भाकृअनुप
ICAR

Land Degradation due to Water-Induced Soil Erosion in India

Indian Council of Agricultural Research
New Delhi

Land Degradation due to Water-Induced Soil Erosion in India

2026

Uday Mandal
Gopal Kumar
M. Madhu
D.R. Sena
D. Mandal
Brij Lal Lakaria

भाकृअनुप
ICAR

Published by

Directorate of Knowledge Management in Agriculture
Indian Council of Agricultural Research
Pusa Campus, New Delhi 110 012

Printed in July 2026

ISBN: 978-81-7164-324-0

Disclaimer

The publisher, authors and editors assume the information in this book was accurate at the time of publication, but they make no express or implied guarantees, and are not liable for any errors or omissions. All sources of information have been duly cited.

Compilation and Technical Editing

Dr Uday Mandal
Senior Scientist (Soil & Water Conservation Engineering)

Dr Gopal Kumar
Principal Scientist (Soil Physics)

Dr M. Madhu
Principal Scientist (Agronomy) & Former Director

Dr D.R. Sena
Principal Scientist (Soil & Water Conservation Engineering)

Dr D. Mandal
Principal Scientist (Soil Science)

Dr Brij Lal Lakaria
Principal Scientist (Soil Science)

ICAR–Indian Institute of Soil and Water Conservation (IISWC),
218 Kaulagarh Road, Dehradun-248195, Uttarakhand, India

Citation

Mandal U, Kumar G, Madhu M, Sena D R, Mandal D and Lakaria B L. 2026. Land Degradation due to Water-Induced Soil Erosion in India. Indian Council of Agricultural Research, New Delhi, 18 p.

Editing

Dr Anuradha Agrawal
Project Director, Directorate of Knowledge Management in Agriculture (DKMA), Indian Council of Agricultural Research (ICAR), New Delhi, India

Design & Production

Punit Bhasin
Incharge, Production Unit, ICAR-DKMA, New Delhi, India

Published by Dr Anuradha Agrawal, Project Director, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, Pusa Campus, New Delhi 110 012, India. Laser typeset and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110 028, India.

FOREWORD

Bharat's journey from a food-deficient nation to one with surplus agricultural production is a remarkable national accomplishment. This progress has been made possible through the tireless efforts of farmers, the scientific strength of the National Agricultural Research, Education and Extension System (NAREES), and the forward-looking policies and programmes formulated by policy makers. Their collective contribution has ensured food and nutritional security and strengthened the rural economy. As we move forward, it is essential to recognize that this achievement has also resulted in increased pressure on natural resources, particularly soil and water. Safeguarding our agricultural gains and ensuring long-term resilience now depend on our ability to manage and conserve these finite resources. Sustainability in Bharat's agricultural sector can be secured only through strengthened natural resource conservation and scientifically informed land stewardship.

In this context, the publication 'Land Degradation due to Water-Induced Soil Erosion in India' is both timely and significant. By presenting an updated national appraisal of water-induced soil erosion and land degradation, it offers valuable insights that will support evidence-based planning, prioritization of vulnerable regions, and targeted conservation interventions. This work contributes directly to national commitments on Land Degradation Neutrality, climate-resilient agriculture, and sustainable development.

The findings indicate encouraging improvements in several regions, reflecting the positive impacts of watershed development programmes, conservation initiatives, and enhanced land management practices, many of which have been strengthened through the scientific contributions, capacity building, and technical support provided by the ICAR-Indian Institute of Soil and Water Conservation (IISWC) and adopted across Bharat. At the same time, the persistence of erosion-prone areas underscores the need for continued scientific innovation, coordinated action, and renewed investment in soil and water conservation.

I truly appreciate the hard work and dedication of the authors and the scientific team at the ICAR–Indian Institute of Soil and Water Conservation (IISWC) in Dehradun. This publication will be a valuable resource for policymakers, planners, researchers, and development professionals who are striving for sustainable and resilient land management. It reflects ICAR's ongoing commitment to safeguarding Bharat's agricultural future, ensuring that prosperity is passed on to the next generations through responsible care of our natural resources.

(Dr Mangi Lal Jat)
Secretary, Department of Agricultural Research and Education (DARE)
& Director General, Indian Council of Agricultural Research (ICAR)

March 17, 2026
New Delhi

MESSAGE

Soil and water are the foundational resources that sustain agricultural productivity, ecological stability, and rural livelihoods. As pressures on these resources intensify due to population growth, land use changes, climate variability, and expanding production needs, the importance of accurate, science-based assessments of land degradation–especially water erosion–becomes ever more critical. Ensuring the long-term sustainability of our agricultural systems requires a clear understanding about vulnerabilities that exist and the way conservation efforts can be directed most effectively.

This publication 'Land Degradation due to Water-Induced Soil Erosion in India' provides a timely and scientifically robust national appraisal of water-induced soil erosion and land degradation. The assessment reports a significant progress in several regions, most notably the reduction in very severely to extremely degraded areas from 36.20 million ha to 22.45 million ha, along with an overall decline in land degraded by water-induced soil erosion. These encouraging trends across multiple landscapes reflect the cumulative impact of watershed development programmes, soil and water conservation initiatives, improved land management practices, and the capacity-building support provided by ICAR–Indian Institute of Soil and Water Conservation (IISWC), Dehradun. These improvements underscore the value of sustained investments in conservation research, field demonstrations, and training—areas in which the Institute has played a pioneering role for decades. Simultaneously, the assessment indicates that 86.04 million ha of land remains affected by water-induced degradation, including 50.64 million ha of agricultural land. This underscores the continued urgency for investment, innovation, and coordinated action. Addressing these vulnerabilities will require region-specific strategies, enhanced adoption of conservation measures, and sustained capacity building across states.

I commend the authors and the scientific team at ICAR–IISWC for producing this comprehensive national appraisal. The insights within these pages will support policymakers, planners, researchers, and field practitioners in advancing Land Degradation Neutrality, climate-resilient agriculture, and sustainable natural resource stewardship. This work strengthens our collective mission of promoting scienceled solutions for conservation and enhancing the resilience of Bharat's agricultural landscapes. It will serve as an essential reference for all those engaged in the vital work of sustainable land and water management.

