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Environmental Impact Assessment of Soil Quarrying from the Hills of Central Kerala, Southwest Coast of India

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Abstract- Ever increasing human requirements and economic developments impose immense pressure on the natural resource base. Kerala state with an area of 38,863 Sq. km is one of the densely populated regions of the world having limited land and non-renewable resource availability. Indiscriminate resource extraction creates serious environmental problems which need to be tackled judiciously by striking a balance between the degree and need for development, and the extent of environmental degradation based on scientific studies. This is essential so as to utilize the natural resources to meet human needs and economic growth on one side and preserve environmental integrity, on the other. The present paper deals with the environmental impacts of soil quarrying from the hills of Central Kerala, especially around Kochi City, one of the fast developing urban-cum-industrial centres in southwest India. A set of recommendations are also given in order to ensure sustainable management of this nature's gift.

Index Terms- Environmental Impact Assessment, Kochi City, levelling of hills and hillocks, soil quarrying

I. INTRODUCTION

Soil quarrying and levelling of hillocks have been reported from all over Kerala. These activities have reached critical levels in the peripheral areas of the major developmental centres in the state (Maya et al. 2012; Padmalal et al. 2015). Although Environmental Impact Assessment studies are made to identify and evaluate the environmental effects of developmental projects, its ripple effects in the mining and quarrying sectors are often ignored and/or underestimated. This, in many of the occasions, has led to serious problems in the socio-environmental setting of the regions located close to the core developmental centres. At the same time, mining and quarrying for minerals and other natural products are inevitable for sustenance of civilization (Bradshaw, 1983; Auty and Mikesell, 1998; Sachs and Warner, 1999; MMSD, 2002). All these point to the imminent need for setting a balance between development and conservation of all our natural resources, including the soil resource, based on scientific planning and management of the environment. Soil is a key component of terrestrial ecosystem which is essential for the sustenance of life on earth. It is the end product of weathering of crustal rocks and is a heterogeneous, polyphasic, particulate, disperse and porous medium evolved through geological processes that took thousands of years (Holmes, 1976). It is the most important non-renewable resource on which agricultural prosperity depends (Tilman et al. 2002). The soil categories in a region are influenced by factors like climate, geology, relief and various biotic components. A major part of Kerala is blanketed by lateritic soil, which is a product of tropical weathering of iron rich parent rocks in which several courses of transformation takes place. In recent years, excessive quantities of lateritic soils are being quarried from the residual hillocks in the lowlands and midlands of the State. This is to meet its ever increasing demand in the construction of roads, embankments, etc. In most cases, no management plan is envisaged in mining areas for enhancing environmental quality. A recent study conducted in the Muvattupuzha river basin revealed that the areas of the river basin especially close to Kochi City and its satellite townships are under immense stress due to rampant mining and quarrying (Maya et al. 2011). These activities take place in a haphazard manner and impose unrest among the local residents. This is just one aspect of the issue. On the other hand, the inevitability of mining and quarrying for building and filling materials cannot be ruled out altogether as these materials are integral components for developmental activities that are designed for raising the economic base, creation of employment opportunities and, ultimately the standard of living of people. Hence, it is essential that utmost care be taken to minimize and/ or mitigate the adverse impacts of soil quarrying for achieving environmental security of the affected region.

II. ENVIRONMENTAL SETTING

The area selected for the present study includes the catchments of Periyar and Muvattupuzha rivers surrounding the Kochi development zone and adjoining satellite townships. The entire area falls within Thrissur, Ernakulam and Kottayam districts of Central Kerala in the southwest coast of India (Fig. 1). The salient features of the rivers in the study area are given in Table 1.The length and basin area of these rivers are 244 km and 5398 km^2 for Periyar and 121 km and 1554 km^2 for Muvattupuzha river basins, respectively. The river basins fall within three distinct physiographic provinces, the highlands (>75 m amsl), the midland (8-75 m amsl) and the lowlands (<8 m amsl); (CESS, 1984). Geologically, the study area is composed mainly of Pre-Cambrian crystalline rocks. A small portion near the river confluence is occupied by recent to sub-recent sediments. The rivers exhibit dendritic to subdendritic drainage pattern. Land use types are distinctly governed by physiography and climate of the area with forests and forest plantations dominating the highlands followed by mixed tree crops in the midlands and agricultural land along with water bodies in the lowlands. Soil is quarried extensively from the hills and hillocks in the midlands of the study area having high population and development pressures.

