ISBN-978-81-924624-9-3

Soil Erosion Status, Priority Treatment Areas and Conservation Measures for Different Districts of Kerala

ICAR-Indian Institute of Soil & Water Conservation (IISWC)
218, Kaulagarh Road, Dehradun (Uttarakhand 248 195)

ISBN-978-81-924624-9-3

Soil Erosion Status, Priority Treatment Areas and Conservation Measures for Different Districts of Kerala

ICAR-Indian Institute of Soil and Water Conservation
218, Kaulagarh Road, Dehradun, Uttarakhand- 248 195

Citation

Hombegowda, H. C., Kannan, K., Kumar, G., Mandal, D., Dogra, P., Kaushal, R. and Madhu, M. 2021. Soil erosion status, priority treatment areas and conservation measures for different districts of Kerala, ISBN-978-81-924624-9-3, 26p.

Guidance and Supervision by

Dr S. Bhaskar, ADG
(Agronomy, Agroforestry & Climate Change), #111, KAB-II, PUSA, NEW DELHI-110012

Compiled and Edited by

H.C. Hombegowda, K. Kannan, Gopal Kumar, Debashis Mandal, Pradeep Dogra, Rajesh Kaushal, and M. Madhu

Published by

Director
ICAR- Indian Institute of Soil and Water Conservation,
218, Kaulagarh Road, Dehradun-248 195

All Rights Reserved:
2021, ICAR-IISWC, Dehradun

FOREWORD

डा. टी. महापात्रा
सचिव एवं महानिदेशक
Dr T. Mahapatra
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि मंत्रालय एवं फारमर्स वेल्फेयर
कृषि भवन, नई दिल्ली 110 001
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE & FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel.: 23382629, 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

Soil and water are the critical natural resources that must be kept in harmony with the environment for agro-ecosystems to be sustainable. In the context of climate change, soil conservation assumes special importance in our planning process. Good quality soil is fundamental to sustainable crop production and its loss by erosion has serious consequences for crop productivity. Present production and actualization of future predictions of crop yields largely depend upon the maintenance and improvement of soil quality. Among many environmental hazards, checking land degradation is of paramount importance Adoption of inappropriate and unscientific land use and management practices for short-term gains and disregarding long term sustainability and environmental security has resulted in accelerated and degradation in Kerala.

Over the years, Kerala's soil has lost its basic texture and water retention capacity leading to soil piping phenomenon which occurs when water erodes beneath the surface of the ground creating an underground tunnel. These tunnels collapse leading to more erosion. In the time of global warming, believed to cause disruptions in weather, the state is considered vulnerable despite its unique geographical features.

ICAR-Indian Institute of Soil and Water Conservation, RC, Udhagamandalam is working in a participatory approach for promotion and propagation of eco-friendly and cost effective conservation measures adopting watershed principles in the agro ecological regions covering the state in collaboration with all the stakeholders involved in natural resource management. In this context, the initiative by ICAR-Indian Institute of Soil and Water Conservation, Dehradun to provide the technical brief on "Soil Erosion Status, Priority Treatment Areas and Conservation Measures for Different Districts of Kerala" is highly appreciated.

Dated the 23rd August, 2021
New Delhi

(T. Mahapatra)

MESSAGE

डा. एस. के. चौधरी
उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)
Dr S. K. Chaudhary
DEPUTY DIRECTOR GENERAL (NRM)

भारतीय कृषि अनुसंधान परिषद
कक्ष क. 101, कृषि अनुसंधान भवन–II, नई दिल्ली 110 012, भारत
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Room No. 101, Krishi Anushandhan Bhavan-II, Pusa, New Delhi-110 012, India
Tel.: +91-11-25848364, 91-11-25848366
E-mail: ddg.nrm@icar.gov.in

I am happy to know that ICAR-Indian Institute of Soil & Water Conservation, Dehradun along with its Research Centre- Udhagamandalam has prepared a technical document on "Soil erosion status, priority treatment areas and conservation measures for different districts of Kerala" in compliance to the recommendations of the Regional Committee-VIII.

The God's own country is threatened due to climate change impact. The risk of soil erosion in south Indian states is more serious as many lands can no longer support a sustained production. Being located in ecologically sensitive zone, Kerala faces the direct impacts of climate change. Even though the soil erosion through water is not a serious problem in major part of the state but yet about 15% of the total area need various kinds of soil and water conservation treatment. The rate of soil erosion in the state has increased substantially after the 2018 flood.

Natural ecosystems by and large have a high resilience for stability and regeneration. However, continued interference and relentless pressures on utilization of resources leads to an upset of this balance. These issues need to be tackled strategically, on priority, to avoid major environmental problems such as depletion of vegetative cover, increase in soil erosion, decline in water table, and loss of biodiversity, all of which directly impact our survival.

I am pleased to note ICAR-IISWC has developed various location specific scientific and technical interventions in collaboration with state government organizations, NGOs and farmer interest groups for the overall development of degraded and wastelands in the agro ecological region covering the state of Kerala

I hope that this document will be helpful for land managers, state government officials and policy makers to execute various cost-effective land-based interventions more efficiently.

Dated the 23rd August, 2021
New Delhi

(S. K. Chaudhary)

PREFACE

The ICAR- Indian Institute of Soil and Water Conservation, Dehradun along with its eight Research Centres (RC) is one of the national Institutes under Indian Council of Agricultural Research, Ministry of Agriculture and Farmer's Welfare, Govt. of India. The institute is nodal organization with mandate of research for management of land degradation and rehabilitation of degraded lands in different agro-ecological regions of the country. The institute is also engaged in imparting training in research methodologies and updated technology in soil and water conservation and watershed management.

Kerala is located at the southernmost part of the Indian peninsula. The state is wedged between Arabian Sea on the west, and Western Ghats and is identified as one of the world's twenty-five biodiversity hotspot, on the east. Soil erosion is affecting 15.1% of state's total geographical area with erosion rates of more than 10 t ha^{-1} yr^{-1}. The resulted production loss is about 0.6 lakh tonnes which amounted to monetary loss of about 1.78 billion. Soil erosion is more prevalent in eastern and central Midlands and in certain undulating pockets of the state where high intensity rainfall and steepness of slope contributes to higher erosion rates. Coastal erosion is also a big problem in the state as about 23% of the coastline along India's mainland is affected by soil erosion.

Effective planning and management of soil water conservation technologies is essential to conserve natural resources and ensure sustainable development. Against this backdrop, Regional committee-VIII recommended developing strategy for arresting soil erosion on priority for sustainable development of the southern region and assigned the responsibility to ICAR-IISWC for developing document on “Soil Erosion Status, Priority Treatment Areas and Conservation Measures for Different Districts of Kerala”. Based on the recommendation of the committee the information has been compiled. The compiled information is largely taken from the previous work of ICAR-IISWC and other organizations working in the field of soil and water conservation in Kerala state. The information will be a ready reckoner for policy makers, researchers, planners, NGOs and extension functionaries working in the field of soil and water conservation. We thankfully acknowledge the support from research team of RC Udhagamandalam; Dr Susan John and Dr V. Ramesh from ICAR-Central Tuber Crops Research Institute, Thiruvanthapuram; Dr U. Surendran from KSCSTE-Centre for Water Resources Development and Management, Kozhikode; Mr Sathyan V.S., Assistant Director of Agriculture, Kerala for their active support.

Though sincere efforts have been made in documenting the information for the benefits of stakeholders involved in soil and water conservation, the scope for its further refinement may still exist. We would welcome and appreciate any constructive suggestions for further improvement of the document.

