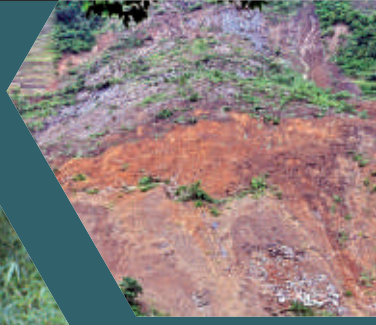
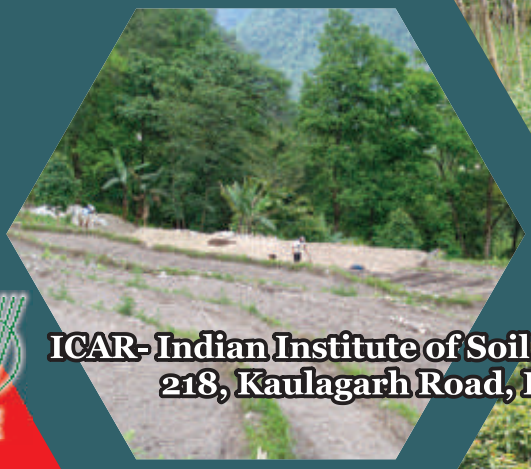
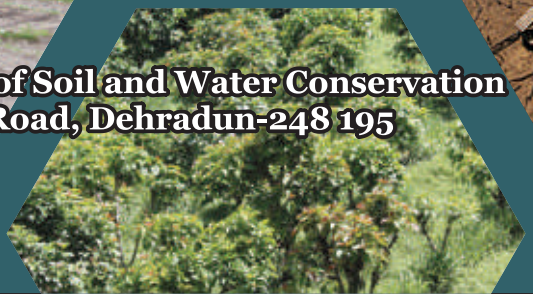
Soil Erosion Status, Priority Treatment Areas and Conservation Measures for Different Districts of Manipur









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

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FOREWORD

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Deputy Director General (Natural Resources Management)

14.03.2024

Foreword

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. Among many environmental hazards, checking land degradation is of paramount importance and the present production and actualization of future predictions of crop yields largely depend upon the maintenance and improvement of soil quality. Practicing inappropriate and unscientific land use and management practices for short-term gains and disregarding long term sustainability and environmental security has resulted in accelerated land degradation in the state of Manipur.

Over the years, the soil erosion through water is a serious problem in major part of the state. Soil erosion is affecting 53.2% area of the total land mass with erosion rates of more than 10 t $ha^{-1}yr^{-1}$ of which 26.7% area falls in severe to very severely category (>20 t $ha^{-1}yr^{-1}$). ICAR-Indian Institute of Soil and Water Conservation, Dehradun is working in a participatory approach for promotion and propagation of eco-friendly and cost-effective conservation measures adopting watershed principles in different agro ecological regions of India 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 area and conservation measures for different districts of Manipur***" is highly appreciated.

I am sure, this document would be beneficial to the stakeholders' who are engaged in the dissemination of soil and water conservation technologies through various livelihood-cum-natural resource management programmes in the state of Manipur.

(S.K. Chaudhari)

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PREFACE

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 and unscientific land use and land management practices. The risk of soil erosion in Indian Himalayan states is more serious as many land can no longer be sustained for production, mainly due to high intensity rainfall, deforestation, overgrazing, forest-fires and faulty land use practices thus leading to their abandonment. About 53.19% of total geographical area (TGA) of Manipur state experiences moderate or moderate to severe soil erosion loss.

In this context, the current technical brief on "Soil Erosion Status and Conservation Measures" for Manipur can serve the purpose of ready-reckoner for the policy-planners. This technical brief broadly divided into six chapters. The compiled information is mainly adapted from the previous work of the ICAR-IISWC and other similar institutes working in the field of soil erosion control in North-Eastern Himalayan states. We sincerely acknowledge Director, ICAR-IISWC, Dehradun for providing all the necessary facilities and guidance to accomplish this endeavor successfully well on the time. We are equally thankful to subject matter experts for their valuable guidance and cooperation. We are also thankful to other faculty members of Division of Soil Science and Agronomy for their help to complete this task successfully.

We not only hope but believe that this technical brief will be very useful for the stakeholders working on soil and water conservation. Mistakes and corrections are vital part of the any document, so comments and suggestions are always welcomed from the readers.

(Authors)

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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 pressure, developmental activities, unscientific land use and land management practices. The risk of soil erosion in Indian Himalayan states is more serious as many lands can no longer be sustained for production, mainly due to high intensity rainfall, deforestation, overgrazing, forest-fires and faulty land use practices thus leading to their abandonment. Further, the average production loss of cereal and millets, oilseed and pulse crops were estimated to be 34%, 40% and 38%, respectively and consequently, average loss considering cereals, oil seeds and pulses together is about 35%. (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

2.1 Land Degradation

In India, about 121.7 Mha area, which includes arable and non-arable lands, is subjected to various forms of land degradation (ICAR 2010), with maximum (82.6 Mha, 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.1.

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 years (Range 8-53 years).

2.3 Production Loss & Monetary Loss

The annual production and monetary losses due to water erosion were estimated for 27 major rainfed cereals, oilseeds and pulses crops, to be 13.4 Mt (Sharda *et al.,* 2010) valued at Rs 29200 crore during 2015-16 (Sharda and Dogra, 2013).

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 displacement of major nutrients like N, P, K and S is 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.

