ENVIRONMENT ENGINEERING TO MITIGATE ENVIRONMENTAL POLLUTION IN GOA WITH SPECIAL FOCUS ON MINING

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Located on the West coast and spanning 7000 sq. km, Goa is India's smallest state by area with nearly 38% of its area is forest. However, it has significant deposits of manganese, bauxite and iron ore. The then Portuguese government handed 700 'mining concessions' to allow people to mine the area. Post liberation, the Government of India cancelled these concessions and provided 'mining leases' under the purview of Indian mining and environmental regulation, in 1987. Despite these measures, the mining industry has grown exponentially – form less than 5 million tonnes in the 1960's to more than nearly 60 million tonnes in 2011, after which an inquiry into illegal mining by the Shah commission and a supreme court interim ban on all extraction occurred. In April 2014, the ban has been lifted and an annual cap of 20 million tonnes has been placed (Goa foundation - *Sweet Land of Mine*, 2009).

The main rivers Mandovi and Zuari both flowing into the Arabian sea are navigable by barges used for transporting the ore. Iron ore, Manganese ore, Bauxite are minerals of economic importance. Besides there are minor minerals like Basalt, Laterite stones and rubbles, River sand, Murrum etc., which are in great demand as construction material. This industry is labour intensive and provides work to large number of people. Mining in Goa today is synonymous with iron ore mining.

Present day mining resumed in 1947 which marks the beginning of modern day mining and export of iron ore. The exports have steadily increased from 4,36,400 tonnes of iron ore in 1951 to 35 million tones in 2008-09. The Goan iron ore is exported to China, Japan, Taiwan, South Korea and Eastern European Countries. Iron ore mining in Goa is completely in the private sector. The Iron ore deposits are distributed over the Northern, Southern and Central Blocks of Goa. The Northern Block deposits are richer both in terms of quality and quantity of the ore, as compared to the Southern and Central Blocks. Infrastructure wise Goa has an advantage over other exporting regions in the countries in view of its being endowed with a deep sea port and waterways that crisscross the territory facilitating barge transport. The two rivers Mandovi and Zuari have proved to be a boon to the working industry as they provide cheap river transport. The Bauxite Mines are situated in South Goa over an area of 1263.678 HA. with estimated reserves of 70 million tons. These are metallurgical grade bauxite which can also be used for various applications such as cement, alumina chemicals, etc. The mines are also in the close proximity of two major ports, viz. Marmugoa Port and Betul Port. It has the following Minor Minerals reserves Basalt, Laterite, River sand, Laterite-Rubble, Laterite boulders, Pebble, Murrum and Lime Shell. The Major Minerals reserves are Bauxite, Iron ore, Manganese ore etc.

The mining belt of Goa covers approximately 700 sq. km and is mostly concentrated in four talukas namely, Bicholim of North Goa district and Salcete, Sanguem and Quepem of South Goa district. Mining and associated activities have greatly affected the natural landscape in and around these areas, which is characterized by the presence of pits and waste rejects. It is divided into three regions based on the concentration of the iron ore, namely, Northern, Central and Southern Zone. Usgao River is the dividing line for northern and central zone and Sanguem River between the central and southern zone. The maximum area under mining is in SanguemTaluka followed by Bicholim, Sattari and Quepem.

Operation mechanism - In Goa, opencast type of mining techniques are used to extract iron/manganese ores. It is carried out by forming systematic benches on the hilltop and along hill slopes and the pits are laterally extended in stages in all directions with increasing depth. In general, bench height and width are maintained at 7m and 10m respectively. The pit configurations are planned in such a way that the overall pits slopes remains at 30 degree or less with the horizontal.

Sequence of mining operation involves -

a. Systematic removal of lateritic overburden. Soft Laterite is removed by dozing and ripping. Drilling and blasting is practiced in hard and compact Laterite

b. Extraction of lumpy ore zone followed by powdery ore zone.

c. Wet or dry processing of the mined material so as to attain the desired cut-off grade of the iron ore. (i.e. 62% of iron) for export purpose.

