ISBN : 978-93-94687-13-4

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






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Citation

Singh, A.K., Dakshnamoorthy, D., Singh, G., Jinger, D., Mandal, D., Dogra, P., Kumar, G., Kaushal, R., Roy, T., Islam, S., Madhu, M. (2023) Soil erosion status, priority treatment areas, conservation measures for different districts of Gujarat, ISBN : 978-93-94687-13-4

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ISBN No.

978-93-94687-13-4

Published by

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

Printed at

Ms. Asian Printery, Nr. Talati Hall, Raipur, Ahmedabad-380001.
Ph.: 079-22148826
Email : asianprintery@gmail.com, asianprintery@yahoo.com • Website : asianprintery.com

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कक्ष क्र. 101, कृषि अनुसंधान भवन-II, नई दिल्ली-110 012, भारत
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09.02.2023

Foreword

Land resources have enormous economic, ecological and social relevance. Gujarat with fourth highest area under land degradation in the country is facing a major challenge to achieve land degradation neutrality. Land degradation due to soil erosion is the major cause of decreasing interest in agriculture among the farmers in the state. The soil erosion in Gujarat is mainly due to excessive deforestation, overgrazing and injudicious land use practices, extension of ravine lands along the major river system. Therefore, identification of priority areas is of vital significance to layout strategies with appropriate conservation measures to arrest land degradation. The restored degraded land will ensure food and livelihood security besides providing ecosystem services.

I recognize the efforts made by the ICAR-IISWC, Dehradun and its Research Center-Vasad in bringing out this valuable publication covering district wise priority of soil erosion areas, its extent, special problems along with district wise bio-engineering measures. The document is in users' friendly mode and will be extremely useful for various stakeholders namely policy planners, field functionaries, students, scientists etc. involved in conservation of land resources in the state.

I congratulate the authors for their diligent efforts in bringing out this comprehensive document which is very timely and pertinent.

(S.K. Chaudhari)

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PREFACE

The ICAR-Indian Institute of Soil and Water Conservation (IISWC), Dehradun is one of the national Institute of Natural Resource Management Division (NRM) of the Indian Council of Agricultural Research, Ministry of Agriculture and Farmer's Welfare, Government of India. The institute alongwith its eight research centers is continuously working for development of location specific cost-effective soil and water conservation technologies, imparting training to state government officials and developing model watersheds as a learning sites for further adoption and upscaling in the field of soil and water conservation technologies and watershed management. The Research Centre (RC)-Vasad located in Gujarat state is mandated to develop land reclamation technologies for ravine infested gullied land along the different river system in Gujarat.

The background of development of this document on "Soil Erosion Status, Priority Treatment Areas and Conservation Measures for Different Districts of Gujarat" lies in the deliberations and subsequent recommendations of the research advisory committee of the institute. The committee stressed on developing strategy for arresting soil erosion and priority for sustainable development of the Western region. On the recommendations and subsequent suggestions of the committee, a team comprising members from the Research Centre Vasad was formulated at the institute.

As per the estimations of the institute about, about 0.69 M ha of the total geographical area (TGA) of the Gujarat experiences a moderate and moderate to severe soil erosion loss due to water erosion thereby leading to an annual production loss of 9% alone in rainfed cereal, oilseeds and pulse crops. Such degradation of land due to various forms of soil erosion leads to decrease in the land productivity, economic losses propels the risk to local food supply system and livelihoods. The recently released IPCC's Sixth Assessment Report (AR6, 2021) predicts increase in the heat waves, droughts, rainfall events and a likelihood of more cyclonic activity for India and the subcontinent over the coming decades. The prediction of more severe rains over Western India in the coming decades further underscores the requirement of refined and redesigned regional coping strategies.

Considering the immediate need of various stakeholders for arresting soil erosion and averting land degradation this document focus on identification of critical areas based on the permissible soil erosion rate and existing erosion rate at a given location in each district of the state. The document contains soil erosion status and erosion induced losses including production and monetary losses at national level as well as for the Gujarat state. Besides, priority map, area under various degrees of risk and district specific agronomic, vegetative and engineering soil and water conservation (SWC) measures have also been presented in details. The list of location specific soil and water conservation and agroforestry measures for each district has been compiled as a ready reckoner for policy makers, researchers, planners, NGO's and and extension functionaries working to address the various forms of land degradation problems.

(Authors)

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1. 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, and unscientific land use and land management practices (NAAS, 2017). The risk of soil erosion in the state of Gujarat is quite serious as many lands can no longer be sustained for production due to extension of ravine lands in to the table lands (Singh et al, 2020).

The Gujarat state is located between 20°01′ to 24°07′ N latitudes and 68°04′ to 74°04′ E longitudes. It covers 19.6 M ha (196,024 km^2) and accounts for 6% of the total geographical area of the country. It has 1,600 km long coast-line which forms its western and south-western boundary. Its northern boundary shares international border with Pakistan. It is bounded by Rajasthan in the North-East, Madhya Pradesh in the East and Maharashtra in the South and South-East. Depending upon the elevation, slope and ruggedness of the terrain, the state is divided into the Central highlands, the Western hills and the West coast. The Central highlands, a wide belt of hilly region, is bordered in the west by the Aravalli ranges; occupying extreme North-Eastern part of the state. The Western hills represented by Sahyadris form a part of the peninsular plateau. The Northern end of Sahyadris with its characteristic North-South cliff and finger-like east-west spurs transgresses into eastern limits of the state. The West coast comprising Gujarat plain, Kathiawar Peninsula and Kutch Peninsular covers major portion of the state. Gujarat plain has progressively built up in the form of successive deltaic plains by the alluvium laid by the Tapi, Narmada, Maji, Sabarmati, Banas and Luni river systems. Kutch Peninsula comprises a central high plateau surrounded by dissected scarps and flat-topped mesas on all sides, excepting in the East. The Rann of Kutch, the remnant of a very late marine transgression, is a flat depositional plain of salt, sand and mud, and is marked with scattered islands (bets) and Banni. The important rock formations are Precambrian, Archaens and Aravallis. The Aravallis are composed of highly metamorphosed quartzites, conglomerates, slates and limestones. Jurassic sandstone is fairly widespread in Kutch and in the north-eastern part of Kathiawar. The cretaceous sandstone is observed as outcrops in parts of Wadhwan (Kathiawar) and Sabarkantha. The Kathiawar Peninsula is mostly covered with Eocene basaltic flows having trappean characteristics. Tertiary rocks are mainly exposed along the coastal region of Surat, Bharuch and South-East of Kathiawar and Kutch. Gypsiferous clay dwarka beds are located along the Western coast of Kathiawar. The large alluvial tract spreading from Surat to Banaskantha is of estuarine, aeolian and marine origin. It has been formed by an extensive Pleistocene sedimentation.

