Paper presented in

Seventh Biennial Conference

Indian Society for Ecological Economics (INSEE)

Global Change, Ecosystems, Sustainability

Host:
Tezpur University

Cohost:
OKD Institute of Social Change and Development

December 4-8, 2013

Sustainable Development - A Path Dependent Analysis to the Rat hole Coal Mining in Jaintia Hills District, India

Lekha Mukhopadhyay

Department of Economics, Jogamaya Devi College, 92 S.P Mukherjee Road, Calcutta 700026 India. E-mail: lekha.mukhopadhyay@gmail.com

Contact number: +919830139230

FAX: 91-33-24127905

Abstract

Three analytical approaches to plan models for sustainable development are identified in the literature: economic analysis, decision analysis and system analysis. Essence of those three are taken together in an integrated framework to devise a diagnostic methodology to the path of (un)sustainable economic development. Driver-Pressure-State-Impact-Response (DPSIR) and Sustainable Livelihood (SL) frameworks, congruent with capital theoretic approach to sustainable development are entwined in the proposed framework. In the context of artisanal rat-hole coal mining of Jaintia Hills District, north east India having its negative impact on bio-geo-chemical environment, shifting agro based livelihood to mine based one, the methodology has been applied and tested by fitting the statistical path coefficient model with time series data. In the chain of causality this structural equation modeling assesses how directly and indirectly in an interactive way each of the components – the coal export demand in Bangladesh, coal demand in cement industry, rapid coal extraction by artisanal method, mining induced increase in surface runoff, increase in fallow land and acid mine drainage over time is impacting the rice and fish production – the key components of agro based livelihood. The impact intensities of these different components are comparable and utilized in characterizing the path of (un)sustainable development. In terms of size effects they are rankable to set the order of priorities in social and environmental management planning.

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Key words: Absolute and relative fit index, DPSIR, Path coefficient analysis, Rat-hole coal mining, Sustainable Livelihood approach

Introduction

Three analytical approaches to plan models for sustainable development are identified in the literature: economic analysis, decision analysis and system analysis. Economic models generally analyses various resource development scenarios with the potential of alternative investment. This approach is principally capital theoretic, quantitative and functions in a given paradigm. According to this capital theoretic approach, switch over from one resource mix to another resource mix, gradual substitution of natural non-renewable capital by manufactured capital through technological progress are the keys to sustainability of an economy whose current growth is dependent on extraction of natural resources. In Dasgupta – Heal – Solow (1974) framework natural resource is required to be 'weak' essential. To achieve the non-decreasing consumption path over time, required condition is that the elasticity of substitution between manufactured capital and natural non-renewable capital must be greater than one. And in case, elasticity is equal to one, the share of manufactured capital in the output must be greater than the share of the natural capital in the output. Hartwick's rule states that to ensure constant sustainable consumption and intergenerational equity, investment in other forms of capital must exceed the monetary value of depletion of natural resources contributing to the production of marketed goods (Howarth, 2007). The central issue in the theory of sustainable development in general, is the interplay of growth and sacrifice in a dynamic economy. For an efficient economy, growth or development can entail diversion of resources from current consumption to investment for future productivity. However for a less developed economy where the current consumption is already low, one cannot contemplate reducing it further. In that case what is the way out to sustainable development? Economic growth further leads to bio-geo physical and chemical changes to the environment, adversely affecting the sensitivity, adaptive capacity and vulnerability of the eco system. It thus attributes to the present and future cost to the sustainable development. The link between growth and environmental degradation (like pollution) has been grounded in environmental economics mostly in terms of Environmental Kuznet curve. It is used to argue how pollution can rise with economic growth and the resources can be expended to reduce pollution (Beckerman, 1992). Other than current low consumption, and environmental cost of development, the associated economic institutions like market mechanism are also important attributes to the path of sustainable development. In the ideal situation as exhaustible resources become scarce, the market price is expected to rise to prevent exhaustion of resources and thereby encouraging the substitution by technological progress. In the ground reality, if price mechanism is institutionally dysfunctional and thus fails to reflect the scarcity of resources it makes the sustainable development more difficult. For an economy considering in the Environment – Economy – Society nexus, the diagnosis of the problem to sustainable development is a very important task. It calls forth the building up of an analytical framework which can characterize in an integrated way pattern and level of the consumption path, cost path of the economic growth due to environmental degradation and exhaustion of natural resources and also the associated institutional dysfunctionalities. This kind of analysis of the sustainable development therefore, must be a structural or path dependent analysis and the policy outcomes from it must be also path dependent.

The decision analysis and system analysis plan models, on the other hand follow the policy oriented approaches to the sustainable development. They analyze various policy alternatives and structural interrelationship between them and forecast the implications in the context of sustainable development objective. They are basically interdisciplinary in character and allow the paradigm shift. Among them, two widely used policy-oriented models are DPSIR (Driver –Pressure –State –Impact –Response; UNEP/RIVM, 1994; RIVM, 1995) framework and Sustainable Livelihood (SL) framework (DFID, 1997; 2000). For integrated environmental assessment as proposed by RIVM, DPSIR framework is a chain of causal links starting from *D*riving forces through *P*ressures to *S*tates finally leading to *R*esponse. Most of the *D*riving forces are found to be laid into the economic activities like industrial production. Smoke emissions and bio geo-physical and chemical impacts on ecosystem are the examples of *S*tates and *I*mpacts respectively. And *R*esponse led to prioritization, target setting, policy making etc In the SL framework on the other hand, the *L*ivelihood comprises capabilities, assets (human, social, natural, physical and financial) and activities or strategies required for the means of living. The proposed methodology in this paper takes the essence of capital approach to sustainable development in the combined DPSIR and SL frameworks. It purports to explain in the SL framework how the chain of causality described by DPSIR can determine the society's long term access to natural, physical and financial capital. This in turn determines the livelihood strategies open to the society and also whether the livelihood outcome is sustainable or unsustainable. This combined framework is applied in an empirical context, namely in Jaintia Hills District in North East India where market driven artisanal 'rat hole' coal mining with its consequent negative impact on environment has caused the shift of livelihood from agro-based to mine based one. The proposed causality model has been developed and tested by the statistical path coefficient analysis. Data for the analysis are basically time series data, collected from various government reports and to some extent the research works in various disciplines. Using the theoretical premises (discussed above), the leading research question of this paper is to diagnose whether the current development path of Jaintia hills district leading to shift from agro based to mine based livelihood is long term sustainable or not. It has been examined in terms of: (i) whether the substitution of exhaustible resources by manufactured capital is occurring or not, (ii) considering the cost of environmental degradation how much net benefit the society is getting from the shift of livelihood over time, and (iii) does the market mechanism reflect the growing scarcity of coal resources which can drive the investor to switch investment from coal sector to other alternative? Section 2 demonstrates the research methodology. Section 3 gives a narrative description of the study area i.e Jaintia Hills District with rat hole coal mining. Section 4 displays the results of path coefficient analysis to characterize and explain the current path of development of Jaintia district. Finally Section 5 reaches the conclusion

