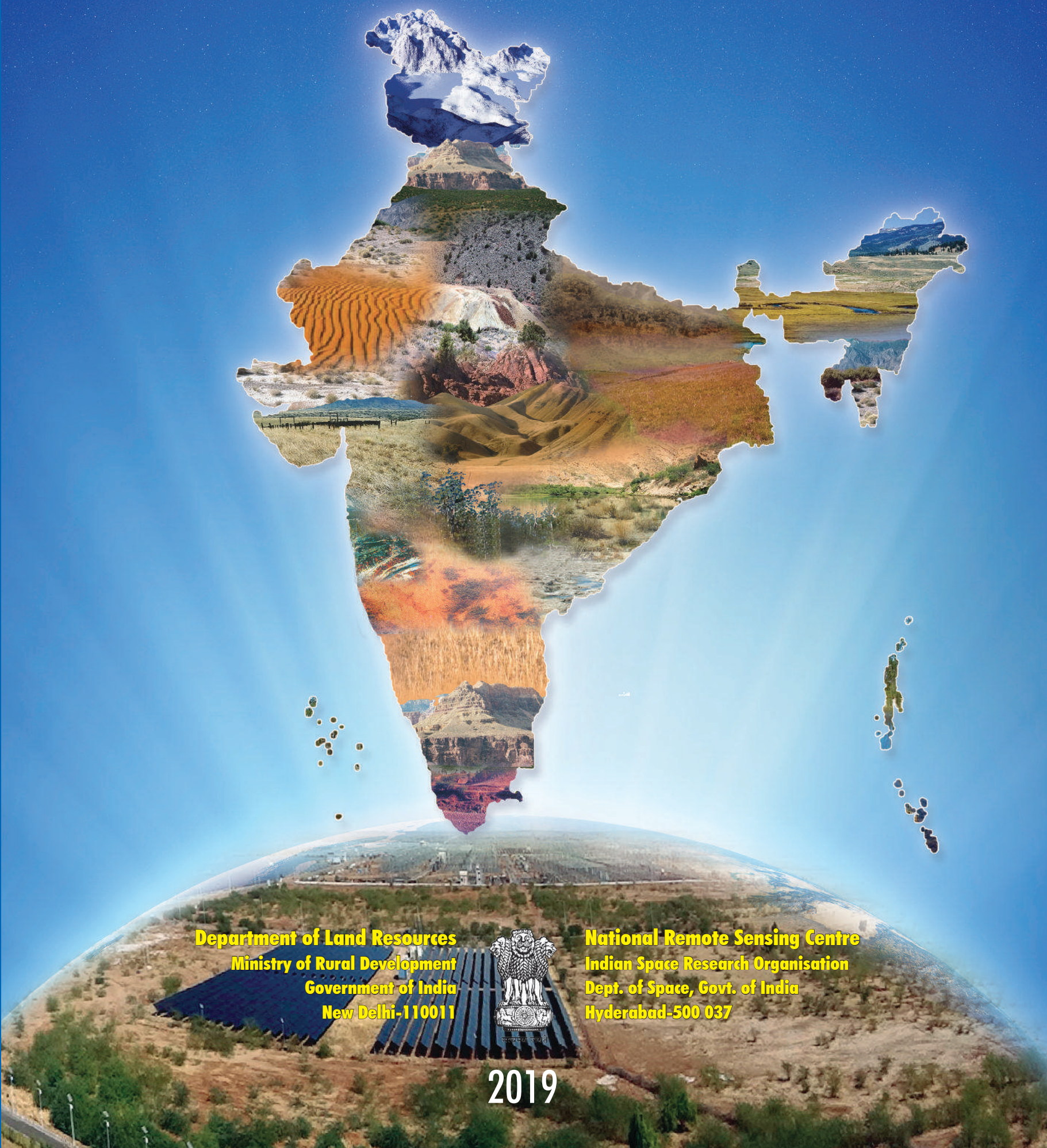
WASTELANDS ATLAS OF INDIA

nrsc

(Change Analysis Based on Temporal Satellite Data of 2008-09 and 2015-16)



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2019

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सत्यमेव जयते

कृषि एवं किसान कल्याण
ग्रामीण विकास तथा पंचायती राज मंत्री
भारत सरकार
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संदेश

मुझे यह जानकर खुशी है कि ग्रामीण विकास मंत्रालय, भारत सरकार के भूमि संसाधन विभाग द्वारा बंजर भूमि संबंधी अद्यतन सूचना पर आधारित "भारत का बंजर भूमि एटलस - 2019" के पांचवें संस्करण का प्रकाशन किया जा रहा है।

