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Natural resource accounting—a means to measure sustainable development in India

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Natural Resource Accounting - A Means to Measure Sustainable Development in India

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1. Introduction

The growing concern for sustainable development has motivated TERI (Tata Energy Research Institute) to explore ways of giving this concept practical shape. Natural resource accounting is an attempt to measure the sustainability of development by correcting the national income accounts for the depletion of natural capital. While the very definition of income is based on the idea of sustainability, the national income accounts largely ignore the running down of natural capital. Is economic development in India leading to unchecked exploitation of the natural resource base on which its economy and people are so dependent?

To answer these questions TERI conducted a natural resource accounting study on India's coal, soil and forest resources with support from the International Development Research Centre, Canada. This study has tried to highlight the discrepancies in the existing system of national income accounts and to amend these to account for natural resource depletion. Specifically, the study developed the physical accounts, valued the depletion and adjusted the gross domestic product to take note of the cost of depletion of soil, coal and forests. The preliminary results from this study were discussed in a workshop held at the India International Centre : *Natural Resource Accounting - A Means to Measure Sustainable Development in India.* This workshop provided us with valuable inputs to improve our study. Alongwith the study of these three resources, this report contains papers on the relevance of this kind of study to developing countries and an overview of valuation methodologies, where there needs to be more discussion and finally some kind of agreement on procedures.

NRA is still a new discipline, requiring inputs from varied disciplines like economics and the physical sciences. This study is a first step for TERI in this field, and is a learning exercise. TERI proposes to continue working on natural resources accounting, and to begin work on more complex environmental accounting. TERI proposes to extend the study to such resources as petroleum, and water (both depletion and degradation). Another major challenge would be to try to value the costs of air pollution, a very serious problem in India.

2. Relevance of natural resource accounting in developing countries

Sujat Kamal

The national income accounts provide a standard framework for measuring a country's macro economic performance. These accounts keep track of transactions during intervals of time; purchases of goods and services, payments to wage and profit earners, import payments and import revenues for goods and services.

Income accounting if properly done is a most useful tool for economic analysis and policy prescriptions. It can indicate the level of economic activity, its valuations from year to year, the size of savings and investment, the limits society can consume out of its current receipts, factor productivity, industrial structure, comparative performance and many other things. Development planners, economists and politicians thus make frequent use of the national income measure of gross national product (GNP) and its variants such as GDP (Gross Domestic Product) and NNP (Net National Product) for a variety of purposes. GDP the most commonly used variant of aggregate income is essentially a short term measure of total economic activity for which exchange occurs in monetary terms within a given year. It is valuable mostly for indicating short to medium term changes in the level of economic activity and it is particularly useful for demand management and stabilization policies. However it is less useful for gauging long term sustainable growth partly because depletion and degradation of natural resources is ignored.

Depletion and degradation of natural resources

As most economists know there are several controversial issues concerning national income accounts such as treatment of subsistence production, other non marketed services, services of long lived consumer durables. Furthermore there is an evident asymmetry in how national income accounts treat man made assets and natural resources. Man made assets-building and equipment, for example, are valued as productive assets and are written off against the value of production as they depreciate. Natural resource assets are not so valued or adequately accounted for in most instances, however and their loss produces no charge in the national income accounts against current income to reflect the decrease in potential future production. If a country is exhausting its renewable or nonrenewable resources its current income will thus be inflated by the sale of natural assets that will eventually disappear. Differences in recording under national accounts may arise depending on whether a resource is publicly or privately owned. Private companies tend to take a long term view of natural assets they own and many make a provision for the decrease in the capital stock of natural resources and in certain countries tax legislation permits such provisions to be excluded from taxable income. No such exclusion is effected in developing countries in which natural resources are exploited by the public sector.

Underlying this asymmetry is the implicit as well as the inappropriate assumption that natural resources are so abundant that they are costless or have no marginal value. Historically they have been regarded as free gifts of nature - a bias that provides false signals for policy makers. This approach ignores the depletion of valuable resources and confuses the sale of commercially marketable natural assets with the generation of income. Thus it promotes and seems to validate the idea that rapid economic growth can be obtained by exploiting a resource base that may be rapidly diminishing. The growth can be illusory and the prosperity it engenders transitory, if the apparent gain in income means permanent loss in wealth, that is, if at least part of the receipts is not redirected in new productive investments. As income is inflated, often consumption is also and the country gets complacent about its economic performance, as result the adjustment in economic policy gets delayed by the seeming prosperity. Costa Rica is a case in point. In the twenty years between 1970 and 1989, the county lost natural resources worth more than a year's gross domestic product (GDP). Appropriate national income accounting methods would have recorded this 5% of GDP loss each year as depreciation of capital. Instead, the annual accounts calculated during those two decades show only a continuous rise in national income and high rate of capital formation-right upto the crash of the 1980s. The economic crash, when it came was called a debt crisis but it was just as much an environmental crisis. In this regard, proper income accounting can be an aid to better decision making but of course it would not guarantee that improved decisions will actually be made.

Existing natural capital of ecological (nonrenewable) and biological (renewable) resources as well as 'flow' resources (such as water) is needed for industrial and agro-industrial production. New geological discoveries as well as recycling and conservation do not reverse the depletion of known stocks. The newly discovered stocks themselves come from a finite stock of resources and they may extend the time span over which the depletion can continue.

Depletion of renewable natural resources can have serious indirect effects by reducing the sustainable flow needed for industrial inputs and ecosystem service.