(Authors)

CONTENTS

List of Tables

List of Figures

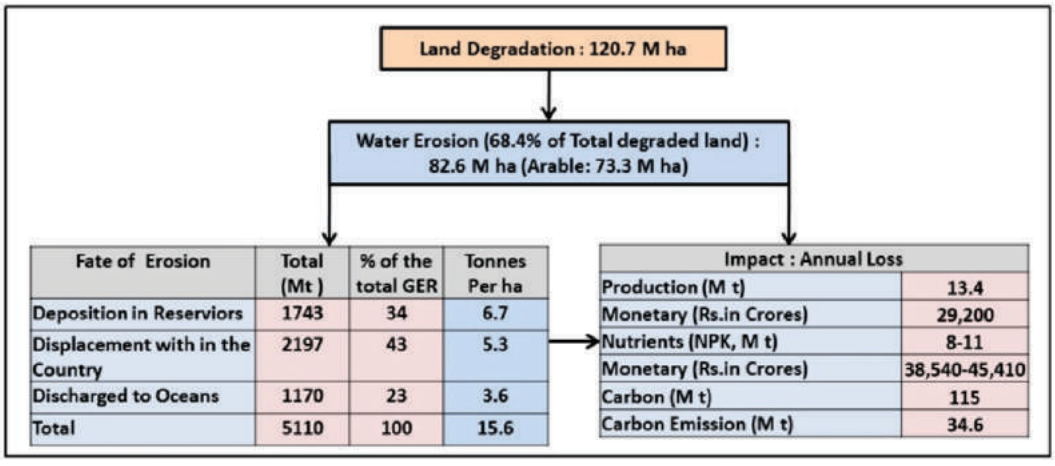
1.0 INTRODUCTION

Soil erosion is one of the most serious environmental concerns affecting all natural and human-managed ecosystems. Soil erosion, besides having significant impact on productivity of cultivated land also adversely affects chemical, physical and biological functions of soil leading to soil degradation and depletion of multiple soil functions. Although soil erosion is a global phenomenon, it has intensified in recent years due to population pressures, developmental activities, unscientific land use and land management practices. Erosion induced loss in crop production and farmers income, are of utmost cocern in India and globally. The total annual production loss was estimated as 13.4 million tonnes @ 15.7% (Sharda et al., 2010). As per valuation based on Government's minimum support prices during 2018-19, the loss was worth Rs 382.78 billion *i.e.* about 0.273% of Gross Domestic Product (GDP) of Rs 140.03 trillion. Further, by adopting a more pragmatic approach it was estimated that productivity loss at state level ranges 0.2-10.9 q ha^{-1} in rainfed crops of cereals, 0.1-6.3 q ha^{-1} in oilseeds, and 0.04-4.4 q ha^{-1} in pulses. India as a whole suffers a loss of 1.63 q ha^{-1} in productivity of rainfed crops (Sharda and Dogra, 2013). This loss was valued at Rs 4631 ha^{-1} considering the minimum support prices during 2018-19. The risk of soil erosion in south Indian states is more serious as many lands can no longer be sustained for production, mainly due to high intensity rainfall, deforestation, overgrazing and faulty land use practices thus leading to their abandonment. About 22%, 9% and 5% of total geographical area (TGA) of Karnataka, Tamil Nadu and Kerala states, respectively, experiences moderate or moderate to severe soil erosion loss (Mandal et al., 2020). Further, these states suffer an annual production loss of 24.6%, 20% and 23.5%, respectively due to water erosion in rainfed cereal, oilseed and pulse crops (Sharda and Dogra, 2013). In an agrarian country like India, assessment of soil erosion risk is of paramount importance to preserve soil's productive potential and ensure sustainable land use (Mandal and Giri, 2021, Sharda and Mandal, 2018). Land managers and policy makers need to have adequate knowledge of intensity and distribution of soil erosion risk areas to check land degradation, and efficiently plan and execute various cost-effective land-based interventions to achieve the targets of land degradation neutrality (LDN) (UNCCD, 2013). Hence, it is imperative to quantify the risks associated with overuse of soil functions, which lead to land degradation and consequently impacting on eco-system services.

2.0 LAND DEGRADATION THROUGH SOIL EROSION AND ITS IMPACTS (NATIONAL LEVEL)

2.1 Land Degradation

In India, about 121.7 M ha area, which includes arable and non-arable lands, is subjected to various forms of land degradation (ICAR 2010), with maximum (82.6 M ha, 68.4%) contribution by water erosion (49% area accounts for soil loss >10.0 t ha^{-1} yr^{-1}). The Soil erosion and other associated losses is presented in Fig. 2.1



Fate of Erosion	Total (Mt)	% of the total GER	Tonnes Per ha
Deposition in Reserviors	1743	34	6.7
Displacement with in the Country	2197	43	5.3
Discharged to Oceans	1170	23	3.6
Total	5110	100	15.6

Impact : Annual Loss	
Production (M t)	13.4
Monetary (Rs.in Crores)	29,200
Nutrients (NPK, M t)	8-11
Monetary (Rs.in Crores)	38,540-45,410
Carbon (M t)	115
Carbon Emission (M t)	34.6

Fig. 2.1: Soil erosion and associated losses in India (GER- Gross erosion rate)

2.2 Gross Erosion Rate

The gross annual soil erosion of our country is 5.11 billion tonnes out of which 34.1 % deposited in the reservoirs, 22.9 % is discharged outside the country (mainly to oceans), and 43.0 % is displaced within the mainland (Sharda and Ojasvi, 2016). Average annual reduction in water storage capacity of dams by 1.2% from 4937 big dams and average life span reduction of dams by 25 yrs (Range 8-53 yrs).

2.3 Production Loss & Monetary Loss

Annual production and monetary losses due to water erosion were estimated by ICAR-IISWC, Dehradun by evolving and adopting a systematic approach which integrates data on erosion category-wise potentially eroded areas under major soil

groups (alluvial, black or red) in each state with productivity loss factors (PLF) of 27 major rainfed crops, including cereals (8), oilseeds (10) and pulses (9), evolved through experimental studies in rainfed areas of different agro-climatic regions of the country. Following this approach, the total annual production loss was estimated as 13.4 million tonnes @ 15.7% (Sharda et al., 2010a). As per valuation based on Government's minimum support prices during 2018-19, this loss was Rs 382.78 billion. The GDP during 2018-19 was Rs 140.03 trillion and the loss was about 0.273% of the GDP. Productivity loss at state level ranges 0.2-10.9 q ha^{-1} in rainfed crops of cereals, 0.1-6.3 q ha^{-1} in oilseeds, and 0.04-4.4 q ha^{-1} in pulses. National average loss in productivity of rainfed crops was estimated to be 1.63 q ha^{-1}(Sharda and Dogra, 2013). This loss was valued at Rs 4631/ha considering the minimum support prices during 2018-19.

2.4 Nutrients Loss

A significant amount (8 to 11 M t of NPK) of nutrients gets transported with runoff and eroded soil leading to net loss of ecosystem services. Soil loss resulting in loss of 5.37 to 8.40 M t of nutrients in India (Sharda and Ojasvi, 2016) estimated total monetary loss of Rs. 38,540 to 45,410 crores annually (2020 price). Further the estimated erosion linked loss of N, P, K, and S nutrient displacement as 4.41 to 9.61, 0.387 to 2.31, 4.43 and 1.27-1.65 million tonnes amounting to the corresponding monetary loss of Rs 13500- 29300, 1850-8320,17300 and 5890-7790 crore rupees (2020 price), respectively.

2.5 Carbon Loss

Release of extra carbon dioxide into the atmosphere by organic matter dislodgement followed by decomposition has serious implications on climate change. The soil pool loses of 1100 Mt C into the atmosphere as a result of soil erosion and another 300-800 Mt C annually to the ocean (Lal, 2011). Quantity of organic C displacement due to water erosion in India is about 115 Mt yr^{-1} which consequently emits about 34.6 Mt of C to the atmosphere; erosion control can reduce C emission by 19.0 – 27.0 Mt yr^{-1}(Mandal et al., 2020).