देश के भूमि संसाधन के अधिकतम उपयोग के लिए बंजर भूमि का वैज्ञानिक आकलन किया जाना अपेक्षित होता है। बंजर भूमि के संबंध में विश्वसनीय डाटा की उपलब्धता के महत्व को ध्याान में रखते हुए, राष्ट्रीय सुदूर संवेदन केन्द्र (एनआरएससी) के सहयोग से भूमि संसाधन विभाग, ग्रामीण विकास मंत्रालय और अंतरिक्ष विभाग, सुदूर संवेदन सेटेलाइट डाटा का इस्तेमाल कर के देश की बंजर भूमि का आकलन करता रहा है और भारत का बंजर भूमि एटलस के नाम से इसका प्रकाशन वर्ष 2000, 2005, 2010 एवं 2011 में किया गया है।

इस संस्करण में बंजर भूमि की अनुमानित स्थानिक सीमा के आकलन के अलावा वाटरशेड विकास कार्यक्रम, बंजर भूमि जीर्णोद्धार कार्यकलाप, वनीकरण, नवीकरणीय उर्जा और उद्योगों के लिए स्थलों की पहचान, और कृषि क्षेत्र में फसलन तथा वृक्षारोपण आदि जैसे विविध क्षेत्रों के लिए उपयोग के लिए संदर्भ सामग्री को समाहित किया जाएगा। मुझे विश्वास है कि इस संस्करण में प्रकाशित की जा रही जानकारी और सूचनाएं देश में भूमि संसाधन के सतत प्रबंधन में बहुत उपयोगी सिद्ध होंगी।

मैं राष्ट्रीय महत्व के इस कार्य को पूरा करने के लिए भूमि संसाधन विभाग और एनआरएससी / इसरो के अधिकारियों को बधाई देता हूं तथा "भारत का बंजर भूमि एटलस - 2019" के संस्कवरण के सफल प्रकाशन की कामना करता हूं।

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MESSAGE

I am immensely pleased to note that National Remote Sensing Centre (NRSC), ISRO, Department of Space and Department of Land Resources (DoLR), Ministry of Rural Development is bringing out "Wastelands Atlas of India-2019", based on the analysis of Indian remote sensing satellite data.

Wastelands assessment is being carried out by NRSC in association with DoLR, MoRD at regular interval since 1986. It has given spatial spread and changes happening in the spatial extent of wastelands in the country. Output from these wastelands mapping exercises has provided vital information for reclamation and afforestation in order to bring such areas under productive use.

I am sure that the wastelands atlas would provide useful inputs to identify specific areas for further reducing their extent. This will also help in identifying areas for productive use / greening, new infrastructure projects and potential solar farms for renewable energy and so on.

I convey my best wishes and congratulate the teams at DoLR and ISRO for this important endeavour which is of great value for national development.

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dt. 26th September, 2019

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FOREWORD

Land is a non-renewable finite resource which supports all primary production systems as well as basic social requirements such as infrastructure, transport and industries etc. India constitutes 17.71 percent of the World's population and 2.4 % of the geographical area. The ever-increasing population has resulted in gradual decrease in per capita availability of land, besides affecting it adversely making it underproductive / unproductive day by day. It is thus imperative on the part of policy makers to keep such precious and finite resources in healthy conditions to ensure basic ecological services unhindered, socio-economic and political security unquestioned and resilience to climate change unchallenged. It is in this background, a robust geospatial information on wastelands assumes utmost significance for devising strategies to bring back such wastelands into the productive folds once again.

Realising the importance of reliable database on wastelands, the Department of Land Resources in collaboration with National Remote Sensing Centre, Department of Space had published Wastelands Atlases of India in the years 2000, 2005, 2010 & 2011. According to these Wasteland Atlases of India, the extent of wastelands in the country was estimated to be 63.85 Mha in Atlas - 2000, 55.64 Mha in Atlas - 2005, 47.23 Mha in Atlas - 2010 and 46.70 Mha in Atlas - 2011.

I am delighted to learn that this is the fifth wastelands mapping exercise carried out by the NRSC/ISRO using Indian Remote Sensing Satellite data. This Atlas provides district and state-wise distribution of different categories of wasteland areas, including mapping of about 12.0849 Mha unmapped areas of Jammu & Kashmir. The changes in wastelands between 2008-09 and 2015-16 have also been well presented. This effort has resulted in estimating the spatial extent of wastelands for entire country and it is found to be 55.76 million hectares (16.96% of geographical area of the country i.e. 328.72 Mha) in the year 2015-16, as compared to 56.60 Mha (17.22%) in the year 2008-09.

I congratulate and compliment the Project Team of the NRSC/ISRO and the associated partners for their relentless efforts in bringing out this Atlas. I am confident that this publication will provide very important information on land resources and will facilitate formulation of suitable development programs in the country by various users at national, international, state government departments and non-governmental organization levels.