General Impact on Environment
Mining has also created a degraded environment and is also a matter of concern. Damage to the environment is mainly done by the reject dumps, pumping out of muddy waters from the working pits including those where the mining operations have gone below the water table, and slimes from the beneficiation plant. The damage is more evidenced during monsoon where the rain water carries the washed out material from the waste dumps to the adjoining low-lying agricultural fields and water streams. It is stated that the slimes and silts, which enter the agricultural field are of such character that they get hardened on drying. The washed out material from the dumps and the flow of slimes from the beneficial plants besides polluting the water causes Siltation of water- ways, especially during monsoon. Such silting of water ways over the years may trigger years even flooding of the adjacent fields and inhabitated areas, especially during monsoon. Several major environmental problems caused due to mining operations are Deforestation, Land degradation, Groundwater pollution, Surface water pollution, Dust pollution,Damage to beaches

Environmental engineering is the integration of sciences and engineering principles to improve the natural environment, to provide healthy water, air, and land for human habitation and for other organisms, and to clean up pollution sites according to Oxford. Environmental engineering can also be described as a branch of applied science and technology that addresses the issue of energy preservation, production asset and control of waste from human and animal activities. Furthermore, it is concerned with finding plausible solutions in the field of public health, such as waterborne diseases, implementing laws which promote adequate sanitation in urban, rural and recreational areas. It involves waste water management and air pollution control, recycling, waste disposal, radiation protection, industrial hygiene, environmental sustainability, and public health issues as well as a knowledge of environmental engineering law. It also includes studies on the environmental impact of proposed construction projects.

Environmental engineers also design municipal water supply and industrial wastewater treatment systems(**Beychok, Milton R. (1967)** as well as address local and worldwide environmental issues such as the effects of acid rain, global warming, ozone depletion, water pollution and air pollution from automobile exhausts and industrial sources. **Turner, D.B. (1994).**

Literature review

Remote sensing and GIS for biodiversity studies
Rocchini, Balkenhol, et. al. (2010) provides a review paper on remotely sensed spectral heterogeneity – variation in visual spectra from the images – and their viability of usage as a proxy for species identification. Heterogeneity refers to the variation on a particular scale, and environmental heterogeneity refers to this variation among species, landscapes, habitats and human land-use. The general consensus is that greater environmental heterogeneity means greater number of niches and hence larger number of species. Remote sensingdata sources and techniques are being rapidly developed but quantitative tests need to be carried out to assess diversity usingthese data and techniques. Also, different statistical and map-based modelling procedures that havebeen proposed for predicting biodiversity by remote should not be more complex than the realitythey are seeking to represent. A major problem with spectral heterogeneity as a proxy for diversity is the inability to account for uniqueness or ecological importance of different habitats.

Yadav, P.K., Kapoor M. and Sarma K. (2012) provide a case study for mapping land cover changes from India, specifically the Nagzira- Navegaon corridor in Central India. They used Landsat imagery for the three time periods of 1990, 1999 and 2009, classified the land into dense forest, open forest, water body and non-forest for both the sets and found

their changes, concentrating on the corridor between two protected habitats. It was found that from 1990 to 1999, a significant part of the forest changed from dense to open forest, probably highlighting insufficient protection. From 1999 to 2009, an opposite trend is seen. The corridor itself was most prone to conversion to non-forest are at the location of roads and other linear projects.

Roy P.S. and Sharma S. (2007) present another case study for such remote sensing-GIS applications from the Central Himalayas. They mapped the fragmentation of forest landscapes within their study area of 5167 sq. km. and found 41% of that forest was fragmented. They also checked it at various scales, from 75x75m to 575mx575m. Studies have found that at least 40m changes are felt in the microclimate from edge effects, thereby rendering literally the whole sample area susceptible to these changes. While the size of fragmentation is very small, the scale of this is alarming throughout the Himalayan region as it can all be classified as highly fragmented.

Menon, S. and Bawa K.S. (1997) perform several analyses – modelling deforestation, biomass estimation, land-use change, fragmentation, and correlation with socioeconomic drivers of land use change. They study two regions of the Western Ghats – the BiligiriRangan Hills and Agastyamalai region. This is one of the first studies in this field of work and hence presents some interesting insight into modelling and methods.

Nagendra, H. and Ostrom E. (2011) perform a meta-analysis of forest-density changes as monitored in sample plots from 53 case studies. They find that while tree changes monitored by the users strongly correlated with randomly distributed forest plots, shrub/sapling changes were less strong. Also, changes are difficult to monitor from field data, and thus local solutions are recommended for monitoring habitats.

