SOIL AND WATER CONSERVATION TREATMENT PLAN FOR RAMANAMALAI RESERVE FOREST

ICAR-INDIAN INSTITUTE OF SOIL AND WATER CONSERVATION

Research Centre, Ballari, Karnataka - 583 104.

CONSULTANCY PROJECT REPORT

SOIL AND WATER CONSERVATION TREATMENT PLAN FOR RAMANAMALAI RESERVE FOREST

भाकृअनुप- भारतीय मृदा एवं जल संरक्षण संस्थान

ICAR- Indian Institute of Soil & Water Conservation

Submitted By

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KARNATAKA FOREST DEPARTMENT

Submitted To

The Deputy Conservator of Forests,
Ballari Division, Karnataka Forest Department,
Govt. of Karnataka, Ballari - 583 104

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CITATION

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Ramanamalai Reserve Forest Hill, Ballari Dist.

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PREFACE

Mining affects natural ecosystems such as soil, water and forests; rehabilitation of affected forests often aims at restoring bio-diversity. Hence, eco-restoration of the mining affected reserve forest is an important step in protection of forest and mitigation of further degradation of the forest and its environment. In this connection, Karnataka Forest Department (KFD) has been proposing major rehabilitation projects in the mining affected reserve forests.

In this context, a consultancy project has been awarded to the ICAR-IISWC, Research Centre, Ballari by KFD for preparation of Soil and Water conservation (SWC) treatment plan for Ramanamalai Reserve Forest, Sandur Taluk, Ballari district of Karnataka. The scientifically designed treatment plan help KFD in effective implementation of site-specific soil and water conservation interventions to enhance the forest restoration and regeneration.

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CERTIFICATE

This is to certify that the Soil and Water Conservation aspects pertaining to ***RAMANAMALAI RESERVE FOREST*** *project has been extensively studied by ICAR - Indian Institute of Soil and Water Conservation, Research Centre, Ballari and suitable treatment measures are recommended in the report entitled* ***"SOIL AND WATER CONSERVATION TREATMENT PLAN FOR RAMANAMALAI RESERVE FOREST"*** *submitted to Forest Department, Ballari Circle.*

This is pertaining to 'DETAILED PROJECT REPORT OF ECO-RESTORATION OF MINING AFFECTED RAMANAMALAI RESERVE FOREST UNDER KMERC' to be submitted by Forest Department, Ballari Circle to Karnataka Mining Environment Restoration Corporation (KMERC), Govt. of Karnataka for the period of 2022-23 to 2031-32.

Ballari

December, 2022

APPROVED BY:

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ACRONYMS AND ABBREVIATIONS

Sl. No.	Acronym	Expansion
1	CN	Curve Number
2	EIA	Environmental Impact Assessment
3	GIS	Geographic Information System
4	RRF	Ramanamalai Reserve Forest
5	SCS	Soil Conservation Service
6	SCT	Staggered Contour Trench
7	USLE	Universal Soil Loss Equation

BACKGROUND

Mining creates immense pressure on the natural resources, resulting in degradation of land including forest ecosystem, water and air. In Ballari, more than 60% mines are located inside forest area. The forest areas are being mined not only for extraction of mineral ores but also used for dumping mine-residuals which lead to the forest degradation to a greater extent. Meanwhile recurring disturbances like fire, grazing, and wood harvesting, illegal encroachments and human-wild animal conflicts will deplete the forest resources further. The Environmental Impact Assessment (EIA) conducted by Nayak (2016) revealed that mining operation and associated activities had negative impact on physical environment of Ballari district. To dump mining residual 336.43 ha, 220.79 ha and 459.29 ha of forest area was utilized in 1991, 2001 and 2011 respectively. In 20 years (1991 to 2011), significant increase in silting of water bodies and fallow land area was reported within 10 km radius of iron ore mining and dumping of mining waste (Nayak, 2016). Further it is estimated from the forest survey of India report of 2011 to 2021 that the total forest cover in Ballari district was decreased by 4.5% in the last decade (Forest Survey of India, 2011 and 2021).

The Hon'ble Supreme Court of India took the cognizance of illegal extraction of iron ore in 2011 and directed State Government to rehabilitate and reclaim the mining leases which are under operation and inactive. The best way to avoid negative environmental impacts and to reinforce positive impacts is to prepare Environmental Impact Assessment (EIA) index maps at the lowest administrative unit like village or mandal and initiatives for proper planning, conservation and optimum utilization of natural resources (Rao and Reddy, 1991). Mining area of about 10913.00 ha allotted to 166 mine companies have been rehabilitated at the cost of Rs. 362.83 crores through engineering structures and biological measures for reclamation of biodiversity (Singh, 2021).

The aim of this consultancy project is to devise a catchment protection plan for sustainable restoration of mining affected reserve forests through engineering and biological measures to mitigate soil erosion and along with moisture conservation for accelerated re-vegetation.

STUDY AREA

The present study was conducted in a Ramanamalai Reserve Forest (RRF), which is located in Sandur taluk of Ballari district of Karnataka (Fig. 1). RRF falls under administrative control of Sandur North range in Ramadurga range of Ballari division. This reserve forest is located 60 km to the West of Ballari city and 16 km from Sandur. Ramanmalai or Ramnadurga is famous hill station with mean temperature in April and May is only 26.7° C. This hilltop is famous for industrial mining due to high quality of Iron and Manganese ores. RRF is spread over Ramnamalai hills which is limited by Hospet taluk in West, Yashwntnagar village in South, Narihall river in South-east, Sandur town and Dowlatpur village in Eastern side. Venkatagiri, Jaisingapur, Emmihatti, Sidddapur and Radhnagar villages are located on North-eastern side of RRF. Mining ores are located on hill top of Ramanamalai Reserve Forest, these mining ores are leased to M/s Ramagad Mineral and Mining Pvt. Ltd., M/S T.M.P.L, M/s Dharmapura Iron Ores, M/s S.A. Thawb and Co., and M/s Veerbhadrappa Sangappa and Co.

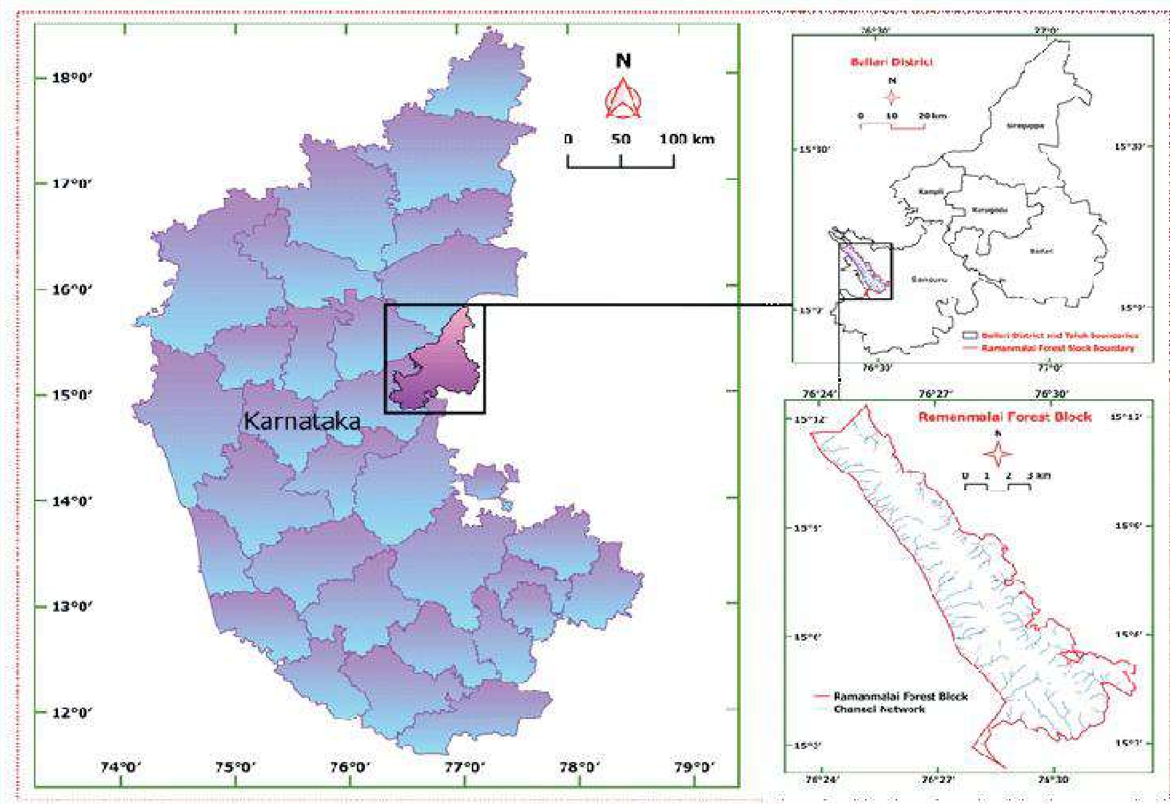

Fig. 1: Location map of Ramanamalai Reserve Forest

The total geographical area of RRF is 6892.6 ha and perimeter of area is 72.96 km. The geographical co-ordinates of forest location are between 15.0388 to 15.2065 North latitude and 76.3958 to 76.5350 East longitude. An elevation of catchment area is ranging from 543 to 1026 m above MSL. The location map of RRF depicted in Fig. 1 above. This reserve forest is categorized in Sandur North Range, Ballari division of Karnataka Forest Department.

The geographical area of district comes under national Agro-climatic region of Southern Plateau and Hill Region (Planning Commission) and in Northern Dry Zone of Karnataka. The 35 years (1984 to 2020) average annual rainfall of the locality is 659.5 mm. A long-term average (1901 to 1970) rainy days for Sandur area is 56 days.