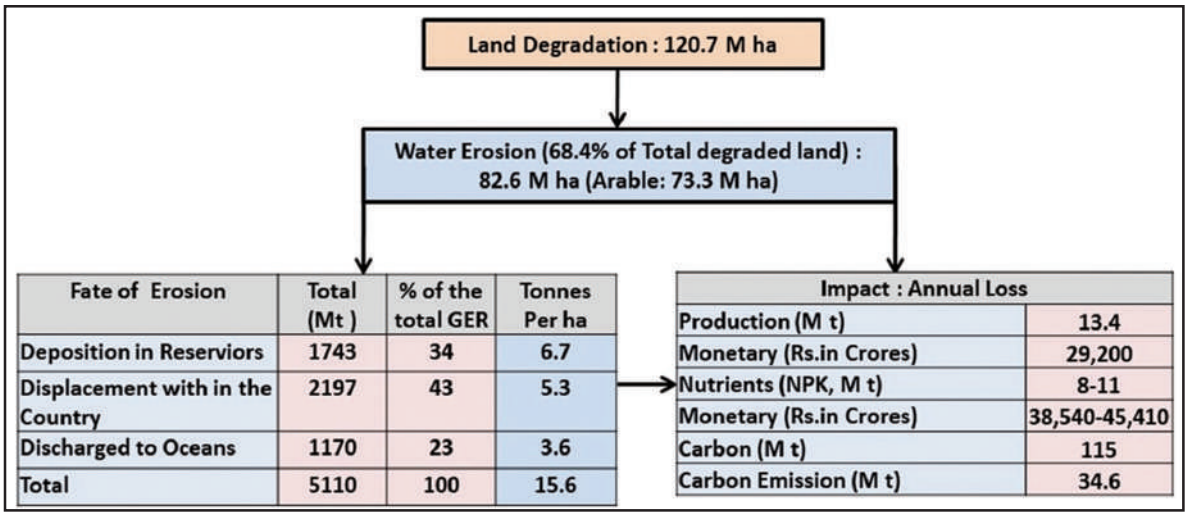
2.5 Carbon Loss

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 is lost 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 Gm^3 was estimated at 1679 Mm^3yr-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 Mm^3. Smaller dams of 1 to 50 Mm^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).



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. 1. Soil erosion and associated losses in India (GER- Gross erosion rate)

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) while soil erosion rates in such area is more than 10 t ha^{-1} yr^{-1}.

The district wise prioritization/risk area was assessed from the data base on potential soil erosion rates and soil loss tolerance limits for the state of Manipur. 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 Manipur state 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 (Kannan et al. 2021).

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 Manipur 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 THE STATE OF MANIPUR

4.1 About the State

Manipur is a state in northeastern India that is known for its rich biodiversity and scenic beauty. However, the state is facing numerous challenges related to land degradation, which is primarily caused by human activities such as deforestation, slash-and-burn agriculture, and mining. The state has witnessed significant deforestation over the years, which has resulted in the loss of valuable forest cover and biodiversity. The main drivers of deforestation in Manipur include logging, shifting cultivation, and urbanization. The state's hilly terrain is highly prone to soil erosion, especially during the monsoon season. The soil erosion has been exacerbated by deforestation and poor land-use practices, which have left the soil vulnerable to erosion. Land degradation has also led to water scarcity in many parts of Manipur. The state's rivers and streams are highly polluted due to indiscriminate dumping of waste and other pollutants, which has further worsened the water scarcity problem. Land degradation has also led to the loss of biodiversity in Manipur. The state is home to numerous endangered species of flora and fauna, which are under threat due to habitat loss and fragmentation. To address these challenges, the state government has initiated several measures such as afforestation programs, soil conservation programs, and watershed development programs. However, much more needs to be done to ensure sustainable land use practices and prevent further land degradation in the state.

4.2 Soil Erosion Rate

Considering the entire dataset of the state, soils were grouped into different classes based on potential erosion rates, soil loss tolerance limits and priority for soil conservation planning. Analysis of soil erosion data revealed that potential soil erosion rates varied significantly across the state, ranging from less than 5 t $ha^{-1}yr^{-1}$ to more than 40 t ha^{-1} yr^{-1}. Soil erosion is affecting 53.19% area of the total land mass with erosion rates of more than 10 t/ha/yr of which 26.65% area falls in severe to very severely category (>20 t $ha^{-1}yr^{-1}$). The results further revealed that depending upon soil depth, the soil loss tolerance limit values throughout the state vary between 5.0 and 10.0 t $ha^{-1}yr^{-1}$. Soils in the districts Ukhrul (N&E), Senepati (N) Bishnupur (S), Chandel (E), Churachandpur (S) and Tamenglong (N-S) have lower T-value ranging between 5.0 and 7.5 t $ha^{-1}yr^{-1}$.

By comparing the potential erosion rates with permissible rates, it is observed that in all, 53.34% land area faces erosion risks. However, there was practically no area falling under very high erosion risk category or priority class 1. The analysis further revealed that 46.46% area is very stable and

requires no conservation measure for treatment. Considering severe and very severe erosion categories together, about 26.6% area is very critical. However, based on the priority classification, only 0.08% area falling under priority classes 1 and 2 is most vulnerable. Owing to the preponderance of forests, barren and uncultivated lands, per capita availability of land for cultivation in the hilly areas of the state is lowest in India. Cultivation has been extended to marginal lands through extensive deforestation resulting in high soil erosion rate (40 t ha^{-1} yr^{-1}) and low productivity. Valley lands are degraded due to the deposition of debris from the upper hill slopes carried by high runoff water. Therefore, such areas are most sensitive and require special care during soil disturbance for cultivation. Jhum cultivation and indiscriminate deforestation lead to accelerated erosion for which proper vegetative cover need to be established on very steep slopes. The spatial distribution of various priority classes delineated by comparing prevailing erosion rates with permissible rates is presented in Fig.2.