Similarly crop production at the expense of soil erosion cannot be sustained. Only careful husbandry of environmental capacities can ensure sustainable and potentially large flows of income in the future. The optimistic agreement that human ingenuity is bound to find substitutes for natural resources being depleted may be generally valid but it would be improper for society to base its behavior on such optimism and would be wrong for economists and accountants not to take rational precautions in case this does not occur.

There is considerable evidence that natural resources both renewable and nonrenewable are being over-depleted in many countries, particularly in parts of Latin America, sub Saharan Africa and South East Asia. If current production and consumption levels are maintained through resource over-depletion there will remain too little of the resource in the future. Natural resource accounting could help to optimize the use of natural resources as factors of production. For example inversion of a quantitative input/output table would indicate the intermediate use of natural resources in the productive process. It would describe the economic aspects of the resource use, such as, which resources would be marketed and in what quantities and values, how to improve the productivity of processing industries to optimize the use of natural resources and what the opportunity costs are of alternatives.

Problems specific to the developing countries

The important question that comes to mind is the applicability of natural resource accounting in the context of physical problems experienced by developing countries. It is clear however that such accounts will not be created unless they correspond to a perceived economic need.

Despite the enormous diversity of structures and economic situations in the developing world, there are a few common features that directly affect natural resource accounts. First, most people are aware of the critical role that natural resources continue to play in the economic activity at all levels (employment, production, export and consumption). Most developing countries, particularly the poorest, depend on the export of primary commodities or one or two products for their growth. Resource generation and improvement thus a vital factor in these economies.

Second the importance of natural resources is made even more important if non-market activities are considered. Another feature of developing countries is the existence of a traditional sector, dominated by non-remunerated activities including self production, self consumption and barter alongside a modern sector which is highly integrated into the international trade system. To date population growth and frequent choice of capital intensive technology have limited the capacity of these countries to absorb the modern sector.

It is therefore the proper functioning of this traditional sector (for example, accessibility of local non replaceable resources) that ensures the basic survival of hundreds of millions of people. The clearest example is noncommercial energy consumption. In Congo for example, firewood represents 80% of all energy sources and takes up 25% of household budgets. During the past decade, its price for village inhabitants has increased tenfold.

A final factor specific to the developing country economies is their dependence on the outside world. This has also had considerable influence on the introduction of resource accounts. On the one hand, the importance of export goods, whose value is often set by the international market and on the other hand the weakness of sectors producing directly for the domestic market sharply reduce the effectiveness of national mechanisms regulating resource supply and demand.

Natural resource accounting as a policy tool

Natural resource accounting could act as a catalyst for framing environmental policy in developing countries. Many of these countries have complained that it is difficult to put the concept of integrated development into practice without a tool to facilitate the distribution of investment to various area of the environment or to identify before and the payers and beneficiaries of the policies envisaged. To a large extent natural resource accounting answers this dual need. In this respect it can fulfill, at the national level the same role of initiator or driving force that impact studies have at the project level. It can supply environmental institutions with the means to open dialogue with economic administrators and members of the scientific community. It can also provide these same institutions with effective management tools in their particular field of competence such as priority criteria and minimal data on anticipated expenditure and its impact. Environmental accounting cannot, of course, substitute for political will but for environmental administrations, which are often weak, it can constitute a powerful means of internal structuring and recognition with respect to other ministerial offices.

The development of natural resource accounting will inevitable encounter a set of serious obstacles. The problem of generally insufficient and poorly dispersed data base is compounded by several factors.

- The shortage of financial and human resources that can be mobilized in the light of other more urgent priorities for statistical data that have not yet been fitted.
- The lack of coordinating structure capable of bringing together multi disciplinary teams
- The unsuitability of a cost-benefit approach in sectors dominated by non-market activities
- The present lack of political demand for this type of tool particularly by economic planning bodies

Several factors can facilitate the setting up of natural resource accounts in the developing countries. Their environmental problems may be more apparent than in industrialized countries, the convergence of requirements for economic and resource statistics may be more obvious and the results of the developed countries can be used.

Conclusion

Natural resources are disappearing with increasing speed in developing countries but national policy makers are not yet considering the implications for future economic productivity. The situation can be reversed if corrective environmental and economic policies are enacted. This is unlikely to happen unless leaders are provided with information that genuinely reflects the relationship between economic development and the natural environment. Natural resource accounts can fill this information gap.

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3. *Economic and physical valuation of soil degradation*

Gautam Sethi, Sujat Kamal and Anil K. Gupta

Introduction

Soil is a vital natural resource and its irreplaceable value as a means of production is widely recognized. It forms a part of our precious heritage that must be used judiciously. To meet the ever-growing needs of society, its use must be limited to its potential. However, in practice, with increasing human and animal pressure on land, this limit has been transgressed in large areas of the globe. The growing demand for fuel, fodder, wood and food have depleted or eliminated protective plant cover extensively and exposed surface soils to processes of degradation. Soil degradation is a crisis that is occurring silently and gradually but one that has extremely serious long-run ramifications. It poses a severe threat to the livelihood and food security of vast numbers of people, especially those who are already on the verge of subsistence.

Soil degradation

Degradation processes are phenomena which cause a decrease in quality. Soil degradation is a process which lowers the current and/or potential capability of soil to serve as a factor of production. The degradation of the soil resource manifests itself in many forms, the major ones being erosion, salinization, alkalization, chemical degradation, physical degradation and biological degradation.

Erosion

"Erosion" means wearing away. This category of degradation includes both water and wind erosion. Water erosion on agricultural land takes place through the agency of rain water. Water erosion may be further sub-divided into splash erosion, sheet erosion, gully erosion and various types of mass movement such as landslides, mudflows and soilfluxion. Wind erosion includes both the removal and deposition of soil particles by wind action and the abrasive effects of moving particles as they are transported. The unit of measurement of erosion is tonnes per hectare per annum.

