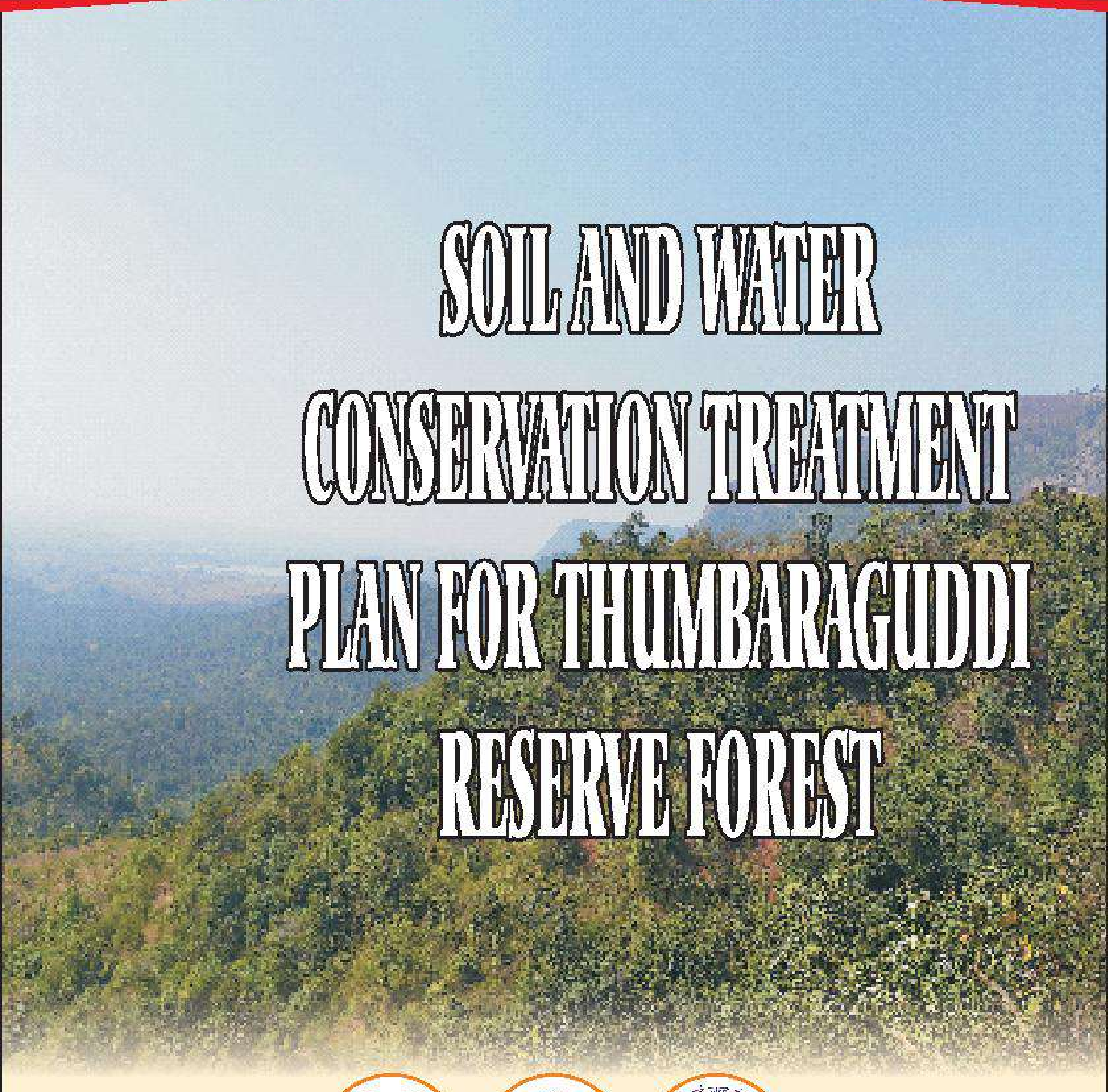

SOIL AND WATER CONSERVATION TREATMENT PLAN FOR THUMBARAGUDDI RESERVE FOREST

ICAR-INDIAN INSTITUTE OF SOIL AND WATER CONSERVATION

Research Centre, Ballari, Karnataka - 583 104.

CONSULTANCY PROJECT REPORT

SOIL AND WATER CONSERVATION TREATMENT PLAN FOR THUMBARAGUDDI RESERVE FOREST

भाकृअनुप- भारतीय मृदा एवं जल संरक्षण संस्थान
ICAR- Indian Institute of Soil & Water Conservation

Submitted By

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ಕರ್ನಾಟಕ ಅರಣ್ಯ ಇಲಾಖೆ
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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Mr. T. Heeralal, IFS (Chief Conservator of Forests, Ballari Circle)

CITATION

Naik, B.S., Ramesha, M.N., Prabhavathi, M., Amrut S Morade, Ravi, K.N and Mohan Kumar, P. 2022. Soil and Water Conservation Treatment Plan for Thumbaraguddi Reserve Forest. ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Ballari, 583 104. pp. 1-27.

COVER PHOTO

Thumbaraguddi 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 biodiversity. 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 Thumbaraguddi Reserve Forest, Sandur Taluk, Ballari district of Karnataka. The scientifically designed treatment plan will help KFD in effective implementation of site-specific soil and water conservation interventions to enhance the forest restoration and regeneration.

Consultancy Team
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ACKNOWLEDGMENTS

We express our sincere gratitude to Shri. Sandip H. Suryawanshi, IFS (Deputy Conservator of Forests, Ballari), Government of Karnataka for entrusting us with the Preparation of SOIL AND WATER CONSERVATION TREATMENT PLAN and for extending all possible facilities to carry out the work smoothly.

We express our sincere gratitude to Shri. T. Heeralal, IFS (Chief Conservator of Forests, Ballari Circle) for his support and critical appraisal of our work and providing us timely suggestions and guidance.

We are highly grateful to Dr. M. Madhu, Director, ICAR-IISWC, Dehradun for his constant encouragement and support, and also for his valuable inputs received from time to time.

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Our sincere thanks to Dr. Shakir Ali, Principle Scientist, ICAR-IISWC, Research Centre, Kota for his constant guidance for preparation of MoU with forest department. We also thank staff in the Technical, administrative and Finance sections of ICAR-IISWC, Research Centre, Ballari and ICAR-IISWC, Dehradun for their logistic support.

We greatly acknowledge Mr. D.K. Girish Kumar, RFO (Sandur South Range), Mr. R. Thippeswamy DRFO, SMB Section and staff of Thumbaraguddi Reserve Forest area for providing us with all possible support in soil sample collection and accompanying during field visits. Finally we also acknowledge the kind co-operation rendered by all officers and staff of KFD, GoK.