(Dr Amaresh Kumar Nayak)
Deputy Director General (Natural Resource Management),
Indian Council of Agricultural Research (ICAR)

March 18, 2026
New Delhi

PREFACE

Water-induced soil erosion remains one of the major drivers of land degradation, affecting productivity, ecosystem services, and the long-term sustainability of landscapes. Reliable and up-to-date information on the extent and severity of erosion is therefore essential for informed planning and effective conservation interventions. Accurate and up-to-date information on the extent and severity of soil erosion is essential for planning effective conservation measures and prioritizing investments. Over the past decade, significant advances have been made in the availability of geospatial data, remote sensing technologies, and analytical tools. At the same time, large-scale watershed development programmes, soil and water conservation interventions, and improved land management practices have influenced the condition of land resources across the country. These developments created a need to revisit and update the national assessment of water-induced soil erosion and land degradation.

This publication presents an updated national appraisal of Land Degradation due to Water-Induced Soil Erosion in India using improved datasets, advanced geospatial techniques, and a harmonized assessment framework. The study provides high-resolution maps and estimates that help identify areas where conservation efforts have yielded positive results, as well as regions that continue to face serious degradation challenges. The findings indicate encouraging improvements in several parts of the country while highlighting the need for continued attention to vulnerable landscapes.

The information presented in this document is expected to support policy makers, planners, researchers, development agencies, and field practitioners in prioritizing, resource allocation, designing and implementation of soil and water conservation programmes more effectively. It will also contribute to national efforts toward sustainable land management, climate resilience, restoration of degraded lands, and achievement of India's commitments under the Sustainable Development Goals (SDGs), particularly SDG 15.3 on Land Degradation Neutrality.

We express our profound gratitude to the Director General, ICAR, for his visionary leadership, encouragement, and unwavering support towards advancing research and development in natural resource management. We sincerely acknowledge the guidance, support, and encouragement received from Dr A. K. Nayak, Deputy Director General (NRM), ICAR, throughout this work. We also express our gratitude to the Directors of ICAR–Indian Institute of Soil and Water Conservation (IISWC) for their guidance and continuous support during the preparation of this publication. We express our sincere appreciation to Dr Adlul Islam for his invaluable assistance in meticulously reviewing, editing, and refining the document. We also gratefully acknowledge Dr R. S. Yadav for his valuable suggestions and constructive inputs. We further acknowledge the contributions of all scientists, technical staff, and institutions whose dedicated efforts made this national assessment possible.

We hope that this publication will serve as a useful reference for informed decision-making and inspire continued efforts toward the conservation and sustainable management of India's precious soil and water resources.

Authors

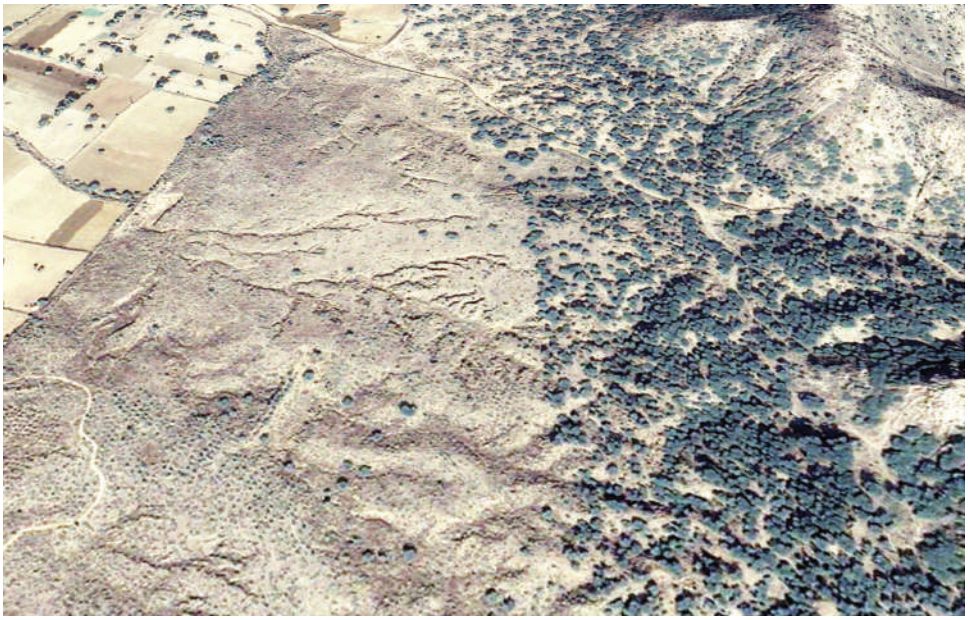
CONTENTS

1. Rationale for Soil Erosion Assessment

Soil erosion and land degradation are among the most critical environmental challenges confronting India today, which threaten agricultural productivity, food security and ecosystem stability across world's most populous nation. Given India's significant dependence on agriculture, its land resources are under increasing pressure from intensive cultivation, deforestation, urbanization and climate variability. The country's diverse physiographic regions, from the Himalayan mountains and Indo-Gangetic plains to the Deccan plateau and coastal lowlands, display varying levels of susceptibility to soil erosion and land degradation.

India experiences multiple forms of land degradation, including water-induced erosion, which accounts for approximately 68% of the total degraded area, as well as wind erosion in arid and semi-arid regions, waterlogging, salinization, and chemical degradation caused by nutrient depletion and contamination. Among these, water-induced soil erosion remains the predominant degradation process, driven by intense monsoonal rainfall, diverse physiographic conditions, fragile soils and unsustainable land-use practices. Consequently, the development of comprehensive soil erosion and land degradation maps has emerged as an essential tool for understanding the spatial distribution and severity of these processes, enabling targeted conservation interventions and promoting sustainable land management practices.

The Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) and later customized to Indian soils, rainfall and land-use conditions by



Singh (1981), was used to carry out the first national-scale assessment of soil erosion in India. That study estimated a gross annual soil loss of about 5,334 million tonnes ($\approx$ 16.4 $t{\cdot}ha^{-1}$) (Narayana and Ram Babu 1983). These estimates later formed the basis of a harmonized national soil erosion map, jointly prepared by ICAR-Indian Institute of Soil and Water Conservation (IISWC) and ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), which has been widely used for planning and conservation prioritization.

However, with the availability of improved spatial datasets, advanced computational tools, including remote sensing, Geographic Information Systems (GIS) modelling frameworks, changing land-use and management practices, large-scale conservation interventions under various programmes and evolving rainfall regimes under climate variability, these legacy maps and figures now urgently require a comprehensive update.

