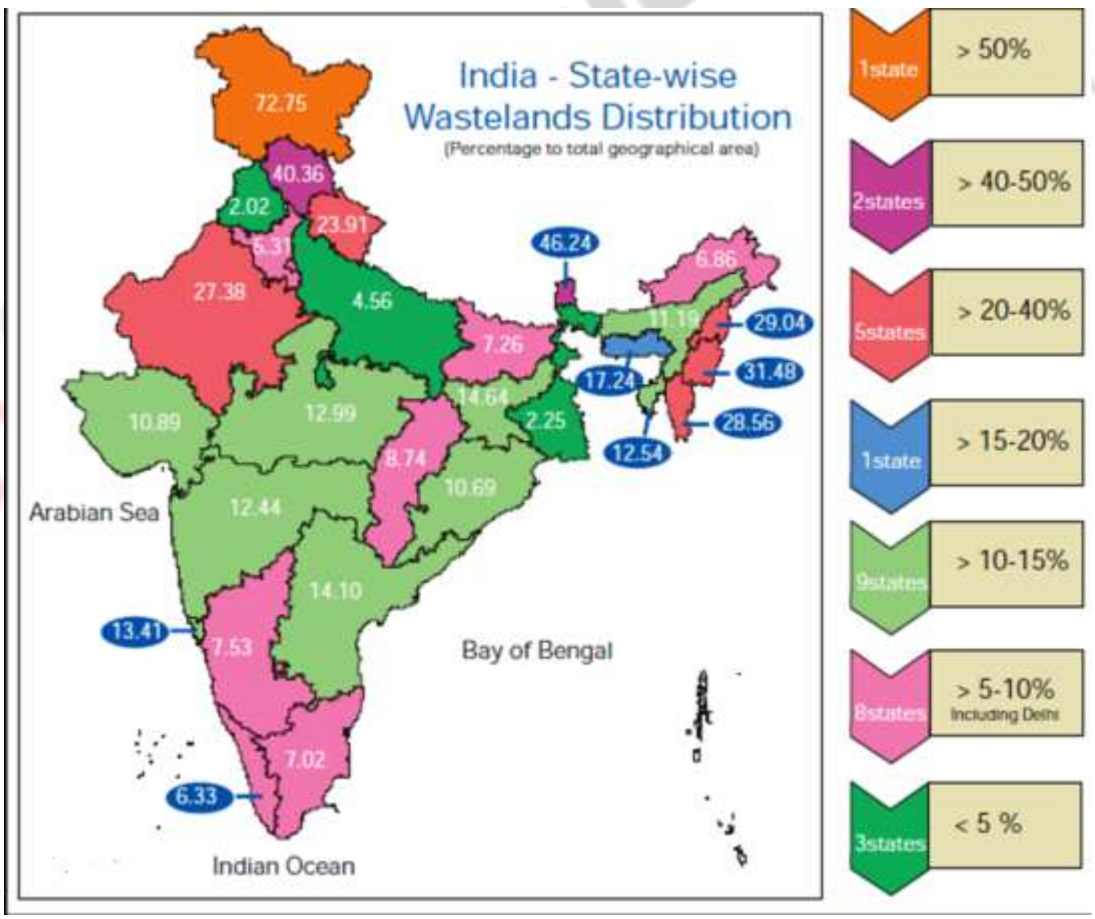


Figure: Showing the values of wastelands to the total geographical areas in different states.

If these wastelands could be brought under cultivation or other uses like afforestation and horticulture, it can help in the socioeconomic development of the people and accelerate the overall economic growth of the country. Approximately 175 million hectares of land are degraded India has total 329 million hectares (mha) of land. The extent of land under agriculture is 143 mha & again 56% of this suffers from varying degrees of degradation. However land degradation due to desertification, soil salinity, water logging, floods/drought, excessive soil erosion due to deforestation, unscientific agricultural practices etc. have resulted in the creation of vast stretches of wastelands and a decrease in per capita cultivable land besides ecological imbalance. Nearly 53 million hectares (Mha) are wasteland and 22 Mha of land have problems of salinity, alkalinity, soil erosion, water logging, shifting cultivation or presently unused because of their undulating nature. The land area prone to floods has doubled from 20 Mha to about 40 Mha in last 10 years. Awareness of this fact has resulted in the formation of the "National Wasteland Development Board" (NWDB) under the auspices of National Land use and Wasteland Development Council (NLWC). The wastelands statistics indicated that about 63.85 million hectares of land, which account for 20.17% of the total geographical area (328.72 million hectares), exist as wastelands in India, National Remote Sensing Agency (NRSA, 2007). Among all the states, Kerala has a minimum 3.73 percent and Jammu and Kashmir has a maximum 64.55 percent of area under wasteland categories.

5. Remote Sensing and wasteland mapping

Information on geographical location, aerial extent and spatial distribution of wastelands is essential for their effective management and sustainable development. Among the new technologies emerged for studying natural resources, remote and Geographical Information System (GIS) are effective technologies for detecting, assessing, mapping, and monitoring the wastelands. Space borne multispectral data, by virtue of providing synoptic views of fairly large areas at regular intervals, have been found to be very effective in providing the necessary information on salt-affected soils and waterlogged areas in a timely and cost-effective manner.

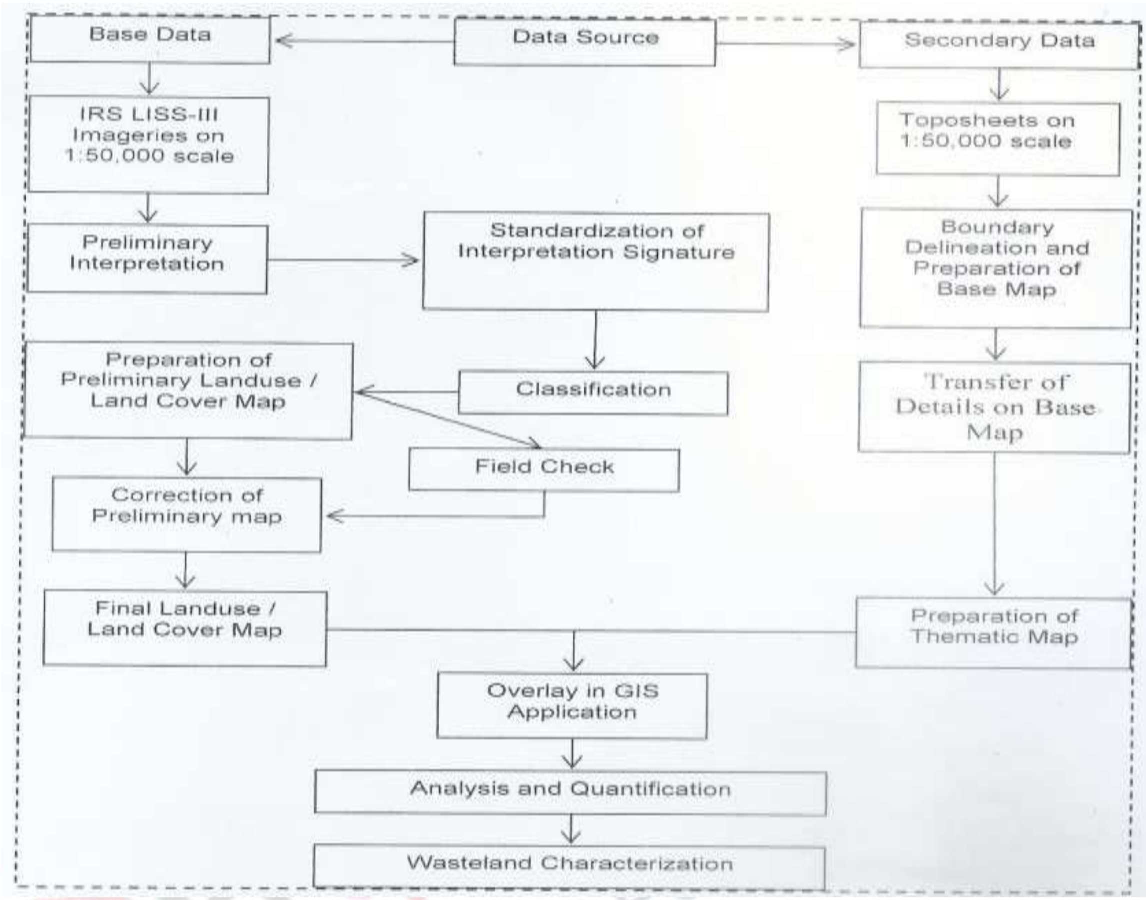
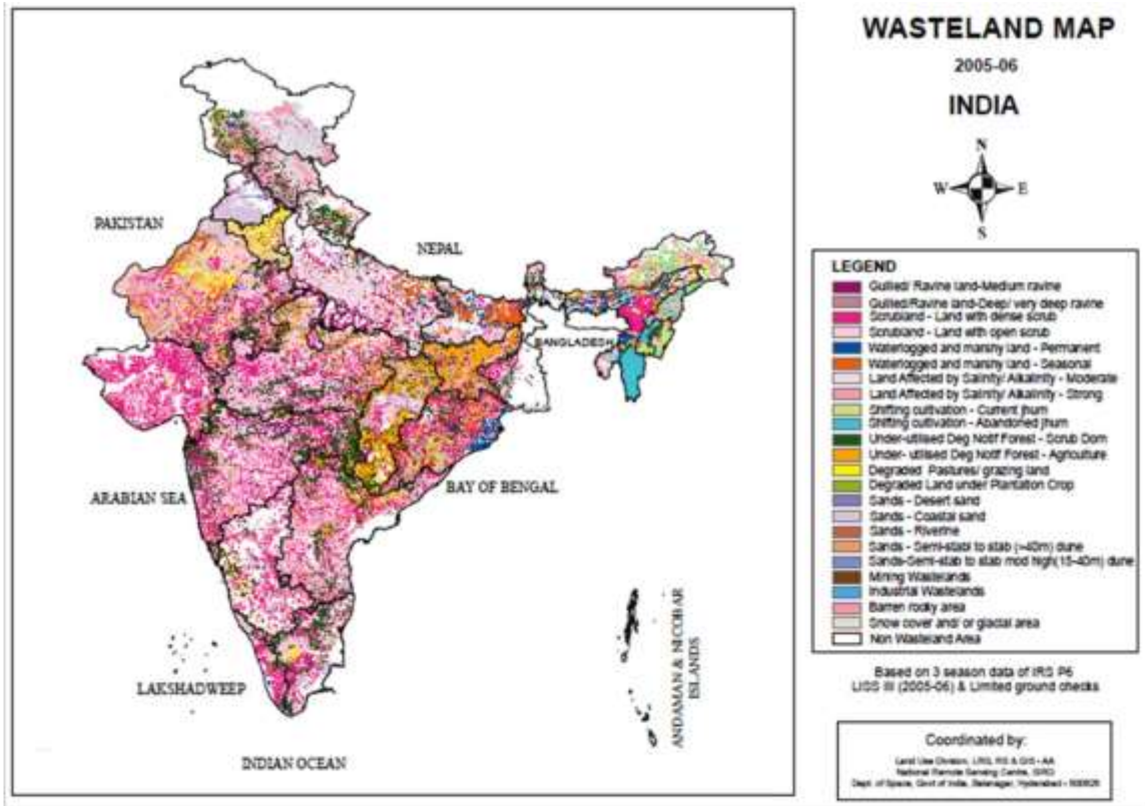