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CERTIFICATE

This is to certify that the Soil and Water Conservation aspects pertaining to THUMBARAGUDDI 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 THUMBARAGUDDI RESERVE FOREST " submitted to Forest Department, Ballari Circle.

This is pertaining to 'DETAILED PROJECT REPORT OF ECO-RESTORATION OF MINING AFFECTED THUMBARAGUDDI 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

Si. No.	Acronym	Expansion
1	CN	Curve Number
2	EIA	Environmental Impact Assessment
3	GIS	Geographic Information System
4	TRF	Thumbaraguddi 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 Thumbaraguddi Reserve Forest (TRF), which is located in Sandur Taluk, Ballari district of Karnataka state (Fig. 1). TRF falls under administrative control of Sandur South range of Balari division in Kumaraswamy hill range. This reserve forest is located 58 km to the South-west of Ballari city and 20 km from Sandur. Kumaraswamy hills range derive its name from Hindu temple located in South-western part of Sandur. This area is famous for industrial mining due to high quality of Iron and Manganese ores. TRF is surrounded by many villages at foothills particularly in southern direction. Jiginahalli, Thumbaraguddi and Yerrayahalli are located South of this reserve forest. Tygadahal and Devramallapur are located in South-eastern foothills while Swamy halli in eastern side of TRF. Northern ridge boundary of TRF is limited by active Iron and Manganese ores. M/s Smiore Pvt. Ltd., M/s Gadagi minerals and M/s Marwa minerals are the major Manganese and Iron ores which limits Northern border of this reserve forest. About 111.68 ha inside the reserve forest is also leased to the mining industry.

The total geographical area of TRF is 1987.62 ha and perimeter is 23.98 km. The location of the TRF project falls under Survey No. 204 of Ankammanahal village, Survey No. 1 of Jigenahalli and Sy. No. 1 of Yarrayyanahalli village of Sandur Taluk, Ballari District. The geographical co-ordinates of forest ranges between 14.9598 to 15.0029 north latitude and 76.5256 to 76.6030 east longitude. An elevation of study area is ranging from 656 to 895 m above MSL. The location map of Thumbaraguddi reserve forest depicted in Fig. 1 below. This reserve forest is categorized in Sandur South Range, Ballari division of Karnataka Forest Department.

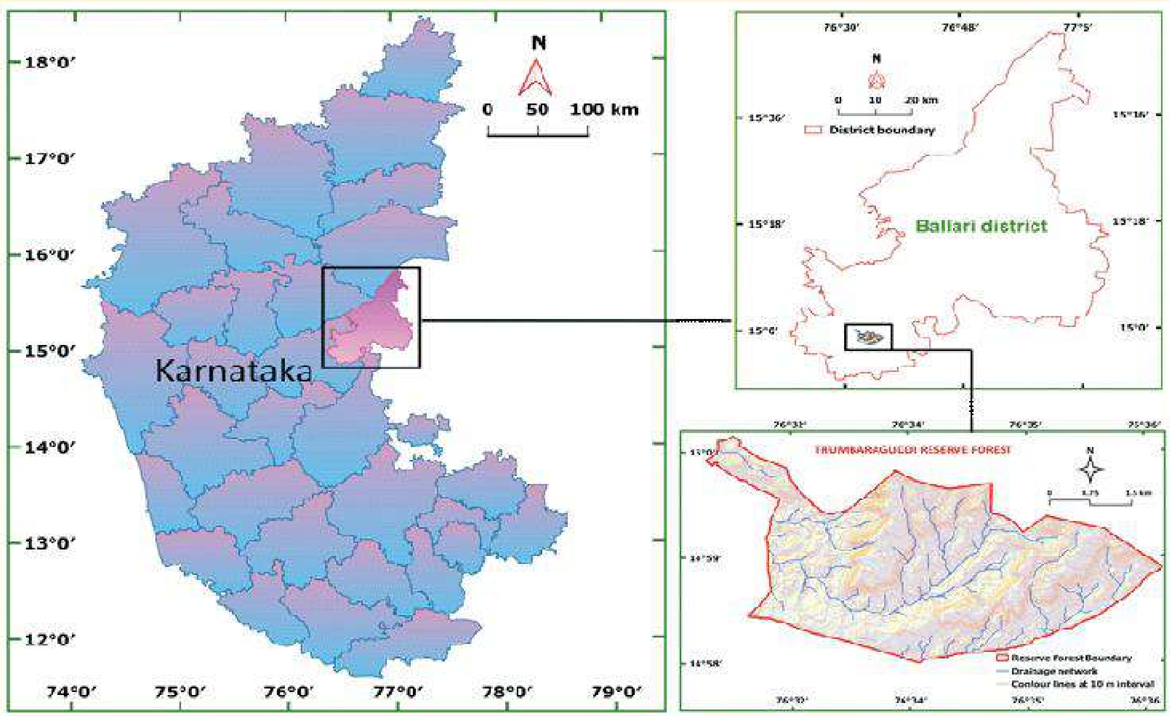

Fig. 1: Location map of Thumbaraguddi Reserve Forest

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 over wood vegetation in Sandur hills consists of trees like *Chloroxylon swietenia, Anogeissus latifolia, Terminalia tomentosa, Terminalia bellirica, Dalbergia paniculata, Boswallia serrata, Acacia chundra, Butea monosperma, Ficus racemosa, Gardenia gummifera, Syzigium cumini and 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

- Lack of dense vegetation (<6%) and majority of the hill exposed to direct erosion risk due to sparse vegetation (77.8%).
- Undulated terrain and steep slope (average slope of reserve forest is 10.50%), shallow soil depth and lack of SWC measures resulting high run-off causing severe erosion (13.76 t ha^{-1} yr^{-1} for average sloping condition)
- The hilltop of reserve forest is surrounded by active mining industries causing high runoff, stream bank erosion and heavy downstream siltation (Fig. 2 and 4).
- 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 (Fig. 3 and 5).

OBJECTIVES OF THE STUDY

- To characterize physiography of Thumbaraguddi Reserve Forest catchment using GIS environment to estimate soil erosion rate and potential runoff volume.
- To identify potential erosion risk areas and preparation of site-specific soil and water conservation treatment plan to mitigate soil erosion.
- To suggest in-situ moisture conservation plan for supporting regeneration of vegetation through site-specific SWC measures.
- To create benchmark data of soil physical and chemical parameters for subsequent monitoring and evaluation.

