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RESEARCH ARTICLE

MINING TOP-SOIL FOR BRICK MAKING AND COST FEEDBACK TO ECONOMY AND ENVIRONMENT– AN ASSESSMENT ON THE BRICK MANUFACTURING OF KHEJURI CD BLOCKS OVER COASTAL MEDINIPUR IN WEST BENGAL, INDIA.

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Abstract

Increased urbanisation and industrialisation in developing countries has created a huge demand for construction activities, which in turn has resulted in the fast growth of the ***brick-making industry***. Unfortunately, brick-kilns are mostly situated on fertile agricultural land, as brick manufacturers need silty clay loam to silty clay soils with good drainage conditions. This article quantifies the agricultural impacts of ***top-soil removal*** for brick-making using ***replacement cost approaches***, for Khejuri CD Blocks of Purba Medinipur District over Coastal Bengal in India. To compute the cost, a survey of 50 farmers each was carried out in two regions—in the north, interior Khejuri (I) and in the south, Coastal Khejuri (II). Besides, 60 soil samples—30 from each region—were analysed from both types of fields—leased land for brick-making and virgin fields. The ***crop yield loss*** due to top-soil removal is found to be much less than expected due to more fertile soil in the region. In the long run, however, the opportunity cost of selling top-soil for brick-making is likely to increase as good quality soils for agriculture become more and more scarce.

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Introduction:-

The removal of topsoil for urban and suburban as well as built-up uses or concretization mainly for brick-making is up-and-coming hastily due to the unbelievable spreading out in urbanization and industrialization with crucial concretization in most of the developing countries like India. Unfortunately, brick kilns are characteristically positioned on fertile agricultural land, as brick manufacturers necessitate silty clay loam to silty clay soils with excellent drainage environment. The concretization, urbanization and the requirement of brick manufacturers has resulted in change in land use pattern as the good agricultural land has been turned into agriculturally sterile lands around several rising cities or flourishing urban patches of the developing world. Quite often soils used in brick-making have high fertility standing and their opportunity cost is also high principally when the soil/brick-earth is removed from river basins with intensive and demanding agricultural production. Local and regional political power and sometimes also administrative invisible and indistinguishable hands play a decisive role in the market for soil/brick-earth especially around metropolitan cities, emerging township areas, rising urban nuclei and newly born rurban signatures in developing countries. Often, many farmers are forced to sell soil for brick-making because their neighbors have sold soil which leaves a 3-6 inches deep gap in the surface levels between those who have sold soil

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and those who have not. Any more important dimension to the problem is the too much depth over which the soil is removed above the approved depth of soil extraction, which renders land unsuitable for agriculture.

Under this backdrop, the main focus of this Paper is to compute and quantify the agricultural impacts of topsoil removal for brick-making. The removal of topsoil has straight and non-stop impact on agricultural crop production through reduced fertility status of soils. As the addition of organic matter in the forms of human and animal wastes and plant residues occurs only over the top layers of soil, removal of topsoil leads to loss of soil fertility. Therefore, the downbeat impact of topsoil removal is calculated in terms of both the lessening in agricultural output and the cost of replacing the nutrients lost. The quantification is vital for the reason that whereas procuring brick earth/soil, this cost is never considered, as this is a communal as well as societal cost.

The quantification of the cost of topsoil removal is carried out using replacement cost approach for Khejuri CD Blocks of Purba Medinipur in West Bengal. The preference of this area because of the region is towards the forefront of concretization due to preventing the frequent fresh and saline flood, upgrading economy and Govt. Residential facilities through different schemes. Rasulpur and Hijli(Hooghly) river basin with many of tidal creeks, channels and canals in and around Khejuri is a major fertile agricultural region facing serious challenges from brick manufacturing. In order to figure the ecological and environmental cost of using top-soil, a survey of 60 farmers is carried out in the region, interior and coastal Khejuri. Apart from the survey, 60 soil samples – 30 from each region - are analyzed from both types of fields i.e., the fields sold / leased land for brick making and virgin fields not exposed to quarry by brick manufacturers.

Location of the Study Area, Khejuri:-

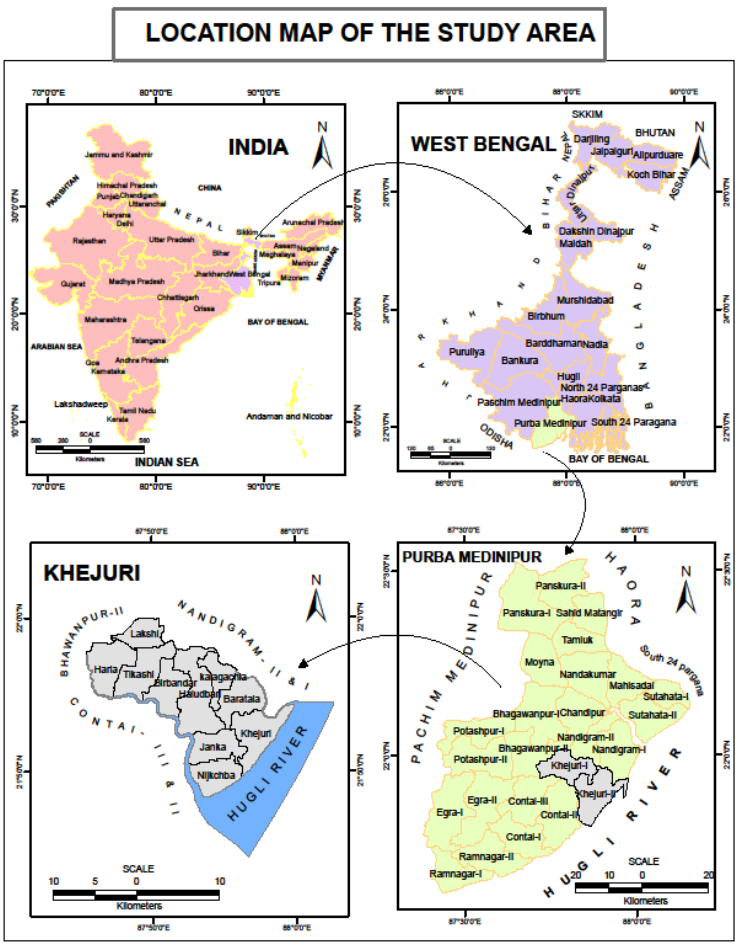

Figure1:-Location Map of Khejuri.

Geographical location of any region reflects it's all of the physical and anthropogenic features more or less. Location helps to estimate the spatial, environmental and also socio-economic entities of the region. Not only that, it depicts the problems and prospects as possible as and helps to plan for prosperity from potentiality.

My study area, Khejuri is, geo-environmentally, one of the important coastal segment reflecting the typical coastal environment over Medinipur as well as West Bengal Coast. Geomorphologically, this region is situated over the 'geomorphic triple junction' of River Hoogly, River Rasulpur and Bay of Bengal, i. e., it shows the well convergence of closing journeys of River Rasulpur and Hooghly and happy beginning of Bay of Bengal. In fact, it has been featured by fluvio-coastal characteriscis in the combination of fluvial and coastal actions. Khejuri is existed on Rasulpur-Pichhaboni basin hydrology over Lower Ganga Course.