The vegetation of Ballari territorial forest division varies from dry mixed deciduous type to thorny scrub types. Southern tropical moist deciduous teak bearing forest (3B/C1) is seen at higher elevations of Sandur. The forests in Sandur hills possess common tree elements like *Chloroxylon swietenia, Anogeissus latifolia, Terminalia tomentosa, Terminalia bellirica, Dalbergia paniculata, Boswallia serrata, Acacia chundra, Butea monosperma, Ficus racemosa, Gardenia gummifera, Syzigium cumini, Tamarindus indica* (Sharnappa and Venkatraju, 2014). This forest also contain some climbers, lianas like *Gymnema selvestre, Cissampleos pareira Tinosporo cordifolia, Bauhinia vahli* and a few parasites forms and epiphytes.

PROBLEMS IDENTIFIED

H Lack of dense vegetation (<2%) and majority of the hill exposed to direct erosion risk due to sparse vegetation (71.3%).

H Undulated terrain and steep slope (average slope of reserve forest is 27.6%), shallow soil depth and lack of SWC measures resulting high run-off causing severe erosion (38.25 t ha^{-1} $year^{-1}$).

H The hilltop of reserve forest has active mining quarries (315 ha) causing high runoff, stream bank erosion and heavy downstream siltation, particularly on eastern hill slopes.

H Blasting, excavation, movement of heavy machineries, mining waste dumping in forest land, vehicle traffic on forest roads *etc.* causing air pollution, dust deposition, mass erosion, and water pollution leading to forest degradation and biodiversity loss.

OBJECTIVES OF THE STUDY

C To characterize physiography of Ramanamalai Reserve Forest catchment using GIS environment to estimate soil erosion rate and potential runoff volume.

C To identify potential erosion risk areas and preparation of site-specific soil and water conservation treatment plan to mitigate mass erosion.

C To suggest plan for *in-situ* moisture conservation and rehabilitation of mine spoil area in reserve forest to support regeneration of vegetation.

C To create benchmark data of soil physical and chemical parameters for subsequent monitoring and evaluation.

METHODOLOGY

The following methodology was adopted for assessment of potential soil and water conservation sites through estimation of soil erosion and run-off areas in the reserve forest and various other parameters as discussed in the chapter.

Benchmark data of soil survey

To create the Bench mark data of soil physical and chemical status of the reserve forest, thirty one systematically collected soil samples from upper, middle and lower reach of RRF were analysed and eight important soil variables were recorded (Table 1). Further, the data was used for assessment of vulnerable sites for run-off and soil loss calculation. This data may be treated as benchmark soil parameters for future impact assessment through monitoring and evaluation of project.

Table 1: Soil physical and chemical parameters studied in RRF

Sl.No	Indicator List	Unit	Methodology	Reference
1.	Soil Organic Carbon	%	Chromic acid wet oxidation method	Walkley and Black, 1934
2.	Available Nitrogen	kg ha^{-1}	Alkaline permanganate method	Subbiah and Asija, 1956
3.	Soil Electrical conductivity (EC)	dS m^{-1}	1: 2.5 soil water suspension	Gupta and Dakshinamoorthy, (1980)
4.	Soil pH	-	1: 2.5 soil water suspension	Gupta and Dakshinamoorthy, (1980)
5.	Bulk density	g cm^{-3}	Cylinder method	Gupta and Dakshinamoorthy, (1980)
6.	Water holding capacity	%	Keen and Raczkowski method	Keen and Raczkowski, 1921
7.	Soil texture	-	International pipette method	Piper, 1966
8.	Volume expansion	%	Keen and Raczkowski method	Keen and Raczkowski, 1921

Database and thematic maps

The study involves use of GIS for preparation of various thematic maps and creation of database through generation of land use map, soil map, contour map, elevation and slope map, stream order, drainage density network map of the reserve forest (Fig. 2). The database for the preparation of various thematic maps was largely extracted from the digital elevation models provided by SRTM and Carto DEM (Version-3R1). The details of overview of data used for the study are presented in Table 2 below.

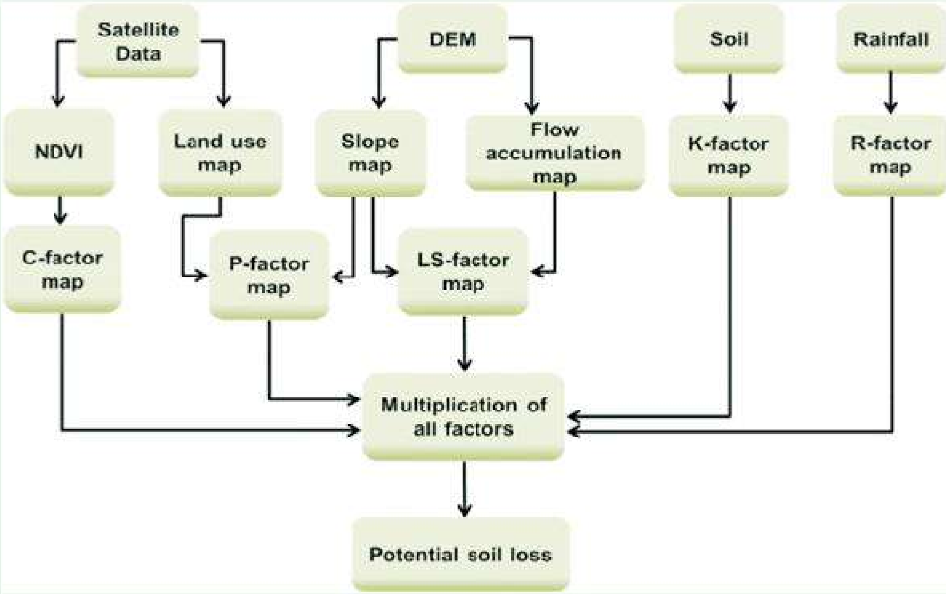

Fig. 2: Flowchart to estimate potential soil loss in GIS environment

Table 2: Overview of data used for study

Sl. No.	Data	Sensor	Source	Usage	Time
1	NASA SRTM-DEM (30 m)	Interferometric SAR radar	https://earthexplorer.usgs.gov/	Digital Elevation Model (DEM) creation	2019
2	Carto DEM (Version 3R1)	Stereoscopic image generating panchromatic cameras	https://bhuvan-app3.nrsc.gov.in/	2.5 m spatial resolution Digital Elevation Model (DEM)	2015
3	Normalized Difference Vegetation Index (NDVI)	Landsat 8 OLI	https://earthexplorer.usgs.gov/	NDVI Map creation with red and NIR bands of 30m resolution	2022
4	Rainfall data	Gridded data (0.25°×0.25°)	https://www.imdpune.gov.in	Rainfall information	1986 to 2020
5	Soil Map	Field data and Lab analysis	ICAR-IISWC, RC, Ballari	Soil data	2022

Runoff yield estimation

The US Soil Conservation Service Curve Number (SCS-CN) method (SCS, 1972) as given in Eq. (i) and (ii) was used for assessing the runoff yield in RRF. This method involves relationship between land use, land treatment, hydrological condition, hydrologic soil group, antecedent soil moisture condition and curve number of the drainage basin. It is widely and efficiently used for planning the structures aimed at water storage and erosion control. The curve number (CN) is the watershed coefficient which represents the runoff potential of the land cover soil complex.

$$Q = (P - 0.2S)^2 / (P + 0.8S) \quad \text{.. (i)}$$

Where,

Q= Surface runoff in mm, P= Rainfall in mm, S= Storage capacity in mm,

$$S = (25400 / CN) - 254 \quad \text{.. (ii)}$$

CN = Value of curve number (CN) depending on land use conditions and hydrologic soil groups.

Hydrological soil group (HSG) of RRF falls under group C and A varying from moderately high runoff potential to low runoff potential. Hence average condition of hydrological soil group 'B' is considered for runoff curve number. Antecedent Moisture Condition-II (AMC-II) was considered here for runoff estimation. RRF comes under degraded scrub with average condition of hydrological soil group 'B' and thus, runoff curve number is 44 has been taken here as per the criteria defined by Tripathi (1999). The Annual runoff yield was determined using the average annual rainfall.

Estimation of Soil loss

The soil erosion rate from RRF area was estimated using Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) as given in Eq. (iii). The USLE was derived empirically from approximately 10,000 plot-years of data obtained from field experiments under natural rainfall (Wischmeier and Smith, 1978) and may be used to calculate erosion at any point in a watershed that experiences net erosion. The equation has become a useful tool for planners to keep soil erosion within permissible limits of soil loss tolerance by managing slope length, terrace spacing and cropping practices (Singh *et al.* 1981). Using GIS, predicted soil loss will be classified into following soil erosion risk classes viz., very low (0–5 t ha^{-1} yr^{-1}), low (5–10 t ha^{-1} yr^{-1}), moderate (10–15 t ha^{-1} yr^{-1}), moderately high (15– 20 t ha^{-1} yr^{-1}), high (20–40 t ha^{-1} yr^{-1}) and very high (>40 t ha^{-1} yr^{-1}) as per Singh *et al.* (1992).

$$A = R\,K\,L\,S\,C\,P \quad \text{.. (iii)}$$

Where, A is computed soil loss (t ha^{-1} yr^{-1}), R is the rainfall-runoff erosivity factor, K is a soil erodibility factor, L is the slope length factor, S is the slope steepness (gradient) factor, C is a cover management factor, and P is a supporting conservation practices factor.

Meanwhile, from the eq. (iii), the rainfall erosivity (R) factor was derived using the relationship between rainfall erosivity index and annual rainfall, developed by Babu *et al.* (2004) with the data available from 123 meteorological observatories in India. The formula as below.

$$Y = 81.5 + 0.380X \text{ .... (iv)}$$

Where, Y is the average annual erosion index ($t\ ha^{-1} cm^{-1}$) and X is the average annual rainfall (mm). For the present study area the average annual rainfall data of surrounding RRF micro-watersheds is 659.5 mm which is taken from IMD gridded data and is used in the calculation of R-factor.

Soil erodibility (K) factor was estimated by an empirical equation developed by Wischmeier *et al.* (1971) and an attribute table was prepared for different soil types using the following relation:

$$100K = 2.1 \times 10^{-4} (12\ OM)\ M^{1.14} + 3.25 (S2) + 2.5 (P3) \text{ ... (v)}$$

Where, OM = organic matter (%), M = (% silt + % very fine sand) x (100 - % clay), S = soil structural code, P = profile permeability class.