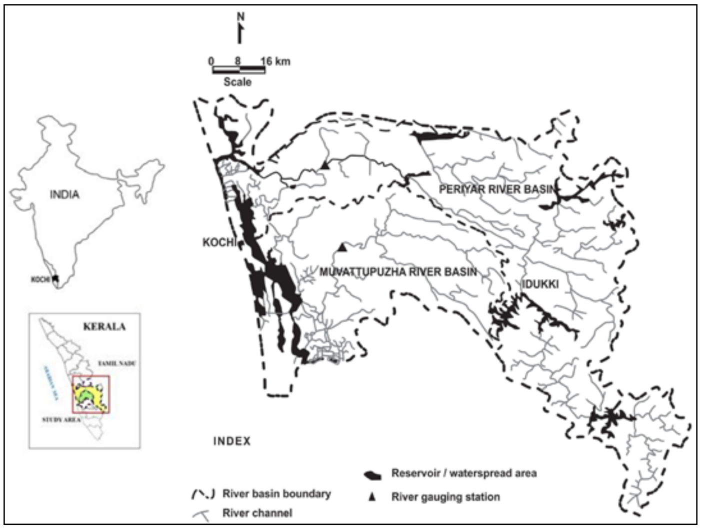

Figure 1: Location map of the study area.

Table 1: Drainage characteristics and other salient features of the rivers in the study area.

Features / Parameters*	Rivers	
	Periyar	Muvattupuzha
River type[(a)] / HWE (m)	M/1830	M/1094
Basin area (km^2)	5398	1554
Basin population (number)	1481305	989342
Average rainfall (mmy^{-1})	3200	3100
River length (km)	244	121
Navigable length (km)	72	25.6
Stream flow (Million m^3y^{-1})	4868	3560
Major reservoirs (number)	11	1

(a)Based on the classification of Milliman and Syvitsky (1992)

The urban centers are mainly concentrated in the midland–lowland stretches of the study area. Kochi City, the largest urban center of Kerala coast and the second largest on the western coast of India is situated in the lowlands of the study area. A host of mega-development projects by the Greater Cochin Development Authority (GCDA) is likely to elevate Kochi City into a key centre of development. The tremendous increase in population, population density and the number of households in the local bodies falling within the Kochi City Region (Kochi Corporation, 3 adjoining Municipalities and 13 contiguous Panchayats) is a clear indication of urban sprawl in the region, which in turn has a direct bearing on the natural resource demand (Fig. 2). The development needs of Kochi City and its satellite townships have greatly reflected on the indiscriminate extraction activities around its economic haulage areas. In addition, discharge of industrial and urban pollutants into the rivers, poor solid waste disposal, intensive use of chemical fertilizers, etc., are some of the other environmental problems in the region.

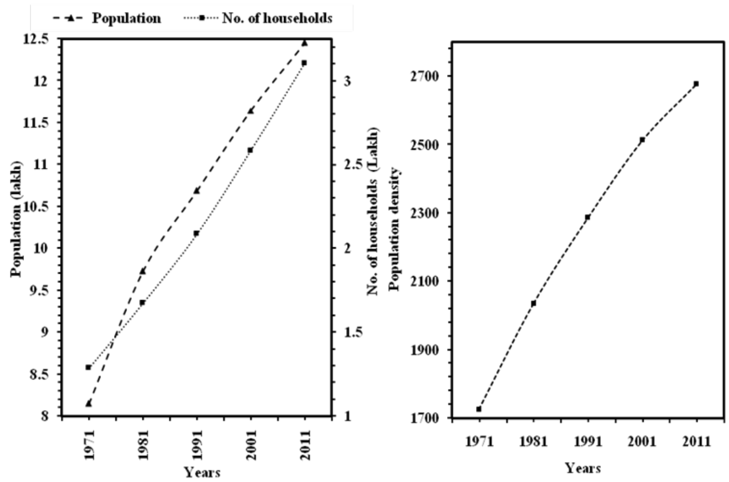

Figure 2: Population growth, decadal addition of households and increase in population density in Kochi City Region.