Geometrically this area is located in between 21°45´N - 22°00´N latitudes and 87°45´E - 88°05´E longitudes. So, it indicates the typical sub-tropical Monsoonal climatic location with its latitudinal and longitudinal entity over Indian sub-continent. Geologically, it is of mostly recent formation which shows the sedimentary and lithological characteristics of recent Quarternery formation.

Administratively, Khejuri is designated as one of the coastal police stations (P. S.) surrounded by Nandigram at the north, Bhagwanpur and Bhupatinagar at the north-west and west, Uttar Kanthi at the south (detouched by river Rasulpur) and River Hooghly and Bay of Bengal at the east and south-east. Khejuri consists of two blocks as Khejuri-I and Khejuri-II and 11-Gram Panchayets (G.P.) named as Haria, Tikashi, Lakshi, Birbandar, Kamarda and Kalagachhia (6) in Khejuri-I CD Block and Baratala, Haludbari, Khejuri, Janka and Nij Kasaba (5) in Khejuri-II CD Block. From the democratic point of view, it is existed as Khejuri Assembly and included of Kanthi Constituency of Purba Medinipur district in West Bengal, India.

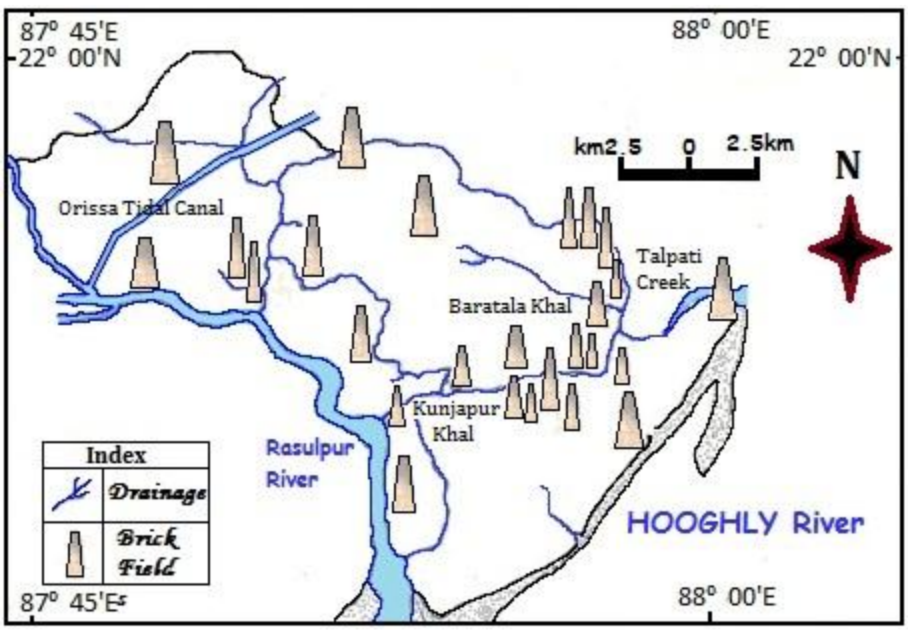

Figure2:-Distribution of Brick Fields in the Study Area.

Objectives:-

- ✪ To enumerate the scenario of top-soil mining for brick making in the study area;
- ✪ To assess the environmental impacts of top-soil removal;
- ✪ To quantify the economic & environmental cost due to it; and
- ✪ To view the remedial measures undertaken for reducing the problems.

Methodology:-

The agricultural impact of removal of topsoil for brick-making is twin, viz,

- ❖ The costs incurred by the farmers in leveling the field and/or mitigating the hardpan (The physical structure of top layers of the soil is generally very conducive for crop growth because of repeated ploughing and other field operation. However, when the topsoil/brick-earth is removed for brick-making, the deeper layers are used for crop cultivation. These deeper layers have harder surface and are not so favorable for crop growth at least in the initial few years immediately after the sale of soil. This is called as the hardpan.) problem by application of tank silt; and

- The loss of soil nutrients.

The quantification of costs of leveling the field and mitigation of hardpan problem is direct, as the actual costs incurred by the farmers in taking up these activities are directly observable. However, quantification of the loss of nutrients is not direct. It leads to reduction in crop yield unless all the critical nutrients required for crop growth, which were lost due to removal of topsoil, are adequately replaced through application of organic matter and inorganic fertilizers.

There is one method from many, widely used in the literature to quantify the nutrient-loss impact of topsoil removal on farm economy: **Replacement cost approach**. This method has been used in the present study about the impact of soil loss. Using the data on input application, cost of cultivation, and crop yields from farms, which have and have not sold topsoil for brick-making, a comparative analysis of net returns from crop production can be carried out to confine the economic losses due to taking away of topsoil. This is called as the 'productivity loss' method. These estimates can be further reinforced and/or cross verified by a comparative analysis of nutrient loss due to topsoil removal and what additional nutrients need to be added to restore the fertility status of the soil, called as 'replacement cost' method.

Valuation of loss in Soil Organic Matter:-

An essential and interrelated issue in valuing the soil fertility loss is the soil carbon or soil organic matter (SOM). SOM is complex and consists of living and dead plant and animal residues of different age, activity and resistance. SOM contributes to soil structure, soil water-holding capacity, soil nutrient content and nutrient exchange capacity and thus soil fertility and agricultural yields in general. However, there have been few attempts in the economic literature to value it even though SOM losses have long been documented as a significant facet of soil degradation in tropical environments. In contrast to the assessment of N, P, and K balances, direct measurements or estimations of carbon inputs and outputs are more difficult (Detwiler, 1985). To obtain a quantifiable proxy for SOM losses, it is possible to analyze soil carbon, which makes up the majority of SOM, over time or between different treatments, with and without soil loss. Even after measuring SOM or soil carbon loss or gain, another key challenge is determining an appropriate price to apply in its evaluation.

Literature Review:-

In this section, we undertake a detailed review of studies on quantification and valuation of soil loss. There is one broad approach available for economic valuation of soil loss, viz., replacement cost approach and the existing literature on this approach are reviewed below. It needs to be mentioned at the outset that rare study (only in South India) exists in India or elsewhere that has tried to estimate the impact of soil loss and productivity due to brick making. As a result, the literature review is tangent to the problem being investigated.

The cost of replacing an ecosystem service with a man-made substitute is used in the replacement cost method as a measure of the economic value of the ecosystem service. As a result, it must be possible to identify a substitute for the ecosystem service. The cost of investment and the maintenance cost should both be integrated in the replacement cost. The method could for example be applied to value the flood protection capacity of wetlands by estimating the cost of replacing this capacity with the use of a human made protection, i.e. some kind of artificial coastal defense such as sea walls.

Gosselink, Odum and Pope (1974) made an early attempt to apply the replacement cost method to value the waste treatment function provided by wetlands. The value estimate was achieved by estimating the cost of sewage treatment as a replacement technique. They argued that this cost could be viewed as the value of the wetland's waste assimilation capacity. The method could also be used to estimate a value of soil fertility by looking at the cost of fertilizers needed to maintain a certain level of productivity.

