Environmental resources and their economics for use

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This article illustrates an approach to the understanding of the environmental resources and their related economics and policy planning for their development and exploitation without any disturbance to the existing balance in the ecosystem. An operational methodology to measure the trade-off between economy and ecology is presented. The mathematics for developing the scenario is evolved to expound the system of analysis. It constitutes the primary goal. It is observed that all economic sectors have indirect environmental linkages and affect the environment of the region. The impact magnitude is, however, steered by the output. The article also elucidates how useful environmental multipliers are for an effective decision-making in resource exploitation.

Keywords: Economics, ecosystem, environment, exploitation, policy-planning, resources.

Concept

THE concepts of resource and environment are closely interlaced. It is imperative that their inherent characteristics and integrated nature are comprehended so that the issues in the management can be totally understood.

Buckminster Fuller commented 'I + environment = universe'; he, however, added that 'Universe – I' was not equal to the environment. The difference is passed over as merely semantic, but is central to understanding. Nature is absolute. It exists with all its variety, regardless of who comprehends it or does not. Environment is relative. The relational quality extends to resource; there are no absolute resources, only things that can be used by some entity and that too under particular environment. There is nothing that has an intrinsic quality of being a resource. A resource is what is used in an environment.

The quality of life of a people in any eventual analysis emerges basically as an expression of the nation's ability to manage its natural and human environment. The environmental resources are there. The onus lies squarely on those in charge of the management of these resources.

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In exploitation of environmental resources, the specified regional society has priority in abstracting the natural resources of the region. And the resources will become useful only when they become meaningful to the specified society and contribute to its development. The system to be evolved is for the absorbance of the end-product by the society in the region.

In terms of exploitation of natural environment, the base unit – an ecosystem is regarded as an 'environmental setting', which can be described by the baseline characteristics of the environment thereof (terrestrial, aquatic, air and human interface) and upon which impacts may occur.

Development may be defined as a quantitative and qualitative process of economic and social changes of lasting character and this can be adequately viewed as a permanent and sequential process of decision-making by participating agents. Planning is, however, a technique destined to change the actual process of decision-making into a rational one. As such, it is a neutral concept not involving ethical and political considerations.

Economy is conceived as a dynamic social entity capable of continual absorption of environmental resources or their derivatives through the establishment of norms of reciprocity, redistribution and exchange. Thus the role of the economy of a nation-state or for that matter, of a national economy, lies in its function of integrating environmental distribution of resources at a specific level. It follows that at any given point of time, the economy of a nation-state is never manifest as a homogeneously distributed entity over the geographical space, because the environmental resource potential of units of geographical spaces varies, for obvious reasons, independently between themselves. Hence each heterogeneous resource space requires a specific and flexible economic modus operandi for being integrated with the economy of that geographical space. So far as the economy and its constituents are concerned, it should be realized that the parts exist for the whole and the whole likewise exists for the parts and the purpose is to maintain the whole body economic in equilibrium and to

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let it grow. The management strategy should evolve accordingly. The probability of occurrence of numerous such resource spaces, mentioned in the preceding paragraph, being high, an integration of the variable rules (mechanism) of the constituent economies within the integrated body economic (political economy) of the nation-state is required in order to obtain fuller absorption of environmental resources, scattered in unequal proportions over the regions. It takes account of the significance of the total environment to the minutest detail of habitats. Every habitat is a subset of the total environment (hence of an ecosystem), and they vary independently between themselves. The habitats would have synergistic properties with respect to the sum of societal environments within a nation-state. Hence the planner, in seeking to identify a transcendent mode of validation of both habitat economies and the national economy, may use the environmental information to effect qualitative changes within the habitat-economies without destroying their primary autonomous identities and at the same time, initiate changes within the national economy in order to derive a new economy to support and bind the hierarchic disposition of these changed entities. Habitat economies must, therefore, be an integral part of the national economy. This process produces integration of local market with the national market through a hierarchic ordering of the autonomous process of absorption of resources within the society. Thus the economic activities of the societies belonging to the nation-state must be partly integrated with the habitats and partly with the body economic of the nation-state.

In a process of development, ecosystems may be viewed as a distinctive blending of common ingredients (environmental resources) progressing along an interdependent course of development. The ingredients form the space–time envelope of the country. The policies to deal with the problems in any region may not be necessarily restricted to designated areas. Instead they should be on a nation-wide basis and graduated regionally. Any intervention in local regional resource management requires understanding of politics. Provincial boundaries have only limited economic relevance, and planning by provinces in isolation is inadequate and in some cases makes little or no sense. Regions ought to be integral components of the national body economics or of the economy as a whole. Such developments should be perceived not only as a process of exploitation of environmental resources as such, but also as one achieving a new balance between diverse claims and facets of economic development in general and relative social responsibilities. Natural environmental resource management in fact contributes to concerted planning for the future and social change.

An integrated policy and planning system is creating a demand for and is a product of an integrated system, which must obviously be related to the same concepts, time horizons and environmental units. There must be unrestricted flow of information between the individual units thus conceived. The policy and planning mechanism may and should be such as to absorb centralized and decentralized as well as managerial and administrative solutions. The centralized solutions safeguard the coherence of the system, while the decentralized solutions guarantee its elasticity. In a well-functioning system, a balance is maintained between the power of central guidance and the relative autonomy of different units.