2.6 Loss in Reservoir Capacity

The total sediment trapped in the reservoirs with a total gross capacity of 299.5 G m^3 was estimated at 1679 M $m^3 yr^{-1}$, as a result of which the average annual capacity loss of the reservoirs was calculated as 1.04% with a range of 0.47 to 3.05% (Sharda and Ojasvi, 2016). Loss of gross storage capacity in the range of 0.50 % to 0.80 % per year is experienced in the case of larger dams with capacity varying from 51 to >1000 M m^3. Smaller dams of 1 to 50 M m^3 capacity experience a reduction in storage capacity ranging from 0.80 % to > 2.00 % per year. The annual total storage loss and dead storage loss in Sardar Sarovar dam has been estimated to be 0.495% and 1.27%, respectively resulting to annual capitalized loss of 1070 to 1137 million rupees for loss in power generation and irrigated area under different scenario of rainfall (Pande et al., 2014).

3.0 THE APPROACH

Soil erosion risk depends upon the balance between prevailing soil erosion rate and the permissible rate or soil loss tolerance limit. While prevailing soil erosion rate is a function of physiographic, edaphic and climatic factors at a given location, the assessment of site-specific soil loss tolerance limit of the location helps in understanding capacity of the soil to withstand the forces of soil erosion. For example, about 32% areas of Peninsular Plateau can only afford a soil loss ranging from 2.5 to 7.5 t ha^{-1} yr^{-1} (NAAS, 2017, Biswas et al., 2015) while soil erosion rates in such area is more than 10 t ha^{-1} yr^{-1} .

The district wise prioritisation/risk area was assessed from the data base on potential soil erosion rates and soil loss tolerance limits for the state of Kerala. The potential soil erosion rate was compared with the value of soil loss tolerance limit, the differences in value of potential soil erosion and soil loss tolerance limit of a place was used for deciding priority class, higher the difference (Potential soil erosion rate – soil loss tolerance limit), higher the priority. Based on the difference of soil erosion and tolerance limits, five priority classes have been defined normalizing the difference values between 35 and 5 t ha^{-1} yr^{-1} (Class 1: > 35 t ha^{-1} yr^{-1}, Class 2 : 25 – 35 t ha^{-1} yr^{-1}, Class 3 : 15 - 25 t ha^{-1} yr^{-1}, Class 4: 5-15 t ha^{-1} yr^{-1} Class 5: < 5 t ha^{-1} yr^{-1}). In addition to the above difference, an area having T-value of 2.5 t ha^{-1} yr^{-1} is considered most sensitive due to shallow soil depth and poor quality, it is highly vulnerable to loss of crop productivity if soil erosion exceeds the T–value. This makes peninsular India an area of great concern from soil erosion point of view. For operational point of view the sum of priority class 1, 2 and 3 has been taken into consideration and the severity of soil erosion risk has been reclassified. According to this re-classification, severity class A, B and C were defined based on the cumulative area of < 50000 ha, 50000-100000 ha and > 100000 ha, respectively.

Soil erosion in a given priority class has to be brought within the permissible rate or T-value to achieve sustainability of production systems, and for carbon sequestration. The identification of critical areas in the priority classes based on the permissible soil erosion rate or T-value at a given location in each district of Kerala and the proposed conservation measures for each district are aimed to reduce soil erosion below the soil tolerance limit.

4.0 EROSION STATUS AND CONSERVATION PLANNING FOR KERALA STATE

4.1 About the State

Kerala is located at the southernmost part of the Indian peninsula. The state is wedged between Arabian Sea on the west, and Western Ghats, identified as one of the world's twenty-five biodiversity hotspot, on the east. Geographically, Kerala can be divided into three distinct climatic regions, *viz*., Eastern Highlands (rugged and cool mountainous terrain), Central Midlands (rolling hills), and Western Lowlands (coastal plains). With 120–140 rainy days per year, Kerala has a wet and maritime tropical climate influenced by seasonal heavy rains of southwest monsoon. The annual average rainfall of the state is 3,107 mm, though drier lowland regions have an average of only 1,250 mm and the mountains of eastern Idukki district receive more than 5,000 mm. Soils are generally very deep and occasionally moderately shallow with rock outcrops in some areas.

4.2 Soil Erosion Rate

A summary of the results for the state of Kerala is given in Table 1, which indicate that overall soil erosion through water is not a serious problem in major part of the state as nearly 84.88% area has soil erosion of less than 10 t ha^{-1} yr^{-1} (Fig. 4.1). Majority of these areas have low slope, high soil depth (>1.5 m) and low drainage density, and therefore lower soil erosion risks. Soil erosion is affecting 15.12% of state's TGA with erosion rates of more than 10 t ha^{-1} yr^{-1}, of which only 0.11% area is very severely affected (>40 t ha^{-1} yr^{-1}). Soil erosion is more prevalent in Eastern and Central Midlands and in certain undulating pockets of the state where high intensity rainfall and steepness of slope has contributed to higher erosion rates (Jose et al., 2011).

4.3 Soil Loss Tolerance Limit (SLTL)

The T-value of the entire state is consistently 10.0 t ha^{-1} yr^{-1}. Although a high rate of soil erosion is permitted in the entire state, there are pockets where potential soil erosion rate is more than the tolerance limit, particularly in hills and uplands of Central Sahyadri, South Sahyadri and Nilgiri regions. Soils of the Coastal Plains and Midlands are stable with higher level of tolerance due to deeper soil depth. However, coastal erosion is a big problem as reported by Mandal and Tripathi (2009). Presently, ~23% of the coastline along India's mainland is affected by soil erosion (Kumar et al., 2006).

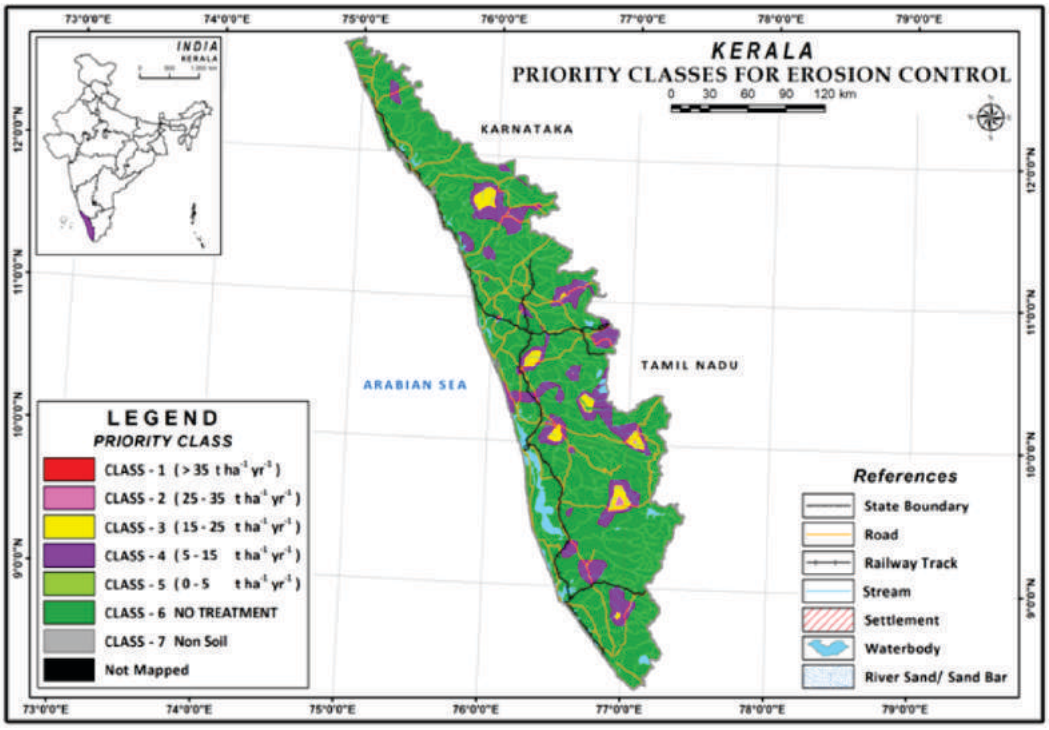


Fig. 4.1: Priority classes for erosion control in Kerala state

4.4 Production and Monetary Loss from Rainfed Crops due to Soil Erosion

The cereal, oilseed and pulse crops lose 23%, 41% and 23% of its production due to water erosion. On an average production loss is about 24% in the State. Out of 0.06 million tonne in total production losses, 95.1% is due to losses in cereals and millets, followed by 2.5% in oilseeds and 2.4% in pulses. In terms of monetary losses, 86.8% of the total loss of Rs 117.8 crores occurs in Kerala due to losses in cereals and millets, followed by 6.5% in oilseeds and 6.7% in pulses. The largest contribution is from paddy (80%) followed by groundnut (4%) and 'other pulses' (4%). The average productivity loss of all these crops together is 479 kg ha^{-1} (Sharda and Dogra, 2013), which in monetary terms was Rs 9440 ha^{-1} during 2018-19. The Gross State Domestic Product (GSDP) of Kerala for 2018-19 at current prices was estimated to be Rs 7,72,894 crore (PRS, 2019). Therefore, the State's loss due to soil erosion by rain water during the cultivation of rainfed cereal, oilseed and pulse crops is equal to 0.02% of its GSDP during 2018-19.