Drechsel, Giordano and Gyiele (2004) provide a conceptual overview and empirical evidence for valuation of soil nutrients using both Productivity Change Approach (PCA) and the Replacement Cost Approach (RCA). They contend that of all methods, these two have been the most commonly applied in the economic evaluation of soil services, especially as related to developing countries. To quote: "In developing countries, and perhaps more generally, the most common methodology for the economic assessment of soil nutrients specifically, as opposed to soil in general, is the RCA. The approach's popularity most likely stems from the fact that it is relatively simple to apply when nutrient loss data are available (Bojö 1996; Predo *et al*. 1997). In essence, the RCA measures the costs that are or might be incurred to replace damaged or lost soil assets, such as nutrients (Grohs 1994)…A key advantage in using the RCA is that market prices are usually available for at least some common nutrients, making assessments simple once the nutrient database is obtained. However, in applying input prices, caution must be used as the appropriate price to apply depends on the purpose of the analysis. Local market prices might be appropriate to determine financial implications for farmers, while a world market price might be used to calculate societal impact at the national or international level".

Gunatilake and Vieth (2000) present a comparison between the replacement cost method and the productivity change method. Both methods are applied to estimate the on-site cost of soil erosion in the upper Mahweli watershed of Sri Lanka. The on-site cost of erosion is defined as the value of lost future productivity due to current cultivation. To estimate the replacement cost information on nutrient loss per ton soil eroded, price of nutrients and the cost of labour spreading fertilizer are required. The cost of repair and maintenance of damages due to soil erosion is also included in the replacement cost. Fertilizers generally used in Sri Lanka are identified and the cost of nutrient replacement is calculated from market prices assuming the use of these fertilizers. The estimated on-site cost value is also used in a cost-benefit analysis and compared to the cost of soil conservation practices. Stone terraces and spill drains are two of the soil conservation measures evaluated in the study.

It is assumed that the productivity of soil can be maintained by replacing the lost nutrients and organic matters artificially. This assumption can be considered as an argument for the idea that the replacement - fertilizers - provides functions that are equivalent in quality and magnitude to the ecosystem service.
Samarakoon and Abeygunawardena (1995) have also applied the replacement cost method to value the on-site cost of soil erosion in an area of Sri Lanka. Two different replacement techniques are examined in their study. The cost of material used and cost of labour make up the replacement cost. The replacement cost is also estimated for the two main rainy seasons in the area. Fertilizers suitable to the area are used to replace lost nutrients. Costs of repairing damaged field structures are also included in the replacement cost.

The third replacement cost study focusing on soil erosion is from Korea (Kim and Dixon, 1986). Arable land is a scarce resource in Korea due to urbanization and industrialization and as a consequence upland areas are also used for farming. Inadequate soil management techniques have made erosion a severe problem in these upland areas. The productivity in the upland areas can be maintained either by physically replacing lost soil and nutrients or by adopting a management technique and this is compared in a cost-benefit analysis. The replacement costs are interpreted as a minimum estimate of the value of measures that will improve on site management practices and thereby prevent damages. The replacement costs are estimated by adding the cost of fertilizer, transport of organic matter, irrigation and the cost of repairing damaged field structures. It is assumed that the productivity in upland areas can be maintained by replacing lost soil nutrients with fertilizer.

In a case study of Changbaishan Mountain Biosphere Reserve in China, the value of benefits derived from the forest ecosystem has been estimated (Xue and Tisdell, 2001), wherein the replacement cost method is used to provide a monetary value of four of the ecosystem services identified. These services include water conservancy, nutrient cycling, pollutant decomposition and disease and pest control. The role of trees in enriching the soil nutrient status has been estimated by multiplying total net nutrient amount maintained in the standing forest by the market price of nutrients, i.e. the market price of chemical fertilizers.

Guo *et al*. (2001) estimate the value of forest ecosystem services in Xingshan County of China. In their study, the replacement cost method is applied to estimate the value of soil conservation. The replacement cost is interpreted as the value of the benefit of restoring the asset. The inorganic nutrients, such as nitrogen, phosphorus and potassium, are also lost due to soil erosion and to replace these nutrients chemical fertilizers are needed. The price of fertilizer is used to estimate this replacement cost.

In a study of impact of reforestation in Thailand, the cost and benefits of reforestation are assessed (Niskanen, 1998). The replacement cost method is used to estimate a monetary value of benefits derived from erosion control provided by the forest plantations. Soil erosion rates are estimated for different land management practices. Then the cost of commercial fertilizers needed to replace lost nutrients in eroded material is estimated as the replacement cost.

Byström (2000) provides another application of the replacement cost method. The value of using wetlands for abatement of agricultural nitrogen load to the Baltic Sea, with regard to a reduction target of 50%, is estimated. The replacement value is defined as the savings in total abatement costs that are made possible by using wetlands as an abatement measure in cost-effective reductions of nitrogen load to the Baltic Sea.

Erstein (1999) refers to several studies where the replacement cost method has been applied to value the on-site cost of soil erosion. In the referred studies the cost of replacing nutrients lost through soil erosion is estimated. The replacement technique used is the application of chemical fertilizers.

Valuation of loss in Soil Organic Matter:-

Kumar (2004) in a recent study using the RCA has analyzed the loss of carbon through erosion and has used the market price of farmyard manure to estimate the price of carbon. As organic carbon is one of the most frequent elements in the topsoil, its inclusion in the valuation process more than doubled the replacement costs computed without including the organic carbon. In a variation to the RCA, Izac (1997) has illustrated how various functions of SOM could be substituted by differing man-made inputs. Individual SOM services could then be valued by using the market price of similar goods or by approximating the value of the next best alternative/substitute good with or without a market price or from farmers' willingness to pay for a corresponding service. In this substitute goods approach, the value of SOM could be considered equivalent to the sum of the costs of the various substitutes. In view of the complexities involved in directly valuing the soil organic matter, one possible method for avoiding the pricing problem for SOM and soil carbon is the use of the PCA, as it values the provision of soil services in general rather than physical quantities.

In the present study, I use the replacement cost approach to value the loss of topsoil due to brick making activities.

Result and Analysis:-

Sampling:-

Khejuri-I and Khejuri-II were selected for the study. In each of these two blocks the list of survey numbers (and the village name) from where topsoil has been leased/given to the brick manufacturers was obtained from the respective Gram Panchayet's Offices, B.D.O. Offices and collector's office, from which 10 villages were chosen at random. In the next stage, 10 farmers were selected at random from each of the 10 villages and these farmers were post-stratified into sellers and non-sellers of soil for brick-making. Hence a total number of 100 farmers were selected, out of which 50- farmers in the coastal section turned out to be sellers of soil and 50- farmers were sellers of soil in the interior study area. Data on land holding pattern, irrigation sources, area and depth of soil sold for brick-making, income obtained from sale of soil, crops cultivated in the last three crop years and detailed information on inputs applied, yield and returns from crop production, were obtained from the farmers through a structured, pre-tested questionnaire. In Interior Khejuri, paddy (Aman and boro rice) is the main crop cultivated, whereas in the coastal region, paddy and vegetables are the major crops. Detailed study on production aspects of paddy in the coastal region and paddy in the interior region are undertaken to quantify the impacts.