This approach to integration of policy and planning systems is much broader than the conventional practice, which restricts the integration of operation of the institutional channel. The efficiency of the institutional channel has little power of its own and the power it has is a function of the integrative forces. The development of an environmental policy and planning is described as the explicit spatial dimension of policy and planning. The sectoral policies relating to the industry have a strong spatial impact on the spatial pattern of human activity. This pattern should accelerate the emergence of new social and functional structures and the latter in turn may generate a new regional pattern. It is not necessary, however, that the new functional structure of the society will be accommodated by the old spatial patterns.

The broad structure of functions underlying the thoughts expressed above is further clarified for the benefit of application in the following passages. Management of local resources has a chance of sustainable outcome where there is a partnership between local/regional people and external agencies (the nation, relevant to a developing economy) and agendas related to their aspirations and circumstances. As said earlier, understanding of politics is the need of local regional resource management. It is pertinent to reemphasize that resource management is situated within a climate, landscape and human context, which leads to a diversified mixed environment. Thus the circumstances call for locally and regionally specific decision-making. The process thus increases complications. In this context, 'e-environment', a method of easy and continuous interaction between the authorities (corporate sector, wherever relevant) and the local/regional people may be introduced, to implement 'intelligent resource management'.

A good practice of environmental resource management arises out of a shared learning from experience between local and national/external agencies, which can be facilitated by 'e-environment' technology. The management must involve multiple sources of information and methods, and link together various knowledge worlds.

The approach to environmental resource management/natural resource management has to take into account participatory mapping analysis and monitoring of the natural resources base in small units/habitats. A management sensitivity group must evaluate and standardize the units as a prerequisite. It may include ecosystem mapping for differentiation, if any. Resource delineation can also be carried out by resource management maps based on scientific technological and commercial parameterization, say mineral management maps or forest management maps for the purpose of exploitation. By monitoring the market price and calculating the cost to be incurred for exploiting the resources, various units can be differentiated and exploited at different time periods or sequentially, etc. The decision will only be motivated by the economics after calculating the environmental multiplier effect. In Nicaragua, Central America, the natural resources base in small watershed is considered as a unit. A watershed is a natural ecosystem in which the relationship between different resources influences land-use patterns at different scales – from the plot to the farm to the watershed level. Watersheds are drained by a single water-course that includes water, soil and vegetation and links upland and downstream areas. These ecosystems are also a scene of action for conflicting interests, which points to the importance of analysing the social construction of landscapes.

The suggested principles of practice in resource management, which reflect efficacy, can be enumerated as:

(a) It must reflect a clear and coherent common agenda among stakeholders.
(b) Resource management should address and integrate the complexities and dynamics of change in human and environmental resource systems and processes, including their local understanding (i.e. sensitivity). Information flow from varied resources is a must.
(c) Good resource management is based on systems approach as well as on flexing strategies. The Indian scenario in tribal/specific ethnic belts reflects the above ethos in terms of environmental resource management. Some examples are entailed.

In India, managing natural resources has been an age-old practice for many local communities in the northeastern states of Arunachal Pradesh, Tripura, Meghalaya, Nagaland, Manipur and Rajasthan in the west.

These communities, to name a few, are the Apatanis of Arunachal Pradesh, Jamatis of Tripura, Khasis of Meghalaya, Meiteis of Manipur, Angami, Chakesang and Konyak of Nagaland, and Bisnois of western Rajasthan (Jodhpur, Jaisalmer and Bikaner – the dry region).

At many instances it has been observed that these tribes (for example, the Apatanis are worth emulating) had traditionally developed efficient community strategies (they continue with the same) with modifications as the ecosystem demands, which exemplifies intelligent and sustainable use of land, water and soil, without causing damage to the resilience of functioning of the ecosystems.

Jhum (shifting cultivation) was probably suitable for the Himalayan ecosystem when population pressure was low. It was practised in a cycle of 20–25 years. Presently, with the frequency of cultivation reduced to 5–6 years, jhum is considered to be the main cause for deforestation in the Eastern Himalayas.

The Apatanis since centuries, however, practised a highly scientific system of irrigating their terraced paddy fields by optimum harvesting of water from the river Kele, after it emerges out of the forest. Water is diverted from the streams to rice fields by making diversions through a network of channels regulated by wooden sluice gates. The flow of water can be regulated by opening or closing these gates. Hollow pieces of bamboo stems are placed in the plots so as to drain the water to other plots. Groundwater that comes through as springs is collected in small ponds. This water can also flow into the terraced fields. The bunds in the rice fields are used for millet cultivation. Modern iron sluice gates now replace wooden gates for efficient regulation of water. Fish is also cultured in the conduits of the bamboo pipes. These channels are, however, covered with bamboo meshes to prevent the escape of the fish to the adjacent field when water is drained. The Government has set up a fish-breeding centre to encourage the practice. The Apatanis also make common salt using plant-based resource (three types of grasses are burnt). It is a rich source of iodine and potassium. These forests which serve as catchments areas are well maintained. Hunting is strictly regulated for sustainable use of wildlife.