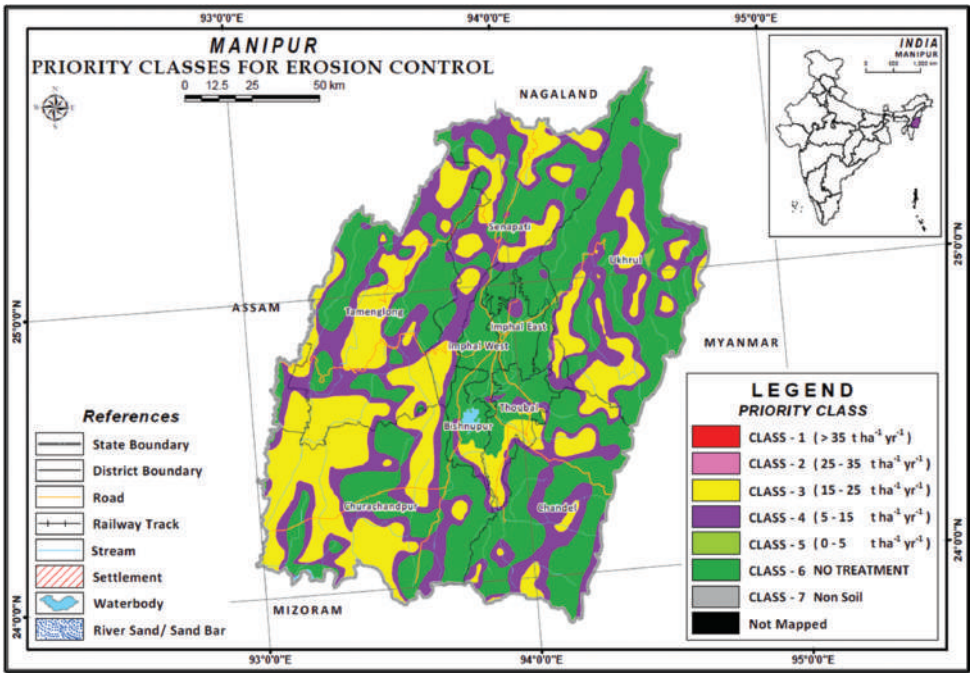


Fig.2 Spatial distribution of soil erosion priority classes of Manipur state

4.3 Soil Loss Tolerance Limit (SLTL)

Based on the T-values, the soils of the state were categorized into various classes. The spatial distribution of tolerance limits in the state is presented in Fig. 3. Overall soil performance was adjudged on the basis of aggregated score and accordingly the soil group was decided. Depending upon soil depth, the soil loss tolerance limit values throughout the state varied between 5.0 and 10.0 Mg ha^{-1} yr^{-1}. Soils under the districts Ukhrul (E&N), Senapati (N), Bishnupur (S), Chandel (E), Churachandpur (S) and Tamenglong (N-S) had lower T-value between 5.0 and 7.5 Mg ha^{-1} yr^{-1}.