The climate of the state is from arid, through semi-arid, to sub-humid tropical monsoonic type. The mean annual rainfall varies between 300 and 2,800 mm, covering 15 to 80% of the mean annual potential evapotranspiration. The mean annual temperature is 26° to

28°C, with summer temperature ranging between 37° and 42°C and winter between 10° and 18°C. The wide variations in climate and topography have resulted in vegetal growth from typical desert plants in Kutch and North-Western parts of the state to moist deciduous forests in Dangs and Valsad. Major concentration in forest is observed all along the Eastern border as well as in the hilly parts of Kathiawar but plains are mostly devoid of full-stocked forest cover. The major types of forests covering about 10% area of the state can be grouped as: tropical moist deciduous, tropical dry deciduous, tropical scrub, dry grasslands and littoral and swampy forests (Jinger et al., 2023). Gujarat soils belong to 5 orders, 11 suborders, 20 great groups and 45 subgroups. Among the different orders, Inceptisols cover 51% of the total area, followed by Entisols, Aridisols, Vertisols and Alfisols covering 14%, 11%, 9% and <1%. Soil great groups identified are Rhodustalfs, Natargids, Salorthids, Fluvaquents, Torripsamments, Ustifluvents and Ustorthents (Sharma et al., 1994). In Gujarat, about 50% of the area is under cultivation, of which, only one-fifth is irrigated. About 10% area is under forests and the remaining 40% is either left barren or unculturable/culturable waste (Jinger et al., 2022). Sorghum, pearl millet, groundnut, tobacco, maize, paddy, wheat, mustard constitute major crops. Of the total cropped area, food crops, cereals and pulses account for 50%; the remaining is under oilseeds, fibres and fodder crops (ICAR, 2010).

Total degraded area in the state is 3,129 thousand ha (about 16% of TGA). The highly affected districts are: Kutch (595 thousand ha), Surendranagar (404 thousand ha), Patan (317 thousand ha), Jamnagar (196 thousand ha) and Surat (192 thousand ha). Among districts affected by water erosion, Surat ranks first with 160 thousand ha, followed by Bharuch (114 thousand ha), Valsad (93 thousand ha), Dangs (84 thousand ha), Porbandar (67 thousand ha), Navasari (66 thousand ha), Dahod (60 thousand ha) and Banaskantha (55 thousand ha). This includes erosion in open forest area also. Saline soils account for 1,559 thousand ha (8% TGA); of which 579 thousand ha is found in Kutch. Other areas affected by salinity are Surendranagar (222 thousand ha), Jamnagar (186 thousand ha), Ahmedabad (159 thousand ha) and Rajkot (106 thousand ha). Sodicity is also a major problem in Gujarat. Sodicity affected areas account for 545 thousand ha and highly affected districts are Kutch (468 thousand ha), Patan (253 thousand ha), Surendranagar (119 thousand ha) and Ahmedabad (96 thousand ha). Wind erosion is observed in Patan district (ICAR, 2010).

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, 2016). 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. This report is a detailed compilation of district wise soil erosion problems in Gujarat along with the available soil and water conservation measures suitable to arrest the problem which will serve as a ready reckoner for land managers and farmers to address the soil erosion problems in their area.

2. LAND DEGRADATION THROUGH SOIL EROSION AND ITS IMPACTS

2.1. Land Degradation: In India, about 120.7 million ha area, which includes arable and non-arable lands, is subjected to various forms of land degradation (ICAR, 2010), with maximum (82.6 million 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 are presented in (Fig.2.1).

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). The average annual reduction in water storage capacity of dams is by 1.2% (data from 4937 big dams) and average life span reduction of the dams by 25 years (Range 8-53 years) due to sedimentation of the reservoirs.

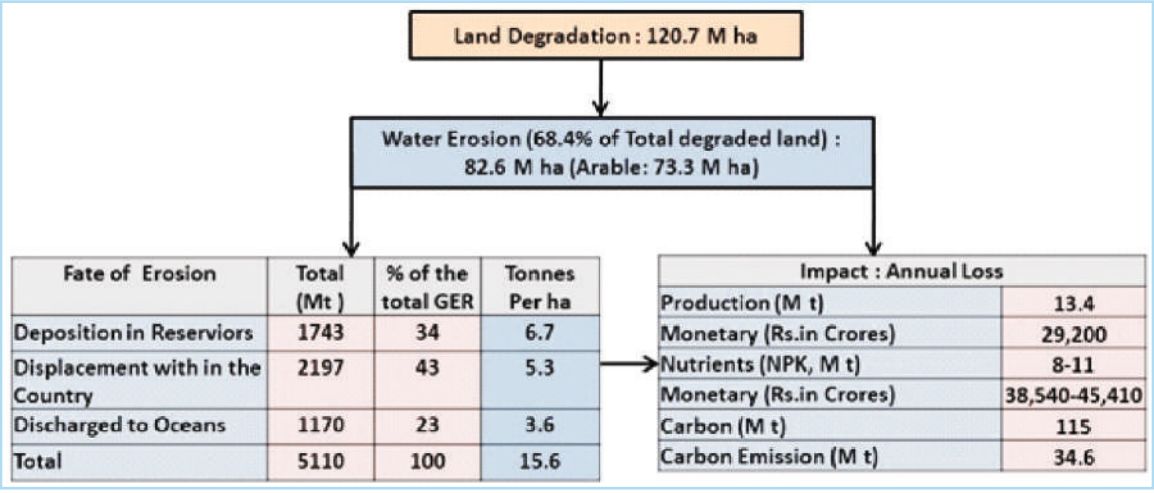
2.3. Production Loss & Monetary Loss: The annual production and monetary losses due to water erosion were estimated for 27 major rainfed cereals, oilseeds and pulses crops, to be 13.4 million tonnes (Sharda et al., 2010) valued at ₹ 29200 crore during 2015-16 (Sharda and Dogra, 2013).

2.4. Nutrients Loss: A significant amount (8 to 11 million tonnes of NPK) of nutrients gets transported with runoff and eroded soil leading to net loss of ecosystem services. The soil loss resulting due to water erosion in India leads to 5.37 to 8.40 million tonnes of nutrients loss from the soil (Sharda and Ojasvi, 2016). The nutrient loss due to water erosion estimated as monetary loss of ₹ 38,540 to ₹ 45,410 crores annually at market price of 2020. Further the estimated erosion linked loss of N, P, K, and S due to displacement of nutrient from the soil due to water erosion is 4.41-9.61, 0.387-2.31, 4.43 and 1.27-1.65 million tonnes amounting to the corresponding monetary loss of ₹ 13500-29300, ₹ 1850-8320, ₹ 17300 and ₹ 5890-7790 crore at market price of 2020, 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 losses of 1100 million tonnes of C into the atmosphere as a result of soil erosion and another 300-800 million tonnes of C annually to the ocean (Lal, 2011). The quantity of organic C displacement due to water erosion in India is about 115 million tonnes per which consequently emits about 34.6 million tonnes of C to the atmosphere; erosion control can reduce C emission by 19.0–27.0 million tonnes per year (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).



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)

3. 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.