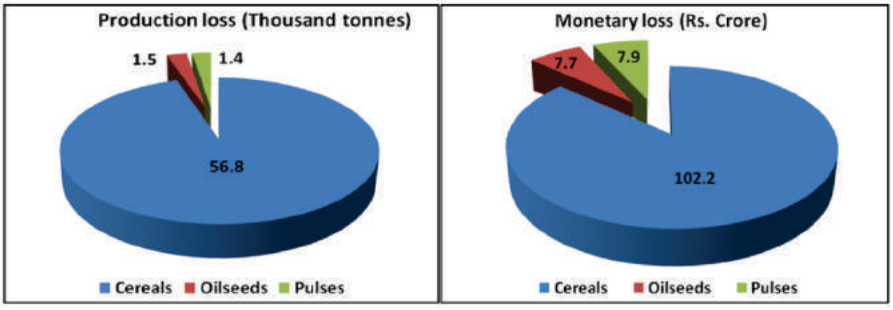


Fig. 4.2. Estimated total production and monetary loss of rainfed crops due to soil erosion in Kerala State

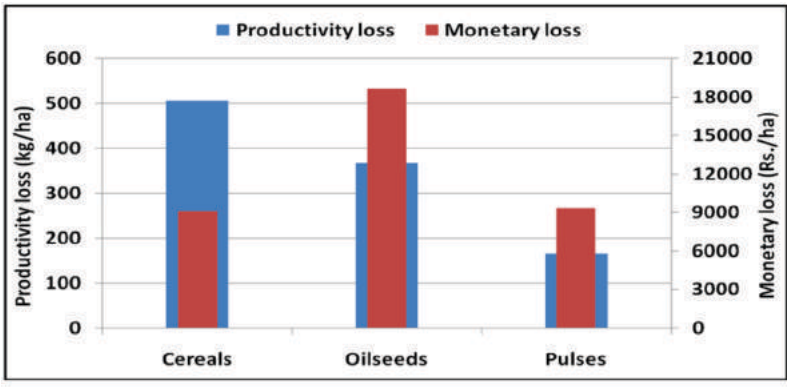


Fig. 4. 3. Estimated productivity (kg ha^{-1}) and monetary loss (Rs ha^{-1}) of rainfed crops due to soil erosion in Kerala State

4.5 Area Under Risk

Estimates based on comparison between prevailing and permissible rates of soil erosion indicate that only 14.84% of state's total geographical area (TGA) requires various kinds of soil management while 85.16% of TGA falls under no treatment category due to higher values of permissible erosion limits (Table 4.1). It is also evident from the analysis that only 0.11% area has high priority for conservation treatment as classified in priority class 2, while there is practically no area which could be classified under priority class 1. The spatial distribution of different priority classes in the state is presented in Fig. 4.1. It is also also suggested that the spatial division of priority areas for conservation actions is an important aspect of conservation planning. Detail account of district wise severity of erosion areas and critical problem with their possible solutions has been given in Table 4.1. The last column of Table 4.1 refers Table 4.2, Table 4.3 and Table 4.4 which are given in the succeeding sections of the document. Table 4.2 which presents soil and water conservation measures, under different land situations, Table 4.3 presents district wise agronomic and vegetative measures and Table 4.4 presents district wise agroforestry measures.

Table 4.1: District wise severity of erosion areas and critical problem with their possible solutions in Kerala

District	TGA (000ha)	Area under risk (000ha)	% area of the district	Special erosion problem	Solutions
Severity of risk-No risk					
Alappuzha	141.5	0.00	0.00	Mining, Urbanization, Flash floods	Table 4.2-Sr No. 6.211, 3.1.1 & 6.2.10 Table 4.4- Sr, No 18
Kannur	296.1	0.00	0.00	Mining, Open Scrub	Table 4.2-Sr No. 3.1.3, 3.2.1, 3.3.2, 4.6, 4.4, 3.1.1, 6.2.3, 4.8 Table 4.4- Sr, No 18, 19, 20
Kasargod	198.9	0.00	0.00	Mining, Open Scrub	Table 4.2-Sr No. 3.1.3, 3.2.1, 3.3.2, 4.6, 4.4, 3.1.1, 6.2.3, 4.8 Table 4.4- Sr, No 18, 19,
Pathanamthitta	265.2	0.00	0.00		Table 4.2-Sr No. 3.1.3, 3.1.2, 7.3, 6.1.6, 6.1.7, 3.2.3, 5.4, 6.2.10, 6.2.4, 4.6 Table 4.4- Sr, No 19, 20, 21
Total	**901.7**	**0.00**	**0.00**		
Severity of Risk-A					
Ernakulam	306.3	11.70 (3:11.7)	3.77	Mining, Urbanization, Flash floods	Table 4.2-Sr No. 3.1.1, 3.1.3, 6.1.1, 3.3.1, 6.2.4 Table 4.4- Sr, No 18,20
Idukki	435.6	34.68 (2:3.7, 3:31.0)	7.78	Soil Piping, Mining. Steep slopes with high intensity rainfall, Gully erosion, Susceptible for Landslides	Table 4.2-Sr No. 3.1.3, 3.1.2, 7.3, 6.1.6, 6.1.7, 3.2.3, 5.4, 6.2.10, 6.2.4, 4.6 Table 4.4- Sr, No 21
Kollam	248.3	1.96 (3:1.96)	0.76	Mining, Open Scrub	Table 4.2-Sr No. 3.1.3, 3.2.1, 3.3.2, 4.6, 4.4, 3.1.1, 6.2.3, 4.8 Table 4.4- Sr, No 19,20
Kottyam	220.6	1.47 (3:1.47)	0.65	Mining, Open Scrub	Table 4.2-Sr No. 3.1.3, 3.2.1, 3.3.2, 4.6, 4.4, 3.1.1, 6.2.3, 4.8 Table 4.4- Sr, No 19, 20
Kozikod	234.5	6.30 (3:6.3)	2.68	Mining, Open Scrub, smaller portion under steep slopes, Barren rocky, Susceptible for Landslide	Table 4.2-Sr No. 3.2.1, 6.2.3, 6.2.4 Table 4.4- Sr, No 18,19
Malappuram	355.4	0.21 (2:0.21)	0.06	Sheet erosion, Mining and quarrying, Susceptible for Landslides	Table 4.2-Sr No. 3.2.1, 6.2.3, 6.2.4 Table 4.4- Sr, No 18,19, 20

