SOIL AND WATER CONSERVATION TREATMENT PLAN FOR MINCHERI 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 MINCHERI RESERVE FOREST

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

Submitted By

The Head,
ICAR- Indian Institute of Soil and Water Conservation (IISWC),
Research Centre, Hospet Road, Ballari - 583 104, Karnataka.

ಕರ್ನಾಟಕ ಅರಣ್ಯ ಇಲಾಖೆ
KARNATAKA FOREST DEPARTMENT

Submitted To

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

PROJECT TEAM

Dr. B. S. Naik, Sr. Scientist (SWCE) and Head (A)
Dr. M. N. Ramesha, Scientist (Forestry)
Dr. M. Prabhavathi, Sr. Scientist (Soil Science)
Mr. Amrut S. Morade, Scientist (Fruit Science)
Mr. K. N. Ravi, Scientist (Agricultural Extension)
Mr. P. Mohan Kumar (TO)

GUIDANCE

Dr. M. Madhu, Director, ICAR-IISWC, Dehradun.
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 Mincheri Reserve Forest. ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Ballari, 583 104. pp. 1-25.

COVER PHOTO

Mincheri Reserve Forest Hill, Ballari

GIS MAPPING

Dr. M. Prabhavathi, Sr. Scientist (Soil Science)
Dr. M. N. Ramesha, Scientist (Forestry)
Mr. P. Mohan Kumar (TO)

LAYOUT DESIGN

Mr. K. N. Ravi, Scientist (Agril. Extension)

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 proposed 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 Mincheri Reserve Forest, Ballari 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.

Project Team
ICAR- Indian Institute of Soil and Water Conservation,
Research Centre, Ballari, 583 104, Karnataka.

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, support and his valuable inputs received from time to time.

We are also thankful to Mr. Mahmad Fayajuddin, ACF, Ballari forest Division for providing required inputs and also extending all necessary support for completion of the report.

Our sincere thanks to Dr. Shakir Ali, Principal Scientist, ICAR-IISWC, Research Centre, Kota for his guidance in preparing MoU/ToR with forest department. We also thank all 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. Raghavendra, RFO, Mr. Rajashekar, DRFO, Mr. Nagaraj Gouda, DRFO, Forest guards of Mincheri Reserve Forest area and students of College of Forestry, Sirasi, Karnataka for providing us with all possible support in soil sample collection and accompanying during field visits.

Project Team
ICAR- Indian Institute of Soil and Water Conservation,
Research Centre, Ballari, 583 104, Karnataka.

भाकृअनुप- भारतीय मृदा एवं जल संरक्षण संस्थान, अनुसंधान केंद्र,
छावनी, बल्लारी -583 104, कर्नाटक, भारत
ICAR- Indian Institute of Soil & Water Conservation,
Research Centre,
Cantonment, Ballari-583 104, Karnataka, India
Office: 08392-242164, (Res) 08392-242534, email: soilcons21bly@gmail.com

CERTIFICATE

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

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

LIST OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

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

BACKGROUND

Mining creates immense pressure on 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 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 & 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 ha was allotted to 166 mine companies to rehabilitate 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 Mincheri Reserve Forest (MRF), which is located in Ballari district of Karnataka (Fig. 1). This reserve forest is located 15 km to the south of Ballari city. Due to its scenic view, nature beauty and proximity to the city, MRF is a popular picnic destination for local visitors, tourists and trekkers. MRF is surrounded by many fringe villages particularly Mincheri and Sanjeevarayana Kote in the North, Bench Kottal in the East, and the Southern border of the MRF is shared with Andhra Pradesh state. Few steel industries namely Yeshashvi Steels and Alloys Pvt. Ltd. and SLV Steels and Alloys Pvt. Ltd. are established in Nemakallu village along with stone crushing units are housed in the forest area which belongs to the state of Andhra Pradesh.

The total geographical area of Mincheri Reserve Forest is 1132.5 ha and perimeter is 30.02 km. The geographical co-ordinates are located between 15.0247 to 15.0560 North latitude and 76.8730 to 76.9615 East longitude. An elevation of study area is ranging from 476 to 736 m above MSL.