(Ruolkhumlien Buhril)

New Delhi
Date : 13th September, 2019

डॉ. कै. शिवन
Dr. K. Sivan

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व
सचिव, अन्तरिक्ष विभाग
Chairman, Space Commission
&
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PREFACE

The finite nature of land resources poses major challenge for food, water and environmental security in a farm - *dependent* economy like India. Development of Wastelands is one of the rnost viable options for improving land productivity. Considering the importance of natural resources inventory, DOS/ISRO has been regularly generating the geospatial information of wastelands at national scale for informed decision making.

In support of natural resources management and governance, ISRO has reasonably good constellation of earth observation satellites, providing periodical, synoptic and systematic information pertaining to land, water, ocean and others. Department of Land Resources (DOLR), Ministry of Rural Development has taken up the initiative to map wastelands of India and are the primary user of this database for planning and reclamation of wastelands.

National Remote Sensing Centre/ISRO has undertaken the delineation of wastelands at 1:50,000 scale since the year 1986 and has brought out Wastelands Atlases during year 2000, 2005, 2010 and 2011 depicting the types and spatial distribution of wastelands in the country. As a follow-up, wastelands change analysis for entire country was carried out by adopting standardized mapping protocols in the year 2008-09 and 2015-16. With this there are multi-time database that could enable very good time series analysis on the subject.

The atlas showcases the role of remote sensing as an indispensable component, in showcasing the landuse improvement feature in the country. The changes in wastelands between 2008-09 and 2015-16 have been well presented in the current atlas on a GIS domain. This national level effort has resulted in estimating the spatial extent of wastelands with regard to different years' data that enable varieties of data analytics with regard to the extent of wastelands in the country.

I am confident that this publication will immensely help the country in taking dynamic decision with regard to improved landuse.

My accolades to the entire project team including the state remote sensing centres, for the efforts in successful completion of these national level pursuit.

Date: September 18, 2019

(कै. शिवन / **K.Sivan**)

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PREAMBLE

It gives me great satisfaction to introduce the "Wastelands Atlas of India - 2019" (Change Analysis based on Temporal Satellite Data of 2008-09 and 2015-16). Till date four cycles of mapping wastelands were completed for the country using remote sensing satellite data on 1: 50,000 scale by National Remote Sensing Centre (NRSC) at the behest of Department of Land Resources (DoLR), Ministry of Rural Development (MoRD), Government of India (GOI). The first Wastelands Atlas was brought out in the year 2000, wherein 63.85 million hectares area was reported under wastelands with 13 classes as decided by a Task Force constituted by the National Wastelands Development Board (NWDB) under the chairmanship of Prof. M. G. K. Menon, the then Member (Science), Planning Commission, GOI. This exercise was carried out using rabi season Landsat TM / IRS LISS-II, LISS-III data on 1:50,000 scale. In the year 2005, the second Atlas was brought out, reporting an area of 55.64 million hectares under wastelands for the year 2003, with 28 classes as decided by a Committee chaired by the Additional Secretary, DoLR, MoRD.

The third exercise was carried out for the year 2005-06 and the atlas was brought out in the year 2010. In this exercise, the mapping protocol was standardized keeping 'open series map' policy for wider public use and also for the first time three season satellite data was employed in mapping wastelands where temporal behavior of wasteland classes was also taken into consideration. An area of 47.23 million hectares was reported under 23 classes of wastelands. Subsequently, wastelands mapping under fourth cycle for 2008-09 was carried out by adopting identical map projection and datum parameters, data sources, classification system, mapping methodology and digital database standards, as were adopted for 2005-06 study.

The current exercise of fifth cycle of wastelands mapping for the year 2015-16, synthesizes the catalytic role of remote sensing data for objective comparison of wastelands between 2008-09 and 2015-16. The changes in wastelands are well articulated and presented in the form of change matrices for better understanding.

The total wastelands area in the country was estimated to 5,57,66.51 Sq.Kms constituting to 16.96% of Total Geographical Area (TGA) in 2015-16 compared to 5,66,070.36 Sq.Kms (17.22% of TGA) in 2008-09 period. Thus, a total of 8,404.86 Sq.Kms area brought to non-wastelands class from 2008-09 to 2015-16.

The results of the study have been presented in an articulate format, which I am sure, as in the past, will be useful to all the stakeholders involved in wastelands mapping, monitoring and reclamation activities.

