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

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Foreword

The coastal regions of Goa are known for its rich diversity of climate, topography, soils, crops, livestock, fisheries etc. Despite the abundance of natural resources, the productivity of the crops and livestock in this region is poor as compared to the inland areas mainly due to its fragile ecosystems which is highly vulnerable to climate aberrations. Unlike, other parts of the country, the region faces unique problems like demographic pressure, land degradation, deforestation, rapid urbanization and industrialization, environmental pollution, climate change effects like increased frequency of floods, cyclones, droughts and sea level rise. There is an urgent need to address these issues through scientific planning and priority setting of research and development activities to cater to the needs of the coastal population.

The ICAR-Indian Institute of Soil and Water Conservation along with ICAR-Central Coastal Agricultural Research Institute have jointly brought out this technical document for the conservation of natural resources in the state of Goa. This document deal with a greater emphasis on district and taluka wise priority of soil erosion areas, its extent, special problems, along with district wise engineering measures, vegetative and agro-forestry measures. The details given in this document is easy to apprehend and prepared in users' friendly mode.

I strongly believe that this document would be very much useful for policy planners, discipline functionaries and all stakeholders engaged in achieving land degradation neutrality ensuring sustainable development of coastal agriculture in the state of Goa.

(S.K. Chaudhari)

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PREFACE

The state of Goa comprises of two districts with a total geographical area of 3.61 lakh ha. Against the total area, 35% is under forests and 44% is gross cropped area. The economy of Goa is primarily driven by tourism followed by agriculture, animal husbandry and fisheries activities. Agriculture contributes to 3.74% of State GDP while secondary and tertiary sectors comprising of industries and services contribute to 80% of the GDP. The latest Agricultural Census report 2010-11 shows that there are 78020 land holdings and the average size of the land holdings is 1.14 ha. 15% of the land holdings and 17% of the area are operated under tenancy and remaining area by wholly owned farmers. Marginal and small land holdings (< 2 ha) constitute 89% of the holdings, but area wise they constitute only 51% of the total area. Goa has impressive socioeconomic indicators, as compared to the other states of the country. The state ranks 4th in the country with 86% literacy rate as per the 2011 census and has the highest per capita income.

The state of Goa receives an average annual rainfall up to 3000 mm, but the utility of the rain water is very limited. About 80% of the soils in Goa are lateritic with gravelly texture and poor water holding capacity. The soils of the regions are acidic in soil reaction and possess multi-nutrient deficiency and farmers are accustomed to apply sub-optimal fertilizer nutrient. The limitations of undulating terrain, multi-nutrient deficiency and poor soil water holding capacity poses a serious challenge to the crop production especially during post-monsoon months. As such, practically after the monsoon season there is no moisture available in the soil. These factors have led to the poor productivity of coconut in the state of Goa. Goa state falls under coastal and island ecosystems which are one of the most fragile ecosystems and are highly vulnerable to the climate change. There are several constraints posing threat to the agriculture and allied activities. Important among these are higher frequency and intensity of the natural disasters like cyclones, flooding, landslides, drought, etc., climate change and sea level rise, drainage congestions, high demographic pressure, deforestation, coastal erosion and accretion, low productivity of the field and horticultural crops and livestock, over-exploitation of the fishery resources, unplanned tourism activities, coastal pollution, etc. To address the land degradation problems and constraints of this region, a detailed technical bulletin has been developed by ICAR-Indian Institute of Soil and Water Conservation, Dehardun and ICAR-Central Coastal Agricultural Research Institute, Goa for priority setting of research and developmental activities for conservation of natural resources.

This document deal with a greater emphasis on district and taluka wise priority of soil erosion areas, its extent, special problems, along with district wise engineering measures, vegetative and agro-forestry measures. The details given in this document is easy to apprehend and prepared for ready to apply mode through the stakeholders throughout the state.

(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 pressures, developmental activities, and unscientific land use and land management practices (Bawa, 2017). The risk of soil erosion in Goa is more serious as many lands can no longer be sustained for production, mainly due to high intensity rainfall, deforestation, overgrazing and faulty land use practices thus leading to their abandonment (Singh et al, 2020).

Fig. 1.1. Different Districts and Taukas of Goa state

The Goa state is situated between 14°53′ 47″ to 15°47′ 59″N latitudes and 73°40′54″ to 74°20′11″ E longitudes. It covers an area of 0.37 M ha (3,702 km^2) and accounts for about 1% of the total geographical area of the country. The state is bounded in the West by the Arabian Sea, in North by Maharashtra, and in the East-South by Karnataka. Against the total area, 35% is under forests cover and 44% is Gross Cropped Area (GCA). The economy of Goa is primarily driven by tourism and mining followed by agriculture, animal husbandry and fisheries activities. Agriculture contributes to 3.74% of State GDP while secondary and tertiary sectors comprising of industries and services contribute to 80% of the GDP (@ current prices, 2015). The latest Agricultural Census report 2010-11 shows that there are 78020 land holdings and the average size of the land holdings is 1.14 ha. 15% of the land holdings and 17% of the area are operated under tenancy and remaining area by wholly owned farmers. Marginal and small land holdings (< 2 ha) constitute 89% of the holdings, but area wise they constitute only 51% of the total area. Goa has impressive socio-economic indicators, as compared to the other states of the country. The state ranks 4th in the country with 86% literacy rate as per the 2011 census and has the highest per capita income.

The census report shows that there are only 31,000 cultivators and 27,000 agricultural labourers as compared to the total population of 14.58 lakh. Most of the farmers are not fully dependent on agriculture and they have supplementary source of income through mining related activities, business, private or Govt. jobs and foreign remittances. It is estimated that the average income of farmers in Goa is ₹91,098 of which ₹16,893 is through farming, ₹15,097 is through Dairying, ₹12,243 through non-farm activities and ₹46,865 through wage labour and salary. The major food crops grown in the state are paddy, cereals, pulses, oilseeds, sugarcane and vegetables. The important horticultural crops of the state are cashewnut, coconut, arecanut, mango, banana, pineapple and spices. Fishing is another important activity covering mainly marine fisheries. Inland fisheries are becoming popular considering the growing demand. The marginal or small farmers of the region have very limited land which is getting further fragmented with each generation and therefore farm enterprises requiring less land but higher productivity and employment opportunities, needs to be integrated with crop production. A judicious mix of one or more intercrops along with the main crop has a complimentary effect through effective recycling of wastes and crop residues and encompasses additional source of income to the farmers. These systems are often less risky, if managed efficiently, they benefit from synergisms among the crops, diversity in produce, and environmental soundness. Further, integration of allied enterprises in the system adds profitability and stability with intermittent returns.