2. Developing the National Soil Erosion Map

The updated national soil erosion assessment was developed by integrating multiple geospatial datasets representing climate, terrain, soils, land use, and conservation practices within a Geographic Information System (GIS) environment. The assessment followed a standardized workflow to generate spatially consistent factor layers and estimate long-term average annual potential soil erosion across India. Advances in earth observation, digital soil information, high-resolution elevation models, and computational capabilities enabled the preparation of a more detailed and contemporary national assessment compared to previous mapping efforts.

2.1 The RUSLE Framework

Potential soil erosion was estimated using the Revised Universal Soil Loss Equation (RUSLE), one of the most widely adopted empirical models for regional and national-scale soil erosion assessment. RUSLE estimates long-term average annual soil loss by integrating the effects of rainfall erosivity, soil erodibility, topography, land cover, and conservation practices. Owing to its robustness, simplicity, and compatibility with GIS and remote sensing datasets, the model has been extensively applied worldwide for erosion risk assessment and conservation planning (Wischmeier and Smith, 1978; Renard et al., 1997).

The Revised Universal Soil Loss Equation (RUSLE) model was used, and its core equation is

$$A = R \times K \times L \times S \times C \times P$$

where: **A** = computed long term average annual potential soil erosion ($t{\cdot}ha^{-1}{\cdot}yr^{-1}$); **R** = rainfall erosivity factor ($MJ{\cdot}mm{\cdot}ha^{-1}{\cdot}h^{-1}{\cdot}yr^{-1}$); **K** = soil erodibility factor ($t{\cdot}ha{\cdot}h{\cdot}ha^{-1}{\cdot}MJ^{-1}{\cdot}mm^{-1}$); **LS** = topographic factor (slope length & steepness); **C** = cover and management factor; and **P** = supportpractice factor.

2.2 Rainfall Erosivity Factor (R-factor)

» IMD Gridded Daily Rainfall (0.25° × 0.25°, 1995 to 2024) and breakpoint rainfall data from nine ICAR-IISWC research stations and one additional site at Papum Pare, Yupia (Arunachal Pradesh) were used and accessed for calibration (Rawat *et al*. 2013).

» Developed locally fitted equations (power/log-linear) to relate annual (or in some cases monthly) rainfall to annual rainfall erosivity.

» Since breakpoint data were available only for 10 sites with acceptable record length, these locally developed equations were preferred over generic literature equations (Weishmier and Smith 1978; Arnoldus *et al*. 1977). The entire country was zoned into 10 Rainfall–Rain-Day classes using IMD Grid defined by the pair of mean monthly rainfall, and number of rainy days (rainfall > 10 mm) in that month. Each zone was assigned a separate regression equation locally developed from the breakpoint data of its representative station(s).

» Zone-specific equations applied to the IMD gridded data falling within each of the 10 zones and generated gridded annual R values at 0.25° × 0.25° resolution.

» Ordinary Kriging method was applied to interpolate the gridded R values, and downscaled to a 30 m × 30 m raster resolution to produce a national R-factor map.

2.3 Soil Erodibility Factor (K-factor)

» Data used: ISRIC SoilGrids (250 m) – texture fractions (sand/silt/clay), sand (0.2–0.10 mm), very fine sand (0.10-0.05 mm), silt (0.05–0.002 mm) and clay (<0.002 mm); NBSS&LUP soil series (vector) – texture class, structure, permeability proxies; FAO/HWSD soil organic carbon (convert to SOM where required)

» Derived raster based saturated hydraulic conductivity properties for permeability coding (Saxton and Rawls 2006) and soil structure code.

» Derived K-factor map of India using reported standard equations (Wischmeier and Smith 1978; Foster *et al.* 1981; Renard *et al*. 1997), and resampled to 30 m × 30 m output via nearestneighbour technique.

2.4 Topography Factor (LS-factor)

» ASTER GDEM v3 (30 m × 30 m) were downloaded, processed and LS-factor map of India (30 m × 30 m spatial resolution) developed, using flowdirection, accumulation and slope by implementing Desmet and Govers (1996) and McCool *et al.* (1989) algorithm for L-factor and S-factor, respectively.

2.5 Cover & Management Factor (C-factor)

» NRSC LULC map for the year 2015-16 with 30 m × 30 m spatial resolution was used, and assigned C-factor value for each NRSC Land Use/ Land Cover class (Urban, Forest Plantation, Scrub Forest, Swamp / Mangroves, Grass / Grazing, Salt-affected Land, Gullied / Ravinous Land, Scrub Land, Sandy Area, Barren Rocky, Rann, Rural, Inland Wetland, Coastal Wetland, River / Stream / Canals, Waterbodies, Mining, Cropland, Plantation, Fallow, Evergreen / Semi evergreen, Deciduous, Current Shifting Cultivation, Snow and Glacier), using literature and experts' judgement.

2.6 Support Practices Factor (P-factor)

» Combining slope classes and LNRSC LULC data of 2015-16, the P-factor value was assigned, using a rule-based approach. Only agricultural land and forest plantation class was considered for assigning P-factor value with combination of various slope classes (0-2; 2-8; 8-15; 15-33; 33-100; and > 100). Used state/agro-ecology specific practice lookup tables to assign unique conservation and corresponding value. Wherever practice data absent, P=1 was assigned as if no support existed.

2.7 Supporting Spatial Datasets

» Survey of India/NRSC administrative boundary was used with WGS 1984 datum and LCC projection for national mosaic.

2.8 GIS Processing and Analysis

» GIS: ArcGIS Pro / QGIS (3.30+); GEE (Google Earth Engine) for big-raster data preprocessing (optional); Python (GeoPandas, Rasterio, RichDEM), R (terra); and Microsoft Excel

2.9 Derivation of the Water Induced Land Degradation Map

Based on the potential soil erosion rate, land degradation map of India due to water-induced potential soil erosion was prepared, using five classes namely, moderately degraded (10-15 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$); moderately severe degraded (15-20 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$); severely degraded (20-40 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$); very severely degraded (40-80 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$); extremely degraded (> 80 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$).