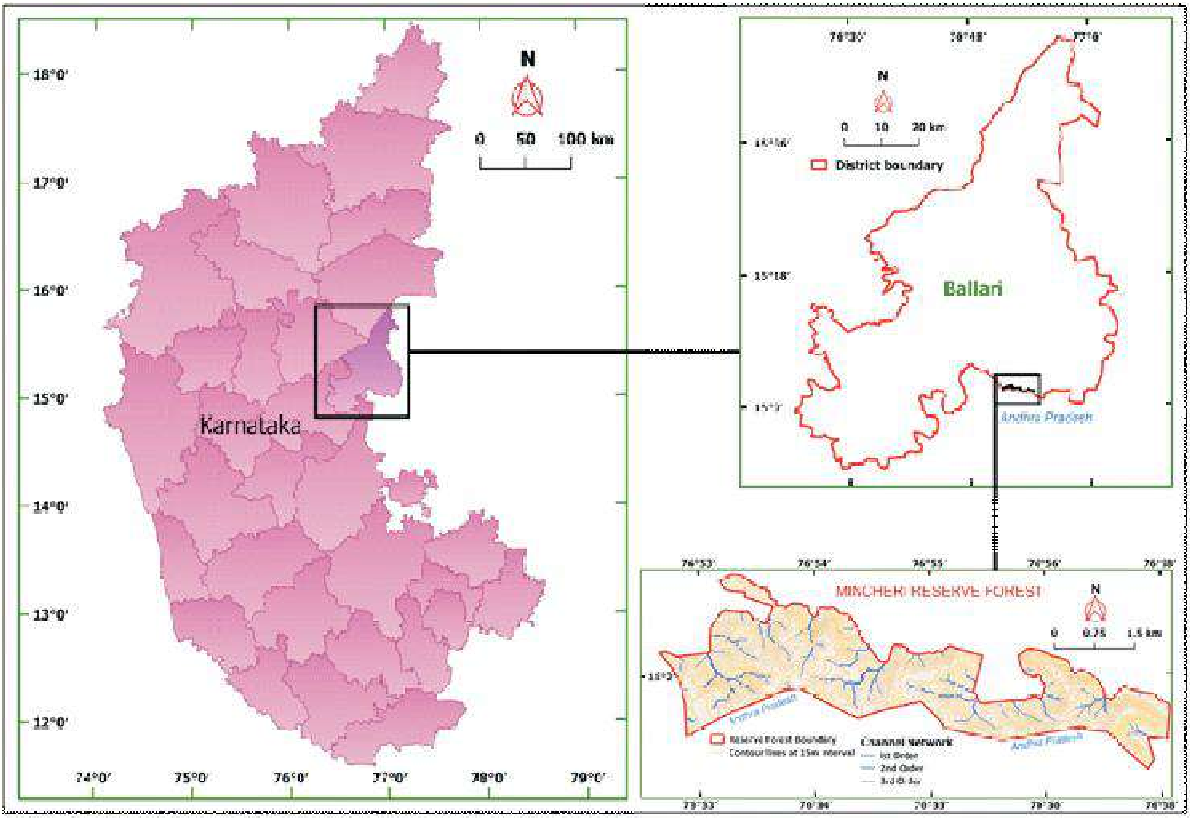

Fig. 1: Location map of Mincheri Reserve Forest

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 average annual rainfall of the locality is 490 mm received in 32 rainy days. Average annual rainfall data of surrounding MRF micro-watersheds is 498.5 mm (1986 to 2020) which is taken from IMD gridded data.

The vegetation of Ballari territorial forest division varies from dry mixed deciduous type to thorny scrub types. The MRF is covered with tropical thorn forest which comes under the forest type of Southern Thorn Forest (Type 6A/C1). The over wood vegetation consists of *Vachellia horrida, V.catechu, V. leucophloea, V. chundra, Albizzia amara, Flueggea leucopyrus, Rhus mysorensis, Dichrostachys cinerea, Prosopis, Ziziphus, Anogeissus, Soymida* etc.

PROBLEMS IDENTIFIED

H Lack of dense tree cover (<15%) and majority of the hill exposed to direct erosion risk due to sparse vegetation

H Undulated terrain and steep slope (average slope of reserve forest is 23.31%), shallow soil depth and lack of SWC measures resulting high run - off causing severe erosion (Fig. 2) ranging 18.52 t $ha^{-1}yr^{-1}$ for average sloping condition and 61.49 t $ha^{-1}yr^{-1}$ for maximum sloping conditions.

H The reserve forest is surrounded by some sponge iron industries causing environmental degradation

H Grazing and encroachments in the surrounding fringes of Reserve Forest.

OBJECTIVES OF THE STUDY

C To characterize physiography of Mincheri Reserve Forest catchment using GIS 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 soil erosion.

C To suggest in-situ soil moisture conservation plan for supporting regeneration of vegetation through site-specific SWC measures .

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

Fig. 2: Glimpses of visit to the major erosion sites of Mincheri Reserve Forest with forest officials.

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 below.

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 MRF were analyzed 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

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. 3). The database for the preparation of various thematic maps was largely extracted from the digital elevation models provided by Shuttle Radar Topographic Mission (SRTM) and Carto DEM (Version-3R1). The details of overview of data used for the study are presented in Table 2.

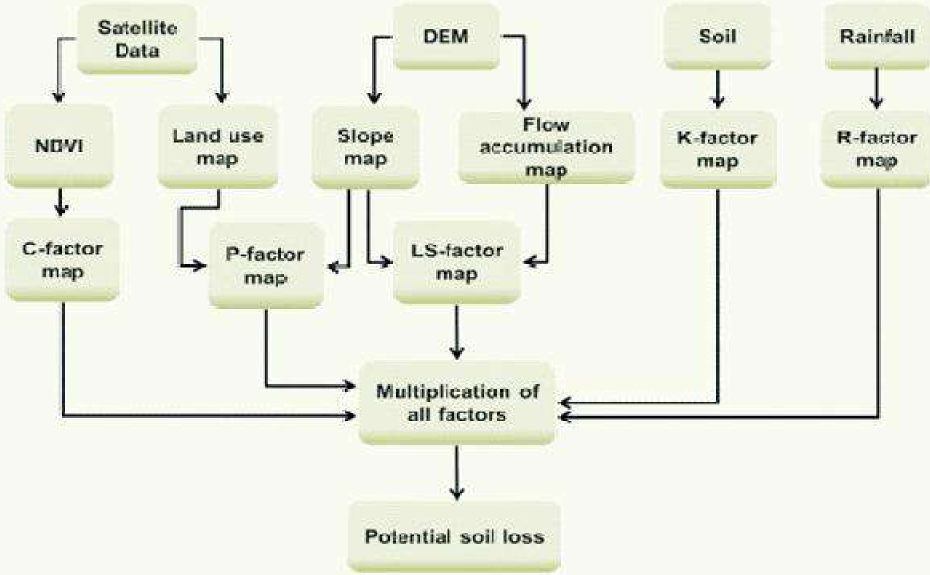

Fig. 3 Flowchart to estimate potential soil loss in GIS environment

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 MRF. 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 to control soil erosion and moisture conservation.

The curve number (CN) is the watershed coefficient which represents the runoff potential of the land cover soil complex.

$Q = (P - 0.2S)^2 / (P + 0.8S)$ .... (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 MRF falls under group A and C varying from low runoff potential to moderately high runoff potential. Hence average condition of hydrological soil group 'B' is considered for runoff curve number. Antecedent Moisture Condition-II (AMC-II) is considered here for runoff estimation. MRF comes under degraded scrub with average condition of hydrological soil group 'B' and thus, runoff curve number is taken as 47, 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 MRF 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 10000 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).

$A = R\,K\,L\,S\,C\,P$ ....(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 equation (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 developed is as below.