Analysis:-

As mentioned, the present study uses the method - Replacement cost approach to quantify the impact of soil loss. In this method, nutrient loss due to topsoil removal is quantified by laboratory analysis of soil samples collected in plots from where topsoil was removed and from plots from where topsoil was not removed. In each region 30 soil samples − comprising 15 from affected plots and 15 from unaffected plots − are analyzed to quantify the differences in the three major plant nutrients viz., nitrogen (N), phosphorous (P), potash (K), the important micronutrients such as iron, zinc, copper and magnesium as well as the organic matter content of the soils. The differences in soil nutrient status between affected and unaffected plots were valued using the current market prices of these nutrients.

Sample Characteristics:-

The present section gives in brief the sample characteristics in the two regions.

Land holding pattern:-

The land holding pattern of sample households as given in Table 1 shows that the average size of operational holding is around 3.10 acres(1 acre = 4050 sq. meter.) in the Interior block of Khejuri while it is little higher at 3.00 acres in Coastal Block of Khejuri and the difference is found to be statistically significant at 5% level. Incidence of tenancy is very meager in both the regions with around 10% of operation holdings constituted by leased-in lands (Table 1).

Table 1:- Land holding pattern among farmers in the two study regions (in acres).

Nature of Lands	Interior Khejuri (N=50)				Coastal Kheuri(N=50)			
	Own land	Leased-in	Leased-out	Net area cultivated	Own land	Leased-in	Leased-out	Net area cultivated
Wet	**3.22** (91.41)	**0.11**	**0.72**	**2.61** (83.47)	**2.59** (83.5)	**0.34**	**0.63**	**2.30** (77.10)
Garden	**0.05** (1.5)	**0.34**	**0.14**	**0.25** (7.98)	**0.30** (9.57)	**0.41**	**0.34**	**0.37** (12.56)
Dry land	**0.25** (7.09)	**0.02**	**0**	**0.27** (8.55)	**0.21** (6.93)	**0.10**	**0**	**0.31** (10.34)
Total	**3.52** (100)	**0.47**	**0.86**	**3.13** (100)	**3.10** (100)	**0.85**	**0.97**	**2.98** (100)

Notes: Figures in parentheses are percentages to total land in the respective categories of land ownership;

Canals from river Rasulpur and Hooghly are the major sources of irrigation in the Southern Coastal Khejuri (II) study area while Canals from Rasulpur-Kalinagar River, Talpati creek, Orissa Tidal Canal, tanks and bore-wells are the major sources of irrigation in the Northern Interior Khejuri (I) study area. About 77% (Coastal region) to 83% (interior region) of the total land holdings fell under wetland cultivation. Wet season paddy cultivation is predominant in both the regions.

Paddy-Fallow and Paddy-Paddy-Fallow are the major cropping sequences during a normal year in the Northern Interior study area, while Paddy-Paddy-Fallow and Paddy-Vegetables-Vegetables are the major cropping sequences in the Southern coastal study area.

Cropping pattern:-

Table 2:-Cropping pattern – Av. area under crops in last 4 years in the 2 study regions (in acres)

Season	Khejuri-I (N =50)			Khejuri-II (N = 50)		
	I	II	III	I	II	III
Paddy	**2.13** (86.69)	**1.44** (76.50)	-	**2.05** (76.98)	**0.80** (52.51)	**-**
Vegetables	**0.25** (10.31)	**0.41** (21.90)	**0.30** (89.87)	**0.56** (21.02)	**0.57** (37.45)	**0.56** (92.35)
Others	**0.08** (3.00)	**0.03** (1.60)	**0.03**(10.13)	**0.05** (2.00)	**0.15** (10.04)	**0.05** (7.65)
Total	**2.46** (100)	**1.87** (100)	**0.33** (100)	**2.66** (100)	**1.52** (100)	**0.61** (100)

Note: Figures in parentheses give percentages to total.

First season refers to the period from June to October; second season from October to February (subsequent calendar year); and the third season from February to May. Table 2 gives the cropping pattern in the two regions. During the first season, paddy accounts for about 87% of area cultivated in the interior region (Khejuri-I) while vegetables accounts for little over 10% of the cultivated area. Paddy is the major crop in second season also for both regions (76% & 53%) while in case of coastal region, vegetables occupy a remarkable portion (37%). Third season is not very important from the view point of paddy cultivation. Only few area is dominated by discrete vegetation cultivation during this season.

It is to be noted that the sale price in the two regions could be understated. This is because our sample consisted of farmers who engaged in these land transactions nearly 4-5 years back, the current price is higher due to increased pressure on the land caused by concretization. Our conjecture got verified during an interview with the bick field managers. According to them, the prevailing land price here is approximately Rs. 1-1.5 lakh/acre, against the stated price of nearly Rs. 75,000/- per acre. An understated land price will have implication for the final results.

In the Southern region (Table 2), Paddy is the major crop in first season while its share is lesser at 64% in the South. The less share of paddy in South is because of the cultivation of vegetables by many farmers, which is an annual crop occupying land for about 10 months to a full year, thereby limiting the land available for paddy cultivation. In the Southern region, vegetables are usually planted during second season soon after the harvest of first season paddy and hence vegetables are the major crop in the second and third season. In the third season, vegetable cultivation is practiced in about 43% of the area in the South while paddy is the main crop cultivated during the third season in the Northern region.

Sale of topsoil for brick-making:-

As per the objective of the study, this subsection deals with the extent of sale of top soil for brick making by the farmers. Out of the 60 farmers selected in each region, 25 farmers in the Khejuri-I and 35 farmers in Khejuri-II turned out to be sellers of topsoil for brick-making. Both the average area and the depth over which the topsoil has been mined for brick-making were higher in the Interior study area as compared to the coastal sector. The average area over which topsoil was mined for brick-making ranged from 1.05 acres in the Coastal to 0.75 acres in the Interior, with an average of one acre for the two regions put together. The average area over which topsoil was mined was not found to be statistically significantly different between the two regions.

The average depth of soil sold worked out to 2.27 feet. Thus on an average about three acre feet of soil has been sold by each of the farmers who resorted to selling the soil. The average quantity of soil sold worked out to about 2.75 acre-feet in the Coastal Region and 2.87 acre-feet in the Interior part, with a mean of 2.81 acre-feet for both the regions put together. The difference in the average quantity of soil sold between the two regions was found to be statistically significant at 1% level. The income realized by sale of soil for brick-making was found to be higher at Rs. 71,125/-per acre in the Coastal Sector as compared to Rs. 80,545/- in the Interior Part with the average income being around Rs. 75,835/- per farm.

Table 3:- Details on sale of soil for brick-making (Mean for farms which sold soil).