Fig. 2: Heavy downstream siltation in third order stream

Fig. 3: Active mining and degraded forest in Northern hilltop of forest

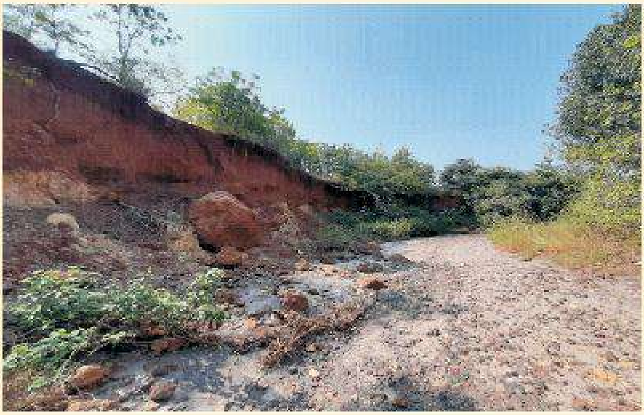

Fig. 4: Streambank erosion/ nala scouring in Thumbaraguddi reserve forest

Fig. 5: Dumping of mining waste on hillslopes and hill cuts along roads

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, six systematically collected soil samples from upper, middle and lower reach of TRF 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 thr ough monitoring and evaluation of project.

Table 1: Soil physical and chemical parameters studied in TRF

SI.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.	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. 6). 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.

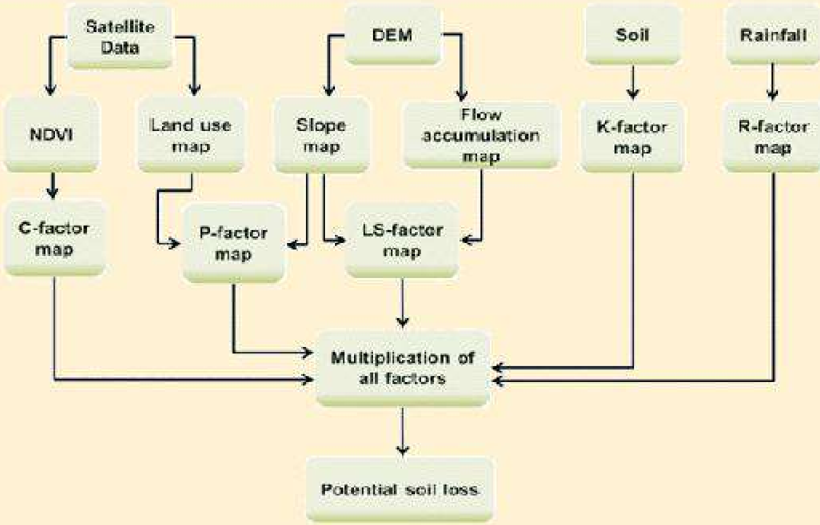

Fig. 6: Flowchart to estimate potential soil loss in GIS environment

Table 2: Overview of data used for study

Sl. No.	Data	Sensor	Source	Usage	Time
1	NASA Shuttle Radar Topographic Mission (SRTM - DEM 30 m)	Interferometric SAR radar	https://earthexplorer.usgs.gov/	Digital Elevation Model (DEM) creation	2019
2	Normalized Difference Vegetation (NDVI)	Landsat 8 OLI	https://earthexplorer.usgs.gov/	NDVI Map creation with red and NIR bands of 30m resolution	2022
3	Land Use and Land Cover	Landsat 8 OLI	https://earthexplorer.usgs.gov/	Red, Blue, green and NIR bands	2022
4	Rainfall data	Gridded data (0.25°×0.25°)	https://www.imdpune.gov.in	Rainfall information	1986 to 2020
5	Soil Erodibility 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) below was used for assessing the runoff yield in TRF. This method involves relationship between land use, land treatment, hydrological condition, hydrologic soil group, and 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,

$S = (25400 / CN) - 254$ ....(ii)

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

Hydrological soil group (HSG) of TRF varies from low runoff potential to moderately high runoff potential. Hence average condition of hydrological soil group considered for runoff curve number. Anteceded moisture condition-II (AMC-II) is considered here for runoff estimation. TRF comes under degraded scrub with average condition of hydrological soil group and so runoff curve number is 44 has been taken here as per the criteria defined by Tripathi (1999). The Annual runoff yield is determined using the average annual rainfall.

Estimation of soil loss

The soil erosion rate from TRF 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 (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).

$A = R\,K\,L\,S\,C\,P$ .... (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.

$Y = 81.5 + 0.380X$ .... (iv)

Where, Y is the average annual erosion index (t ha-1cm-1) and X is the average annual rainfall (mm).

For the present study area the average annual rainfall data of surrounding TRF micro-watersheds is 658.5 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 relation:

$100K = 2.1 \times 10\text{-}4\ (12\ OM)\ M\ 1.14 + 3.25\ (S2) + 2.5\ (P3)$ ... (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 .... (vi) and S = (sin?/0.0896)1.3 ....(vii)

Where, AS: catchment area (m2) and ?: slope angle in degrees.

The C value was calculated using the eq. (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 .... (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.7) of Thumbaraguddi Reserve Forest. The most of forest land is covered with sparse vegetation (77.8%), while 5.7% area is under dense vegetation. Barren land and built-up area from reserve forest contributes <1% of total geographical area of forest. The vegetation is confined mostly to the chains of hillocks favoring rich growth on hill slopes along the streams or nala. The hill tops are barren with few shrubs, trees and grasses therefore this part is subjected to high wind erosion. Data received from Forest Department states, about 111.7 ha (6%) and 24 ha (1.27%) area inside the Thumbaraguddi Reserve Forest is under mining lease and railway tracks, respectively.