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

Where, Y is the average annual erosion index ($t\,ha^{-1}\,cm^{-1}$) and X is the average annual rainfall in mm. For the present study area, the average annual rainfall data of surrounding MRF micro-watersheds is 498.5 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:

$100K = 2.1 \times 10^{4} (12 \times OM)\, M^{1.14} + 3.25 (S2) + 2.5 (P3)$ ………… (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 L (slope length) and S (slope steepness) factors as given below:

$L = 1.4 (AS/22.13)^{0.4}$ …………. (vi) and

$S = (\sin?/\ 0.0896)^{1.3}$ …………(vii)

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

The C value is 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 0.6 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. 4) of MRF. The most of forest land is covered with sparse vegetation (84.77%), while 14.52% area is under dense vegetation. Barren land and shrubby grasslands from reserve forest contributes <1% of the total geographical area of forest.

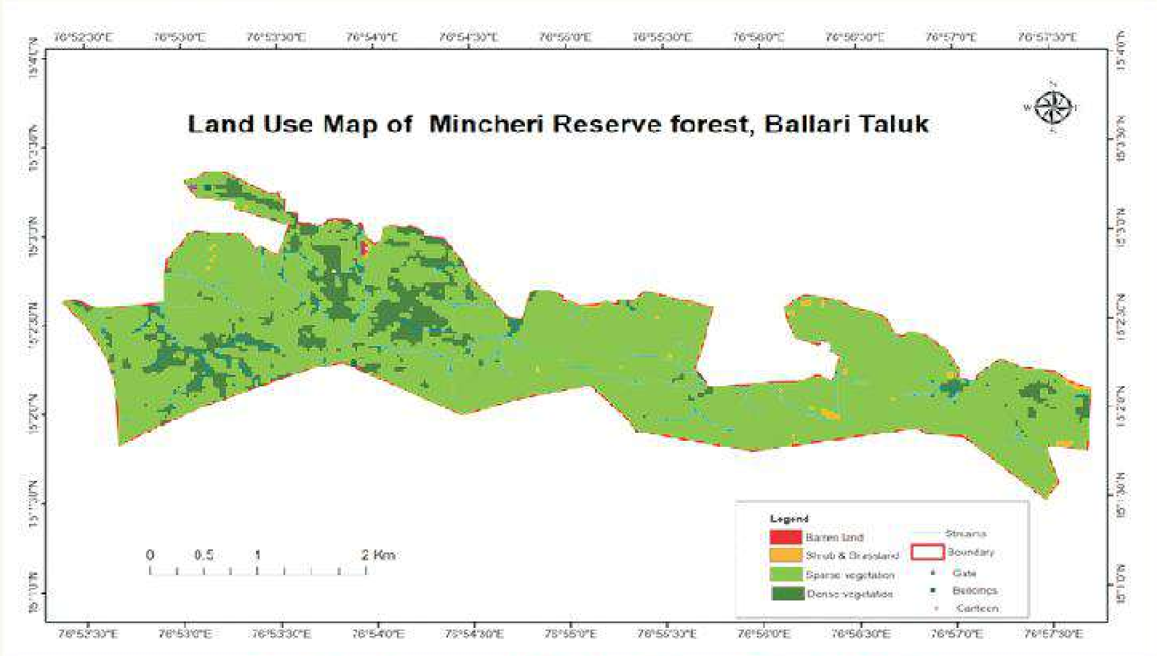

Fig. 4: Land use map of Mincheri Reserve Forest, Ballari

Geomorphology and lithology

The geomorphology of MRF is spread over dissected hills and valleys with Pediment Pediplain complex. Metamorphosed volcanic rocks of Mincheri formation are composed mainly of basalt, banded iron, dolerite, gabbro and grey hornblende biotite gneiss (GSI, 2022).

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 MRF and laboratory analysis of soil samples revealed following soil texture map (Fig. 5) and soil physico-chemical properties (Table 3 and 4). Majority of forest area had sandy clay texture followed by sandy clay loam and loamy sand. An average bulk density (g cm^{-3}), porosity (%), water holding capacity (%) and volume expansion (%) of MRF soils is 1.49, 37.86, 36.69 and 16.52 respectively. The gravel percent in soil was ranged from 25.4 to 68.5% and soil percent from same samples was ranged from 31.5 to 74.6%.

Table 3: Soil physical properties in Mincheri Reserve Forest

Sl. No	Texture	Sand (%)	Silt (%)	Clay (%)	Bulk density (g cm^{-3})	Porosity (%)	Water holding capacity (%)	Volume expansion (%)
1	Sandy clay loam	62.24	16.0	21.76	1.50	38.99	36.45	15.61
2	Sandy loam	64.25	18.0	17.75	1.36	38.71	42.56	19.37
3	Loamy sand	82.20	8.0	9.80	1.61	37.13	30.98	12.64
4	Sandy loam	60.24	20.0	19.76	1.50	36.60	36.75	18.44

Table 4: Soil chemical properties in Mincheri Reserve Forest

Sl. No	pH	EC (dS m^{-1})	Organic carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorous (kg ha^{-1})
1	6.61	0.06	1.02	545.7	66.7
2	6.16	0.10	0.45	633.5	17.9
3	6.26	0.05	0.66	432.8	47.5
4	6.63	0.05	0.95	564.5	40.6

Mean pH and EC values of 6.42 and 0.07 dS m^{-1}, respectively signifies 'neutral' soil reaction status. Average soil organic carbon was 0.77% and available nitrogen ranged from 432.8 to 633.5 kg ha^{-1}, indication 'medium' to 'high' soil fertility status. Similar trend for available phosphorous content was observed and the values were ranged from 17.9 to 66.7 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 and available nitrogen.