The LS factor expresses the effect of topography (hill slope length and steepness) on soil erosion. L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 22.04 m of slope length under identical conditions. The slope steepness factor (S), is the ratio of soil loss from the field slope gradient to that from a 9% slope under otherwise identical conditions. The LS-factor was determined from the equation used by Jain *et al.* (2010) for the calculation of the S (slope steepness) and L (slope length) factors:

$$L = 1.4 (AS/22.13)^{0.4} \text{ .... (vi) and } S = (\sin ? / 0.0896)^{1.3} \text{ ....(vii)}$$

Where, AS : catchment area (m^2) and ?: slope angle in degrees.

The C value was calculated using the equation (viii) developed by De Jong (1994) for the study area with similar land use of degraded forest. As such negligible mechanical or biological measures are adopted in forest area; a conservation practice (P) factor value of 1.0 is assigned to degraded forest land and lands with scrub/rock outcrop.

$$C = 0.431 - 0.805\ NDVI \text{ .... (viii)}$$

Proposed treatment map

Using land use, land cover, soil type, run-off potential, soil loss, catchment area, drainage area and density, the vulnerable sites of soil erosion were identified and potential soil and moisture conservation treatment map was generated using GIS. Further, the plan was used for ground truthing and based on the visible observations and scientific calculations, possibilities of construction of cost-effective site-specific soil and water conservation interventions were identified and recommended for implementation.

RESULTS AND DISCUSSION

Land use and land cover

The land use gives the information of land cover of the area including forest, urban, agriculture, barren and water body. The NDVI values derived from LANDSAT images were used to derive land use map (Fig.3) of RRF. Total area under RRF is 6892 ha. The most of forest land is covered with sparse vegetation (71.33%), while 1.34% area is under dense vegetation. Built-up area or mining quarries and barren land around them contributes 315 ha (4.6%) of total geographical area of forest. The shrubs and grassland occupy around 22% area of reserve forest (Fig. 4). The vegetation is confined mostly to the chains of hillocks favoring rich growth on hill slopes along the streams or *nala.* Recent afforestation activities taken-up is reserve forest was visible during ground-truthing survey. The hill tops are barren with few shrubs, trees and grasses therefore this part is subjected to high wind erosion.

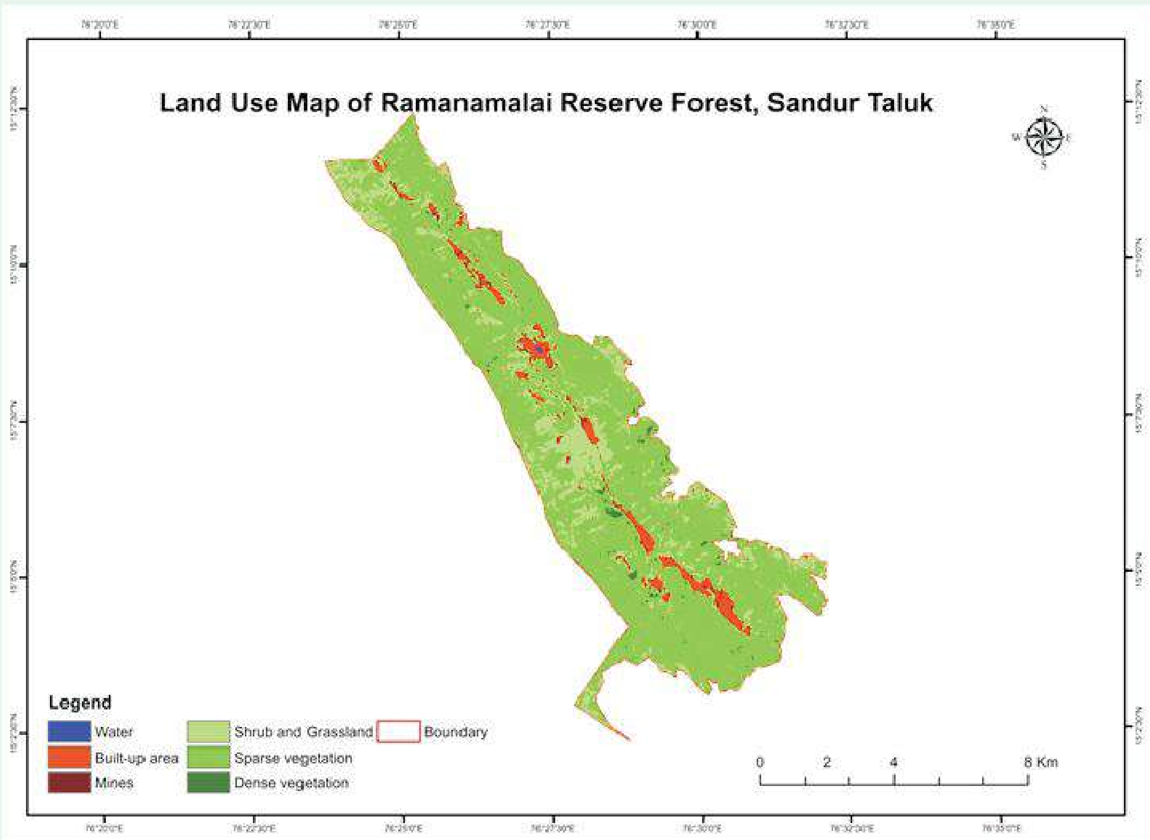

Fig. 3: Land use map of Ramanamalai Reserve Forest, Ballari

Fig. 4: Shrubs and grassland in Ramanamalai Reserve Forest

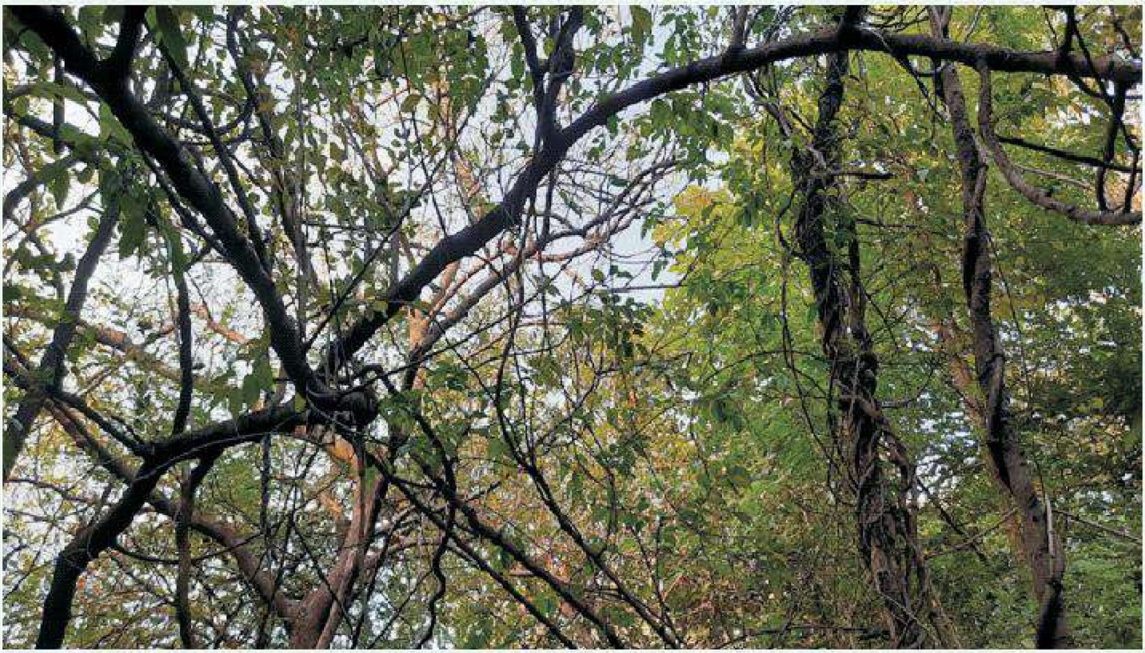

Fig. 5 Canopy cover at Western foothills in Ramanamalai Reserve Forest

Geomorphology and lithology

The geomorphology of Ramanamalai Reserve Forest is spread over moderately dissected structural hills and valleyes. Active mining quarries and mine-waste dump is also reported on hilltops. Metamorphosed volcanic rocks of Ramanamalai formation are composed mainly of Banded ferruginous chert, Banded iron formation, Biotite Gneiss, Dolomitic limestone, Meta-Gabbro, Laterite, Mandaniferrous phyllite, Meta-Basalt, and Quartzite (GSI, 2022). Sandur hill ranges are as old as 2.2 billion years and belongs to Precambrian rocks.

Soil characteristics

The soil map of study areas would reveal major soil classes. Soil maps used to know soil physical and chemical properties like texture, imperviousness, infiltration, porosity, fertility status etc. Systematic soil sampling in RRF and laboratory analysis of these soil samples revealed following soil erodibility (K) map (Fig.6) and soil physico-chemical properties (Table 3 and Table 4). Soil erodibility (K) is the intrinsic susceptibility of a soil to erosion by runoff and raindrop impact. Soil texture is the principal factor affecting 'K' factor, but soil structure, organic matter content, and permeability also contributes. The range for K value was 0.13 to 0.61 in RRF, the higher class (0.49 to 0.61) in and around central ridge. Majority of forest area had sandy clay loam texture and Gravel content of the soil varied from 58.53 to 88.49 %. An average bulk density (g cm^{-3}), porosity (%), water holding capacity (%) and volume expansion (%) of RRF soils is 1.46, 35.41, 39.09 and 19.05 respectively. Mean pH and EC values of 6.41 and 0.12 dS m^{-1} , respectively signifies 'neutral' soil reaction status. Average soil organic carbon was 0.90%. It was observed that soils of Ramanamalai Reserve Forest has low to high content of available nitrogen with a mean of 538.4 kg ha^{-1} and medium to high content of available phosphorous with a mean of 64.80 kg ha^{-1}.Fine root dynamics, nitrogen fixation by tree and grass species along with forest leaf litter fall is responsible better soil organic carbon.