2 Rat-hole coal mining in Jaintia Hills District, Meghalaya, India

Jaintia hills district lying between 25°5′ N - 25°4′ N in latitudes and 91°51′ E - 92°45′ E in longitudes, covering an area of 3819 km^2 is one of the seven districts of the state of Meghalaya. It has an international boundary in the south by Bangladesh. The population of the district is 392852 (2011 census) of which 96% is tribal. According to the Geological Survey of India in 1974, the total coal reserve in the district is 39 million tons. Sutnga, Lakadong, Musiang-Lamare, Khilehriat, loksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal bearing areas of the district that altogether cover 57.9 km^2 (Sahu & Goel, 2004)). Jaintia Hills district although constitutes only 7.48% of the total coal reserve of the state, it contributes 75% of the total coal production. (Sarma, 2005). After the independence of Bangladesh in 1971 and Jaintia got its district autonomy in 1972, coal extraction in Jaintia district has been rapidly rising (Figure 2). From 1975 till 2007 coal production has increased by 161%. There are at least five possible reasons for this rapid unregulated depletion of coal resources. Firstly there is rising demand for coal export to Bangladesh and secondly the rising demand in Meghalaya and other states in India for coal as fuel in industrial production. Jaintia coal is sub-bituminous with high sulphur (principally organic) content (more than 5%; Behra, 2007). It is mostly used as fuel in the small and medium scale industries like cement, bricks, tea, fertilizer etc in Bangladesh

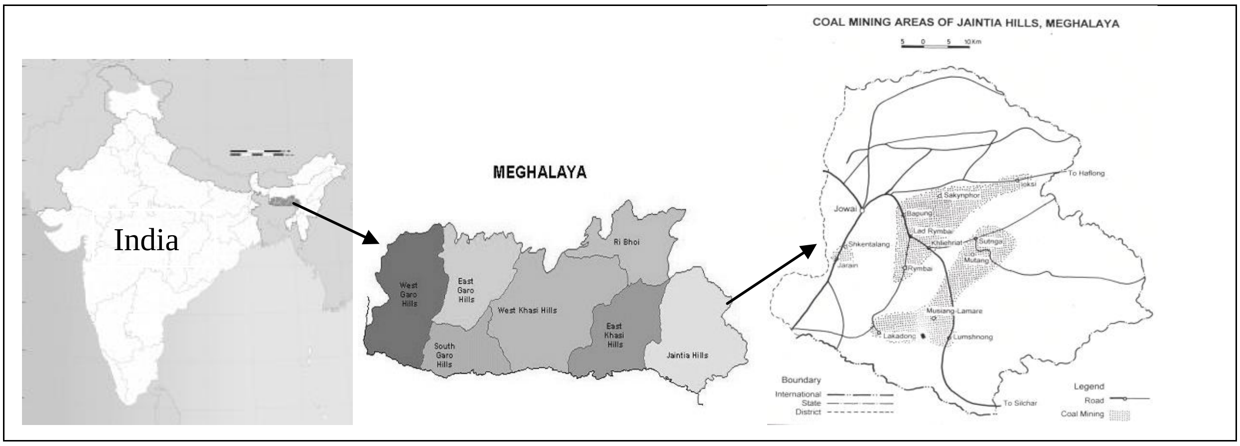
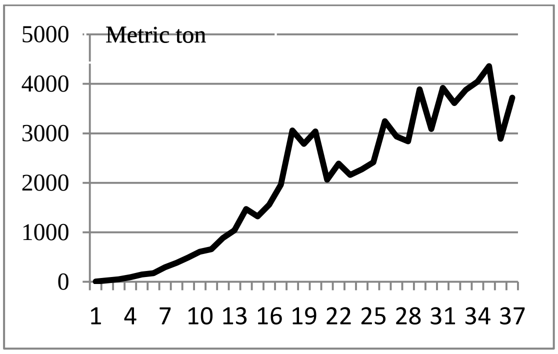
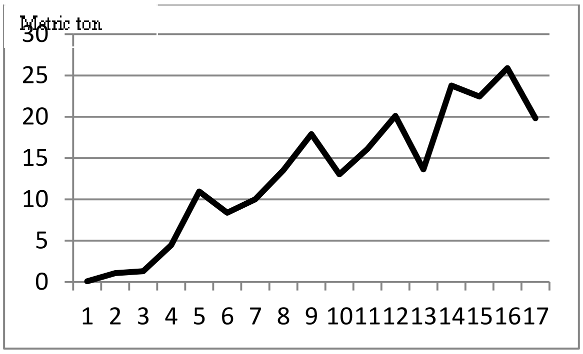