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 Gujarat. 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 5 and 35 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 Western 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 districts of Gujarat 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 GUJARAT

4.1. About the state: Gujarat is located in Western part of India covering TGA of 19.6 M ha, which is about 6% of the total geographical area of the country. Depending upon the elevation, slope and ruggedness of the terrain, the state is divided into the Central highlands, the Western hills and the West coast. The climate of the state is from arid, through semi-arid, to sub-humid tropical monsoonic type. The mean annual rainfall varies between 300 and 2,800 mm, covering 15 to 80% of the mean annual potential evapotranspiration (Singh et al., 2019).

4.2. Soil erosion rate: Analysis of soil erosion data revealed that soil erosion rates vary enormously across the state, ranging from less than 5 t ha^{-1} yr^{-1} in 0.01% area to very severe (> 40 t ha^{-1} yr^{-1}) in 10.64% area. Percentage of area under slight (<10 t ha^{-1} yr^{-1}), moderate (10-20 t ha^{-1} yr^{-1}) and severe (20-40 t ha^{-1} yr^{-1}) soil erosion classes are 16.07, 61.23 and 10.99, respectively. Analysis of the data also revealed that nearly 82.96% area across the state has erosion rates of more than 10 t ha^{-1} yr^{-1}, which indicates that soil erosion is a serious problem in major parts of the state. The severity of soil erosion is due to aggressive climatic conditions coupled with steep topography and erodible soils (Kumar et al., 2021). Although occurrence of severe droughts is a common feature in north Gujarat, excessive soil erosion due to heavy rain in 2015 indicates high erosion vulnerability of the agricultural land (Singh et al., 2019). Intense rain after a prolonged drought increases the risk of soil erosion.

4.3 Soil loss tolerance limit (SLTL): Data pertaining to soil loss/erosion tolerance limits indicated that it varies between 2.5 and 12.5 t ha^{-1} yr^{-1}. The areas having lower T-values ranging from 2.5 to 5.0 t ha^{-1} yr^{-1} are most sensitive and need greater attention for adopting soil and water conservation measures to minimize further deterioration. Soil erosion risk map of the state showing different priority classes and their extent is given in (Fig. 4.1).

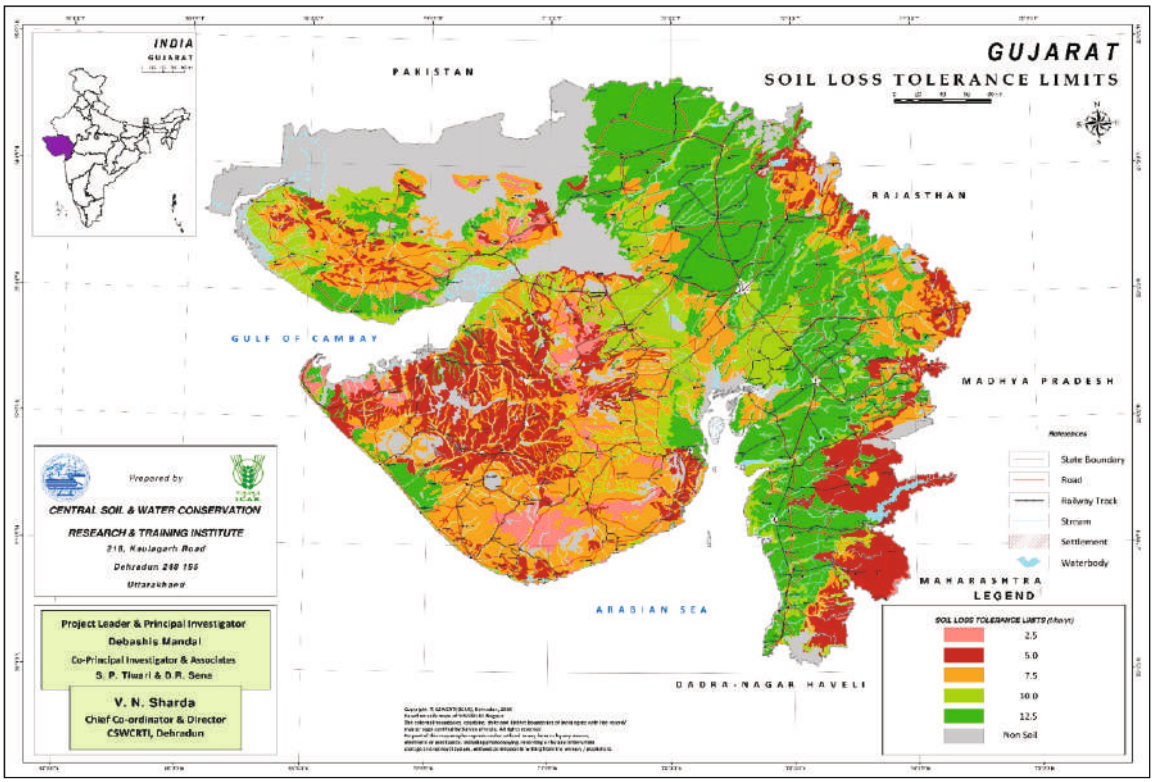


Fig. 4.1: Priority classes for erosion control in Gujarat state

4.4. Production and monetary loss from rainfed crops due to soil erosion

The average production loss of cereal and millets, oilseed and pulse crops were estimated to be 9%, 9% and 8%, respectively and consequently, average loss considering cereals, oil seeds and pulses together is about 9%. Out of 0.52 million tonne total production losses, 40.6% is due to losses in cereals and millets, 45.2% in oilseeds and 14.3% in pulses (Fig. 4.2). In terms of monetary losses, 57.5% of the total loss of ₹18,812 million occurs in Gujarat due to production losses in oilseeds, followed by 21.4% in pulses, and 21.0% in cereals and millets (Fig. 4.3). The largest contribution is from groundnut (27%) followed by castor (15%), and other pulses (14%) (Rao et al., 2022).

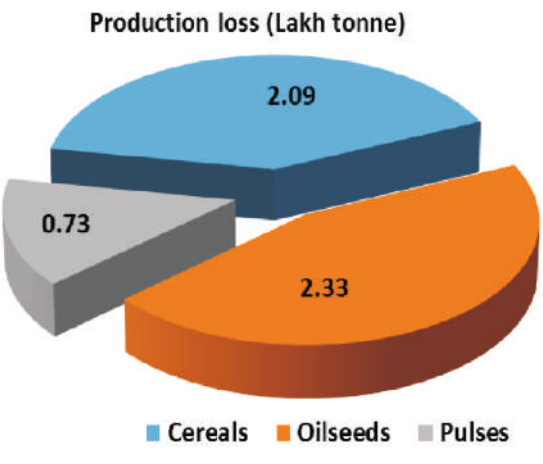


Fig. 4.2. Estimated total production loss of rainfed crops due to soil erosion in Gujarat State

The productivity losses of cereal and millets, oilseed and pulse crops were estimated to be 119 kg ha^{-1}, 84 kg ha^{-1} and 99 kg ha^{-1}, respectively. The average productivity loss of all these crops together is 98 kg ha^{-1} (Sharda and Dogra, 2013), which in monetary terms was ₹ 3577 ha^{-1} during 2018-19 (Fig. 4.4). The Gross State Domestic Product (GSDP) of Gujarat for 2018-19 at current prices was estimated to be ₹14,96,013 crore at prices for year 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 0.13% of its GSDP during 2018-19.