Salinization and alkalization

Salinization and alkalization (or sodication) connote the presence of excess salts in the soil. Specifically, salinization is the process of accumulation of soluble salts in soil. The intensity and depth of accumulation vary with the amount of water available for leaching. Salinization may take place through capillary rise of saline ground water and by inundation with sea water in marine and coastal soils. Salinization is quite common in arid and semi-arid regions. Alkalization is the process by which soils with high exchangeable sodium and pH greater than 8.5 are formed; often sodium carbonate and sodium bicarbonate are formed in extreme cases of alkalization. Such soils are called *sodic soils* or *alkali soils*.

Chemical degradation

The leaching of bases and build up of toxicities other than those due to excess of salts fall in this category. The toxicity increase is registered in parts per million (ppm) per annum.

Physical degradation: Physical degradation refers to adverse changes in the physical properties of soil including porosity, permeability, bulk density and structural stability. The metric of bulk density is grams per centimeter cubed per annum ($gms/cm^3/y$).

Biological degradation

Biological degradation refers to processes that increase the humus mineralization rates. It is measured in percent per annum.

Soil degradation in India

The biggest single threat to Indian agriculture is the growing mismanagement of our soils. The formation of 1 cm of soil *in situ* can take about 500 to 1000 years depending on the nature of the parent material and the intensity of weather. However, the resource can easily be destroyed in 30 - 40 years by our short-sightedness and abuse. In India, soil degradation is prevalent in its various manifestations[1]. In many cases, more than one problem exists simultaneously in a particular area. As the following table shows, about 175 million hectares (m ha) or 53% of the total geographical area of the country has been estimated as the problem area. Of this, 150 m

[1] The categorization used by Indian soil scientists to assess degradation does not exactly conform to the above classification. Therefore, we discuss degradation processes in India separately in this section.

ha is subject to erosion and the rest is degraded through ravines and gullies, shifting cultivation, water logging, alkalinity and salinity.

Table 1: Distribution of estimated area subject to soil degradation (million hectare)[2].

	With 1980-81 land utilization statistics	With 1984-85 land utilization statistics
Geographical area	329.00	329.00
Area subject to water and wind erosion	150.00 (45.59)[3]	144.63 (43.96)
Water logged area	6.00 (1.82)	8.53 (2.59)
Alkali soils	2.50 (0.76)	3.58 (1.09)
Saline soils	5.50 (1.67)	5.50 (1.67)
Ravines and gullies	3.97 (1.21)	3.97 (1.21)
Area subject to shifting cultivation	4.36 (1.33)	4.91 (1.49)
Ravine and torrents	2.73 (0.83)	2.73 (0.83)
Total problem area	175.06 (53.21)	173.65 (52.78)

Source: Indian Agriculture in brief, 1994.

Erosion

Of the 150 m ha reported to be subject to erosion, 69 m ha is considered to be critically eroded[4]. As stated above, erosion is caused by two agents — wind and water. Wind erosion is prevalent in Rajasthan, Haryana, Gujarat, the Indo-Gangetic plain and almost the entire Deccan as well as the coastline. However, its severity is experienced largely in the three states. Water erosion is seen in its worst form in the Himalayan watershed that sustains a huge population and replenishes several perennial river systems. It is also manifest in other mountain chains such as the Vindhyas and the Eastern and the Western ghats.

2 Source: Indian Agriculture in Brief. 1994.

3 Figure in parentheses denotes percentage of area degraded in the relevant category with respect to total land area of the country.

4 The reference for data in this section is Das. D.C. (1985).

Gullies and ravines

Ravines are the most spectacular form of erosion. They are mainly found within a kilometer or so along the rivers Yamuna, Mahi and Sabarmati in the states of Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat. On the other hand, gullies are seen in the Eastern India plateau, the Deccan plateau and the foothills of the Himalayas. They generally originate on ill-managed slopes. While about 4 m ha are already affected, another 4 to 6 m ha are threatened.

Shifting cultivation

Shifting cultivation, or *jhumming*, is a traditional way of growing crops on hill slopes by slash and burn method. Degradation due to this factor is being accentuated by a shortening of fallow period which, in turn, is due to the rising population pressure. According to the Task Force Report, *jhumming* is being practiced on an area of approximately 1 m ha each year. This area is spread over 13 states and 2 Union Territories. In terms of severity, however, this practice is confined to the North-East and parts of Orissa and Andhra Pradesh.

Water logging

Water logging may take place primarily due to two reasons: surface flooding and rising of the water table. The National Committee on Agriculture (NCA) has reported that of the 6 m ha of water logged area, 3.4 m ha is due to the former and the rest due to the latter cause. Recent surveys carried out by other bodies (such as the *Rashtriya Barh Ayog* and the Central Ground Water Board) indicate that the problem has exacerbated the problem. Consequently, we need extensive and periodic surveys to assess its danger.

Alkalinity

The NCA report states that 3.58 m ha is subject to the problem of alkalinity. However, later studies carried out in the states of Punjab, Haryana and Uttar Pradesh reveals that the problem of alkalinity has increased by approximately 0.34 m ha. However, some analysts estimate the current problem area to be as much as 4.00 m ha.

Salinity

The problem of salinity is present both in inland as well as coastal areas, unlike that of alkalinity. An estimate states that 5.5 m ha of Indian soils are saline, 1.5 m ha of which lies in the black soils region and another million ha in arid and semi-arid regions of Gujarat and

Rajasthan. Apart from affecting the productivity of the soil, salinity is also turning the ground water brackish in the states of West Bengal, Tamil Nadu, Orissa, Maharashtra, Kerala, Karnataka, Gujarat, Andhra Pradesh and Goa.