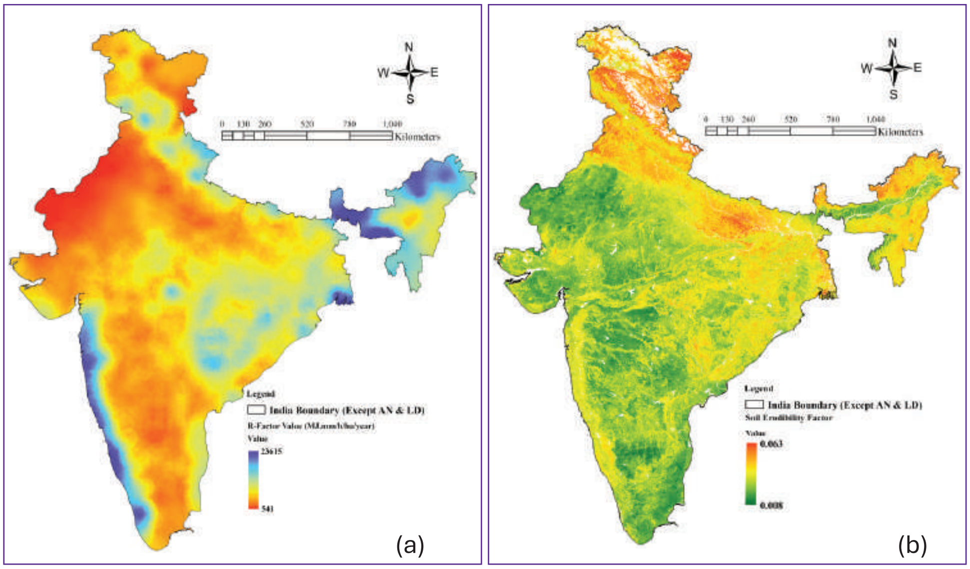
3. National Assessment of Water-Induced Soil Erosion

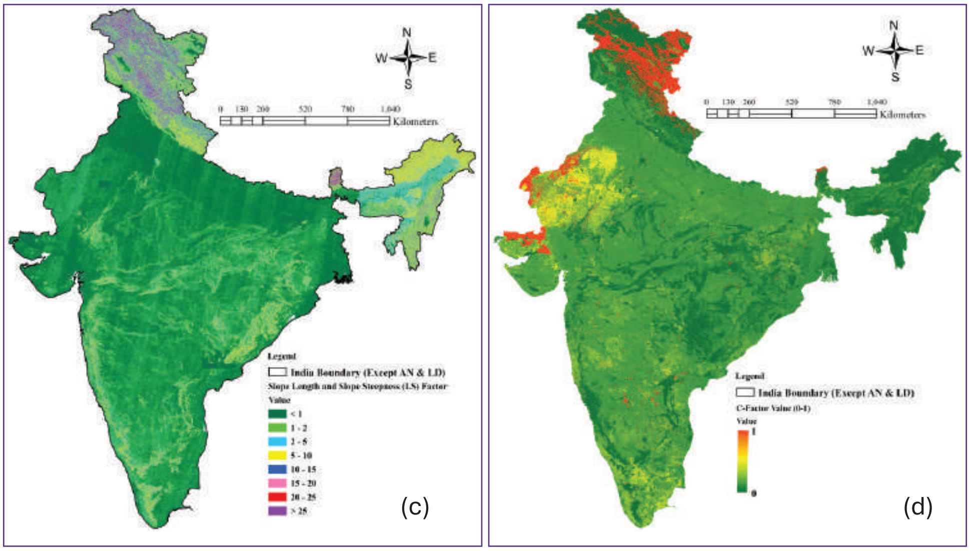
3.1 Spatial Distribution of RUSLE Factors

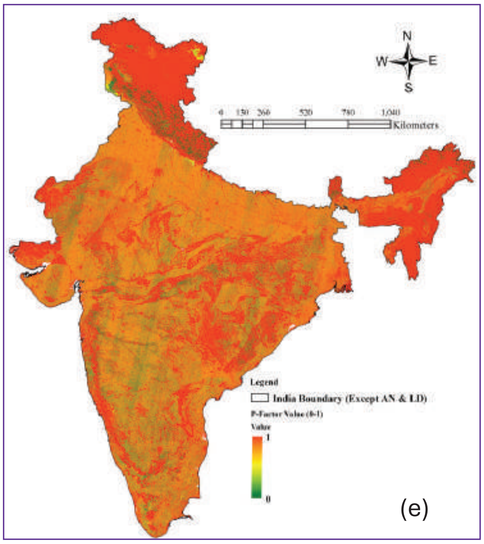
Potential soil erosion is governed by the interaction of climatic, topographic, soil, vegetation, and conservation management factors. To characterize these spatial controls consistently across the country, five RUSLE factor layers, R (rainfall erosivity), K (soil erodibility), LS (slope length and steepness), C (cover & management), and P (support practice), were developed using harmonized national datasets. The layers were prepared as 30 m × 30 m GeoTIFF raster datasets in the Lambert Conformal Conic (LCC) projection and subsequently integrated to generate the national potential soil erosion map. The spatial distribution of these factors is illustrated in Figure 1.

3.2 Potential Soil Erosion (PSE)

Water-induced potential soil erosion (PSE) map of India, derived using RUSLE model is shown in Figure 2a. Average potential soil erosion rate for India was 18.80 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$. Area under agriculture (crop land, agriculture plantation, current shifting cultivation, and fallow land) is about 174.53 Mha, derived from NRSC LULC







- R-factor value varies from 541 to 23615 $MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot yr^{-1}$ with mean value 6665 $MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot yr^{-1}$.
- K-factor value varies from 0.0086 to 0.0628 $t \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}$ with mean value 0.0299 $t \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}$.
- LS-factor value ranges from 0.03 to 411 with mean value 2.48.
- C-factor value varies from 0 to 1 with mean 0.1765.
- P-factor value varies from 0 to 1 with mean 0.6849.

Figure 1. (a) Rainfall erosivity (R); (b) Soil erodibility (K); (c) Topographic (LS); (d) Cover and management (C); (e) Support practice (P) factor map of India

map (2015-16) of India (1:50,000). Average potential soil erosion under agriculture land (PSEA) for India is about 7.55 $t \cdot ha^{-1} \cdot yr^{-1}$ (Figure 2b), where the percentage area under various categories of PSEA was calculated with respect to total analyzed area i.e., 299.32 Mha. This is the first kind of estimation for the country, where agriculture is the