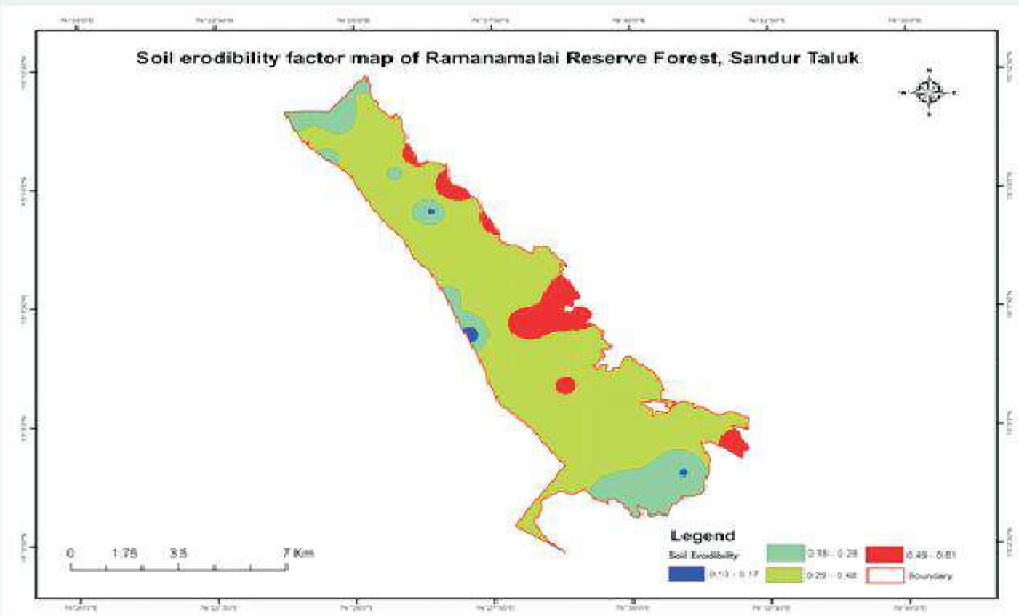

Fig. 6: Soil erodibility factor map of Ramanamalai reserve forest

Table 3: Soil physical properties in Ramanamalai Reserve Forest

Sl. No.	Texture	Clay (%)	Silt (%)	Sand (%)	Bulk density (g cm^{-3})	Porosity (%)	Water holding capacity (%)	Volume expansion (%)
1	Sandy loam	12.8	22.0	65.2	1.29	37.61	43.11	17.84
2	Sandy clay loam	28.8	20.0	51.2	1.37	33.70	47.31	30.99
3	Sandy clay loam	24.8	18.0	57.2	1.41	37.25	40.23	19.66
4	Clay loam	32.8	28.0	39.2	1.34	31.98	42.53	24.82
5	Sandy clay loam	20.8	18.0	61.2	1.17	46.87	52.41	14.20
6	Sandy loam	18.8	12.0	69.2	1.13	38.91	51.47	19.32
7	Sandy clay loam	24.8	22.0	53.2	1.19	33.65	46.73	22.19
8	Sandy clay loam	26.8	16.0	57.2	1.10	37.72	47.11	14.30
9	Sandy clay loam	32.8	14.0	53.2	1.29	32.04	49.87	32.12
10	Sandy clay loam	22.8	22.0	55.2	1.35	29.25	34.05	16.71
11	Sandy loam	18.8	10.0	71.2	1.36	26.98	36.07	22.19
12	Sandy clay loam	28.8	18.0	53.2	1.75	31.43	26.87	15.60
13	Sandy clay loam	20.8	14.0	65.2	1.71	17.87	21.03	18.17
14	Sandy clay loam	30.8	24.0	45.2	1.16	29.96	43.83	21.09
15	Sandy loam	18.8	12.0	69.2	1.42	27.36	34.34	21.36
16	Loam	22.8	32.0	45.2	1.46	44.00	37.18	10.17
17	Sandy loam	10.8	12.0	77.2	2.08	40.49	24.72	10.88
18	Sandy clay loam	24.8	18.0	57.2	1.57	44.26	33.37	8.22
19	Sandy clay loam	22.8	14.0	63.2	1.82	39.25	29.06	13.62
20	Sandy clay loam	32.8	18.0	49.2	1.36	45.26	41.69	11.50
21	Sandy loam	14.8	10.0	75.2	2.33	28.20	17.45	12.48
22	Sandy loam	18.8	10.0	71.2	1.45	37.28	39.32	19.89
23	Sandy clay loam	24.8	18.0	57.2	1.31	35.25	40.69	18.00
24	Sandy clay loam	22.8	16.0	61.2	1.41	35.84	43.93	26.18
25	Sandy clay loam	20.8	10.0	69.2	1.34	38.22	43.29	19.86
26	Sandy clay loam	24.8	8.0	67.2	1.22	34.93	42.54	17.14
27	Sandy loam	14.8	8.0	77.2	2.30	31.05	22.32	20.23
28	Sandy clay loam	20.8	10.0	69.2	1.18	37.27	51.14	23.19
29	Sandy clay loam	24.8	10.0	65.2	1.27	35.32	47.32	24.82
30	Sandy clay loam	18.8	10.0	71.2	1.37	32.46	37.61	19.12
31	Sandy loam	16.8	10.0	73.2	1.64	46.19	43.19	24.80
Average		22.6	15.6	61.8	1.46	35.41	39.09	19.05

Table 4: Soil chemical properties in Ramanamalai Reserve Forest

S. No	pH	EC	OC (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorous (kg ha^{-1})
1	5.69	0.06	0.45	451.6	83.7
2	6.61	0.16	1.21	689.9	91.0
3	6.63	0.14	1.61	658.6	47.4
4	6.59	0.09	1.38	520.6	49.1
5	6.92	0.16	1.58	802.8	40.7
6	6.98	0.18	1.72	733.8	49.1
7	5.98	0.10	1.67	777.7	42.3
8	6.75	0.15	1.64	733.8	83.7
9	6.45	0.07	0.79	564.5	40.7
10	7.28	0.19	1.45	639.7	45.7
11	6.89	0.07	0.29	558.2	50.9
12	6.62	0.11	0.62	257.2	52.7
13	6.46	0.09	1.69	934.5	50.9
14	5.86	0.09	1.44	627.2	145.1
15	5.76	0.07	1.59	470.4	54.5
16	6.70	0.07	0.73	539.4	116.5
17	6.42	0.34	0.20	181.9	74.6
18	6.44	0.17	0.21	238.3	58.2
19	5.10	0.14	0.20	181.9	91.0
20	7.87	0.58	0.12	81.5	98.9
21	8.02	0.08	0.23	106.6	86.1
22	6.34	0.13	0.68	840.4	74.6
23	5.86	0.07	0.45	439.0	58.2
24	6.36	0.08	1.44	533.1	54.5
25	6.42	0.10	0.65	934.5	15.9
26	6.09	0.12	0.31	583.3	52.7
27	5.93	0.03	0.06	106.6	74.6
28	6.08	0.06	0.85	721.3	37.5
29	6.30	0.07	0.74	570.8	50.9
30	5.20	0.05	0.67	439.0	104.5
31	5.98	0.05	1.14	771.5	32.8
Average	6.41	0.12	0.90	538.4	64.8

Hydrological soil groups

Soils can be classified into four classes A, B, C and D based on soil texture and soil water infiltration rate (USDA and NRCS, 2007). The group 'A' soils have low runoff potential due to high water infiltration rate (>25mm hr^{-1}) even when thoroughly weighted and consisting chiefly of deep, well to excessively drained sands or gravels. Group 'B' as moderately low runoff potential means soils having moderate infiltration rates (12.5 to 25 mm hr^{-1}) when thoroughly weighted.

This soil consists chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse texture. Group 'C' as moderately high runoff potential, which means soils having a low infiltration rate (2.5 to 12.5 mm hr^{-1}) when thoroughly wetted and consisting chiefly or moderately deep to deep, moderately well to well-drained soil with moderately fine to moderately coarse texture. Group 'D' soils as high runoff potential which covers soils having very low infiltration rates (<2.5 mm hr^{-1}) when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with permanent high-water table, soils with a clay pan, or clay layer at or near the surface, and shallow soils over nearly impervious material (Subramanya, 2008; Kadam et *al.*, 2017; Kolekar *et al.,* 2017). Soils from Ramanamalai Reserve Forest falls under hydrological group C and A, indicating moderately high runoff and moderately low runoff potential, respectively (Table 5).

Table 5: Hydrological soil groups in Ramanamalai Reserve Forest

Soil texture class	Area (ha)	Area (%)	Hydrological soil group
Sandy clay loam	3817	55.38	C
Sandy loam	1622	23.53	A
Clay loam	683	9.91	D
Loam	770	11.17	B

Slope map

The slope map provides information on the degree of steepness of the area, which helps to identify the runoff generated in that area. The slope of prevailing land also governs suitability of engineering measures, structural design, vertical and horizontal interval of structures. Breaking the slope length reduces runoff velocity and soil erosion thereby. The slope classes 'nearly level' and 'gentle' are considered more suitable for rainwater harvesting (Kolekar *et al.,* 2017). About 15% area of RRF falls under very-very steep slope and an average slope of entire area is 27.6%. The slope of RRF was divided into following nine classes and area (total and percent) under particular slope class is given here (Table 6 and Fig. 7). About 68% area of reserve forest is on steep slope signifying high soil erosion and runoff potential.

Table 6: Slope distribution in Ramanamalai Reserve Forest

Slope (%)	Description	Area (ha)	% of TGA
0 to 1	Nearly level	29.26	0.42
1 to 3	Very gently sloping	206.10	2.99
3 to 5	Gently sloping	344.02	4.99
5 to 10	Moderately sloping	905.76	13.14
10 to 15	Strongly sloping	738.39	10.71
15 to 25	Moderately steep to steep	1326.13	19.24
25 to 33	Steep	898.79	13.04
33 to 50	Very steep	1414.64	20.53
>50	Very-very steep	1028.73	14.93

Elevation and contour map

The topography of the study area shows relief and relatively strong slope (Fig. 8). The elevation of RRF is ranging from 543 m at foot hills to 1026 m in central ridge. The basin relief is 483 m. The contour intervals with 20 m are also depicted in fig. 8.