It is clear from the above description that the degradation of the soil resource is already widespread and threatens more regions. There is an urgent need to conserve the productivity of the unaffected soil and prevent further decline in the productivity of the degraded ones. As a first step to fulfil this need, soil scientists, planners and policy-makers require precise quantitative estimates of the "value" of the extent of degradation that is occurring presently. To this end, the construction of "soil accounts" is imperative.

Gross National Product and Conventional SNA

Gross National Product (GNP) serves as the basis of the calculation of the Net National Product (NNP) which is the 'national income' of an economy. For resource-dependent economies like India, evaluation of economic performance and estimates of macro-economic aggregates are seriously distorted by the failure to account for natural resource depletion. The current system of national accounts reflects the Keynesian macro-economic model which was dominant when the system was developed. Keynes and his contemporaries were primarily concerned with the Great Depression and the business cycle. Specifically, their efforts were directed towards explaining how economies could remain at less than full employment for long periods. The possible scarcity of natural resources did not figure in their concerns.

The scenario today is drastically different, especially for the developing world. Many resource-dependent countries are heavily burdened with debt. Indeed, natural resource assets are drawn upon to finance economic growth. The revenues derived from such extraction are invested in industrial capacity, infrastructure and other priority areas. This 'metamorphosis' of assets is not illegitimate *per se*, insofar as the national accounting system recognizes that the process has resulted in the exchange of one asset for another.

If a farmer cuts and sells the timber in his woods to raise money for a new barn, his private financial account would reflect the acquisition of a new asset (the barn) and the loss of an old asset (the timber). Since the barn is more useful to him than the lost timber, he considers himself better off than before. However, in the national income accounts, income and investment would rise as the barn is built, but *income also rise as the timber was cut!* The value of the timber, less that of all intermediate purchases, would be credited to value added in the logging industry. ***The loss of a valuable asset would not be reflected anywhere!***

Sustainable Development and Revised SNA

A national accounting system that draws attention to depleting asset positions may alter policy-makers to the need for policy changes. A policy structure based on the paradigm of sustainable development may mitigate the rapid erosion of the natural resource assets. "Sustainable development", in the present context, has been described variously as living on the planet's income instead of depleting nature's capital, as meeting the needs of today's population without compromising the ability of future generations to meet theirs, and as the management of natural, human and capital assets so as to increase long-term wealth and well-being. By each of these definitions, sustainable development is clearly an important objective for all societies. It is clear, therefore, that the construction of natural resource "accounts", including those for the soil resource, has a strong basis.

Evaluation of soil degradation: underlying principles

The underlying principle of the methodology is as follows. Land possesses a degree of resistance to natural forces that cause degradation. The balance between climatic aggressivity and this natural resistance of land to it determines the natural risks of degradation in a particular area. Human action can either increase or decrease the natural resistance of land to degradation forces. Thus, degradation gets affected also by the manner in which the human element modifies the balance between climatic aggressivity and the natural resistance of land.

This implies that soil degradation is a *dynamic* process. Therefore, it makes sense to distinguish between the *extent* of degradation and the *rate* of degradation. Clearly, the two notions are dissimilar. Land may be getting degraded at a very rapid rate but may not yet be seriously affected. On the other hand, it may have been seriously degraded in the past but the current rates may be only slight. A comprehensive analysis ought to concern itself with both notions. However, in this study, our focus shall be on the *annual rate* of degradation since we are primarily concerned with point-to-point changes in land quality.

Outline of methodology

The general structure of the methodology to measure the degradation of the soil resource may be outlined in the following manner.

$$Z = f\,(A, B, C, D, \ldots.)$$

where *f* is the theoretical model developed in the context of the degradation type ***Z*** caused by the factors ***A,B,C,D,*** etc[5]. The theoretical models that may be used in this case shall fall into one of two broad categories described below. Consequently, the estimation of the extent of the degradation of the soil resource can take one of the following routes[6].

Productivity index (PI) method

1. First, the geographical unit of analysis is defined.
2. For each unit of analysis, the dominant soil type is identified.
3. The major crop cultivated on the dominant soil type is identified.
4. Simultaneously, a land productivity index (**lpi**) is defined with respect to a set of key variables.
5. Time-series data on these variables is obtained for each unit. This determines the time-series data with respect to the **lpi**.
6. This information with respect to the **lpi** is then used in conjunction with the average price of the crop identified above to obtain the extent of depreciation of the soil resource in each unit.

In this methodology, the unit of analysis (e.g., village, block, district etc.) is first defined. Then, for each such unit, both the dominant soil type as well as the crop grown on it are identified. For each soil type, a land productivity index is subsequently defined. This index may be based on a number of parameters like soil depth, bulk density, moisture, storage capacity, apparent hydraulic conductivity, non-capillary pore space, water table depth, slope etc. The index, therefore, maps the physical and chemical properties of each soil type to its maximum potential yield. More often than not, this output has a well-defined market value. Therefore, changes in land quality get reflected in the maximum marketable value of the yield of the land in question. Any degradation of the land resource can then be translated into a quantum of money and this sum may be adjusted against the GDP of the economy.

A variant of this method forms the basis of the software package EPIC (Erosion Productivity Index Calculator) used by Robert Repetto and his colleagues at the World

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5 Clearly, the dimensions of these factors and the form of *f* must be chosen in a manner that does not result in an inconsistency with respect to the unit chosen for *Z*.

6 For an economist, the results of the two would be exactly identical if the real world was strictly characterized by neo-classical institutions.