The Jamatias have a long tradition of managing forests that surround their villages. The objective is to extract the natural resources that the environment is endowed with, on a sustainable basis. The Jamatias of 'Killa' village in southern Tripura, collectively own their forests and have named it as Asha Van (Forests of Hope). They have rules to govern the extraction of resources from the environment. Women folk are active in protecting the forest. Similarly, the Khasis and Meiteis maintain forests as abodes of their ancestors and forest gods, and preserve them.

The Angami, Chakesang and Konyak farmers practice jhum cultivation, but do not cut down the Alder nepalancies tree in their jhum land. This tree is grown along with the crops like maize, millet, etc. These alder trees develop nodules in the root system, which fix atmospheric nitrogen. Regular pollarding of these tree stumps adds nutrients to the soil. The Bisnois communities in West Rajasthan also live in harmony with nature. Among 29 principles propounded by the founder of this sect, which concern the sustainable management of natural resources, cutting and lopping of green trees are banned. Groves are maintained (local name is oran) for the animals to graze and birds to feed. Orans are important recharges of rain water in the aquifers in this desert region. The Bisnois do not cut Khejari trees even from their cultivating fields – a traditional native system of agro-forestry. This is because the Khejari trees enrich the soil nitrogen and during drought and famine, the bask is mixed with flour for consumption.

In Bikaner, the *Salvadora oleoides* (Jhar) tree is revered because of its high salt tolerance; but the Bisnois cut the *Prosopsis jieliflora* (exotic Bilyati Babul) tree, realizing that it is an exotic weed to meet their fuelwood requirements. They do not allow the indigenous *Prosopsis cineraria* to grow. Due to their traditional conservation management efforts, resource use has been on a sustainable basis. Due to such conservation efforts, the blackbuck and Indian gazelle are seen along with human habitations.

In Jaisalmer, a separate community maintains the oran, with a concentration of Ber (*Zyphus mummularia*) trees known for their large fruits. Solar energy is used to extract underground water to irrigate the oran. Oran resources are meant for animals and avifauna to ensure their survival in the desert conditions.

It is thus observed that our traditional systematic knowledge is being utilized for the betterment of the local society. A similarity can be drawn from the experiences of the recent tsunami in the Indian Ocean. The traditional knowledge gathered from natural observation saved the Andaman tribes when the tsunami hit them. A management system derived from the knowledge helps in the so-called sustainable management of the resources in our environment. Both modern analytical tools and traditional theories should be considered together during planning and sustainable management of the natural resources at least in India (where traditional knowledge is available). The cost of implementation is also expected to be lower in this case.

Public policy decision-makers do usually come across the trade-off problem of initiating regional economic development growth while taking concomitant care of conservation of the regional natural resources and environment. The problem faced is that the plans of regional economic growth may run counter to the goals of resources and ecological preservation. However, with a low economic activity, it is possible to maintain a pristine environment. The other alternative is to go for an intense level of economic activity with environmental/natural resources seriously depleted or the environment polluted. Leontief's input–output inter industry models can quantify the above relationships. Inter-industry analysis depicts the interrelationships between different economic sectors of a regional economy and may be used for impact analysis. There is no reason, however, to only pay attention to the economic multipliers, i.e. sales income and employment. Multipliers associated with natural resources and pollutants are also applicable. The basic theme of the following paragraphs focuses on this aspect.

Earlier studies[1,2] have combined inter-industry procedures with ecological data to measure the effects on the regional resources and the pollution arising out of the increased sectoral output. Harris and Chang[3] generalized resource multipliers and expanded them to include both economic and resource effects.

The general composition of a development plan of a region diagnoses the position of a region with respect to the nation as a whole with the help of the input–output tables, giving a monetary value to each of the contributions made by the region.

The problems faced by the manager are the limited availability or non-availability of regional input–output models and direct resource coefficients required to generate economic–ecological trade-offs. However, we are suggesting an operational approach to avoid the hassle and estimate the trade-offs described above. The format of the national input–output table can be used along with a procedure given for specifying a regional input–output model (location quotient approach) and a method for simultaneously calculating the economic and environmental impacts associated with an application to a region. The input–output table must account for both primary and secondary products. This means that input–output industries along with input–output commodities are taken into consideration. An input–output industry is a grouping of industries established and classified by standard industrial codes, while an input–output commodity consists of characteristic products by the corresponding input–output industry. The input–output commodity is the primary product of an input–output industry plus the production of the same input–output commodity by other input–output industries.

Methodology

The rupee flow table (Format 1)

Format 1 describes the rupee flow of goods and services throughout the regional economy. In Format 1, the commodities appear as rows while the industries that produced these commodities as primary products appear along the column head. Therefore, going along the rows of the table, commodity sales to industries and final demand users can be seen, and tracing down a selected column the purchase of commodities and value added by each industry can be shown.

In mathematical notation, industry total gross output (G_j), that is, output of both primary and secondary products by an industry, is presented below as:

$$G_i = \sum_{i=1}^{m} U_{ij} + VA_j, \quad j = 1, 2, ..., n, \qquad (1)$$

where G_j is the total output by industry j (primary and secondary products), U_{ij} the rupee value of commodity inputs i, including imports of produced commodities, scrap, and imports of non-comparable commodities used by industry j, VA_j the value added by industry j, m the number of commodities, including scrap and non-comparable imports, and n the number of industries.