Kotha M. and Kunte P.D. (2013) studied Goa's Land-cover changes using similar techniques as Roy and Sharma. The looked at 4 different land forms – settlement, vegetation, open land and water bodies – and found their temporal distribution each decade, over 4 decades. They used Landsat imagery, used GIS to vectorize this data and found the net areas and changes in the same. Other image pre-processing techniques were also used. They found that in the first decade change, the vegetation fell sharply and the settlement area increased considerably, but the subsequent decade, a slight increase in green cover despite a lower but increasing settlement area indicates some afforestation measures. As highlighted in the abstract, this remains a preliminary study, aimed at obtaining base-line information on Goa's landscape.

METHODOLOGY

Approach and field survey

The village of Bicholim and the village of Valpoi are taken as locations of study. Bicholim has long been the centre of mining activity in Goa and considered a mining centre. Valpoi is located at the foothills of the ChorlaGhat and has little or no mining activity in the area around it. Moreover, the forested areas around Valpoi are rich in biodiversity and present an interesting case of contrast with the locations in Bicholim.

The price of land in India is set by the government which sets the guidance value. The market value is over and above this guidance value, and there are no official records of the same. Thus, once could either obtain this information from real-estate agents or from the persons involved in the transaction. Due to paucity of contacts in the regions, the author approached the house owners themselves. However, after surveying 5 households, the variance of information collected, specifically land prices was too high to obtain any tangible information. The quoted values of land prices at the time of purchase varied from Rs.400/sq. ft. to Rs.3/sq. ft.! There was difficulty in communicating in English, many didn't remember the rates and/or had no access to official rates. Most importantly, people were sceptical about revealing information, especially since we the issue of mining was sensitive in the area with the Goan public divided in their opinion of the same, and the people near mines bearing the brunt of the economic burden from the mining ban.

Thus the methodology involved created a framework for this analysis with more reliable land prices obtained later. Therefore, the spatial attributes table – of distances from different land use variables from each household was obtained.

GIS analysis

Each Taluka in Goa is divided into villages, and the delimitation of these villages has been obtained from the village maps as a part of the 2021 Goa Regional Plan, accessed in the Goa Files website (goafiles.com, hosted by BITS-Pilani professor Dr.Solano and available for free). Bicholim and Sattari are the two Talukas, and Bicholim village and Valpoi villages are the two villages from the respective talukas that have been considered for this study.

The regional plan also specifies the different classification of land – as agricultural land, commercial land, mining area, protected area, etc., apart from roads, prominent locations, rivers, and also numbered plots.

VALPOI MAP DETAILS*

Type of Land-use	Area in km2	% of total area
Built up area	3.61338598	29.37335064
Roads	0.620898563	5.047307791
Vegetation	6.258476527	50.87539125
protected area	0.068695487	0.558428199
Non-Development Slopes	2.360105226	19.18538421
Mhadei River	0.889560068	7.231267275
Agriculture	1.265262191	10.28536397

Size of valpoi boundary   12.30157916

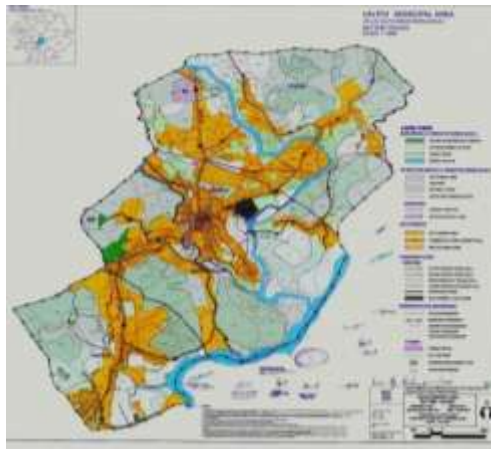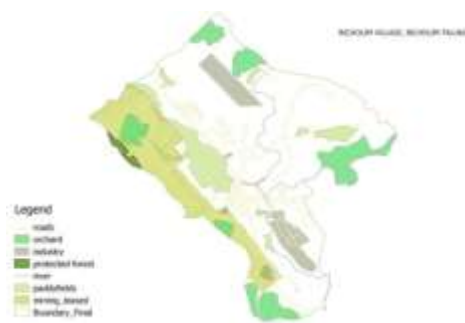* - Land-use overlap and hence do not add up to size of boundary

Fig1. VALPOI VILLAGE, SATTARI TALUKA (Source: goafiles.com)