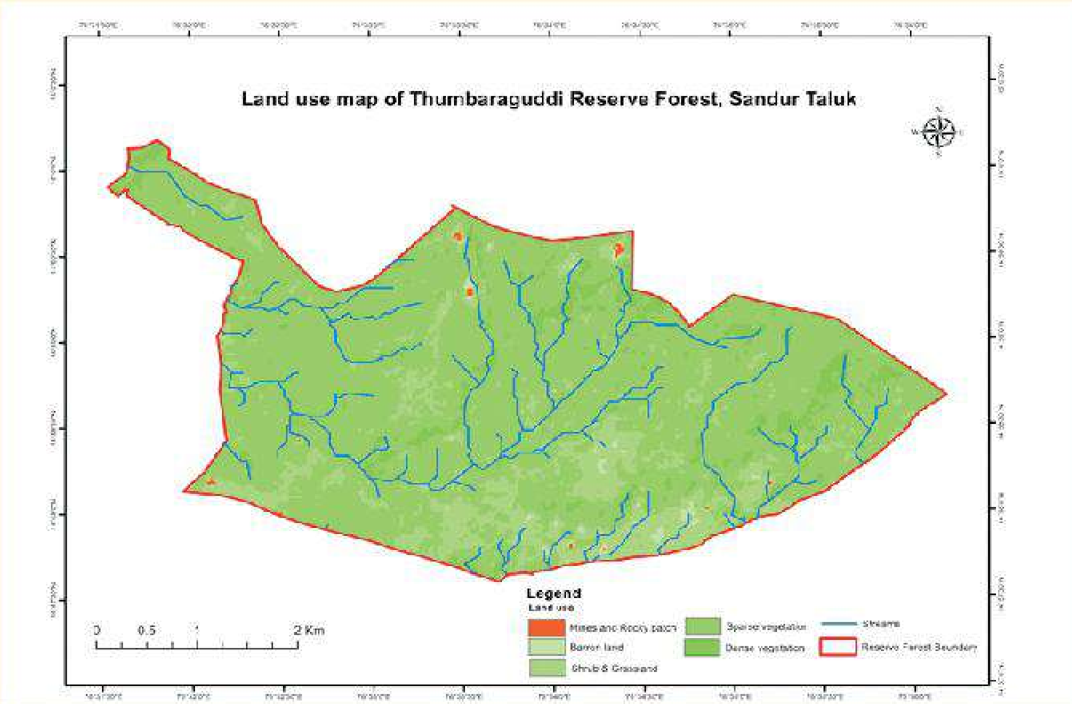

Fig. 7: Land use map of Thumbaraguddi reserve forest, Ballari

Geomorphology and lithology

The geomorphology of TRF is spread over moderately dissected hills and valleys with Pediment Pediplain complex and pond. Metamorphosed volcanic rocks of Thumbaraguddi formation are composed mainly of banded ferruginous chert, Dolerite, Gabbro, Grey granite, Laterite, Mandaniferrous phyllite, Meta-Basalt, Migmatite Gneiss 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 the study area depicts 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 TRF and laboratory analysis of these soil samples revealed following soil erodibility (K) map (Fig.8) and soil physico-chemical properties (Table 3 and 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 0.26 to 0.48 in TRF, the higher soil erodibility (>0.48) is in North-eastern ridge and lower (0.26 to 0.28) is located on central hill slope. Majority of forest area had sandy clay loam texture. An average bulk density (g cm^{-3}), porosity (%), water holding capacity (%) and volume expansion (%) of TRF soils is 1.27, 45.29, 47.74 and 15.29, respectively.

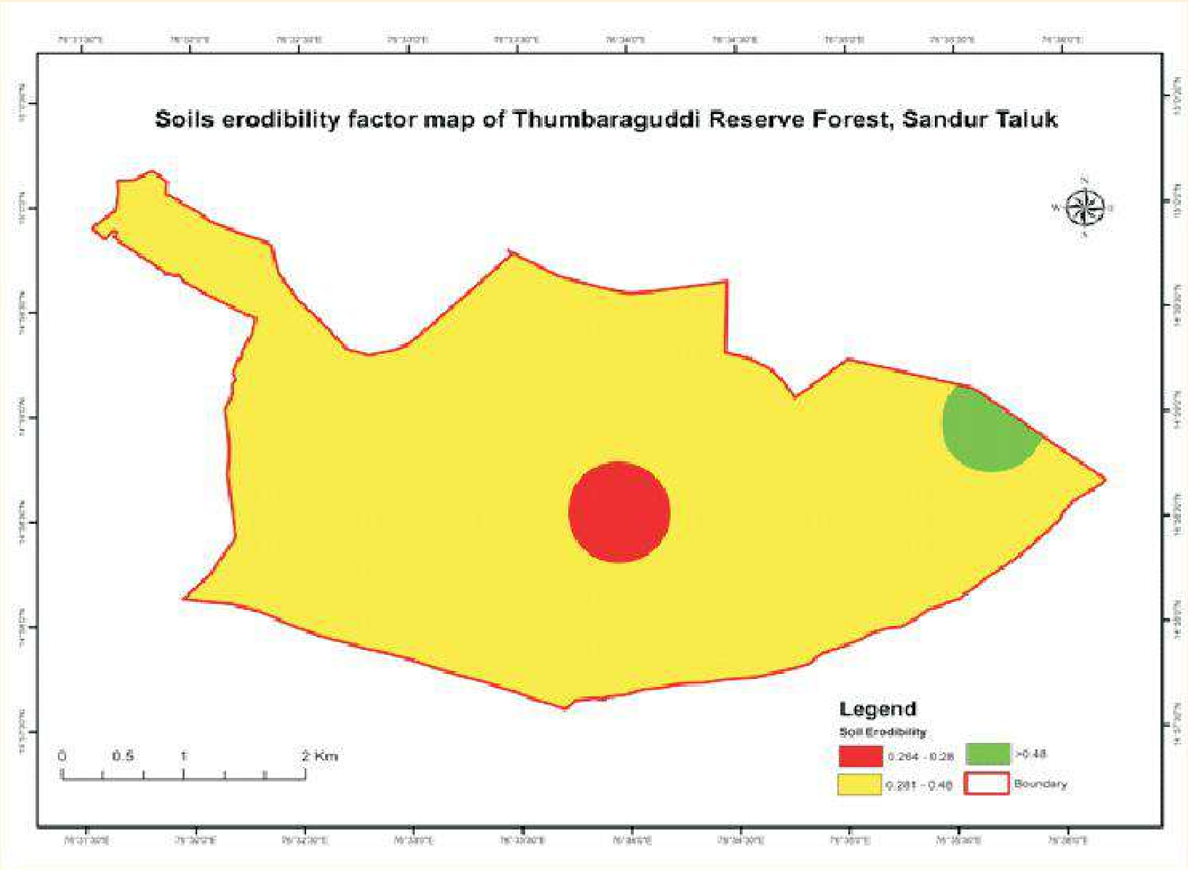

Fig. 8: Soil erodibility factor map of Thumbaraguddi reserve forest

Table 3: Soil physical properties in Thumbaraguddi Reserve Forest

Sl. No	Texture	Sand (%)	Silt (%)	Clay (%)	Bulk density (g cm^{-3})	Porosity (%)	Water holding capacity (%)	Volume expansion (%)
1	Sandy clay loam	22.8	20.0	57.2	1.31	40.71	44.68	17.89
2	Sandy clay loam	20.8	16.0	63.2	1.27	46.67	47.35	13.38
3	Sandy clay loam	20.8	16.0	63.2	1.39	45.37	45.53	17.74
4	Sandy clay loam	36.8	20.0	43.2	1.22	47.77	53.54	17.46
5	Clay loam	30.8	24.0	45.2	1.27	46.85	49.27	15.51
6	Sandy clay loam	26.8	18.0	55.2	1.18	44.39	46.05	9.76

Table 4: Soil chemical properties in Thumbaraguddi Reserve Forest

Sl. No	Texture	pH	EC (dS m^{-1})	Organic carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorous (kg ha^{-1})
1	Sandy clay loam	6.14	0.70	0.48	1066.0	52.9
2	Sandy clay loam	5.95	0.77	1.26	583.0	8.6
3	Sandy clay loam	6.27	0.49	1.02	496.0	54.8
4	Sandy clay loam	6.22	0.14	1.57	684.0	8.6
5	Clay loam	7.72	0.26	0.26	470.4	77.6
6	Sandy clay loam	5.62	0.29	0.40	470.4	28.0

Mean pH and EC values of 6.32 and 0.44, respectively signifies 'neutral' soil reaction status. Average soil organic carbon was 0.83% and available nitrogen and phosphorous was ranged from 470.4 to 1066.0 and 8.6 to 77.6 kg ha^{-1} respectively, indicating 'medium' to 'high' soil fertility status. Fine root dynamics, nitrogen fixation by tree and grass species along with forest leaf litter fall is responsible better soil organic carbon and available nitrogen.