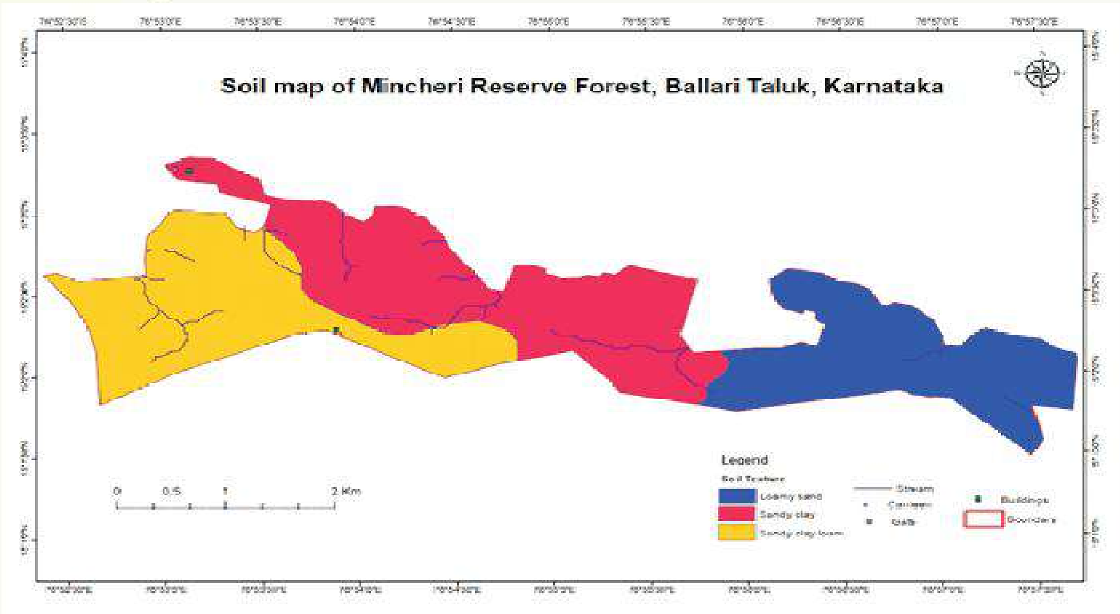

Fig. 5: Soil texture map of Mincheri Reserve Forest

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 of MRF falls under hydrological group A and group C, indicating low runoff potential and moderately high runoff potential respectively (Table 5).

Table 5: Hydrological soil groups in Mincheri Reserve Forest

Sl. No.	Texture	Hydrological soil group	Water infiltration capacity	Area (ha)	Area in Percentage
1	Sandy clay loam	C	Low	365	32.24
2	Sandy loam	A	High	446	39.43
3	Loamy sand	A	High	321	28.33

Slope map

The slope map provides information on the degree of steepness of the area, hence 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). The slope of MRF is ranged from 0 to 69.60% and an average slope of entire area is 23.31%.The slope of the area of MRF was divided into following nine classes and area (total and percent) under particular slope is given here (Table 6 and Fig. 6). More than 80% area of reserve forest is on steep slope signifying higher soil erosion potential.

Table 6: Slope distribution in Mincheri reserve forest

Slope (%)	Description	Area (ha)	% of TGA
0-1	Nearly level	1.95	0.17
1-3	Very gently sloping	11.98	1.06
3-5	Gently sloping	27.49	2.43
5-10	Moderately sloping	121.67	10.75
10-15	Strongly sloping	154.83	13.68
15-25	Moderately steep to steep	329.54	29.12
25-33	Steep	224.67	19.85
33-50	Very steep	228.76	20.22
>50	Very very steep	30.74	2.72

Elevation and contour map

The topography of the study area shows high relief and relatively steep slope (Fig. 7). The elevation of Mincheri reserve forest is ranging from 736 m in South-eastern part to 476 m in North-eastern part. The basin relief is 260 m. The contour map of 20 m interval was prepared (Fig. 7).

Drainage density

Drainage density (D) 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 (D) 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) (Smith, 1950). 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.

Since MRF has steep topography and many outlets with high stream length (339 km) from smaller catchment (11.3 km^2), its average drainage density is exceptionally high (29.95 km km^{-2}). Western half (Fig.8) of the reserve forest has higher density than Eastern half due to higher elevation, steep slopes and valleys. 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 MRF, drainage texture is 101 km^{-1}.

Runoff estimation for Mincheri Reserve Forest

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

From equation (i), total annual runoff yield (Q) is calculated as **267.54** mm (53.66% of rainfall)
Again applying equation (ii), potential maximum retention (S) is determined as 286.42 mm.
Total annual runoff yield in volume = Area of the catchment × runoff depth
= 1132.5 ×10000× (267.54/1000) = **3029890.5 m^3**

Soil loss calculation for Micheri Reserve Forest

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

R= 270.93
K=0.602
L=269
S= 3.35° (Avg. slope)
=11.12° (Max. slope)
C= 0.238, P= 0.6
A= 20975.85 ton (18.52 t ha^{-1} yr^{-1} for average sloping condition)
= 69637.55 ton (61.49 t ha^{-1} yr^{-1} for maximum sloping condition)