शांतनु Santanu Chowdhury

September 11, 2019

(Santanu Chowdhury)

भारतीय अन्तरिक्ष अनुसंधान संगठन इसरो isro **Indian Space Research Organisation**

ACKNOWLEDGEMENTS

Increasing population giving rise to pressure on demand for land based products / services which include agricultural as well as non agricultural purposes all over the world. In India, this demand for land has led to over-utilization of land resources regardless of their potential and limitations, resulting in the creation of vast stretches of wastelands. It has become imperative to identify lands suitable to create infrastructure, improve agriculture production, develop industrial zones etc.,. Thus, there is a persistent need of reclaiming those wastelands that have the potential for recuperation. The Department of Land Resources (DoLR) as the nodal agency in land resources management is striving to realize the same through various initiatives. Geospatial data generation of wastelands is one such enterprising step undertaken by National Remote Sensing Centre (NRSC) at the behest of DoLR, primarily to showcase their spatial distribution and changes across the country.

It is with great esteem that NRSC acknowledges the initiative of DoLR for entrusting this national level endeavor with its profuse support in funding this project. The Project Team would like to place on record the ardent support provided by Shri Ruolkhumlien Buhril, IAS, Secretary, Shri Anant Kumar Singh, IAS, Secretary (Former), Mrs. Veena Ish, Special Secretary (Former), Shri. Umakant, IFS, Joint Secretary (WM), Dr. C. P. Reddy, Deputy Commissioner, DoLR, Ministry of Rural Development in supporting this imposing national project.

On behalf of the entire Project Team, special note of gratitude is due to Dr. K. Sivan, Chairman, Indian Space Research Organisation and Secretary, Department of Space for evincing keen interest in the project. The Project Team is grateful to Shri. Santanu Chowdhury, Director, NRSC, for providing technical guidance and necessary facilities during the course of project execution.

Profound gratitude is due to Shri AS Kiran Kumar, former Chairman ISRO and Secretary, Department of Space, Dr. YVN Krishna Murthy and Dr. VK Dadhwal former Directors of NRSC, for their valuable guidance and abundant support in realising this project.

Accomplishment of a national project within a short time is a herculean task without the ardent support of all the State Remote Sensing Centres, Academia and allied institutions, Regional Remote Sensing Centres, North Eastern Space Applications Centre, across the country who obliged out-rightly to associate in this task. The Team acknowledges the unstinted support of Directors / Heads / General Managers and Scientists who burnt candles at both ends to accomplish this task.

Dr. T. Ravisankar, Dr. G. Ravi Shankar and all the Scientists from Land Use & Cover Monitoring Division deserve foremost commendation who stood the test of time with their inexhaustible stamina in completing the project. Thanks to Sri. P. V. Raju and Dr. Satish Ch. Jayanthi for meticulously going through the manuscript.

Thanks are due to Dr. N. Aparna, Group Head, NRSC Data Centre and her team who worked against the clock in satellite data planning and procurement required for the project.

Our special thanks go to the QC teams of NRSC for the untiring efforts in bringing out quality products of this project. Finally, our heartfelt thanks are due to all the Officials of DoLR and Officials of NRSC Administration, Finance & Accounts and Purchase & Stores for extending their valuable support in realizing this project.

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EXECUTIVE SUMMARY

National assessment of wastelands began in 1984 as a demonstrative exercise of remote sensing application for identification and mapping of wastelands in the country on 1:1 million scale. Thereafter NRSA/NRSC has become the principal organisation to provide national level geospatial information on wastelands at the behest of the Department of Land Resources, Government of India.

This was followed by two efforts to map Wastelands at 1:50,000 scale at national level for use in treating such wastelands through various programs. All these three efforts were made using satellite data acquired during single season (Rabi). However, from 2005-06 onwards, satellite data acquired during Three seasons viz., Kharif, Rabi and Zaid were used to harness its potential for understanding the temporal behavior of wastelands for their improved delineation and value-addition to the final output. A standard mapping protocol with 23 wastelands classes, amenable to change detection studies aligned towards DoLRs requirements was adopted in this exercise.

The first wastelands change analysis study with an overarching goal of comparison of wastelands classes between 2005-06 and 2008-09 was accomplished based on the exploratory analysis of multi-temporal satellite data acquired during this period.

The present atlas synthesizes the catalytic role of remote sensing data in highlighting geospatial changes in wastelands that happened between 2008-09 and 2015-16. Resourcesat LISS III data acquired during Kharif, Rabi and Zaid seasons during 2015-16 amounting to about 900 scenes have been used to accomplish this task. The vector layer generated for the year 2008-09 was updated using the satellite data of 2015-16. The change vectors were later confirmed with limited field checks before finalising the wastelands layer of 2015-16 and tabulated the results. These changes are well articulated and presented in the form of change matrices for better understanding.