Figure1: Coal mining area of Jaintia Hills District of Meghalaya, India

and in India. It is not used by power plants and nor useful for manufacturing industries because of its high sulphur content. Demand for coal as input for cement and brick production i.e. in construction industry in Meghalaya may be an indicator of industrialization and infrastructural development in the state, while coal extraction in response to the rising export demand is purely a market driven phenomenon. Increasing demand for Meghalaya coal in Bangladesh is evident by the export trend over the time (Figure 3). Dawki –Tambil road that crosses the border of Bangldesh with land customs station at Dawki in Jaintia district plays a significant role



Coal extraction –Jaintia Hills District: 1974-75 -2009-10
Figure 2



Coal Export to Bangladesh from Meghalaya: 1989-90-2005-06
Figure 2

in coal exporting activities. During 2005-06 for example, 70% of the total royalty from coal export to Bangladesh enjoyed by Meghalaya is contributed by Jaintia district itself (Rout, 2006). Third reason for rapid coal extraction in the district is an under-current apprehension of take-over of coal by public sector. Given the typical constitutional right of land ownership enjoyed by tribal community (Sixth Schedule of the Constitution of India), state government of Meghalaya cannot and does not intervene into artisanal private mining in tribal land. But there is every possibility that any day government can take over the ownership of the coal mines by revising the constitution. The State Government drafted a mining and mineral policy as per directives in 2004 by Supreme Court but kept in abeyance to enact the laws under pressure of powerful mining lobbies both at state and at the central level (Statesman, May13, 2012). Fourth driving force for rampant coal mining is poverty. Wherever the landowner needs some emergency cash and expects that there may be coal, forest cover is cleared and a shaft of diameter varying from 3m to 10m is sunk. Hole is dug into coal seam and goes deeper and deeper for several kilometers following the seam. These burrows or holes are big enough to accommodate just one person to crawl in with tools and basket or wheeled cart to carry out coal to the depots located near the main road. This is known as "rat-hole mining" as it is similar to the burrow making by the rats. There are approximately 5000 coal mines in this district. 99% of the workers in the mines are migrant from Bangladesh, Nepal and Assam Bihar and Jharkhand (the number of Nepalis workers estimated as 1,50,000; Madhavan, 2005). According to an estimate from a NGO 70,000 (50000 from a different source of information and there is a debate about the exact number!), children in the age between 7 to 17 are working in these private mines as the casual labor under private contractors without any security to their lives (Impulse 2011). Daily wage rate for mine workers (particularly for digging and cutting the coal with maximum life risk) is much higher than the agricultural wages (Lamin, 1995). The coal bed and seams in this particular area are horizontal to ground and few meters deep in the form of thin seam (30 to 212 cm in thickness; Guha Roy 1992) lying along the bedding planes of the host rock. Due to this peculiar geological characteristic of the coal beds in this area, the large scale mining is not economically profitable. Fourth important reason for rapid extraction is the undefined property rights to the coal underground. The tribal community land has been gradually privatized to reap the immediate benefit from mining (McDuie-Ra, 2007) without getting concerned with the long term environmental consequences and with the consequence when the coal resource will be totally exhausted. When the land owner starts digging burrow it is within his private land jurisdiction but as he enters underground the earth there is no private property demarcation; like ground water, coal becomes a common pool resource under open access regime. As he cannot restrain his competitive neighbor to encroach upon coal resource in 'his' region, he wants to extract rapidly as much as he can.   All these factors lead to rampant unscientific coal mining in this area. Although it is completely illegal and unscientific, government collects huge revenue in the form of royalty and transport tax from mine owners (Blahwar 2010).

The rampant unscientific archaic rat hole coal mining along with the absence of post mining treatment and management of mined areas are making the fragile ecosystems of the hilly area more vulnerable to environmental degradation. Mining induced deforestation leads to the increasing surface runoff and thus washing off the soil nutrients. Mine spoils or over burden create extremely rigid substrata for the plant growth. Continued soil acidification due to acid mine drainage and toxic elements of coal spoils like Al, Fe, Mn, Cu have caused enormous damage to the plant biodiversity in this area (Sarma,2005). Due to mining induced changes in land use pattern and soil pollution the area of fallow land has steadily increased (Figure 3 and 4). Between 1975 and 2007, there has been decrease in forest area by 12.5%, while area under mining has increased three fold (Sarma et.al, 2010). The cultivable waste land in Jaintia district is found to be the highest (31%) in the state of Meghalaya

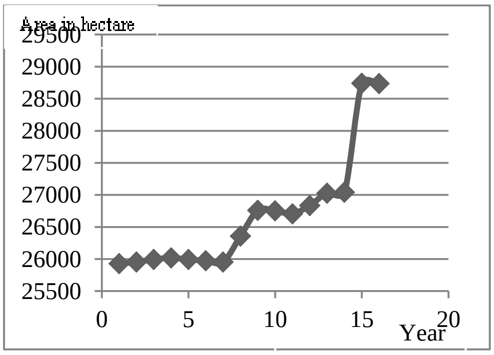


Figure 3 Area of fallow land (in hectare) in Jaintia Hills district: 190-91 -2007-08

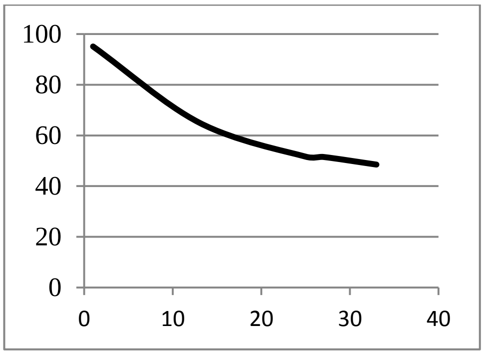


Figure 4 Dense forest area (Log Sq Km)   1975 -2007

Acid mine drainage (AMD) in the surface water bodies, in the river streams from the active coal mines (while dewatering the mines in the post monsoon period to start mining in the dry winter period (Blahwar, 2010)), coal dumps and abandoned mines is a very common phenomenon in Jaintia district. It is indicated by low pH (between 2-3), high conductivity, high concentration of sulphates, iron and toxic heavy metals, low dissolved oxygen (DO) and high BOD in the river stream water (Blahwar, Ibid; Swer & Singh,2004) in the coal belt area. Pyrite from surrounding coal gets quickly hydrolyzed in slightly acidic water, releases protons and sulphate further adding acidity and increasing sulphate concentration. pH values (annually on an average) in stream Kyrukhla in Khilehriat coalfield area since 1994-95 till 2007-08 is observed to be steadily declining (Figure 5).

