Cost Benefit Analysis studies for Conversion of Underground Mine to Open Cast Mine of Venkatesh Khani Coal Mines of SCCL

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1 Introduction

Singareni Collieries Company Limited (also known as SCCL) is jointly owned by the Government of Telangana (51%) and the Government of India (49%). It comes under the Department of Energy of Telangana Government. The Union Government's administration of the company is held by the Ministry of Coal.

The Singareni Collieries Company Ltd. (SCCL) currently operates 24 underground mines and 18 open cast mines. These 42 mines are spread over six districts of Telangana which are Komaram, Bheem Asifabad, Mancherial, Peddapalli, Jayashankar Bhupalpalli, Bhadradri Kothagudem and Khammam. In the Godavari valley coalfield – There is a gap of 19.5 MT between demand and supply. To bridge this gap, SCCL is undertaking expansion of existing opencast mines, conversion of underground mines to opencast and opening new mines in the lease hold area. SCCL is also to open a new coal mine (Naini Coal Block) in Odisha State.

Figure i: Study Area

The study area of 650 Ha is located at Ramavaram RF, Kothagudem Forest Division in Bhadradri Kothagudem district of Telangana. Its geographical coordinates are Latitude 170 27’18” N to 170 28’04” N and Longitude 800 37’30” E to 800 39’45” E. The maximum temperature varies between 22.5 to 40.6°C with wind speed of 5.6m/s for south to south-west direction. The relative humidity ranges between 42.6 percent and 99.9 percent. The annual rainfall is 1150.7mm. There is presence of red soil.

The present assignment deals with calculating a revised benefit cost ratio taking into account the costs related to Ecosystem Services. These costs have not been accounted for in the original NPV calculations. The result is a revised Benefit-Cost ratio after considering the costs of ecosystem services that have not been taken into account in the original ratio.

2 Ecosystem Services

Ecosystem Services

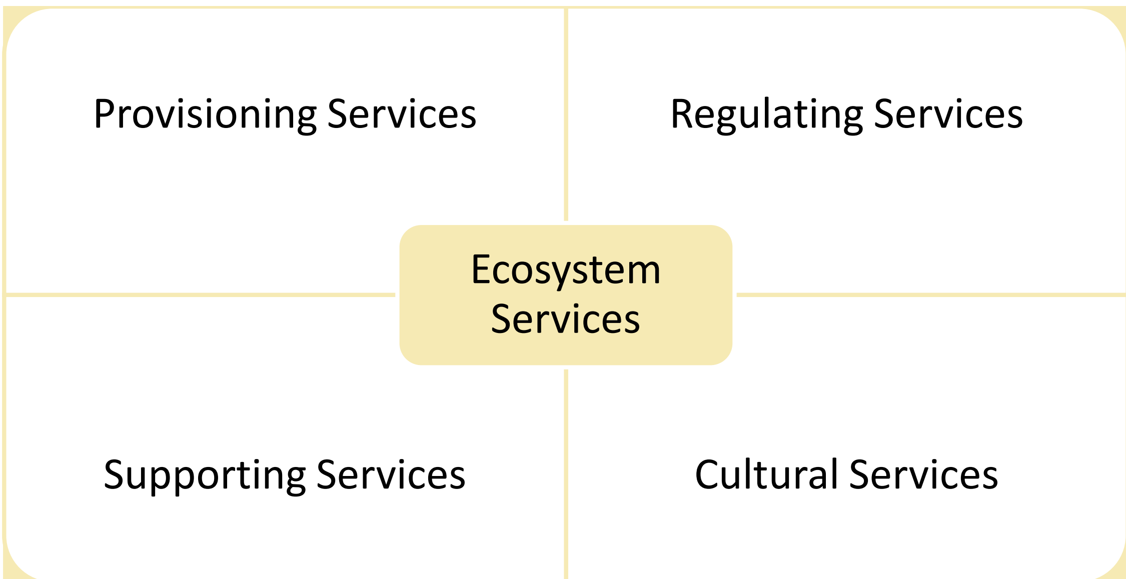
Benefits (in terms of goods or services) provided by nature that are of fundamental importance to human well-being, health, livelihoods, and survival and include provisioning services, regulating services, cultural services, and supporting services

The first study on the concept of the ecosystem was done by Daily et al. (1997). According to the study, ecosystem services are "a wide range of conditions and processes through which natural ecosystems, and the species that are a part of them, help sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods, such as food, forage timber, biomass, fuel, natural fibre, and many pharmaceuticals, industrial products, and their precursors".

Some common examples of ecosystem services are carbon sequestration and storage, air and water purification, flood mitigation, soil fertility, generation, renewal and preservation of soils, wastes decomposition, pollination, seeds dispersal, nutrients cycling, protection from the sun's harmful ultraviolet rays, partial stabilization of climate, moderation of weather events, aesthetic beauty, etc.

The flow of ecosystem goods and services in a region is determined primarily by its spatial dimensions. It also depends on the extent, the type, layout, and the associated ecosystem which are supplying the resources. For instance, the value of water quality service offered by a waterbody can critically be affected by the amount of nutrients cycled, sediments retention, waste detoxification etc. It may also be dependent on the location and soil type.

The Millennium Ecosystem Assessment (MEA) report of 2005, defines ecosystem services as the benefits people obtain from ecosystems. It categorizes ecosystem services under the following four categories.



There are few other studies where ecosystem services classification is based on the functional groups (de Groot et al., 2002, MA, 2005) such as habitat, production, regulation, carrier, and information services. The other classification (Norberg, 1999) is through organizational groupings. It includes services associated with certain species, that regulate some exogenous input, or that are related to the organization of biotic entities.

Another classification is through descriptive groupings, such as renewable non-renewable, resource goods, physical structure services, biotic services, biogeochemical services, information services, and social and cultural services (Moberg and Folke, 1999).