The total wasteland area of the country was observed to be 5,57,665.51 sq. km. (16.96 % to TGA) in 2015-16, while it was 5,66,070.36 sq. km. in 2008-09 (17.22%). During this period 14536 sq. km. of wastelands are converted in to non wastelands categories. There is a net conversion of 8,404.86 sq. km. (0.26 %) of different wasteland categories in the country during 2008-09 to 2015-16. A reduction in wastelands area was observed in the categories of Land with Dense Scrub, Waterlogged and Marshy land, Sandy areas, Degraded pastures/grazing land and Gullied and/or ravinous land.

1.0 Introduction

Land is a ubiquitous resource which is primarily providing the requirements of the basic elements of the life support system of our planet. As the demand of the escalating population is increasing, the tendency to overexploit this pristine resource is robbed of its legendary resilience. As a key provider of food, water, shelter and employment, the land, especially the productive land, is subjected to coerce with tremendous pressure making it turn into wastelands. In order to increase the biomass production and to restore the environmental health, preventive and curative measures need to be employed for rehabilitation of wastelands / degraded lands. In order to ensure food security, there is an urgent need to improve the productivity of existing cultivated lands, and to bring additional land under plough. The wastelands which are unutilized and have potential to produce food grain and provide vegetation cover, may significantly contribute in this endeavor. Information on the nature, extent, severity and dynamics of degradation is vital in this endeavor.

1.1 Project Background

Wastelands were portrayed in a spatial form for the first time in the year 1984 by NRSA/NRSC on 1:1 Million scale, which was coincided with the formation of the National Wastelands Development Board (NWDB). A modest beginning was made by the Government of India to tackle the challenge and the need for treating such wastelands across the country. Based on the requisition, maps depicting the spatial distribution of wastelands at 1 : 50,000 scale were made available for the country at district level to plan reclamation measures spreading across the years 1986-2000, 2003 and 2005-06. However, for the first time, wastelands change analysis was attempted between 2005-06 and 2008-09 time periods which brought out objective comparison of wastelands across the country. At the behest of DoLR, Ministry of Rural Development, NRSC has undertaken the current task of wastelands change analysis using temporal satellite data of 2008-09 and 2015-16. The favourable outcome of this study can be ascribed to the use of standardized mapping protocol, identical datum and map projection parameters, co-registered three seasons satellite data of 23 metres resolution amenable for mapping at 1 : 50,000 scale. The classification system adopted during earlier exercises encompassing 23 classes, mapping methodology and digital database standards were adhered to in the current study. The unsurveyed area which hitherto was not able to be accomplished because of its in accessibility in the State of Jammu & Kashmir has been mapped in the current exercise, which was also updated for the year 2008-09. The limited ground data collection in these areas was well substituted by referring to high resolution satellite data. The influence of this is seen in slight increase in the area estimates of wastelands both in 2008-09 and 2015-16.

1.2 Goal and Objectives

The paramount goal of the current study is to articulate the spatial changes of different wastelands categories that happened between 2008-09 and 2015-16 for the country at 1 : 50,000 scale. Following are the detailed objectives that have been set forth for the study to further substantiate the above stated goal.

- Update wastelands maps of 2008 - 09 with 2015 -16 Resourcesat-2 LISS-III data and generate wastelands map of 2015-16;
- Identify and depict areas with major wastelands change between 2008 - 09 and 2015 -16;

- Creation of wastelands geospatial database and disseminating through Bhuvan geo-portal; and
- Preparation of wastelands category-wise spatial change statistics and summation in the form of atlas

1.3 Deliverables

Considering the project background and the primary intent of the project, following deliverables have been envisaged from the outcome of the project.

- Geospatial wastelands information and changes thereon between 2008-09 and 2015-16 at district-level
- State wise seamless geospatial wastelands information of 2015-16 for all the States and Union Territories.
- Atlas with maps and statistics.

2.0 Classification System

The wastelands classification system for 1: 50,000 scale that has been followed in the project is given in Table 1. In order to facilitate comparison between the two temporal wastelands vector datasets with respect to different classes and their spatial statistics and to identify the type of change, the number of wastelands classes in 2015-16 was kept the same as it was in 2008-09. Thus, the number of wastelands classes during both the mapping cycles remained 23. Nine non-wastelands classes have been shortlisted as the probable changes of wastelands to these classes during the course of change analysis (Table-2). The schema for classification was finalized after elaborate discussions with DoLR, MoRD. Feature codes for all the categories were discussed and finalized, keeping in view the NNRMS standard. The description of individual classes is given in Annexure-I.