Palakkad	448.2	1.58 (2:0.1, 3: 1.4)	0.34	Mining, Open Scrub, Barren rocky, Degraded lands	Table 4.2-Sr No. 3.2.1, 6.2.3, 6.2.4, 7.5, 6.1.6, 6.2.4, 4.6 Table 4.4- Sr, No 21, 22
Thiruvananthpuram	265.2	0.03 (3:0.03)	0.01	Urbanization, flash floods	Table 4.2-Sr No 3.2.1, 3.1.1, 3.3.1, 6.1.1, 3.2.3, 3.2.1, 6.2.3, 4.6, 4.4. Table 4.4- Sr, No 18,19, 20
Thrissur	218.9	18.94 (3:18.94)	6.17	Mining, Open Scrub	Table 4.2-Sr No. 3.1.3, 3.2.1, 3.3.2, 4.6, 4.4, 3.1.1, 6.2.3, 4.8 Table 4.4- Sr, No 18, 19,20
Wayanad	302.7	15.9 (2:0.2, 3:15.7)	7.42	Soil Piping, Mining, Steep slopes with high intensity rainfall, Susceptible for Landslides	Table 4.2-Sr No. 3.1.3, 3.2.1, 3.3.2, 4.6, 4.4, 3.1.1, 6.2.3, 4.8 Table 4.4- Sr, No 21
Total	**2983.5**	**92.8**	**0.89**		

Note: A= < 50,000 ha area is critical; B= between 50,000-1,00000 ha area is critical; C= > 1,00000 ha area is critical in a district. Critical area is the sum of area under priority class 1, 2 and 3. Data in Parentheses shows area under different priority class based on difference between potential erosion (Er) and soil loss tolerance limit (T) i.e. $(E_r - TL)$; 1: $(E_r - TL)$ >35 t ha^{-1} yr^{-1}, 2: $(E_r - TL)$ in the range of 25-35 t ha^{-1} yr^{-1}, 3: $(E_r - TL)$ in the range of 15-25 t ha^{-1} yr^{-1}. Table 4.2 represents different soil and water conservation measures for different land situations, Table 4.3 represents details of agronomical and vegetative measures and Table 4.4 represents district wise potential agroforestry systems (AFS)

Table 4.2: Soil and water conservation measures for different soil erosion priority classes

S. No.	Conservation Measures		Slope <10%		Slope-10-33%	
			Low priority class		High priority class	
			Arable land	Non arable land	Arable land	Non arable land
1.0	**Agronomic Measures (upto 6%, agronomic measures alone; >6% with other land management practices) refer Table 4.3 for details**					
	1.1	Contour cultivation/farming	√		√	
	1.2	Inter or mixed cropping	√		√	
	1.3	Green manuring & Recycling crop residues	√		√	
	1.4	Crop rotation	√		√	
	1.5	Mulching	√		√	
	1.6	Conservation tillage/Conservation agriculture	√		√	
	1.7	Cover crops	√		√	
	1.8	Fodder/ tea/ medicinal-aromatic crops on the bunds & terrace riser			√	
	1.9	Broad bed and furrow (Black soil)	√			
	1.10	Furrow opening in between the lines (Black soil)	√			

2.0	**Vegetative Measures (At lower slope-alone, at higher slope with other conservation measures**					
	2.1	Vegetative barrier*/Mixed vegetative barriers*	√	√	√	√
	2.2	Vegetative strips*		√	√	√
	2.3	Vegetally* guarded conservation trenches and ridges (VGCTR)		√		√
	2.4	Afforestation/reforestation		√		√
	2.5	Grassed waterways	√	√	√	√
	2.6	Live vegetative check dam (Bamboo)		√		√
	2.7	Stream bank stabilization with bamboo and other species		√		√
		*Species: Vetivera grass (*Vetiveria zizanioides)* ; Guatemala grass (*Tripsacum laxum*); Weeping love grass (*Eragrostis curvula);* Lemon grass (*Cymbopogon citratus);* Rosha/ palma rosa grass (*C. martinii);* Malabar (*C. flexuosus);* Hybrid Napier; Agave (*Agave americana & Agave sisalana);* Geranium (*Pelargonium graveolens);* Mulberry (*Morus alba); Pineapple (Ananas comosus)*				
3.0	**Mechanical/Engineering Measures**					
	3.1	**Bunding**				
	3.1.1	Contour/Field bunding/Trench-cum-bund	√	√	√	√
	3.1.2	Graded bunding (uniformly and variable graded)-Black soils	√			
	3.1.3	Stone bund (Where stones are available onsite)	√	√	√	√
	3.1.4	Compartmental Bunding	√		√	
	3.2	**Trenching**				
	3.2.1	Contour trenching		√		√
	3.2.2	Continuous contour trenching	√			√
	3.2.3	Contour staggered trenching		√		√
	3.2.4	Graded trenching		√		√
	3.2.5	Water absorption trenches		√		√
	3.2.6	Half-moon trenches/terraces	√	√	√	√
	3.2.7	Recharge pit		√		√
	3.3	**Terracing (Bench)**				
	3.3.1	Leveled terrace	√		√	
	3.3.2	Inward sloping	√		√	
	3.3.3	Outward sloping	√		√	
	3.3.4	Puertorican type/vegetative	√		√	
	3.3.5	Half-moon terraces			√	√
	3.3.6	Conservation bench terracing	√			
	3.3.7	Narrow based terracing			√	

4.0	**Drainage Line Treatments (DLTs)**					
	4.1	Earthen Check dam		√		
	4.2	Sandbag check dam		√		
	4.3	Brush wood check dam (BWCD)		√		√
	4.4	Loose boulders check dam (LBCD)		√		√
	4.5	Gabion check dam		√		√
	4.6	RR check dam		√		√
	4.7	Gabion terrace support wall		√		√
	4.8	Retaining wall/ Revetment		√		√
	4.9	Silt detention tank		√		√
5.0	**Water Harvesting**					
	5.1	Community pond/Ooranies	√	√	√	
	5.2	Embankment pond		√		
	5.3	Pond renovation & Desilting	√	√	√	
	5.4	Farm pond-Dugout	√		√	
	5.5	Subsurface runoff collection wells			√	
	5.5	Pond lining	√	√	√	
	5.6	Roof top water harvesting	√		√	
	5.7	Diversion Based water harvesting			√	√
Special Problem Area						
6.0	**Mine spoil area/ Land Slide Prone Area**					
	6.1	**Vegetative**				
	6.1.1	Vegetative hedges		√		√
	6.1.2	Brushwood check dam				√
	6.1.3	Watling (live)				√
	6.1.4	Double-row Brushwood dam / Log wood brush filled check dam				√
	6.1.5	Grassed contour barrier		√		√
	6.1.6	Bamboo plantation		√		√
	6.1.7	Afforestation		√		√
	6.1.8	Aerial seeding (very high slope or unapproachable area)				√
	6.1.9	Turfing/Soding				√
	6.2	**Mechanical/Engineering Measures**				
	6.2.1	Contour bunds/Stone bund		√		√
	6.2.2	Stone wall				√

	6.2.3	Staggered trenches and planting		√		√
	6.2.4	Loose Boulder check dam (locally available)				√
	6.2.5	Diversion drain/ Interceptor drain				√
	6.2.6	Nala bunds		√		
	6.2.7	Gabion check dam				√
	6.2.8	Gabion drop structures				√
	6.2.9	Toe wall/toe drain				√
	6.2.10	Retaining wall				√
	6.2.11	Jute geo textiles for slope stabilization/ Coir Jeo textiles for stabilization of land slide areas (Slope >33%)				√
	6.2.12	Stream Channelization (Retaining wall, Bank protection walls. Spurs with apron etc)		√		√
7.0	**Gullied and Ravine Land**					
	7.1	Bio fencing/social fencing		√		√
	7.2	Peripheral bund		√		√
	7.3	Peripheral bund supported by close plantation of bamboo		√		√
	7.4	Safe disposal of water from gully head- Piped/chute spillway-		√		√
	7.5	Bamboo on ravine bed and grass on slope		√		√
	7.6	Bamboo based live check dams		√		√
	7.7	Alternate land use system/Agroforestry		√		√
	7.8	Mechanical/Engineering measures		√		√
	7.9	Earthen check dam		√		√
	7.10	Boribund check dam		√		√
	7.11	Silt retention tank		√		√
	7.12	Staggered trenching + plantation		√		√

Note 1: District wise details of agronomic and vegetative measures for Kerala is referred in Table 4.3