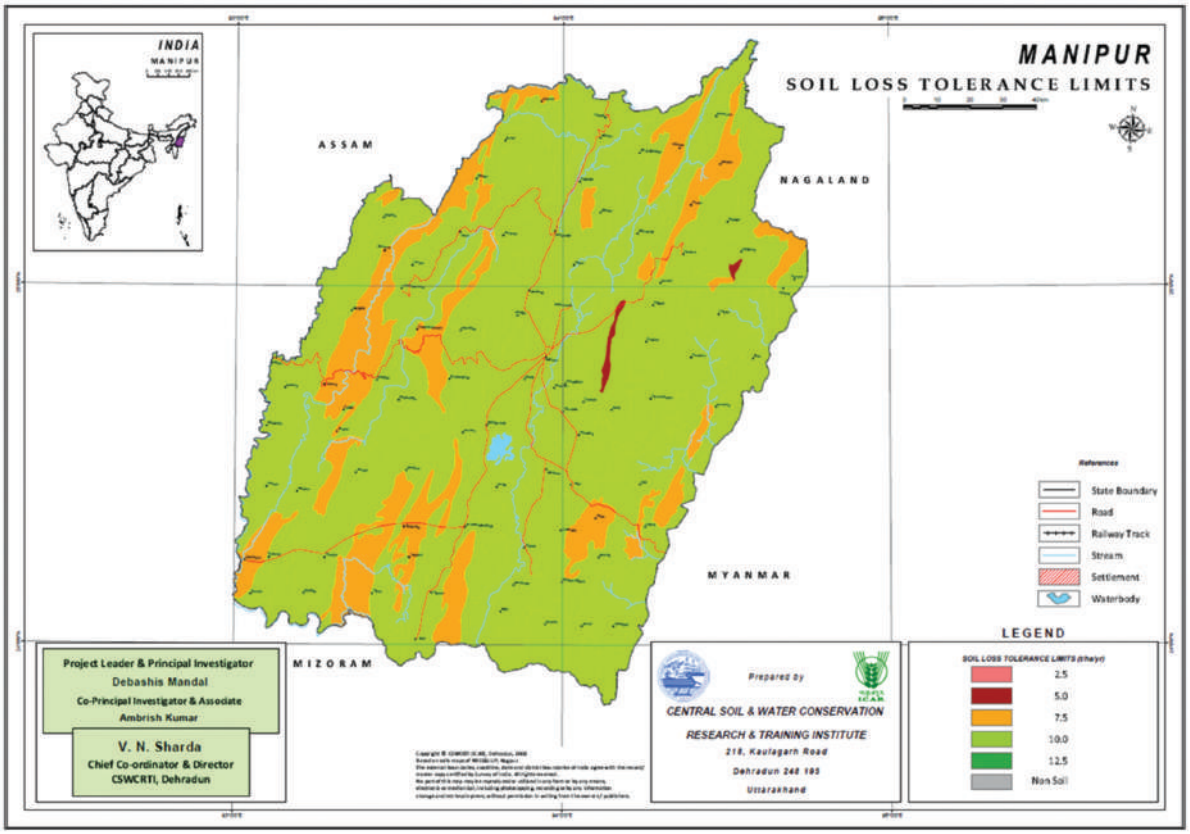


Fig.3 Spatial distribution of soil Loss Tolerance Limit map of Manipur state

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

The average production loss of cereals & millets and pulse crops were estimated to be 23% and 26%, respectively, and consequently, average loss considering cereals and pulses together is about 23%. Out of 0.07 million tonne total production losses, 98.9% is due to losses in cereals & millets and 1.1% in pulses (Fig. 4a). In terms of monetary losses, 96.6% of the total loss of Rs 1304 million occurs in Manipur due to production losses in cereals & millets, followed by 3.4% in pulses (Fig. 4b). The largest contribution is from paddy (94%) followed by other pulses (3%), and maize (3%).

The productivity losses of cereal & millets and pulse crops were estimated to be 575 kg ha^{-1} and 100 kg ha^{-1}, respectively. The average productivity loss of all these crops together was 547 kg ha^{-1} (Sharda and Dogra, 2013), which in monetary terms was Rs 9782 ha^{-1} during 2018-19 (Fig 5). The Gross State Domestic Product (GSDP) of Manipur for 2018-19 at current prices was estimated to be Rs 26,978 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 0.48% of its GSDP during 2018-19.

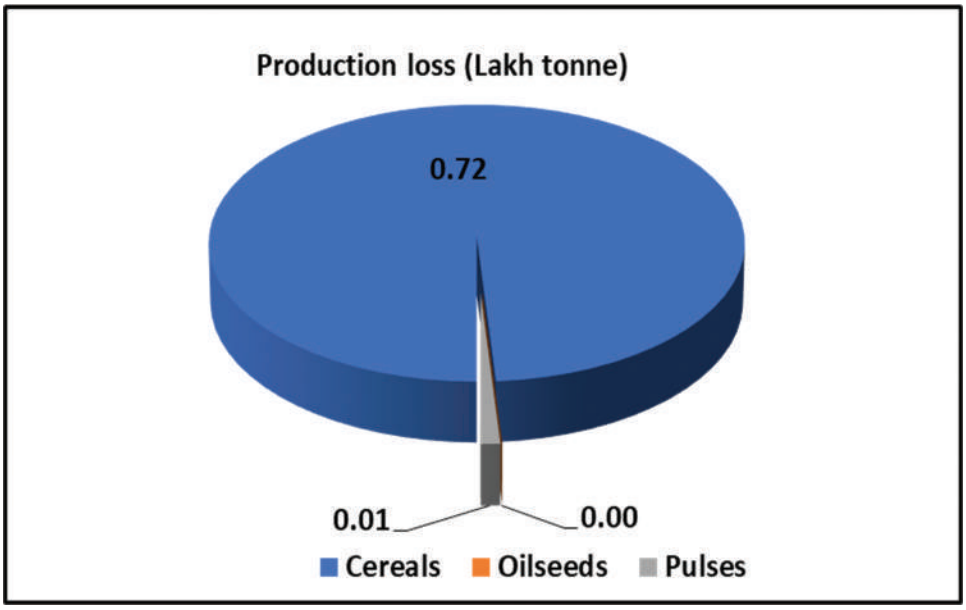


Fig. 4a Estimated total production loss of rainfed crops due to soil erosion in Manipur State

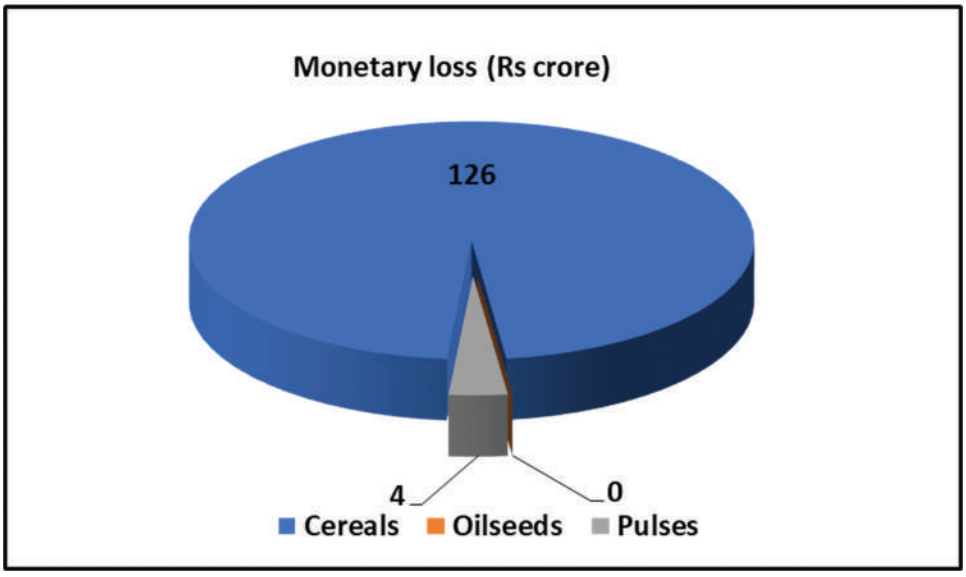


Fig. 4b Estimated total monetary loss of rainfed crops due to soil erosion in Manipur State