Drainage density map

Drainage density is defined as the ratio of total length of all streams to the area of the basin or watershed. It represents the closeness of the spacing of channels. It is expressed as km km^{-2}. It is one of the important indications of the linear scale of landform elements in stream eroded topography and it varies inversely with the length of the overland flow. In the areas of higher drainage density, the infiltration is less and runoff is more. Drainage density is collectively influenced by climate, topography, soil infiltration capacity, vegetation, and geology. It is mathematically expressed as:

$$Drainage\ density\ (D) = \frac{Cumulative\ length\ of\ all\ streams\ segment}{Area\ of\ wtershed}$$

There are five classes of drainage density with the following value ranges (km km^{-2}), i.e., very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8), and very fine (>8) (Chandrashekar et al., 2015). However, based on some definitions about D classes, it can be highlighted that there are two main classes, low/coarse and high/fine class. Unfortunately, there are no value ranges for both two main classes of drainage density. Low class of 'D' shows a poorly drained basin with a slow hydrologic response. Surface runoff is not rapidly removed from the watershed making it highly susceptible to flooding, gully erosion etc. (Rai *et al.*, 2017).

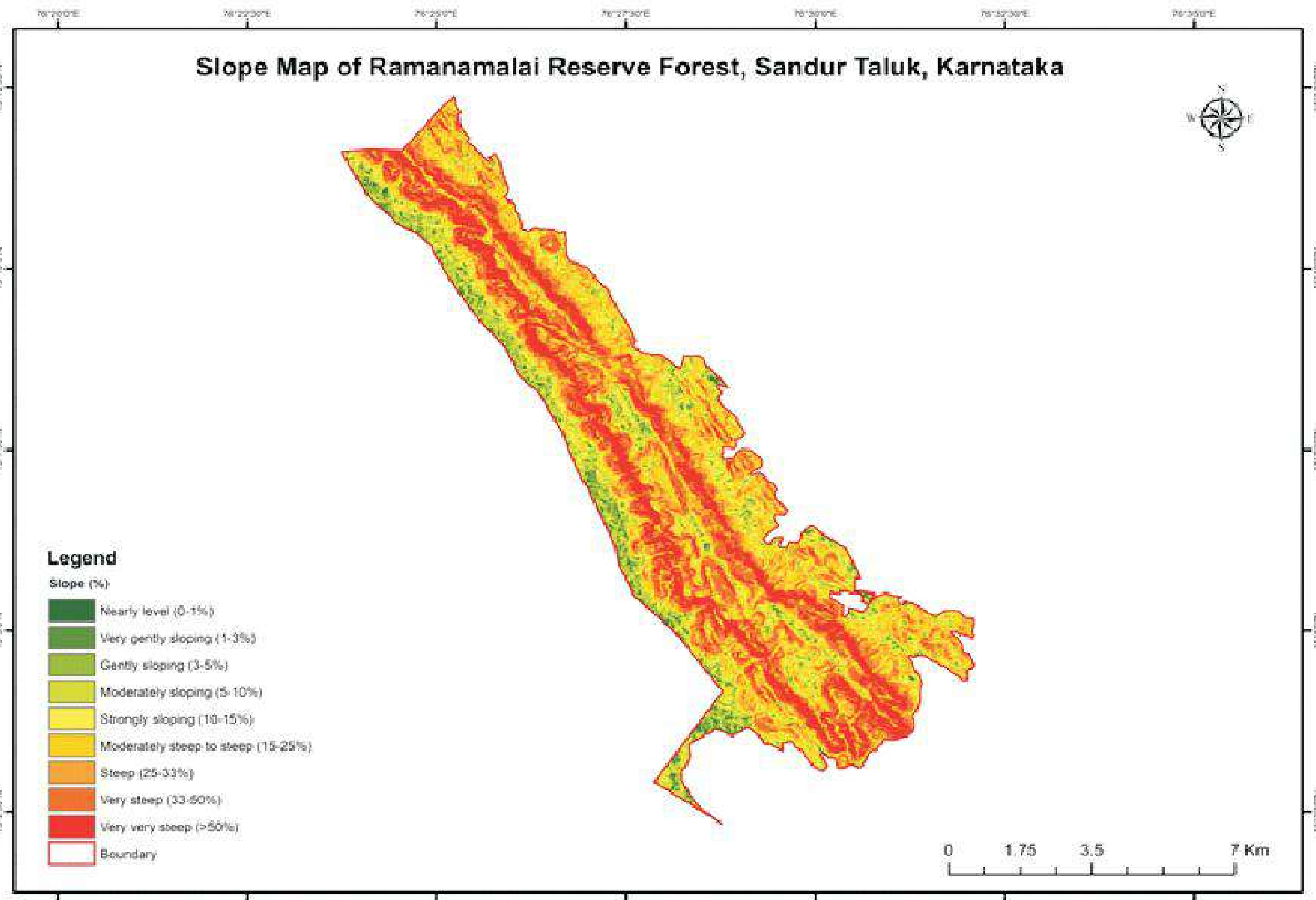

Fig. 7 : Slope map of Ramanamalai Reserve Forest

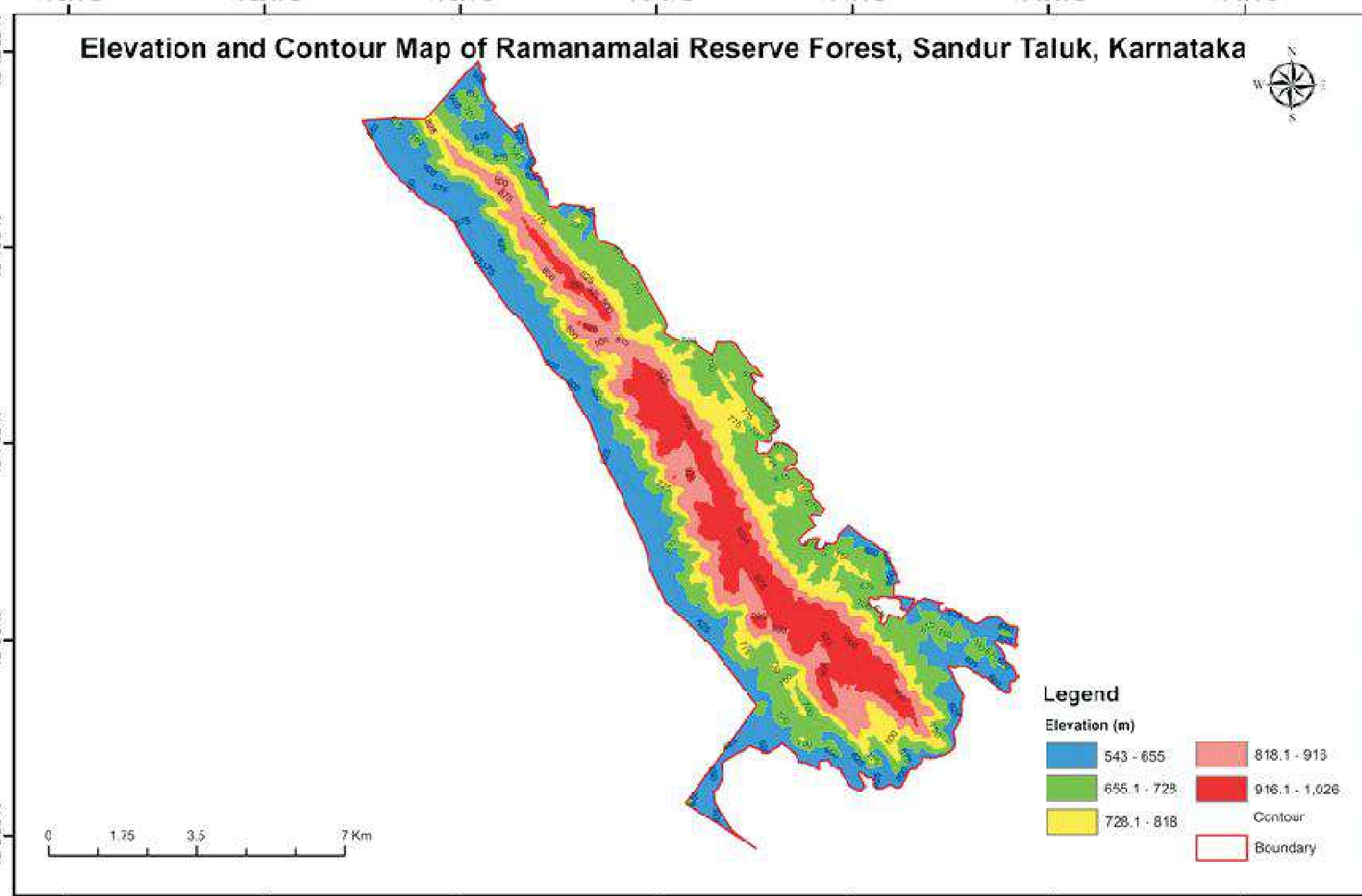

Fig. 8 : Elevation and contour map of Ramanamalai Reserve Forest

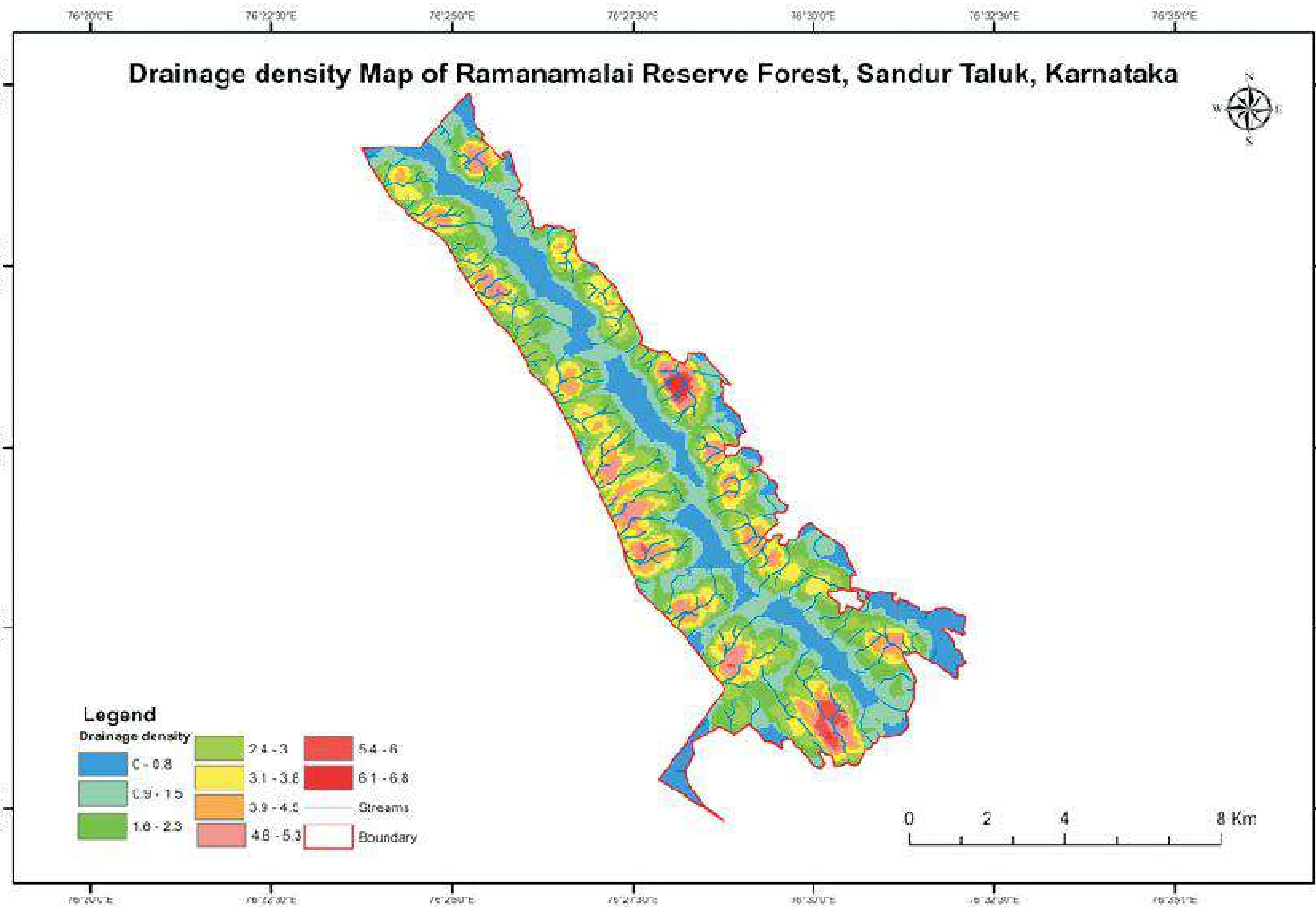

Fig. 9: Drainage density map of Ramanamalai Reserve Forest

Total stream length in Ramanamalai reserve forest is 104.4 km. This catchment has many outlets (>40), mostly arising from second or third order streams. It has 201 primary, 52 secondary and only 5 third order of streams. The length of third order stream is only 2.73 km. RRF has average slope of 27.6% and 43 outlets with stream length (104 km) from very large catchment area of 69 km^2. It has 'very coarse' drainage density of 1.51 km km^{-2}. Very fine drainage density (>8) was reported along second and third order streams of catchment (Fig. 9). Average drainage density of 1.51 km km^{-2} indicates lower runoff generation potential considering vegetation, rainfall and slope factor. Drainage texture is another parameter to decide vulnerability of watershed to water erosion. Drainage texture is arrived by dividing total number streams in watershed by perimeter of watershed. In case of RRF, drainage texture is also as low as 3.53 km^{-1}.