Note 2: For concept, design and estimates of soil and water conservation measures, kindly refer, Mishra, P. K., Jual, G. P., Tripathi, K. P., Ojasvi, P. R., Shrimali, S. S., Sena, D. R., Kumar, A., Patra, S. 2017. Field manual on soil and water conservation structures, ICAR, New Delhi, ISBN: 978-81-7164-167-3

Note 3: For agroforestry solutions for soil water conservation in and Kerala kindly refer Table 4.4

Table 4.3: District wise severity of erosion areas and critical problem with their possible solutions in Kerala

[District Details- District: Name of District, TGA: Total Geographical area (000, ha), A(Er): Area under erosion risk ('000 ha), Er (%): erosion risk area as a percentage of TGA, Sp.P.: Special erosion problem]

S. No.	Cropping System (Intercropping, mixed cropping, Conservation Agriculture, crop rotation, etc.)	Green manuring, Cover crops and Mulching	Protection-cum Productive Vegetative Barriers (Grasses/Fodder/Medicinal-Aromatic Crops /Tea/ Pineapple etc.)	Special problem area: Grassed waterways/live check dams/Mine spoil area/ Land Slide Prone Area
Severity of Risk-No risk				
1	**District: : Alappuzha, TGA : 141.5, A (Er): 0.00, Er (%): 0.00, Sp. P.: Mining, Urbanization, Flash floods**			
	Paddy – green manuring crops Tapioca cultivation with furrow system Coconut with Arecanut Multi-storey coconut agro forestry system with nutmeg and other tree spices	Green manuring with *Dhaincha* Leaf litter mulch for moisture conservation and to improve fertility Crop reside incorporation in coconut and Arecanut plantation	Turfing with geo textiles Vegetative hedge with Gliricidia, lemon and vetiver grass	Culvert with sluice Afforestration with the following species - *Casurina, Cashew, Bamboo, Thespesia popullnea, Gliricidia sepium, Mango* and *Artocarpus*
2	**District: Kannur, TGA: 296.1, A (Er): 0.00, Er (%): 0.00,Sp. P.: Mining, Open Scrub**			
	Coconut plantation Areca nut plantation Cashew plantation Pepper + Silveroak Bannana Mixed plantation of Coconut and Arecanut Homegardens with multiple species	improve fertility *Gliricidia* and *Leucaena* green manure crops in the boundaries Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation	Vetiver and lemon grass along the stream	Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia sepium, Tectona grandis, Grevillea robusta, Bambusa bambus, Erythrina, Pterocarpus* and *Legestromia spp.*
3	**District: Kasargod, TGA: 198.9, A (Er): 0.00, Er (%): 0.00, Sp. P.: Mining, Open Scrub**			
	Coconut plantation Areca nut plantation Cashew plantation Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Mixed plantation of Coconut and Arecanut Coconut + nutmeg + Cinamomum, Clove with pinapple Pepper + Silveroak Homegardens with Jack fruit, Mango and other timber tree species	Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Leaf litter mulch for moisture conservation and to improve fertility Sunhemp and Diancha are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Afforestration with the following species - *Casurina, Cashew, Bamboo, Thespesia popullnea, Gliricidia sepium, Mango* and *Artocarpus*

4	**District: Pathanamthitta, TGA: 265.2, A (Er): 0.00, Er (%): 0.00**			
	Coconut plantation Areca nut plantation Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Mixed plantation of Coconut and Arecanut Coconut + nutmeg + cinamomum, Clove with pinapple Pepper + Silveroak Homegardens with Jack fruit, Mango and other timber tree species Tapioca cultivation under terracing	Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Leaf litter mulch for moisture conservation and to improve fertility Sunhemp and Diancha are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Live check dam with *Erythrina* Afforestration with the following native tree species *Acacia mangium, Ailanthus*, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia Sepium, Tectona grandis, Girevillea robusta, Bambusa bambus, Erythrina, Pterocarpus* and *Legestromia spp.*
	TGA (000 ha): 901.7**, Area under Severity of risk -No risk: 0.00, % of TGA under risk: 0.00**			
	Severity of Risk-A			
5	**District : Ernakulam, TGA: 306.3, A (Er): 11.70 (3:11.7), Er (%): 3.77, Sp. P.: Mining, Urbanization, Flash floods**			
	Paddy – green manuring crops Tapioca cultivation with furrow system in the terrace Coconut + Arecanut Multi-storey coconut agro forestry system with nutmeg and other tree spices Mixed plantation of Coconut and Arecanut Homegardens with Jack fruit, Mango and other timber tree species	Green manuring with Dhaincha Leaf litter mulch for moisture conservation and to improve fertility Crop reside incorporation in Coconut and Arecanut plantation	Turfing with geo texttiles Vegetative hedge with Gliricidia, lemon and vettiver gras Planting grasses along contour bund	Culvert with sluice Live check dam in the mid land Afforestration with the following species - *Casurina, Cashew, Bamboo, Thespesia popullnea, Gliricidia sepium, Mango* and *Artocarpus*
6	**District: Idukki, TGA: 435.6, A (Er): 34.68 (2:3.7, 3:31.0), Er (%): 7.78, Sp. P.: Soil Piping, Mining. Steep slopes with high intensity rainfall, Gully erosion, Susceptible for Landslides**			
	Tea gardens Coffee and Cardamom grown under native shade trees Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Mixed plantation of Coconut and Arecanut Coconut + nutmeg + Cinamomum and Clove Pepper + Silveroak Homegardens with Jack fruit, Mango and other timber tree species	Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Leaf litter mulch for moisture conservation and to improve fertility Sunhemp and diancha are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Live check dam in the upper reaches Grassed water ways with bamboo and Lemon grass Afforestration with the following native tree species *Acacia mangium, Ailanthus*, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia Sepium, Tectona grandis, Grevillea robusta, Bambusa bambus, Erythrina*

7	**District: Kollam, TGA: 248.3, A (Er): 1.96 (3:1.96), Er (%): 0.76, Sp. P.: Mining, Open Scrub**			
	Colocasia, Pineapple and Elephant yam Coconut plantation Areca nut plantation Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Tapioca cultivation with furrow system in the terrace Coconut + nutmeg + cinamomum, Clove with pinapple Pepper + Silveroak Homegardens with Jack fruit, Mango and other timber tree species Tapioca cultivation under terracing	Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Leaf litter mulch for moisture conservation and to improve fertility Sunhemp and Diancha are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Live check dam Afforestration with the following native tree species *Acacia mangium, Ailanthus*, *Atrocarpus*, *Macaranga pelteta, Thespesia popullnea, Gliricidia Sepium, Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*
8	**District: Kottyam, TGA: 220.6, A (Er): 1.47 (3:1.47), Er (%): 0.65, Sp. P.: Mining, Open Scrub**			
	Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Coconut plantation Arecanut plantation Mixed plantation of Coconut and Arecanut Coconut + Nutmeg + Cinamomum, Clove with Pinapple Pepper + Silveroak Homegardens with Jack fruit, Mango, Nutmeg and other timber tree species Tapioca cultivation under terracing	Leaf litter mulch for moisture conservation and to improve fertility Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Sunhemp are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Live check dam Afforestration with the following native tree species *Acacia mangium, Ailanthus*, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia Sepium, Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*
9	**District: Kozikod, TGA: 234.5, A (Er): 6.30 (3:6.3), Er (%): 2.68, Sp. P.: Mining, Open Scrub, smaller portion under steep slopes, Barren rocky, Susceptible for Landslide**			
	Coconut plantation Areca nut plantation Cashew plantation Pepper + Silveroak Tapioca cultivation under terracing Bannana Mixed plantation of Coconut and Arecanut Homegardens with multiple species	Leaf litter mulch for moisture conservation and to improve fertility *Gliricidia* and *Leucaena* green manure crops in the boundaries	Mixed vegetative barrier with pineapple and grasses in plantation crops Vetiver and lemon grass along the stream	Afforestration with the following native tree species *Acacia mangium, Ailanthus*, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia sepium, Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*