Hydrological soil groups

Soils, in general has been classified into four classes A, B, C and D based on soil texture and soil water infiltration rate (SCS, 1972, USDA and NRCS, 2007). The group 'A' soils have low runoff potential due to high water infiltration rate (>25 mm hr^{-1}) even when thoroughly wetted 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 wetted. 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; Kolekar *et al.,* 2017). Soils from Thumbaraguddi reserve forest falls under hydrological group C, indicating moderately high runoff potential with low infiltration rate (Table 5).

Table 5: Hydrological soil groups in Thumbaraguddi Reserve Forest

Sl.No	Texture	Hydrological soil group	Water infiltration capacity	Area (ha)	Area in Percentage
1	Sandy clay loam	C	Low	1235.67	62.17
2	Clay loam	D	Very low	751.97	37.83

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).

Table 6: Slope distribution in Thumbaraguddi reserve forest

Slope (%)	Description	Area (ha)	% of TGA
0 to 1	Nearly level	53.8	2.7
1to 3	Very gently sloping	287.9	14.5
3 to 5	Gently sloping	367.0	18.5
5 to 10	Moderately sloping	596.8	30.0
10 to 15	Strongly sloping	222.5	11.2
15 to 25	Moderately steep to steep	249.1	12.5
25 to 33	Steep	131.1	6.6
33 to 50	Very steep	76.7	3.9
>50	Very-very steep	2.6	0.1

The slope of TRF is ranged from 0 to 60.10% and an average slope of entire area is 10.50%. The slope of TRF was divided into following nine classes and area (total and percent) under particular slope class is given here (Table 6 and Fig. 9). More than 23% area of reserve forest is on steep slope signifying high soil erosion potential.

Elevation and contour map

The topography of the study area shows relief and relatively strong slope (Fig. 10). The elevation of Thumbaraguddi reserve forest is ranging from 656 m in Southern part to 895 m in Northern part. The basin relief is 139 m. The contour intervals with 20 m are also depicted in figure 10.

Drainage density

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:

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

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).

Besides, low class of D has a permeable subsoil material, dense vegetation and low relief. High class of D shows a quick hydrological response to rainfall events. Besides, high class of D has an impermeable subsoil material, sparse vegetation and high/mountainous relief.

Total stream length in TRF is 43.7 km. These catchments have two outlets and have significant length (6 km) of third order stream. TRF has average slope of 10.5% and two major outlets with stream length (43.7 km) from medium catchment area (19.87 km^2); it has coarse drainage density of 2.20 km km^{-2}. Very fine drainage density (>8) was reported along second and third order streams of catchment (Fig. 11). Average drainage density of 2.20 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 Thumbaraguddi reserve forest, drainage texture is also as low as 3.13 km^{-1}.