Figure: An overview of Wasteland mapping methodology (NRSC, 2000).

In the visual interpretation of satellite data, high soil moisture and surface waterlogged areas are identified as deep dark grey to light black in color described that areas with high water logging risk. To study the spatial dynamics of wastelands, and to evaluate the utility of high resolution satellite data for wasteland mapping, the IRS P6 satellite data(23.5x 23.5 m) and topographical maps are generally used (Scale = 1:50000). The dynamic nature of wasteland categories warrants the uses of multi-season satellite data for their accurate delineation. Hence, such images need to be geo-referenced in a common coordinate and projection system. The Planning Commission of India has recognized GIS as "*an invaluable planning tool in land use and wasteland development for identifying treatment areas and models, making trade-off calculations in choosing from competing land uses, and carrying out simulations and impact assessments. The management of "wastelands*" is a priority area in the context of national development. In 1991, the Ministry of Environment and Forest (MoEF) embarked upon an ambitious project to apply GIS technology for wasteland management. This was based on prior work carried in 1986 when the Department of Science (DoS) under the National Wasteland Identification Project developed detailed wasteland maps of 147 districts in the country with a 1:50,000 scale. In this project, a Task Force was identified to evolve a suitable wasteland classification system. The classification system evolved and approved by the Planning Commission comprises of the following categories (NWDB, 1987):

i. Gullied and/or ravenous land
ii. Upland with or without scrub
iii. Waterlogged and marshy land
iv. Land affected by salinity/alkalinity(coastal or inland)
v. Shifting cultivation area
vi. Sandy (desert or coastal)
vii. Mining/industrial wastelands
viii. Under-utilized/degraded notified forest land
ix. Degraded pasatures/grazing land
x. Degraded land under plantation crops
xi. Barren rocky/stony wastes/sheet-rock areas
xii. Steep-sloping areas, and
xiii. Snow covered and/or glacial areas

The application of remotely sensed data in mapping degraded lands space borne sensors started with the launch of the first Earth Resources Technology Satellite (ERTS-1 / Landsat-1). However, the satellites Landsat-TM, SPOT and Indian Remote Sensing (IRS) Satellites with better spatial and spectral resolution, enabled to map and monitor degraded lands more efficiently. GIS proved to be an effective tool in handling spatial data available at different scales, voluminous point data such as soil information, rainfall, temperature etc. and socioeconomic data and to perform integrated analysis of data on various resources of any region and to arrive at optimum solutions for various problems.



Remote sensing imagery is vital for the understanding of land cover change, and thus forms an essential element of any effort to track land degradation and desertification trends. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. These studies may be helpful for the planners and stack holders in the process of overall sustainable development of the study area. For detection of temporal changes in the wastelands, two period data sets i.e., IRS, *Linear Imaging Self-Scanning* (LISS III) are used. The geo-database generated using Arc GIS and on screen digitization techniques, shows the type, extent and spatial distribution of different wasteland categories present in the area. The procedure involved in wasteland mapping using satellite data consists of input data, preparatory work and methodology. The methodology normally adopted for mapping at any scale consists of preparation of base map, on –line visual interpretation of satellite data, development of legend, ground truth collection, analysis of soil samples, classification of degradation classes and finalization of maps in light of field information and analytical data. Thus, geocoded FCC products on 1:50000 scale are used for visual interpretation. The image characteristics, such as colour, tone, texture, pattern, shape, size, location and association enable one to identify and delineate different types of wastelands. These delineations, however, are tentative and subject to confirmation in the field. Therefore, ground truth forms a vital input to mapping with remote sensing data. The key for interpretation is subject to changes depending upon the season, scale and resolution of the imagery. Certain categories of wastelands like salt-affected land, water-logged/ marshy land and sandy areas can be easily delineated by virtue of their spectral separability, pattern and location; whereas gullied or ravenous land, shifting cultivation etc. can be delineated with moderate success. However, undulating upland with or without scrub cannot be easily delineateddue to similar reflectance pattern with fallow land. The issue can be resolved to some extent using multidate images.

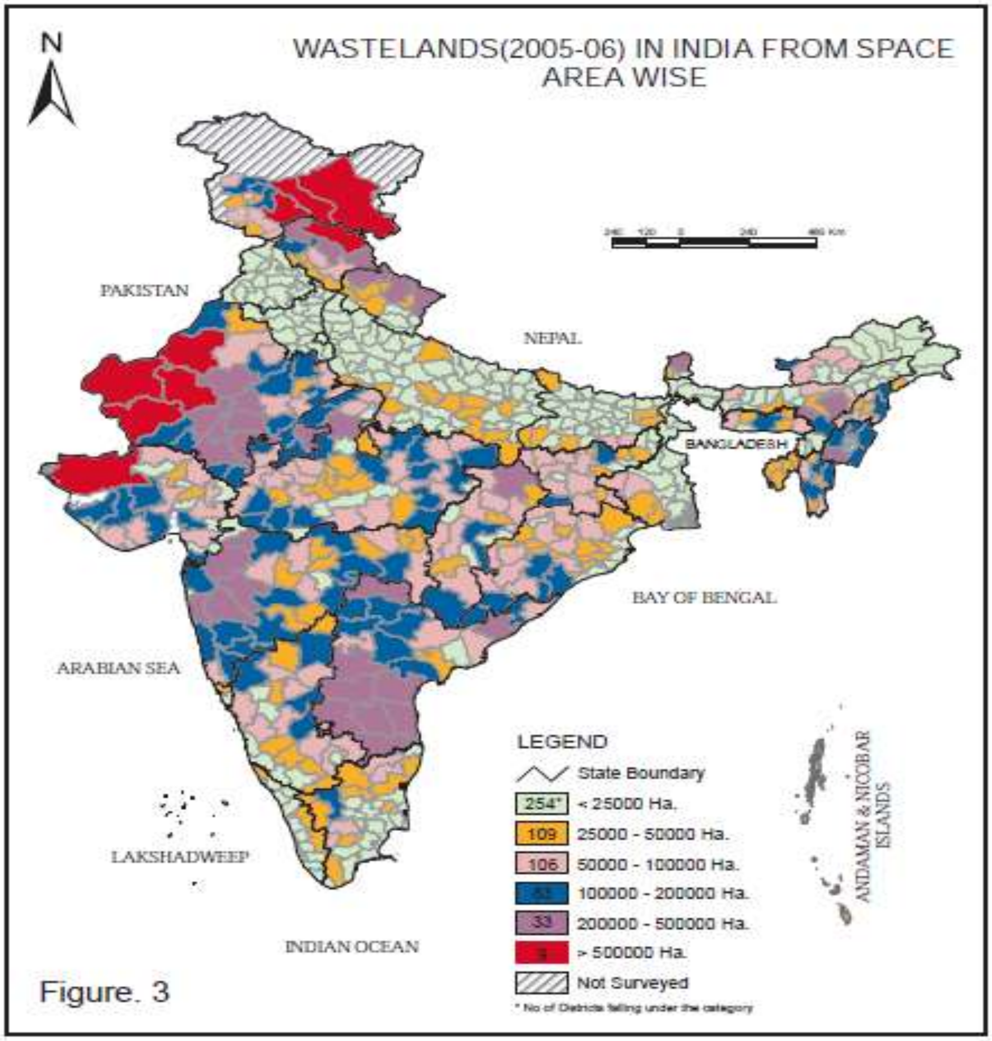


Figure 3: Area-wise Wasteland Map of India (Source:- 1:50000 Wasteland maps)