Table – 1: Wastelands Classification system

S.No	Change Category	WL15-16
1	Gullied and/or ravinous land (Medium)	1
2	Gullied and/or ravinous land (Deep)	2
3	Land with Dense Scrub	3
4	Land with Open Scrub	4
5	Waterlogged and Marshy land (Permanent)	5
6	Waterlogged and Marshy land (Seasonal)	6
7	Land affected by salinity/alkalinity (Medium)	7
8	Land affected by salinity/alkalinity (Strong)	8
9	Shifting Cultivation Current Jhum	9
10	Shifting Cultivation Abandoned Jhum	10
11	Under - utilised/degraded forest (Scrub domain)	11
12	Under - utilised/degraded forest (Agriculture)	12
13	Degraded pastures/grazing land	13
14	Degraded land under plantation crop	14
15	Sands Riverine	15

S.No	Change Category	WL15-16
16	Sands Coastal	16
17	Sands-Desertic	17
18	Sands-Semi Stab Stab>40m	18
19	Sands-Semi Stab Stab 15- 40m	19
20	Mining Wastelands	20
21	Industrial Wastelands	21
22	Barren Rocky/Stony waste	22
23	Snow covered/Glacial area	23

Note: This classification system is evolved, based on the recommendations of Technical Task Force Group-1986 constituted by Planning Commission.

Table – 2: Probable Non-Wastelands Classes in 2015-16 Considered for Change Analysis

24	Built up	24
25	Industrial Area	25
26	Cropland	26
27	Fallow Land	27
28	Plantation	28
29	Forest-Dense/Open	29
30	Forest Plantation	30
31	Grasslands	31
32	Waterbodies	32

3.0 Methodology

The methodology essentially involves geo-referencing of satellite data, delineation of wastelands categories through on-screen visual interpretation technique based on legacy data and limited ground truth, quality check, harmonization with land degradation, land use/ land cover datasets and seamless database creation.

3.1 Input Data

The following input data has been used for carrying out the study.

- Wastelands vector layer created using multi-temporal satellite data of 2008-09
- Ortho-rectified Resourcesat-1 LISS-III imagery for year 2015-16 representing all three major cropping seasons of India (Kharif, Rabi and Zaid).
- High resolution satellite data available on Bhuvan along with legacy spatial data on wastelands and land use, reports, atlases have been consulted for improvements in interpretation process.
- Limited ground truth

3.2 Input Data Preparation

The LISS III data sets were checked for consistency with respect to band to band registration to ensure geometric accuracy up to sub-pixel level followed by ortho-rectification of the data using Shuttle Radar Topographic Mission (SRTM) DEM through an automated process.

3.3 Approach

The approach basically involved overlay of wastelands vector data of 2008-09 onto the 2015-16 LISS-III imagery and updating of wastelands categories by redrawing the boundary of 'change' areas through on- screen visual interpretation techniques.

Methodology involved the following steps:

- Overlay of 2008-09 wastelands vector layer on to the images of 2015-16
- Updating of wastelands categories depicted in 2008-09 layer with that of 2015-16 satellite data to find out the 'change' areas
- Extraction of wastelands change areas
- Random sample ground checks
- Extraction of area statistics and tabulation
- Atlas and reports

3.4 Image Interpretation

Wastelands (WL) 2008-09 vector layer was overlaid on the 2015-16 Rabi data. Changes in the polygons i.e., decrease, increase, new areas and change from one class to another class are identified and polygons are modified accordingly. The procedure is followed for the entire image grid-wise using the 15' x 15' grid. For new areas from non-wastelands category to a wasteland class, the new polygons are drawn and appropriately recoded. For change from one wasteland class to another, the polygons are selected and the attribute table is updated to an appropriate class once the modification of the wastelands polygons is complete for rabi season, then the data is updated using the satellites images of other two seasons. The change map between 2008-09 and 2015-16 was made ready after updating with Three season satellite data, and the new attribute codes of wastelands polygons are generated. Change statistics and change matrix tables are generated from the attribute data.

3.5 Refinements in 2008-09 Database

During the process of the interpretation for 2015-16, the wastelands vector database of 2008-09 was used as a base. In the span of more than Five years many developments have taken place in the process of satellite image data processing. These developments have led to preparation of more accurate thematic information derived from this imagery. Keeping these in view Version - 2 of wastelands database were prepared before proceeding to carryout current exercise of wastelands change analysis. Following are some of the factors which necessitated in bringing out Version - 2 Wastelands database for the year 2008-09:

3.5a Availability of Additional Satellite Data

It was envisaged to use 3 seasons' data during this project as was done during the earlier two exercises. Use of three season data has its limitation in delineating some of the classes, especially which are season specific. Use of multiple images can make the interpretation more robust thereby improving the classification accuracy. Availability of time series satellite data across the year helped in bringing out improvement in the classification process.