III. MATERIALS AND METHODS

Environmental data on soil quarrying, quantity of resource extraction and other baseline information needed for the study was collected through extensive field surveys in the study area covering Periyar and Muvattupuzha river basins. The relevant information were obtained through select weighing of the loaded vehicles moving out of the quarry locations, questionnaire surveys with quarry operators, labourers, lorry drivers, officials of Mining and Geology Department and local people, and also from the available secondary data of Mining and Geology Department, District Administration/ Revenue departments, District and State Industrial Departments and the Panchayat Raj Institutions. The locations of the soil quarries in the study area was mapped in 1:50,000 scale of Survey of India topobase maps. Geometric correction and ground truth verifications were carried out using Global Positioning System (GPS), and ancillary data from topographic maps and Google Earth images. Environmental Impact Assessment (EIA) has been carried out to evaluate the major environmental and social impacts of the soil quarrying activities in the study area. The Rapid Environment Assessment Matrix (RIAM) proposed by Pastakia (1998) was adopted to assess the environmental impacts of soil quarrying in the study area. Interviews helped to explore different stakeholders views on the various negative and positive attributes of soil quarrying in specific areas. The purpose of the survey was to identify and address the key environmental issues in order to mitigate negative and to enhance positive impacts, if any. Field surveys were of immense use in understanding the public perception, especially in the quarrying hot spots.

IV. RESULTS

Soil and earth are synonymous when used in the context of building construction. In engineering, the term 'soil' refers to subsoil, and should not be confused with the geological or agricultural definition of soil, which includes the weathered organic material or topsoil. Topsoil is generally removed before any engineering works are carried out, or before soil is excavated for use as a building material. Therefore there are several ways in which soil may be classified: by geological origin, by mineral content (chemical composition), by particle size or by consistency (mainly related to moisture content). In the case of soil quarrying, loosening, loading and transporting takes place in varying combinations, depending on the shape, size and depth of the pit, the local topography and the output required. Generally speaking, soils that are good for building construction are characterized by good grading, i.e. they contain a mix of different-sized particles similar to the ratios where all voids between larger particles are filled by smaller ones. Laterite soil generally gives very good results, especially if stabilized with cement or lime. The laterite and associated soils constitute about 60 percent of the total geographical area of Kerala state and is spread along the midland region (Varghese and Byju, 1993). In recent years, excessive quantities of lateritic soils are quarried from the residual hillocks in the lowlands and midlands of Kerala that are close to developmental centres (Plate 1). Till 1990's the rate of transformation of hillocks in the state was gradual; however, the activity became rampant in the second half of 1990's due to the increase in demand of construction materials. Many of the wetlands in the state have undergone the process of filling using the excavated soil, with the remaining ones like the Aranmula paddy fields facing imminent threat of land use conversion (Plate 1).

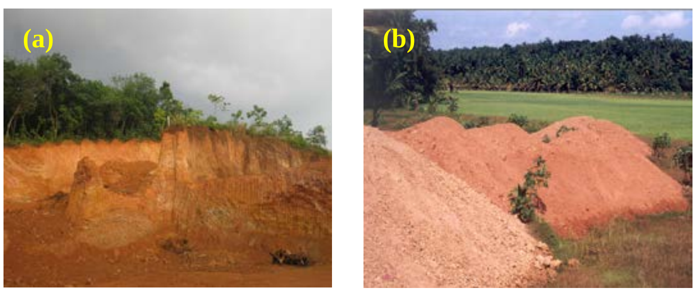

Plate 1: Few scenes of soil quarrying in the study area. (a) A portion of a hill is being excavated; (b) The quarried soil is being used for reclaiming wetlands.