North Goa: The geographical area of North Goa district is 1463 km^2 and accounts for 40% of the total geographical area of Goa State. North Goa has 166 villages with 102 Village Panchayats. The average annual rainfall of the district is 3473 mm. Mandovi, Tiracol and Chapora are the major rivers in the district. The types of soil available in the district are sandy, red loamy, coastal alluvium and laterite. Two talukas of the District, Bicholim and Sattari are rich in iron ore deposits. As per Census, 2011, the district has total population of about 8.18 lakh (56.10% of the total population of the state), the sex ratio is 959 per 1000 males and literacy rate is 81.06%. North Goa District has five talukas and it is estimated that there are 15,000 cultivators and 14,000 agricultural labourers in the District. There are 45,891 landholdings with total area of 51,375 ha. The average size of land holding is 1.12 ha and 80% of it is below 1 ha. The marginal and small landholdings (<2 ha) constitute 91% of the total land holdings which is 51% of the area of landholdings. The cropping intensity is as low as 121%. Plantation crops, viz., cashew, arecanut, coconut and food crops like paddy and vegetables are the major agricultural crops in the District.

South Goa: The geographical area of South Goa district is 2239 km^2. The boundaries of the district are well defined in the north by river Zuari, in the east by Belgaum district, in the south by Uttar Kannada district of Karnataka State and in the west by the Arabian Sea. The district is endowed with rich natural resources such as forests, navigable rivers and valuable mineral deposits like iron ore, manganese ore, agriculture land, natural harbour and beautiful coastline. The major food crop of the district is paddy and plantation crop is sugarcane. Besides, horticulture crops like cashew, coconut, mango and arecanut are also grown in the district. South Goa is a biodiversity rich region located along the Western Ghats, with 65% of geographical area under forest cover. Two perennial rivers viz, Zuari, Galgibag and three ephemeral rivers, viz., Sal, Saleri, Talpona flow in South Goa. The average rainfall of the district is 3085 mm and 90% of the rains are received from June to September. Of the net sown area of 63697 ha, 23% of area is under irrigation in the district. Salaulim Irrigation Project is the only irrigation project with Culturable Command Area of 9537 ha. The predominant economic activities of the district are mining, tourism and farming. The Micro

Small and Medium Enterprises sector covers a wide spectrum of rural based industries. There are nine Industrial Estates in the district, with the prominent being Verna Industrial Estate. Major cultivated crops of the district are paddy, sugarcane, pulses and vegetables. Cashew and coconut is the major plantation/horticulture crop, while mango, arecanut, oil palm and spices like pepper and nutmeg are also cultivated. However, the productivity levels of crops are much lower than other States. More than 50% of the demand of fruits, vegetables, milk and meat are met from the neighbouring States. Out of 63697 ha net sown area of the district, cashew accounts for 19093 ha i.e. 30% of net sown area. Vengurla 4, Vengurla 7 and Balli 2 are the suitable varieties grown in the district. Cashew liquor industry is unique to Goa. It is the only State where the cashew apple is commercially used for distilling liquor, popularly known as "Feni", for which Geographical Indicator status has also been accorded. The local Goan varieties of Mango, viz., Mancurad fetches high price in the local market. Besides, there are a number of minor fruits like kokum, noni, jamun, jackfruit, etc., which are yet to be commercially used. South Goa District has seven talukas and it is estimated that there are 16000 cultivators and 13000 agricultural labourers in the District. There are 32129 land holdings of which 88% are cultivated by marginal and small farmers, constituting 52% of the total holding area of holdings. The average land holding of farmers is 1.17 ha. While Sanguem, Darbandora, Quepem and Cancona are predominantly agricultural areas, Ponda, Salcete and Mormugao blocks are comparatively urbanised. The cropping intensity is low at 120%.

Over time the cultivable, agricultural and plantation area has reduced from 326,671 ha during 1989-90 to 323,976 ha in 1992-93. There has been 6% increase in forest area during the last 5 years. The area sown more than once fluctuates between 3% and 6%. Conversely there has been a decrease in the area of cultivable wasteland from 21% to 16%. This indicates an awareness of the people to use irrigation potential for double cropping and greening of the state. Large areas in Sanguem, Sattari, Canacona and Quepem talukas are under woodland forests and cultivable wastelands. An upward trend in the area under Rabi paddy and pulses has been observed in the state

Goa is divided into Konkan coast and Central Sahyadri. The Konkan coast is sub-divided into fluvio-littoral marine landform and dissected hilly laterite landform and the Central Sahyadri into granite and granite-gneiss landform, quartzite/schistose landform and basalt landform.

Goa is almost covered by rocks of the Goa group belonging to the Dharwar Super group of the Archaean/Proterozoic age, excepting a narrow strip at the north-eastern corner that is occupied by Deccan Trap of the Upper Cretaceous to Lower Eocene age. The Goa state soil geological group consisting of green schist species of metamorphic rock is divided into Barcem formation, Sanvordem formation, Bicholim formation and Vageri formation in the ascending order of superposition. This group is correlated with the Chitradurga group of Karnataka and has been intruded by granite-gneiss, felspathic gneiss, hornblende granite and porphyritic granite. These intrusions have been recognized as peninsular gneisses in the contiguous areas of Karnataka as a basement to the Dharwar Super group in the Shimoga-Goa schist belt. These rocks are overlaid by Deccan traps represented by massive and vesicular metabasalt (Maji et al., 2010).

The state has a warm tropical climate with an average annual temperature of 26.4°C; December to February weather is cool and pleasant. Difference between the mean annual summer temperature and mean annual winter temperature is 4°C. South-west monsoon provides a total annual precipitation of about 3,265 mm from June to October.

Vegetation of Goa consists of dense forests of dry to moist deciduous types. Moderately sloping lands with laterite outcrops are covered by grass and shrubs. Evergreen forests are seen only on the higher altitude areas of the Eastern part of the State. The coastal tracts with marine alluvium are mainly covered by plantation crops. The border line of Arabian Sea and the West coast are thickly palm fringed with a small area covered by mangroves. Patches of scrub vegetation with other xerophytic plants (growing on rocks, sand or gravels of which substratum is physically dry) are found in association with tropical fruit trees, jackfruit and cashew etc. (Maji et al., 2010).

According to soil classification the Goa state soils can be classified under 4 orders, 7 sub-orders, 12 great groups and 18 sub-groups (Soil Survey staff, 1992). Prominent great groups are: Paleustalfs, Haplustalfs, Psammaquents, Ustipsamments, Ustorthents, Tropaquepts, Humitropepts, Ustropepts, Dystropepts, Haplustults, Kanhaplustults and Paleustults (Harindranath et al., 1999).

. Degraded and wastelands account for 122 thousand ha, which is about 33% of TGA of the state. Acid soils (pH <5.5), a major problem, account for 103 thousand ha, which is about 28% of TGA of the state. Mining is one of the major concerns causing land degradation. About 12 thousand ha have been rendered wastelands due to mining (3% of TGA). South Goa has more degraded area compared to North Goa.