However, Boyd and Banzhaf, 2007 and MA, 2005 consider ecosystem services as only those goods and services that are directly enjoyed, consumed or used by humans as Final Ecosystem Goods and Services (FEGS). It identifies the following four types of ecosystem goods and services.

Directly usable final ecosystem goods and services	Used directly by the human population (e.g., recreational or protective services, foodstuffs and feed production, timber yield, contribution to renewable energy)
Input factors for market goods	Not directly consumed (e.g., pollination as an agricultural input)
Natural/healthy living environment	Qualities of health-related environmental media are summarized (e.g., air quality)
Intermediate ecosystem goods and services	Offer humans no direct benefit

According to Staub et al. (2011) ecosystem services “concentrates on those aspects of ecosystems that have a recognizable connection to (human) welfare, and is used or valued in some form or other by the human population”.

3 Sediment Delivery Ratio (SDR)

3.1 Introduction

Sediment generation and transport is a natural ecosystem process. At landscape scales, erosion generates sediments and is mainly transported by water. The sediment is transported to and deposited in floodplains and the sea. It enriches the floodplains and coastal areas, and has led to the formation of deltaic regions. Natural vegetation cover is a vital element in this process, it slows down the process of erosion and traps substantial part of the sediment within the catchment. Without adequate natural vegetation, soil erosion and transport processes are much accelerated. These lead to poor soil quality, excessive siltation in river and streams, leading to increased flooding and shortening of lifespan of reservoirs due to siltation. An imbalance in sediment erosion and transport has far reaching consequences from local to regional scales. Thus, forests provide an important Ecosystem service by regulation of sediment dynamics.

3.2 Data acquisition

3.2.1 Land Use Land Cover (LULC)

The LULC raster was sourced from the European Space Agency (ESA) initiated - WorldCover project. The land cover product is at 10 m resolution for the year 2020 and is based on both Sentinel-1 and Sentinel-2 data, containing 11 land cover classes out of which 7 land cover classes were witnessed in our study area.

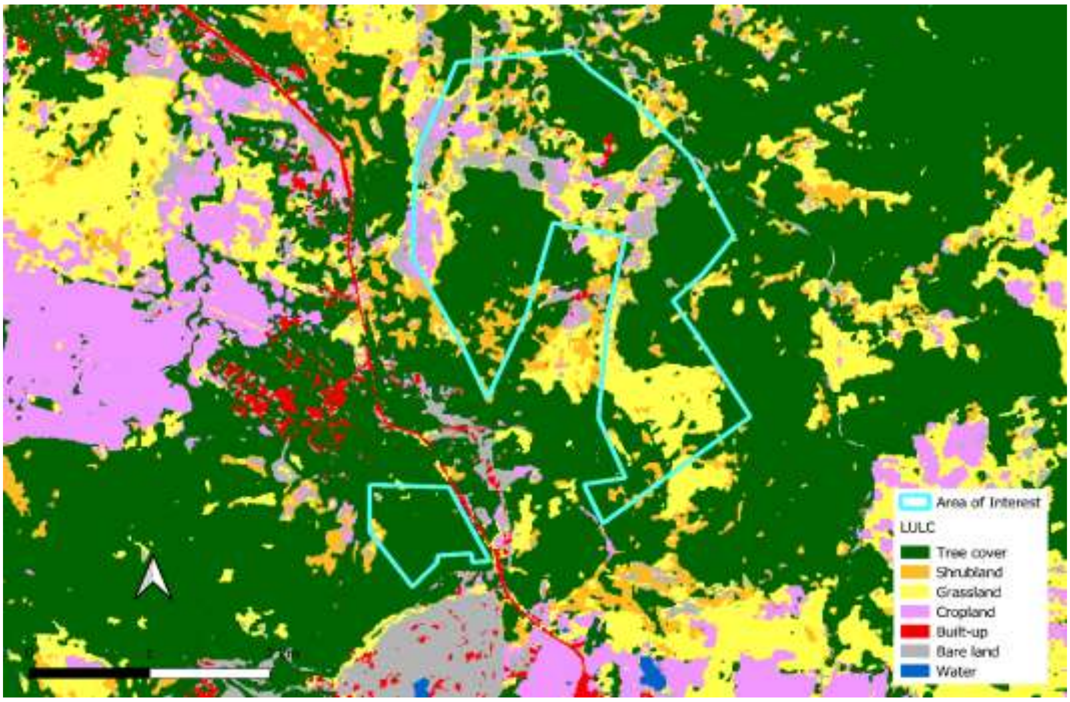


Figure ii: LULC of the study area

3.2.2 Watersheds

InVEST tool DelineateIT is used to delineate watersheds. Watershed creation tools provided with GIS software, as well as some hydrology models, recommends to use the DEM that is being used in the InVEST modeling, such that the watershed boundary corresponds correctly to the topography.

3.2.3 Digital Elevation Model

A digital elevation model (DEM) is a raster map of elevation, where each pixel's value is its elevation above sea level (usually in meters). The Bhuvan website hosted by the National remote sensing center was used for the same. The satellite referred is Cartosat-1: CartoDEM Version-3 R.