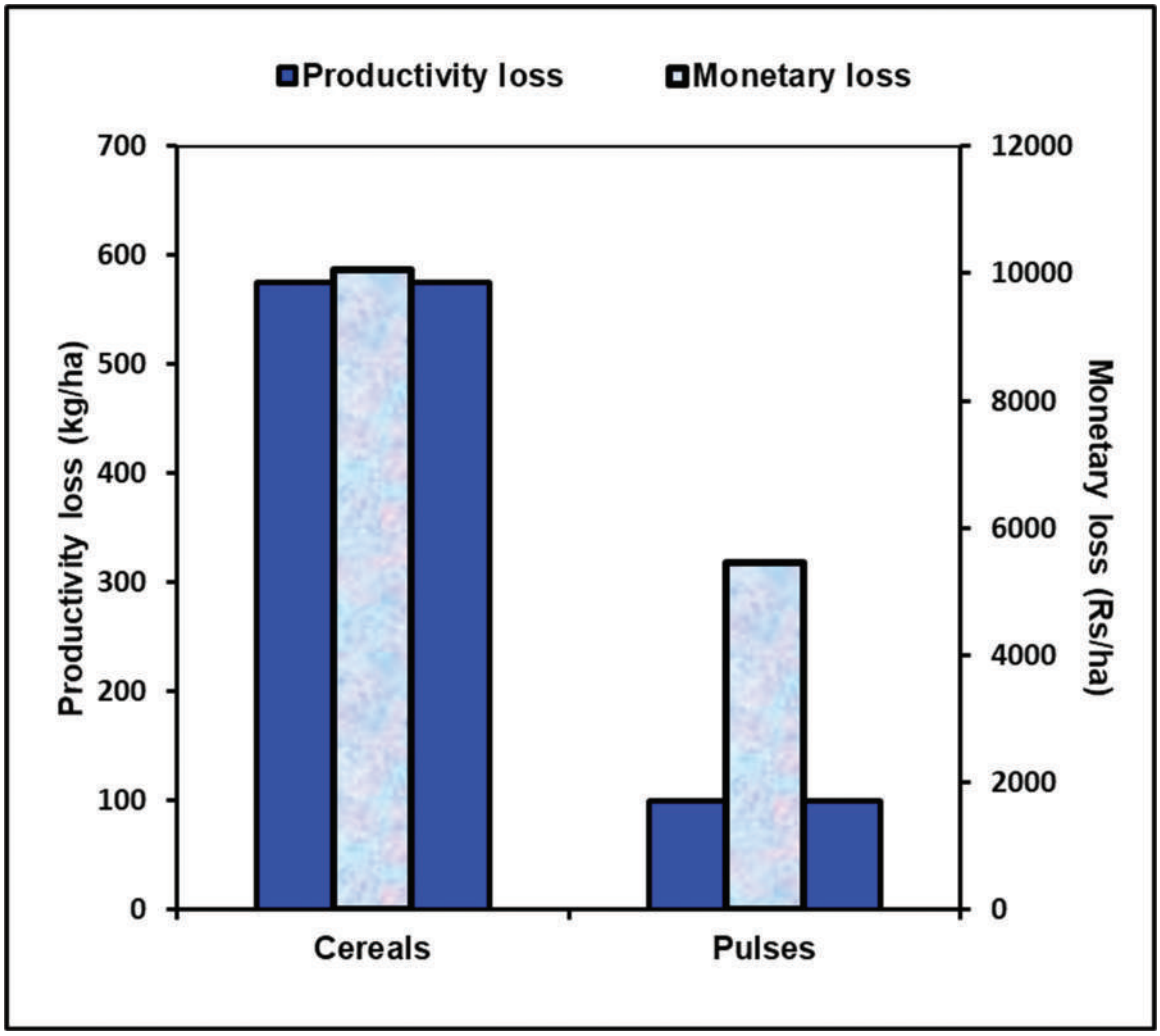


Fig. 5 Estimated productivity (kg ha^{-1}) and monetary loss (Rs ha^{-1}) of rainfed crops due to soil erosion in Manipur State

Table 1. District wise severity of erosion areas and critical problem with their possible solutions in Manipur