Goa has more than 700 square kilometres under mining and two talukas (Bicholim and Sattari) in North Goa, one of the two districts in India's smallest state, have around 50 % of these mines. According to the Goa's Directorate of Mines Geology, in 2011, there were 27 mines in Bicholim and 11 in Sattari. In the ISRO atlas this area is shown to have large swathes vegetative degradation, with severe scrub degradation making most of it. Also, more than 50 % of the land in the district is degraded, according to the atlas. Of this, 43 % is because of vegetation. The report indicated that about 2,800 hectares of land was under encroachment and of this, 578 ha was being actively mined. This encroached area also included wildlife sanctuaries and reserved forests. When it rains the area around the mines becomes red with lateritic soil.To get a tonne of ore, 2.5 to 3 tonnes of overburden (soil) needs to be extracted. This overburden is mostly dumped outside mine-leased area on revenue and agricultural land which leeches out. Lack of planning could become the biggest degrader of land in Goa, even bigger than mining. The spotlight on mining is intense but small changes in land use pattern go unnoticed, especially for real estate and tourism.

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 leads to land degradation and consequently impacting on eco-system services.

2.0. LAND DEGRADATION THROUGH SOIL EROSION AND ITS IMPACTS

1.1. **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 (Maji et al., 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).

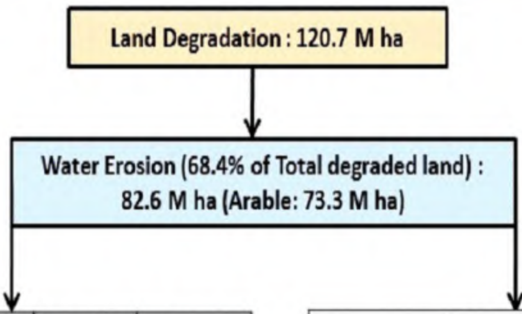
1.2. **Gross Erosion Rate**: The gross annual soil erosion of our country is 5.11 billion tonnes out of which 34.1% deposited in the reservoirs, 22.9% is discharged outside the country (mainly to oceans), and 43.0% is displaced within the mainland (Sharda and Ojasvi, 2016). Average annual reduction in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

1.3. **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).

1.4. **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. 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 ersoion 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 rupees at market price of 2020, respectively.

1.5. **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 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 yr^{-1} 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).

1.6. **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^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 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. 2.1. 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. The state of Goa is characterised by its unique undulated topography where the slope of the land varies from 0-28% with an average slope of 14.41%. The state also receives excessive rainfall of more than 3000 mm/year. Soil erosion losses in Goa vary from moderate (< 15 t ha^{-1} y^{-1}) to extremely severe (> 80 t ha^{-1} y^{-1}) classes while the national average soil loss in India is 15.59 t ha^{-1} y^{-1}. The permissible soil loss limit for India is 11.2 t ha^{-1} y^{-1}. The cultivation of crops like cashew, mango and coconut helps to reduce erosion losses compared to fallow or barren lands. The detrimental effects of soil erosion are reflected in the land's declining productivity.

Soil erosion in a given area has to be limited within the permissible rate or T-value to achieve sustainability of production systems, and also carbon sequestration. The identification of critical areas in the the different districts based on the permissible soil erosion rate or T-value at a given location in each districts of Goa and the proposed conservation measures for each district are aimed to reduce soil erosion below the soil loss tolerance limit.

4.0. EROSION STATUS AND CONSERVATION PLANNING FOR THE STATE OF GOA

4.1 About the State: Soil erosion is a serious problem in Goa in hilly areas in particular. Indiscriminate destruction of forests and woodlands leads to terrain deformation and accelerate soil erosion. The three Tehsils mainly Satari, Sanguem and Canacona fall in the Western Ghat areas. The Western Ghats are one of the world's biodiversity hotspots with over 5,000 flowering plants, 139 mammals, 508 birds and 179 amphibian species. At least 325 globally threatened species occur here. The watershed of the hilly terrain forms catchments for major rivers of the State, but are subjected to various biotic interference like fire hazard, over grazing and improper land use planning and management. Although there is sufficient forest cover in the state, still most of the areas have been subject to soil erosion. Due to undulating topography and acidic lateritic soil, the surface runoff is high which in turn accelerate soil erosion and prevents percolation of water into sub-soil. The coastal erosion is a concern in Goa and the state is employing a number of soil erosion measures like stepped sea walls, concrete blocks, earthen embankments, sand bag embankments, geo-tubes and others.

Beach erosion is a phenomena in which beach sand gets eroded either due to human factors or natural processes. It's a natural phenomena in which beach sand moves away, either due to wind or wave action. If this movement of sand away from beach is more or there is no or very little addition of sand by waves, beach erosion takes place. Past few years, Goan beaches are facing the acute problem of erosion with beach sand get washed off from the shore by waves. Because of this the level of water increases and usable area of beach decreases. Various beaches of North Goa like Colva, Donapaula, Sinqueiim, and Candolim have faced this erosion problem. Beach erosion leads to economical as wells as environmental concerns and need to be addressed. There are several ways in which beach erosion can be controlled or managed. The various hard and soft measures can be adopted to minimize this beach erosion.

For control of beach erosion, various hard (seawalls, bulkheads, revetments, groins, jetties) and soft measures (dune rehabilitation, dune vegetation, green belts, Biorock, geotubes, geotextile sand containers) could be adopted depending upon the local conditions to minimize the severity of beach erosion. The hard options are expensive, not-eco-friendly and usually massive in size. They are normally made of materials like rubble, mound, concrete. Pilarczyk (2005) reported that coastal structures like seawalls, dikes, revetments provide direct protection to the beaches, whereas groins and offshore breakwaters provide indirect method of shore protection. In contrast, soft options are usually not expensive, not massive in size, and mostly eco-friendly. These are options like sand bypassing, dune rehabilitation, dune vegetation, beach face dewatering, sand fencing, green belts, Bio-rock, geo-tubes, geo-textil, sand containers etc. There are also proactive methods such as flood proofing, setback limits, zoning, relocation, abandoning, demolition.

Developing vegetative cover can restrict sand movement and erosion. Transplanting of marram grass (*Ammophila arenaria*) to the face of eroded dunes will enhance natural development of vegetative cover and reduce direct sea wave attack. Sand couch grass (*Elymus factas*) or lyme grass (*Leynus arenarius*) are tolerant to inundation by sea water. They act like surface cover and reduce wind speed across the surface by trapping and holding sand intact. Koerner (2000) reported that geotextile tubes can provide better protection for beach erosion. Geotextile tubes of diameters of up to 3 m, made up of woven or knitted high strength fabric have been effectively used to control both inland and oceanfront erosion.

4.2 Soil Erosion Rate: In the present study, the quantitative data of soil loss were estimated following the Universal Soil Loss Equation (USLE) and using the derived information on factors of rainfall erosivity (R), soil erodibillty (K), topography (LS), cover and management (C) and conservation practice (P). Based on soil loss estimates the state has been grouped into the following classes of erosion vulnerabilities.