Resources Institute to assess the degradation of the soils of Java. Instead of structuring a relationship between productivity and soil parameters and soil parameters and erosion, it measures the effect on productivity due to erosion directly. Therefore, this method is essentially empirical in nature as against the former which is based on scientific analyses. Additionally, it concentrates on only one form of degradation viz., erosion. These features may be treated favorably or otherwise, depending on the aim of the analysts' exercise.

Replacement cost (RC) method

1. As a first step, the basic forms of degradation of the soil resource (for example, erosion, leaching, water-logging, salinity etc) which are relevant for India are identified.
2. Data is obtained for each degradation type.
3. This information is then translated into the extent of corrective measures required to restore the quality of land.
4. Using the average cost of each measure, an estimate of implementing these measures is obtained.

This viewpoint considers various categories of land degradation. For each category (viz. erosion, salinity, water-logging) data on the extent of annual net damage is obtained. Based on this information, one can outline the processes required to reverse the degradation. The cost of undertaking these programs can be used to make the requisite adjustment.

Comparisons and critique

It would be obvious to all readers that, while analyzing the impact on any plot of land, the former methodology focuses on its output whereas the latter does so on the inputs it uses. From the economists' point of view, in a neo-classical world, the market would not allow arbitrage possibilities and would consequently generate a price vector that would make the choice between the two approaches redundant. Clearly, the real world does not conform to such rules; the degree of their absence in the developing world begin even more marked due to the existence of structural and institutional rigidities. Therefore, a judicious weighing of the pros and cons of the two methodologies becomes imperative.

Methodology ***RC*** uses a number of simplifying assumptions. For instance, it implicitly contends that a ton of fertilizer (for example, urea) added to soil is a perfect substitute of an equal amount of the lost nutrient in its natural form. Additionally, it also assumes that the impact of the different types of degradation is additively separable. Through such a premise, symbiotic processes amongst different forms of degradation is ruled out. On the other hand, ***PI*** suffers from serious definational problems. For instance, how does one define the 'major' soil type? Should it be the soil type that covers (in terms of land area) the largest fraction of the unit of analysis? Or, alternatively, should it be the soil type that cover the largest fraction of the cultivated area of the unit of analysis? One can also choose the soil category upon which the crop with the highest monetary value is cultivated.

While choosing between these methodologies, we must bear in mind that the aim of the incorporation of natural resources in the national income accounts is to focus on long run sustainability. Given this perspective, it is felt that ***PI*** may give biased results since it depends critically on the prices of the major crops under consideration. A piece of land may *not* be getting seriously degraded but the price of the crop grown on it may be fairly high. In such a case, the "value of degradation" shall be unduly excessive. The opposite phenomenon can also occur in many cases. ***RC***, on the other hand is seen to much safer inspite of its simplistic approach.

Additionally, from an empirical point of view, work in the context of developing a land productivity index has commenced only recently[7]. Therefore, even on account of data requirements, ***PI*** cannot be pursued at present in the Indian case.

Application of methodology RC: The Indian case

The execution of methodology **RC** begins with the identification of the various forms of degradation. Unfortunately, in the context of India, data on none of the forms of degradation other than erosion is available in an exhaustive sense[8]. Accordingly, this work is limited to water erosion which is the most important and serious type of soil degradation with respect to India. The most significant effect of erosion takes the form of soil wash-off. Concomitantly, this causes loss of valuable nutrients, Erosion also leads to siltation of rivers and reservoirs which, in turn, lead to the occurrence of floods downstream. We consider both these facets in the sections below.

Narayana and Babu (1983) present a method to arrive at a first approximation of soil erosion, sediment load of rivers and sedimentation in reservoirs. In their analysis. existing

[7] This is being pursued at the Agricultural Physics Division, IARI, under the guidance of Dr R P Gupta, Coordinator, All India Coordinated Project on Soil Physical Conditions Improvement.

[8] Dhruv Narayan & Ram Babu (1983).

annual soil loss data for twenty different land resource regions of the country (which. by definition. are mutually exclusive as well as mutually exhaustive). sediment loads of some rivers and rainfall erosivity for thirty six river basins and seventeen catchments of major reservoirs are utilized. On the basis of this information. statistical regression equations are developed for predicting sediment yield. This data is then coupled with the derived Universal Soil Loss Equation (USLE) parameter values to obtain annual sediment loads. sediment deposition in reservoirs and sediment lost to the sea[9].

Estimation of loss of nutrients

For the sake of simplicity. we limit ourselves to the three macro-nutrients (Nitrogen (N). Phosphorus (P) and Potassium (K)) in this study. As stated above. in their analysis. Narayana and Babu (1983) divide the country into "**Land Resource Regions" (LRRs)** and provide estimates of erosion occurring in them. However. since each LRR may be characterized by more than one soil type. the computation of the extent of nutrient loss cannot be carried out directly. To do this. one needs to possess information about the various soil types *within* each land resource region. For this purpose, a soil map of India may be obtained and the two maps over-layed. the resultant **polygons** are named **Land Resource-Soil Type (LRSTs)** for the sake of brevity.

Next. we need to compute the erosion occurring in each LRSTs. To make this estimate. we need to devise a set of weights that disaggregates the erosion occurring in each LRR into the erosion occurring in each LRST within that LRR. The factors that are considered to construct these weights is the proportion of area. ***Pr***. of each LRST with respect to the LRR to which it belongs.

The basis of taking these factor to construct the weights is as follows. *Ceteris paribus*. the erosion in each LRST is directly proportional to the proportion of area of that LRST with respect to the LRR to which it belongs. The rationale for excluding other relevant determinants such as erodibility factor. slope-length factor. etc is that they have *already* been incorporated through the USLE.