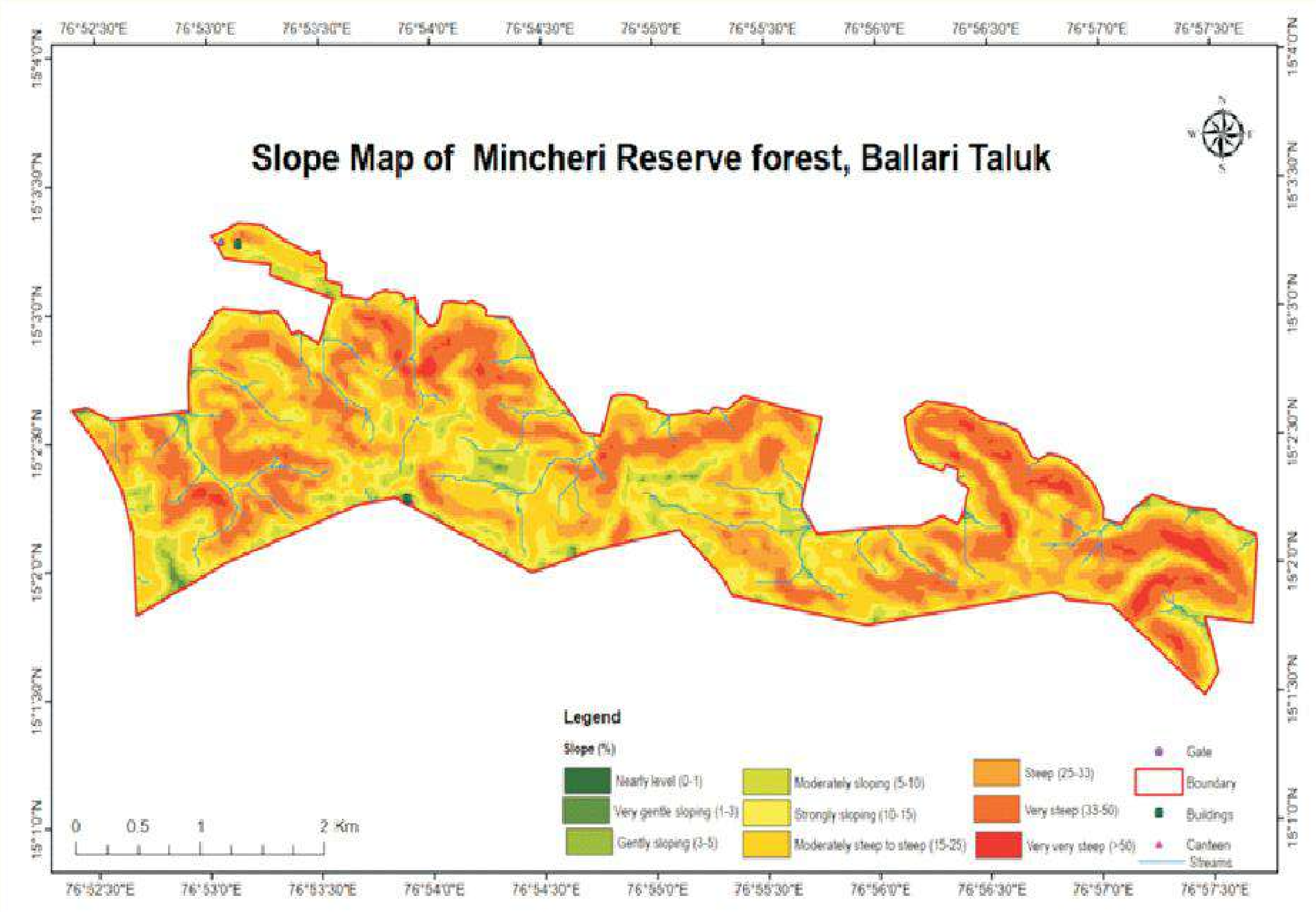

Fig. 6 : Slope map of Mincheri Reserve Forest

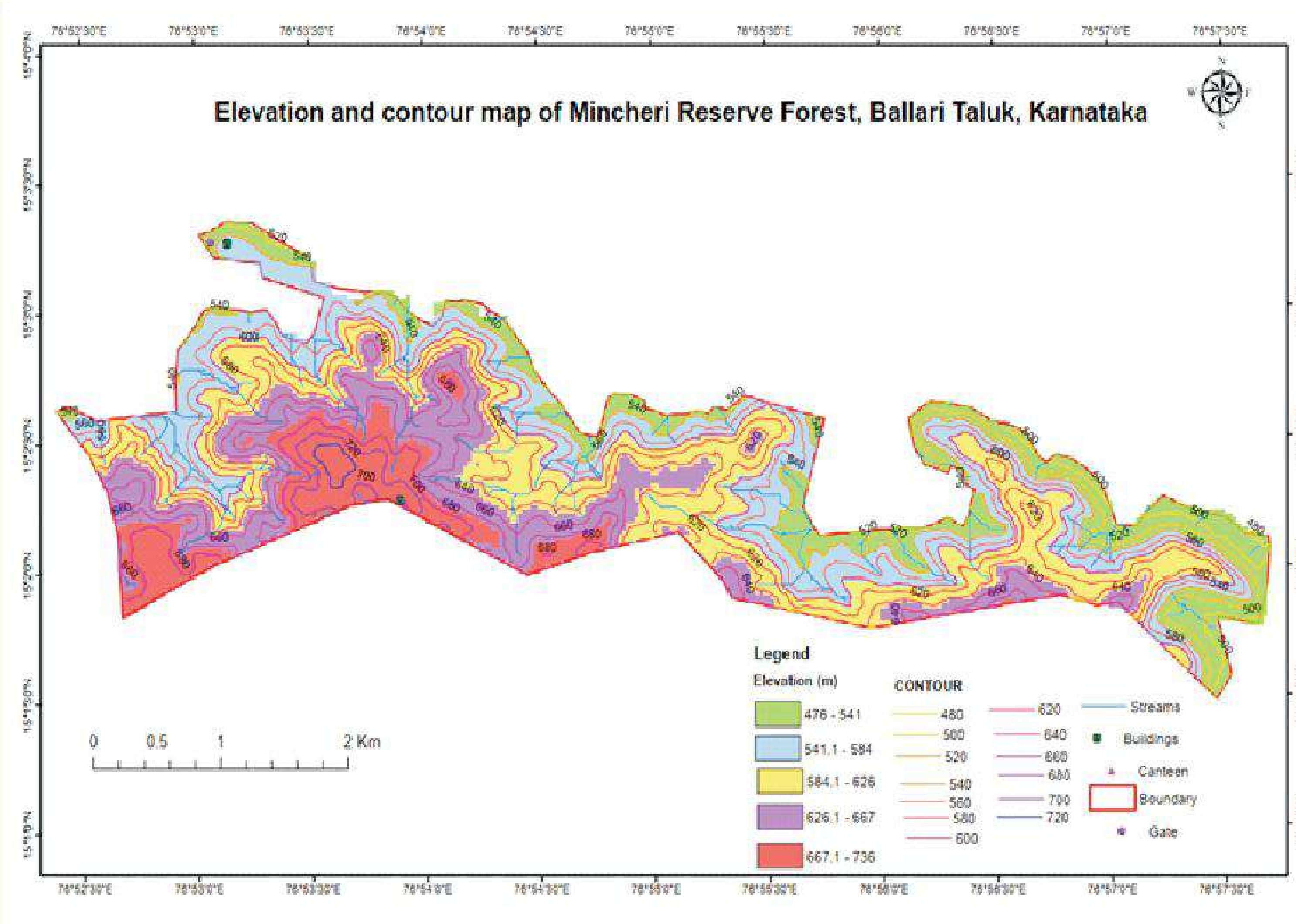

Fig. 7: Elevation and contour map of Mincheri Reserve Forest

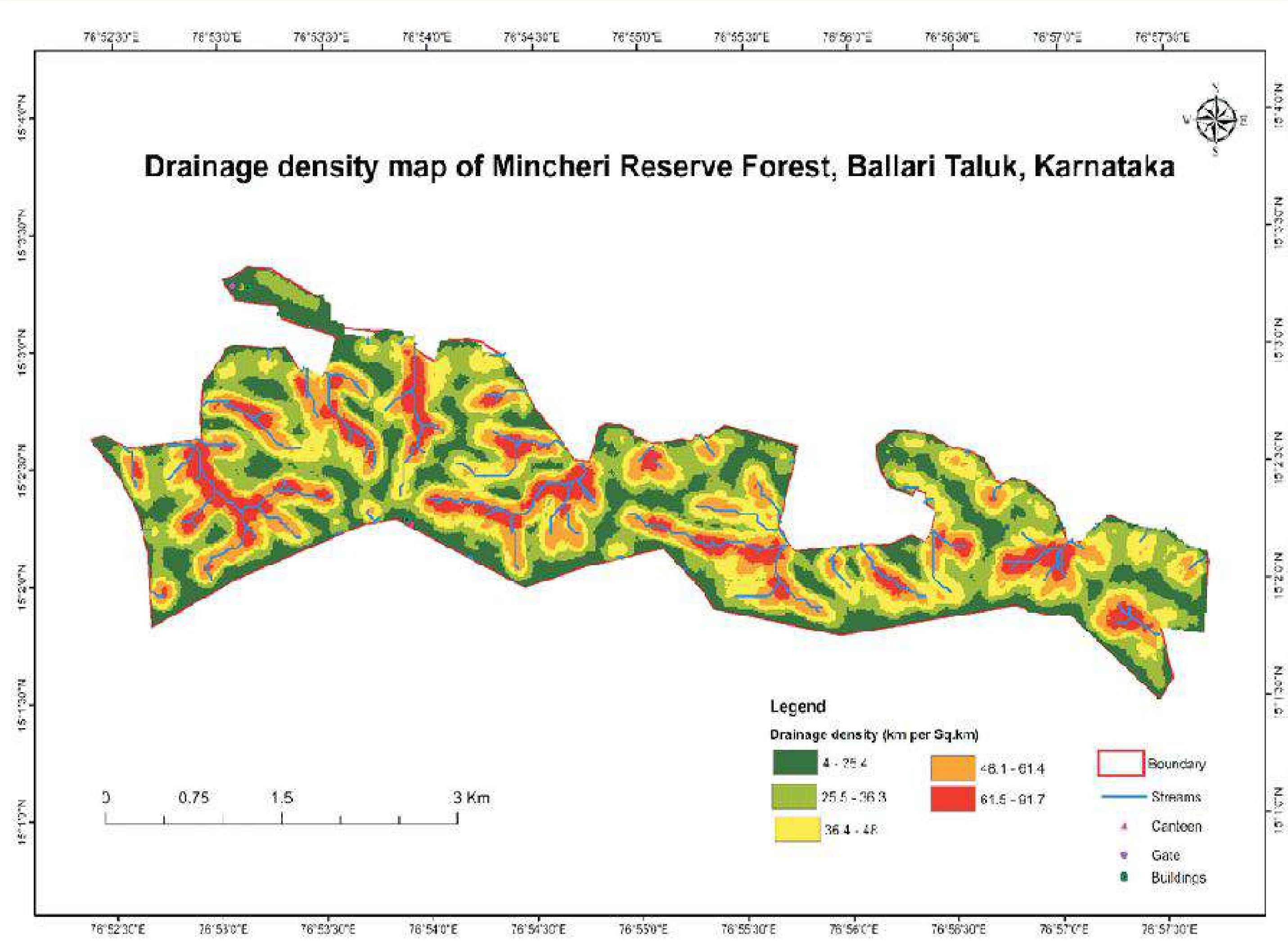

Fig. 8: Drainage density map of Mincheri Reserve Forest

PROPOSED SOIL AND WATER CONSERVATION TREATMENT PLAN

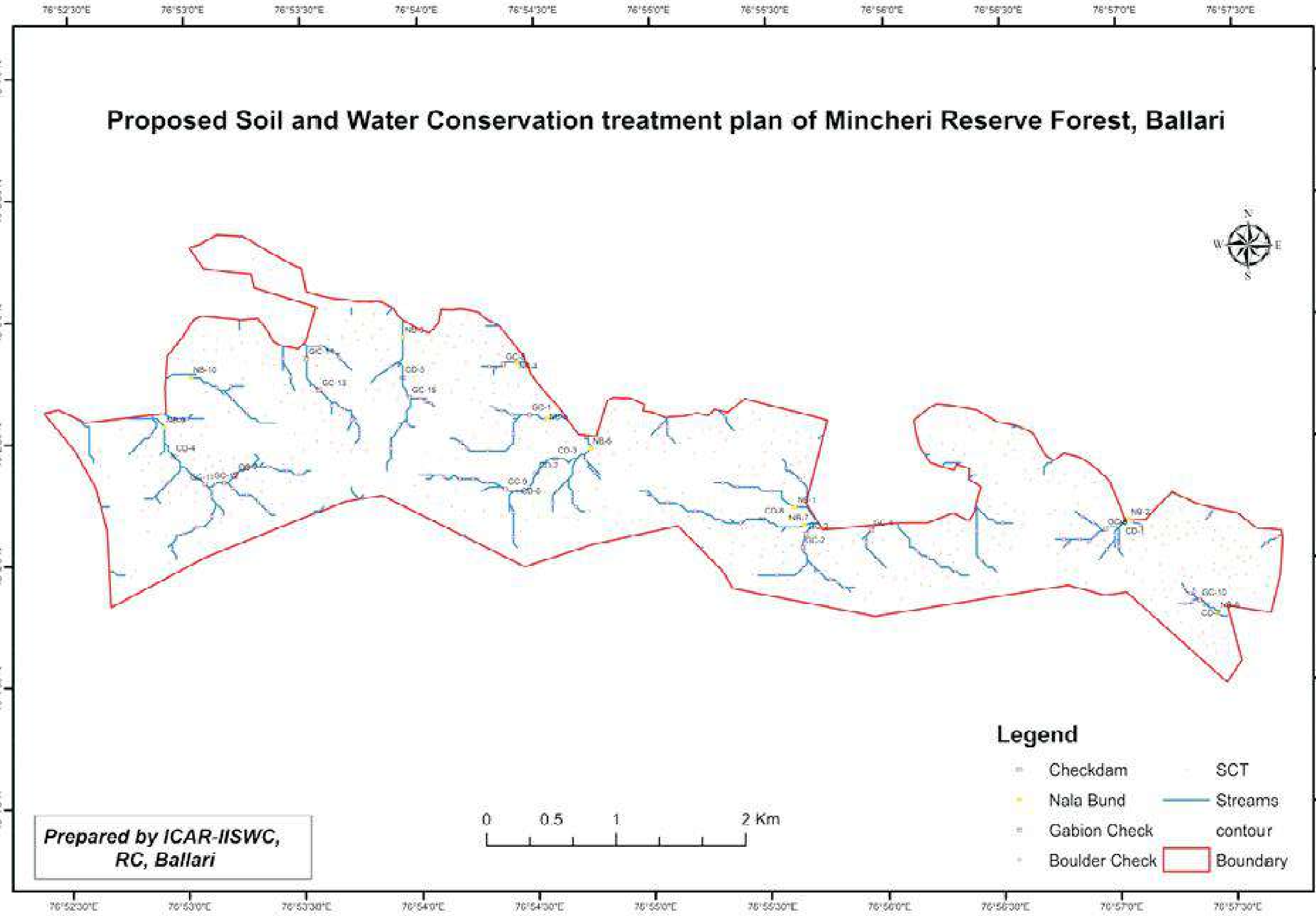

Fig. 9: Proposed Soil and Water Conservation Treatment Map and Plan

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 soil and water conservation 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 & 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. 9). The following criteria were adopted for identifying potential site-specific SWC sites.

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

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	20-100
4	Nala bunds with spill way	≤ 15	Down stream	III or IV	30-100
5	Staggered Contour Trench (SCT)	33-50	Upper /middle / lower reach	-	-

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

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