District	TGA (000ha)	Area under risk (000ha)	% Area of the district	Special erosion problem	Solutions
Severity of Risk-No risk					
-Nil-					
Imphal West	48.79	0	0	Flash flood inundation and soil erosion, Siltation, deforestation and watershed degradation	Table 2-Sr No. 3.1.1, 3.1.3, 5.1 to 5.7, 6.1.1, 6.1.5, 7.6, 7.7
Severity of Risk-A					
Bishnupur	48.06	6.72(3:6.72)	13.99	Flash flood inundation and soil erosion, Siltation, deforestation and watershed degradation	Table 2-Sr No. 3.1.1, 3.1.3, 5.1 to 5.7, 6.1.1, 6.1.5, 7.6, 7.7
Imphal East	72.33	16.17(3:16.17)	22.36	Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation	Table 2-Sr No. 3.1.1, 3.1.3, 5.1 to 5.7, 6.1.1, 6.1.5, 7.6, 7.7
Thoubal	71.38	21.03(3:21.03)	29.46	Flash flood inundation and soil erosion, Siltation, deforestation and watershed degradation	Table 2-Sr No. 3.1.1, 3.1.3, 5.1 to 5.7, 6.1.1, 6.1.5, 7.6, 7.7
Chandel	320.76	38.55(3:38.55)	12.01	Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation	Table 2- Sr No.2.1 to 2.4, 3.1.1, 3.1.1.2, 3.2,1, 4.1 to 4.9, , 5.1 to 5.7, 6.1.1, 6.1.5, 7.7
Severity of Risk-B					
Ukhrul	450.22	80.45(2:1.06; 3:79.39)	17.87	Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation	Table 2- Sr No.2.1 to 2.4, 3.1.1, 3.1.1.2, 3.2,1, 4.1 to 4.9, , 5.1 to 5.7, 6.1.1, 6.1.5, 7.7
Senapati	347.62	90.22 (2:0.625; 3:89.59)	25.95	Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation	Table 2- Sr No.2.1 to 2.4, 3.1.1, 3.1.1.2, 3.2,1, 4.1 to 4.9, , 5.1 to 5.7, 6.1.1, 6.1.5, 7.7
Severity of Risk-C					
Tamenglong	417.13	153.70 (2:0.109; 3:153.59)	36.84	Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation	Table 2- Sr No.2.1 to 2.4, 3.1.1, 3.1.1.2, 3.2,1, 4.1 to 4.9, , 5.1 to 5.7, 6.1.1, 6.1.5, 7.7
Churachandpur	456.37	187.64 (3:187.64)	41.11	Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation	Table 2- Sr No.2.1 to 2.4, 3.1.1, 3.1.1.2, 3.2,1, 4.1 to 4.9, , 5.1 to 5.7, 6.1.1, 6.1.5, 7.7
Total	2232.73	592.72	26.54		

Note 1: District wise details of agronomic and vegetative measures for Manipur is referred in Table 3.0

Note 2: 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 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)**				
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/ strip cropping	√		√	
1.8	Fodder/ tea/ medicinal-aromatic crops on the terrace riser			√	
1.9	Ridge and furrow (Deep soils)	√			
1.10	Dead Furrow opening in between the crop lines (Deep soils)	√			
1.11	Horticulture: Cultivationof vegetables / spices	√		√	
1.12	Emplacement of Coir/jute geotextiles on contours	√		√	
2.0	**Vegetative measures (At lower slope-alone, at higher slope with other conservation measures**				
2.1	Vegetative barrier*	√	√	√	√
2.2	Agri-horticulture		√	√	√
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: Bajra Napier (BN) hybrid, guinea grass, setaria, sorghum, maize, oat, cowpea, guar, *Melia azedarach, Morus alba, Ulmus wallichiana, Morus serrata, Bauhinia variegate*, *Leucaena leucocephala*				

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 (Katta-carat)		√		
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				√
6.1.10	Geo-textiles		√		√
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 Manipur is referred in Table 2.1 **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

Table 3. District wise severity of erosion areas and critical problem with their possible solutions in Manipur

[District Details: Name of District, Total Geographical area, TGA (000, ha), area under erosion risk (A(Er)) ('000 ha), erosion risk area as a percentage of TGA (Er (%)), Special erosion problem (Sp.P)]				
S. N.	**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/ etc.)**	**Special problem area: Grassed waterways/live check dams/Mine spoil area/ Land Slide Prone Area**
	Severity of Risk-No risk			
1.	**District: Imphal West, TGA :48.7, A(Er): 0, Er(%): 0%, Sp.P: Flash floods and drought, Siltation, Unlined natural water channels, deforestation**			
	Rice, rapeseed, mustard, sesame, pea, lentil, black gram, wheat, Jute potato Banana, jackfruit, Assam Lemon, papaya, litchi Rice (DS)- Toria /Lentil/ Sesamum/ Wheat /Potato/ Rabi vegetables Summer vegetables/ Black gram/ Sesame (kharif) - Toria/Lentil/ Wheat/Potato/Rabi vegetables	Green manuring with Cowpea, Leaf litter mulch for moisture conservation and to improve fertility Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba)*	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrierconstruction of boulder and bamboo spurs	Construction of of embankment, drainage channel and sluices in the flood prone area converting critical flood prone agricultural lands into forestry plantations including bamboo plantations Bioshielding of river banks using species like Vetiver (*Chrysopogon zizanioides*).
	Severity of Risk-A			
2.	**District: Bishnupur, TGA: 48.06, A(Er): 6.72, Er(%): 13.99%, Sp.P : Flash floods and drought, Siltation, Unlined natural water channels, deforestation**			
	Rice, rapeseed, mustard, sesame, pea, lentil, black gram, wheat, Jute potato Banana, jackfruit, AssamLemon, papaya, litchi Rice (DS)- Toria /Lentil/ Sesamum/ Wheat /Potato/ Rabi vegetables Summer vegetables/ Blackgram/ Sesame (kharif) - Toria/Lentil/ Wheat/Potato/Rabi vegetables	Green manuring with Cowpea, Leaf litter mulch for moisture conservation and to improve fertility Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba)*	• *Grewia optiva, Celtis australis,* bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrier construction of boulder and bamboo spurs	Construction of embankment, drainage channel and sluices in the flood prone area converting critical flood prone agricultural lands into forestry plantations including bamboo plantations Bioshielding of river banks using species like Vetiver (*Chrysopogon zizanioides*).
3.	**District: Imphal East, TGA: 72.33, A(Er): 16.17, Er(%): 22.36%, Sp.P: Flash floods and drought, Siltation, Unlined natural water channels, deforestation**			
	Rice, rapesed, mustard, sesame, pea, lentil, black gram, wheat, Jute potatoBanana, jackfruit, Assam Lemon, papaya, litchi Rice (DS)- Toria /Lentil/ Sesamum/ Wheat /Potato/ Rabi vegetables	Green manuring with Cowpea, Leaf litter mulch for moisture conservation and to improve fertility	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress	Construction of of embankment, drainage channel and sluices in the flood prone area converting critical flood prone agricultural lands into forestry plantations