10	**District: Malappuram, TGA: 355.4, A (Er): 0.21 (2:0.21), Er (%): 0.06, Sp. P.: Sheet erosion, Mining and quarrying, Susceptible for Landslides**			
	Coconut + Arecanut Multi-storey coconut agro forestry system with nutmeg and other tree spices Tapioca cultivation with furrow system in the terrace Mixed plantation of Coconut and Arecanut with fruit trees Homegardens with Jack fruit, Mango, Nutmeg and other timber tree species Paddy – green manuring crops	Green manuring with Dhaincha Leaf litter mulch for moisture conservation and to improve fertility Crop reside incorporation in Coconut and Arecanut plantation	Turfing with geo texttiles Vegetative hedge with Gliricidia, lemon and vettiver gras Planting grasses along contour bund	Culvert with sluice Live check dam in the mid land Afforestration with the following species - Acacia mangium, Ailanthus, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia sepium* *Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*
11	**District: Palakkad, TGA: 448.2, A (Er): 1.58 (2:0.1, 3: 1.4), Er (%): 0.34, Sp. P.: Mining, Open Scrub, Barren rocky, Degraded lands**			
	Paddy – green manuring crops Coconut + Arecanut Multi-storey coconut agro forestry system with nutmeg and other tree spices Tapioca cultivation with furrow system in the terrace Mixed plantation of Coconut and Arecanut with fruit trees Homegardens with Jack fruit, Mango, Nutmeg and other timber tree species Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops	Leaf litter mulch for moisture conservation and to improve fertility Green manuring with Dhaincha Crop reside incorporation in Coconut and Arecanut plantation	Turfing with geo texttiles Vegetative hedge with Gliricidia, lemon and vettiver grass Planting grasses along contour bund	Stream bank stabilization with bamboo like species and agroforestry Live check dam in the mid land Afforestration with the following species - *Acacia mangium, Ailanthus,* Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia sepium* *Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*
12	**District: Thiruvananthpuram, TGA: 265.2, A (Er): 0.03 (3:0.03), Er (%): 0.01, Sp. P.: Urbanization, flash floods**			
	Colocasia, Pineapple and Elephant yam Coconut plantation Areca nut plantation Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Tapioca cultivation with furrow system in the terrace Coconut + nutmeg + cinamomum, Clove with pinapple Pepper + Silveroak Homegardens with Jack fruit, Mango and other timber tree species Tapioca cultivation under terracing	Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Leaf litter mulch for moisture conservation and to improve fertility Sunhemp and Diancha are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Live check dam Afforestration with the following native tree species *Acacia mangium, Ailanthus*, Atrocarpus, *Macaranga pelteta,Thespesia popullnea, Gliricidia sepium, Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*

13	**District: Thrissur, TGA: 218.9, A (Er): 18.94 (3:18.94), Er (%): 6.17, Sp. P.: Mining, Open Scrub**			
	Paddy – green manuring crops Coconut + Arecanut Multi-storey coconut agro forestry system with nutmeg and other tree spices Tapioca cultivation with furrow system in the terrace Mixed plantation of Coconut and Arecanut with fruit trees Homegardens with Jack fruit, Mango and other timber tree species	Green manuring with Diancha Leaf litter mulch for moisture conservation and to improve fertility Crop reside incorporation in Coconut and Arecanut plantation	Turfing with geo texttiles Vegetative hedge with Gliricidia, lemon and vettiver gras Planting grasses along contour bund	Culvert with sluice Live check dam in the mid land Afforestration with the following species - Acacia mangium, Ailanthus, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia sepium Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*
14	**District: Wayanad, TGA: 302.7, A (Er): 15.9 (2:0.2, 3:15.7), Er (%): 7.42, Sp. P.: Soil Piping, Mining, Steep slopes with high intensity rainfall, Susceptible for Landslides**			
	Coffee and Cardamom grown under native shade trees Coconut + Areca nut plantation Rubber plantation with *Mucuna, Pueraria* and *Calopogonium* cover crops Mixed plantation of Coconut and Arecanut Coconut + nutmeg + cinamomum and Clov Pepper + Silveroak Homegardens with Jack fruit, Mango and other timber tree species	Cover crops like *Mucuna, Pueraria* and *Calopogonium* grown under rubber plantation Leaf litter mulch for moisture conservation and to improve fertility Sunhemp and diancha are cultivated as green manuring crops	Mixed vegetative barrier with pineapple and quick growing grasses in plantation crops Vetiver and lemon grass along the stream Planting grasses along contour bund	Live check dam in the upper reaches Grassed water ways with bamboo and Lemon grass Afforestration with the following native tree species *Acacia mangium, Ailanthus*, Atrocarpus, *Macaranga pelteta, Thespesia popullnea, Gliricidia sepium, Tectona grandis, Grevillea robusta, Bambusa bambus* and *Erythrina*
	TGA (000 ha): 2983.5, Area under Severity of risk A: 92.8, % of TGA under risk: 0.89			

Note: Severity risk-No risk: Area under (Er-T) >15 t ha^{-1} yr^{-1} is nil however some area having more than 10 t ha^{-1} yr^{-1} need to be treated. Severity Risk A= < 50,000 ha area is critical; severity Risk B= between 50,000-1,00000 ha area is critical; Severity Risk C= > 1,00000 ha area is critical in a district. Critical area is the sum of area under priority class 1, 2 and 3. Data in Parentheses shows area under different priority class based on difference between potential erosion (Er) and soil loss tolerance limit (T) i.e. (E_r – TL); 1: (E_r – TL) >35 t ha^{-1} yr^{-1}, 2: (E_r – TL) in the range of 25-35 t ha^{-1} yr^{-1}, 3: (E_r – TL) in the range of 15-25 t ha^{-1} yr^{-1}. Table4.2 represents different soil and water conservation measures for different land situations, Table 4.3 represents details of agronomical and vegetative measures and Table 4.4 represents district wise potential agroforestry systems (AFS).

Table 4.4: Agroforestry solutions for soil water conservation in Kerala

S. No.	Agro Ecological region	Districts	Agroforestry system	Non-arable land	Special Problem (Gully/Mining/any other)
1	Coastal plains	Thruvanathapuram Alappuzha, Ernakulam, Thrissur, Malappuram Kozhikode, Kannur and Kasargod	Coconut based multispecies gardens, Home gardens, Multipurpose trees in farm boundary Plantation crop combination production system Hedge row bio-fences	*Casuarina, Cashew Thespesia populnea, Giliricidia sepium, Mango*	Stream back erosion
2	Midland Laterites	Thruvanathapuram Kollam, Pathanamthitta, Kottayam, Ernakulam, Malappuram, Kozhikode, Kannur and Kasargod	Home gardens, Coconut based multispecies, Silvipasture system Multipurpose trees in farm boundary, Plantation crop combination production system Hedge row bio-fences	*Acacia mangium, Ailanthus, Atrocarpus, Macaranga pelteta, Thespesia populnea, Giliricidia sepium Tectona grandis, Bambusa bambos, Erythrina, Morus alba*	Loose boulder check dams, Gabion structures for gully control
3	Foothills	Thruvanathapuram Kollam, Pathanamthitta, Kottayam, Ernakulam, Malappuram, Palakkad, Kannur	Coconut based multispecies Home gardens, Silvipastoralism Multipurpose trees in farm boundary, Plantation crop combination, production system	*Acacia mangium, Ailanthus, Atrocarpus, Macaranga pelta, Thespesia popullnea, Giliricidia sepium Tectona grandis, Bambusa bambos*	Retaining wall, Agroforestry against flash flood, Jungle stone Check dam, Blasted rubble check dam, Check bund, Concrete weir, Concrete check dam,
4	High hills	Iddukki, Palakkad, Wayanad	Tea gardens with shade trees, Coffee plantations with shade trees, Home Gardens, Areca Nut gardens, Energy plantations and wood lands,	*Acacia mangium, Ailanthus, Atrocarpus, Macaranga peltata, Thespesia populnea, Giliricidia sepium Tectona grandis Erythrina indica, Mangifera indica, Artocarpus heterophyllus, Grevillea robusta, Melia dubia, Areca catechu* and *Tectona grandis*	Land slide control measures. Retaining wall, LBCD, GCD, gabion drop pits for gully control. Agroforestry, Jungle stone Check dam, Blasted rubble check dam, Check bund, Concrete weir, Concrete check dam,
5	Palakkad plains	Palakkad	Mango based agri horti system	*Acacia mangium, Ailanthus, Atrocarpus, Macaranga peltata, Thespesia populnea, Giliricidia sepium Tectona grandis, Bambusa bambos*	Stream bank stabilization