Let Er_z is the erosion occurring in land resource region z. Given this information. the extent of nutrient loss may be computed with the help of the nutrient factors in various soil types.

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[9] See Appendix I for a full discussion on the USLE.

$$X_{ij} = \alpha_{ij} \cdot Er_{zi}$$

for i ε {1,2,...,18}; j ε {N,P,K}; z ε {A,B,...,S}

Where Er_{zi} is the erosion occurring in land resource region z having soil type i
α_{ij} is the percentage of nutrient j in soil type i[10]
X_{ji} is the extent of loss of the nutrient j in soil type i

Summing up over all the LRSTs, the total amount of each nutrient lost in the country can be obtained.

$$X_j = \Sigma_i X_{ij}$$

To convert this information into value terms, each nutrient loss figure may be multiplied by its price (P_j) and the resultant numbers summed up.

$$V = \Sigma_j P_j * X_j$$

where P_j is the price of nutrient j.

The figure thus obtained is the cost of replacing the (annually) lost nutrients.

Presentation of results

The presentation of results begins by illustrating the land resource classification.

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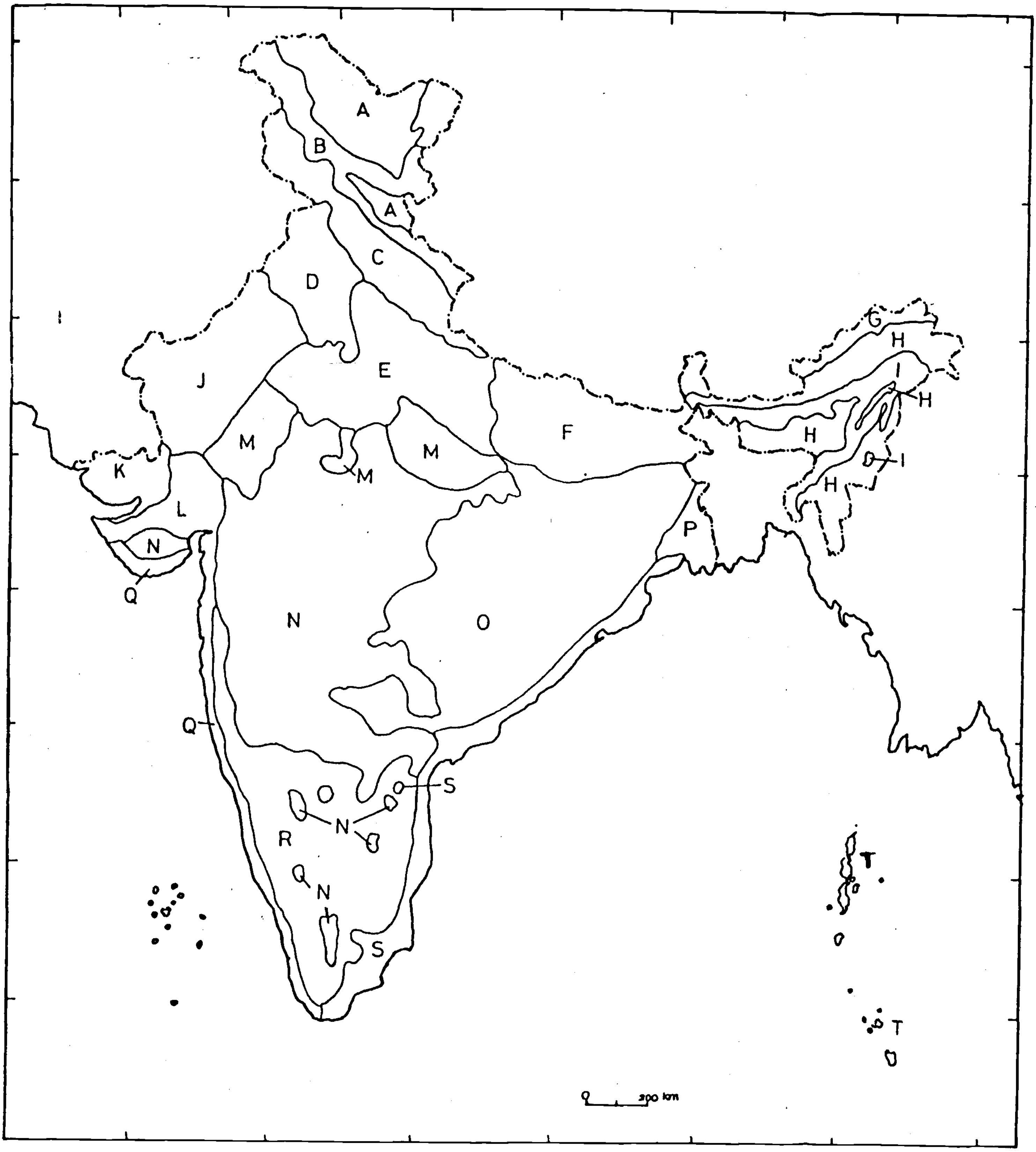
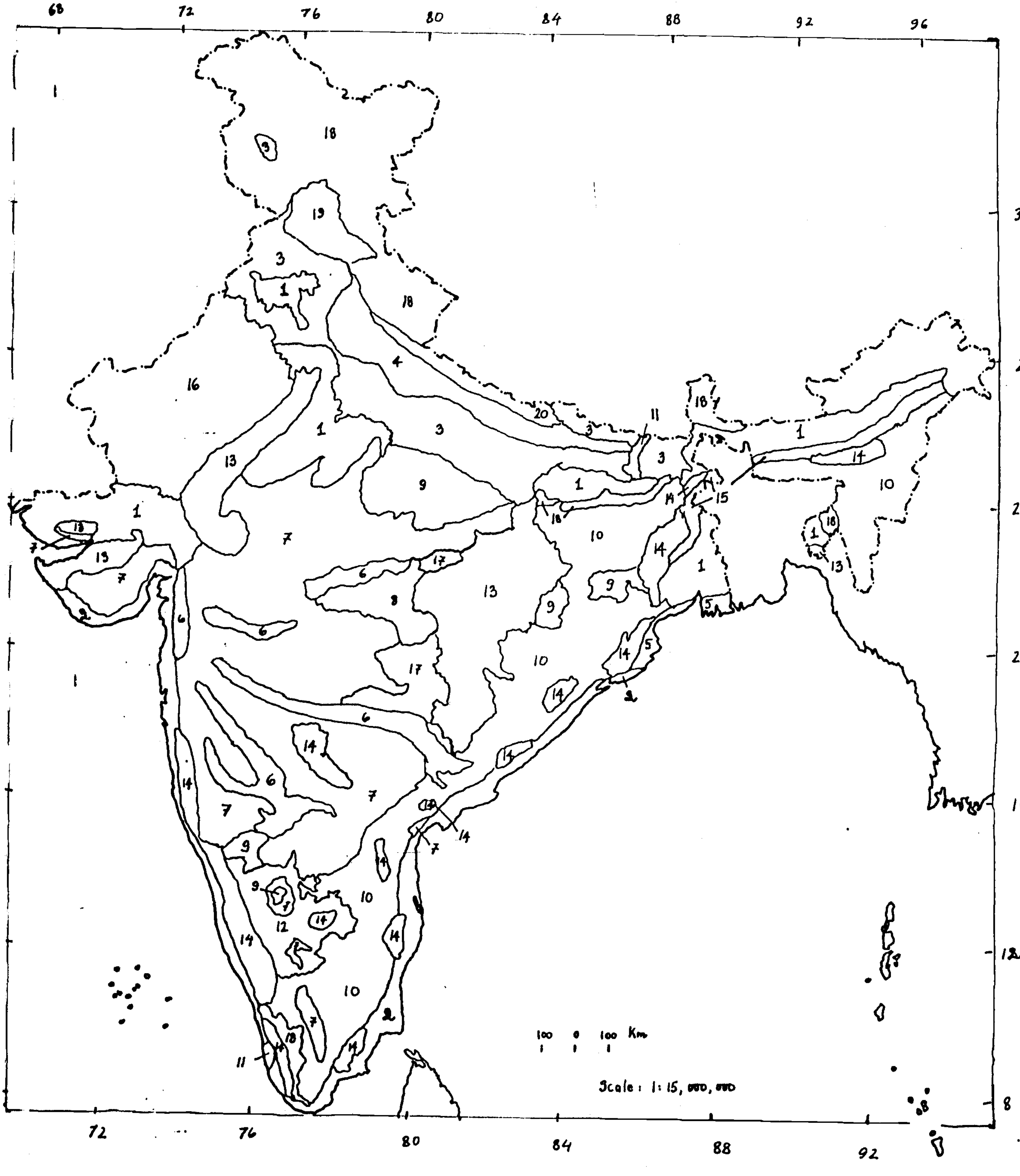
10 Across space, each soil type has a (largely) uniform chemical composition though there may exist certain differences within a range. Das and Chatterjee (1982) amongst other soil scientists, have tabulated the chemical composition of the soils of India. The mean of this data was computed for each nutrient and for each soil type.