	Summer vegetables/ Blackgram/ Sesame (kharif) - Toria/Lentil/ Wheat/Potato/Rabi vegetables	Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba*)	Vetiver with reed barrier construction of boulder and bamboo spurs	including bamboo plantationsBioshielding of river banks using species like Vetiver (*Chrysopogon zizanioides*).
4.	**District: Thoubal, TGA: 71.38, A(Er): 21.03, Er(%): 29.46%, Sp.P: Flash floods and drought, Siltation, Unlined natural water channels, deforestation**			
	•Rice, rapeseed, mustard, sesame, pea, lentil, black gram, wheat, Jute potato Banana, jackfruit, Assam Lemon, papaya, litchi Rice (DS)- Toria /Lentil/ Sesamum/ Wheat /Potato/ Rabi vegetables Summer vegetables/ Blackgram/ Sesame (kharif) - Toria/Lentil/ Wheat/Potato/Rabi vegetables	Green manuring with Cowpea, Leaf litter mulch for moisture conservation and to improve fertility Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba*)	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrier construction of boulder and bamboo spurs	Construction of embankment, drainage channel and sluices in the flood prone area converting critical flood prone agricultural lands into forestry plantations including bamboo plantations bioshielding of river banks using species like Vetiver (*Chrysopogon zizanioides*).
5.	**District: Chandel, TGA: 320.76, A(Er): 38.55, Er(%): 12.01%, Sp.P: Flash floods and drought, Siltation, Unlined natural water channels, deforestation**			
	Rice Rape & Mustard Maize Sugarcane Sesame Wheat Jute Arhar Cotton Black gram Pea Green gram Horticultural crops - Fruits Pineapple Banana Orange Lime & lemon Papaya Ginger Turmeric Potato Chilli Onion Arecanut Autumn rice – Summer Blackgram Autumn rice- Toria Autumn rice as mixed crop with maize, sesame Winter rice –Toria	Green manuring with *Dhaincha* during summer.	Vegetative Barriers with *Vetiver zizanioides* and *Cenhrus ciliaris* at field bunds	Boulder gabions for hill slops stabilization and river bank erosion controlIn hillocks with moderate slope cash crops like Coffee, Rubber are grown for soil conservation and optimum use of land on a sustained basis in Assam promotion of agro-forestry in different agro-climatic zones, with special attention to the hill areas for improvisation of traditional agricultural practices like shifting cultivation (jhum), to reduce ill effects on environment and increase
6.	**District: Ukhrul, TGA: 450.22, A(Er):80.45, Er(%): 17.87%, Sp.P: Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation**			
	Maize, ginger, turmeric, chili and other vegetables. Some horticultural crops cultivation, such as pineapple, orange, papaya and banana	Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba*)	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrier construction of boulder and bamboo spurs	Boulder gabions for hill slops stabilization and river bank erosion control promotion of agro-forestry in different agro-climatic zones, with special attention to the hill areas for improvisation of traditional agricultural practices like shifting cultivation (jhum), to reduce ill effects on environment and increase productivity.

7.	**District: Senapati, TGA: 347.62, A(Er): 90.22, Er(%): 25.95%, Sp.P: Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation**			
	Maize, ginger, turmeric, chilies and other vegetables. Some horticultural crops cultivation, such as pineapple, orange, papaya and banana	Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba)*	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrier construction of boulder and bamboo spurs	Boulder gabions for hill slops stabilization and river bank erosion control Promotion of agro-forestry in different agro-climatic zones, with special attention to the hill areas for improvisation of traditional agricultural practices like shifting cultivation (jhum), to reduce ill effects on environment and increase productivity.
8.	**District: Tamenglong , TGA:417.13, A(Er): 153.70, Er(%): 36.84%, Sp.P: Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation**			
	Maize, ginger, turmeric, chilies and other vegetables. Some horticultural crops cultivation, such as pineapple, orange, papaya and banana	Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba)*	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrier construction of boulder and bamboo spurs	Boulder gabions for hill slops stabilization and river bank erosion control Promotion of agro-forestry in different agro-climatic zones, with special attention to the hill areas for improvisation of traditional agricultural practices like shifting cultivation (jhum), to reduce ill effects on environment and increase productivity.
9.	**District: Churachandpur, TGA: 456.37, A(Er): 187.64, Er(%): 41.11%, Sp.P: Shifting cultivation (Jhoom), Steep slope cuttings, Heavy siltation, landslides, deforestation and watershed degradation**			
	Maize, ginger, turmeric, chilies and other vegetables. Some horticultural crops cultivation, such as pineapple, orange, papaya and banana	Sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*) and guar (*Cyamopsis tetragonoloba)*	bamboo/brush wood/boulder spurs, boulder revetments with vegetative support, loop cutting works Vetiver alone Vetiver with Porcupines (permeable spurs) Vetiver with underwater flexible mattress Vetiver with reed barrierconstruction of boulder and bamboo spurs	Boulder gabions for hill slops stabilization and river bank erosion control Promotion of agro-forestry in different agro-climatic zones, with special attention to the hill areas for improvisation of traditional agricultural practices like shifting cultivation (jhum), to reduce ill effects on environment and increase productivity.
	TGA (000 ha):2232.70, Area under risk (000 ha) : 592.72, % of TGA under risk: 26.54			

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}.