5.0 CONCLUSION

Water erosion is though not a major problem in Kerala as compared to other adjoining states, the over all about 15% of the total geographical area need soil and water conservation (SWC) treatments. The rest about 85% have erosion rate lower than the tolerance limit therefore no priority treatment is warranted however, field level agronomic and vegetative measures are recommended for these lands also. Idduki district is having the highest area *i.e.* 34.68 thousand hectares of land in the need of SWC interventions followed by Thrissur (18.94 thousand hectare) and Waynad (15.9 thousand hectare). Idduki is also having 3.7 thousand hectares under high erosion risk (risk category 2) followed by Malappuram (0.21 thousand hectare) and Palakkad (0.1 thousand hectare).

Most of the erosion prone area is in the hills and upland of central Sahyadri, south Sahyadri, and Nilgiris. Coastal erosion is also a major problem as it effects about 23% of the coast line.

In addition to soil erosion problem on arable and non-arable lands, associated special problems like mine spoilt, landslides prone area, open scrub, sea water ingress, flood and water scarcity *etc.* make the land treatment more challenging. A wide range of soil and water conservation measures including agronomic and vegetative measures for different land situations and agroforestry measures for different districts have been suggested. The suggested measures aim reducing soil erosion below the soil loss tolerance limit of the area. The uniqueness of the present approach is that it integrates soil erosion risk areas with production losses of major crops, which would immensely benefit land use planners and policy makers to identify and prioritize the areas for execution of site specific best management practices and bring soil erosion rates within the permissible limits, thus saving on scarce financial resources.

6.0 REFERENCES

Biswas, H., Raizada, A., Mandal, D., Kumar, S., Srinivas, S. and Mishra, P. K. 2015. Identification of areas vulnerable to soil erosion risk in India using GIS methods, Solid Earth, 6, pp1247–1257, doi:10.5194/se-6-1247-2015

Down to Earth, 2016. Deluge despite deficit

(https://www.downtoearth.org.in/archives?get_year=2016&lang=english)

https://kvk.icar.gov.in/Contigencyplan/Bangalore%20Ruralaa9ac6f8-8669-4334-9c7e-42c240301a88.pdf

https://pmksy.gov.in/mis/Uploads/2016/20161224053438358-1.pdf

https://cdn.s3waas.gov.in/s35751ec3e9a4feab575962e78e006250d/uploads/2019/11/2019112613.pdf

https://cdn.s3waas.gov.in/s35751ec3e9a4feab575962e78e006250d/uploads/2019/11/2019112613.pd

https://krishi.icar.gov.in/jspui/bitstream/123456789/30676/1/KAR11

https://krishi.icar.gov.in/jspui/bitstream/123456789/30676/1/KAR11

http://cwc.gov.in/sites/default/files/reference-manual-climate-change-adaptation-guidelines.pdf)

https://pmksy.gov.in/mis/Uploads/2016/20161220120144836-1.pdf.

http://www.icarkvkmandya.com/districtProfile.html.

ICAR, 2010. Degraded and Wasteland of India – Status and Spatial Distribution. ICAR, New Delhi, pp 1–167(by Maji, A.K., Reddy, G.P.O., and Sarkar, D).

Jiayin, H., Baoan, H., Xiangjun, T., Jin, C., & Long, L. 2020. Concept and practice of open-pit mining area restoration and reuse-taking an open-pit coal mining area in Datong, Shanxi as an example. In E3S Web of Conferences (Vol. 145p. 02014). EDP Sciences.)

Lal, R. 2011. Soil Carbon Sequestration. SOLAW Background Thematic Report- TR04B

Mandal, D., and Giri, N. 2021. A brief history of soil erosion and conservation policy in India. Current Science (Forthcoming)

Mandal, D., Giri, N. and Srivastava, P. 2020. The magnitude of erosion-induced carbon (C) flux and C-sequestration potential of eroded lands in India, European Journal of Soil Science, 72(2):pp151-168. https://doi.org/10.1111/ejss.12886

NAAS. 2017. Mitigating land degradation due to water erosion. Policy Paper No. 88, NAAS, New Delhi, 20p.

Pande, V. C., Kurothe, R. S., Sena, D. R. and Kumar, G. 2014. Cost of siltation in Sardar Sarovar reservoir:implications for catchment treatment, Current Science, 106: pp35-39

Prasad, Y.G., Venkateswarlu, B., Ravindra Chary, G., Srinivasarao, Ch., Rao, K.V., Ramana, D.B.V., Rao, V.U.M., Subba Reddy, G. and Singh, A.K. (2012). Contingency Crop Planning for 100 Districts in Peninsular India. Central Research Institute for Dryland Agriculture, Hyderabad 500 059, India. 302p. http://nicra-icar.in/nicrarevised/images/statewiseplans/Contingency%20crop%20bk_27-7-2012%20Full%20Book%20Proof%2028-7-2012-High-1.pdf

Sharda, V.N. and Dogra, P. 2013. Assessment of productivity and monetary losses due to water erosion in rainfed crops across different states of India for prioritization and conservation planning. Agricultural Research, 2(4): pp382-392. DOI 10.1007/s40003- 013-0087-1.

Sharda, V.N. and Mandal, D. 2018. Prioritization and Field Validation of Erosion risk areas for combating land degradation in north western Himalayas. Catena, 164:pp71-78.

Sharda, V.N. and Ojasvi, P.R. 2016. A revised soil erosion budget for India: Role of reservoir sedimentation and land-use protection measures. Earth Surf. Process. Landforms, 41, pp2007-2023.

Sharda, V.N., Dogra, Pradeep and Prakash, C. 2010. Assessment of production losses due to water erosion in rainfed areas of India. Journal of Soil and Water Conservation, 65(2): pp79-91.

UNCCD, 2013. Achieving Land Degradation Neutrality at the country level Building blocks for LDN target setting, pp1-32 (https://www.unccd.int/sites/default/files/documents/160915_ldn_rgb_small%20(1).pdf accessed on 18th May, 2021)

Agronomic conservation measures for arable lands

Ginger cultivation with mulching

Live mulching with legumes in coconut plantation

Tapioca cultivation under plastic mulching

Terrace cultivation with fodder grasses in the raiser

Vegetable intercrop under coconut plantation

Cover crop Mucana under Rubber plantation

Agroforestry practices / measures

Multitier coconut cropping system

Multitier homegarden system

Coconut + Arecanut + Pepper cropping system

Coffee shade tree agroforestry

Tea plantation with silver oak

Coco grown under coconut system

Erosion control measures

Live check dam

Grass cover in sloppy areas

Terrace support wall in tea garden

Rubber check dam

Stone bunding in coconut plantation

LBCD & GCD for gully erosion

Erosion control measures

Terrace cultivation

Slopy open area protection with Mucana cover

Gully erosion control by geo jute with grass cover

Cashew nut plantation with Mucana cover crop

Loose bounder check dam for gully control

Trench-cum-half moon basin

Engineering / Bio engineering measures

Gabion stream bank protection wall

Gabion terrace support wall

Gabion terrace support wall

Terrace with stone support wall

Gabion check dam

Masonry check dam

भाकृअनुप
ICAR

IISWC

ICAR-Indian Institute of Soil & Water Conservation (IISWC)

218, Kaulagarh Road, Dehradun (Uttarakhand 248 195)