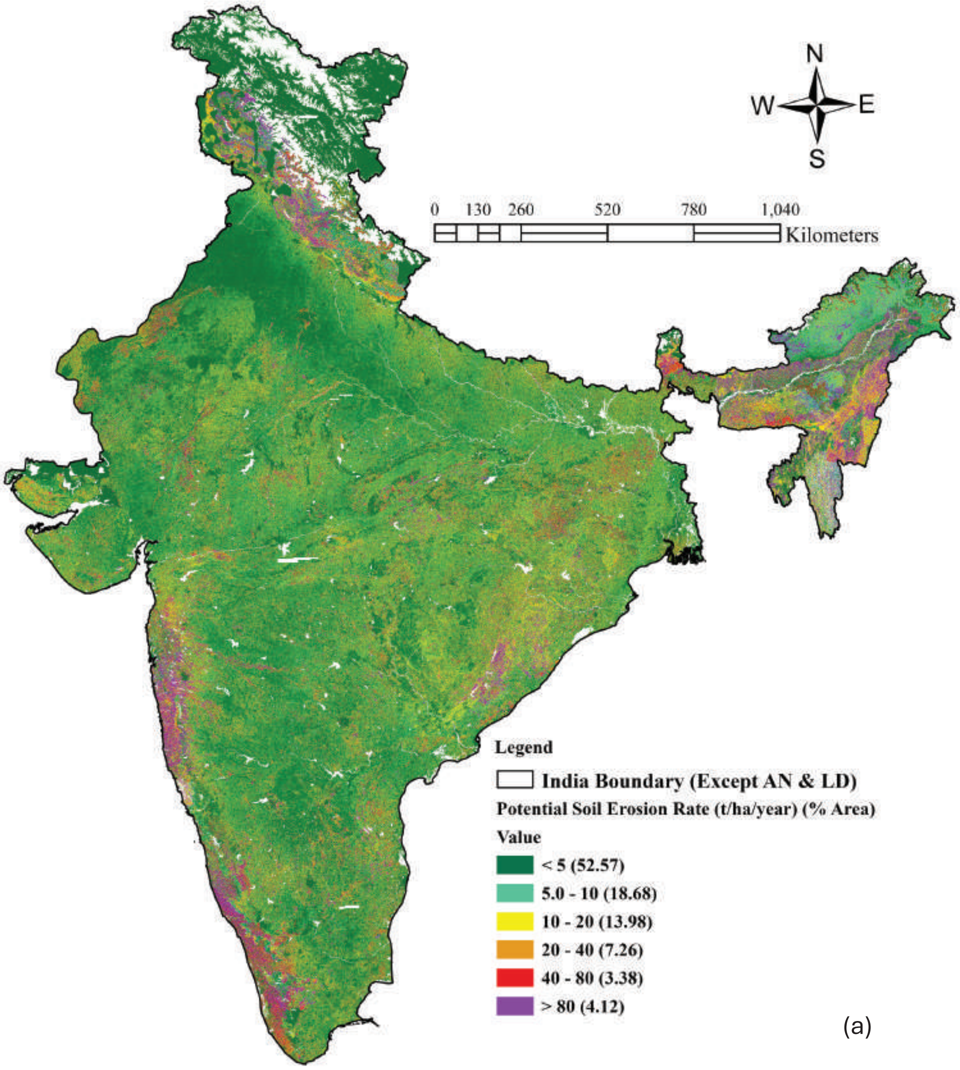


Figure 2. (a) Water-induced potential soil erosion (PSE)

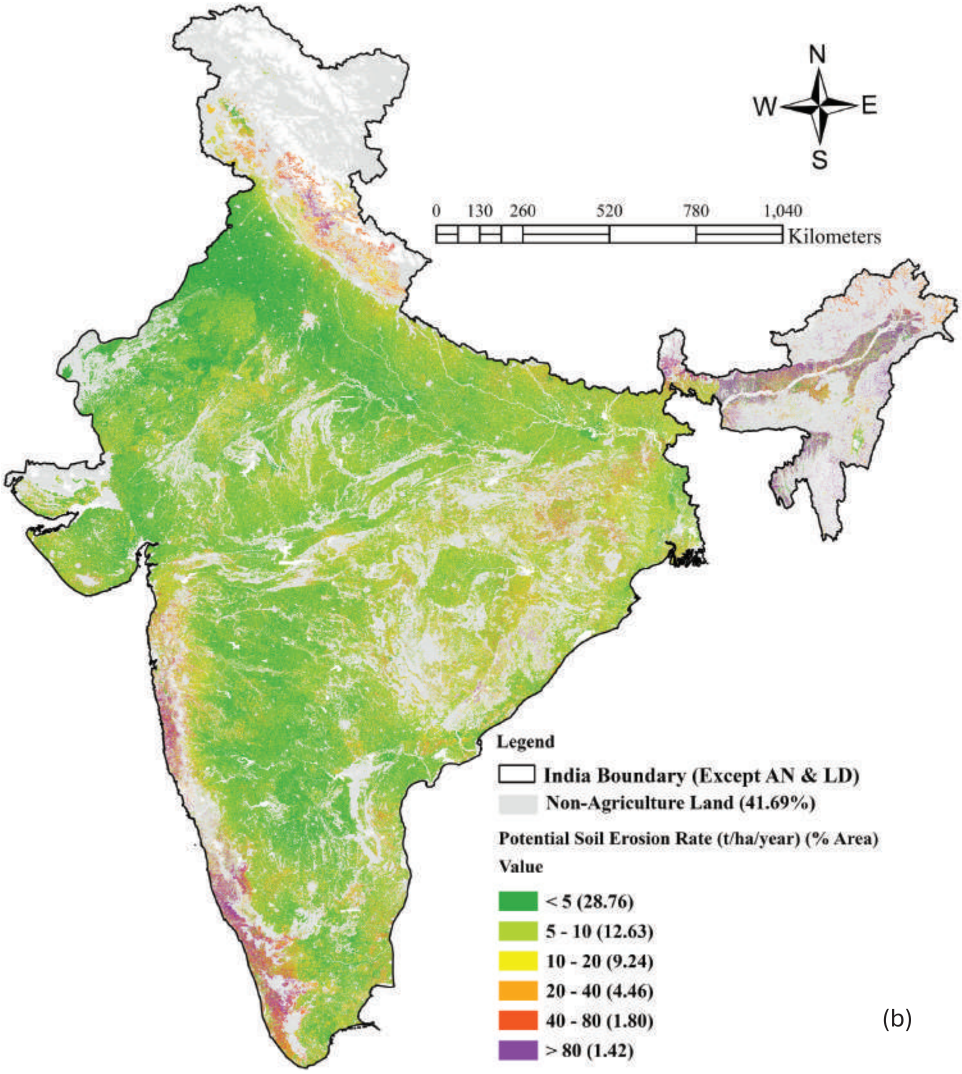


Figure 2. (b) Water-induced potential soil erosion limit to agriculture land (PSEA)