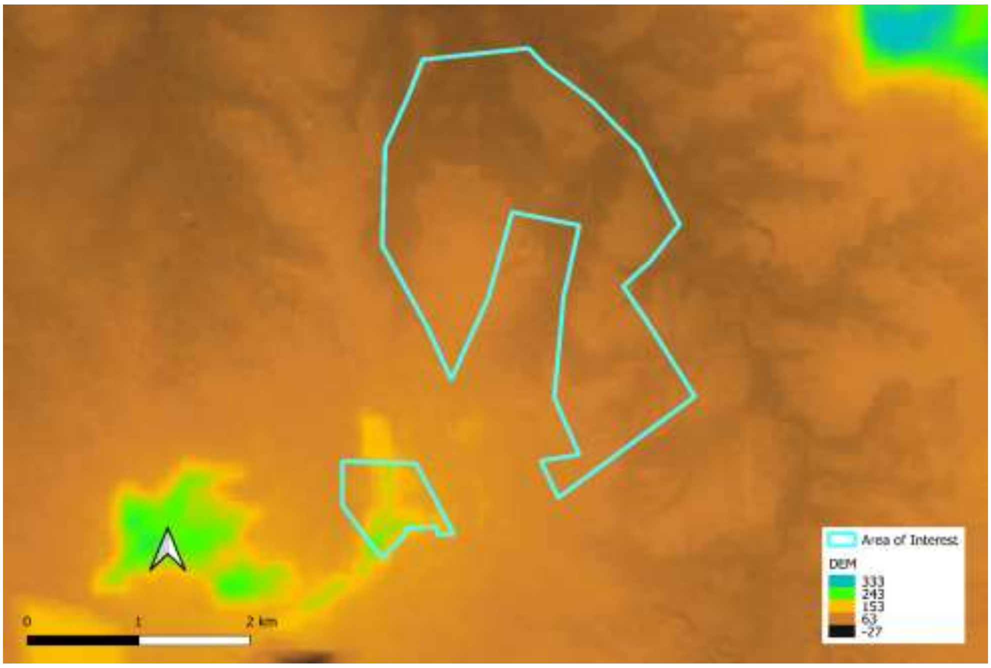


Figure iii: DEM of the study area

3.2.4 Erosivity

Rainfall Erosivity Index (R) is obtained from the country specific equations derived based on extensive literature search. The raster file of rainfall erosivity is obtained by using the formula: **R = 81.5 + 0.38P,** where R is the rainfall erosivity and P is the mean annual precipitation (Babu, B. L., & Kumar, 2004; Jain & Das, 2010; Benavidez, Rubianca, Jackson, & Max, 2018).

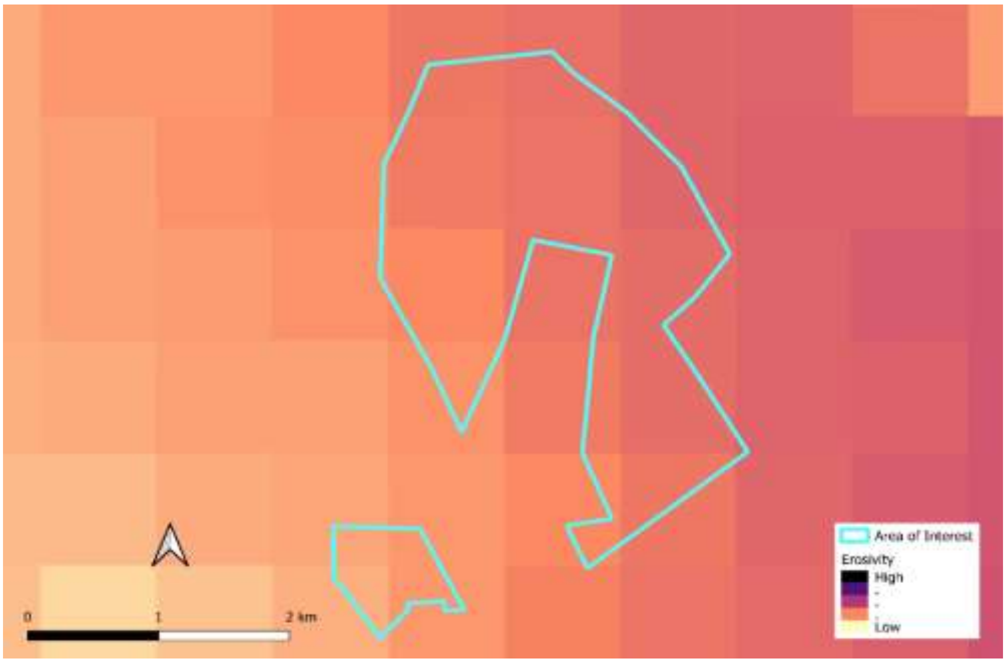
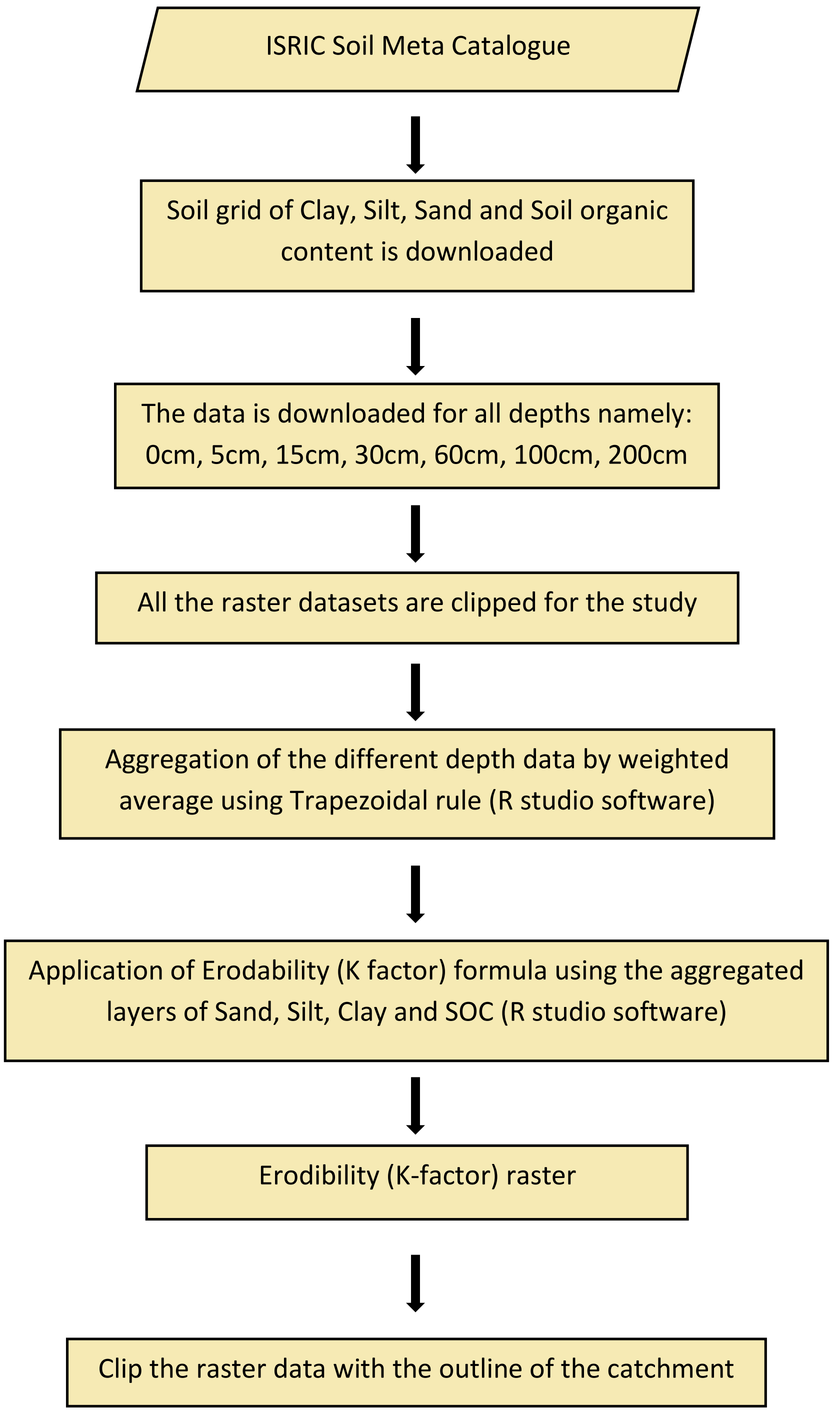