Soil is quarried from Periyar and Muvattupuzha river basins in the study area (Fig. 3). Table 2 shows the estimated quantity of soil extraction from the river basins of the study area. Soil quarrying is reported from 56 local bodies (52 grama panchayats and 4 Municipalities) of which 6 are in the lowlands, 30 in the midlands and 20 in the highlands (Table 2). Active soil quarries are located in only 22 local bodies in the study area. They together extract an amount of 2.79 x 10^6 ty^{-1} of soil from 71 active quarries (Muvattupuzha - 60, Periyar - 11). Maximum quantity of soil is extracted from Muvattupuzha river basin (2.105 x 10^6 ty^{-1}). An amount of 0.689 x 10^6 ty^{-1} of soil is extracted from Periyar basin. A total of 283 soil quarries are located in the study area; of which 143 are in Periyar (active – 11; abandoned – 132) and 140 in Muvattupuzha river basin (active – 60; abandoned – 80). The labour force engaged in the soil quarrying sector in the entire study area was estimated to be about 715.

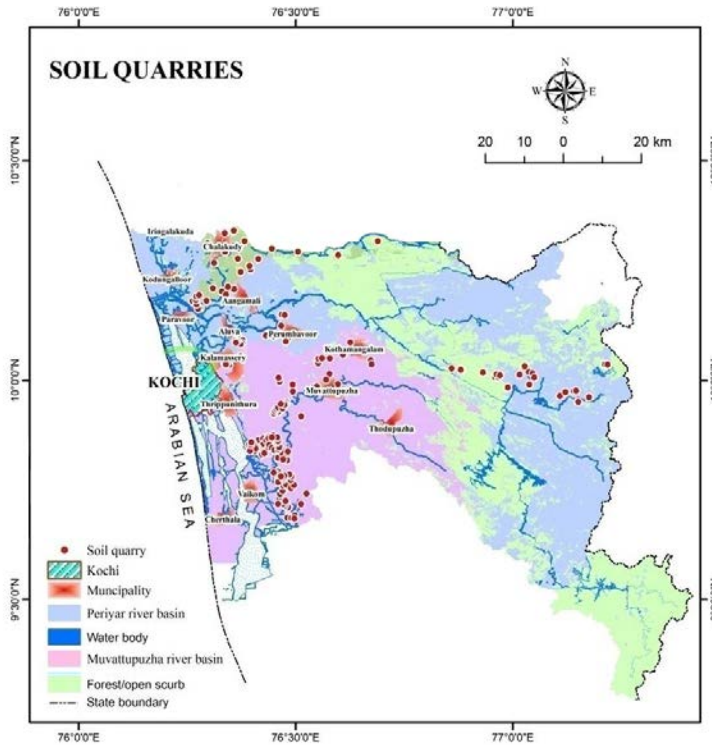

Figure 3: Locations of soil quarries in the river basins of the study area.

Out of the total soil quarries, 35 are in the lowlands, 156 in the midlands and 92 in the highlands. Mechanical type of soil extraction is observed in most of the quarries. A total of 0.413 x 10^6 ty^{-1} of soil was quarried from the lowlands of the region. In the lowlands, active soil quarrying is taking place only in 2 local bodies of Muvattupuzha basin. But an extensive work force (92 labourers) is engaged in the 6 active soil quarries in the area. The midlands of the study area rank top in soil extraction compared to the other two physiographic zones (i.e., highland and lowland). Out of the 30 local bodies involved in soil quarrying in the midlands, 23 are in the Muvattupuzha basin and 7 in Periyar basin. Only 18 local bodies have active soil quarries in the midlands. They together extract an amount of 2.362 x 10^6 ty^{-1} of soil from the hills and hillocks in the region. Maximum quantity of soil extraction in the midlands is from the 54 active soil quarries in the Muvattupuzha river basin (1.692 x 10^6 ty^{-1}). Considerably lesser quantity of soil is extracted from the Periyar river basin (0.67 x 10^6 ty^{-1}). Estimates show that, nearly 80% of the total quantity of soil extracted from the Muvattupuzha river is from the midlands, alone. Estimates show that 617 labourers are working in the 63 active soil quarries in the midlands (Table 2). The work force employed in the soil quarries of Muvattupuzha basin in the midlands (520) are almost five times than Periyar (97). At present, there are only two active soil quarries in the highland part of the study area which falls in Idukki district. The total number of abandoned soil quarries in the highland is 90 indicating that the activity was rampant in the region in the past (Table 2).