Sl. No	Loose Boulder checks	Geo-coordinates	
		Longitude (E)	Latitude (N)
1	LBC-1	76.89787	15.04683
2	LBC-2	76.90499	15.04679
3	LBC-3	76.90535	15.0466
4	LBC-4	76.90288	15.04161
5	LBC-5	76.90332	15.04121
6	LBC-6	76.9048	15.04101
7	LBC-7	76.90538	15.0439
8	LBC-8	76.90582	15.04376
9	LBC-9	76.90655	15.04348
10	LBC-10	76.90664	15.04218
11	LBC-11	76.9006	15.03939
12	LBC-12	76.90166	15.03923
13	LBC-13	76.90278	15.0391
14	LBC-14	76.90474	15.03881
15	LBC-15	76.90657	15.03509
16	LBC-16	76.90658	15.03678
17	LBC-17	76.90774	15.03851
18	LBC-18	76.90976	15.03825
19	LBC-19	76.91085	15.03779
20	LBC-20	76.90943	15.03736
21	LBC-21	76.91111	15.03712
22	LBC-22	76.91241	15.03945
23	LBC-23	76.91185	15.04028
24	LBC-24	76.91793	15.04178
25	LBC-25	76.91719	15.04263
26	LBC-26	76.9177	15.04253
27	LBC-27	76.92183	15.0432
28	LBC-28	76.92617	15.03964
29	LBC-29	76.92707	15.03884
30	LBC-30	76.92162	15.03867
31	LBC-31	76.92267	15.03838
32	LBC-32	76.92512	15.03809
33	LBC-33	76.91621	15.03816
34	LBC-34	76.9166	15.03781
35	LBC-35	76.91767	15.03733
36	LBC-36	76.91964	15.03676

37	LBC -37	76.92155	15.03608