Scrap is defined as unplanned output by an industry which, for example, could be leftover rails in the railroad industry that may be sold to steel industries. Provisions to handle scrap will be discussed later. Imports have two classifications: comparable and non-comparable. Comparable imports are those imports of commodities which are comparable to domestically produced commodities. Comparable imports are entered as negative values so that each row total will be domestically produced commodities. Non-comparable imports are those imports which are not comparable to domestically produced commodities and are shown as a row value.

The summation of the row entries in the use Format 1 (Q_i) gives the total output of commodity i, which includes both scrap and non-comparable imports.

$$Q_i = \sum_{j=1}^{n} U_{ij} + E_i, \quad i = 1, 2, ..., m, \tag{2}$$

where Q_i is the total output of commodity i, including scrap and non-comparable imports, E_i the final demand, including exports less imports for commodity i, m the number of commodities plus scrap and non-comparable imports, and n the number of industries.

The industry-by-commodity table (Format 2)

Format 2 is an industry-by-commodity matrix, which is the reverse of Format 1 and describes the rupee value of primary and secondary products produced by each industry. Along the main diagonal of Format 2 is the primary product of the industry listed at each row heading. Other row values off the main diagonal are the secondary products of the particular industry. The column entries of Format 2 show the amount of commodity produced by each industry sector.

In mathematical notation, the summation of row entries in Format 2 provides the total output of industry i, i.e. G_i

$$G_i = \sum_{j=1}^{m} V_{ij} + H_i, \quad i = 1, 2, ..., n, \tag{3}$$

where V_{ij} is the value of commodity j produced by industry i, with zero values for non-comparable imports and scrap entries, and H_i is the rupee value of scrap produced by industry i.

Column entries for scrap and non-comparable entries have zeros, which reflects the fact that there are no national production functions for imports or scrap. By going down the column of Format 2, each V_{ij} in the commodity value j produced by each industry i so that the columnar summarization yields total commodity j output (Q_j).

The market share table

From Format 2, a market share table can be developed which shows the proportional share of commodity j produced by industry i as:

$$d_{ij} = V_{ij/Q\,j}, \quad i = 1, 2, ..., n, \tag{4}$$

$$j = 1, 2, ..., m, \tag{5}$$

where d_{ij} is the percentage of commodity j produced by industry i.

In the market share matrix, there are values for the first ($m - 2$) columns; however, the last two columns representing the scrap and non-comparable imports sector are zero. Also, the relationship of Format 1 and the market share table can be shown as:

$$V = D\hat{Q}$$

where V is the ($n \times m$) Format 1 with zeroes in columns for non-comparable imports and scrap sectors, D is the ($n \times m$) market share table of d_{ij}s, and $\hat{Q}$ is the ($m \times m$) matrix of zeroes except along the main diagonal, which gives the total output of commodity j output.

The commodity-by-industry direct requirements table

In the commodity-by-industry direct requirements table, each element in Format 1 (U_{ij}) is divided by its corresponding column sum (G_j), which gives the value of commodity i necessary to produce a rupee's worth of output of industry j output or can be stated as:

$$b_{ij} = U_{ij/Gj}, \quad i = 1, 2, ..., m, \tag{6}$$

$$j = 1, 2, ..., n, \tag{7}$$

where b_{ij} is the proportional amount of commodity i necessary to produce a dollar's worth of output of industry j.

In relating the direct requirements table to the rupee flow table, the following matrix equation can be derived:

$$U = B\hat{G},$$

where U is a ($m \times n$) portion of the use table, B is the ($m \times n$) direct requirements table, and $\hat{G}$ is the ($n \times n$) matrix of zeroes except for the main diagonal, which gives the total output of industry j.

Tracing down the column entries of the direct requirements matrix gives a production recipe for each commodity by a particular industrial sector in its production process.

The scrap vector

As mentioned earlier, scrap is unplanned output of an industry. If scrap is produced, it is assumed to be produced in a fixed proportion to the industry's output. Scrap is treated, however, in such a way as to prevent its requirement as input from generating output in industries from which it is produced. The scrap coefficients are defined as:

$$P_i = h_i/G_i, \quad i = 1, 2, 3, \ldots, n, \tag{8}$$

where P_i is the proportion of scrap to total output of industry i, and h_i is the rupee value of scrap produced by industry i as shown in the Format 2.

The matrix relationship of scrap production to industry output can be given as:

$$H = \hat{P}G, \tag{9}$$

where H is a $(n \times l)$ vector of scrap production, P is a $(n \times n)$ matrix of zeroes except the main diagonal, which contains the individual P_i values or the fixed percentage of the industry's output that is scrap, and G is a $(n \times l)$ vector of total output of the industry.

The total requirements table

The development of the commodity-by-commodity table will require estimating the M matrix. This matrix describes the relationship between total final demand and total commodity output, or can be stated as:

$$Q = ME. \tag{10}$$

Equation (2) can be stated in matrix form as:

$$Q = Ui + E, \tag{11}$$

where Q is a $(m \times l)$ vector of total commodity outputs, including scrap and non-comparable impacts, U is a $(m \times n)$ intermediate portion of the rupee flow table, i is a $(n \times l)$ summation vector of ls, and E is a $(m \times l)$ vector of final demands, including exports less imports.