1. Very slight (< 5.0 t $ha^{-1}yr^{-1}$)
2. Slight (5- 10 t $ha^{-1}yr^{-1}$)
3. Moderate (10-15 t $ha^{-1}yr^{-1}$)
4. Moderately severe (15-20 t $ha^{-1}yr^{-1}$)
5. Severe (20-40 t $ha^{-1}yr^{-1}$)
6. Very severe (40-80 t $ha^{-1}yr^{-1}$)
7. Extremely severc (> 80 t $ha^{-1}yr^{-1}$)

The soil loss under different classes is given in Table 4.1. The status of soil loss in Goa state shows that very slight (< 5.0 t $ha^{-1}yr^{-1}$) soil loss was observed in Salcete, and Canacona talukas of South Goa district covering an area of about 9.6 % of the TGA of the state. Slight (5-10 t $ha^{-1}yr^{-1}$) soil loss was noticed in Satari, Salcete, Sanguem, Quepem and Canacona talukas and covers with an area of 15 %. Moderate (10-15 t $ha^{-1}yr^{-1}$) and moderately severe (15-20 t $ha^{-1}yr^{-1}$) soil loss was observed in Satari, Salcete, Sanguem, Quepem and Canacona talukas and covers with an area of 8.8 and 8.9 %, respectively. Severe (20-40 t $ha^{-1}yr^{-1}$) and very severe (40-80 t $ha^{-1}yr^{-1}$) soil loss was reported from Pernem, Bardez, Bicholim, Satari, Tiswadi, Ponda, Quepem and Sanguem talukas and covers with an area of 26.9 and 22.0 %, respectively. Extremely severe (> 80 t $ha^{-1}yr^{-1}$) soil loss was observed mainly in Pernem and Bicholim talukas of North Goa district and covers with an area of 4.1 %. The highest soil loss values are spatially correlated with the steepest slopes, which indicate that soil erosion is a serious problem in North Goa district of the state. The severity of soil erosion in the state is due to changing climatic conditions coupled with steep topography and erodible soils (Reddy et al., 2013).

Table 4.1. Soil erosion priority classes for Goa state of India

S.No.	Taluka	Area in ha								
		< 5 t $ha^{-1}yr^{-1}$	5-10 t $ha^{-1}yr^{-1}$	10-15 t $ha^{-1}yr^{-1}$	15-20 t $ha^{-1}yr^{-1}$	20-40 t $ha^{-1}yr^{-1}$	40-80 t $ha^{-1}yr^{-1}$	> 80 t $ha^{-1}yr^{-1}$	Water Bodies	Total
North Goa										
1	Bardez	0	0	45.27	335.02	10149.63	12141.68	2118.42	1606.97	26397
2	Bicholim	0	70.5	351.03	233.04	5419.11	13665.82	3799.61	340.89	23880
3	Pernem	0	263.32	1817.09	1923.75	3534.99	7305.68	9478.42	845.75	25169
4	Satari	3724.43	11140.35	5371.62	4604.11	18630.71	5190.51	0	284.27	48946
5	Tiswadi	0	1970.58	2271.6	1555.55	5773.87	4032.22	1277.55	4475.63	21357
6	Ponda	0	104.04	1107.54	3242.53	9989.02	13692.08	24	1118.77	29278
Sub-Total		3724.43	3724.43	13548.79	10964.15	11894	53497.33	56027.99	16698	8672.28
South Goa										
7	Canacona	17150.43	8263.03	2328.36	1891.66	5068.14	405.91	0	96.48	35204
8	Marmugao	0	0.26	105.07	302.46	4047.91	3950.46	0	2506.84	10913
9	Quepem	2222.33	4618.34	4150.38	5004.63	10618.31	5040.42	0	170.59	31825
10	Salcete	6843.39	5386.29	4335.68	3059.75	5432.21	3488.67	0	748	29294
11	Sanguem	4312.02	22674.68	9458.52	9807.55	20288.08	15223.39	0	1917.76	83682
Sub-Total		30528.17	30528.17	40942.6	20378.01	20066.05	45454.65	28108.85	0	5439.67
12	**Total**	**34252.6**	**54491.39**	**31342.16**	**31960.05**	**98951.98**	**84136.84**	**16698**	**14111.95**	**365945**

Source: Reddy et al., (2013)

In Goa as per the erosion classes, it is evident that moderate (10-15 t ha^{-1} yr^{-1}), moderately severe (15-20- t ha^{-1} yr^{-1}), severe (20-40 t $ha^{-1}yr^{-1}$), very severe (40-80 t $ha^{-1}yr^{-1}$) and extremely severe (> 80 t ha^{-1} yr^{-1}), classes covers an area of 8.8, 8.9, 26.9, 22.0, and 4.1 % of TGA, respectively and exceeded the tolerance limit of 12.5 t ha^{-1} yr^{-1} as given in Table 4.1. It is also evident that the surface soil is lost every year from different regions of the state leading to a huge amount of nutrient loss (major and micro nutrients) annually. In terms of equivalent nutrient loss added through fertilizer usage accounts to a significant loss of nutrients annually. Looking to the above data senario, it is evident that there is an urgent need to have soil conservation planning based on priority treatment area in the different districts of the Goa state.

The soil loss to the extent of 20-40 t ha^{-1} yr^{-1} is observed in 26.9% area followed by 40-80 t ha^{-1} yr^{-1} soil loss in 22% area dominantly in Northern and Central parts of the state. Soil loss of 5-10 t ha^{-1} yr^{-1} was found in 15.5% area mostly in Eastern and Southern parts of the state. District and Taluka wise status of soil erosion in given in Table 4.1. The erosion status shows that extremely severe (>80 t ha^{-1} yr^{-1}) soil erosion was mainly observed in Pernem, Bicholim, Bardez and Tiswadi talukas of North Goa district. Very severe (40-80 t ha^{-1} yr^{-1}) soil erosion is dominant in Ponda, Bardez and Bicholim talukas of North Goa district and Sanguem taluka of South Goa district. Severe (20-40 t ha^{-1} yr^{-1}) soil erosion was observed in Sanguem and Quepem talukas of South Goa district, whereas in North Goa district severe (20-40 t ha^{-1} yr^{-1}) soil erosion was noticed in Satari, Bardez and Ponda talukas. Moderately severe erosion (15-20 t ha^{-1} yr^{-1}) is observed in Sanguem and Quepem (South Goa) and Satari and Ponda talukas of North Goa. However, moderate (10-15 t ha^{-1} yr^{-1}) soil erosion was mainly noticed in Senguem, Salcet, Quepem and Canacona talukas of South Goa and Satari and Tiswadi talukas of North Goa district. Slight (5-10 t ha^{-1} yr^{-1}) and very slight (< 5 t ha^{-1} yr^{-1}) soil erosion was encountered in Canacona and Salcete talukas of South Goa district. The erosion status indicated that North Goa district suffers severe to extremely severe erosion compared to South Goa. The talukas showing severe to extremely severe erosion needs first priority for treatment through different conservation measures as suggested in this document. The areas suffering from moderate to moderately severe erosion need second priority for adoption of soil and water conservation measures to protect natural resources.