AMD has been injurious to aquatic biota, including fish, amphibians, aquatic plants and insects (Swer & Singh 2004). AMD has also created a major constraint to the availability of potable water (Dkhar, 2010). Rice

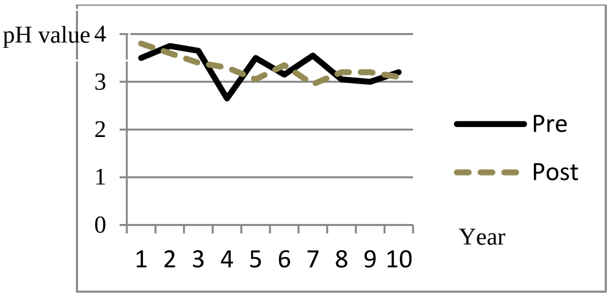


Figure 5 Average pH value of water in Kyrukhla stream in pre and post monsoon period: 1994 -2003

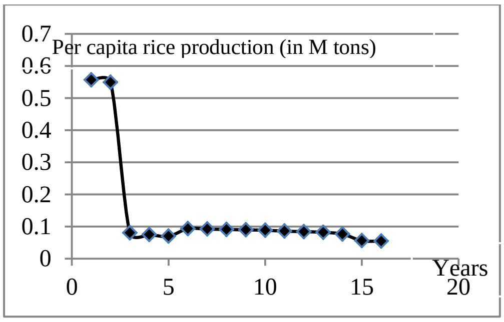
productivity on an average in the coalfield area is observed to be 860 kg/ha (where soil pH on an average is 3.54) compared to 1926 kg/ha in non-mined area (where soil pH is 4.35 on an average) and 1123 kg/ha in the abandoned mining sites. Rice crop shoot in the coal mined area is 2.75 gram per pot compared to 7.90 gram per pot in non-mined area (Choudhury et.al 2010)

Soil pH in the dumping site of the coal field area is around 2.42 and 2.56 in the paddy field nearby (Barua, Khare et.al 2010). Representative soil samples from different land uses (viz., non-mined, coal-mined and 4 years abandoned mining sites) of the three major coal belts viz., Bapung, Sutnga and Khliehriat in Jaintia Hills district show that coal mining has caused the decrease in the soil pH by about one unit compared to the soil free from mining activity where pH is 4.35).

Along with rapid expansion of rat hole coal mining in Jaintia there has been increase in income and employment of a section of people associated with mining activities. The disparities in wage rates (daily wage rate in coal mining is higher than the agricultural wage rates; Sahu and Goel 2004) also has increased. The local people usually don't sell their labor in the mines and most of the time they lease out their land to the coal traders and exporters. The major influx of labor comes from migration. The area under agricultural land has been steadily declining for diversification to coal mining. The overall socio economic impact is the undergoing shift from agro based livelihood to coal based livelihood. If the present rate of coal extraction continues it is apprehended that coal reserve would be exhausted within next 15 years. With this ground reality at the back drop, and theoretical propositions of sustainable development, this current research work is built up on a key premise that the on-going shift of livelihood from agro based to coal based is not sustainable. While characterizing the development path it further intends to identify which factor(s) are playing the significant role (impacting) to make the existing development path (un)sustainable. And what are its policy implications? In an elaborative way, the broad objective of this research work is to indicate how the negative impact of coal mining in Jaintia Hills district can be reduced while improving the long term sustainable livelihood. This entails two immediate research assignments: (1) how we can measure the impact intensity of each factor? And, (2) how we can make the different impact intensities comparable so that one can rank them to prioritize in policy formulations.

3 Analytical methodologies

In the present research work we have utilized and combined the Driver-Pressure-State-Impact-Response (DPSIR) and the Sustainable Livelihood (SL) framework concepts. These two together in an integrated way, constitute the high level scenario framework, which is fitted into the statistical path coefficient analysis. In Meghalaya after the food processing, the second largest investment (more than 3.6 million Rupees) is made in cement industry. Coal is significantly used as input in cement production. The production in cement industry in Meghalaya is considered as a potential indicator of alternative form of industrialization and coal export is an indicator of outflow of capital from production sector to the export market sector to Bangladesh. These two in the present analysis have been proposed to be tested as the *D*riving forces to rapid coal extraction that lead to the *P*ressure on environment indicated by increase in surface runoff (associated with mining induced deforestation), fallow land and acid mine drainage indicated by pH and sulphate concentration in the stream flow in the coal belt area. These mining induced pressure and impact are changing the livelihood strategies from agro based to mine based. This change is reflected in per capita decline in rice p roduction and fish production over time Figure 6 and 7) – the two key indicators of agro



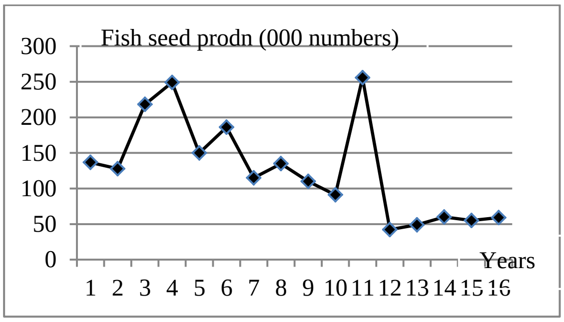


Figure 6 Fish seed production: 1991-92 – 2006-07   Figure 7 Per capita rice production : 1990-91 – 2006-07

based livelihood. This integrated framework by a stylized chain of causality, not only explains the impact generating process at various levels in economy-environment-society nexus, but also characterizes the path of development of the society. The methodology has been devised to assess how directly and indirectly in an interactive way various economic components, like coal export demand, cement production, hydrological components like surface run off, hydro- geochemical components like those water quality indicator of acid mine drainage (here only pH value and sulphate concentration in a particular stream water) and land diversification over time are affecting the rice and fish production – the key components of agro based livelihood in Jaintia Hills District. The schematic representation of our proposed methodology is given in Figure 8. Five types of capital (natural, physical, social, human and financial) are involved in economic activities and environmental changes that shape up the livelihood strategies and outcomes. The statistical Path Analysis with the time series data is done. Since it is based upon the secondary data, the choice of the scenario framework is partially dependent on the availability of information. Due to paucity of data, the declining trends of rice production and fish production have been studied separately by two distinct path models.