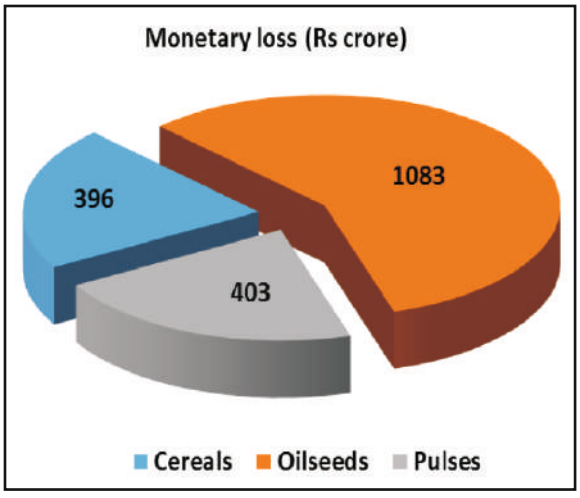


Fig. 4.3. Estimated total monetary loss of rainfed crops due to soil erosion in Gujarat State

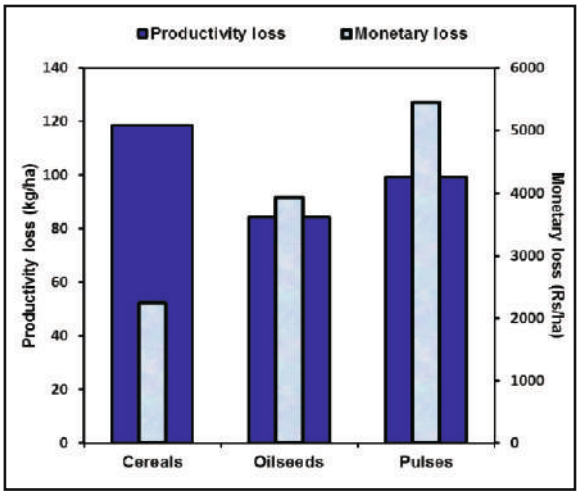


Fig. 4.4. Estimated productivity (kg ha^{-1}) and monetary loss (₹ ha^{-1}) of rainfed crops due to soil erosion in Gujarat State

4.5. Area under risk and treatment measures: It is evident that only 8.61% of TGA of the state requires different degrees of soil erosion management and 91.39% of TGA falls under no treatment category in view of the fact that soil loss is within permissible erosion limits. Though 8.61% area of the state falls under severe and very severe soil erosion categories, 5.79% has high priority from conservation point of view with a T-value upto 7.5 t ha^{-1} yr^{-1} (Fig 4.1). Similarly, though 2.82% area has prevailing soil erosion rates of less than 10 t ha^{-1} yr^{-1} but 5.65% area still falls under priority classes 4 and 5 requiring less degree of conservation treatment. Delineating critical land degradation areas through prioritization process is crucial for developing open-space plans that protect soil and water resources, and in turn the ecosystems. 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) and (Table 4.3) which are given in the succeeding sections of the document. (Table 4.2) presents soil and water conservation engineering 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 Gujarat

S.No.	District	(Area in 000'ha)				
		TGA	Area under risk	% area of the district	Special erosion problem	Conservation measures
Severity of risk-No risk						
1	Botad	259.41	0.00	0.00	Salt affected lands, Sea water intrusion, loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06
2	Devbhumi Dwarka	430.56	0.00	0.00	Coastal erosion, Loss of agricultural land due to urbanization, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 07

3	Gir Somnath	227.89	0.00	0.00	Coastal erosion, Loss of agricultural land due to urbanization, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 07
4	Jamnagar	649.65	0.00	0.00	Loss of agricultural land due to Industrialization salt affected lands, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06
5	Patan	577.52	0.00	0.00	Ravine problem, Mining, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5,1.6,1.7,1.8,1.11,2.1,2.2,2.3,2.4,2.5,3.1.1,3.2.7, 3.3.1,4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2,6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 04

6	Porbandar	229.34	0.00	0.00	Coastal erosion, Salt affected lands, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 07
	Total	**2374.37**	**0.00**	**0.00**		
					Severity Risk- A	
7	Ahmedabad	712.40	4.12 (4:4.12)	0.58	Ravine problem of agricultural land due to urbanization, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 03
8	Amreli	725.57	0.44 (4:0.44)	0.06	Ravine problem, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06

9	Anand	320.04	7.20 (4:7.20)	2.25	Ravine problem & Salt affected lands, Loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 03
10	Aravalli	325.76	0.31 (3:0.31)	0.10	Saline and Sodic soils, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.4, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 04
11	Banas Kantha	1062.97	9.82 (2:0.03, 3:0.24, 4:9.55)	0.92	Gully erosion, Ravine problem, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 04

12	Bharuch	664.49	50.13 (1:17.32, 2:17.63, 3: 2.12, 4:13.05)	7.54	Ravine problem, Saline and Sodic soils, Loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1,4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2,6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 02
13	Bhavnagar	854.91	0.34 (4:0.34)	0.04	Ravine problem & Salt affected lands, Sea water intrusion, Loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06
14	Chhota Udaipur	346.13	54.77 (1:19.52, 2:17.02, 3:11.83, 4:6.40)	15.82	Gully erosion, Ravine problem	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 6.2.12, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 03

15	Dahod	364.24	16.69 (1:0.05, 2:0.25, 3:16.39)	4.58	Gully erosion, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 6.2.12, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 03
16	Gandhinagar	211.31	2.29 (4:2.29)	1.09	Ravine problem, Loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 04
17	Junagadh	655.64	10.96 (2:6.50, 3:4.42, 4: 0.04)	1.67	Ravine problem, Loss of agricultural land due to urbanization, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 07

18	Kutch	4385.29	10.13 (4:10.13)	0.23	Ravine problem & Wind erosion, Salt affected lands, Sea water intrusion, Open scrub	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 2.1, 2.2, 2.3, 2.4, 2.5, 3.3.8, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 6.1.1, 6.1.2, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.1.10, 6.2.10, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 05
19	Kheda	341.25	8.67 (4:8.67)	2.54	Ravine problem, Loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 6.2.12, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 03
20	Mahesana	439.93	6.41 (4:6.41)	1.46	Ravine problem, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 04

21	Mahisagar	251.54	0.07 (1:0.03, 2:0.01, 3:0.03)	0.03	Water erosion, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 6.2.12, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 03
22	Morbi	508.54	1.16 (1:0.31, 2:0.85)	0.23	Saline Soil	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06
23	Navsari	222.24	30.47 (1:0.02, 2:18.57, 3: 11.88)	13.71	Saline soil and Mining, loss of agricultural land due to urbanization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 02

24	Panchmahals	329.14	14.80 (1:5.76, 2: 5.22, 3: 2.22, 4: 1.60)	4.50	Ravine problem, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 6.2.12, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 03
25	Rajkot	760.39	0.10 (4:0.10)	0.01	Ravine problem, Loss of agricultural land due to Industrialization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06
26	Sabar Kantha	416.79	17.50 (1:0.06, 2: 0.03, 4: 17.41)	4.20	Ravine problem	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 04