All these landscape features were converted into a vector map of the same. Only the different land use types were found out. The vector image is shown below –
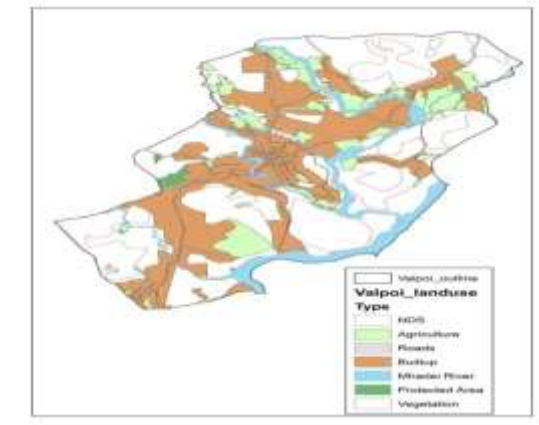
Similarly, the Bicholim village and the corresponding Bicholim vector image

Vector image –

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BICHOLIM MAP DETAILS*

Type of Land-use	Area in km2	% of total area
Area under mining lease	2.571741897	17.57581249
Industrial area	0.831651241	5.683675443
Vegetation	1.380255309	9.43294836
protected area	0.077588905	0.530258515
Non-Development Slopes	0.732408532	5.005430383
Built-up area	7.947848742	54.31723121
Agriculture	1.090784239	7.454643596

Size of Bicholim boundary
14.63227886

* - Land-use overlap and hence do not add up to size of boundary

RESULTS

Bicholim is mainly a mining taluka but one would expect that the mining will stay far from the residential area. However, one can see that 17% of the village's area is under active mining lease, and the location of the mines is 124m from the nearest settlement. This indicates that in regions where the economic effects of mining are significant, the environmental and health diseconomies are neglected by the people concerned. This observation is also buttressed by the field survey where all people living very close to the mines in Lamgoa, Bicholim answered that there were negatives of mining but the positive impact it had on livelihoods were also significant.

One must also note that while 17% of the area is leased for mining, all area is not mined. Several agricultural areas lie within these leased areas, and so do forests, including protected areas. Even settlements can be found inside these areas, separated by a non-development slope region.

For the village of Valpoi, it is found that while like Bicholim (50%) it too has a large built-up area (29%), the amount of forested area (vegetation and non-development slopes) forms a significant 69%. The forested area in Bicholim (including vegetation, non-development slopes and protected area) include just 14.5%. A key difference is that 0.5% of this forest is protected while none of the forests in Valpoi – classified as vegetation and non-developmental slopes is protected. In terms of agriculture, Valpoi has a little much area under agricultural cultivation than Bicholim, (10% and 7% respectively) but the corresponding built-area is significantly smaller.

In the field survey conducted, the land pieces was bought between 1975 and1992. The average household numbered 4.6, the average number of trees per plot was 17.5 trees, the average size of each plot was 675 sq. m. (approximately 120ft x 60 ft) and the average number of rooms was 3. All field correspondents reported a positive effect of mining on the livelihood people and all of them also reported a negative impact of mining on air quality. Health and water quality had either worsened or remained the same while mining seemed ot have no effect on civic amenities, they felt.

House no.	Impact on water quality	Impact on livelihood	Impact on civic amenities	Impact on air quality	Impact on Health
1	-ve	+ve	No change	No change	No change
2	- ve	+ ve	- ve	- ve	- ve
3	- ve	+ ve	+ ve	- ve	No change
4	No change	+ ve	No change	- ve	- ve
5	No change	+ ve	No change	- ve	- ve

The prices quoted varied from Rs.13 per sq m, to Rs.400 per sq. m, and the information was deemed unreliable for these numbered varied too much, and were counter intuitive – the price of plot 4 was reported as Rs.13/- when it was bought in 1983 but the price of patches bought in 1982 and 1975 – much before plot 4 – were priced Rs. 100 and Rs.400 respectively. Also, all these survey plots were from the same neighbourhood of Lamgao, and hence the variability was difficult to not attribute to interviewee bias. Since the prices were also rounded to the nearest hundred (usually), it seemed like the residents had no exact memory of the prices, and thus heightening our margin of error.

The opinion of the interviewed residents was fairly uniform on the impacts of mining.

QUESTIONAIRE:

The following question were made to the people in the bicholim mining area regarding their livelihood and how mining has affected them

Behavioural questions – Impact of mining

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