Details	**Coastal Khejuri (II)**			**Interior Khejuri (I)**			**Mean of two regions**
	Min.	**Max.**	**Mean (Std. Dev.)**	**Min.**	**Max.**	**Mean (Std. Dev.)**	
% of farmers who sold soil	-	-	23	-	-	35	**29**
Av. Land area in which soil was sold (acre)	0.08	1.75	1.05 (1.16)	0.10	1.90	0.75 (0.65)	**0.90**
Depth of soil sold (feet)	1.50	3.00	2.17 (1.32)	1.50	3.50	2.37* (0.81)	**2.27**
Quantity of soil sold (acre-feet)	0.25	9.50	2.75 (1.46)	0.35	10.10	2.87** (1.24)	**2.81**
Av. income from sale of soil (Rs./acre-farm)	11,000	1,80,000	71,125 (34,580)	15000	2,30,000	80,545** (36,240)	**75,835**
Notes: Figure in parenthesis give the standard deviation; * and ** indicate that the figures are statistically different at 5% and 1% level respectively from the corresponding figures for the other region.							

Source: Field survey

The higher income in the North Khejuri (I) is due to the heavy demand for soil compared to the South Khejuri(II) and also higher land value in the North, as the areas from where topsoil is removed are located close to the Haria sub-urban area and fertile agricultural patrs.

An analysis of reasons for sale of soil reveal that about 8% of the farmers in the Interior Khejuri (I) and 17% of the farmers in the coastal Khejuri (II) resorted to sale of topsoil mainly to level the land (Table 4). Poor quality of top soil with low production and not interested in agriculture due to marginal benefit were two major reasons attributed for sale of soil in both the regions. About two-third of the farmers in both of the North and South sold soil for this reason.

Table 4:- Reason for sale of topsoil for brick making (% of farmers reporting various reasons).

	Reason	Coastal Khejuri (II)	Interior Khejuri (I)	Mean
1	Level the land	16.52	8.38	**12.45**
2	Poor quality of topsoil & Low Production	33.64	30.90	**32.27**
3	Not interested in active agriculture	34.55	37.96	**36.26**
4	Urgent need for liquidity	15.29	22.76	**19.03**

Source: Field Survey

Perceived impact of topsoil mining:-

Table-5 and 6 report the perceived impact of brick-earth removal on soil quality and yield respectively. About 1/4th of the farmers in both the regions have reported that there was no perceptible change in the quality of soil after the topsoil was removed (Table 5). Consequently, a similar percentage of farmers in both the regions reported that they did not experience any substantial loss in crop yield (Table 6). A majority of the farmers were of the view that even if the crop yield decrease in the first few seasons following the sale of soil, the fertility is restored in the ensuing seasons with the addition of organic matter from crop residues and farmyard manure and also by adding inorganic fertilizers. On an average, over one-fourth of the farmers in both the regions perceived that the removal of topsoil had not significant impact either on soil quality or on crop yield (row 3, Tables 5 and 6). Close to one-third of the farmers in both the regions reported that there was a decline in soil quality, while about 10% in Coastal Khejuri and 11% of the farmers in Interior Khejuri reported an increase in crop yield. These are the farmers who resorted to sale of topsoil for leveling the field and bringing the land under irrigation which were not irrigable hitherto due to uneven topography of the land. Six to nine percent of the farmers sold the entire plot of land to the brick units and hence could not report on the soil quality and crop yield impacts.

Table 5:- Perceived impact of topsoil removal on Soil quality (N = 100).

Details	Frequency (% of farmers reporting)	
	Coastal Khejuri (II/N-50)	Interior Khejuri (I/N-50)
Decline in soil quality	33.74	37.72
Improvement in soil quality	9.35	13.80
No change in soil quality	29.65	25.18
Land abandoned after sale of soil or sold the entire land to brick manufacturer	27.26	23.30

Source: Field survey

Table 6:- Perceived impact on Yield of topsoil removal in the two regions (N = 200)

Details	Frequency (% of farmers reporting)	
	Coastal Khejuri (II/N-50)	Interior Khejuri (I/N-50)
Decline in yield	30.34	35.50
Increase in crop yield	11.20	10.19
No change in crop yield	33.90	28.75
Land abandoned after sale of soil or sold the entire land to brick manufacturer	24.56	25.56

Source: Field survey

Economic costs of using topsoil for brick making:-

Replacement Cost Method: Impact of topsoil removal on fertility status and its economic costs:-

Soil samples from plots from which topsoil was sold and plots from which soil was not sold for brick-making were subjected to chemical analysis in the soil testing laboratory to examine the loss in fertility status if any due to the removal of topsoil. Table-7 reports the results of the soil analysis.

Table 7:- Comparison of soil fertility status in mined and unmined plots.

Details	Plots from which topsoil was not removed			Plots from which topsoil was removed		
	Interior (N=15)	Coastal (N=15)	Average	Interior(N=15)	Coastal (N=15)	Average
Major nutrients (kg/acre)						
Nitrogen (N)	38.35	35.67	**37.01**	16.45 (57.11)	22.24 (37.65)	**19.35 (47.72)**

Phosphorous (P)	4.31	3.97	**4.14**	3.34 (22.51)	2.82 (28.97)	**3.18 (23.19)**
Potash (K)	59.90	63.85	**61.88**	40.89 (31.74)	49.23 (22.90)	**45.06 (27.18)**
Micronutrients (kg/acre)						
Copper (Cu)	2.75	2.13	**2.44**	1.42(48.36)	1.09 (48.83)	**1.25 (48.77)**
Iron (Fe)	28.56	27.61	**28.09**	21.07 (26.23)	18.97 (31.29)	**20.02 (28.73)**
Zinc (Zn)	1.53	1.87	**1.70**	1.06 (30.72)	1.03 (44.92)	**1.05 (38.24)**
Manganese (Mn)	17.09	19.88	**18.49**	10.95 (35.93)	12.11 (39.08)	**11.53 (37.64)**
Organic matter	1687.07	1984.76	**1835.92**	1103.9 (34.57)	1511.1(23.86)	**1307.5(28.78)**

Note: Figures in parentheses are % changes in respective nutrient levels in mined plots vis-a-vis unmined plots

The plots from which soil was removed for brick-making are found to have lost substantial amount of nitrogen (N) and potash (K), while the loss in phosphorous (P) was not substantial as the phosphorous content of soils are found to be much lesser in nature. Though the topsoil in Southern region are found to be more fertile in N and K before soil mining, the impact of topsoil removal on the fertility status was found to be higher in Northern region in terms of loss in N and K. The net loss in nutrient status of the soils due to topsoil mining is given in Table 8.

On an average removal of topsoil has resulted in a loss of about 11.2 kg of N, 1.1 kg of P and 19 kg of K in the Interior Khejuri while the corresponding figures for the Coastal region are 10.9 kg of N, 1.2 kg of P and 19. kg of K. In percentage terms the nutrient loss was the lowest in the case of P, which varied from 22.51% in the Interior to 28.97% in the coastal region (Table 7). Though the loss in absolute terms was the lowest in the case of P, the percentage loss was the highest in this nutrient between plots with and without topsoil mining.

Soil mining has also led to the significant loss of micronutrients, and the percentage reduction varied from about 26.23% for Iron (Fe) in the interior to about 48.83% for Copper (Cu) in the Coastal Region. The differences in organic matter content of the soils between plots from where soil was removed and plots from which top soil was not removed is very merger probably due to the very poor base level organic contents of these soils.