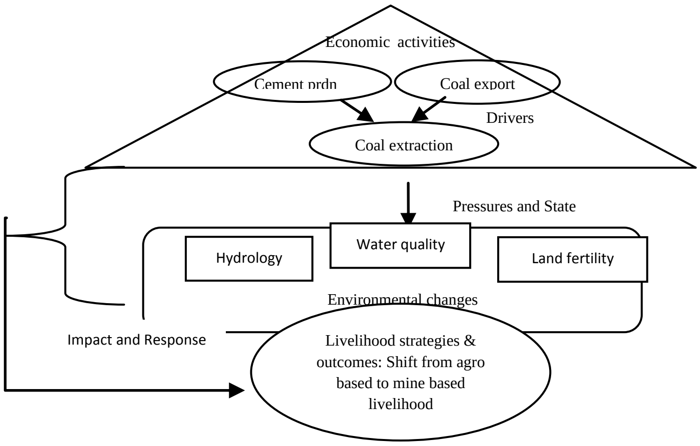
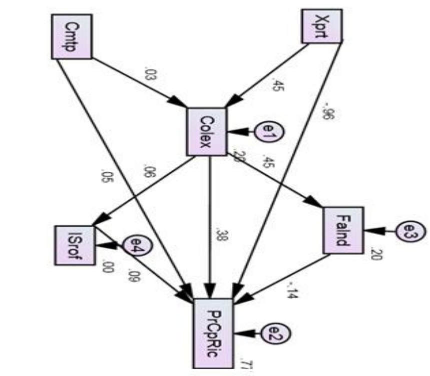


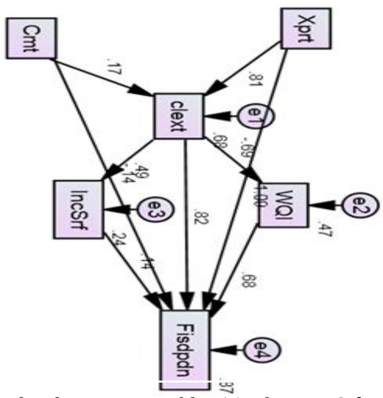
Figure: 8 Integrated analytical framework proposed and used in the present work

The computer generated path models (AMOS; IBM SPSS 20) to explain that decline in per capita rice (PrCpRic) and fish seed (Fisdpdn) production are shown in Figure 9a and 9b. The rice-coal extraction and fish-coal extraction paths are studied with 18 years' (1990-2007) and 10 (1994-95 -2003-04) years' time series data respectively. 18 years' and 10 years' data are considered as 18 and 10 set of observations.



Observed endogenous variables (4): Colex, ISrof, Falnd, PrCpRic
Observed endogenous variables (2): Xprt, Cmtp
Unobserved exogenous variables (4): e1. e2. e3. e4

Figure 9A Rice-coal path diagram



Observed endogenous variables (4): clext, IncSrf, WQI, Fisdpdn
Observed endogenous variables (2): Xprt, Cmt
Unobserved exogenous variables (4): e1. e2. e3. e4

Figure 9B Fish-coal path diagram

Since agricultural production in Jaintia district is principally rain fed, mining induced change in water quality in river stream does not affect rice production, water quality index (WQI; considering pH and sulphate concentration of the water in the river) value is not chosen in rice-coal path model. Acid mine drainage affects the soil quality and thus the agriculture. Since time series data for soil quality (like total metal load via chemical extraction/digestion of the sediments, (Gilchrist et.al, 1994), or bio-availability of that load (Keon et al 2001; Swartz et al 2004) are not consistently available, area of fallow land (Falnd as a proxy of degraded soil) instead is taken into account. Data for mining induced increase in surface runoff (IncSrf) is generated by using the formula: $IncSrf_t = (P_t - ET_{\mathrm{Re}\,f})* Frstlost_t$ where P: rainfall precipitation, ET: evapotranspiration, Frslost- area of loss of forest estimated from percentage change of area from dense forest area to coal mine area from satellite imagery data of 1975,1987, 1999, 2001 and 2007 (Sarma Tripathi and Kushwaha, 2010). For ET we have taken the average of the values of crop-evapotranspiration in Jaintia on the basis of the data from 1901-2001(India Waterportal)[1]. For water quality analysis we have considered 10 (1994-95 -2003-04) years' pH and sulphate concentration data of the water in Kyrhukhla stream, at Khliehriat flowing at the heart of coal belt area. Low pH value and high sulphate concentration are the indicators of acid mine drainage (AMD). But they are not all. Due to the non-availability of data following the basic premise of Gray Kuma on MAMDI (Modified Acid Mine Drainage Index; Gray, 1996 or Kuma, et.al 2011), we have re-normalized the scoring system for these two constituents - pH and sulphate and re-constructed MAMDI. (Constrained by data, our index is not much rigorous one and cannot capture some of the toxic elements of AMD, particularly metallic ones). Following Kuma et.al (2011) and considering the fact that pH may have more of an effect on the benthic community in the river than sulphate, dissolved oxygen levels on fish health, greater weight has been put (0.55) on pH and lesser (0.45) on sulphate. The formula we used for constructing index is: $(\text{pH score} + \text{Sulphate score})^2/100$. The pH score and sulphate score we used here are taken from Kuma et.al (ibid). We have chosen one particular river stream as a representative of all AMD affected streams in Jaintia. This choice is justifiable. When we plotted different data sets from the various referred studies (spatial) on AMD in Jaintia districts (Das et.al 2011, Sahoo et.al 2012, Blahwar, 2010; Meghalaya SPCB) primarily focussing on sulphate, pH, and conductivity as primary variables the behaviour of these three variables location and time wise were fairly universal[2].