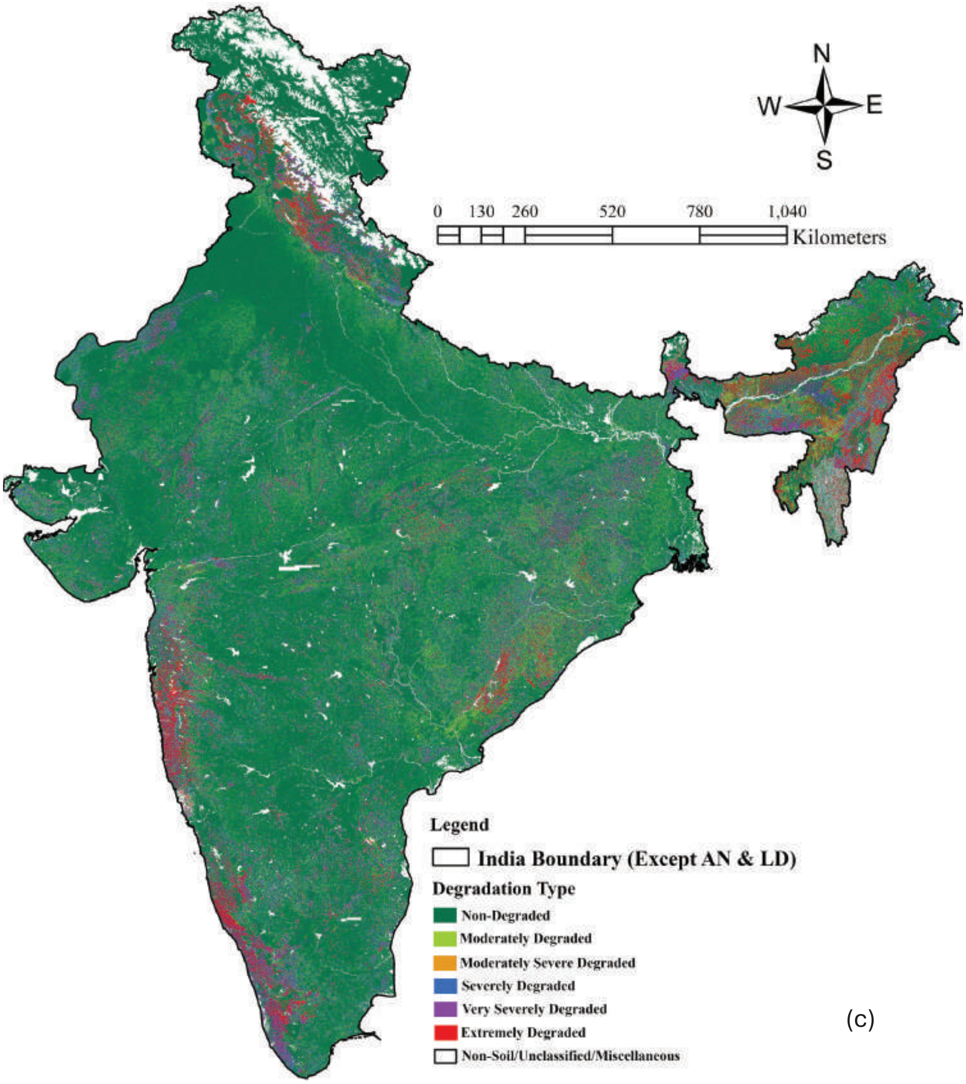


Figure 2. (c) Land degradation (LD) due to water-induced potential soil erosion

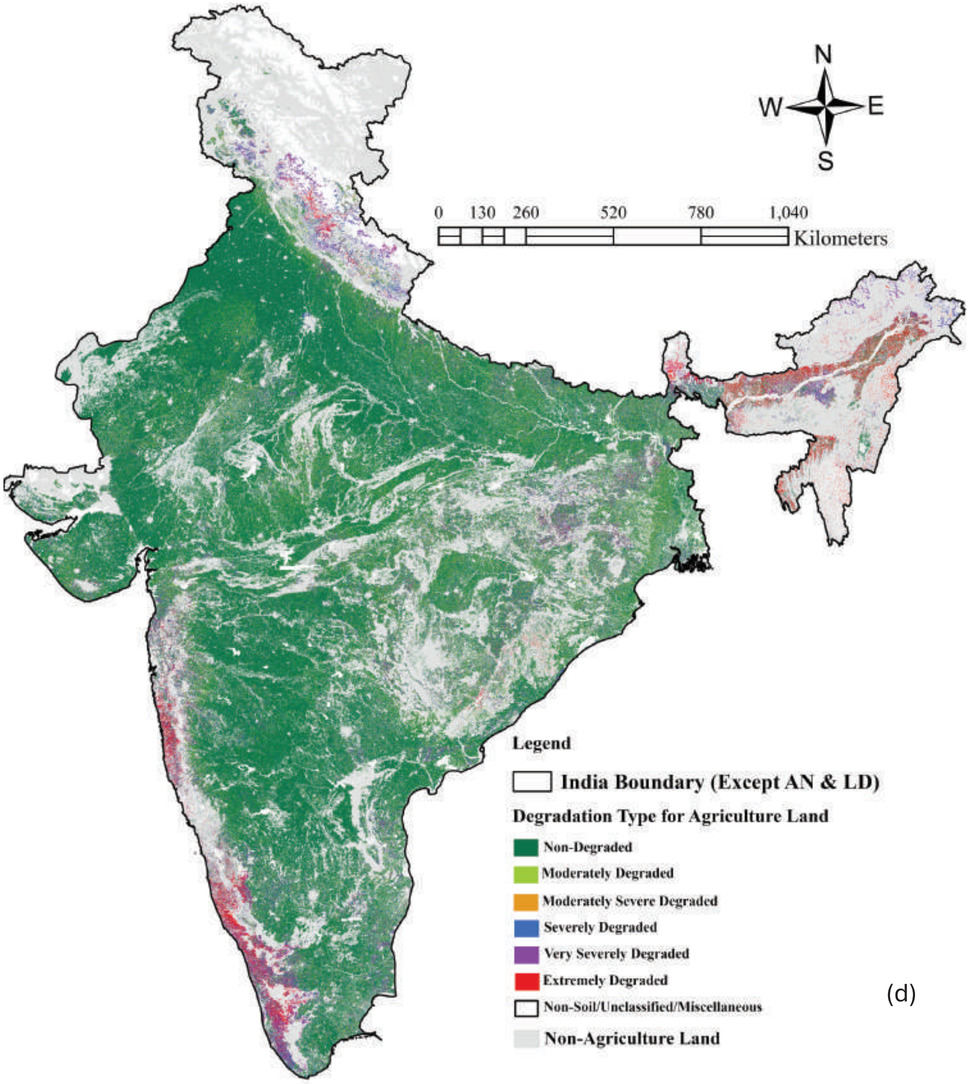


Figure 2. (d) Land degradation due to water-induced potential soil erosion limit to agriculture land