Figure iv: Erosivity map of the study area

3.2.5 *Soil Erodibility (K Factor)*

Soil erodibility factor gives the susceptibility of soil particles to detach and transport by rain fall or runoff. The raster data gives the erodibility factor for each pixel value. The ISRIC Soil metadata has been used to obtain layers of percentage sand, percentage clay, percentage silt and percentage soil organic carbon at various depths of soil. These raster layers are further processed as shown in the following flowchart by keeping (Tomislav, et al., 2017) and (Yang, et al., 2018) as reference.

Steps followed:



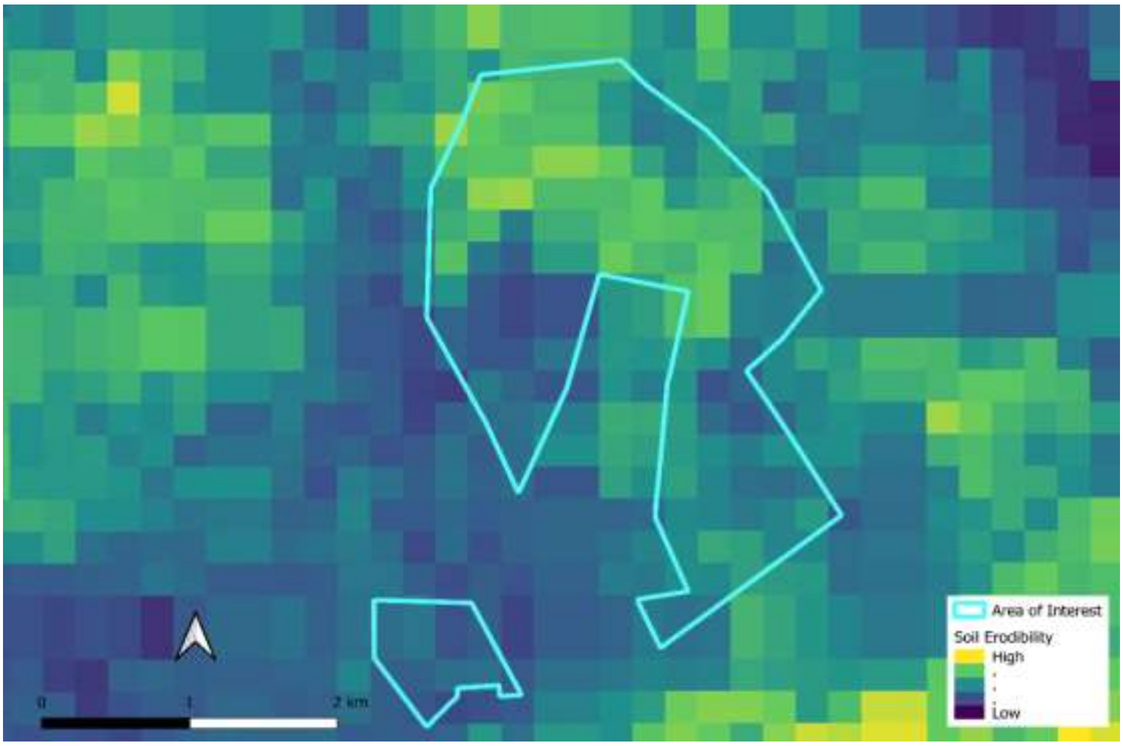


Figure v: Erodibility map of the study area

3.2.6 Biophysical Table

Table 1: Biophysical table used for SDR modelling

Description	lucode	usle_c	usle_p
Cropland	40	0.9	1
Water	80	0	1
Bare land	60	0.9	1
Shrubland	20	0.01	1
Grassland	30	0.01	1
Built-up	50	1	1
Tree cover	10	0.001	1

usle_c: It is the cover management factor. It accounts for the specified crop management relative to tilled continuous fallow.

usle_p: It is the support practice factor. It accounts for the effects of contour ploughing, strip-cropping or terracing relative to straight-row farming up and down the slope.