Runoff estimation for Ramanamalai Reserve Forest

Using the US Soil Conservation Service Curve Number method (SCS-CN) presented in eq. i and ii the runoff yield in Ramanamalai reserve forest was estimated as below.

From equation (i), total annual runoff yield (Q) is calculated as 385.40 mm (58.43% of rainfall).

Again applying equation (ii), potential maximum retention (S) is determined as 323.27 mm.

Total annual runoff yield in volume = Area of the catchment × runoff depth

$$= 1132.5 \times 10000 \times (385.40/1000) = 2656408.04\ m^3$$

Soil loss calculation for Ramanamalai Reserve Forest

Using the formulas as described in methodology, the value of R, K, L S, C and P factors obtained are as below.

R= 332.11

K=0.608

L=553.98

S= 4.11^0 (Avg. slope)

C= 0.573, P= 1.0

A= 263689.62 tons (38.25 t ha^{-1} yr^{-1} for average sloping condition)

PROPOSED SOIL AND WATER CONSERVATION TREATMENT PLAN

Based on the land cover, soil texture, slope steepness, stream density, stream orders, length of flow and drainage map, the runoff potential zones are identified and suitable sites for soil and water conservation structures are selected in GIS environment. Various measures/structures like staggered contour trenching, loose boulder checks, gabion checks, check dams and nala bunds are proposed as treatment measures (Table 8, 9, 10 and 11). Again, by visiting the reserve forest sites, ground truthing was done for suitable sites of proposed soil and water conservation structures across the existing streams/nalas. The proposed treatment plan is given in enclosed map (Fig. 10).The following specifications were adopted for identifying potential site-specific SWC sites.

Table 7. Criteria adopted for selection of site-specific potential SWC measures in RRF.

Sl. No.	Structure	Slope (%)	Location	Stream	Catchment (ha)
1	Loose boulder checks (Gully checks)	≤ 45	Up stream	I or II	1-10
2	Gabion checks	≤ 35	Mid stream/ Down stream	II	10-100
3	Check dams	≤ 25	Down stream	II to III	40-180
4	Nala bunds with spill way	≤ 15	Down stream	II or III	90-250
5	Staggered Contour Trench (SCT)	33-50	Upper reach/middle reach/lower reach	-	-

Note : Specifications are suitable to Ramanamalai Reserve Forest considering actual drainage, catchment area and existing slope percentage. .