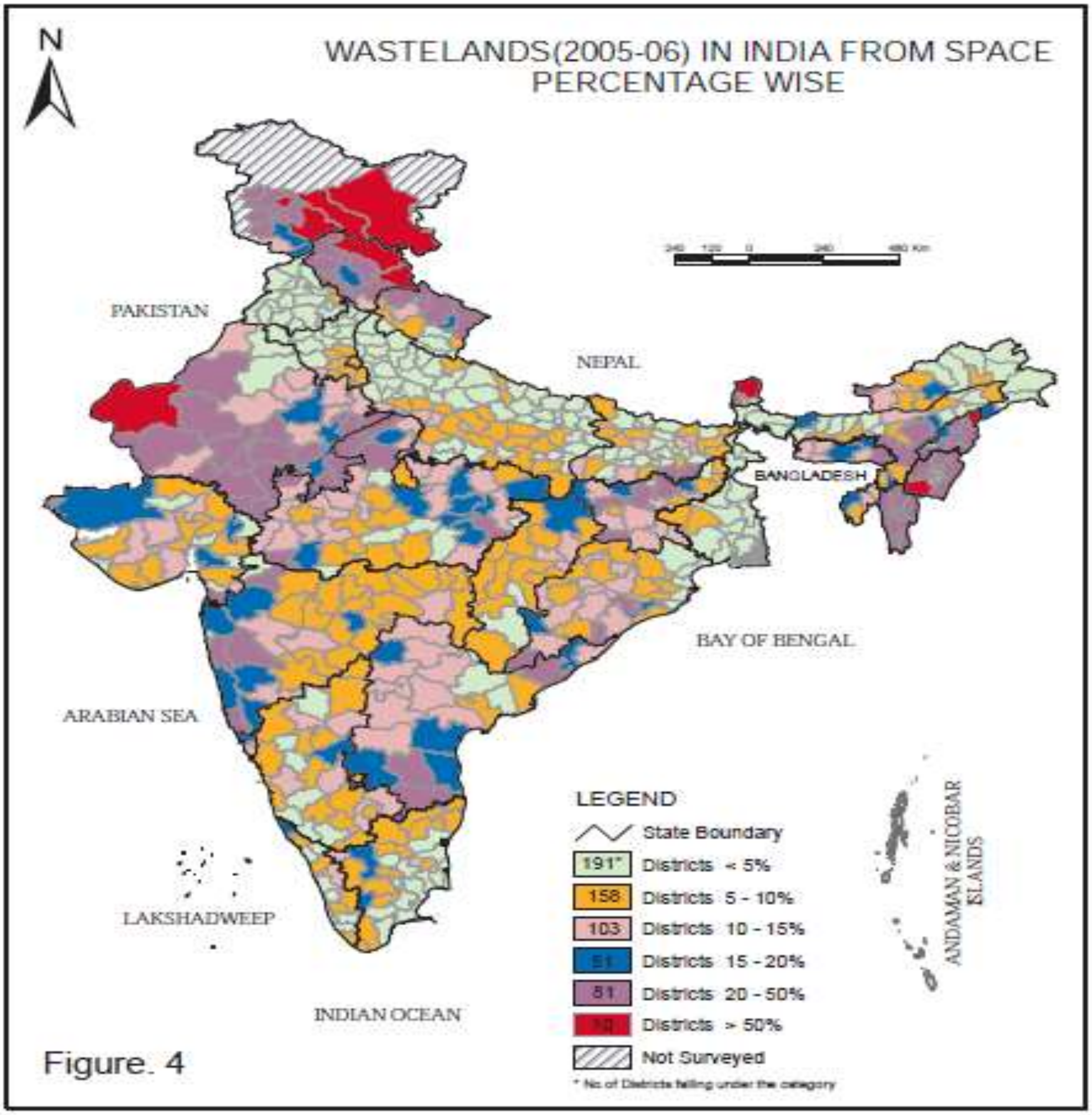


Figure 4: Wasteland Map of India (Source:- 1:50000 Wasteland maps)

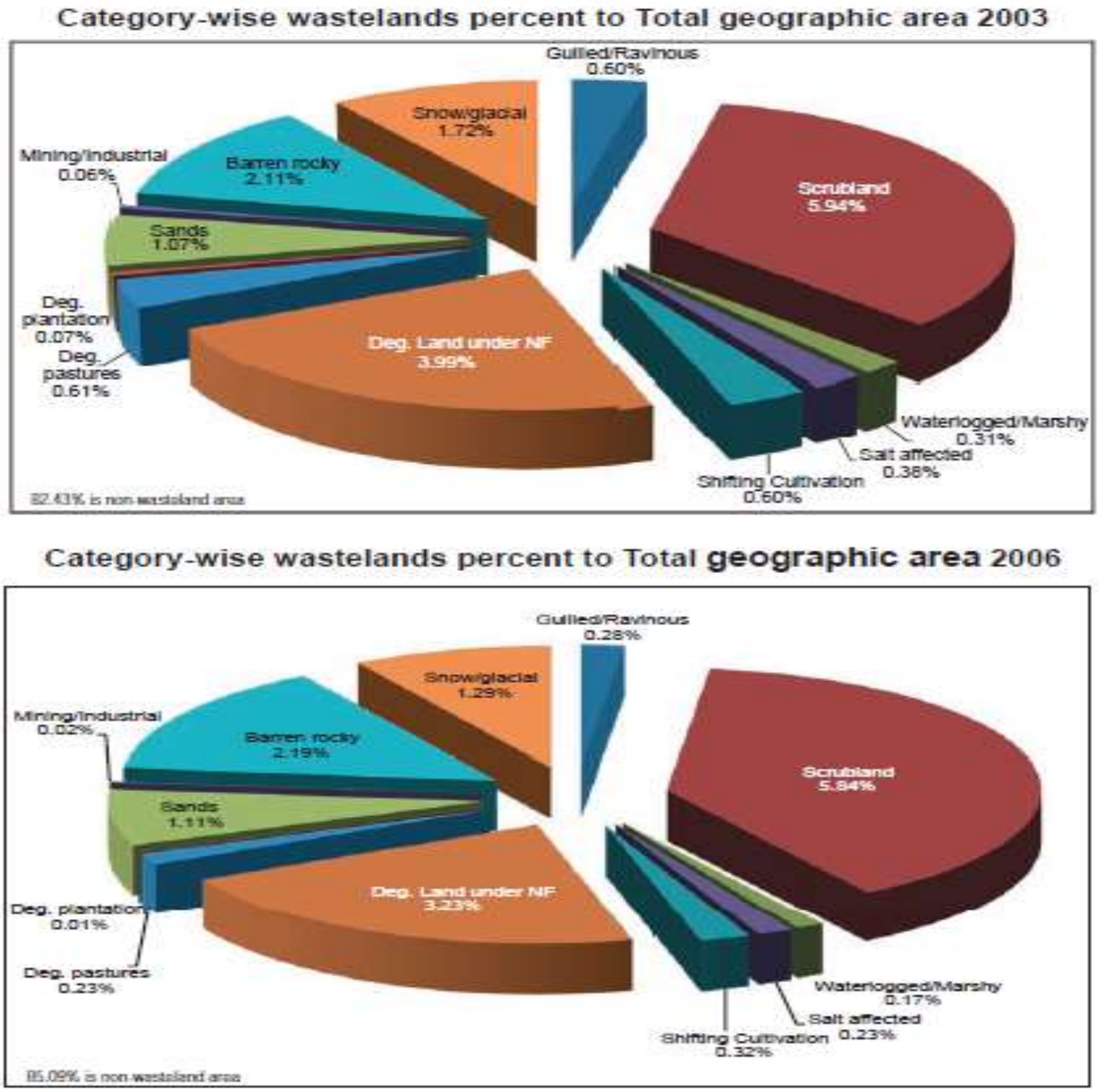


Figure 5: Category-wise Wasteland to TGA (Source: Wasteland Atlas of India,2010)