Both of these values are obtained by referring to the UN-FAO documentation provided in the appendix of the InVEST – SDR documentation (FAO, 2006).

3.2.7 Other Model Parameters

3.2.7.1 Threshold Flow Accumulation

A threshold flow accumulation of value of 5000 is taken by referring to the InVEST, Sediment Delivery Ratio (SDR) specific documentation.

3.2.7.2 Borselli K Parameter

A default value of 2 was used by referring to the InVEST, Sediment Delivery Ratio (SDR) specific documentation.

3.2.7.3 Borselli IC0 Parameter

A default value of 0.5 was used by referring to the InVEST, Sediment Delivery Ratio (SDR) specific documentation.

3.2.7.4 Maximum SDR Value

A default value of 0.8 was used by referring to the InVEST, Sediment Delivery Ratio (SDR) specific documentation.

3.2.7.5 Maximum L Value

A default value of 122 was used by referring to the InVEST, Sediment Delivery Ratio (SDR) specific documentation.

3.3 Method

The Land use pattern of the current scenario of the study area was used to run the SDR model in InVEST. Another land use raster was created with the change in the land use type of the study area from forest. Shrub-land and grassland to bare land as the area would be converted into an open cast. This was new land use raster was used as an input file in the SDR model with other parameters remaining same. The difference in the results of both the models was obtained to know the sediment deposition in the streams or lower elevation area due to the loss of vegetation in the study area.

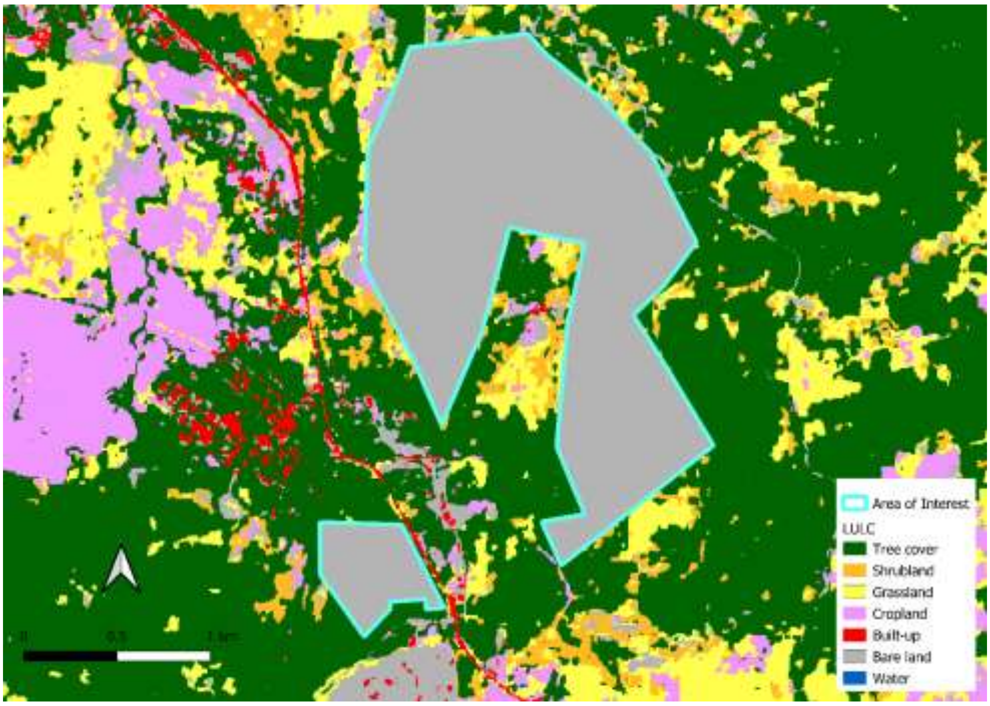


Figure vi: Modified LULC of the study area

3.4 Results

Table 2: Results of SDR

Description	Result
Total Sediment deposited per year	9203 tonnes
Soil erosion per hectare	13.94 tonnes

4 Ecosystem Services from Forests

In this study, the Millennium Ecosystem Assessment (MEA) framework has been used to assess the economic valuation of the various ecosystem services. These ecosystem services are valued using direct methods or the benefits-transfer method. The following section provides information regarding the ecosystem services, the methodology used for physical quantification and economic valuation, and the results. Overall, 16 services are being evaluated. Out of these, two services i.e., water provisioning, and Sediment retention are evaluated for the study area, using InVEST modeling software. For the remaining ecosystem services, suitable methods are used for evaluation.

4.1 Provisioning Services

Provisioning services are manifested in the goods people obtain from ecosystems such as food and fiber, fuel in the form of wood or non-woody biomass, and water from rivers, lakes, and aquifers. The above-mentioned list of provisioning services has been already taken into account in the calculation of the NPV in the original benefit-cost ratio.

4.2 Regulating Services

Regulating services provided by ecosystems are diverse and include the impacts of pollination and pest and disease regulation on the provision of ecosystem goods such as food, fuel, and fiber. Currently, the economic values of nine services from this category (gene-pool, gas regulation, pollination, biological control, water purification, water provisioning, sediment retention, carbon storage and, carbon sequestration) have been evaluated. Information is provided in the tables listed below. The values are estimates and further information would yield an appropriate estimate for accounting purposes.

4.2.1 Genepool protection

The economic value of biodiversity in this study is envisioned in terms of the value of information and insurance.

a. **Biological Information Value:** Biodiversity, as we know, is a result of the continuous evolutionary process that has taken place over thousands of years. Thus, a stock of information is representedby various life forms. All the evolutionary process has taken place in various environmental contexts, thus enabling organisms to become more resilient to natural changes. Unique and endemic species throughout the various ecosystems have evolved various forms of defense mechanisms such as chemical compounds for survival. These compounds have an immense potential to cure human illnesses. For example, leukemia is today treated with compounds derived from the rosy periwinkle of Madagascar, and the bark of the Pacific yew tree is the sourceof treatment for ovarian cancer. Such chemicals are of potential value to the pharmaceutical industry. Additionally, wild cultivars and wild crop varieties are vital genetic repositories that play an essential role to ensure food security.

b. **Insurance Value:** Another way of product’s approach to the value of biodiversity is the economicvalue of products derived from the value of the information contained in it.