We run the statistical path analysis with the available data. The path analysis belongs to the class of structural equation modelling which purports to fit the proposed structural model against the null model that assumes that there is no relation between the variables proposed in structural model. It is recursive. Each variable enters stage by stage to explain the variable followed in the next stage. This kind of structural model shows the potential causal dependencies. In our particular context for example, at stage 1 coal export in Bangladesh (Exprt) and cement production (Cmtp) enter to explain rapid coal extraction (Colex) and at stage 2, Colex enters to explain increase in surface run off (ISrof) and area of fallow land (Falnd) and finally, ISrof and Falnd enter to explain the per capita rice production (PrCpRic). Path coefficients estimated from layered multiple regression analysis show the effect size of each of the observed component and they are displayed against their respective arrows in the path diagram (Fig.9A and Fig.9B) Effects are direct and indirect. Indirect effects or impacts are those which are mediated by others. Maximum Likelihood method of estimation is used and thus it does not assume uncorrelated error terms. The path coefficients we considered here are standardized coefficients based on standardized data. They thus show the relative importance of each of the proposed independent variables. Although the coefficients are regression coefficients, this type of structural equation modelling is more general than regression models themselves. Any particular variable can act as dependent variable at one layer and independent at other. So far the examination of "fit" of an estimated path model is concerned, it consider how well it models the data. It thus tests the "fit" against the "null" model that presumes no correlation between the observed variables. Thus rejection of "null" model in the path analysis implies goodness of fit. There are varying fit indices found in the literature (Bentler, 1990; Kline 2011) categorized under Absolute Fit Index (AFI) and Relative Fit Index (RFI). Absolute indices are computed using formulae that include discrepancies (matrix of residuals) and degrees of freedom (df) and sample size. It is absolute in the sense that it does not compare the estimated model with any other model. Formulae for relative indices consider discrepancies of the estimated model from a "null" model. Roughly for AFI and RFI values above 0.9 are considered to be adequate. Among AFIs most common used measure is Chi-square $\left(\chi^2\right)$. Relative χ^2 , Comparative Fit Index (CFI), Tucker Lewis Index (TLI) belong to the RFIs. Relative $\chi^2 = \frac{\chi^2}{df}$, CFI $= 1 - \frac{\hat{\delta}_M}{\hat{\delta}_B}$ where, $\hat{\delta}_M = \max\left(\chi_M{}^2 - df_M, 0\right)$ where δ measures the degree of misspecification of the model. Subscript *M* and *B* indicate estimated and base or null models respectively. The formula for TLI $= 1 - \frac{\chi_M{}^2 / df_M}{\chi_B{}^2 / df_B}$.

Among the indices based on residuals that look at discrepancies between observed and predicted covariances, there are Root Mean Squared Residuals (RMR), Root Mean Squared Error of Approximation etc.

Among the various Fit Indices criteria, we found that proposed Rice- coal path model have satisfied the acceptable threshold levels of relative χ^2 and RMR. The Fish- coal Path model on the other hand satisfies χ^2 fit and Relative χ^2 (Table 1).

Fit Index	Acceptable Threshold Levels	Rice –coal path model	Fish-coal path model
Chi sq (Absolute Fit)	Low chi-sq to d.f with an insig p value p ≥ 0.05	0.02	0.05
Relative chi-square (Chi-sq/df)	2.1 (Tabachnic& Fidel (2007); 3.1 (Kline, 2005)	3.46	2.12
RMR (Root mean square residual)	Good models have small (RMR<0.10)	0.05	0.16

Table 1: Rice-coal and Fish-Coal Path models and model fit indices

4 Results of the statistical path analysis

The results of the statistical path analysis (Table 2, Table 3, and Table 4) establish that export of coal in Bangladesh has the largest size effect (in terms of direct, indirect and overall effects with statistical significance) to explain the variability in per capita rice production. And in all the cases the effect is negative. Due to the direct (unmediated) effect of xprt on PrCpRic, when xprt goes up by 1 standard deviation, PrCpRic goes down by 0.958 standard deviations. This is in addition to the indirect (mediated) effect that xprt has on PrCpRic. And in terms of indirect (mediated) effect also export has the largest effect on per capita rice production. So far the fish seed production is concerned, the direct effect of export (negative) is the largest and the effect (positive) of water quality (acid mine drainage) index is the second largest. Pearson correlation coefficient between Water Quality Index (WQI) and fish seed production (Fisdpdn) is the largest among all others.

		cmt	xprt	Colex	isrf	Falnd	PrCpRic
cmt	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	18					
xprt	Pearson Correlation	-.001	1				
	Sig. (2-tailed)	.996					
	N	18	18				
Colex	Pearson Correlation	.033	.446	1			
	Sig. (2-tailed)	.895	.063				
	N	18	18	18			
isrf	Pearson Correlation	.595**	.036	.059	1		
	Sig. (2-tailed)	.009	.888	.816			
	N	18	18	18	18		
Falnd	Pearson Correlation	-.138	.776**	.449	-.035	1	
	Sig. (2-tailed)	.585	.000	.062	.890		
	N	18	18	18	18	18	
PrCpRic	Pearson Correlation	.126	-.829**	-.097	.105	-.670**	1
	Sig. (2-tailed)	.619	.000	.701	.678	.002	
	N	18	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

Table 1: Pearson correlation matrix in case of Rice –Coal Path analysis

Dep var		Indep var	Estimate
Colex	<---	xprt	0.446*
Colex	<---	cmt	0.034
isrf	<---	Colex	0.059
Falnd	<---	Colex	0.449*
PrCpRic	<---	Colex	0.377*
PrCpRic	<---	xprt	-0.958**
PrCpRic	<---	Falnd	-0.137
PrCpRic	<---	isrf	0.092
PrCpRic	<---	cmt	0.048

Note : ** significantly different from zero at the 0.001 level (two-tailed)
* significantly different from zero at the 0.05 level (two-tailed).