For example, agriculture class (non-wastelands) has the strongest seasonal fluctuation of its reflectance characteristics with a tendency to have a similar spectral response as that of shrubs, grasses and fallow land. With the scope of more number of usable growing season images, the accuracy of delineation of wastelands categories improved. Similarly, areas inundated with water are to be classified as waterlogged with appropriate imagery. If image is acquired during lean period, the feature will tend to be interpreted as a non-wastelands. This is analogous to Snow / Barren Rocky / Degraded Pastures / Grazing Lands.

3.5b Accessibility to High Resolution Images

Accessibility to high resolution data (Cartosat PAN, LISS-IV etc.) has resulted in availability of more detailed information on wastelands with crisper feature boundaries that enabled their delineation with better precision. These datasets provided a wealth of information, especially for inaccessible and disturbed areas where ground data collection was a constraint.

3.5c Concurrent Mapping of Land Use / Land Cover with Wastelands

This is the first change analysis exercise taken up concurrently with land Use / land cover (LULC) mapping using same satellite imagery of 2015-16 under the ISRO-NNRMS program at an interval of 5 years. Outcome of LULC mapping was published on ISRO Geo web portal Bhuvan and this data was shared with many users like Ministry of Statistics & Programme Implementation, Ministry of New and Renewable Energy, State Government Department etc.

In this exercise, total geographical area is assigned to one or another category of LULC class. In the case of wastelands mapping, only areas under wastelands are classified leaving aside the non-wastelands. Furthermore, most of the wastelands classes are integral part of LULC database.

Due to this reason wastelands classes are necessitated to be harmonised with respect to LULC.

3.5d Interchange of Region Specific Classes

Certain classes like Snow Covered areas in Himalayan states, Rann in Gujarat & Rajasthan, Shifting Cultivation in North Eastern states needs to be revisited due to availability of more temporal data and accessibility to high resolution data, which in turn helped in better delineation.

For example, Interpretation of snow covered areas require satellite data acquired during least snow cover period, which was a limitation with three season satellite data. So also for the Rann wherein the peripheral areas are interpreted as Salt Affected / Water Logged / Scrub. Similarly is the case with Shifting Cultivation areas in the North Eastern States.

3.5e Feedback

The users of wastelands database have provided feedback for the improvement in the wastelands classes for the year 2008-09.

This is an accepted process of bringing out improved Version of thematic database prepared using satellite remote sensing data which is also being followed in the LULC mapping process. The same process has been extended in creating Version - 2 wastelands database.

3.6 Ground Truth Collection

Once the polygons were updated with a WL_Code, the doubtful classes / areas in the database were verified on the ground for improving the accuracy of interpretation. It was ensured that at least 20% ground truth collection of the change areas was done.

3.7 Geodatabase Creation & Mapping Standards

Geodatabase consists of vector data on various wastelands categories and an associated metadata, which describes the data content. These categorical data sets are the primary source of input for GIS database under NNRMS Repository. The tolerable limit for registration of image to the spatial framework in thematic mapping is half pixel i.e., 12m (approx.) considering the resolution of LISS III data. Albers Equal Area Projection (AEA) with WGS-84 datum has been adopted in the current mapping exercise. The positional accuracy is maintained at 50m (i.e., 1 mm of scale) RMSE. Minimum Mappable Unit (MMU) is size of the smallest feature that would be mapped at a scale and is defined at 3mm x 3mm of scale. For, 1:50,000 scale, the MMU is 22,500 sq.m. and all features below this area were not considered for mapping. The thematic accuracy of classification/mapping were maintained at 90% with 85% confidence level. The thematic maps will be stored in digital formats and in the form of a printed Atlas. The accuracies of the output of wastelands maps would depend upon the GIS database standards.

Details of the above NNRMS standards adopted in this project are provided under Annexure - II

3.8 Quality Assurance Mechanism

A two-fold quality assurance mechanism involving in-process quality control by the Internal Quality Checking (IQC) team members at Partner Institutions and external quality audit by External Quality Checking (EQC) team was adopted. IQC team consists of experts from participating organisation (organisation involved in mapping exercise or a specific study area) and EQC team composed of serving as well as retired experts from ISRO / DOS centres. The digital database quality standards finalized under NNRMS Programme of Natural Resources Repository (NRR) were followed in this project. The QAS standards included parameters such as geo-rectification accuracy, interpretation, classification, area estimation, geodatabase etc.

IQC was done for all the input and output products. Once the IQC Team cleared the outputs and other intermediate products, the EQC team evaluated the quality of the product, by evaluating a minimum of 20% of the products. The products whose samples did not meet the quality standards were reworked for incorporation of necessary corrections in the sample as well as in rest of the products. On incorporating the suggested changes in all the products based on the advice of the EQC, the IQC team ensures compliance and then the products are accepted. Only those outputs meeting the accuracy standards were cleared for incorporation in to the geo database.