Therefore, biodiversity is a precondition for all the other values derived from the forests. On this basis, the economic value of biodiversity as insurance is the insurance premium the consumers have to pay for the preservation of these services. The diversity contains millions of years of information and this brings resilience to the environmental change where it protects other functions of forests. Therefore, the economic value of a patch of forest must be equal to its informational value plus its insurance value.

Due to the lack of site-specific data for estimating the value of gene-pool protection, the benefit transfer method has been used. The economic value derived from a meta-analysis study by Costanza et al. (2014) was used for calculation purposes. All analyses have made the assumption that the conversion rate from US Dollars to Indian Rupees is Rs.81.78. Table 3 provides the summary of the methodology used for estimating the flow value of gene pool protection services.

Table 3: Summary of methodology used for flow value for gene pool protection

Ecosystem Service Method	Gene pool Protection	
	Benefits transfer	
	Data used	Data sources
Benefits transfer value	Rs. 111079.35/ha/year	Costanza et al. (2014)
Total physical area	Total forest area – 650 ha	
Economic value	Rs. 7.22 crore / year	

4.2.2 Biological control

Forests and other natural ecosystems are known to control the populations of disease-inflicting organisms (Viruses, bacteria, parasites, etc.), their hosts, and intermediate vectors (rodents, insects, etc.). Deforestation reduces the diversity of the interactions between organisms and this results in the unbalanced population distribution of species, thereby, increasing the possibility of the spread of disease-infected organisms. Due to inadequate site-specific studies and data for estimating the economic value of biological control, the method of benefits transfer has been used.

Based on unit area values of biological control (@ Rs. 715/ha/year) for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of the ecosystem service has been derived at the division level. Table 4 provides the summary of the methodology used for estimating the flow value of biological control services.

Table 4: Summary of the methodology used for economic value of biological control

Ecosystem Service Method	Biological Control	
	Benefits transfer	
	Data used	Data sources
Benefits transfer value	Rs. 715/ha/year	Costanza et al. (2014)
Total physical area	Total forest area – 650 (ha)	
Economic value	Rs. 0.05 crore / year	

4.2.3 *Pollination*

Pollination is fundamental for agricultural production, and plant reproduction. It also maintains terrestrial biodiversity. Most of the world's major crops are consumed by humans and the majority of the wild flowering plants depend on animal pollination. Forests with their diversity of species depend on pollination and also provide a valuable service function for the surrounding areas. Due to a lack of data for pollination values in the state, the benefit transfer method has been used to estimatethe economic value.

Based on unit area values of pollination for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of the ecosystem service has been derived(@ Rs. 1950/ha/year) as shown in table 5.

Table 5: Summary of the methodology used for flow value of pollination

Ecosystem Service Method	**Pollination**	
	Benefits transfer	
	Data used	**Data sources**
Benefits transfer value	Rs.1950/ha/year for tropical forests	Costanza et al. (2014)
Total physical area	Total forest cover – 650(ha)	
Economic value	Rs. 0.13 crore / year	

4.2.4 *Gas regulation*

Forests are also known to regulate the local climate and improve air quality. Trees provide shade but they have a significant influence on rainfall and water availability. Forests also remove toxic airpollutants from the atmosphere. Site-specific studies related to the economic value of air quality improvement by forests are not available; hence, the benefit transfer method has been used.

Based on the unit area values of gas regulation for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of the ecosystem service has been derived(@ Rs. 780/ha/year). Table 6 provides the summary of the methodology used for estimating the flow value of gas regulation services.

Table 6: Summary of the methodology used for economic value of gas regulation services in the study area

Ecosystem Service Method	**Gas Regulation**	
	Benefits transfer	
	Data used	**Data sources**
Benefits transfer value	Rs.780/ha/year for tropical forests	Costanza et al. (2014)
Total physical area	Total forest cover 650 (ha)	
Economic value	Rs. 0.05 crore / year	

4.2.5 *Carbon storage (Stock value)*

1. **<u>As per the ASFR-2021 Report,</u>**
    a. The carbon stock value of the entire Indian forests is 7204 Million tonnes and the total area of forests present in the country is 7,13,789 sq.km. Hence carbon stock per hectare can be calculated by dividing the total carbon stock by total area (7204 x 1000000/713789 x 100). This gives a carbon stock of 101 tonnes per hectare.
    b. The value of carbon Stock per hectare will be = 101 * 86 *81.78 = Rs. 7,10,341/ Ha
    c. The value of Carbon Stock for 650 Ha will be = 7,10,341*650= 46.17 Crores.

2. **<u>As per the Indian State Of Forest Report -2017</u>**
    a. As per the report (table 8.6) the carbon stock for the Tropical Dry deciduous Forests per hectare is 95.54 tonnes. Accordingly, the Carbon stock for 650 Ha. will be = 650*95.54 = 62,101 tonnes.
    b. The value of carbon Stock for 650 Ha in rupees will be = 62,101*86*81.78 = 43.67 crores.

The carbon stock value of **43.67 crores** is chosen as this value of carbon stock resembles more with the forests present in the study area.

4.2.6 *Water provisioning*

Forests play an essential role in extending water supply to the landscape. Forests have a significantlydominant effect on the hydrological processes at the watershed level. The forest canopy cover intercepts precipitation and reduce their intensity of impact on the forest floor. Part of the water evaporates back into the atmosphere, part contributes to surface run-off and part of the precipitation is absorbed by the roots and later enters the atmosphere through transpiration. Once the soil moisture reaches its field or saturation capacity, the remaining water recharges thegroundwater table. Table 7 provides the summary of the methodology used for estimating the flow value of water provisioning services.