The costs of replacement of the nutrients were estimated using the loss in nutrient status of soils and the respective market prices of the nutrients (Table 8).

Table 8:- Cost of replacement of soil fertility status due to top-soil removal for brick-making.

Details	**Loss in nutrient status of soil due to removal of topsoil in Kg/acre**							**Cost of replacement of nutrients (Rs./acre)**		
	Interior Khejuri(15)			**Coastal Khejuri(15)**			**Average for both regions**	**Interior Khejuri**	**Coastal Khejuri**	**Average**
	Min.	**Max.**	**Mean (S.D.)**	**Min.**	**Max.**	**Mean (S.D.)**				
Nitrogen	4.57	18.90	**11.22 (4.83)**	4.21	19.10	**10.92 (4.59)**	11.07	182.33	177.45	**179.89**
Phosphorous	0.43	3.01	**1.10 (0.41)**	0.31	3.24	**1.20 (0.35)**	1.15	24.2	26.4	**25.3**
Potash	10.21	31.40	**18.98(11.12)**	11.11	29.56	**19.08(12.02)**	19.03	351.13	352.98	**352.06**
Copper	0.35	2.22	**1.15 (0.27)**	0.25	2.04	**0.99 (0.21)**	1.07	51.75	44.55	**48.15**
Iron	10.33	21.20	**15.18 (4.13)**	10.10	20.27	**16.02 (3.89)**	15.60	683.1	720.9	**702.00**
Zinc	0.32	1.53	**0.71 (0.21)**	0.27	1.58	**0.82 (0.26)**	0.77	31.95	36.9	**34.65**
Manganese	2.89	8.05	**5.51 (1.19)**	2.58	7.79	**4.88 (1.31)**	5.20	247.95	219.60	**234.00**
Organic matter	75.97	915.41	**373.09(41.2)**	83.21	879.80	**403.07(43.08)**	388.08	1865.45	2015.35	**1940.40**
Total cost	-	-	-	-	-	-	-	3437.26	3594.13	**3516.45**

Notes: The cost of replacement of nutrients is calculated using the current market prices of N, P and K (Price in Rs. /- per kg of N = 12-20.5, Price of P = 20-24, Price of K = 16-21, organic matter = 4-6 per kg, and 44-46 per kg for micronutrients respectively); The cost of nutrients were worked out using the current market prices of fertilizers supplying these nutrients and their nutrient content.

The costs of replacement of micronutrients such as iron and manganese (Mn) were higher than the other nutrients mainly because of higher losses in these nutrients due to soil mining and also due to the higher market prices of these nutrients. The value of iron lost due to soil mining was about Rs. 683/- per acre in Interior Khejuri and Rs. 721/- per acre Coastal Khejuri, while the value of manganese was Rs. 248/- per acre in Interior Khejuri and Rs. 220/- per acre in Coastal Khejuri. The loss in organic matter due to soil mining was the highest in physical terms while its monetary value was in the range of Rs. 1865/- to Rs. 2015/- per acre. Among the major nutrients, the average cost of replacement of N was about Rs. 180/- per acre, followed by K at Rs. 352/- per acre and P at Rs. 25/- per acre. The total cost of replacing the nutrients lost due to soil mining worked out to Rs. 3437/- per acre in the Interior Khejuri and Rs. 3594/- in the Coastal Khejuri with an inter-regional average of Rs. 2465 per acre. When compared to the income realized by farmers through sale of soil the cost of replacement of nutrients lost in the process of soil mining appears to be meager (It is to be noted that this is an underestimation because there is a foregone income for the period for which land is leased / sold. Inclusion of the forgone income only will reflect the true cost to the farmer for leasing or selling), which is probably the reason behind farmers resorting to sale of topsoil at a moderate depth of about three feet.

Table 9:-Input application, yield and cost and returns from rice cultivation **(Physical inputs and yield in kg/acre: Costs and returns in Rs./acre)**

Sl. No.	**Crop**	**North (Interior)/ Khejuri-I**				**South (Coastal)/ Khejuri-II**			
		Farmers who sold soil (N = 15)		**Farmers who did not sell (N = 25)**		**Farmers who sold soil (N = 15)**		**Farmers who did not sell (N = 25)**	
		Quantity	**Value**	**Quantity**	**Value**	**Quantity**	**Value**	**Quantity**	**Value**
1	**Human labour (man days/acre)**	87	19140	91	20020	89	19580	84	18480
2	**Machine hours (Machine hours/acre)**	10	2700	11	2970	11	2970	13	3510
3	**Bullock power (Bullock days / acre)**	12	2400	11	2200	12	2400	07	1400
4	**Farmyard manure**	1000	345	970	335	1020	352	930	321
5	**Seed**	33.5	1005	31.5	945	36.0	1080	30.3	909
6	**Nitrogen**	42.0	844.50	36.9	742	39.3	790	31.2	627
7	**Phosphorous**	36.0	732.30	33.3	677.4	36.0	732.30	30.0	609
8	**Potash**	30.0	630.00	24.0	504	33.0	693	27.0	567
9	**Gypsum**	7.50	82.50	9.6	105.6	8.10	89.1	8.70	95.7
10	**Pesticides**	1.95	230.00	2.58	304.3	2.50	295	2.16	255
11	**Total cost of cultivation**	-	28,109.3	-	28,803.3	-	28,981.4	-	26,773.7
12	**Yield**	2160	27,000 .0	2520	31500.0	2040	25,500	2580	32,250.0
13	**Gross margin**	-	-1109.3 (Loss)	-	2696.7 (Profit)	-	-3481.4 (Loss)	-	5,476.3 (Profit)

Table10:-Economic impact of topsoil/brick-earth removal for brick-making (Rs./acre).

Sl. No.	Details	Interior Khejuri	Coastal Khejuri	Average
1.	Application of tank silt for leveling and overcoming the hardpan problem	7850	8376	8113
2.	Cost of replacement of soil nutrients	3437	3594	**3516**
3.	Total cost of replacement, tank silt application and leveling (1+2)*	11,287	11,970	11,629

Remedial Measures Undertaken:-

To offset the likely negative effect of topsoil removal on soil quality and crop yield most farmers resorted to strategies such as application of tank silt, high dose of inorganic fertilizers in the ensuing few seasons and / or farm yard manure and green manure. Table 11 gives a list of remedial measures undertaken to restore the soil quality.

Table 11:-Remedial measures undertaken to restore soil quality & costs Incurred.