4.3. Soil Loss Tolerance Limit (SLTL) : This is a limit which denotes the maximum level of soil erosion that will permit crop productivity to be sustained economically and indefinitely. Considerable work has been done on this aspect and the tolerance limits were ranging from 2.5 to 12.5 t ha-1 yr-1 has been suggested by (Mannering, 1981). Soil loss in excess of 12.5 t ha-1 yr-1 affects the effectiveness of water conservation structures. At this stage, the gully formation starts which in turn obstructs the cultural operation (Singh et al. 1981). The Soil Loss Tolerance Limit map of Goa (Fig 4.1.) indicates the T-value or tolerance limit ranging between 2.5 to 12.5 t ha-1yr-1. A lower T-value indicates top priority in terms of soil and water conservation (SWC) measures while a higher T-value for a soil reflects better resilience of the soil. The T-value combined with the erosion rates of any area helps to prioritize the SWC measures for any District/Taluka.

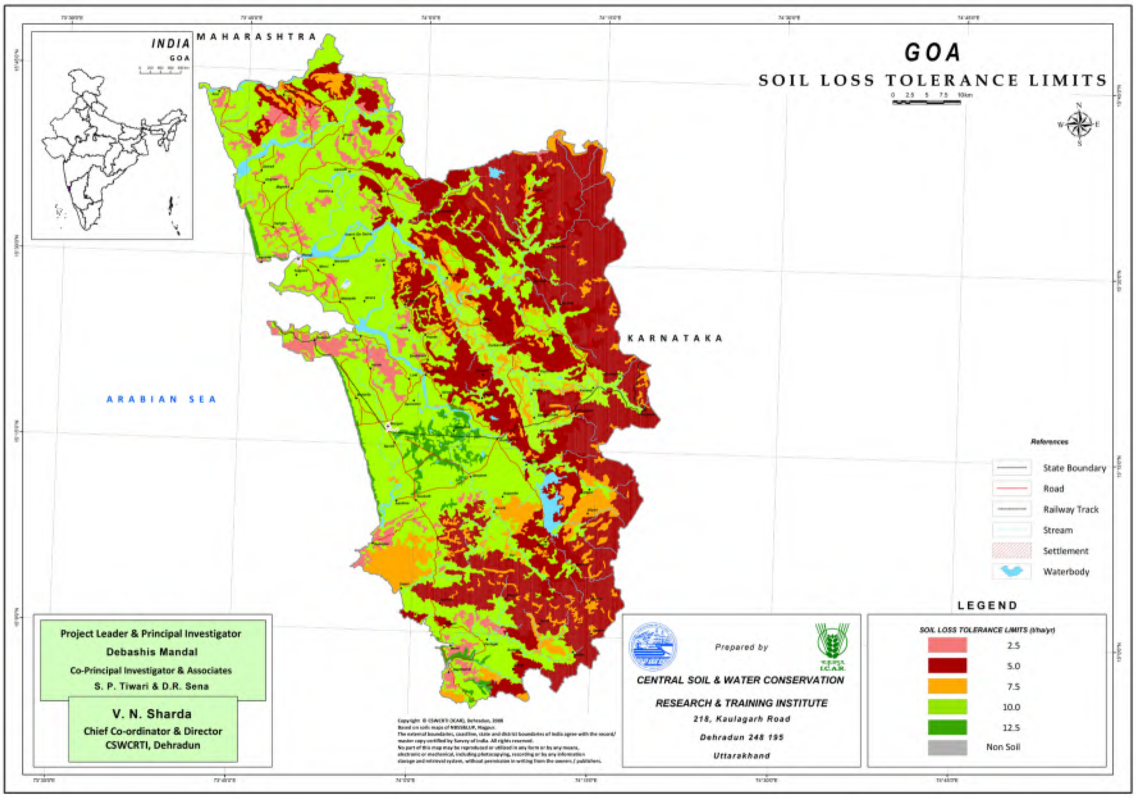


Fig. 4.1: Soil Loss Tolerance Limit map for erosion control in Goa state

Table 4.2. Area under different soil loss tolerance limit class in Goa state

Sr. No.	Soil Loss Tolerance limit (t ha^{-1} yr^{-1})	Area (ha)
1	≤ 2.5	18402.775
2	2.5 - 5	134028.25
3	5 - 7.5	31284.364
4	7.5 - 10	158260.55
5	10 - 12.5	7473.3747
6	Non-Soil (Settlement, Road etc.)	415.32543
7	Waterbody	16080.36
	Total	**365945**

The soil loss tolerance limit (T) values for Goa varied between 2.5 and 12.5 Mg ha^{-1} yr^{-1}, indicating a high degree of soil heterogeneity with respect to soil depth, infiltration, bulk density, organic matter content, erodibility and pH within the same physiographic region. The area under different soil loss tolerance limit classes is presented in Table 4.2. Almost 43% area in the state has a T-value of >10 t ha^{-1} yr^{-1} followed by 36% area with a T-value of 5 t ha^{-1} yr^{-1}. In North Goa Districts, Talukas like Satari, parts of Bicholim, Ponda has a T-value of 5 t ha^{-1} yr^{-1} which is of great concern; while in South Goa District Taluka like Dharbandora, Sanguem, parts of Canacona has similar T-values. Near the coast line the Mormugao Taluka in South Goa Disrict and Pernem Taluka in North Goa District has a very low T-value of 2.5 t ha^{-1} yr^{-1}. In general the inland areas have lower T-values and the coastal areas have a higher T-value as evident from Fig 4.1.

Beach erosion is a phenomena in which beach sand gets eroded either due to human factors or natural processes. It's a natural phenomena in which beach sand moves away, either due to wind or wave action. If this movement of sand away from beach is more or there is no or very little addition of sand by waves, beach erosion takes place. Past few years, Goan beaches are facing the acute problem of erosion with beach sand get washed off from the shore by waves. Because of this the level of water increases and usable area of beach decreases. Various beaches of North Goa like Colva, Donapaula, Sinqueiim, and Candolim have faced this erosion problem. Beach erosion leads to economical as wells as environmental concerns and need to be addressed. There are several ways in which beach erosion can be controlled or managed. The various hard and soft measures can be adopted to minimize this beach erosion.

For control of beach erosion, various hard (seawalls, bulkheads, revetments, groins, jetties) and soft measures (dune rehabilitation, dune vegetation, green belts, Biorock, geotubes, geotextile sand containers) could be adopted depending upon the local conditions to minimize the severity of beach erosion. The hard options are expensive, not-eco-friendly and usually massive in size. They are normally made of materials like rubble, mound, concrete. Pilarczyk (2005) reported that coastal structures like seawalls, dikes, revetments provide direct protection to the beaches, whereas groins and offshore breakwaters provide indirect method of shore protection. In contrast, soft options are usually not expensive, not massive in size, and mostly eco-friendly. These are options like sand bypassing, dune rehabilitation, dune vegetation, beach face dewatering, sand fencing, green belts, Bio-rock, geo-tubes, geo-textil, sand containers etc. There are also proactive methods such as flood proofing, setback limits, zoning, relocation, abandoning, demolition.