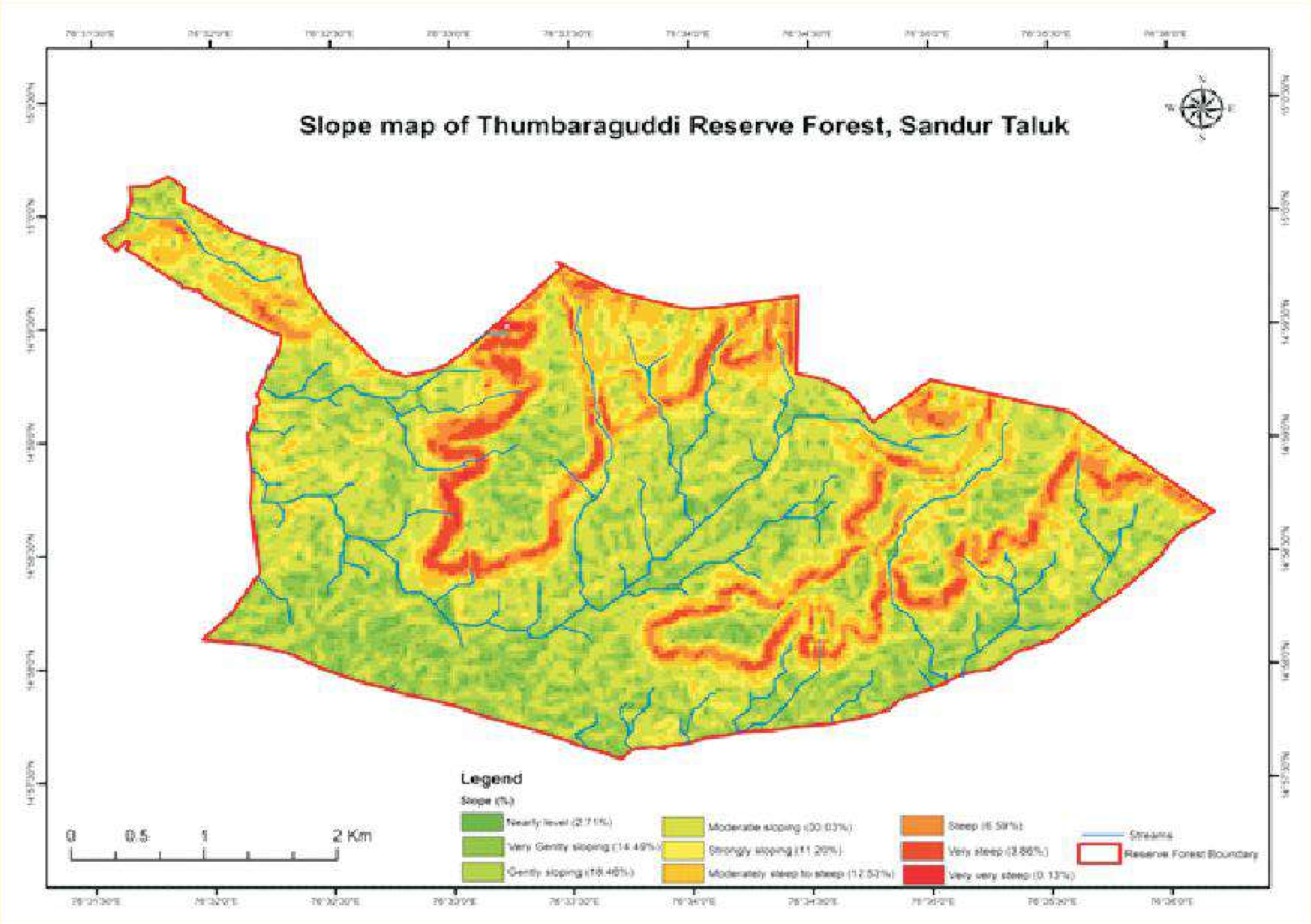

Fig. 9 : Slope map of Thumbaraguddi Reserve Forest

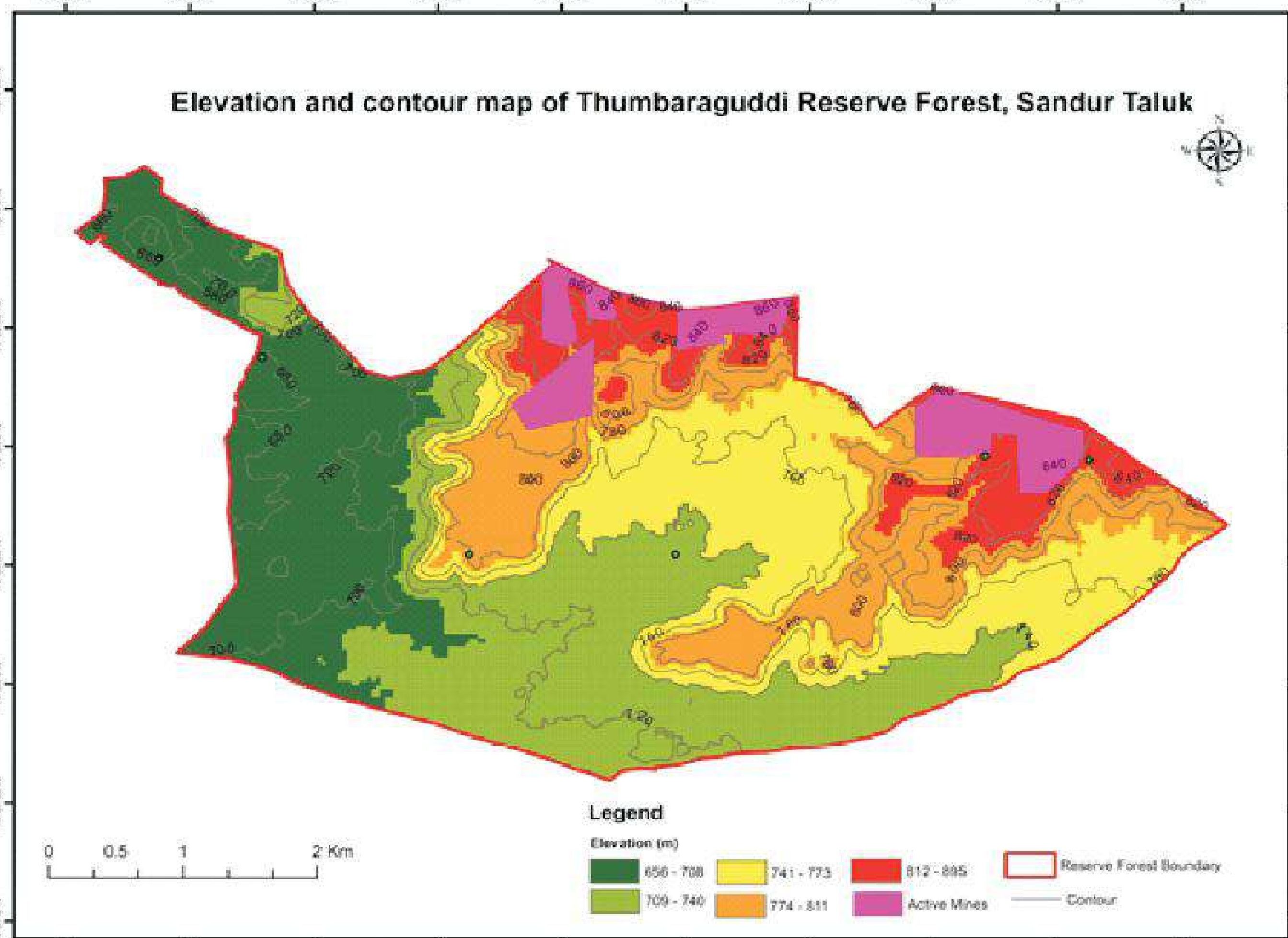

Fig. 10: Elevation and contour map of Thumbaraguddi Reserve Forest

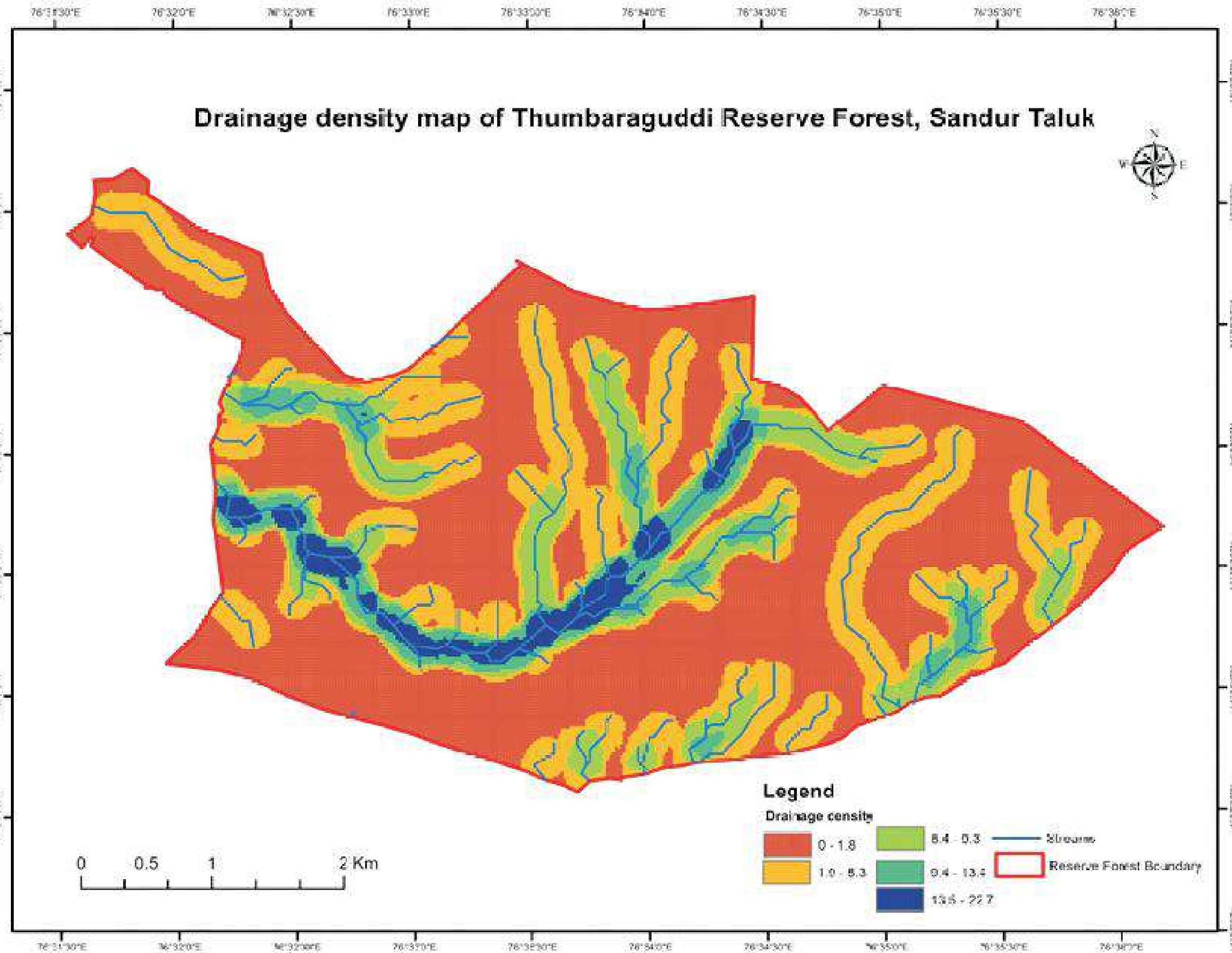

Fig. 11: Drainage density map of Thumbaraguddi Reserve Forest

Runoff estimation for Thumbaraguddi reserve forest

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

From equation (i), total annual runoff yield (Q) is calculated as 384.52 mm (58.39% 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

$$= 1987.5 \times 10000 \times (384.52/1000) = 7642335\ m^3$$

Soil loss calculation for Thumbaraguddi 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= 331.73

K=0.487

L=336.86

S= 1.205° (Avg. slope)

C=0.417, P=1.0

A=27345.52 tons (13.76 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. 8). The following specifications are adopted for identifying potential site-specific SWC sites (Table 7).

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

Sl. No.	Structure	Slope (%)	Location	Stream	Catchment (ha)
1	Loose boulder checks (Gully checks)	≤45	Up stream	I or II	< 5
2	Gabion checks	≤35	Mid stream/ Down stream	II or III	20-50
3	Check dams	≤25	Mid stream/ Down stream	II to IV	87-412
4	Nala bunds with spill way	≤15	Down stream	III or IV	90-330
5	Staggered Contour Trench (SCT)	33-50%	Upper reach/middle reach/lower reach	NA	NA

Note: Specification values are based on the Thumbaraguddi Reserve Forest actual drainage, catchment area and existing slope percentages under which decision for site selection made on scientific and practical experience.