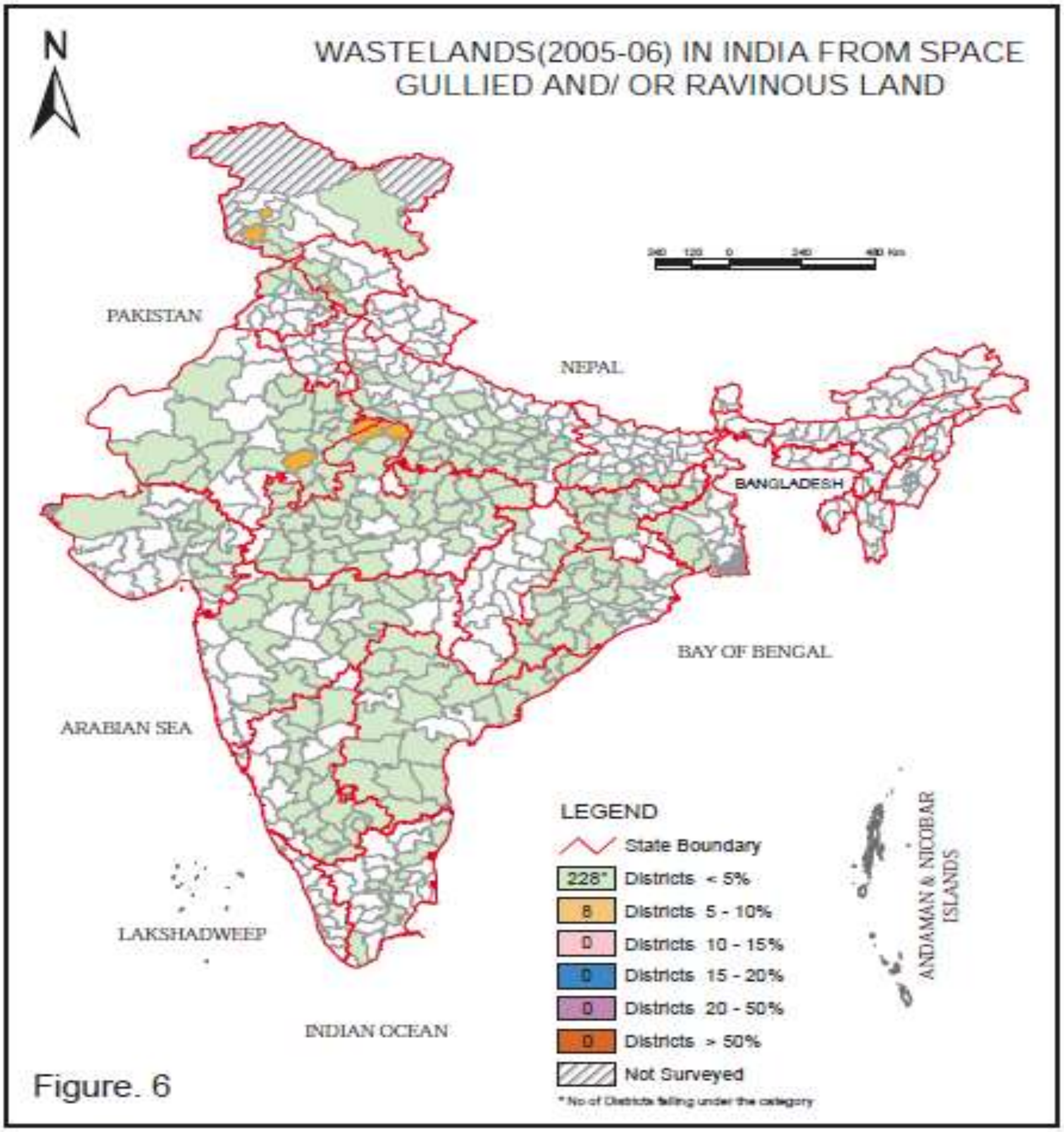


Figure 6: Gullied and/or Ravinous Land

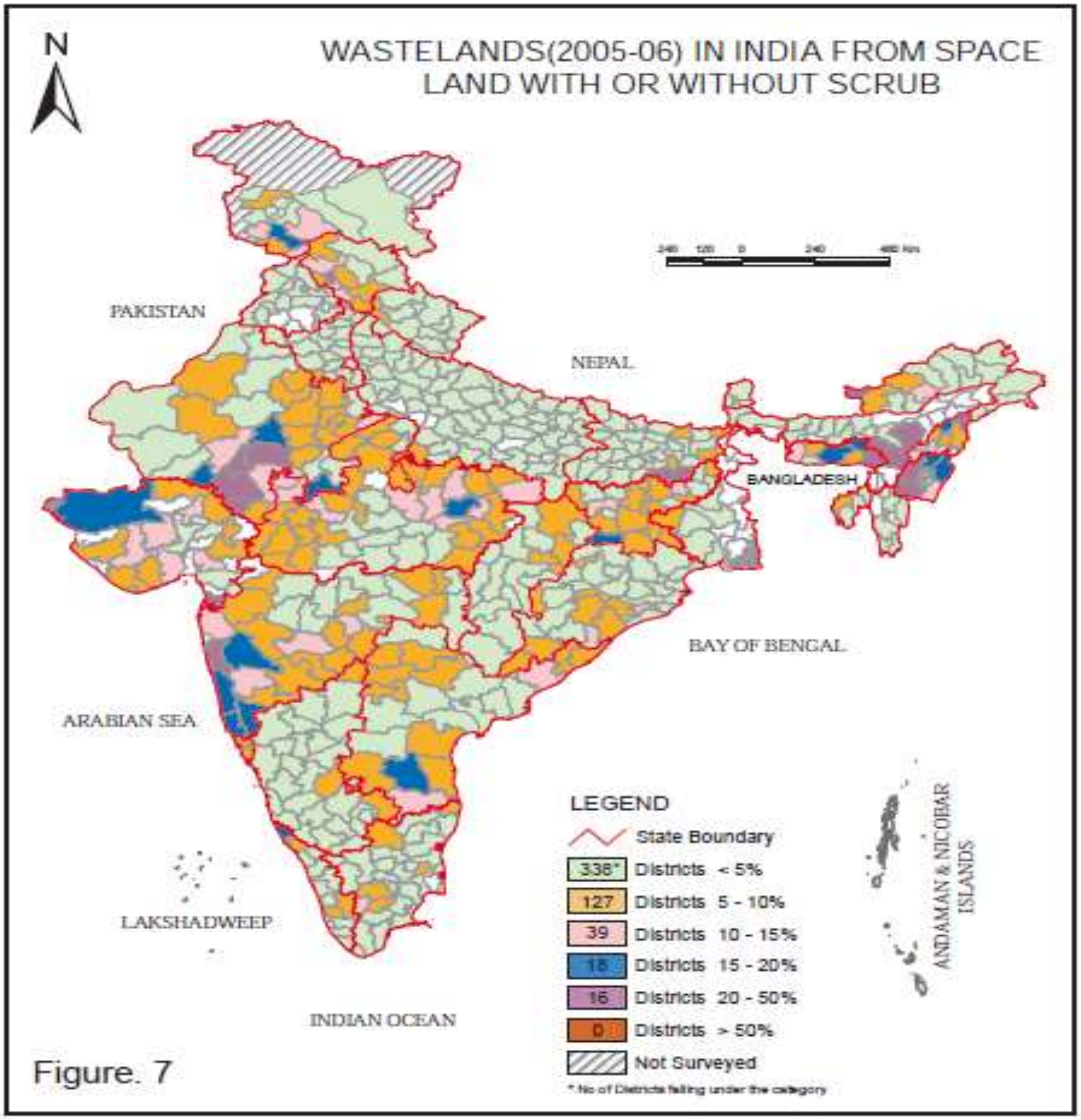


Figure 7: Land with or without scrub

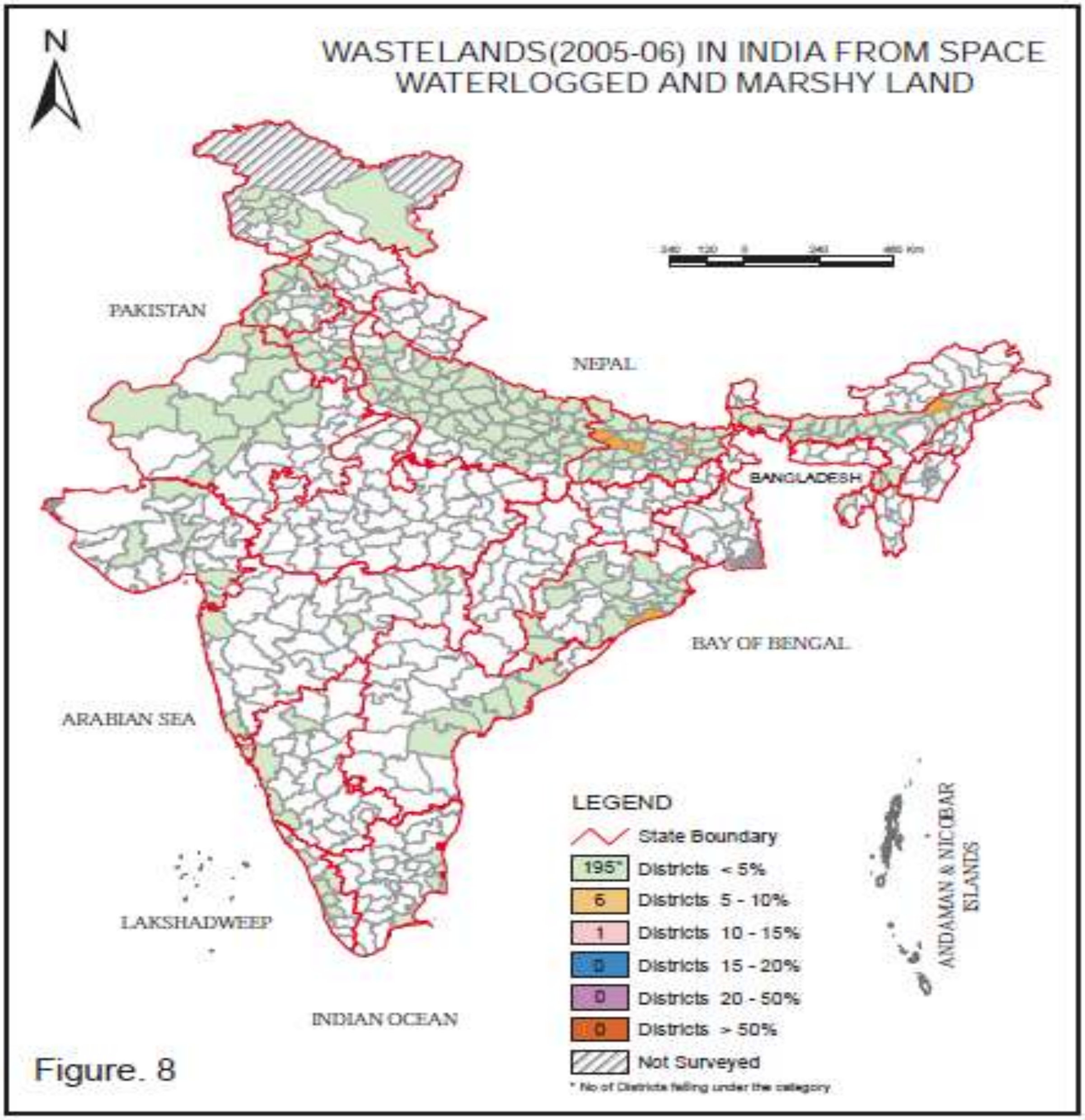


Figure 8: Waterlogged and Marshy Land

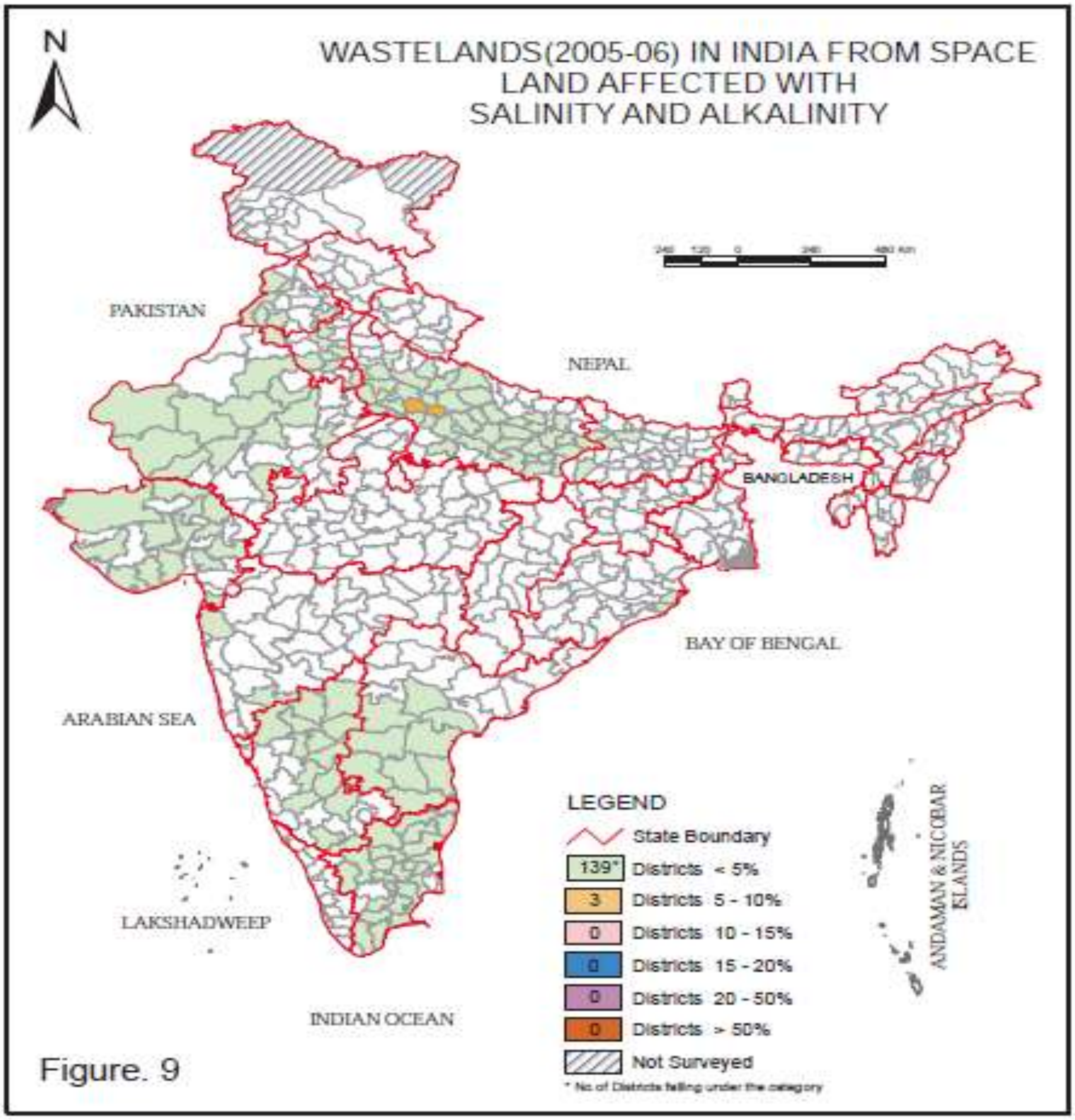


Figure 9: Land affected with salinity and alkalinity

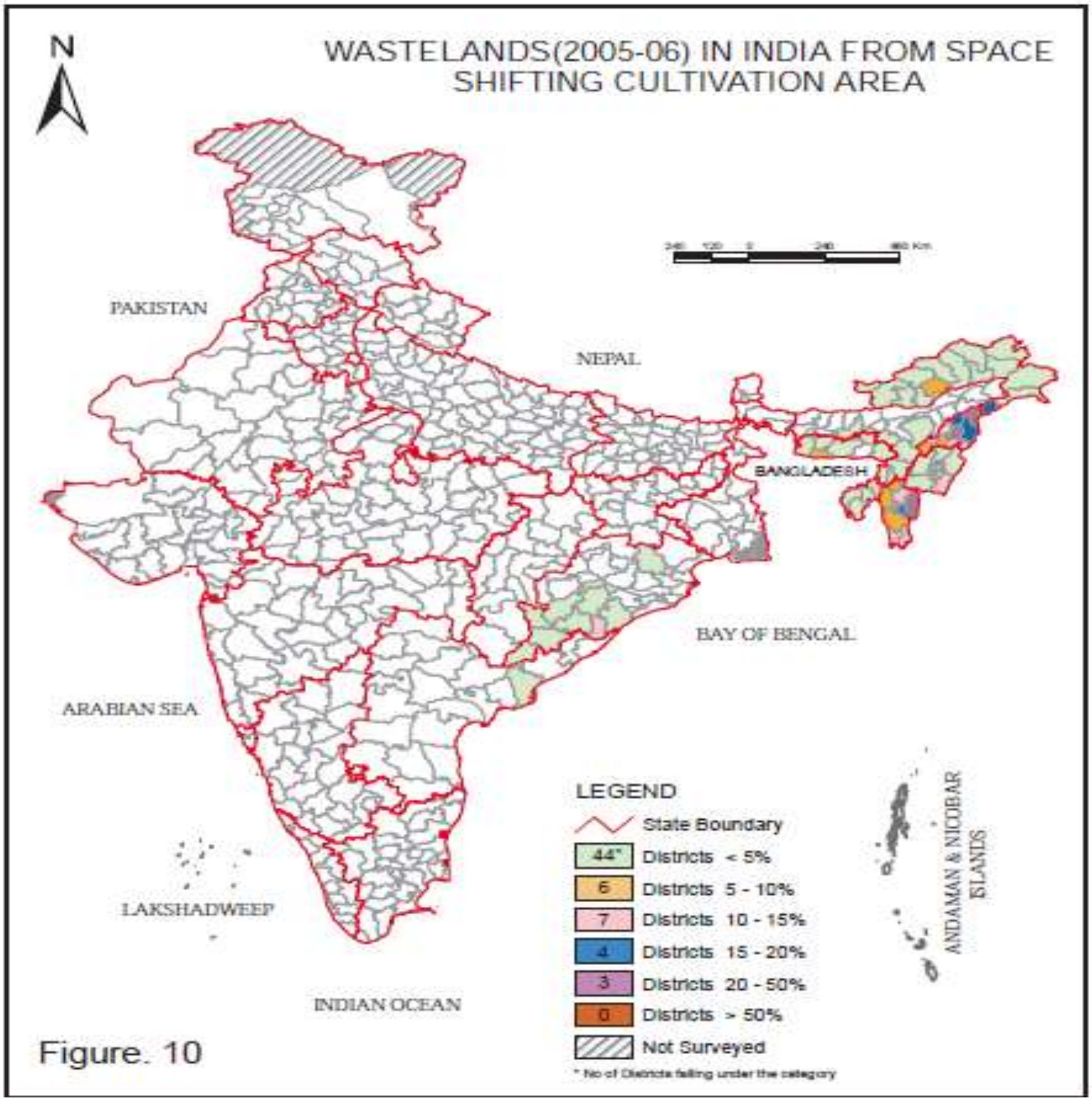


Figure 10: Shifting Cultivation Area

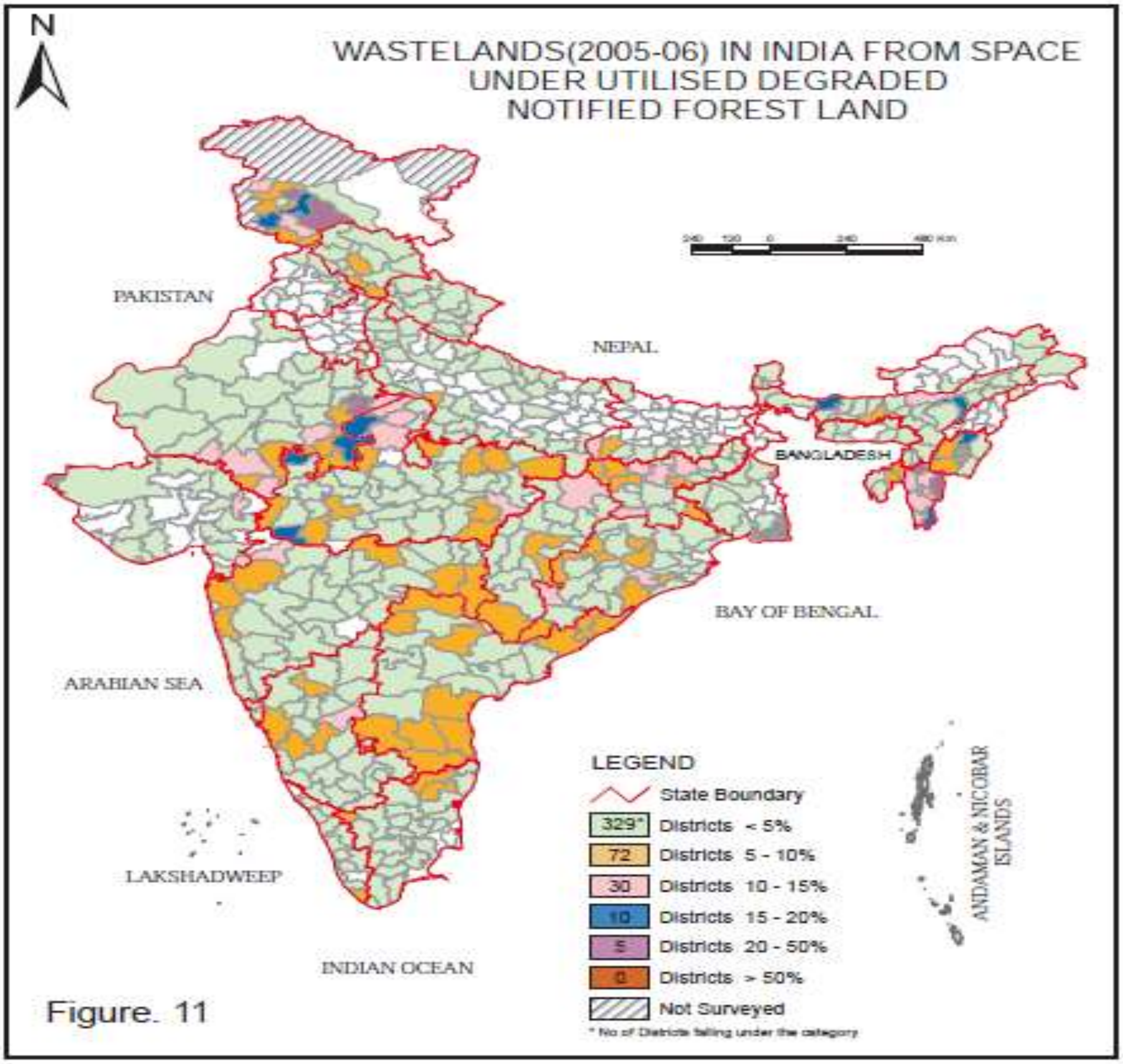


Figure 11: Under-utilised degraded Notified Forest Land

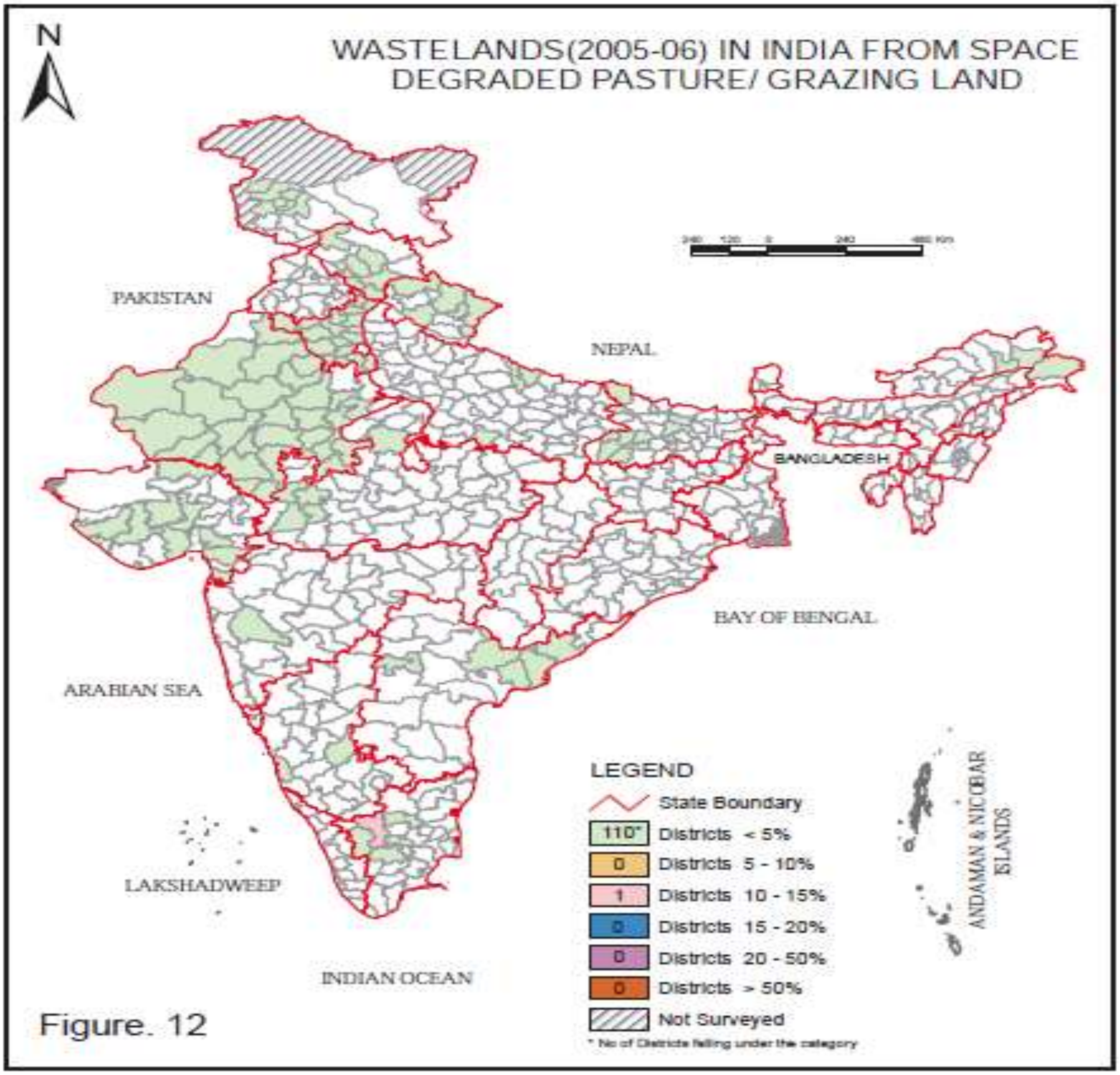


Figure 12: Degraded Pasture/Grazing Land

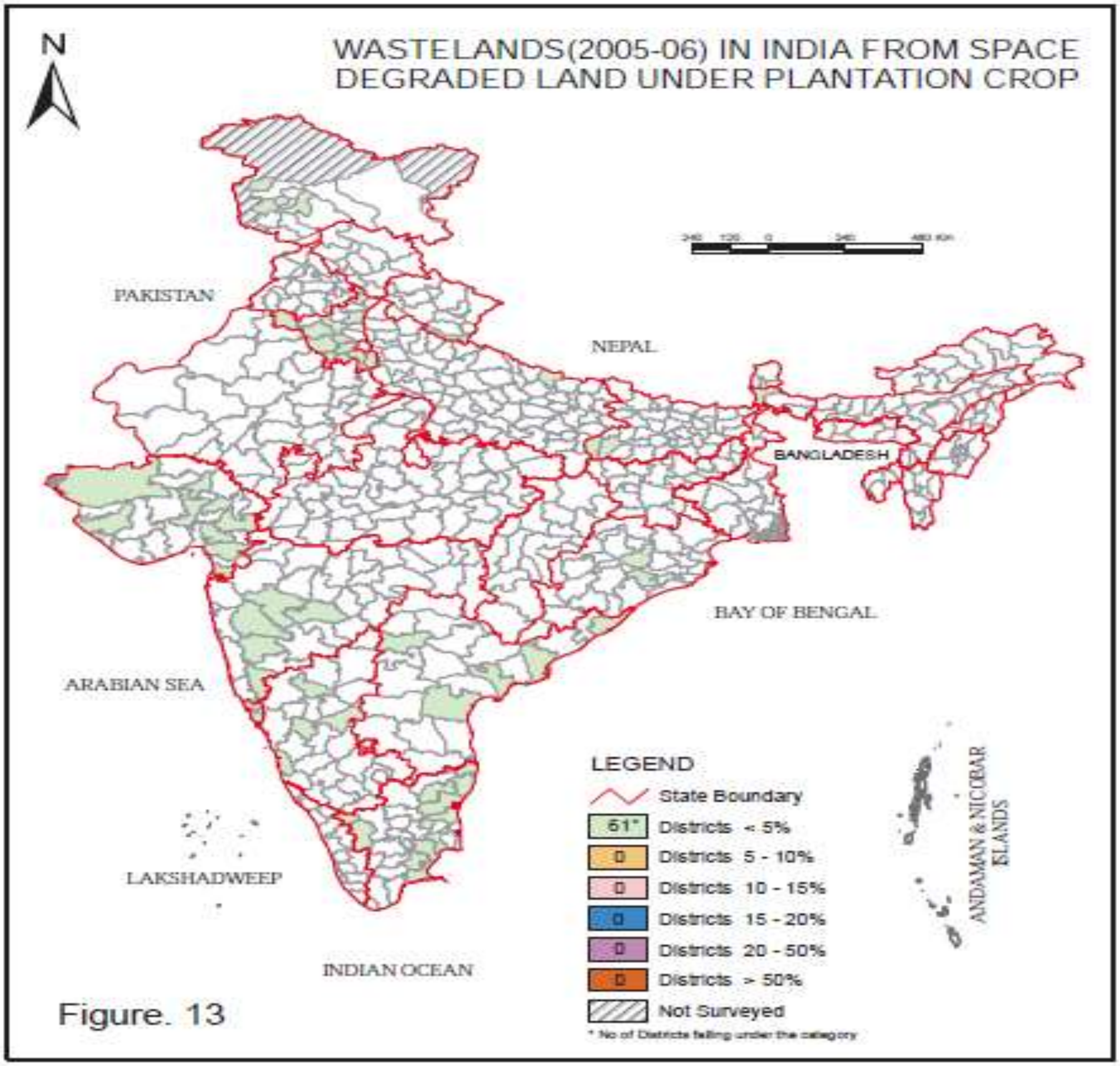


Figure 13: Degraded Land under Plantation Crop

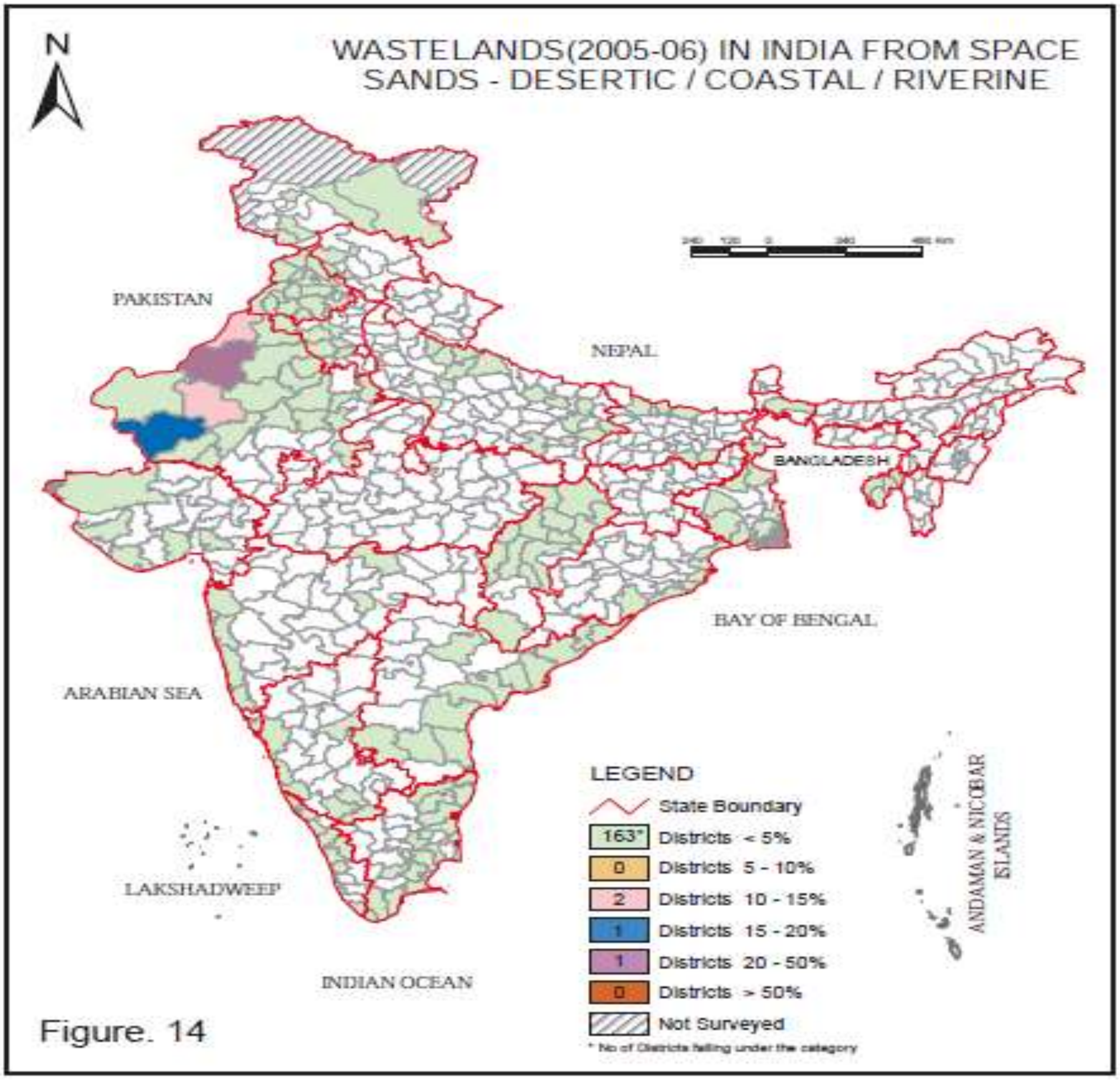


Figure 14: Sands- Desertic/ Coastal/ Riverine

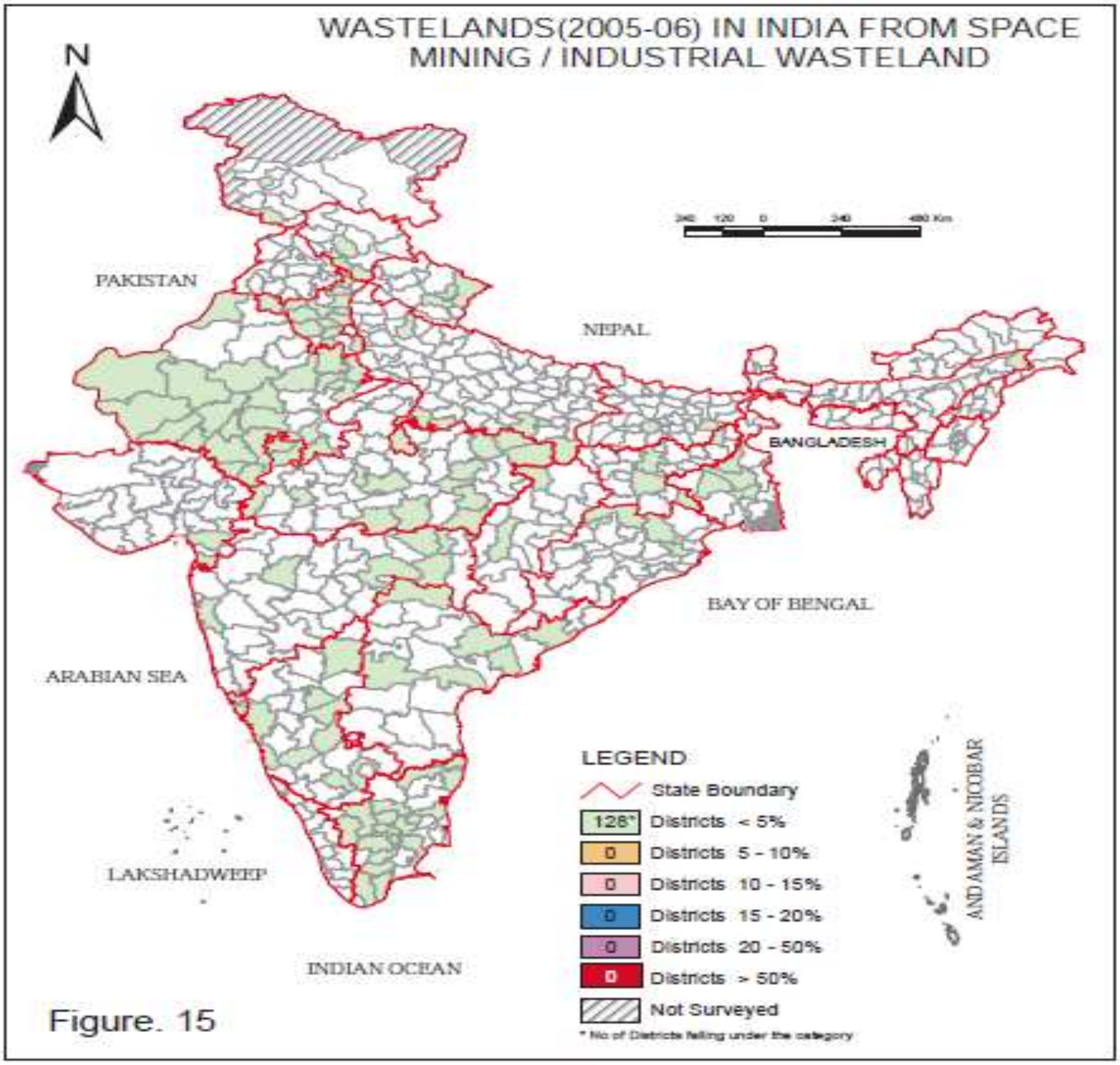


Figure 15: Mining/Industrial Wasteland

6. Inventory of wastelands in India

Using space-borne multi-spectral data, maps, showing extent, spatial distribution and magnitude of eroded lands, salt-affected soils, waterlogged areas, shifting cultivation, to name a few, at 1:250,000 and 1:50,000 scales have been generated. The saline soils appear in different shades of white tone with fine to coarse texture on the False Colour Composite (FCC) prints of the satellite data, owing to presence of the salts, and are recognizable under normal crop growth. For assessing these soils, the National Remote Sensing Agency has prepared maps on 1 : 250,000 scale using satellite data from Landsat *Thematic Mapper* (TM)/IRS sensors in association with other central and state