PROPOSED SOIL AND WATER CONSERVATION PLAN

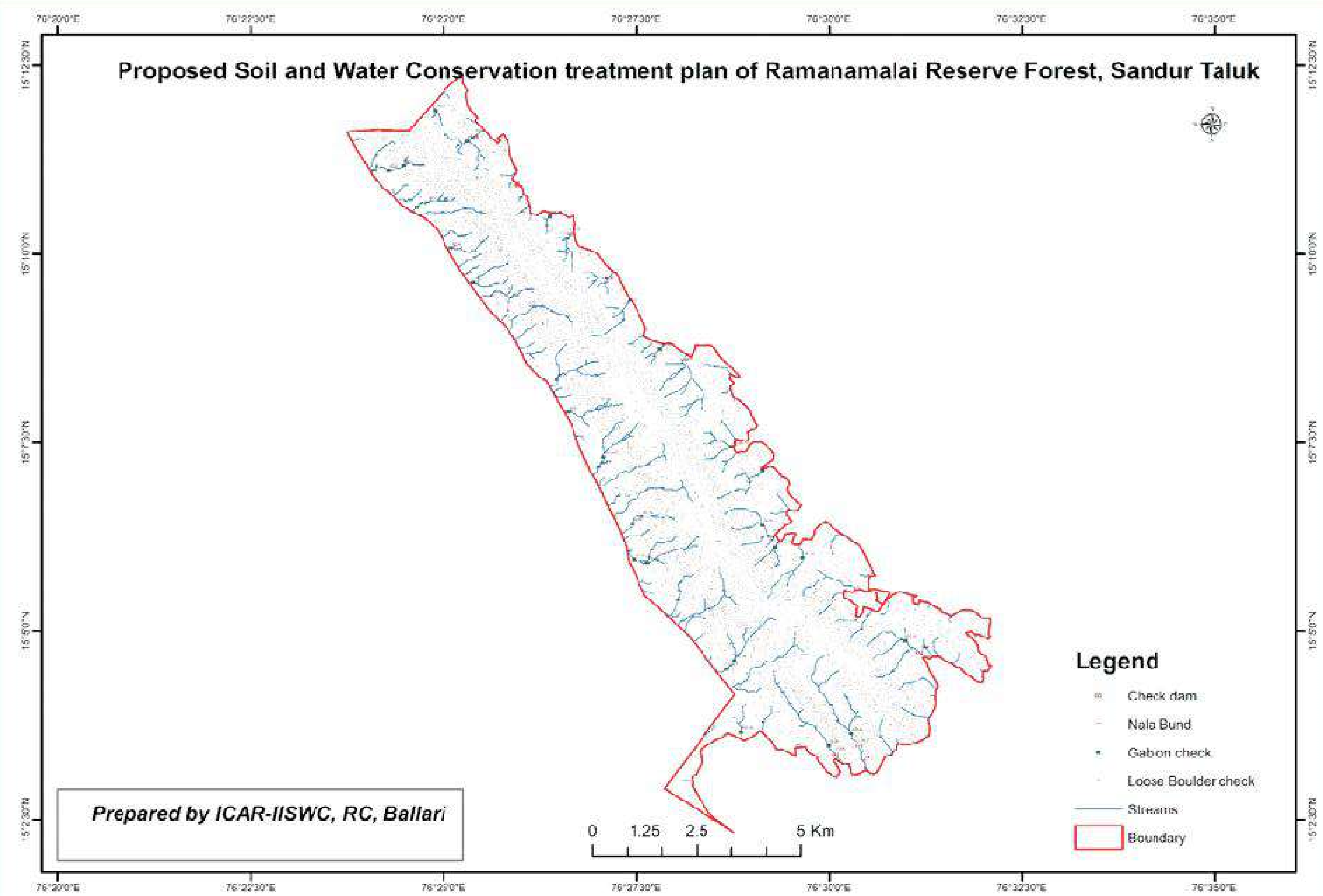

Fig. 10 Proposed Soil and Water Conservation Treatment Map and Plan

Table 8. Details of proposed loose boulder checks and their geo-coordinates

Sl. No	Loose boulder checks	Geo-coordinates	
		Latitude (N)	Longitude (E)
1	LBC-1	15.06282	76.48052
2	LBC-2	15.06344	76.48572
3	LBC-3	15.06031	76.51102
4	LBC-4	15.05786	76.51279
5	LBC-5	15.07146	76.48898
6	LBC-6	15.06965	76.49013
7	LBC-7	15.06701	76.49168
8	LBC-8	15.0638	76.49384
9	LBC-9	15.06121	76.49758
10	LBC-10	15.07404	76.49653
11	LBC-11	15.07644	76.49723
12	LBC-12	15.07251	76.4996
13	LBC-13	15.07025	76.49777
14	LBC-14	15.06681	76.50046
15	LBC-15	15.06376	76.50198
16	LBC-16	15.06375	76.50518
17	LBC-17	15.06595	76.50503
18	LBC-18	15.06485	76.51833
19	LBC-19	15.07217	76.51848
20	LBC-20	15.07288	76.52054
21	LBC-21	15.07912	76.51289
22	LBC-22	15.07475	76.51385
23	LBC-23	15.07898	76.51712
24	LBC-24	15.08176	76.50982
25	LBC-25	15.08313	76.51274
26	LBC-26	15.07955	76.52269
27	LBC-27	15.07978	76.52089
28	LBC-28	15.08383	76.507
29	LBC-29	15.08702	76.50867
30	LBC-30	15.09086	76.50097
31	LBC-31	15.09328	76.49658
32	LBC-32	15.09501	76.50035
33	LBC-33	15.09337	76.50432
34	LBC-34	15.10318	76.50069
35	LBC-35	15.09717	76.49294
36	LBC-36	15.09569	76.49002
37	LBC-37	15.09309	76.48787

38	LBC-38	15.09943	76.48565
39	LBC-39	15.10072	76.48755
40	LBC-40	15.09815	76.48902
41	LBC-41	15.10282	76.48442
42	LBC-42	15.10383	76.48547
43	LBC-43	15.10333	76.4878
44	LBC-44	15.10589	76.47953
45	LBC-45	15.10565	76.4807
46	LBC-46	15.10632	76.48251
47	LBC-47	15.11033	76.48079
48	LBC-48	15.10899	76.48477
49	LBC-49	15.11459	76.48019
50	LBC-50	15.1165	76.48278
51	LBC-51	15.11804	76.48165
52	LBC-52	15.1177	76.48431
53	LBC-53	15.12115	76.47836
54	LBC-54	15.12161	76.47532
55	LBC-55	15.12316	76.47674
56	LBC-56	15.12617	76.47531
57	LBC-57	15.12499	76.47464
58	LBC-58	15.12524	76.47682
59	LBC-59	15.12776	76.47841
60	LBC-60	15.13196	76.46945
61	LBC-61	15.13441	76.47155
62	LBC-62	15.13494	76.47287
63	LBC-63	15.1362	76.46701
64	LBC-64	15.13826	76.46950
65	LBC-65	15.13893	76.46554
66	LBC-66	15.14107	76.46803
67	LBC-67	15.14238	76.46777
68	LBC-68	15.13789	76.47136
69	LBC-69	15.14046	76.46999
70	LBC-70	15.14377	76.46233
71	LBC-71	15.14442	76.46174
72	LBC-72	15.14587	76.46060
73	LBC-73	15.15196	76.45537
74	LBC-74	15.15331	76.45553
75	LBC-75	15.15465	76.45399
76	LBC-76	15.16181	76.44955

77	LBC-77	15.1615	76.44908
78	LBC-78	15.16052	76.44929
79	LBC-79	15.16069	76.45191
80	LBC-80	15.1663	76.44427
81	LBC-81	15.16657	76.44314
82	LBC-82	15.16733	76.44233
83	LBC-83	15.17011	76.44323
84	LBC-84	15.17273	76.43893
85	LBC-85	15.17451	76.43876
86	LBC-86	15.17623	76.43390
87	LBC-87	15.17897	76.43346
88	LBC-88	15.18215	76.43121
89	LBC-89	15.18615	76.42407
90	LBC-90	15.1874	76.42414
91	LBC-91	15.19039	76.42354
92	LBC-92	15.19213	76.41797
93	LBC-93	15.19153	76.42024
94	LBC-94	15.19046	76.41971
95	LBC-95	15.19602	76.42271
96	LBC-96	15.20192	76.41741
97	LBC-97	15.1966	76.41583
98	LBC-98	15.19753	76.41479
99	LBC-99	15.19199	76.39810
100	LBC-100	15.19053	76.40424
101	LBC-101	15.18872	76.40204
102	LBC-102	15.18682	76.40115
103	LBC-103	15.18753	76.40855
104	LBC-104	15.1864	76.41168
105	LBC-105	15.18633	76.41227
106	LBC-106	15.18626	76.41053
107	LBC-107	15.18658	76.40959
108	LBC-108	15.18124	76.40767
109	LBC-109	15.18013	76.40670
110	LBC-110	15.18058	76.40590
111	LBC-111	15.17994	76.41103
112	LBC-112	15.17855	76.40935
113	LBC-113	15.17854	76.40836
114	LBC-114	15.17922	76.41587
115	LBC-115	15.17878	76.41705

116	LBC-116	15.17869	76.41875
117	LBC-117	15.17836	76.41745
118	LBC-118	15.17837	76.41568
119	LBC-119	15.17575	76.42477
120	LBC-120	15.17656	76.42143
121	LBC-121	15.17619	76.41964
122	LBC-122	15.17575	76.41642
123	LBC-123	15.17578	76.41313
124	LBC-124	15.17077	76.42088
125	LBC-125	15.17123	76.41935
126	LBC-126	15.17114	76.42214
127	LBC-127	15.17137	76.41780
129	LBC-129	15.16921	76.42496
128	LBC-128	15.16994	76.42576
130	LBC-130	15.16842	76.42425
131	LBC-131	15.16745	76.42327
132	LBC-132	15.16785	76.41955
133	LBC-133	15.16731	76.42133
134	LBC-134	15.16575	76.42334
135	LBC-135	15.16525	76.42226
136	LBC-136	15.16458	76.42115
137	LBC-137	15.16359	76.42337
138	LBC-138	15.16282	76.42238
139	LBC-139	15.16221	76.42160
140	LBC-140	15.16398	76.42924
141	LBC-141	15.16371	76.42809
142	LBC-142	15.16345	76.42700
143	LBC-143	15.16275	76.42609
144	LBC-144	15.16189	76.42470
145	LBC-145	15.1608	76.42423
146	LBC-146	15.1606	76.42985
147	LBC-147	15.16012	76.42829
148	LBC-148	15.15979	76.42686
149	LBC-149	15.15944	76.42548
150	LBC-150	15.15976	76.42413
151	LBC-151	15.15901	76.43144
152	LBC-152	15.15804	76.43089
153	LBC-153	15.15777	76.43018
154	LBC-154	15.15805	76.42932

155	LBC-155	15.15832	76.42822
156	LBC-156	15.15776	76.42704
157	LBC-157	15.15742	76.42554
158	LBC-158	15.15896	76.43508
159	LBC-159	15.15832	76.43345
160	LBC-160	15.15776	76.43246
161	LBC-161	15.15717	76.43141
162	LBC-162	15.15597	76.43073
163	LBC-163	15.15434	76.43058
164	LBC-164	15.15286	76.42988
165	LBC-165	15.15255	76.44339
166	LBC-166	15.1534	76.44175
167	LBC-167	15.15413	76.44006
168	LBC-168	15.15496	76.43820
169	LBC-169	15.15497	76.43640
170	LBC-170	15.15406	76.43520
171	LBC-171	15.15328	76.43363
172	LBC-172	15.15256	76.43218
173	LBC-173	15.15029	76.43536
174	LBC-174	15.14877	76.43372
175	LBC-175	15.14614	76.43463
176	LBC-176	15.14505	76.43726
177	LBC-177	15.14459	76.43495
178	LBC-178	15.1451	76.44160
179	LBC-179	15.14229	76.44125
180	LBC-180	15.14248	76.44800
181	LBC-181	15.14171	76.44655
182	LBC-182	15.13999	76.45000
183	LBC-183	15.14003	76.44745
184	LBC-184	15.14068	76.44599
185	LBC-185	15.13256	76.45039
186	LBC-186	15.13202	76.44895
187	LBC-187	15.12908	76.44764
188	LBC-188	15.13112	76.44702
189	LBC-189	15.13146	76.44475
190	LBC-190	15.12818	76.45337
191	LBC-191	15.12671	76.45214
192	LBC-192	15.12408	76.45122
193	LBC-193	15.1269	76.45655

194	LBC-194	15.12566	76.45562
195	LBC-195	15.12466	76.45364
196	LBC-196	15.12035	76.46109
197	LBC-197	15.11984	76.45931
198	LBC-198	15.1191	76.45761
199	LBC-199	15.11844	76.45517
200	LBC-200	15.11662	76.45281
201	LBC-201	15.11441	76.46662
202	LBC-202	15.11473	76.46417
203	LBC-203	15.11448	76.46053
204	LBC-204	15.11376	76.45867
205	LBC-205	15.11348	76.45646
206	LBC-206	15.11339	76.45443
207	LBC-207	15.10867	76.46478
208	LBC-208	15.10841	76.46571
209	LBC-209	15.10852	76.46327
210	LBC-210	15.1088	76.46238
211	LBC-211	15.10442	76.45863
212	LBC-212	15.10493	76.46023
213	LBC-213	15.10316	76.46530
214	LBC-214	15.10273	76.46366
215	LBC-215	15.10158	76.46196
216	LBC-216	15.09996	76.46126
218	LBC-218	15.10042	76.46421
217	LBC-217	15.10115	76.46650
219	LBC-219	15.1016	76.46857
220	LBC-220	15.09892	76.46319
221	LBC-221	15.09419	76.46790
222	LBC-222	15.09251	76.46763
223	LBC-223	15.09038	76.46744
224	LBC-224	15.09476	76.47706
225	LBC-225	15.09251	76.47740
226	LBC-226	15.08848	76.47453
227	LBC-227	15.08893	76.47323
228	LBC-228	15.08728	76.47222
229	LBC-229	15.08673	76.47012
230	LBC-230	15.08606	76.46913
231	LBC-231	15.08562	76.46836
232	LBC-232	15.07965	76.48154