Table 3a.Standardized direct effects in case of rice – coal path

Variable	cmt	xprt	Colex	Falnd	isrf
Colex	0	0	0	0	0
Falnd	0.015	0.2	0	0	0
Isrf	0.002	0.026	0	0	0
PrCpRic	0.011	0.143	-0.056	0	0

Table 3b. Standardized indirect effects in case of rice – coal path

	cmt	xprt	Colex	Falnd	isrf
Direct effect	5	1 (-)*	2 (+)*	3 (-)	4 (+)
Indirect effect	3	1	2	NIL	NIL

Table4: Ranking of size effect on per capita rice production

Impact of export driven coal extraction on environmental components, particularly on fallow land (Falnd) and water quality index (acid mine drainage) are statistically quite significant. When coal extraction goes up by one unit standard deviation (SD) area of fallow land rises by 0.45 SD. Again when coal extraction goes up by one unit SD, WQI falls by 0.69 SD.

		Cmt	Xprt	clext	IncSrf	WQI	Fisdpdn
Cmt	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	10					
Xprt	Pearson Correlation	-.734*	1				
	Sig. (2-tailed)	.016					
	N	10	10				
clext	Pearson Correlation	-.470	.762*	1			
	Sig. (2-tailed)	.170	.010				
	N	10	10	10			
IncSrf	Pearson Correlation	-.211	.500	.451	1		
	Sig. (2-tailed)	.558	.141	.191			
	N	10	10	10	10		
WQI	Pearson Correlation	.620	-.800**	-.647*	-.397	1	
	Sig. (2-tailed)	.056	.005	.043	.255		
	N	10	10	10	10	10	
Fisdpdn	Pearson Correlation	.614	-.784**	-.345	-.272	.809**	1
	Sig. (2-tailed)	.059	.007	.329	.448	.005	
	N	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Table 5: Pearson correlation matrix in case of Fish –Coal Path

Dep Var		**Indep var**	**Estimate**
clext	<---	Xprt	0.807**
clext	<---	Cmt	0.173
WQI	<---	clext	-0.689*
IncSrf	<---	clext	0.493
Fisdpdn	<---	IncSrf	0.14
Fisdpdn	<---	WQI	0.68**
Fisdpdn	<---	clext	0.823**
Fisdpdn	<---	Xprt	-1.086**
Fisdpdn	<---	Cmt	-0.141

Note : ** significantly different from zero at the 0.001 level (two-taile
* significantly different from zero at the 0.05 level (two-tailed).
Table 6a.Standardized direct effects in case of fish – coal path

Standardized Indirect Effects

	Cmt	Xprt	clext	IncSrf	WQI
clext	0	0	0	0	0
IncSrf	0.085	0.398	0	0	0
WQI	-0.119	-0.556	0	0	0
Fisdpdn	0.073	0.342	-0.399	0	0

Table 6b. Standardized indirect effects in case of fish – coal path

	Cmt1	Xprt1	Colex1	ISrof1	WQI
Direct effect	4 (-)	1 (-)	2 (+)*	4 (+)	3 (+)*
Indirect effect	3 (+)	2 (+)	1 (-)	NIL	NIL

Table 7: Ranking of size effect on fish seed production

5 Conclusion

From the results of the statistical analysis we can reach some important conclusions on the coal based economic development in Jaintia district. Rising coal export from Meghalaya to Bangladesh, acts as the major driving force to rapid coal extraction. This indicates that there is flight of capital from coal mining through the export market and thus no repatriation of profit from coal sector for industrialization is taking place. The shift of livelihood from agro based to coal based along the existing development path occurs which is unsustainable because export is the major driver to the coal extraction. After coal reserve will be exhausted, this development path will no more sustain. Thus the basic premise of Heal-Solow-Dasgupta- Hartwick theory to sustainable development i.e. substitution of natural capital by manufactured capital does not hold good. Increasing the area of fallow land and water quality deterioration has a long term negative impact on rice and fish production making them unsustainable. To redirect the growth path toward economy –environment –sustainability, the policies are required to intervene in the export market mechanism which is oligopolistic in nature and mostly controlled by the traders and contractors in Bangladesh border area. To build up the potential of sustainability in economic development of this hilly district in north east India export market regulation, gradual substitution of capital from coal mining to manufacturing industry, along with hydro geological, hydro geochemical and land diversification management can be included into the policy formulations.

* **Acknowledgement**: This paper is a part of the research work funded under Fulbright Nehru Environmental Leadership Program (2012 -13) and done in collaboration with Stockholm Environment Institute (SEI), US organization; Davis, CA, USA. A version of this paper has been presented in International Conference on Inequality and Sustainability, 9-10 November 2012, Tufts University, Medford, MA and also in the Theory Colloquia in the Department of Economics, University of California, Riverside, on January 9, 2013. The author expresses her heartiest gratitude to particularly David Purkey (SEI, Davis, CA), Chris Schwartz (SEI, Boston, MA) and Eric Kemp Benedict (SEI, Bangkok, Thailand) and A. Colin Cameron of Department of Economics, UC Davis. Their valuable interaction with me and academic support helped me to enrich this work.

[1] For estimation methodology in case of IncSroff, I am thankful to Vishal Mehta, Senior Scientist, SEI, Davis, CA

[2] I am most sincerely grateful to Chris Swartz, Senior Scientist, SEI, Boston, MA for his active guidance while choosing the water quality parameter.