government organizations. A digital atlas for India has been prepared. This information is being used for planning land reclamation and soil conservation programmes. Estimated area of wastelands in the country stands at 63.85 million hectares. Each maps shows village, forest compartment and micro watershed boundaries. Following 13 categories of wastelands can be identified and mapped on 1:50, 0000 scale using Remote Sensing technology.

Sl. No	**Categories**	**% of total geographical area covered**
1.	Gullied and/or ravinous land	0.65
2.	Land with or without scrub	6.13
3.	Waterlogged and marshy land	0.52
4.	Land affected by salinity/alkalinity coastal/inland	0.65
5.	Shifting cultivation area	1.11
6.	Underutilized /degraded notified forest land	4.44
7.	Degraded pastures/grazing land	0.82
8.	Degraded land under plantation crops	0.18
9.	Sands-Desertic/coastal	1.58
10.	Mining/industrial wastelands	0.04
11.	Barren rocky/stony waste/sheet rock area	2.04
12.	Steep sloping area	0.24
13.	Snow covered and/or glacial area	1.76

	Total waste land area	**20.17**

For mapping wastelands, both visual as well as digital analyses of satellite data were undertaken. In all 532 districts out of 584 districts were covered by visual analysis of satellite data and remaining 52 districts were mapped using digital analysis. Various categories of wastelands were identified and mapped based on image characteristics such as tone, colour, texture, pattern, shape, size and association. Apart from the wasteland categories, transport network (roads, railways), habitations and village boundaries were shown on the final maps so that the planners can easily locate various wastelands on the ground at the time of formulation and execution of various projects related to management and reclamation of wastelands.