Developing vegetative cover can restrict sand movement and erosion. Transplanting of marram grass (*Ammophila arenaria*) to the face of eroded dunes will enhance natural development of vegetative cover and reduce direct sea wave attack. Sand couch grass (*Elymus factas*) or lyme grass (*Leynus arenarius*) are tolerant to inundation by sea water. They act like surface cover and reduce wind speed across the surface by trapping and holding sand intact. Koerner (2000) reported that geotextile tubes can provide better protection for beach erosion. Geotextile tubes of diameters of up to 3 m, made up of woven or knitted high strength fabric have been effectively used to control both inland and oceanfront erosion.

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 39%, 39% and 23%, respectively, and consequently, average loss considering cereals, oil seeds and pulses together is about 38%. Out of 0.04 million tonne total production losses, 95.3% is due to losses in cereals and millets, 0.6% in oilseeds and 4.1% in pulses (Fig. 4.2). In terms of monetary losses, 86.9% of the total loss of Rs 784 million occurs in Goa due to production losses in cereals and millets, followed by 11.6% in pulses, and 1.5% in oilseeds (Fig. 4.3). The largest contribution is from paddy (87%) followed by other pulses (12%), and groundnut (2%).

The productivity losses of cereal and millets, oilseed and pulse crops were estimated to be 1089 kg ha^{-1}, 599 kg ha^{-1} and 212 kg ha^{-1}, respectively. The average productivity loss of all these crops together is 927 kg ha^{-1} (Sharda and Dogra, 2013), which in monetary terms was ₹17,833 ha^{-1} during 2018-19 (Fig. 4.3). The Gross State Domestic Product (GSDP) of Goa for 2018-19 at current prices was estimated to be ₹77,172 crore at price of 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 0.10% of its GSDP during 2018-19.

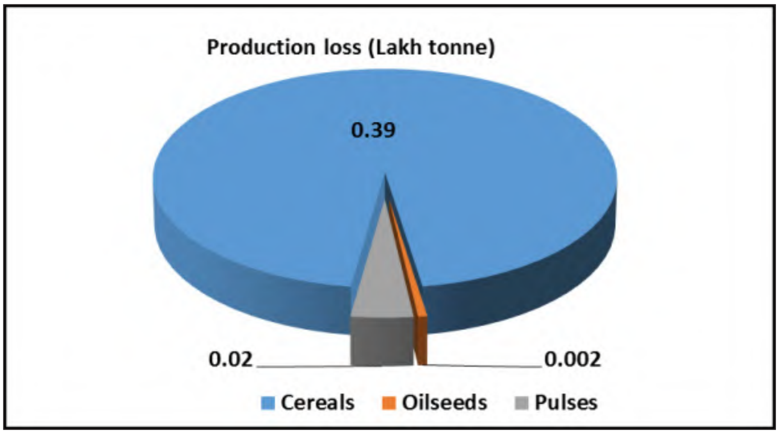


Fig. 4.2 Estimated total production loss of rainfed crops due to soil erosion in Goa State

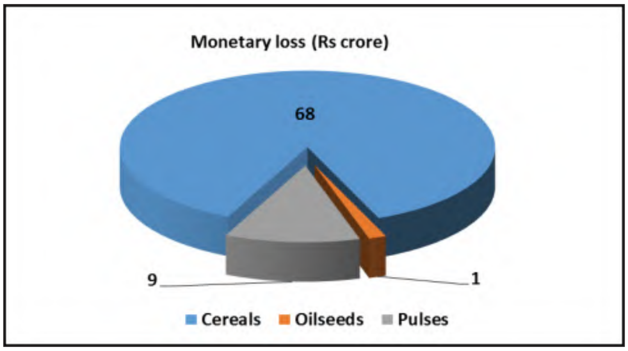


Fig. 4.3. Estimated total monetary loss of rainfed crops due to soil erosion in Goa State

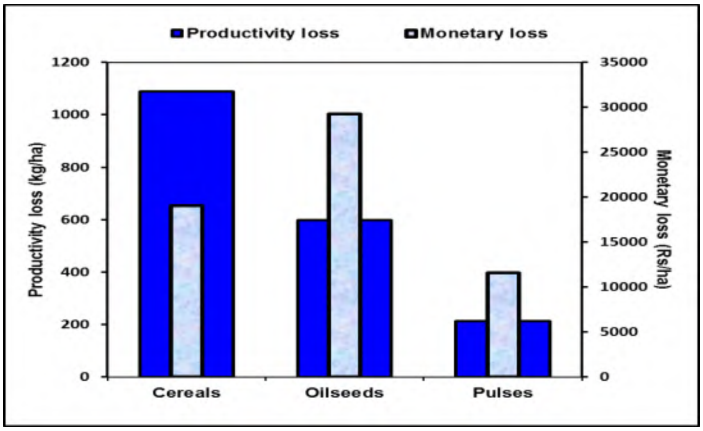


Fig. 4.4. Estimated productivity (kg ha^{-1}) and monetary loss (₹ ha^{-1}) of rainfed crops due to soil erosion in Goa State

4.5 Area under Risk: It is evident that 81% of TGA of the state requires different degrees of soil erosion management and only 19% of TGA falls under no treatment category in view of the fact that soil loss is within permissible soil erosion limits. Though 75.80% area of the state falls under severe and very severe soil erosion categories, 32% has high priority from conservation point of view with a T-value upto 12.5 t ha^{-1} yr^{-1} (Fig 4.1). Similarly, though 29.9% area has prevailing soil erosion rates of less than 10 t ha^{-1} yr^{-1} but 10.80% 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, Table 4.3 and Table 4.4 which are given in the succeeding sections of the document. Table 4.2 which presents soil and water conservation 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 4.3 District wise severity of erosion areas and critical problem with their possible solutions in Goa state

		Area in 000'ha				
S. No.	District	TGA	Area under risk	% of TGA	Special erosion problem	Conservation measures
1	North Goa	175.02	149.08	40.74	Gully erosion, Acid soils, Mining	Table 4.2 - Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.3, 4.4, 4.5, 4.6, 4.7, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.1.6, 5.1.7, 5.1.8, 5.1.9, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.2.11, 5.2.12, 6.4, 6.5, 6.6, 6.7, 6.8. Table 4.3 - Sr. No. 1
	Total	175.02	149.08	40.74		
2	South Goa	190.92			Coastal Erosion, Mining, Forest cover destruction	Table 4.2-Sr. No. 1.1, 1.2, 1.3, 1.4, 1.5, 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.1.6, 5.1.7, 5.1.8, 5.1.9, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.2.11, 5.2.12, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9 Table 4. 3- Sr. No. 2
	Total	370.20	114.00	31.15		

Note: Table 4.4 represents different soil and water conservation engineering measures for different land situations, Table 4.5 respresents details of agronomical and vegetative measures and Table 4.6 represents district wise potential agroforestry systems.