5.0 CONCLUSION

Water erosion is a major problem in Manipur. Analysis of soil erosion data revealed that potential soil erosion rates varied significantly across the state, ranging from less than 5 t $ha^{-1}yr^{-1}$ to more than 40 t ha^{-1} yr^{-1}. Soil erosion is affecting 53.19% area of the total land mass with erosion rates of more than 10 t/ha/yr of which 26.65% area falls in severe to very severely category (>20 t $ha^{-1}yr^{-1}$). The results further revealed that depending upon soil depth, the soil loss tolerance limit values throughout the state vary between 5.0 and 10.0 t $ha^{-1}yr^{-1}$. Soils in the districts Ukhrul (N&E), Senepati (N) Bishnupur (S), Chandel (E), Churachandpur (S) and Tamenglong (N-S) have lower T-value ranging between 5.0 and 7.5 t $ha^{-1}yr^{-1}$. By comparing the potential erosion rates with permissible rates, it is observed that in all, 53.34% land area faces erosion risks. However, there was practically no area falling under very high erosion risk category or priority class 1. The analysis further revealed that 46.46% area is very stable and requires no conservation measure for treatment. Considering severe and very severe erosion categories together, about 26.6% area is very critical. However, based on the priority classification, only 0.08% area falling under priority classes 1 and 2 is most vulnerable. Owing to the preponderance of forests, barren and uncultivated lands, per capita availability of land for cultivation in the hilly areas of the state is lowest in India. Cultivation has been extended to marginal lands through extensive deforestation resulting in high soil erosion rate (40 t $ha^{-1}yr^{-1}$) and low productivity. Valley lands are degraded due to the deposition of debris from the upper hill slopes carried by high runoff water. Therefore, such areas are most sensitive and require special care during soil disturbance for cultivation. Jhum cultivation and indiscriminate deforestation lead to accelerated erosion for which proper vegetative cover need to be established on very steep slopes.

In addition to soil erosion problem on arable and non-arable lands, associated special problems like mine spoilt, landslides prone area, open scrub, river 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.

The document will help prioritizing the area to be treated and the selection of specific SWC measures for execution of site-specific best management practices.

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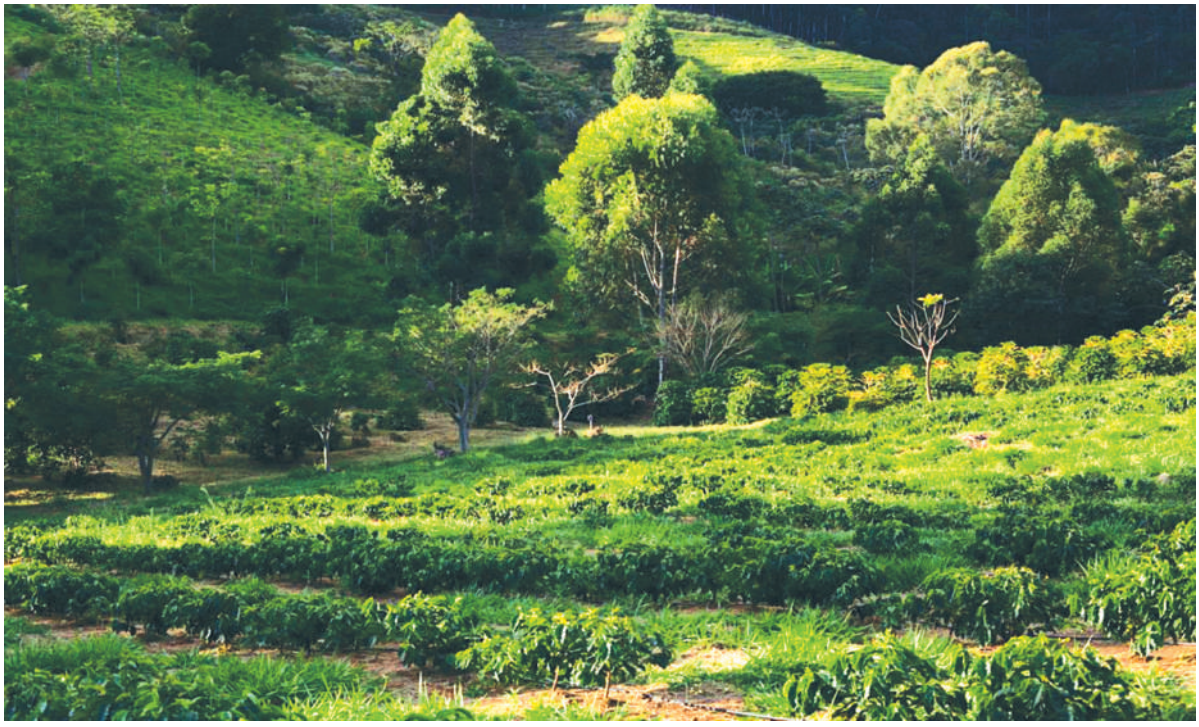

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Terraced Agriculture in Meetei Leibak (Manipur) Source: Dr. Naorem Iboton Singh (Former DEAN, Central Agricultural University, Imphal)

Landslide at Tupul, Manipur (2022) Source: Shankar Khangembam

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