References

ARGHYAM (2012). India Waterportal, Bangalore, India. http://www.indiawaterportal.org/data Accessed 1 November, 2012

Bentler, P.M. (1990). Comparative Fit Indexes in structural models, *Psychological Bulletin*, 107(2), 238-246

Blahwar, B. (2010) Identification of the extent of artisanal coal mining and related acid mine water hazards using remote sensing and field sampling: a case study in Jaiñta Hills of North - eastern India. *Enschede, University of Twente Faculty of Geo-Information and Earth Observation (ITC).* http://www.itc.nl/Pub/Home/library/Academic_output/AcademicOutput.html?p=8&y=10&l=20 . Accessed 9 May, 2012

Beckerman, Wilfred (1992). Economic Growth and the Environment: Whose Growth? Whose Environment?, *World Development* 20 (4), 481-496

Behra, P. (2007). Volatile displacement of Meghalaya coal – a pointer to explore low sulphur coal, *Journal of Earth System Science*, 116 (2), 137-42

DFID (2000). Sustainable Livelihoods Guidance Sheets. Department for International Development. www.livelihood.org/info/info_guidancesheets.htm. Accessed 15 October, 2012

Das, M & Ramanujam, P. (2011). Metal content in water and filamentous algae Microspora quadrata hazen from coal mine impacted streams of Jaintia hills district, Meghalaya, India, *International Journal of Botany*, 7(2), 170-176

Dasgupta, P and G, Heal (1974). The Optimal depletion of exhaustible resources, in Symposium on the Economics of Exhaustible Resources, *Review of Economic Studies* 42, 3-28

Gray N. F. ( ). The Use of an Objective Index for the Assessment of the Contamination of Surface Water and Groundwater by Acid Mine Drainage, Journal of CIWEM

Guha Roy, P.K. (1992). Coal mining in Meghalaya and its impact of environment. In: Environment, conservation and wasteland development in Meghalaya, Meghalaya Science Society, Shillong

Hazarika, S (2000). Rites of passage: border crossings, imagined homelands, India's East and Bangladesh (New Delhi: Penguin).

Homer-Dixon, T (1994). Environmental scarcities and violent conflict: evidence from cases, *International Security*, 19(1), 5 – 40.

Howarth, Richard B. (2007). Towards an operational sustainability criterion, *Ecological Economics* 63, 656-663

Impulse (2011). An Exploratory Study of Children Engaged in Rat Hole Mining in the Coal Mines of Jaintia Hills District, Meghalaya. hrn.or.jp/activity/2011/02/08/201102_Meghalaya.pdf Accessed 3 August, 2012

Keon, N.E, Swartz, C. H., Barbander, D. J., Harvey, C. & Hemond H. F. (2001) Validation of an arsenic sequential extraction method for evaluating mobility in sediments, *Environmental Science & Technology*, 35, 2778-2784

Kline, Rex B. (2011). *Principles and Practice of Structural Equation Modelling*, Third Edition

Kuma J. S, P. L Younger, W. K Buah. (2011). Numerical Indices of the Severity of Acidic Mine Drainage: Broadening the Applicability of the Gray Acid Mine Drainage Index, *Mine Water Environment* 30, 67–74

Lamin, H. (1995). *Economy and Society in Meghalaya*, Har-Anand Publication, New Delhi, pp. 109-129

Madhavan, P. (2005). Ant people, *Eastern Panorama*, 14(6), 8 – 10.

McDuie-Ra, Duncan (2007). Anti-development or identity crisis? Misreading civil society in Meghalaya, India, *Asian Ethnicity*, 8(1)

RIVM (1995). A General Strategy for Integrated Environmental Assessment at the European Environment Agency. European Environment Agency. Copenhagen, Denmark

Rout, L (2006). Impact of coal mining and trading on the economy of Meghalaya: a case study Jaintia Hills district; a Ph. D dissertation

Swartz, C. H., Keon, N.E, Badruzzman, B., Ali, A., Barbander, D., Jay, J., Besancon, J., Islam, S., Hemond H. F., & Harvey, C. (2004). Mobility of arsenic in a Bangladesh aquifer: Inferences from geochemical profiles, leaching data, and mineralogical characterization, *Geochimica et Cosmochimica Acta*, 68(22), 4539-4557

Sahoo, P., Tripathy, K. S., Equeenuddin, & S. M., Panigrahi, M. K. (2012). Geochemical characteristics of coal mine discharge vis-à-vis behaviour of rare earth elements at Jaintia Hills coalfield, northeastern India, *Journal of Geochemical Exploration* 112, 235–243

Sahu B.P & Goel, N.P. (2004). Social and environmental impact assessment of mining in Meghalaya: a case study of Jaintia hills in Zahid Husain and N.K Barik (eds): *Development and Environment; development of* *geoenergy resources and its impact on environment and man of north east India*, Regency Publications, N Delhi, India

Sarma, K (2005). Impact of coal mining on vegetation: a case study in Jaintia district of Meghalaya, India

Sarma, K., Tripathi, R.S. & S.P.S. Kushwaha, (2010). Land use/land cover change analysis in coal mine affected areas in Jaintia Hills district of Meghalaya, northeast India using remote sensing and GIS technique. *Indian Journal of Tropical Biodiversity*, 16(1), 43-50.

Solow, R. M (1974). The Economics of Resources or Resources of Economics, papers and proceedings of the 86th Annual Meeting of AEA, *American Economic Review*, 64(2), 1-14

Stiglitz, J (1974). Growth with exhaustible natural resources: efficient and optimal growth paths in Symposium on the Economics of Exhaustible Resources, *Review of Economic Studies* 42, 123-37

Swain, A. (1996). Displacing conflict: environmental destruction in Bangladesh and ethnic conflict in India, *Journal of Peace Research*, 33(2), 189 – 204

Tabachnick, B.G. and Fidell, L.S. (2007). *Using Multivariate Statistics* (5th ed.). New York: Allyn and Bacon.

UNEP/RIVM (1994) An Overview of Environmental Indicators: State of the art and perspectives. UNEP/EATR.94-01, RIVM/402001001, Nairobi