Table 1: Area statistics of water-induced potential soil erosion (PSE) overall and PSE limit to Agriculture Land (PSEA) map of India

Erosion Type	Soil Erosion Rate ($t{\cdot}ha^{-1}{\cdot}yr^{-1}$)	Revised (2025)		Agriculture Land	
		Area (Mha)	% Area	Area (Mha)	% Area
Very low	0 - 5	157.36	52.57	86.08	49.32
Low	5 - 10	55.92	18.68	37.80	21.66
Moderate	10 - 20	41.85	13.98	27.66	15.85
High	20 - 40	21.74	7.26	13.34	7.64
Vary High	40 - 80	10.11	3.38	5.39	3.09
Severe	> 80	12.34	4.12	4.25	2.43
Degraded Land + Non-Degraded Land		299.32	100		
Non-Soil/Unclassified/Miscellaneous		28.58			
Total Area		327.9*			
Total Agricultural Area (A)				174.53	58.31
Non-Agricultural Land (B)				124.78	41.69
Total Analysed Area (A+B)				299.32	100

*The 0.83 Mha area (Andaman and Nicobar Islands & Lakshadweep Island) was not considered in this study. Total geographical area of India is 328.73 Mha.

back bone of the development. Area statistics under various categories of erosion rate overall and from agricultural land are given in Table 1.

» Average potential soil erosion rate for India is 18.80 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$.
» Under the very low erosion category, 121.8% increase in area as compared to previous estimate.
» Average potential soil erosion rate from agriculture land is about 7.55 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$, reflecting improved agriculture with soil and water conservation measures at ground level.

The comparative analysis of soil erosion assessments conducted in 2010 and 2025 revealed significant shifts in the spatial distribution and intensity of soil erosion across India (Table 2). Specifically, areas with very high erosion rates (>40 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$) decreased from 41.98 Mha to 22.45 Mha, a reduction of 46.5%. Similarly, high erosion areas (20-40 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$) declined from 31.44 Mha to 21.74 Mha, representing a 30.9% decrease. The combined area under high and very high erosion

Table 2: Area statistics and comparison of PSE from previous assessment

Erosion type	Soil erosion rate ($t{\cdot}ha^{-1}{\cdot}yr^{-1}$)	Previous assessment (Maji *et al.* 2010)		Revised assessment (2025)	
		Area (Mha)	% Area	Area (Mha)	% Area
Very low	0-5	70.96	24.46	157.36	52.57
Low	05-10	64.09	22.09	55.92	18.68
Moderate	10-20	82.38	28.40	41.85	13.98
High	20-40	31.44	10.84	21.74	7.26
Vary High	> 40	41.98	14.47	22.45	7.50
Total Eroded Area		290.07	100	299.32	100
Non-Soil/Unclassified/Miscellaneous		25.93		28.58	
Total Area		316.00		327.9*	

*The 0.83 Mha area (Andaman and Nicobar Islands & Lakshadweep Island) was not considered in this study. Total geographical area of India is 328.73 Mha.

categories decreased from 73.42 Mha (25.31% of total eroded area) in 2010 to 44.19 Mha (14.76%) in 2025, representing a decline of 29.23 Mha (39.8%). The most striking observation is that the area under the very low erosion category (0-5 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$) showed a significant increase of 86.40 Mha, expanding from 70.96 Mha (24.46%) in 2010 to 157.36 Mha (52.57%) in 2025. Conversely, the moderate erosion category (10-20 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$) experienced a substantial decline from 82.38 Mha (28.40%) to 41.85 Mha (13.98%), a reduction of 49.2%. The low erosion category (5-10 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$) also decreased from 64.09 Mha (22.09%) to 55.92 Mha (18.68%), though the decline was more modest at 12.7%. This downward shift across multiple erosion classes suggests a systematic improvement in soil conservation status rather than isolated successes in specific regions.

The observed transition from moderate-to-severe erosion classes to lower erosion categories is consistent with the cumulative effects of improved watershed management, afforestation, soil and water conservation measures, and sustainable land management interventions implemented across different regions of India over the past two decades. At the same time, the improved assessment also reflects the use of higher-resolution geospatial datasets, updated land-use information, and refined analytical methods employed in the present study. Consequently, the observed changes should be interpreted as the combined outcome of both actual landscape changes and advances in national-scale geospatial assessment, rather than solely as changes in land condition.

3.3 Water-Induced Land Degradation in India

Based on the soil erosion rate criteria, land degradation map of India was generated and shown in Figure 2c. Similarly, land degradation map of India in respect to agriculture land was also generated and shown in Figure 2d. Comparative analysis of land degradation conducted in 2010 and 2025 revealed significant shifts in the spatial distribution and intensity of land degradation area across India (Table 3). Overall, degraded area significantly decreased from the previous assessment. Non-degraded area substantially increased from 164.08 Mha (56.57%) to 213.27 Mha (71.25%). Out of 213.27 Mha, 123.88 Mha is from Agriculture Land (174.53 Mha, nearly 53% area of total geographical area of India). Moderately degraded area reduced from 36.51 Mha to 26.91 Mha. Very severely to extremely degraded area also reduced

- There is decrease in degraded land from 125.99 Mha in 2010 to 86.04 Mha in 2025
- Out of 86.04 Mha, 50.64 Mha area is under agriculture domain, first kind of information generated for India.
- Non-degraded land increased from 164.08 Mha to 213.27 Mha.

from 36.20 Mha to 22.45 Mha. Degraded land area decreased from 125.99 Mha (39.87%, before harmonization) to 86.04 Mha (26.23%) due to water-induced potential soil erosion. Out of 86.04 Mha, 50.64 Mha area is under agriculture domain, which needs immediate attention.