Details of Remedial measure	**Frequency (% of farmers reporting)**			**Average additional expenditure on various measures (Rs./acre)**		
	Interior	**Coastal**	**Mean**	**Interior**	**Coastal**	**Mean**
Application of tank silt for leveling the field	16.8	8.5	**12.65**	4528	5204	**4866**
High fertilizer application to restore nutrient status.	35.0	27.5	**31.25**	501	410	**455**
Application of farmyard manure and green manure for restoring the organic matter of the soils.	37.6	42.8	**40.2**	1050	980	**1015**
None	10.6	21.2	**15.9**	-	-	**-**
Total	100.00	100.00	100.00	**6079**	**6594**	**6336**

Source: Own compilation based on Survey

The table also gives the expenditure incurred to undertake these measures. Leveling the soil and overcoming the hardpan of soil layers, which are exposed for cultivation after the removal of topsoil, are the most expensive remedial measure undertaken by farmers. However, this is not the case with all the farmers who have sold soil. Most of the farmers resorted to deep ploughing to break the hardpan. Only about 13% of the farmers resorted to application of tank silt to overcome the hardpan problem. This accounted for an average cost of Rs. 4866 per acre. Restoring organic matter is another important remedial measure. However, as a cheaper and readily available source of organic matter, farmyard manure is applied in higher quantities so as to offset the negative impact of topsoil removal. About 43% of the farmers who sold topsoil attempted to restore the organic matter content of the soil by applying a high dose of farmyard manure at an average additional (imputed) cost of about Rs. 1015 per acre. These costs are not out-of-pocket expenses for the farmers as the farmyard manure is often available within farm.

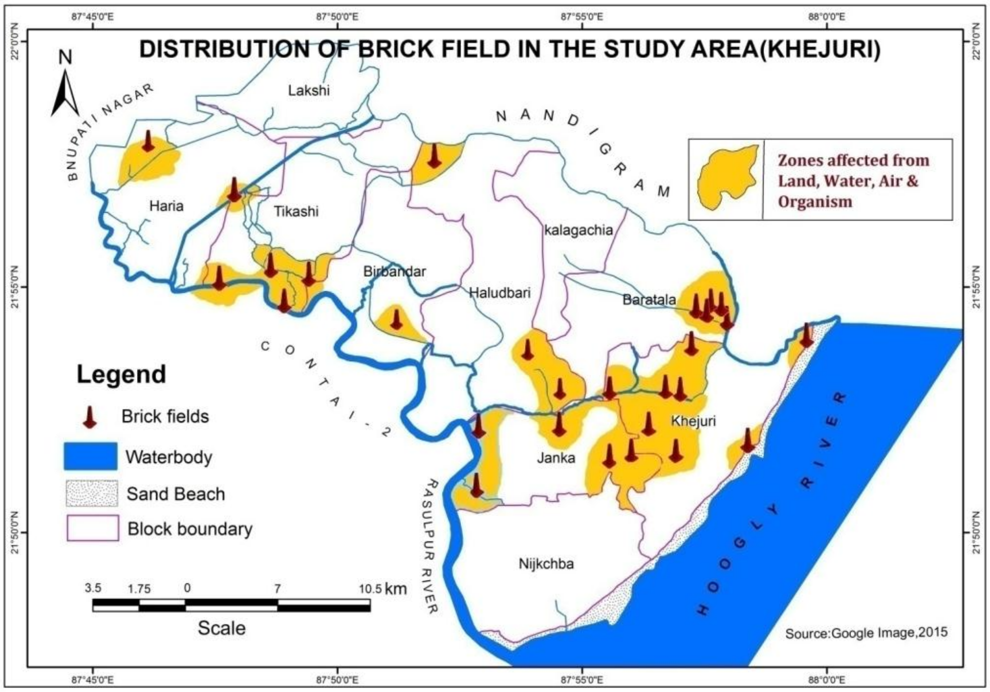

Figure7:- Environmentally Degraded Zones due to Brick Manufacturing

Application of higher dose of inorganic manure/fertilizer is the next important strategy to revive soil fertility, which has been adopted by little more than one-third of the farmers. The average additional expenditure on inorganic fertilizers purchased in the market is Rs. 455 per acre. The remaining 16% of the farmers resorted "do nothing" strategy. On the whole the farmers seem to have spent only a very meager fraction of the total income from sale of soil on remedial measures to restore the soil fertility. Out of the average revenue of Rs. 54,000 per acre from the sale of soil only about Rs. 6336 per acre (≅ 3.3%). has been spent on remedial measures to improve the fertility status of the soil. Most farmers were of the firm view that soil is infinitely renewable resource both in terms of quality and quantity and hence there is nothing wrong in selling the soil.

Conclusions:-

The removal of topsoil for uptown and built up uses mainly for brick-making is growing rapidly due to increased concretization, urbanization and industrialization in many developing countries. Unfortunately, brick kilns are mostly situated on fertile agricultural land, as brick manufacturers need silty clay loam to silty clay soils with good drainage conditions. Under this backdrop, the main focus of this Paper is to quantify the agricultural impacts of topsoil removal for brick-making. The quantification of the cost of topsoil removal is carried out using replacement cost approach for Khejuri CD Blocks over Coastal Medinipur District in West Bengal of India. The choice of this area is because the region is in the forefront of coastal urbanization and development and trying to create the residential opportunity against frequent flood tendency from heavy rain, rivers and sea. In order to compute the environmental cost of using top-soil, a survey of 100 farmers each is carried out in two regions – Northern/ Interior Khejuri-I and Southern Coastal Khejuri-II Blocks. Apart from the survey, 60 soil samples – 30 from each region - are analyzed from both types of fields i.e., the fields sold / leased land for brick making and virgin fields not exposed to excavation by brick manufacturers.

The survey yields that of the 100 farmers, 55 farms in the South turned out to be sellers of soil and 47 farms were sellers of soil in the Northern study area. The economic impacts of topsoil removal revealed that the total cost of replacing the nutrients, leveling the land and application of tank silt worked out to be nearly Rs. 2,600 in the South and Rs. 2,350 per acre in the North with an inter-regional average of Rs. 2,475 per acre. The total income loss due to yield reduction caused by topsoil removal was found to be Rs. 2,585 in the North and Rs. 3,928 per acre per year in the South with an interregional average of about Rs. 3,250 per acre per annum. The study found a difference of about Rs. 780 between the two approaches viz., replacement cost approach and productivity change approach. This difference seems to be reasonable because the removal of topsoil leads to loss of certain unquantifiable, qualitative properties of topsoil, which are not reflected in the replacement cost approach but still lead to yield loss.

A comparison of the revenue realized by selling topsoil for brick-making with the economic losses associated with it reveal that the revenue from sale of soil (≅Rs. 54,000 per acre) more than offsets the loss in yield and soil nutrients in the short run. Hence, it becomes economically rational to sell the soil at least in the short run and this decision gains strength when the farmers face liquidity crunch together with the offer of high prices for their soil. Given the uncertainty involved in agriculture activities, the option of selling soil becomes more lucrative. The proximity of the plots to the brick-kilns with suitable road link and the need for leveling the field to provide surface irrigation by gravity flow are the other important factors that induce the farmers to sell soil for brick-making. Interestingly, out of the average revenue of from the sale of soil only about 3.3% has been spent on remedial measures to improve the fertility status of the soil. They survey yielded that most farmers were of the firm view that soil is infinitely renewable resource both in terms of quality and quantity and hence there is nothing wrong in selling the soil.