Table 2: Soil quarrying and other relevant details of the river basins in the study area with respect to different physiographic zones.

Physiography	River basins	Extraction (x 10^6 ty^{-1})	No. of quarries		Lf (no.)	Local bodies
			Act Q.	Abn Q.		
Lowland	PRB	Nil	Nil	22	Nil	3
	MRB	0.413	6	7	92	3
Midland	PRB	0.670	9	27	97	7
	MRB	1.692	54	66	520	23
Highland	PRB	0.019	2	83	6	19
	MRB	Nil	Nil	7	Nil	1

Act Q. - Active quarry; Abn Q. - Abandoned quarry; Lf – Labour force; ty^{-1}- Tonnes per year

V. ENVIRONMENTAL IMPACT ASSESSMENT

EIA is a process of analyzing the various pros and cons of an action or a set of actions that would affect the environmental conditions/ parameters that have been considered as significant in a given scenario. Depending on the location and magnitude of quarrying, the importance of environmental impacts would also vary (Ramachandran and Padmalal, 1997). Various studies have been conducted so far on the devastating effects of resource extraction on the environment and the ways to assess them. Some of the notable works were of Kondolf (1998), Tadesse (2000), Haupt et al. (2001), Folchi (2003), Mirmohammadi (2009), Collins et al. (2013) and Orr and Krumenacher (2015). The RIAM technique is a semi-quantitative impact assessment approach that utilizes standardized evaluation criteria and rating scales. It has been favored in many studies from various sectors (El-Naqa 2005; Kankam-Yeboah et al. 2005; Kuitunen et al. 2008; Ijas et al. 2010; Mondal et al. 2010; Gilbuena et al. 2013; Upham and Smith 2014) primarily due to its simplicity and robust application. RIAM allows both quantitative and qualitative data to be assessed. In RIAM, initially the impacts of the project activities are evaluated against the environmental components/ subcomponents. RIAM is based on a standard definition of the important assessment criteria, as well as the means by which semi-quantitative values for each of these criteria can be decided (Pastakia, 1998). For each individual environmental component a score is assigned which provides a measure of the impact expected for the component. The important assessment criteria fall in two groups: (1) Group A—criteria that are important to condition and, (2) Group B—criteria that are of value to the situation. A series of simple formulae allow the scores for the individual components to be determined on a defined basis. The process for the RIAM can be expressed as:

$(a1) \times (a2) = aT$ (1)

$(b1) + (b2) + (b3) = bT$ (2)

$(aT) \times (bT) = ES$ (3)

Where,

a1 and a2 are the individual criteria scores for Group A,
b1, b2 and b3 are the individual criteria scores for Group B,
aT is the result of multiplication of all A scores,
bT is the result of summation of all B scores, and
ES is the environmental score for the condition,
The judgments on each component are made in accordance with the criteria and scales as shown in Table 3.

Table 3 Assessment criteria for RIAM.

Group	Criteria	SCALE	DESCRIPTION
A	A1: Importance of condition	4	International importance
		3	National importance
		2	Outside of local condition
		1	Local condition
		0	No importance
	A2: Magnitude of change/ effect	+3	Major positive benefit
		+2	Significant improvement
		+1	Improvement in status quo
		0	No change/ status quo
		-1	Negative change
		-2	Significant negative change
		-3	Major negative change
B	B1: Permanence	1	No change/ not applicable
		2	Temporary
		3	Permanent
	B2: Reversibility	1	No change/ not applicable
		2	Reversible
		3	Irreversible
	B3: Cumulative	1	No change/ not applicable
		2	Non-cumulative/ single
		3	Cumulative/ synergistic

RIAM requires specific assessment components to be defined through a process of scoping, and these environmental components fall into one of four categories, which are defined as follows:

- Physical/ Chemical (PC): All physical and chemical aspects of the environment.
- Biological/ Ecological (BE): All biological aspects of the environment.
- Sociological/ Cultural (SC): All human aspects of the environment, including cultural aspects.
- Economic/ Operational (EO): Qualitatively to identify the economic consequences of environmental change, both temporary and permanent.