Using the commodity-by-industry direct requirements matrix (eq. (7)), the $(n \times \mathrm{l})$ G vector of total output of industry and eq. (11) yields:

$$Q = BG + E. \tag{12}$$

Using the market share matrix derived in eq. (5), the $(m \times l)$ vector of total output of commodity and eq. (3) in matrix form yields:

$$G - H = D\hat{Q}. \tag{13}$$

Substituting eq. (9) into eq. (13) and solving for G yields:

$$\begin{aligned} G - \hat{P}G &= D\hat{Q}, \\ (1 - \hat{P})G &= D\hat{Q}, \\ G &= (I - P)^{-1}DQ. \end{aligned} \tag{14}$$

Substituting $W = (I - P)^{-1}D$ yields

$$G = W\hat{Q}. \tag{15}$$

The W matrix changes the commodity outputs to industry outputs by inflating commodity output by scrap. Premultiplication of the market share matrix D by $(I - P)^{-1}$ weights the industry output requirements to produce a rupee's worth commodity by the share of total commodity output produced by each industry.

Substituting eq. (15) into eq. (12) and solving for Q gives:

$$\begin{aligned} Q &= BWG + E, \\ (I - BW)Q &= E, \\ Q &= (I - BW)^{-1}E, \end{aligned} \tag{16}$$

where $(I - BW)^{-1}$ is the M matrix relating commodity output to total final demand. The column sums are commodity output multipliers which estimate the total requirements of all commodities necessary to produce one rupee of total final demand for commodities listed at the column head.

The second total requirements table is the industry-by-commodity total requirements table, which is represented by matrix N. This matrix describes the relationship between total industry output (G) and total final demand as:

$$G = NE, \tag{17}$$

As W translates commodity output, N is solved directly as:

$$N = W(I - BW)^{-1}, \tag{18}$$

$$G = W(I - BW)^{-1}E, \tag{19}$$

where $W(I - BW)^{-1}$ is the matrix N which relates total industry output to final demand. The column sums are called industry output multipliers, which relate to the total requirements of all industries necessary to supply one rupee of total final demand for the commodity named at the head of the column. These two total requirements tables estimate the overall impact on commodity output and industry production from changes in total final demand.

Location quotient technique (modified from Mustafa and Jones[4])

The location quotient process is based on comparing the relative importance of an industry in a region to that in the nation. The location quotient is defined as:

$$LQ_i = (Z_i/Z)/(X_i/X), \quad (20)$$

where Z_i is the regional output of industry i for the base year, X_i the national output of industry i for the base year, Z the total regional output for the base year and X the total output for the base year.

Location quotients compare the percentage share of a particular sector's output of a region with the percentage share of that sector's output of the nation. If a region's share is equal to the nation's share, then the location quotient is one, and the industry in the region is assumed to be self-sufficient. If the industry of the region produces more than its proportional share, the location quotient is greater than 1. The industry of the region is assumed to export the surplus production.

However, if an industry of a region produces less than its proportional share, the location quotient is less than 1 and the region is assumed to import the deficit production.

If the location quotient is 1 or more, all national technical coefficients for that sector's row may be used directly to represent regional direct requirements coefficients. However, if the location quotient is less than 1, the national coefficients of the sector's row are reduced proportionately to account for the region's deficit production. The location quotient procedure is used to derive the regional industry by commodity table.

The regional industry-by-commodity table (ref. Format 2)

The initial step in producing regional inter-industry tables from the formatted input–output model is to develop a regional industry-by-commodity table. In this table, the regional industries are assumed to produce the same primary and secondary products as the national industries and each regional industry is proportionately identical to its corresponding national industry in the production of primary and secondary products. From these assumptions, the regional elements of Format 2 are derived as:

$$v_{ij} = \frac{V_{ij} g_i}{G_i}, \quad (21)$$

where v_{ij} is the regional elements, V_{ij} the national elements, G_i the national total output of industry i, and g_i the regional total output of industry i.

Regional total commodity outputs necessary for estimation of the regional use table can be derived from the regional table as:

$$q_j = \sum_{i=1}^{n} v_{ij}, \quad j = 1, a, \ldots, m, \quad (22)$$

where q_j is total regional output of commodity j, m the number of commodities, and n the number of industries.

The regional rupee flow table (ref. Format 1)

After total commodity outputs are derived, the regional table can be estimated.

Regional and national commodity outputs are used to derive location quotients because commodity outputs do not include scrap and secondary products like industry output totals.

The procedures for the location quotient algorithm follow essentially those of Mustafa and Jones[4], except that the table is balanced so that row totals equal regional commodity output values and column totals equal regional industry output totals. A unique feature of the regional table is that an imports row is necessary at the regional level because the region imports from both national and international suppliers, while the national economy only imports from international sources.

For the inter-industry format, the general procedure[5] is followed with the inter-industry-by-commodity matrix depicting the economic sector interrelationships. To derive environment multipliers, it is first necessary to estimate direct environmental requirements. Direct environmental requirements show the quantity of a particular environmental factor used per unit of industrial sector output, or:

$$r_{ij} = L_{ij}/G_i, \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, u, \quad (23)$$

where r_{ij} is the amount of environmental factor j used per unit of industry i output (if the jth environmental factor is a resource, the coefficient r_{ij} is positive, whereas if the jth environmental factor is a pollutant, r_{ij} is negative).