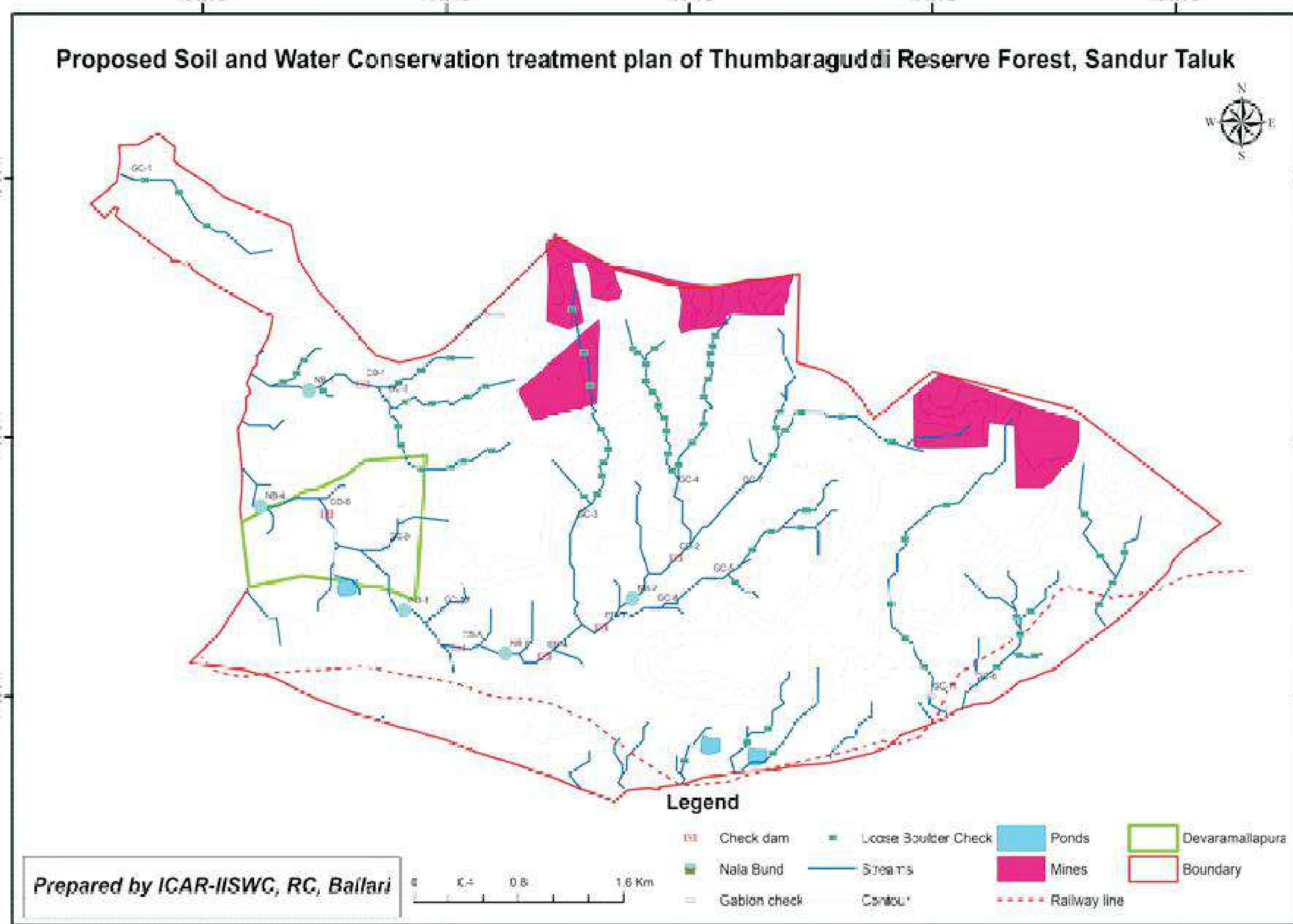

Fig. 8: Proposed soil and water conservation treatment map and plan

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	14.989902	76.568433
2	LBC-2	14.989223	76.568259
3	LBC-3	14.988742	76.568115
4	LBC-4	14.988064	76.568104
5	LBC-5	14.987074	76.567946
6	LBC-6	14.985978	76.567667
7	LBC-7	14.984218	76.567653
8	LBC-8	14.983015	76.566854
9	LBC-9	14.989059	76.562829
10	LBC-10	14.988783	76.56313
11	LBC-11	14.989073	76.564311
12	LBC-12	14.988067	76.563715
13	LBC-13	14.986953	76.563707
14	LBC-14	14.986253	76.564161
15	LBC-15	14.98541	76.564547
16	LBC-16	14.984625	76.564969
17	LBC-17	14.983751	76.565101
18	LBC-18	14.982288	76.565234
19	LBC-19	14.9816	76.565936
20	LBC-20	14.981198	76.565494
21	LBC-21	14.983041	76.580556
22	LBC-22	14.984683	76.577089
23	LBC-23	14.985043	76.572851
24	LBC-24	14.984969	76.57432
25	LBC-25	14.98379	76.573221
26	LBC-26	14.98396	76.572591
27	LBC-27	14.982186	76.572368
28	LBC-28	14.991551	76.558661
29	LBC-29	14.988795	76.55947
30	LBC-30	14.986654	76.559899
31	LBC-31	14.983847	76.560648
32	LBC-32	14.982583	76.561125
33	LBC-33	14.981739	76.56081
34	LBC-34	14.980885	76.56070

35	LBC-35	14.979666	76.560371
36	LBC-36	14.979553	76.559473
37	LBC-37	14.988445	76.55033
38	LBC-38	14.987673	76.548297
39	LBC-39	14.986833	76.546717
40	LBC-41	14.988298	76.540255
41	LBC-41	14.987481	76.539742
42	LBC-42	14.986897	76.538836
43	LBC-43	14.986334	76.541568
44	LBC-44	14.986594	76.552759
45	LBC-45	14.98596	76.551478
46	LBC-46	14.985522	76.548992
47	LBC-47	14.985627	76.547208
48	LBC-48	14.982503	76.553194
49	LBC-49	14.98183	76.551226
50	LBC-50	14.981428	76.550356
51	LBC-51	14.981295	76.548366
52	LBC-52	14.982839	76.546882
53	LBC-53	14.984052	76.546684
54	LBC-54	14.978638	76.574692
55	LBC-55	14.977539	76.574311
56	LBC-56	14.977279	76.57225
57	LBC-57	14.976113	76.570945
58	LBC-58	14.974027	76.569808
59	LBC-59	14.978987	76.584329
60	LBC-60	14.976781	76.58148
61	LBC-61	14.972602	76.580465
62	LBC-62	14.97044	76.581499
63	LBC-63	14.96861	76.582775
64	LBC-64	14.971823	76.589102
65	LBC-65	14.972174	76.590093
66	LBC-66	14.970698	76.589373
67	LBC-67	14.969283	76.590361
68	LBC-68	14.969318	76.589325
69	LBC-69	14.968591	76.587766
70	LBC-70	14.978417	76.593764
71	LBC-71	14.975708	76.594836
72	LBC-72	14.973976	76.595666
73	LBC-73	14.975949	76.596496

74	LBC -74	14.972588	76.594759
75	LBC -75	14.963012	76.572375
76	LBC -76	14.964597	76.572032
77	LBC -77	14.963732	76.570623
78	LBC -78	14.962507	76.566351
79	LBC -79	14.996961	76.53 3595
80	LBC -80	14.999145	76.531702
81	LBC -81	14.999886	76.529399

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

S.No	Name	Latitude (N)	Longitude (E)
1	GC -1	15.000047	76.528285
2	GC -2	14.985839	76.545826
3	GC -3	14.977765	76.558831
4	GC -4	14.979985	76.565756
5	GC -5	14.974278	76.568134
6	GC -6	14.967325	76.586178
7	GC -7	14.979957	76.570118
8	GC -8	14.972375	76.564311
9	GC -9	14.976294	76.545925
10	GC -10	14.972261	76.549668
11	GC -11	14.966673	76.583196

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

S.No	Name	Latitude (N)	Longitude (E)
1	CD -1	14.98672	76.544298
2	CD -2	14.975567	76.565773
3	CD -3	14.971112	76.560664
4	CD -4	14.969237	76.556743
5	CD -5	14.969828	76.550924
6	CD -6	14.97841	76.54182

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

S.No	Name	Latitude (N)	Longitude (E)
1	NB -1	14.986355	76.540608
2	NB -2	14.972963	76.562786
3	NB -3	14.972211	76.547119
4	NB -4	14.978896	76.537278
5	NB -5	14.96943	76.554086

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	Boulder checks (Gully checks)	81	0.25	20.25
2	Gabion checks	11	0.6	6.6
3	Check dams	6	15	90
4	Nala bunds with spill way	5	11	55
5	Staggered Contour Trench (SCT)*	15340	0.00072	11.04
Estimated cost* (Rs. in lakhs)				**182.89**

*Area under more than 33% slope will be covered under Staggered Contour Trenches (see slope details in Table 6) with trench size 2 x 0.6 x 0.6 m3 (200 trenches per ha). However, SCT will be avoided in steep slopes of more than 50%.

Note: Rates are based on the pervious estimations of forest department. But, Cost may vary as per the site requirement and design specification of structure. Estimated cost is only tentative, it 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 exact actual amount may be estimated by forest department based on conditions and requirements.

CONCLUSION

The Thumbaraguddi Reserve Forest area is vulnerable to soil erosion due to steep slopes (>20% of reserve forest area), scanty vegetation/degraded scrubs (>90% of reserve forest area), heavy runoff and low infiltration rate with majority of area existing under sandy clay loam soil. Present land use map reveled that only 5.7% area of reserve forest is under dense vegetation. Steep slope, smaller catchment area and undulated topography existed in reserve forest. Higher annual runoff of 7642335 m^3 (58.39% of rainfall) was estimated, and annual soil loss to the tune of 27345.52 tons (13.76 t ha^{-1} yr^{-1}) has been computed for average sloping condition. There is an urgent need of soil and water conservation measures to control 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 Thumbaraguddi 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 soil erosion. The catchment area treatment in reserve forest area can cause significant increase in ground water level in water bodies and bore wells located in downstream arable lands.

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