From the formulae given previously, Environmental Score (ES) is calculated and recorded. To provide a more certain system of assessment, the individual ES scores are banded together into ranges where they can be compared. Table 4 gives the ES values and range bands currently used in RIAM. Once the ES score is set into a range band, these can be shown individually or grouped according to component type and presented in whatever graphical or numerical form the presentation requires.

Table 4: Conversion of environmental scores to range bands (Pastakia, 1998; Yousefi et al. 2009, 2010).

ES	RV		Description
	RV(A)	RV(N)	
72 to 108	E	5	Major positive impact
36 to 71	D	4	Significant positive impact
19 to 35	C	3	Moderate positive impact
10 to 18	B	2	Positive impact
1 to 9	A	1	Slight positive impact
0	N	0	No change/ status quo
-1 to -9	-A	-1	Slight negative impact
-10 to -18	-B	-2	Negative impact
-19 to -35	-C	-3	Moderate negative impact
-36 to -71	-D	-4	Significant negative impact
-72 to -108	-E	-5	Major negative impact

RV Range Value; RV(A) Alphabetic Range Value; RV(N) Numeric Range Value; ES Environmental Score

The effects of soil quarrying is directly dependent on the method of quarrying adopted in the region, geological settings, human settlement in the area and depth of the quarry. The impact assessment performed using RIAM method for soil quarrying of hills and hillocks in the study area is depicted in Table 5 and the results are summarized in Table 6 and Fig. 4. Mechanical mining using heavy earth moving equipments is common in the study area for commercial purposes whereas manual mining is carried out only in small areas particularly for house constructions. Both manual and mechanical mining in the long term imposes significant negative impacts on landscape, landuse, soil and landform features (Table 5).

Impact on physical and chemical components: Land is a valuable asset that needs to be preserved for maintaining the social, cultural, spiritual, political and economic life of the people of a region. A landscape comprises visual features of an area including the physical elements such as landforms, biotic components of flora and fauna, the abstract elements such as lighting and weather conditions and the human elements otherwise referred as the built-in environment (Hobbs and Harris, 2001). The worst impact of soil quarrying is hill degradation and leveling, especially in the midlands. Degradation of connected ecosystems of hills like the valleys and the nearby wetlands is an inevitable outcome of hill leveling in the study area. The mechanical quarrying and vehicular movements would aggravate the issue further. The mechanical quarrying of soil from hills may markedly change the landform features of the basin area, resulting in instability of the adjacent land, buildings/ houses, loss of biodiversity and vegetation, accelerated erosion and caving of soil masses, etc. Lack of sufficient benches in the quarry faces could adversely affect the stability of the neighboring areas in the long run. In addition to stability problems, uncontrolled soil quarrying operations could result in extensive modification of the landscape and/or aesthetics of the region (ES -36). The rural landscape development possibilities which is integral to strengthen the tourism potential of the region is detrimentally affected by the visual scars created as a result of haphazard extraction of soil from the hills and hillocks. Through massive removal of soil and/or leveling of hillocks, the medium for holding rain water (i.e., aquifer) will be lost forever. This will result in the lowering of water table to significant levels causing drinking water problems in the affected area. Soil quarrying from hill ecosystems will disturb the course of the water flow which may tend to change direction. Soil quarrying also causes significant negative impact on air quality (ES-42). The exposed quarry grounds due to removal of vegetation and disintegration of soil masses cause wind borne particulates which are liable to remain in the atmosphere for long and cause atmospheric pollution. Mechanical quarrying processes enhance manifold the particulate load in the atmosphere which cause respiratory ailments or other health effects when absorbed through the skin. The removal of soil, its loading, movement of the loaded vehicles, etc., could reduce substantially the ambient air quality through increased emission of particulate matter. Further, the fugitive dust emission during mining would deteriorate the air quality of the surrounding areas. Rise in noise level due to mechanical mining and loading is another form of atmospheric pollution. The small landholders adjoining the mining hotspots are the ultimate victims of the adverse impacts of the activity.