Table 7: Economic value and methods used for the estimation of water provisioning services

Ecosystem Service Method	**Water provisioning**	
	Benefits transfer	
	Data used	**Data sources**
Physical estimation	Average water recharge value of forest – 73 m^3/ha/year	GIST Monograph 7 (2006)
Per Unit Value	Rs. 18.43 /m^3 is considered as the economic value of differential water recharge happening because of forests	World Bank (2013)
Total physical volume	47450 m^3/year	
Economic value	Rs.0.09 crores / year	

4.2.7 *Sediment regulation*

Forests with varying levels of canopy cover and soil properties play a vital role in holding the soil physical structure and thus ensuring its stabilization. In this study, the economic value has been estimated using the avoided offsite costs from sedimentation. Information from secondary literature has been used to estimate the contribution of forests in preventing soil erosion compared to managed ecosystems. Sediment retention values provided by running the Sediment Delivery ratio models of InVEST was used for the physical quantification; the study recorded that 13.94 tons of sediment retention capacity is provided by each hectare of forests in the study area each year. Table 8 provides the summary of the methodology used for estimating the flow value of sediment regulation.

Table 8: Economic value and methodology for sediment regulation

Ecosystem Service Method	Sediment Regulation	
	InVEST modelling	
	Data used	Data sources
	Total sediment lost in the watershed – 9203 tonnes	InVEST Result
Cost of Substitute	Dredging cost @ Rs 285 per 1.2 c.m.	Dredging Corporation of India
Economic value	Rs. 0.25 crores/year	

4.2.8 Water purification

Forests not only regulate the flow of water but also help in maintaining its quality. In evaluating the water purification service of the forests, the number of beneficiaries dependent around the study area has been assumed. Further, the per capita per day domestic water requirement is calculated to derive total domestic water requirement. This quantity is then multiplied with the average cost of treating water to obtain the cost of water purification.

Table 9: Economic value and methods used for the estimation of water purification services

Ecosystem Service Method	Water purification	
	Benefits transfer	
	Data used	Data sources
Physical estimation	Average number of population surrounding the forest area - 2000	
Per capita per day consumption	200 liters per capita per day	Assumption
Nominal cost of water treatment	Rs.10 per m^3	Nominal price
Economic value	Rs.0.15 crores / year	

4.2.9 Climate regulation

Climate regulation refers to the maintenance of a favorable climate, both at local and global scales, which has important implications for health, crop productivity, and other human activities. Forest ecosystems help in climate regulation by trapping moisture and cooling the earth's surface, thus regulating rainfall and temperature.

Due to the lack of site-specific studies for estimating the economic value of climate regulation, the method of benefits transfer has been used. Based on the unit area value of climate regulation for differenttypes of ecosystems from a meta-analysis study (Costanza et al., 2014), the economic value of this ecosystem service has been derived (@134904Rs. /ha/year). Table

10 provides the summary of the methodology used for estimating the flow value of climate regulation services.

Table 10: Summary and methodology used for the flow value of climate regulation services

Ecosystem Service Method	Climate regulation	
	Benefits transfer	
	Data used	Data sources
Benefits transfer value	Rs. 134904 /ha/year for tropicalforests	Costanza et al. (2014)
Total physical area	Total forest area - 650 Ha	
Economic value	Rs. 8.77 crore / year	

4.2.10 *Waste assimilation*

Due to the lack of site-specific studies for estimating the economic value of climate regulation, the method of benefits transfer has been used. Using the estimate of economic value of waste assimilation for tropical forest (Rs. 7920 /ha/year) from a global meta-analysis study Costanza et al., 2014), the economic value of this ecosystem service has been derived (4389.97 crores/year). Table 11 provides the summary of the methodology used for estimating the flow value of waste assimilation services.

Table 11: Summary and methodology used for the flow value of waste assimilation services

Ecosystem Service Method	Waste assimilation	
	Benefits transfer	
	Data used	Data sources
Benefits transfer value	Rs. 7920 /ha/year for tropical forests	Costanza et al. (2014)
Total physical area	Total forest area - 650 (ha)	
Economic value	Rs. 0.51 crore/ year	

4.3 Supporting Services

Supporting services provide the basic infrastructure of life such as providing mechanisms to harnessthe sun's energy, forming and maintaining the fertility of the soils, and cycling of water and nutrients in the ecosystems. Supporting services lay the basic foundation for the production of all other ecosystem services and are strongly interrelated to the physical, chemical and biological interactions.

5.3.1 *Habitat for species*

The forests provide habitats for some of the major species in India such as the tiger, and sloth bear, caracal, etc. In fact, forests are also genetic repositories for living organisms and, hence contribute to species preservation in case of species loss outside forest areas.

Due to the lack of site-specific studies for estimating the economic value of habitat provisioning, the method of benefits transfer has been used. Based on the unit area value of habitat/refugia for different types of ecosystems from a meta-analysis study, the economic value of this ecosystem service has been derived (@ Rs. 2535/ha/year). Table 12 provides the summary of the methodology used for estimating the flow value of habitat for species.

Table 12: Summary for flow value of habitat for species

Ecosystem Service Method	Habitat for species	
	Benefits transfer	
	Data used	Data sources
Benefits transfer value	Rs. 2535/ha/year for tropicalforests	Costanza et al. (2014)
Total physical area	Total forest area - 650 (ha)	
Economic value	Rs. 0.16 crores / year	

5.3.2 *Nutrient cycling*

Forests with complex ecological structure avoid erosion of soil through runoff in streams. An indirect benefit of avoided soil erosion is the retention of nutrients and regulated discharge duringrainfall. According to the literature survey, nutrient cycling is estimated using the replacement cost of fertilizers and thus, a similar approach is used here in the valuation.