L_{ij} is the total quantity of environmental factor j used in product by industry i, and G_i is total industry output by sector i. Using the direct environmental coefficients and industry by commodity total requirement matrix, total regional resource use of pollution emissions created by changes in commodity final demand sales can be estimated. These total environmental impacts can be shown in matrix T as:

$$T = N'R, \quad (24)$$

where T is an $(n \times k)$ matrix of direct and indirect environmental use for n sectors and k environmental factors; the elements of T are t_{ij}. If the jth environmental factor is a pollutant, the coefficient will be negative. For the 'jth environmental factor, t_{ij} is assigned the jth environmental factor-final demand coefficient'.

R is $(n \times k)$ matrix of direct environmental coefficients for n sectors and k environmental factors; the elements of R are r_{ij}.

N is $(n \times m)$ matrix of industry-by-commodity total requirements.

Employment and income multipliers are derived using the same procedure as shown in eqs (23) and (24). An explanation for deriving employment and income multipliers has been elucidated by Harris and Ching[3].

It may be mentioned here that the environmental interrelationships of both primary and secondary products of any economic sector (local/regional/national) can be calculated following the UN input–output model format.

Regional environmental multipliers

The procedure/methodological format used to formulate the various matrices and tables is presented here. The work was carried out under a contract with an organization and the data therefrom illustrate a particular location in USA, where the various sectors of the economy were active vis-à-vis pollution.

Tables 1–4 exemplify multiplier analysis in an environmental perspective (two environmental factors – water resource and SPM emitted are considered, while water use and air pollution for each individual sector as illustrated in the tables are calculated).

The objective of the analysis is to compare the changes in a limited water resource or in the pollution emissions to development alternatives.

Table 1 shows the effects on regional water use, particulate emissions, income and employment from changes in commodity sales to final demand. The basic data are not given for obvious reasons; only the calculated inter-industry environmental multipliers are projected to demonstrate how they can affect the decision-making process.

From Table 1 and following procedures outlined by Harris and Ching[3], water self, water income and water employment multipliers are calculated as in Table 2. Particulate self, particulate income and particulate employment multipliers are shown in Table 3.

The direct water multiplier for the agriculture–industrial sector is 9.5266, which means for each US$ 1000, increase in output by the agriculture–industrial sector requires 9.5266 acre-ft. The direct particulate coefficient is interpreted as for each US$ 1000 increase in output by the mining–industrial sector, approximately 2.26 tonnes of particulates are emitted. The final demand-water multiplier for agriculture sector is 13.93 acre-ft. Thus, when sales to final demand by agri-commodity sector increases by US$ 1000, regional water use increases by 13.93 acre-ft. From Table 1, it can be seen that the final demand particulate multiplier for mining industry sector is 2.42. Therefore, when sales to final demand increases by US$ 1000, regional particulate emissions increase by

Table 1. Direct water coefficient, direct particulate coefficient, water final demand multipliers, income multipliers, and employment multipliers per, say, US$ 1000.00 of output (1000 units of currency worth output, say, we take US$ 1000 dollar of output) by a sector in a regional economy

Sector	Direct water coefficient (acre-ft)	Direct particulate coefficient (tonnes)	Water final demand multiplier (acre-ft)	Particulate final demand multiplier (tonnes)	Income final demand multiplier (rupees)	Employment final demand multiplier (labour)
Agriculture	9.5266	(–) 0.6993	13.9253	(–) 1.0545	0.6860	0.0356
Mining	0.1587	(–) 2.2576	0.1857	(–) 2.4157	0.7545	0.0279
Construction	0.0006	(–) 0.9260	0.0569	(–) 0.9645	0.6109	0.0348
Manufacturing (non-durable)	0.0107	(–) 0.0118	4.9668	(–) 1.4424	0.6973	0.0347
Manufacturing (durable)	0.1470	(–) 0.0113	0.5090	(–) 0.1734	0.5647	0.0301
Transportation, communication, public utilities	0.0024	(–) 0.1515	0.0523	(–) 0.3057	0.8344	0.0409
Wholesale and retail trade	0.0013	(–) 0.0	0.0381	(–) 0.0224	0.8969	0.0831
Finance, insurance and real estate	0.0001	(–) 0.0	0.0419	(–) 0.0313	0.8314	0.0213
Services	0.0442	(–) 0.0	0.1766	(–) 0.0500	0.7573	0.0644

Table 2. Multipliers by sectors in the regional economy

Sector	Water self multipliers	Water income multipliers (acre-ft)	Water employment multipliers
Agriculture	1.46	20.29	391.16
Mining	1.17	0.25	6.66
Construction	94.81	0.09	1.64
Manufacturing (non-durable)	464.19	7.12	143.14
Manufacturing (durable)	3.46	0.90	16.91
Transportation, communication, public utilities	21.8	0.06	1.28
Wholesale and retail trade	29.33	0.04	0.46
Finance, insurance and real estate	419.02	0.05	1.97
Services	4.00	0.23	2.74