Land Resource Regions (LRRs) of India[11]



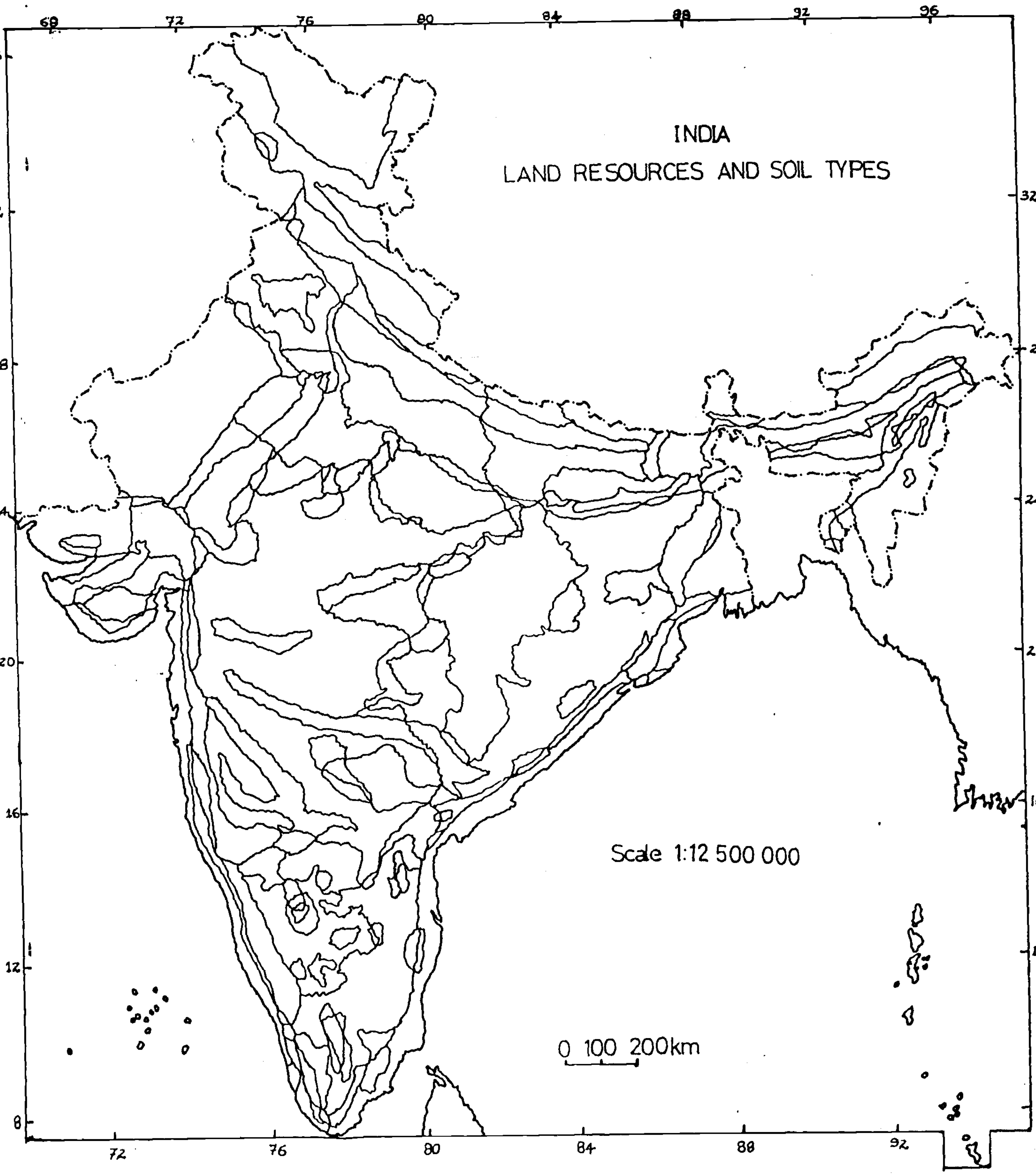
[11] Labelled as A, B ... S.