27	Surat	441.29	29.15 (1:3.89, 2:22.53, 3: 2.09, 4: 0.62)	6.60	Ravine problem, Loss of agricultural land due to industrialization, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 02
28	Surendranagar	912.88	41.14 (1: 19.46, 2:17.67, 3: 4.01)	4.51	Saline and Sodic Soil	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 06
29	Tapi	323.00	34.87 (1:0.20, 2:30.69, 3: 3.98)	10.80	Saline, Sodic soil and Mining, Loss of agricultural land due to industrialization, Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 02

30	Vadodara	409.02	13.60 (4:13.60)	3.33	Ravine problem, Loss of agricultural land due to industrialization Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.11, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2,6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 6.2.12, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr.No. 03
	Total	**15984.73**	**365.14**	**2.28**		
Severity of risk- B						
31	Narmada	283.41	79.09 (1:24.30, 2:37.94, 3: 8.70, 4: 8.15)	27.91	Ravine problem, Loss of agricultural land due to industrialization Sea water intrusion	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 02
	Total	**283.41**	**79.09**	**27.91**		

Severity of risk- C						
32	Dangs	172.55	109.62 (1:0.10, 2:109.43, 3: 0.09)	63.53	Gully erosion, Mining	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 01
33	Valsad	300.86	136.21 (1:0.05, 2:112.20, 3:23.95)	45.27	Water logging, Sea water intrusion, Loss of agricultural land due to industrialization	**Table No. 4.2** Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1.1, 3.2.7, 3.3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.6, 6.1.1, 6.1.6, 6.1.7, 6.1.8, 6.1.9, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.10, 6.2.11, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 **Table No. 4.4** Sr. No. 01
	Total	**473.41**	**245.83**	**51.93**		

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, 3 and 4. 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}, 4: Ravine and Gullied land. Table 4.2 presents different soil and water conservation engineering measures for different land situations, Table 4.3 presents agronomic and vegetative measures and Table 4.4 presents district wise potential agroforestry systems (AFS).

Table 4.2 : Soil and water conservation engineering 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	√		√	
	1.8	Medicinal and aromatic crop cultivation			√	
	1.9	Broad bed and furrow (Black soil)	√			
	1.10	Furrow opening in between the lines (Black soil)	√			
	1.11	Cutivation of fodder grasses	√		√	
	1.12	Sand treatment (Marling) for improvement of soil texture and soil physical properties	√		√	
	1.13	Bio-drainage or sub - surface drainage system	√		√	
2.0	**Vegetative measures (At lower slope -alone, at higher slope with other conservation measures**					
	2.1	Vegetative barrier*/Mixed vegetative barriers*	√	√	√	√
	2.2	Afforestation/Reforestation		√		√
	2.3	Grassed waterways	√	√	√	√

	2.4	Live vegetative check dam with different species along with Bamboo		√		√
	2.5	Stream bank stabilization with bamboo and other species		√		√
		**Species* : Vetivera grass *(Vetiveria zizanioides);* Lemon grass *(Cymbopogon citrates);* Rosa/palma rosa grass *(C. martinii);* Hybrid Napier*;* Agave *(Agave Americana & Agave sisalana);* Mulberry *(Morus alba);* Para grass *(Panicum maximum);* Marvel grass *(Dicantum anuulatum);* Buffel grass *(Cenchrus ciliaris*)*;* Indian Tree of Heaven (*Ailanthus excels*)*;* Malabar neem (*Melia dubia*)*;* Babul (*Acacia nilotica*).				
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)	√	√	√	√
	3.2	**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 banch terracing			√	
	3.3.8	Conservation ditch		√		√

4.0	**Drainage Line Treatments (DLT 's)**					
	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	Plastic head wall composite check dam/Masonary 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	√	√	√	
	5.2	Embankment pond		√		
	5.3	Pond renovation & Desilting	√	√	√	
	5.4	Dugout type farm pond	√		√	
	5.5	Sub surface water harvesting structures (Dykes) with sub-surface 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**					
	6.1	**Vegetative Measurers**				
	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	Wind break/Shelter belts	√		√	
	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 drain for collecting seepage water through earthen dam and convey it to outlet				√
	6.2.10	Retaining wall for slopes				√
	6.2.11	Jute geo textiles for slope stabilization/ Coir Jeo textiles for stabilization of slopy lands (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 with chute spillway		√		√
	7.3	Peripheral bund supported by close plantation of fast growing tree species along with 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		√		√
	7.13	Pre-fabricated drop structure on the gully head		√		√

Note 1: District wise details of agronomic and vegetative measures for Gujarat is given in (Table 4.3).

Note 2: For concept, design and estimates of soil and water conservation engineering mentioned above. 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 solution for Soil and Water conservation in Gujarat, Kindly refer (Table 4.4).

Table 4.3. District wise area under various erosion risk and the possible agronomic and vegetative measures for Gujarat

District Details: Name of District, Total Geographical area TGA ('000 ha), Area under erosion risk ('000 ha), Erosion risk area as a percentage of TGA, Special erosion problem				
Sr. 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
1	**Severity of risk- No risk**			
	District: Botad , TGA: 259.41, A(Er): 0.0, Er (%): 0.0, Sp.P: Salt affected land			
	Cropping System: **Cotton** (G. Cot-13, G. Cot-21 and ADC-1) + Green gram (GM-4`) **Fallow- Wheat** Fallow - Gram, GG-2 Cotton / Wheat / Sorghum **Fallow - Wheat** **Cotton** (G. Cot - 13 , 21 and ADC-1) + **Sesamum**	Sunhemp and Cluster bean for green manuring	Planting of Berseem (Egyptian clover) around the bunds, Intercropping with Sesamum, Ragi, Groundnut, Castor Chillies, Cluster bean, etc., serve as an insurance against crop failure and provide prevention against soil erosion.	Every year ground water recharging through farm pond/ deepening the village pond and check dam should be implemented through Public Private Partnership (PPP)

2	**District: Devbhumi Dwarka TGA: 430.56 A(Er): 0.0, Er (%): 0.0, Sp.P: Salt affected land**			
	Groundnut-wheat Intercropping: Groundnut + Greengram / sesame / sorghum /castor Cotton-wheat Pearl millet-wheat Fallow-castor	Greengram/blackgram/ cowpea as green manuring as well as cover crops.	Weeding and inter-culture operation to fill soil cracks, mulching with wheat straw or shredded cotton stalk or mulching with plastic film of 25 micron or dust mulching	
3	**District : Gir Somnath, TGA: 227.89, A(Er): 0.0, Er (%): 0.0, Sp.P: Salt affected land**			
	Groundnut-wheat Cotton-wheat Pearl millet-wheat Sugarcane Pulses	Residue retention of groundnut and other pulse crops for moisture conservation. Green manuring of greengram for improving soil health.	Keep 45 cm and 60 cm row spacing for bunch and semi spreading groundnut, respectively. Mulching with wheat straw or shredded cotton stalk, mulching (Plastic film 25 micron, inter tilling. Inter tilling. Spray of 1 % N through urea after relief of drought in pearl millet.	
4	**District: Jamnagar TGA: 649.65, A(Er): 0.0, Er (%): 0.0, Sp.P: Salt affected land**			
	Groundnut, Bajra, Castor	Green manuring with Dhaincha during summer in the rice field , Planting *Gliricidia sepium* on the field bund	Vegetative Barriers with *Vetiveria zizanioides* and *Cenchrus ciliaris* at field bunds.	