3.9 Database Organisation

All the databases were first checked for edge-matching across inter- district and inter-state borders so that data gaps and overlaps are eliminated amongst the datasets of different states. The wastelands feature classes are also matched across these borders to maintain the data continuity and to facilitate

generation of a seamless dataset for the entire country. Entire wastelands mapping exercise is carried out by following NNRMS Image and GIS database standards. The NNRMS standard followed in the project is given under Annexure-II.

3.10 Spatial Statistics

The area statistics on various wastelands classes for 2015-16 and changes observed in wastelands status during 2015-16 vis-a vis 2008-09 (Category-wise; and state-wise at national level; category-wise and district-wise at state level; and category-wise at individual district level) were generated. A change matrix table depicting the inter-class change during 2015-16 and 2008-09 has also been generated at national and state levels. The data are presented in tables in the subsequent pages. The area estimation has been done adopting individual district geographical area as per earlier Wastelands Atlas 2011 (based on multi-season satellite data of 2008-09) records. For individual states, the spatial distribution of wastelands classes for 2015-16 and the spatial changes during 2008-09 and 2015-16 were depicted in the form of maps. Since latest district boundary is not available in GIS format, the layer used in previous cycle has been followed. Some of the wastelands changes, as observed on satellite images, have been captured and presented in the Atlas, for visual appreciation and better understanding of the results.

3.11 Results

The results from analysis of statistics are presented and discussed for drawing valid conclusions from the study.

- In the Table: State wise total area under wastelands reveals the spatial extent of different categories of wastelands in each state. The total wastelands area of the country was observed to be 5,57,665.51 sq. km. in 2015-16, while it was 5,66,070.36 sq. km. in 2008-09. This indicates a conversion of 8,404.86 sq. km. of different wastelands categories in the country to non-wastelands during 2008-09 to 2015-16.

- Comparison of wastelands statistics of all the states indicated a decrease in wastelands in 18 states and an increase in wastelands in 11 states of the country. A major positive change is observed in the state of Rajasthan with a conversion of 4,803.56 sq. km. of sandy wastelands area to non-wastelands. This was followed by Uttar Pradesh and Bihar states where a respective change of 1,082.29sq. km. and 1,130.07 sq. km. wastelands area has been brought under utilization. Conversely, increase in wastelands was observed in the states of Odisha (465.82sq. km.) followed by Assam (406.69sq. km.), Telangana (377.79 sq. km.) and Chhattisgarh states (373.54 sq. km.).

- A reduction in wastelands was observed in the category of 'Land with Dense Scrub' followed by 'Snow/Glacial Cover' and 'Sands-Semi Stabilized - 15- 40m'. 'Barren Rocky/Stony waste' and 'Land with Open Scrub' followed by 'Under-utilised/Degraded Forest (Agriculture domin)' are the wastelands categories that indicated a marked increase from 2008-09 to 2015-16 (Table: category wise total area under wastelands). Statistics indicate that highest change from wastelands to non-wastelands area is recorded under 'Cropland' class in 2015-16. A considerable change has also been observed in Forest (Open/Dense) and Fallow Land classes from 2008-09 to 2015-16.

- A total of 90,950 polygons (summing up to 14,536.33 sq. km. of land) were converted to non-wastelands from 2008-09 to 2015-16, while 25,994 polygons (an area of 6131.47 sq. km.) were noticed to be converted from non-wastelands to wastelands in the same period (Table: India-Wastelands Area Change Matrix).

- Interclass wastelands changes have dominantly taken place between Snow Covered/Glacial and Barren Rocky classes, Land with Dense Scrub and Land with Open Scrub, Shifting Cultivation Abandoned and Current Shifting Cultivation. The decrease in 'Snow Covered/Glaciers' may be attributed to the seasonal dynamics of snowfall pattern, which exhibits inter-annual variations. This decrease has come expectedly from surrounding 'Barren Rocky/Stony Waste' class whose spatial extent increased upon conversion from Snow Cover.

An area of 1,20,849.00 sq. km. of Jammu & Kashmir was not mapped in the previous Wastelands Mapping cycles. In the current excercise, this area is also mapped. Due to this inclusion, Wastelands area has been revised from 75,435.77 sq. km. to 1,76,080.25 sq. km. for 2008-09. For the year 2015-16, Wastelands area is reported to be 1,75,697.01 sq. km. Hence, there is a net reduction of Wastelands by 383.24 sq. km. (0.17%) in Jammu & Kashmir state.