Table 4.4. Soil and water conservation engineering measures for different soil erosion priority classes in Goa state

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	**Vegetative measures (At lower slope-alone, at higher slope with other conservation measures**					
	1.1	Vegetative barrier*/Mixed vegetative barriers*	√	√	√	√
	1.2	Afforestation/reforestation		√		√
	1.3	Grassed waterways	√	√	√	√
	1.4	Live vegetative check dam with different species along with Bamboo		√		√
	1.5	Stream bank stabilization with bamboo and other species		√		√
		**Species:* Vetivera grass *(Vetiveria zinanoides) ;* Lemon grass *(Cymbopogon citrates);* Rosa/ palma rosa grass *(C. martinii);* Malabar *(C. flexuosus);* 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*).				
2.0	**Mechanical/Engineering Measures**					
	2.1	**Bunding**				
	2.1.1	Contour/Field bunding/Trench-cum-bund	√	√	√	√
	2.1.2	Graded bunding (uniformly and variable graded)-Black soils	√			
	2.1.3	Stone bund (Where stones are available onsite)	√	√	√	√
	2.1.4	Compartmental bunding	√		√	
	2.2	**Trenching**				
	2.2.1	Contour trenching		√		√
	2.2.2	Continuous contour trenching		√		√
	2.2.3	Contour staggered trenching		√		√
	2.2.4	Graded trenching		√		√
	2.2.5	Water absorption trenches		√		√
	2.2.6	Half-moon trenches/terraces	√	√	√	√
	2.2.7	Recharge pit		√		√
3.0	**Drainage Line Treatments (DLT's)**					
	3.1	Sandbag check dam		√		

	3.2	Brush wood check dam (BWCD)		√		√
	3.3	Loose boulders check dam (LBCD)		√		√
	3.4	Gabion check dam		√		√
	3.5	Plastic head wall composite check dam/Masonary check dam		√		√
	3.6	Gabion terrace support wall		√		√
	3.7	Retaining wall/ Revetment		√		√
	3.8	Silt detention tank		√		√
4.0	**Water Harvesting**					
	4.1	Community pond	√	√	√	
	4.2	Embankment pond		√		
	4.3	Pond renovation & Desilting	√	√	√	
	4.4	Dugout type farm pond	√		√	
	4.5	Sub surface water harvesting structures (Dykes) with sub-surface runoff collection wells			√	
	4.6	Pond lining	√	√	√	
	4.7	Roof top water harvesting	√		√	
	4.8	Diversion based water harvesting			√	√
Special Problem Area						
5.0		**Mine spoil area**				
	5.1	**Vegetative**				
	5.1.1	Vegetative hedges		√		√
	5.1.2	Brushwood check dam				√
	5.1.3	Watling (live)				√
	5.1.4	Double-row Brushwood dam / Log wood brush filled check dam				√
	5.1.5	Grassed contour barrier		√		√
	5.1.6	Bamboo plantation		√		√
	5.1.7	Afforestation		√		√
	5.1.8	Aerial seeding (very high slope or unapproachable area)				√
	5.1.9	Turfing/Soding				√
	5.2	**Mechanical/Engineering Measures**				
	5.2.1	Contour bunds/Stone bund		√		√
	5.2.2	Stone wall				√
	5.2.3	Staggered trenches and planting		√		√
	5.2.4	Loose Boulder check dam (locally available)				√

	5.2.5	Diversion drain/ Interceptor drain				√
	5.2.6	Nala bunds		√		
	5.2.7	Gabion check dam				√
	5.2.8	Gabion drop structures				√
	5.2.9	Toe drain for seepage control				√
	5.2.10	Retaining wall for slopes				√
	5.2.11	Jute geo textiles for slope stabilization/ Coir Jeo textiles for stabilization of slopy lands (Slope >33%)				√
	5.2.12	Stream Channelization (Retaining wall, Bank protection walls. Spurs with apron etc)		√		√
6.0	**Gullied Land**					
	6.1	Bio fencing/social fencing		√		√
	6.2	Safe disposal of water from gully head-Piped/chute spillway-		√		√
	6.3	Alternate land use system/ Agroforestry		√		√
	6.4	Mechanical/Engineering measures		√		√
	6.5	Earthen check dam		√		√
	6.6	Boribund check dam		√		√
	6.7	Silt retention tank		√		√
	6.8	Staggered trenching + plantation		√		√
	6.9	Pre-fabricated drop structure on the gully head	√		√	

Note 1: District wise details of agronomic and vegetative measures for Goa is given in Table 4.5.
Note 2: For concept, design and estimates of soil and water conservation measures 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 Goa, Kindly refer Table 4.6.

Table 4.5 District wise area under various erosion risk and the possible agronomic and vegetative measures for Goa state

<table>
<tr><td>1</td><td colspan="4">North Goa, TGA: 175.03, Er (% of TGA): 40.73%, Special Problem: Gully erosion, Acid soils, Mining</td></tr>
<tr><td></td><td>Upland medium deep to shallow soils
Rice
Finger millet
Groundnut
Niger (Karla)
Sugarcane
Mid-land medium deep soils
Low land deep soils
Hill slope shallow soils</td><td>Intercropping of Wheat + Chickpea for moisture conservation or crop insurance.

Dapog nursery raising /sowing of sprouted seed.

Sunn hemp as green manure.

Green gram/black gram/cowpea as cover crop.

Mulching with glyricidia leaves.</td><td>Saccharum spontaneum (Kanna), Eulaliopsis binata (Bhabar grass), Pennisetum purpureum, Vetiver zizanioides for moisture conservation and reducing soil erosion by binding the soil by fine roots.</td><td>For flood: provide drainage by constructing drainage channel of 25-30 cm deep.

For deforestation and mine rehabilitation: Cassia mimosoides, Bothriochola pertusa, Cymbopogon spp, Cassia auriculata, Tephrosia purpurea, Indigofera cassioides, Accacia catechu, and Albizia lebbeck.</td></tr>
<tr><td>2</td><td colspan="4">South Goa, TGA: 190.92, Er (% of TGA): 31.15%, Special Problem: Coastal erosion, Mining, Deforestation</td></tr>
<tr><td></td><td>Upland (Terrace Sorad) shallow to moderately deep
Paddy – Pulses
Maize
Paddy – Paddy
Paddy – Groundnut
Paddy – Vegetables</td><td>Sun-hemp and Dhaincha are cultivated as green manuring crops</td><td>Horticulture/ Plantation crops like cashew, pine apple, coconut, mango and Banana.</td><td>Cultivation of flood resistant red rice variety.