5	**District: Patan TGA: 577.52, A(Er): 0.0, Er (%): 0.0, Sp.P: Wind erosion, Mining**			
	Bajra- Mustard, Bajra-Cumin, Pulse-Wheat Cotton Bajra - Mustard, Bajra-Cumin, Pulse-Wheat	Cover crop with cowpea/ greengram/blackgram. Green manuring with Sun hemp	Conservation of soil moisture by hoeing and weeds use as mulch Mulching of farm by product @ 10 t/ha (Castor shell or Bajra husk)	
6	**District : Porbandar, TGA: 229.34, A(Er): 0.0, Er (%): 0.0, Sp.P: Salt affected lands**			
	Groundnut Pearl millet Sorghum Cotton - sorghum	Residue retention of groundnut and other pulse crops for moisture conservation. Cover crop with cowpea/ greengram/blackgram.	Vegetative Barriers with *Vetiver zizanioides* and *Cenhrus ciliaris* at field bunds.	
	TGA (000 ha): 2437.4, Area under Severity of risk -No risk category :0.0, % of TGA under risk: nil			
	Severity Risk : A			
7	**District: Ahmadabad, TGA: 712.40 A(Er): 4.12, Er (%): 0.57, Sp.P: Gully erosion, Ravine problem**			
	Cotton +Green gram Castor + Pearl millet Paddy –Wheat Fallow–Wheat Fallow –Gram Cotton +Sesamum Castor+ Sesamum	Green manuring with Dhaincha during summer Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

8	**District : Amreli, TGA: 725.57, A(Er): 0.44, Er (%): 0.06, Sp.P: Gully erosion, Ravine problem**			
	Groundnut Cotton Wheat Sesame Bajra (Pearl Millet)	Green manuring with San hemp during summer, Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
9	**District : Anand TGA: 320.04, A(Er): 7.20, Er (%): 2.25, Sp.P: Gully erosion, Ravine problem**			
	Rice Wheat Bajra Tobacco Cotton	Cover crop with cowpea/ greengram/blackgram. Planting *Leucaena leucocephala* on the field bund.	Vegetative Barriers with *Vetiveria zizanioides* and *Cenchrus ciliaris* at fild bunds. Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
10	**District: Aravalli, TGA: 325.76, A(Er): 0.31, Er (%): 0.09, Sp.P: Salt affected soils**			
	Wheat Cotton-Wheat, Groundnut-Wheat and Maize Wheat Cotton (Bt) Pigeopea Chickpea Soybean Blackgram	Cover crop with cowpea/ greengram/blackgram. Planting *Leucaena leucocephala* on the field bund.	Vegetative Barriers with *Vetiveria zizanioides* and *Cenchrus ciliaris* at fild bunds. Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	

11	**District: Banas Kantha, TGA: 1062.97 , A(Er): 9.82, Er (%): 0.92, Sp.P: Gully erosion, Ravine problem**			
	Bajra, Castor Cluster bean, Mung bean, Moth bean, Groundnut Cotton Blackgram, Tur Maize + Tur Fennel	Green manuring with Sannhemp during summer Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
12	**District : Bharuch, TGA: 664.49, A(Er): 50.13, Er (%): 7.52 Sp.P: Gully erosion, Ravine problem**			
	Cotton, Pigeonpea, Paddy, Sorghum, Sugarcane	Cover crop with cowpea/ greengram/blackgram. Green manuring with Sannhemp during summer	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots. Vegetative Barriers with *Vetiveria zizanioides* and *Cenhrus ciliaris* at fild bunds.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
13	**District : Bhavnagar, TGA: 854.91, A(Er): 0.34, Er (%): 0.4 Sp.P: Gully erosion, Ravine problem**			
	Cotton, Groundnut Pearl millet, Green gram Wheat	Cover crop with cowpea/ greengram/blackgram. Green manuring with Sannhemp during summer	Mulching with wheat straw or shredded cotton stalk, mulching (Plastic film 25 micron, 200 kg/ha), inter tilling	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

14	**District : Chhota UdaipurTGA: 346.13, A(Er): 54.77, Er (%): 15.82 Sp.P: Gully erosion and open mining**			
	Cotton, Maize Pigeon pea, Paddy Soybean, Sorghum	Cover crop with cowpea/ greengram/blackgram. Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
15	**District : Dahod, TGA: 364.24, A(Er): 16.69, Er (%): 4.58, Sp.P: Gully erosion**			
	Maize, Paddy Wheat, Gram Soy bean, Pigeon pea	Green manuring with Dhaincha during summer. Cover crop with cowpea/ greengram/blackgram.	Intercropping of maize + pigeon pea for reducing weed growth and impact of rainfall to cause soil erosion.	
16	**District : Gandhinagar, TGA: 211.31, A(Er): 2.29, Er (%): 1.08 Sp.P: Gully erosion, Ravine problem**			
	Cotton Castor Wheat Pearl millet Paddy Green gram Fodder crop- Jowar Maize-local	Green manuring with Dhaincha during summer. Cover crop with cowpea/ greengram/blackgram.	Vegetative Barriers with *Vetiver zizanioides* and *Cenhrus ciliaris* at field bunds.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

17	**District : Junagadh, TGA: 655.64, A(Er): 10.96, Er (%): 1.67, Sp.P: Gully erosion, Sea water intrusion**			
	Groundnut Wheat Cotton Sugarcane Pearl Millet Green gram	Green manuring and cover cropping with green gram.	Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
18	**District : Kutch, TGA: 4385.29, A(Er): 10.13, Er (%): 0.23, Sp.P: Gully erosion, wind erosion, Ravine problem**			
	Cotton-Wheat/Groundnut-Wheat /Pearl Millet /Green gram / Castor Cotton/Wheat, Moth bean, Jowar, Maize (local), Sesame	Residue retention of groundnut and other pulse crops for moisture conservation. Cover crop and green manuring with moth bean	Vegetative Barriers with *Vetiveria zizanioides* and *Cenhrus ciliaris* at field bunds. Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water. Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

19	**District : Kheda, TGA: 341.25 , A(Er): 8.67, Er (%): 2.54, Sp.P:Gully erosion, Ravine problem**			
	Paddy Cotton Tobacco Maize Pearl millet Fennel Cumin	Planting *Leucaena leucocephala* on the field bund. Green manuring with Dhaincha during summer.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
20	**District: Mahesana, TGA: 439.93, A(Er):6.41, Er (%):1.46, Sp.P: Ravine problem, Gully erosion**			
	Pearl millet Cotton Castor Pulses Sesame	Green manuring and cover cropping with green gram and cow pea.	Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
21	**District : Mahisagar, TGA: 251.54, A(Er): 0.07, Er (%): 0.03, Sp.P: Gully erosion, Mining**			
	Wheat Cotton Maize Groundnut Castor Pigeon pea Pearl millet Chick pea Gaur seed Maize + Pigeon pea Greengram/Blackkgram	Residue retention of groundnut and other pulse crops for moisture conservation.	Intercropping with pulse crops serve as an insurance against crop failure and provide prevention against soil erosion.	