38	LBC -38	76.92289	15.0359
39	LBC -39	76.92547	15.03232
40	LBC -40	76.92718	15.03278
41	LBC -41	76.93019	15.03144
42	LBC -42	76.92973	15.03177
43	LBC -43	76.92922	15.03199
44	LBC -44	76.92841	15.03253
45	LBC -45	76.9326	15.03338
46	LBC -46	76.93179	15.03455
47	LBC -47	76.93817	15.03248
48	LBC -48	76.93695	15.03295
49	LBC -49	76.93619	15.03343
50	LBC -50	76.9355	15.03384
51	LBC -51	76.94006	15.03322
52	LBC -52	76.93973	15.03524
53	LBC -53	76.94158	15.03575
54	LBC -54	76.94597	15.03461
55	LBC -55	76.94625	15.03434
56	LBC -56	76.94731	15.03615
57	LBC -57	76.94811	15.03569
58	LBC -58	76.94782	15.03447
59	LBC -59	76.94906	15.03388
60	LBC -60	76.94965	15.03491
61	LBC -61	76.9471	15.03459
62	LBC -62	76.9482	15.03483
63	LBC -63	76.94993	15.03409
64	LBC -64	76.94979	15.03444
65	LBC -65	76.95149	15.03553
66	LBC -66	76.95094	15.0358
67	LBC -67	76.95636	15.03607
68	LBC -68	76.95665	15.03653
69	LBC -69	76.96042	15.03422
70	LBC -70	76.96114	15.03463
71	LBC -71	76.95457	15.03123
72	LBC -72	76.95528	15.03093
73	LBC -73	76.955	15.03082
74	LBC -74	76.95461	15.03013
75	LBC -75	76.95516	15.03028