233	LBC-233	15.08033	76.47913
234	LBC-234	15.07818	76.48043
235	LBC-235	15.07826	76.47984
236	LBC-236	15.07616	76.48577
237	LBC-237	15.07545	76.48437
238	LBC-238	15.07398	76.48277
239	LBC-239	15.06983	76.48333
240	LBC-240	15.07253	76.48207

Table 9. Details of proposed gabion checks and their geo-coordinates

Sl. No	**Gabion checks**	**Latitude (N)**	**Longitude (E)**
1	GC-1	15.18613	76.40809
2	GC-2	15.1851	76.40478
3	GC-3	15.18512	76.40149
4	GC-4	15.17809	76.41312
5	GC-5	15.17697	76.41088
6	GC-6	15.16792	76.41832
7	GC-7	15.16043	76.42310
8	GC-8	15.13899	76.44102
9	GC-9	15.1317	76.44345
10	GC-10	15.12172	76.45122
11	GC-11	15.11959	76.45023
12	GC-12	15.10868	76.45959
13	GC-13	15.10699	76.45736
14	GC-14	15.09835	76.46083
15	GC-15	15.09921	76.45777
16	GC-16	15.07685	76.47950
17	GC-17	15.075	76.47786
18	GC-18	15.06102	76.48098
19	GC-19	15.06061	76.50484
20	GC-20	15.058	76.49977
21	GC-21	15.08126	76.51657
22	GC-22	15.09952	76.49429
23	GC-23	15.10188	76.48843
24	GC-24	15.10683	76.48544
25	GC-25	15.1187	76.48549
26	GC-26	15.12404	76.47885
27	GC-27	15.14555	76.46343
28	GC-28	15.17492	76.43965
29	GC-29	15.19155	76.42178
30	GC-30	15.19828	76.41479

Table 10. Details of proposed check dams and their geo-coordinates

Sl. No	Check dam	Latitude (N)	Longitude (E)
1	CD -1	15.19265	76.42331
2	CD -2	15.17114	76.44414
3	CD -3	15.16148	76.45239
4	CD -4	15.1 434	76.46856
5	CD -5	15.1044	76.48749
6	CD -6	15.07866	76.51955
7	CD -7	15.05791	76.50647
8	CD -8	15.05619	76.50136

Table 11. Details of proposed nala bunds and their geo-coordinates

Sl. No	Nala bund	Latitude (N)	Longitude (E)
1	NB -1	15.15556	76.45626
2	NB -2	15.14232	76.46855
3	NB -3	15.05461	76.50749

COST ESTIMATION FOR CONSTRUCTION OF SWC MEASURES

Table 12. Tentative cost/budget for the proposed SWC structures

Sl. No.	Particulars of structure	Total proposed structures (Nos.)	Unit rate (Rs. in lakhs)	Total cost (Rs. in lakhs)
1	Loose boulder checks (Gully checks)	240	0.25	60
2	Gabion checks	30	0.6	18
3	Check dams	8	15	120
4	Nala bunds with spill way	3	11	33
5	Silt Deposition Tank (SDT)**	3	11	33
Estimated cost* (Rs. in lakhs)				**264**

**Silt deposition tanks of size 55 m x 25 m x4 m may be constructed at suitable sites near and below the existing mining Zone (SDT not shown in Treatment map considering flexibility of construction at convenient sites).

Note: Estimated cost is only tentative. Cost may vary as per the site requirement and design specification of structure. Cost may considerably increase or decrease as per the design specification, upper/middle/lower reach of the construction site and availability of material, transportation of materials, men and equipments in the difficult reserve forest hill terrain. The actual amount may be estimated by forest department based on conditions and requirements.

CONCLUSION

The Ramanamalai Reserve Forest area is highly vulnerable to soil erosion due to steep slopes, scanty vegetation, heavy runoff and low infiltration rate with existing sandy clay loam soil. Present land use map reveled that only 1.34% of reserve forest is under dense vegetation and most of forest land is covered with sparse vegetation (71.33%). Majority of reserve forest area (68%) is on steep slope signifying high soil erosion and run-off potential and steep topography has led to very coarse drainage density of 1.51 km km^{-2}. Total annual runoff yield of RRF is 3029890.5 m^3 or 385.40 mm of annual rainfall i.e. 53.66% of rainfall was estimated and annual soil loss to the tune of 263689.62 ton (38.25 t ha^{-1} yr^{-1}) has been computed for average sloping condition. Hence, there is an urgent need of soil and water conservation measures to control high soil erosion and further degradation of the reserve forest to ensure sustenance of growth and vegetation. The maps are prepared using geospatial techniques and can be used for effective planning of forest resources. The proposed treatment plan for the Ramanamalai Reserve Forest showing suitable sites for soil and water conservation structures can be used for effective implementation of treatment measures and for efficient moisture conservation and control of soil erosion which in turn can ensure sustenance in growth of vegetation.

REFERENCE

Babu, R., Dhyani, B. L., and Kumar, N. (2004). Assessment of erodibility status and refined Iso-Erodent Map of India. Indian Journal of Soil Conservation, 32(2), 171-177.

De Jong, S. M. (1994). Derivation of vegetative variables from a Landsat TM image for modelling soil erosion. Earth Surface Processes and Landforms, 19(2), 165-178.

Forest Survey of India. (2011). India state of Forest Report, https://fsi.nic.in/cover_2011/karnatka.pdf

Forest Survey of India. (2021). India state of Forest Report, https://fsi.nic.in/isfr-2021/chapter-13.pdf

GSI, 2022. Geomorphology and Lithology, Geological Survey of India, Government of India, Kolkatta, India (Date of download: 26.11.2022). https://bhukosh.gsi.gov.in

Gupta, R. P., and Dakshinamoorthy, C. (1980). Procedures for physical analysis of soil and collection of agrometeorological data. Indian Agricultural Research Institute, New Delhi, 293.

Jain, M. K., Mishra, S. K., and Shah, R. B. (2010). Estimation of sediment yield and areas vulnerable to soil erosion and deposition in a Himalayan watershed using GIS. Current Science, 213-221.

Kadam, A. K., Kale, S. S., Umrikar, B. N., Sankhua, R. N., and Pawar, N. J. (2017). Identifying possible locations to construct soil-water conservation structures by using hydro-geological and geospatial analysis. Hydrospatial Anal, 1(1), 18-27.

Keen, B. A., andRaczkowski, H. (1921). The relation between the clay content and certain physical properties of a soil. The Journal of Agricultural Science, 11(4), 441-449.

Kolekar, S., Chauhan, S., Raavi, H., Gupta, D., and Chauhan, V. (2017). Site selection of water conservation measures by using RS and GIS: a review. Advances in Computational Sciences and Technology, 10(5), 805-813.

Nayak, L. T. (2016). Environmental Impact of Iron ore Mining in Bellary District, Karnataka: Using Geo-Spatial Techniques. National Geographical Journal of India, 62(1), 61-74. Retrieved from https://ngji.in/index.php/ngji/article/view/458

Piper, C.S., 1966. Soil and plant analysis (Asian edition). Hans Publishers., Bombay, India. pp. 223-237

Rai, P. K., Mishra, V. N., andamp; Mohan, K. (2017). A study of morphometric evaluation of the Son basin, India using geospatial approach. Remote Sensing Applications: Society and Environment, 7, 9-20.

Rao, S. M. and Reddy, O. (1991). Environmental Impact Assessment: A case study of Anantapur District, Geographical Review of India,Vol.61. No.1.

Sharnappa, W and Venkatraju, 2014. Plant biodiversity of Sandur forests in Bellary district. Abstract in proceedings of National level conference on "Recent trends in Biosystematics" held at J.S.S. College, Dharwad on 30/09/2014 to 01/10/2014. pp-22.

Singh, G., Ram Babu, Narain, P., Bhusan, L.S. and Abrol, I.P. (1992) Soil erosion rates in India. Journal of Soil and Water Conservation 47, 97-99.

Singh G, Ram Babu and Chandra, S. (1981). Soil loss prediction research in India; Tech. Bull. T-12/D-9, Central Soil and Water Conservation Research and Training Institute, Dehradun, India.

Singh, U. V., (2021).Breakthrough in improvement of environment and forest ecosystem through rehabilitation of mines and reclamation of biodiversity in iron ore mines at Bellary sector of Karnataka India.European Journal of Applied Sciences, Volume 9(1): 282-299.

Smith, S. K.(1950). Standards for grading texture of erosional topography. American Journal of Science, 1950, vol. 248 (9),pp.655-668, doi:10.2475/ajs.248.9.655

Soil Conservation Services.(1972). National Engineering Handbooks, Section-4 Hydrology, Washington DC.

Subbiah, B.V. and Asija, G.L. (1956) A rapid procedure for the estimation of available nitrogen in soils. Current Science 25, 259-260.

Subramanya, K. (2008). Engineering Hydrology. Tata McGraw-Hill Publishing Company Limited, New Delhi, India. 155-160 pp.

Tripathi MP. (1999). Hydrological modeling of small watershed, Unpublished Ph.D. Thesis, Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur.

U.S. Department of Agriculture and Natural Resources Conservation Service. (2007). NationalEngineering Handbook, Part 630 Hydrology, Chapters 7: Hydrologic Soil Groups. Washington, DC. Available online at http://directives.sc.egov.usda.gov/.

Wischmeier, W. H., Johnson, C. B. and Cross, B. V. 1971. 'A soil erodibility nomogram for farmland and construction sites', Journal of Soil and Water Conservation. 26, 189-193.

Wischmeier, W.H and Smith, D.D. (1978). Predicting rainfall erosion losses – A guide to conservation planning. Agriculture Handbook No. 537, USDA.

Walkley, A., and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science, 37(1), 29-38.

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