Table 5: Environmental components and impact categories of soil quarrying from the study area (after Pastakia, 1998).

Environmental Components	Assessment criteria					ES	RV
	Group A		Group B				
	A1	A2	B1	B2	B3		
Physical & Chemical components (BE)							
Landscape	2	-2	3	3	3	-36	-D
Land stability	1	-2	3	3	3	-18	-B
Landuse	1	-2	3	3	3	-18	-B
Soil	1	-3	3	3	3	-27	-C
Landform	1	-3	3	3	3	-27	-C
Aesthetics	2	-2	3	3	3	-36	-D
Air quality	2	-3	2	2	3	-42	-D
Noise level	1	-2	2	2	3	-14	-B
Ground water	2	-2	3	3	3	-36	-D
Surface water	2	-2	2	2	3	-28	-C
Biological & Ecological components (BE)							
Flora	1	-2	2	2	3	-14	-B
Fauna	1	-2	2	2	3	-14	-B
Ecosystem services	1	-3	3	3	3	-27	-C
Habitat loss	1	-2	3	3	3	-18	-B
Habitat fragmentation	2	-2	3	3	3	-36	-D
Social & Cultural components (SC)							
Public safety	1	-2	1	1	1	-6	-A
Health impairment	2	-2	1	1	1	-12	-B
Living conditions	2	-2	3	3	3	-36	-D
Heritage sites	3	-2	3	3	3	-54	-D
Livelihoods	2	-2	3	3	3	-36	-D
Economic & Operational components (EO)							
Employment	2	2	2	2	3	28	C
Land value	1	2	3	3	3	18	B
Land holdings	1	-3	3	3	3	-27	-C
Economic base	2	2	2	2	3	28	C
Construction sector	3	3	3	3	3	81	E
Agriculture	1	-2	2	2	3	-14	-B
Tourism	3	-2	2	2	3	-42	-D
Infrastructure	2	-2	3	3	3	-36	-D

Impact on biological components: Hill ecosystems are unique in several respects and offers habitat for a variety of plants and animals. Resource extraction cause significant negative impacts on flora and fauna of the affected area. The land use change due to quarrying causes loss of native/ agricultural vegetations in the area. Biotic and abiotic components of hill ecosystems operate in a balanced relationship. The top soil is the abode of many soil microorganisms which maintain the fertility of soil for plant growth. Therefore, obliteration of top soil in due course could reduce the net bio-productivity of the area. The activity inevitably leads to changes in soil profile, quality and processes detrimentally affecting the functioning of the entire ecosystem. Further, quarrying disturbs the natural habitats of certain animals inhabiting in the affected area and can even lead to habitat destruction. Levelling of hill ecosystems would result in significant negative impact on the biological diversity due to habitat fragmentation (ES-36). Degradation of some midland laterite hills in the study area has affected the sacred groves which are unique to these hills. Stripping of these hillocks along with its biological wealth is a huge loss to mankind.

Table 6: Summary of assessment/ scores of RIAM for soil quarrying.

ES	RV	RVN	Environmental components				Total	Final(1)
			PC	BE	SC	EO		
72-108	E	5	0	0	0	1	1	5
36 to 71	D	4	0	0	0	0	0	0
19 to 35	C	3	0	0	0	2	2	6
10 to 18	B	2	0	0	0	1	1	2
1 to 9	A	1	0	0	0	0	0	0
0	N	0	0	0	0	0	0	0
-1 to -9	-A	-1	0	0	1	0	1	-1
-10 to -18	-B	-2	3	3	1	1	8	-16
-19 to -35	-C	-3	3	1	0	1	5	-15
-36 to -71	-D	-4	4	1	3	2	10	-40
-72to-108	-E	-5	0	0	0	0	0	0

ES Environmental Score, RV Range Value, RVN Range Value Numerical, PC Physical and Chemical, BE Biological and Ecological, SC Social and Cultural, EO Economic and Operational. (1) Product of range values (numerical) and total score of environmental components.