Physical quantification of nutrient cycling has been estimated using estimates of **soil erosion avoided**and the **concentration of NPK** (nitrogen, phosphorus, potassium) is derived from the GIST study conducted in 2006. According to the study, each kg of avoided erosion contains 2.32 g of nitrogen, 0.044 g of phosphorus, and 8.25 g of potassium. This physical estimate is then used along with the price of NPK fertilizers in India to obtain the economic value of nutrient cycling from forest areas as shown. Table 13 provides the summary of the methodology used for estimating the flow value of nutrient cycling/retention.

Table 13: Summary and methodology used for the flow value of nutrient cycling services

Ecosystem Service Method	Nutrient cycling (InVEST)	
	Substitution cost and Benefits transfer method	
	Data used	Data sources
	Total sediment lost in the watershed – 9203 tonnes	InVEST Result
	Each kg of avoided erosion contains 2.32 g of nitrogen, 0.044 g of phosphorus and 8.25 g of potassium	GIST Monograph 7 (2006)
Cost of substitute	Price of NPK – Rs.178	Indian Fertilizer Scenario 2017
Economic value	Rs. 0.16 crores /year	

5 Summary of Ecosystem Services Valuation

The economic valuation process has revealed that the forests of the study area provide ecosystem services worth about Rs. 175 crores as stock, and an annual flow of about Rs. 10.5 crores. Table: 17 and Table: 18 shows the summary of flow values of 11 ecosystem services that are mapped. **The valuation of genepool services of Rs 7.33 crores per year has not been taken into account in the calculation of the ecosystem services in Table 14, because the surrounding forest contains the same species as the study area, and the future benefits of this genepool are available for human well-being even if the study area is converted to open cast mining**.

Table 14: Summary of ecosystem flow values per annum

Ecosystem Services	Economic Value (crores)
Water Provisioning	0.09
Water Purification	0.15
Sediment Regulation	0.25
Nutrient Cycling	0.16
Biological Control	0.05
Pollination	0.13
Habitat for Species	0.16
Gas Regulation	0.05
Climate Regulation	8.77
Waste Assimilation	0.51
Total (Flows)	**10.32**

Table 15: Summary of ecosystem stock values

Ecosystem Services	Economic Value (crores)
Carbon Stock	**43.80**

6 Conclusion

The economic value of loss of eco-system services due to diversion of forests shall be the net present value (NPV) of the forest land being diverted as prescribed by the Ministry of Environment, Forests and Climate Change (MoEF&CC). In this study, in addition to the ecosystem services accounted in the calculation of NPV, certain additional services such as water provisioning, water purification, sediment regulation, nutrient cycling, biological control, pollination, habitat for species, gas regulation, climate regulation and waste assimilation services are also assessed and their respective flow values have been included in the calculation of a **revised NPV.** This is done by assuming a flow period of 25 years with a discount rate of 10% per year. A stock value of carbon from the existing forests has also been assessed and added to the cost of the project. Finally the **revised cost and benefit ratio** has been calculated which comes up to **1: 12.53**. The details of the cost benefit analysis is given in the table number 16, 17 and 18 of the annexures.

7 Appendix

7.1 Net Present Value (NPV) calculation of additional ecosystem services

In calculating the net present value (NPV), the stock value has been considered for only the 0th year. The flow values of ecosystem services are considered for the next twenty five years. Hence, a sum of 10.32 crore has been considered starting from 'year 1' with a discount rate of 10 % for a period of 25 years.

Table 16: Net Present Value calculation of flow values (in Rs crores)

Year	Cost	Present Value of Cost
0	43.8	43.80
1	10.32	9.38
2	10.32	8.53
3	10.32	7.75
4	10.32	7.05
5	10.32	6.41
6	10.32	5.83
7	10.32	5.30
8	10.32	4.81
9	10.32	4.38
10	10.32	3.98
11	10.32	3.62
12	10.32	3.29
13	10.32	2.99
14	10.32	2.72
15	10.32	2.47
16	10.32	2.25
17	10.32	2.04
18	10.32	1.86
19	10.32	1.69
20	10.32	1.53
21	10.32	1.39
22	10.32	1.27
23	10.32	1.15
24	10.32	1.05
25	10.32	0.95
	Total	**137.35**
		13734.51 (Rs. lakhs)

7.2 Estimation of Benefit – Cost ratio (with ecosystem services accounted as additional costs)

Table 17: Estimation of costs (in Rs. Lakhs)

I.	ESTIMATION OF COSTS				
S. No.	**Parameters**	**Unit**	**Rate Per Unit/Basis**	**Quantity**	**Value**
1	Ecosystem Services	Lakh/Ha	8.03	649.30	5213.89
2	Loss of Animal husbandry productivity		10% of NPV		521.39
3	Cost of Human Resettlement	Lakh/PDF	20	100	2000
4	Loss of Public Facilities	Cr./Km	4	5	2000
5	Possession Value of Forest Land Diverted		30% of NPV		1564.17
6	Cost of Suffering to Oustees		1.5 times of 2 years wage cost		362.7
7	Habitat Fragmentation Cost		50% of NPV		2606.95
8	Compensatory of Forestation	Lakh/Ha	6.5	1298.60	8440.92
	Total Cost (A)				**22710.01**
	Additional Costs				**13734.51**
	Revised Total Cost (C)				**36444.51**

Table 18: Estimation of benefits (in Rs Lakhs)

II.	ESTIMATION OF BENEFITS		
1	Increase in Productivity	As per detailed project report	6729.28
2	Benefit to Economy		334540.51
3	No of population benefited		
4	Economic benefits due to direct and indirect employment		114796.02
5	Economic benefits due to compensatory afforestation		422.05
		Total Benefits (B)	**456487.86**
		Benefit Cost Ratio (B/A)	**20.10**
		Revised Benefit Cost Ratio (B/C)(additional cost)	**12.53**

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