Table 3. Particulate self multiplier, particulate income multiplier and particulate employment multiplier in the regional economy. Particulate self multipliers are derived for sectors, which directly emit particulates during their production

Sector	Particulate self multiplier	Particulate income multiplier (tonnes)	Particulate employment multiplier
Agriculture	(–) 1.51	(–) 1.54	(–) 29.62
Mining	(–) 1.07	(–) 3.20	(–) 86.58
Construction	(–) 1.04	(–) 1.58	(–) 27.72
Manufacturing (non-durable)	(–) 122.23	(–) 2.07	(–) 41.57
Manufacturing (durable)	(–) 15.35	(–) 0.31	(–) 5.76
Transportation, communication, public utilities	(–) 2.02	(–) 0.37	(–) 7.47
Wholesale and retail trade		(–) 0.02	(–) 0.27
Finance, insurance and real estate		(–) 0.04	(–) 1.47
Services		(–) 0.07	(–) 0.78

Table 4. Estimated change in regional income, water use, particulate emissions due to US$ 100,000 change in final demand in each commodity sector of the economy (case-example)

Sector	Income (US$ 1000)	Water (acre-ft)	Particulates (tonnes)	Employment (FTE's)
Agriculture	68.6	1392.5	(–) 105.5	3.6
Mining	75.5	18.6	(–) 241.6	2.8
Construction	61.1	5.7	(–) 96.5	3.5
Manufacturing (non-durable)	69.7	496.7	(–) 144.2	3.5
Manufacturing (durable)	56.5	50.9	(–) 17.3	3.0
Transportation, communication, etc.	83.4	5.2	(–) 30.6	4.1
Wholesale and retail trade	89.7	3.8	(–) 2.2	8.3
Finance, insurance and real estate	83.1	4.2	(–) 3.1	2.1
Services	75.7	17.7	(–) 5.0	6.4

2.42 tonnes. Final demand income and final demand employment multipliers in Table 1 show increase in regional income and employment, if a commodity sector increases sales to final demand by US$ 1000.

Sectoral water self multipliers are described in Table 2. The water self multiplier gives an indication of the total quantity of water required from the region when the direct water using industrial sector, increases water use by 1 acre-ft. In Table 2, it is observed that the finance, insurance and real estate sector has a water self multiplier of 419.02.

This means that when the finance, insurance and real estate industrial sector increases water use by 1 acre-ft in their production process it requires a total regional water use of approximately 419.02 acre-ft.

As observed in Table 1, the finance, insurance and real estate sector is a low direct water user. However, on account of its inter-relationship with high direct water users, the water self multiplier for the fire, insurance and real estate sector is large. The latter industrial sector has a large water self multiplier because of its low direct water use coefficient. This implies that for the fire, insurance and real estate industrial sector, to increase water use by 1 acre-ft, the industrial sector would need approximately a 10 million dollar increase in production.

Water multipliers are useful in assessing water-use requirements to changes in output by various industrial sectors in the economy. However, these multipliers alone do not adequately evaluate the trade-off between household income and water use. Table 2 shows the effects on regional water use from a one-unit increase in sectoral household income by a given sector. For example, water use increases by approximately 0.05 acre-ft from a US$ 1 increase in household income by the fire, insurance and real estate industrial sector. Regional water requirements from an one-unit increase in employment by given economic sector is presented in Table 2. For example, total regional water use increased by 1.97 acre-ft per one-unit increase in employment by the fire, insurance and real estate sector. Water employment multipliers like water income multipliers derive approximations of trade-off between sectoral employment growth and water use.

It is known that with regional growth, resources are not only depleted, but pollution may also increase. The particulate self multiplier as shown in Table 3, gives an indication of total particulates emitted into the regional environment when the direct particulate emitting sector increases emissions by one tonne of particulate in its production process. The manufacturing non-durable sector (Table 3) has a particulate self multiplier of 122.23. This indicates that when the manufacturing non-durable sector increases particulate emissions by one tonne in its production process, total particulate emissions in the regional economy, because of the interactions among the economic sectors, increases by 122.23 tonnes. As with the water-self multipliers, an industrial sector like the manufacturing non-durable one is a low direct particulate emitting sector. However, since the other regional industrial sectors are characterized by interdependencies, the manufacturing non-durable sector has a large particulate self multiplier. For the manufacture of non-durable sector, to increase particulate emissions by one tonne, production by this sector would have to increase by approximately US$ 93,500, which contributes to the size of the particulate self multiplier.

It is thus seen that particulate multipliers are useful in assessing pollution emission into the environment. However, to evaluate trade-offs between regional household income and/or regional employment increases to particulate emissions in the region, particulate income and particulate employment multipliers (Table 3) are to be used. It is noted here that particulate emissions increase by approximately 2.07 tonnes from a US$ 1 increase in household income by the manufacturing non-durable sector.

Regional particulate emission from a one-unit increase in employment by a given inter-industrial sector is shown in Table 3. For example, total regional particulate emissions increased by 41.57 tonnes per one-unit increase in employment by the manufacturing non-durable sector. Particulate employment multipliers like particulate income multipliers derive approximate trade-offs between industry sectoral employment growth and particulate emissions.