The prices offered by the brick kilns to good quality soil (clay silt and clay loam soils which are more suitable for brick-making) has increased tremendously in recent past due to increasing demand for soil compounded by increased scarcity of good quality soil. This is an outcome of increase in the number of brick-kilns spurred by rapid urbanization and industrialization in the post-liberalization era, which in turn has created huge demand for construction activities. Discussions with a cross-section of villagers reveal that decline in the profitability of agriculture associated with higher risks, increase in cost of labour for agricultural activities especially around the cities, and the tendency among younger generations in the villages to move away from agriculture have all contributed for the declining importance of agriculture in village economy which indirectly contributes for the decision to sell soil and / or land to the brick-kilns.

The crop yield loss due to topsoil removal has been much less than expected in the regions we have studied, because of the fact that both of these regions are endowed with very deep vertisols, (relatively more fertile soils) and hence the deeper layers of soils quickly become suitable for crop production with suitable remedial measures at low cost. Further, some of the farmers have undertaken remedial measures such as application of tank silt, higher dose of organic manure and inorganic fertilizers to make up for the loss in fertility due to the removal of topsoil, which have all resulted in the restoration of soil fertility to some extent.

References:-

1. Aluoch, G.O. (1997) Effect of Brick Making on Social Forestry in East Gem, South Nyakach and North Maragoli Locations of Lake Victoria Basin-Kenya, (http://www.iufro.org/iufro/ iufronet/d6/wu60603/proc1997/aluoch.htm accessed in January 2004).
2. Barbier, E.B. (1998) The economics of soil erosion: Theory, methodology and examples, in *The Economics of Environment and Development. Selected Essays*, E.B. Barbier, ed. Cheltenham, UK: Edward Elgar, pp. 281–307;
3. Basak, R. K. (2010), Soil Testing and Recommendation: A Text Book, Kalyani Publishers;
4. Bojö, J. (1996) “The costs of land degradation in sub-Saharan Africa”, *Ecological Economics*, 16, pp. 161-73;
5. Brady, N.C. (1984), The Nature and Properties of Soils, New York: MacMillan Publishing Company;
6. Byström, O (2000) “The replacement value of wetlands in Sweden”, *Environmental and Resource Economics*, 16, pp. 347-62;
7. Das, D. K. (2000), Introductory Soil Science, Kalyani Publishers;
8. Detwiler, R.P. (1985) “Land use change and the global carbon cycle: The role of tropical soils”, *Biogeochemistry*, 2(1), pp. 67- 93;
9. Drechsel, P., M.Giordano and L.Gyiele (2004) Valuing Nutrients in Soil and Water: Concepts and Techniques with Examples from IWMI Studies in the Developing World, IWMI Research Report 82, Colombo: International Water Management Institute;
10. Enters, T. (1998) ‘A framework for the economic assessment of soil erosion and soil conservation’ in *Soil erosion at multiple scales*, F.W.T. Penning de Vries; F. Agus; J. Kerr, eds. Wallingford: CAB International, IBSRAM, pp. 1-20;
11. Erenstein, O. (1999), The economics of soil conservation in developing countries: The case of crop residue mulching. Unpublished Thesis, Wageningen: Wageningen University;
12. Francisco, H.A. and M.S. de Los Angeles (1998) Soil resource depreciation and deforestation: Philippine case study in resource accounting, Planning and Statistics Branch, Policy and Planning Division, Forestry Department, Rome: Food and Agriculture Organization;
13. Gosselink, J.G., Odum, E.P. & Pope, R.M. (1974), The value of the tidal marsh, LSU-SG-74-03, Center for Wetland Resources, Louisiana State University;

14. Grohs, F. (1994), Economics of soil degradation, erosion and conservation: A case study of Zimbabwe. Arbeiten zur Agrarwirtschaft in Entwicklungsländern. Kiel: Wissenschaftsverlag Vauk Kiel KG;
15. Gunatilake, H.M. and Vieth G.R. (2000), "Estimation of on-site cost of soil erosion: A comparison of replacement and productivity change methods", *Journal of Soil and Water Conservation*, 55, pp. 197-204;
16. Guo, Z., Xiao, X., Gan, Y. and Zheng, Y. (2001), "Ecosystem functions, services and their values – a case study in Xingshan County of China", *Ecological Economics*, 38, 141-54;
17. Izac, A.N. (1997), "Developing policies for soil carbon management in tropical regions" *Geoderma*, Vol. 79, pp. 261-76;
18. Kathuria, V. (2007), Utilization of Fly-ash by Brick Manufacturers – Environmental Costs vs. Benefits, Report submitted to Ministry of Environment and Forests, Govt. of India, N. Delhi;
19. Kathuria, V., Balasubramanian, R. (2013), Environmental Cost of Using Top-soil for Brick-Making: A Case Study from Tamil Nadu, India, Review of Market Integration August 2013 vol. 5 no. 2 171-201;
20. Kim, S. H. and Dixon, J. (1986), Economic valuation of environmental quality aspects of upland agriculture projects in Korea, in Dixon, J. and M. Hufschmidt (eds.) *Economic valuation techniques for the environment - A case study workbook*. Baltimore, London: The Johns Hopkins university press;
21. Kumar, P. (2004), *Economics of soil erosion: Issues and imperatives from India.* New Delhi: Concept Publishing Company;
22. MoEF (2003), Notification, New Delhi, August 27, 2003 (https://envfor.nic.in/legis/hsm/so979 (e).htm accessed on 01.06.2005);
23. Nagornny, V.D. and Raghav, J. S. (2012), Soil Fertility Management, Kalyani Publishers;
24. Niskanen, A. (1998), "Value of external environmental impacts of reforestation in Thailand", *Ecological Economics*, 26, 287-97;
25. Predo, C., Grist, P., Menz, K. and R.F. Rañola Jr. (1997), Two approaches for estimating the on-site costs of soil erosion in the Philippines: 2, The replacement cost approach. *Imperata Project Paper 1997/8*, CRES (Center for Resource and Environmental Studies), Canberra, Australia: The Australian National University;
26. Rainer, S. (2001), Treatment of Contaminated Soil: Fundamentals, Analysis, Applications, Springer Verlag, Berlin;
27. Reddy, R. N. (2010), Soil Engineering: Testing, Design and Remediation, Gene-Tech Books, New Delhi-110002;
28. Samarakoon, S. and P. Abeygunawardena (1995), "An economic assessment of on-site effects of soil erosion in potato lands in Nuwara Eliya district of Sri Lanka", *Journal of Sustainable Agriculture*, 6, pp. 81-92;
29. Sarkar, D. and Haldar, A. (2005), Physical and Chemical Methods in Soil Analysis, New Age Pvt. Ltd. Publishers, Daryaganj, New Delhi;
30. Savalia, S.G., Golakiya, B.A. and Patel, S.V. (2009), Textbook of Soil Physics: Theory and Practices, Kalyani Publishers;
31. Voroney, R. P. (2006), "The Soil Habitat in Soil Microbiology", Ecology and Biochemistry, Eldor A. Paul (ed.);
32. Xue, D. and C. Tisdell (2001), "Valuing ecological functions of biodiversity in Changbasin Mountain Biosphere Reserve in Northeast China", *Biodiversity and Conservation*, 10, 467-81.