6.1 Barren lands: those ecosystems in which less than one third of the area has vegetation or other cover. In general, Barren land has thin soil, sand or rocks. It is unsuitable for Agriculture, due to both climatic and terrain factors such lands will be deteriorating and needs soil management.

6.2 Salt affected area: this land is generally characterized as the land that has an adverse effect on the most of the plants. These are found in river plains and in associated with irrigated lands. The salt affected land is generally characterized as the land that has adverse effects on the growth of plants due to the excessive presence of soluble or high exchangeable Sodium.

6.3 Gullied land: Gullies are narrow and deep channels developed as a result of wearing away of soil by running water. Gullies develop from the rills which are tiny channels a few centimeters deep, formed by the impact of rainfall and wearing action of runoff generated.

6.4 Sandy areas: Composed of or covered with relatively large particles; granular and occur as a sandy plain in the form of sand dunes, beach sands and dune (wind blown) sands.

6.5 Stony waste: these are the rock exposure often barren and devoid of soil cover and vegetation, and not suitable for cultivation. It also does not support ground water recharge and habitat for ground flora and fauna.

6.6 Land with or without Scrub: Scrub is a landscape; need to exclude areas which are not capable of being grazed. Scrub lands are seen along the ridges and valley complex, linear ridges and steep slope areas. Most of these areas are characterized by the presence of thorny scrub and herb species; many hillocks of steep and dome shaped are associated with poor vegetal cover. Land under this class is generally prone to degradation/deterioration and may not have scrub cover. Generally it is confined to uplands.

7. Wasteland reclamation

There is an urgent need to reverse the trend of wasteland generation and restore the wastelands to their production potential in order to meet the demands of increasing population and other developmental activities.

Remote sensing also forms a critical element in early warning systems for drought and famine. Many national reports to the United Nations Convention to Combat Desertification now feature estimates of land degradation based on remote sensing data. Planning for development of degraded lands including erosion affected and waterlogged soils calls for up-to-date information on their geographical location, aerial extent and spatial distribution, conventionally the information on different categories of wastelands is arrived at by compilation from village records, which is primarily statistical in nature.

Wasteland type	**Reclamation methods**	**Suggested land use**	**Remarks**
Gullied and / or ravenous land	Leveling of gullies or ravines construction of check dams	Afforestation, Food and fuel Agrohorticulture	Reduce erosion
Upland with or	Contour bunding	Natural generation of	Protection and

without scrub	Contour trenching Contour terracing	forest cover	survival of plants are very important.
Degraded/ underutilsed forest land	Regulate grazing activity. Restrict illegal forest felling	Terrace cultivation Permanent cultivation	
Stony wastelands	Regulate grazing activity	Pasture development	
Wet land	Passage to the logged water	Fish/Prawn faming	

In recent years, there has been an increased concern among planners in the country, on the types of wastelands and their precise spatial distribution and timely availability of the information. With the advent of remote sensing, a major technological breakthrough has happened in the method of acquiring information about natural resources. Land degradation study requires an accurate assessment of how wide spread it is, how severe the damage is and whether or not it is practically controllable or reversible.

8. Conclusion

The data derived from the Satellite and topographic studies have brought out the factor that wasteland should be managed properly. The potentiality of satellite imaginary for the preparation of accurate baseline information is well acknowledged and rose. The RS/GIS technology is the master tool in managing the wastelands of the country, starting from mapping, characterization, possible reasons, protection and reclamation of wastelands. At each step of management, RS/ GIS are economically sound, speedy and accurate method. Generation of human resource and skilled personnel having proper training on RS/GIS can contribute a lot in the entire process.

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