From Tables 1 and 2, the existence of ecological linkages for sectors which do not directly emit particulates into the air in their production processes is comprehended. Such an ecological linkage occurs from the economic inter-dependencies among regional sectors. The service industrial sector has no direct effect on the environment from particulate emission. However, this sector must purchase inputs from other regional industry sectors, which do directly emit particulates into the air. Thus, the service sector, through its purchases causes increased production by the supplying sectors, which may indirectly cause increased particulate emissions to occur. As, for example, when the service sector increases employment by one employee, regional particulate emissions will increase by 0.78 tonnes (Table 3). Therefore, all economic sectors indirectly have environmental linkages and affect the environment of the regions when they increase output.

The inter-industry environmental model can provide decision-makers and planners with information concerning the trade-off between income or economic expansion and the inputs on regional resources supplies and quality of environment. Since industry sectors have large income or employment multipliers and a high level of economic inter-dependence with other regional industry sectors, the industry sector as a whole will require substantial quantities of the regional resources and may considerably damage regional environmental quality in the specified area (as has been considered here as a case). The discussion presented is centred around water as the resource of the region and the particulate multipliers as well as their use for regional economic development. The basic point made is that physical environmental multipliers (water in this case, but it can be any other resource and/or particulate multipliers (it could be any other polluting substance–solid/liquid/air)) are just as important for economic development considerations as the traditional economic multipliers (output, income and employment multipliers).

It has been observed that particulate emissions (pollution) increase with increase in employment and household income. Therefore, in any regional planning development, balance is the most important aspect among resource, technology, output, employment, income and physical environment (for the ideal growth). Else, environment quality will be affected.

Table 4 shows the estimated change in regional income, employment, water use and particulate emission due to a US$ 100,000 change in final demand, for each commodity sector. The mining sector has a water self multiplier of 1.17 and a particulate self multiplier of 1.07. Although these multipliers are small, the total input on water use (in this specified regional economy) and particulate emissions due to a US$ 100,000 change in final demand for the mining commodity sector yield a total change in water use of approximately 18.6 acre-ft and total change in particulate emissions of 241.6 tonnes. On the other hand, the wholesale and retail sector has a relatively large water self and particulate self multiplier. However, a US$ 100,000 change in sales to final demand by this sector yields only a total change in water use of particulate emissions of 2.2 tonnes. Thus, one unit simply utilizes the magnitudes of the water self and particulate self multipliers, but the impact is in terms of changes in final demand for the product of the commodity sector in question. If water and particulate multipliers are interpreted correctly, they have a definite place in evaluating the input of growth or decline in a particular economy. They are no less important than the typical measures of income and employment.

Water and particulate multipliers provide a way of assessing the inputs of alternative economic development on regional water use and particulate emissions. By embodying the operation of a regional economy (input/output models) and the use of water/or any resource by regional economic sectors (water/resource coefficients) or particulate emissions (it could be any effluent/emission which pollutes) by regional sectors (direct particulate/effluent coefficients), the water/resource and particulate/effluent multipliers form a crucial link between an economic development strategy and a scarce natural resource and/or quality of regional physical environment. Thus water and particulate multiplier analysis is a convenient way of relating the multiplier objectives of regional water use, particulate emissions, and a particular economic development alternative. Besides these there are political, social, legal and other aspects that enter into regional decision-making.

Multiplier analysis allows comparisons of the change in a limited resource or the pollution emissions to regional development alternatives. In the present example, if the change in water use of particulate emissions due to an economic development action does not exceed the perennial pumping yield of the available water resource or threshold level for particulate emissions, the planner is free to select the most appropriate alternatives. However, if total water use and particulate emissions resulting from expansion in a particular economic sector exceeds resource availability and/or particulate emission standards, that alternative action should be eliminated from consideration on the basis of resource availability and/or environmental quality. However, due importance should be given to technology. If by a change in technology, the development alternative options become wider and the total resource use and emissions resulting from expansions in a regionally relevant economic sector do not exceed the resource availability and the emission standards, such alternative actions should be taken. In such a case, however, the return on investment becomes the vital node.

The approach proposed here, assumes the level of physical resource and environmental quality for a given regional economy to be known with certainty. Such an assumption is never completely satisfied because resource and pollution levels are always associated with probability distributions. However, accompanying this analysis with the knowledge of the most likely and least likely estimates of water availability and environmental quality will provide sufficient information to the decision-maker. However, the model is here performed in a static time period. A dynamic inter-industry environmental model would incorporate the dynamics of economic growth, resource use and pollution emissions and abatement, which could be used by regional decision-makers to develop appropriate time path expansions of their economies.

An environmental manager has to accept that there will usually be environmental changes when a decision-making process is initiated on the allocation of natural and artificial resources that will make optimal use of the environment to satisfy the economic needs for an indefinite period of time. The crucial point is to decide when destructive creation (during the course of so-called development) has begun or is likely to begin. He has to act to stop/prevent it. Otherwise the natural process cycle, which regenerates the resource, will be broken due to impairment (overexploitation leads to impairment) of the ability to regenerate.

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ACKNOWLEDGEMENTS. The first author is grateful to Prof. Satyesh C. Chakraborty and Prof. William D. Copeland.

Received 28 February 2007; revised accepted 7 November 2007