22	**District : Morbi, TGA: 508.54, A(Er):1.16, Er (%): 0.23 Sp.P: Salt affected land**			
	Groundnut/Cotton-Wheat Sesamum Pulses (Green gram, Black gram, Cow pea Sesamum Cumin	Residue retention of groundnut and other pulse crops for moisture conservation.	Intercropping with pulse crops serve as an insurance against crop failure and provide prevention against soil erosion.	
23	**District : Navsari, TGA: 222.24, A(Er): 30.47, Er (%):16.170, Sp.P: Salt affected land, Mining**			
	Paddy Sugarcane Sorghum Indian bean Ragi	Green manuring with Dhaincha during summer.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	
24	**District: Panchmahals, TGA: 329.14, A(Er): 14.80, Er (%): 4.50, Sp.P: Gully erosion, Ravine problem**			
	Maize Paddy Pigeon pea Wheat Castor Maize + Pigeon Pea/Green gram/ Black gram Direct seeded paddy	Green manuring with Dhaincha during summer.	Intercropping with pulse crops serve as an insurance against crop failure and as a preventive against soil erosion.	Bamboo + *Cenhrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

25	**District : Rajkot, TGA: 760.39, A(Er): 0.10, Er (%): 0.01, Sp.P: Gully erosion, Ravine problem**			
	Groundnut /Cotton-Wheat Sesamum Pulses (Green gram, Black gram, Cow pea Sesamum Cumin	Residue retention of groundnut and other pulse crops for moisture conservation. Green manuring and cover cropping with green gram and cow pea.	Intercropping with pulse crops serve as an insurance against crop failure and as a preventive against soil erosion.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
26	**District: Sabar kantha, TGA: 416.79, A(Er): 17.50, Er (%): 4.20, Sp.P: Gully erosion, Ravine problem**			
	Maize Cotton Wheat Groundnut Pulses Castor Cropping System: Cotton-Wheat, Groundnut-Wheat and Maize Wheat Cotton (Bt)	Zero tillage + Residue retention of groundnut and other pulse crops for moisture conservation.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
27	**District: Surat, TGA: 441.29, A(Er): 29.15, Er (%): 6.60, Sp.P: Gully erosion, Ravine problem**			
	Paddy Sorghum Wheat Sugarcane Cotton	Green manuring with Dhaincha during summer.	Vegetative Barriers with *Vetiveria zizanioides* and *Cenchrus ciliaris* at field bunds.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

28	**District : Surendranagar, TGA: 912.88, A(Er):41.14, Er (%): 4.51, Sp.P: Ravine problem, Salt affected lands**			
	Cotton Sesame Pearl millet Cumin Wheat Castor Groundnut Pulses	Zero tillage + crop residue retention for moisture conservation. Green manuring and cover cropping with green gram and cow pea.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	
29	**District : Tapi, TGA: 323.0 A(Er):34.87, Er (%): 10.80, Sp.P: Ravine problem, Salt affected lands**			
	Paddy Sorghum Sugarcane Groundnut Cotton	Green manuring with Dhaincha during summer. Green manuring and cover cropping with green gram and cow pea.	Intercropping with pulse crops serve as an insurance against crop failure and as a preventive measure against soil erosion.	
30	**District : Vadodara, TGA: 409.02, A(Er):13.60, Er (%): 3.33, Sp.P: Ravine problem**			
	Cotton Pigeon pea Paddy Maize Wheat Pearl millet / Fodder Sorghum	Green manuring with Dhaincha during summer. Green manuring and cover cropping with green gram and cow pea.	Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.

	TGA (000 ha) : 15984.7, Area under severity risk A (000 ha) : 365.14, % of TGA under risk: 2.28			
	Severity Risk :B			
31	**District: Narmada, TGA: 283.41 , A(Er):79.09, Er (%): 27.91, Sp.P: Ravine problem**			
	Paddy Cotton Pigeon pea Sorghum Sugarcane	Green manuring with Dhaincha during summer. Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots. Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water.	Bamboo + *Cenchrus ciliaris* planting or live check dam of bamboo for reducing the soil erosion.
	TGA (000 ha) : 283.41, Area under severity risk B (000 ha) : 79.09, % of TGA under risk: 27.91			
	Severity Risk :C			
32	**District: Dangs, TGA: 172.55, A(Er):109.62, Er (%): 63.53, Sp.P: Water logging, Salt affected lands**			
	Paddy Gram Finger millet Groundnut Wheat Direct seeded Rice	Green manuring with Dhaincha during summer. Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots.	

			Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water.	
33	**District : Valsad, TGA: 300.86, A(Er):136.21, Er (%): 45.27, Sp.P: Water logging, Salt affected lands**			
	Paddy Directed seeded paddy Finger millet Sugarcane Indian bean Niger	Green manuring with Dhaincha during summer. Planting *Leucaena leucocephala* on the field bund.	Planting of aromatic plants (Lemon grass) for moisture conservation and reducing soil erosion by binding the soil by fine roots. Planting of fodder grasses like Napier and Guinea for augmenting fodder yield as well as conserving soil and water.	
16	**TGA (000 ha) : 473.41, Area under severity risk category C (000 ha) : 245.83, % of TGA under risk: 54.4**			

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, 3 and 4. 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}, 4: Ravine and Gullied land. Table 4.2 presents different soil and water conservation engineering measures for different land situations, Table 4.3 presents agronomic and vegetative measures and Table 4.4 presents district wise potential agroforestry systems (AFS).