Coastal erosion: Use of Vetiver grass (Khas grass, Lavancha) or Vetiveria zizanoide for dune stabilization.</td></tr>
<tr><td></td><td>Mid-land (Morad) moderately deep to deep
Rice-groundnut
Sugarcane
Low land deep to very deep soils
Rice-Rice
Coastal lowlands deep to very deep soils (Khazan)
Rice-Fallow</td><td></td><td></td><td>Bio-shielding of the coast through planting of following species of grass and trees: Spinifex littoreus, Ipomoea pes-caprae, Canavalia spp, Pandanus spp, Borassus flabellifer and Morinda citrifolia.</td></tr>
</table>

Note: Table 4.4 represents different soil and water conservation engineering measures for different land situations, Table 4.5 respresents details of agronomical and vegetative measures and Table 4.6 represents district wise potential agroforestry systems.

Table 4.6. Agroforestry solution for soil and water conservation in Goa state

	Region	District	Agroforestry measures
1.	Western Ghat Zone	North Goa	**a) Agri-horticulture system** *Mangifera indica/ Phyllanthus emblica* + *Cicer arietinum/Glycine max* **b)Agri-silviculture** *Tectona grandis* + Vigna unguiculata / Vigna mungo **c) Silviculture** *Azadirachta indica/Eucalyptus camaldulensis/Melia Azadirachta/Tectona grandis/ Hardwickia binata/Acacia nilotica/Zizyphus mauritina*
	Coastal zone	South Goa	a) Arecanut black plantations: *Grevillea robusta, Tectona grandis* in border b) *Anacardium occidentale* based agroforestry system*c)*Coffee based agroforestry system: *Grevillea robusta, Acrocarpus fraxinifolius, Erythrina variegata, Tectona grandis* d) Rubber plant based agroforestry sysytem: *Hevea brasiliensis* with *Grevillea robusta, Acrocarpus fraxinifolius, Erythrina variegata, Tectona grandis* e) Black plantatoions: *Tectona grandis, Santalum album, Acacia magium, Aquilaria malaccensis, Acaia auriculiformis* f) Monoculture of *Anacardium occidentale, Casuarina equisetifolia, Acacia catechu, Swietenia mahagoni, Vataria indica, Calophyllum inophyllum*g, g) *Soppina Betta* AFS: *Terminalia tomentosa, T. pniculata, Terminalia eliptica,Erythrina indica, Carea arborea, Artocarpus heterophyllus* h*)*Home gardens: *Hopea parviflora, Hopea wightiana, Ailanthus triphysa, artocarpus heterophyllu, artocarpus hirsutus, Cocos nucifera* a) Monoculture of *Anacardium occidentale, Casuarina equisetifolia, Acacia catechu, Swietenia mahagoni* b) Mixtures of*Anacardium occidentale,gardenia gummifera, Casuarina equisetifolia, Acacia catechu, Swietenia mahagoni, Thespesia populnea, Terminalia arjuna, Terminalia tomentosa,* *Hopea wightiana* c) Mangrove rehabilitation: *Rhizophora mucronata, Sonneratia caseolaris, Avicennia officinalis, Sonneratia alba, Bruguiera sexangula* and *Kandelia candel.* a) Monoculture of *Anacardium occidentale, Casuarina equisetifolia, Acacia catechu, Swietenia mahagoni* b) Mixtures of *Anacardium occidentale, Gardenia gummifera, Casuarina equisetifolia, Acacia catechu, Swietenia mahagoni, Thespesia populnea, Terminalia arjuna, Terminalia tomentosa,* *Hopea wightiana* c) Mangrove rehabilitation: *Rhizophora mucronata, Sonneratia caseolaris, Avicennia officinalis, Sonneratia alba,Bruguiera sexangula* and *Kandelia candel* d) Legume covers:: *Desmanthus virgatus, Cassia tora, Stylosanthes hamate, Mucuna pruriens, Mimosa pudica, Tephrosia purpurea* d) Preventing firewood collection from open scrub and protection against annual bushfire

5.0. SALIENT RECOMMENDATIONS

Though Goa is small by its size, covering only 0.11 % of the TGA of the country, it is affected by varied degree of land degradation problems. By virtue of its unique coastal and island ecosystem with long coast line, the presence of Western Ghats, lateritic soils and presence of important mineral ores poses, the State faces multiple challenges related to land degradation and soil and water conservation. This document examines the water induced soil erosion situation in the two districts of Goa and accordingly suggests the SWC measures. Some of the recommendations for enhancing productivity of natural resources, achieving climate resilience and averting land degradation are suggested as follows:

- Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* in Cashew is found suitable in reducing runoff, with maximum soil and water conservation efficiency and increase in carbon sequestration and microbial activity.

- Continuous contour trenching + vegetative barrier (*Vetiveria zizaniodes*) is effective in reducing runoff under Mango and improving soil fertility and moisture content in the post monsoon months.

- Circular trenching in coconut has resulted in reduction of runoff, increase in plant growth and reduction in nutrient loss. Continuous contour trenching with vegetative barrier in mango and circular trenching in coconut are suitable soil and water conservation measures for high rainfall regions of West coast of India to conserve the soil and water resources.

- An integrated farming system (IFS) with farm area of 0.8 ha with plantation crops: cashew (Bhaskara) + pineapple (Giant Kew), coconut (Benaulim) + pineapple (Giant Kew) + noni + tapioca, arecanut (Mangala) + banana (G-9), piggery, poultry and composting is recommended for upland situations of Goa. The IFS system fetches a net annual income of ₹1.18 lakh over the lone plantation crop system.

Though the West coast region of India receives abundant rainfall, the utility of the rain water is limited. Thus, low cost silpaulin lined water harvesting structures namely jalkunds of different capacities (large: 3500 m^3, medium: 1400 m^3; small: 300 m^3) are suggested as effective water harvesting structures for improving the water availability and productivity in the State. The smaller size jalkunds are strongly recommended which are more affordable and useful to the small and marginal category of farmers.

The mining activities being carried out in these fragile coastal ecosystems need to be scientifically planned, taking into consideration its impact on natural resources. The piling of wastes needs to be planned and suitable physical and biological measures for reclamation need to be attempted, for survival of vegetation. Mitigation of environmental hazards causing soil, water and air pollution need to be given priority and proper management of these natural resources through multiple uses needs to be explored and implemented as per site suitability. The appropriate policy interventions are required to restrict the improper land use conversion in the state.

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PHOTOGRAPHS














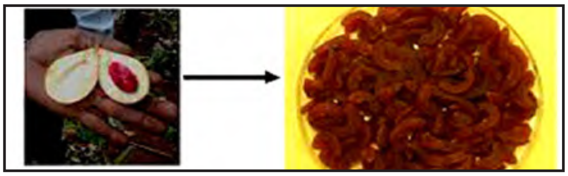



धन्वंतरी वाटिका
Dhanvantari Garden
















Potential Fishing Zone Advisory
Earth station
Satellite
Ocean
Medium
Fishing
Processing
Extension
Scientist
Maps and charts
Fish catch
Chlorophyll and SST distribution
Flow
Validation




Areal photograph of Goa state showing the land degradation due to mining

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