Impact on socio-economic components: Apart from the above mentioned adverse effects, soil quarrying could also bring certain short-term positive benefits to the people of the area. Soil quarrying can contribute positive impacts by way of creation of employment opportunities, enhancement of economic base and also land value. Among the two forms of soil quarrying usually practiced - mechanical and manual - the former contributes only low positive impacts whereas the later produce medium positive impacts. There is a high positive impact on land value, at the same time a high negative impact on the land holdings, landuse, landscape and aesthetics. Soil quarrying makes it difficult to restore the hill ecosystem to a pre-mine landscape, particularly because a portion or whole of the hill is siphoned off leaving open pits behind (Plate 1). Most of the impacts of the activity are negative on various environmental components but a few may be positive benefits like employment and revenue generation, although only till the resource is exhausted. Thus, uncontrolled stripping of soil from hills results in detrimental environmental as well as social implications. Fig. 4 shows the final results of assessment using RIAM method of soil quarrying activities in the region.

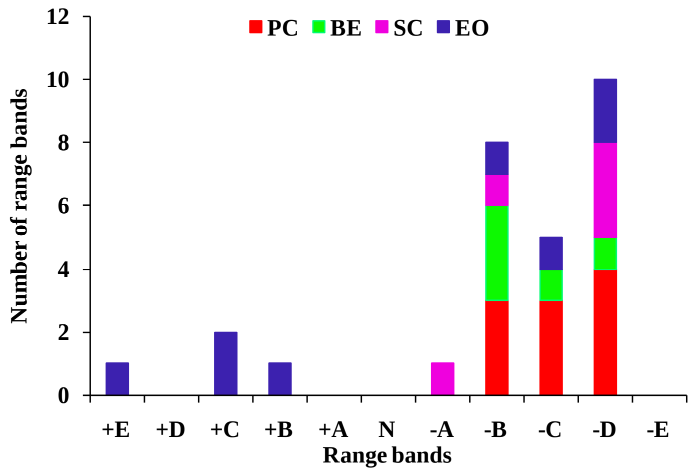

Figure 4: Graphical representation of summary of RIAM analysis of soil quarrying. PC Physical and Chemical, BE Biological and Ecological, SC Social and Cultural, EO Economic and Operational components.

VI. CONCLUSION

From the above observations and discussions, it is evident that indiscriminate soil quarrying over the years has imposed irreparable damages to the hill ecosystems in the southwest coast of India. The hill/hillocks as well as its soil apron have many beneficial natural functions. Soil, the end product of crustal weathering which has evolved through a process that took thousands of years, is the abode for many micro-organisms that are essential for maintaining fertility of the ecosystem. In most cases the surface and subsurface flow of water is sustained by the soil profile in a hill ecosystem. Therefore, obliteration of hills/hillocks and its sub-surface aquifers through indiscriminate quarrying will lead to irreparable damages to the living environment. Therefore, every effort has to be made to regulate soil quarrying and leveling of hillocks within the resilience capability of the region through appropriate mitigation measures. The following are some of the recommendations to contain the adverse impacts of soil extraction:

1. Soil quarrying, if permitted based on scientific studies, should be done under the strict vigilance and control of the Mining and Geology Department, Pollution Control Board, Public Health Department and Revenue Department. This is to ensure that the activity is taking place as per the rules and regulations.
2. Quarrying has to be carried out from the highest point towards the base of the hillocks. This may be done leaving a buffer width not less than 1m from the boundary of the neighboring plot(s).
3. Regular wetting (water spraying) of the ground has to be done in dry periods on the roads and the adjoining regions of the quarry to reduce dust pollution during quarrying or transportation of the quarried soil.

4. Quarrying has to be done with sufficient slope (less than 45° from horizontal level) and benches (bench width of 1m for every 5m height).

5. The boundary of the excavated areas should be fenced appropriately to avoid accidents/risk to humans.

6. The boundaries of the plot that are prone to caving should be strengthened with granite walls or concrete structures.

7. The fertile top soil should be collected separately and used for refilling the area after completion of the quarrying process.

8. Awareness campaign should be conducted among people about the various impacts of soil quarrying and leveling of hillocks, present state of hill ecosystems, finite character of the resource, use of alternative materials and immediate need for control measures.

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