Table 4.4 : Agroforestry solution for soil and water conservation in Gujarat

S. No.	Agro climatic zones	Districts	Agroforestry System
1.	Southern Hills	Dang, Valsad	a) Agri-silviculture Teak + Rice/Sugarcane/Okra b) Agri-horticulture Mango + Rice/Chilli/Okra c) Horti-silviculture Teak + Mango/Sapota
2.	Southern Gujarat	Navsari, Tapi, Narmda, Surat, Bharuch	a) Horti-silviculture Teak/Casuarina spp. /Eucalyptus + Mango/ Sapota /Guava b) Agri-silviculture Teak + Rice/Mustard/Maize c) Agri-horticulture Mango/Guava/Sapota/Jamun/Coconut+ Greengram/Gram/Pea/Sugarcane/Wheat d) Homegardens Teak + Turmeric/Banana/Chilli/Okra/Tomato e) Horti-pasture Mango/Sapota + Maize/Sorghum/Napier/ Lucerne/Vetivar/Lemon grass
3.	Central Gujarat	Anand, Vadodara, Dahod, Kheda, Panchmahal, Mahisagar, Chhota Udaipur, Ahmedabad	a) Silvipasture Melia + Lemon grass Latthi bans + Anjan grass b) Horti-silviculture system Melia + Dragon fruit c) Agri-horticulture Sapota + Castor/Cowpea Drumstick + Green gram/Fennel
4.	North Gujarat	Banaskantha, Gandhinagar, Mehasana, Patan, Sabarkantha, Aravalli	a) Agri-silviculture system Khejri/Ardu/Neem/Shisham/Anjan tree + Cowpea/Greengram/Cluster bean/Wheat b) Agri-horticulture system Ber/Sapota+Pearl millet/Green gram/Sorghum c) Silvi-pastoral system Khejri/Ber/Kher/Ardu+Anjan grass/Dhaman grass/Sevan grass/ Stylosanthes

5.	North-West Arid	Kutch	a) Agri-silviculture Melia + Foxtail millet b) Silvi-pastoral system Neem/Subabul/Israeli babool + Anjan grass/Dhaman grass c) Agri-horticulture Ber/Aonla/Custard apple+Cow pea/Castor/ Sesame/Cluster bean
6.	North Saurashtra	Amreli, Jamnagar, Rajkot, Surendranagar, Morbi, Bhavnagar, Botad	a) Agri-silviculture Melia + Black gram Melia + Castor b) Silvo-aromatic system Ardu + Isabgol/Kalmegh c) Boundary plantation Ardu + Neem
7.	South Saurashtra	Junagadh, Porbandar, Gir Somnath, Devbhoomi Dwarka	a) Boundary plantation Casuarina /Eucalyptus b) Agri-silviculture Imli/Shirish/Casuarina/Eucalyptus + Cow pea/Groundnut c) Horti-silviculture Casuarina/Eucalyptus + Mango/Sapota

5. CONCLUSION

In India, land resources have enormous economic ecological and social relevance. Land, water and forests are the main life support systems of rural people. Gujarat continues to occupy a distinctive position in the Indian economy. With about 5 per cent of the country's population and about 6 per cent of the country's geographical area, Gujarat accounts for 7.2 per cent of India's GDP due to its rapid industrialisation and tremendous growth rate in the service sector (Directorate of Economic & Statistic, 2013, GoG). The agricultural sector of Gujarat, compared to the rest of India, is also on an upward trajectory far greater than any other state. Gujarat has the second highest per capita income among the major states of India. It contributes to about 16 percent of the country's industrial production. The state has witnessed an annual average growth of 9 per cent in the last three years and an average industrial growth of 15 per cent for the same period. This high growth rate and increased urbanisation is due to the fast industrial growth and the growth of the tertiary sector. At present, the urban population in Gujarat is 42.58 per cent (Directorate of Economic & Statistic, 2013, GoG).

Factors like a growing population, rapid industrialisation and urbanisation, and insistent demands from the agricultural sector are all exerting pressure on land that is already scarce. It is important to utilise natural resources in a sustainable manner. Proper management of land, water, forests and wildlife is very crucial for sustainable development. There is a distinct link between industrialisation and urbanisation. Industrialisation contributes to urbanisation and has increased the urban sprawl in Gujarat adding pressure to land. Urbanisation industrialisation and increase in population has also led to increased per capita waste generated and its unscientific disposal. Increase in waste generated areas is being untreated and dumped on land, degrading its quality. Industrialisation and population are not the only issues that degrade land resources. Agricultural practices in Gujarat have also led to the degradation of its soil quality. High cropping intensity and modernisation of agricultural practices through the increased use of chemical fertilisers, mono-cropping and groundwater exploitation are degrading the land resources.

Gujarat is the state with fourth highest area under desertification/land degradation with respect to the county's TGA (Desertification & Land degradation Atlas of India, SAC, 2016). Total 96400 sq. km. area of the country is undergoing land degradation i.e., 29.32% of the Total Geographic Area (TGA) of the country during 2011-13. The state is observed with 52.29% of the total geographical area under desertification/land degradation for the period of 2011-13, which is the highest percentage area any state in the country has (Desertification & Land degradation Atlas of India, SAC, 2016). There is a cumulative increase of 1854 sq. km. (0.94% increase) area undergoing process of land degradation in Gujarat between the time periods of 2003-05 to 2011-13. The most significant process of land degradation observed in the state due to water erosion (19.67% recorded in 2011-13 and 19.30% in 2003-05) followed by salinity (13.48% recorded in 2011-13 and 13.47% in 2003-05), vegetation degradation (11.82% in 2011-13 and 11.49% in 2003-05) and wind erosion (6.00% in 2011-13 and 6.01% in 2003-05).

The severe soil erosion in hilly terrain, open scrub forest devastation, mining, rapid urbanization and industrialization of productive agricultural land, coastal erosion, wind erosion, saline and sodic soils, ravine and gullied lands are the special problem of Gujarat. Almost all the possible bio-engineering measures suitable for application in different part of Gujarat state has been suggested in this document. The proposed approach considered the soil erosion risk areas along with integration of the production losses of major crops. The wide range of agronomic and vegetative measures, engineering measures and agroforestry measures have been suggested with aim to bring down the erosion rate below the soil loss tolerance limit. The document will help prioritizing the area to be treated and the selection of specific soil and water conservation measures for execution of site-specific best management practices.

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PHOTOGRAPHS

Brick masonry drop cum water harvesting structure

Bamboo based bio-engineering measures for reclamation of ravine land

Peripheral bund supported with Bamboo for table land near to gully head in ravines

Conservation agriculture practices for resource conservation and enhancing crop productivity

Cost effective runoff filters for artificial groundwater recharge

Julkund for rainwater harvesting and supplemetal irrigation for plantation establishment in ravines

Multi-purpose water harvesting system on the gully head for runoff conservation and recycling of stored water

Castor and cow pea based cropping system for soil and water conservation and enhancing the water use efficiency in water scarce areas

Bori-bund for preventing soil loss from ravine lands and moisture conservation

Melia dubia and lemon grass based silvi-pasture system for reclamation and productive utilization of deep ravine

Fodder grass filter strips for resource conservation and enhancing the productivity of table land near to gully head in ravine

Melia dubia + Dragon fruit based Horti-Silvi system for reclamation and productive utilization of deep ravine

Alinathus excelsa based agroforestry system for reclamation and productive utilization of degraded lands

Broad Bed Bench Terraced land with Sapota + Castor + Cow Pea based agroforestry system for stabilization of ravine slopes

Plastic head wall embedded composite check dams for reducing the cost of construction and easy construction in remote location in ravine

Crop residue mulching for moisture conservation in cotton based cropping system for reducing the weeds population for resource use efficiency

Erosion productivity relationship studies for different length and slope condition of Gujarat

Erosion productivity relationship studies for different integrated nutrient mamagement in pearl millet based cropping system

Plastic sheet embedded loose boulder gully plugs for water harvesting and controlling gully erosion in ravine

Tobbaco based conventional cropping system practiced by the farmers in Gujarat

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