Table 3: Land degradation overall and limit to agriculture land area statistics due to water-induced potential soil erosion and comparison with the previous assessment

Land Degradation Type	Soil erosion rate ($t \cdot ha^{-1} \cdot yr^{-1}$)	Previous assessment (Maji et al. 2010)		Revised assessment overall (2025)		Limit to agriculture land (2025)	
		Area (Mha)	% Area	Area (Mha)	% Area	Area (Mha)	% Area
Non-Degraded	< 10	164.08	56.57	213.27	71.25	123.88	70.98
Moderately Degraded	10 - 15	36.51	12.59	26.91	8.99	17.96	10.29
Moderately Severe Degraded	15-20	21.00	7.24	14.94	4.99	9.70	5.56
Severely Degraded	20 - 40	32.28	11.13	21.74	7.26	13.34	7.64
Very Severely Degraded	40 - 80	23.24	8.01	10.11	3.38	5.39	3.09
Extremely Degraded	> 80	12.96	4.47	12.34	4.12	4.25	2.43
Degraded Land + Non-Degraded Land		290.07	100	299.32	100		
Non-Soil/Unclassified/ Miscellaneous		25.93		28.58			
Total Area		316.00		327.9*			
Degraded Land		125.99#	39.87	86.04	26.23	50.64	29.02
Total Agricultural Land (A)						174.53	58.31
Non-agricultural Land (B)						124.78	41.69
Total Analysed Area (A+B)						299.32	

#Before harmonization; *The 0.83 Mha area (Andaman and Nicobar Islands & Lakshadweep Island) was not considered in this study. Total geographical area of India is 328.73 Mha.

4. SUMMARY

A water induced potential soil erosion map of India was developed using updated high-resolution datasets, innovative methodologies and advanced technologies integrated with GIS platform. The revised estimation indicated a countrywide average water-induced potential soil erosion rate of 18.80 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$. This estimate is higher than the previous value of 16.4 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$ reported by Narayana and Ram Babu (1983). This increase may be attributed to changes in rainfall erosivity patterns associated with climate change, land use/land cover alterations, deforestation, inadequate conservation measures, and the adoption of updated methodologies and high-resolution datasets.. Globally, soil erosion rates are projected to increase by 30% to 66% during the period 2015–2070 under various climate-economic scenarios (Sartori *et al.*, 2024). However, an average potential soil erosion rate of 7.55 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$ was observed for agricultural lands in India, reflecting improvements in agricultural practices and the implementation of soil and water conservation measures at the field level.

The area under the 'very low erosion category' (< 5 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$) increased substantially by 86.40 Mha, representing a 121.8% rise. The total land degradation area declined significantly from 125.99 Mha (before harmonization) to 86.04 Mha. Of this, approximately 50.64 Mha (equivalent to 29.02% of the total agricultural land area) falls under degraded agricultural land. The non-degraded land area increased from 164.08 Mha to 213.27 Mha, of which 123.88 Mha corresponds to agricultural land. Although the proportion of land under moderately severe to severe and severe to extremely degradation categories has decreased, the remaining affected area of 44.19 Mha remains substantial, highlighting the continued need for intensive conservation efforts. These areas likely represent critical degradation hotspots characterized by steep slopes, highly erodible soils, intense rainfall, and

unsustainable land-use practices. Therefore, targeted interventions focusing on these persistent hotspots are essential to achieve further progress in land conservation and sustainable management.

The development of potential soil erosion and land degradation maps at a spatial resolution of 30 m × 30 m provides a robust scientific foundation for evidence-based decision-making aimed at safeguarding soil health for present and future generations, while sustaining the livelihoods of millions dependent on land resources. The delineation of potential soil erosion and land degradation zones equips policymakers and planners with critical spatial information to prioritize watersheds and regions requiring immediate conservation interventions. Furthermore, it facilitates efficient resource allocation under government initiatives such as the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and the National Mission for Sustainable Agriculture, supports the formulation of climate change adaptation strategies through the identification of vulnerable landscapes, and contributes to India's commitment to achieving land degradation neutrality under the United Nations Convention to Combat Desertification (UNCCD).

References

Desmet P J J and Govers G. 1996. A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *Journal of Soil and Water Conservation,* **51**(5), 427–33.

Foster G R, Lane L J, Nowlin J D, Laflen J M and Young R A. 1981. Estimating erosion and sediment yield on field-sized areas. *Trans. ASAE* 24:1253–62.

Maji A K, Obi Reddy G P and Sarkar D. 2010. *Degraded and Wastelands of India, Status and Spatial Distribution*. Indian Council of Agricultural Research and National Academy of Agricultural Science, New Delhi, 158 p.

McCool D K, Dossett M G and Yecha S J. 1981. *A portable rill meter for measuring field soil loss. In Erosion and Sediment Transport Measurement*, Proc. Florence Symp., pp. 479–84. Int. Assoc. Hydrol. Sci. Publ. No. 133.

Narayana V V D and Ram Babu. 1983. Estimation of soil erosion in India. *Journal of Irrigation and Drainage Engineering,* **109**(4), 419–34.

National Remote Sensing Centre. 2019. *Land use/land cover database on 1:50,000 scale, Natural Resources Census Project, Version 1.0 (2015-16)*. Indian Space Research Organization.

Rawat J S, Joshi R C and Mesia M. 2013. Estimation of erosivity index and soil loss under different land uses in the tropical foothills of Eastern Himalaya (India). *Tropical Ecology,* **54**(1): 47-58.

Renard K G, Foster G R, Weesies G A, McCool, D K and Yoder D C. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with RUSLE* (Agriculture Handbook No. 703). United States Department of Agriculture (USDA), Washington, D.C. https://naldc.nal.usda.gov/catalog/CAT30915237

Sartori M, Ferrari E, M'Barek R, Philippidis G, Boysen-Urban K, Borrelli P, Montanarella L and Panagos P. 2024. Remaining Loyal to Our Soil: A Prospective Integrated Assessment of Soil Erosion on Global Food Security. *Ecological Economics*, **219**: 108103.

Saxton K E and Rawls W J. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Science Society of America Journal,* **70:** 1569–78.

Wischmeier W H and Smith D D. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning with the Universal Soil Loss Equation (USLE)* (Agriculture Handbook No. 537). United States Department of Agriculture (USDA), Washington, D.C. https://naldc.nal.usda.gov/catalog/CAT87208376

भाकृअनुप
ICAR

ISBN:9788171643240

@InAgrisearch | @icarindia | @officialicarindia | www.icar.org.in | @icarindia