76	LBC-76	76.90372	15.0391
77	LBC-77	76.8822	15.03441
78	LBC-78	76.88301	15.03549
79	LBC-79	76.88399	15.03596
80	LBC-80	76.88506	15.03667
81	LBC-81	76.88203	15.03907
82	LBC-82	76.88073	15.04229
83	LBC-83	76.88758	15.03813
84	LBC-84	76.88658	15.0386
85	LBC-85	76.89138	15.03948
86	LBC-86	76.88904	15.03701
87	LBC-87	76.88838	15.03763
88	LBC-88	76.89046	15.03976
89	LBC-89	76.88914	15.04005
90	LBC-90	76.88817	15.04005
91	LBC-91	76.8867	15.03944
92	LBC-92	76.88531	15.03893
93	LBC-93	76.88505	15.03806
94	LBC-94	76.88333	15.04339
95	LBC-95	76.88234	15.04341
96	LBC-96	76.88649	15.04552
97	LBC-97	76.88764	15.04366
98	LBC-98	76.8866	15.0447
99	LBC-99	76.88552	15.04548
100	LBC-100	76.89025	15.04746
101	LBC-101	76.8908	15.04617
102	LBC-102	76.89559	15.04251
103	LBC-103	76.89531	15.04317
104	LBC-104	76.89454	15.04396
105	LBC-105	76.89361	15.04418
106	LBC-106	76.89503	15.04322
107	LBC-107	76.89421	15.04745
108	LBC-108	76.89374	15.0479
109	LBC-109	76.89282	15.04828
110	LBC-110	76.89784	15.04123
111	LBC-111	76.89844	15.0426
112	LBC-112	76.89910	15.0429
113	LBC-113	76.90036	15.04442
114	LBC-114	76.90075	15.0443
115	LBC-115	76.90000	15.04463

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

Sl. No	Gabion checks	Longitude(E)	Latitude(N)
1	GC-1	76.90781	15.04346
2	GC-2	76.92726	15.03420
3	GC-3	76.92750	15.03515
4	GC-4	76.93217	15.03536
5	GC-5	76.94896	15.03529
6	GC-6	76.88757	15.03999
7	GC-7	76.8868	15.03954
8	GC-8	76.90598	15.04693
9	GC-9	76.90603	15.03839
10	GC-10	76.95569	15.03039
11	GC-11	76.88459	15.03889
12	GC-12	76.88597	15.03897
13	GC-13	76.89277	15.04525
14	GC-14	76.89194	15.0474
15	GC-15	76.89922	15.04472

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

Sl. No	Check dam	Longitude (E)	Latitude (N)
1	CD-1	76.95022	15.03567
2	CD-2	76.90828	15.03941
3	CD-3	76.90964	15.04042
4	CD-4	76.88236	15.04082
5	CD-5	76.89875	15.04605
6	CD-6	76.90701	15.03824
8	CD-7	76.95619	15.03005
9	CD-8	76.92445	15.03617

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

Sl. No	Nala bunds	Longitude (E)	Latitude (N)
1	NB-1	76.92672	15.03697
2	NB-2	76.95065	15.03594
3	NB-3	76.89878	15.04882
4	NB-4	76.90693	15.04706
5	NB-5	76.90907	15.04318
6	NB-6	76.91218	15.04113
7	NB-7	76.92735	15.03573
8	NB-8	76.95702	15.02952
9	NB-9	76.8817	15.04278
10	NB-10	76.88364	15.04622

COST ESTIMATION FOR CONSTRUCTION OF SWC MEASURES

Table 12. Tentative cost 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)	115	0.25	28.75
2	Gabion checks	15	0.6	9
3	Check dams	9	15	135
4	Nala bunds with spill way	10	11	110
5	Staggered Contour Trenches	45752	0.002	91.5
	Estimated cost* (Rs. in lakhs)			374.25

*Area under 33-50% slope will be covered under Staggered Contour Trenches (see slope details in Table 6) with trench size 2 x 1 x 1 m (Appox. 200 trenches per ha).

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 Mincheri Reserve Forest area is highly vulnerable to soil erosion due to steep slopes, scanty vegetation/degraded scrubs, high drainage density, heavy runoff and low infiltration rate with existing sandy clay loam soil. Present land use map reveled that only 14.52% area of reserve forest is under dense vegetation. Steep slope, smaller catchment area and undulated topography has led to exceptional high drainage density of 29.8 km km^{-2}. Higher annual runoff of 3029890.5 m^3 (53.66% of rainfall) was estimated, and annual soil loss to the tune of 20975.85 ton (18.52 t ha^{-1} yr^{-1}) and 69637.55 ton (61.49t ha^{-1} yr^{-1}) has been computed for average sloping condition and for maximum sloping condition, respectively. 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 Mincheri 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. The catchment area treatment in reserve forest area can cause significant increase in water availability in Reserve Forest area and also groundwater level in bore wells located in downstream arable lands.

REFERENCE

Babu, R., Dhyani, B. L., & 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., & 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., & 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.

Keen, B. A., &Raczkowski, 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., & 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., & 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.

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, 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). National Engineering Handbook, Part 630 Hydrology, Chapters 7: Hydrologic Soil Groups. Washington, DC. Available online at http://directives.sc.egov.usda.gov/.

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

Walkley, A., & 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.

ICAR-INDIAN INSTITUTE OF SOIL AND WATER CONSERVATION

Research Centre, Ballari, Karnataka - 583 104.