Soil Map of India[12]



[12] Labelled as 1, 2, ..., 18. The index is given in Appendix II.

Overlay of Land Resource Regions and Soil Maps of India[13]



[13] Labelled as A1, A2, ..., B1, ..., S18.

The areas of the polygons obtained through the overlay of two maps, $Ar(z_i)$[14], were obtained through manual measurement. These are as follows.

Table 2: Areas of LRSTs (sq. cms.)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Row sum
1				12.77	21.25	14.19		9.43	16.63	0.86	19.34	12.82	4.12	9.70		13.99			1.65	136.75
2												1.57		0.49			28.50		37.14	67.70
3		1.13	6.17	26.68	36.51	37.29				0.14			0.73		0.47					109.12
4			4.13		22.88	12.58														39.59
5																2.45			4.54	6.99
6												0.25		15.64	7.37			2.71		25.97
7											1.26	7.45	7.26	198.83	21.26		1.97	35.12		273.15
8														14.80	4.78					19.58
9					2.76	0.30							27.39	2.65	11.09			5.45		49.64
10						4.57								8.57		93.17		55.00	11.43	172.74
11						2.57		35.31	10.05								1.04			48.97
12														2.33				25.63		27.96
13				0.54	7.53			0.33	0.39		3.93	8.07	17.29	6.62	76.58					121.28
14						1.73		9.74	6.29					5.79	19.48	0.78	7.75	23.24	20.44	95.24
15				3.88	9.46					85.00	0.24		7.79							106.37
16														2.61	19.82					22.43
17	56.38	56.31	41.06	0.93		5.17	17.43	28.29	1.32						0.51		0.94	4.63		212.97
18			5.64		1.53	5.39														12.56
Col sum	56.38	57.44	57.00	44.80	101.92	83.79	17.43	83.10	34.68	86.00	24.77	30.16	64.58	268.03	161.36	110.39	40.20	151.78	75.20	1549.01

The "col sum" referred to is simply the column sum of the relevant entries. It shows the area computed on the map of the various land resource regions. For example, the "col sum" of B is 57.44. This simply means that the area of LRR B on the map is equal to 57.44 square centimeters. The entries under "row sum" have an analogous meaning; the areas in this case refer to the areas under various soil categories.

[14] z refers to the land resource region category and i to soil type category.

Using the scale of the map (1 cm = 45.45 kms), we convert this information into actual areas.

Table 3: Areas of LRSTs (million hectares)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Row sum
1				2.64	4.39	2.93		1.95	3.44	0.18	4.00	2.65	0.85	2.00		2.89			0.34	28.25
2												0.32		0.10			5.89		7.67	13.99
3		0.23	1.27	5.51	7.54	7.70				0.03			0.15		0.10					22.55
4			0.85		4.73	2.60														8.18
5																0.51			0.94	1.44
6												0.05		3.23	1.52			0.56		5.37
7											0.26	1.54	1.50	41.08	4.39		0.41	7.26		56.44
8														3.06	0.99					4.05
9					0.57	0.06							5.66	0.55	2.29			1.13		10.26
10						0.94								1.77		19.25		11.36	2.36	35.69
11						0.53		7.30	2.08								0.21			10.12
12														0.48				5.30		5.78
13				0.11	1.56			0.07	0.08		0.81	1.67	3.57	1.37	15.82					25.06
14						0.36		2.01	1.30					1.20	4.02	0.16	1.60	4.80	4.22	19.68
15				0.80	1.95					17.56	0.05		1.61							21.98
16														0.54	4.10					4.63
17	11.65	11.63	8.48	0.19		1.07	3.60	5.85	0.27						0.11		0.19	0.96		44.00
18			1.17		0.32	1.11														2.60
Col sum	11.65	11.87	11.78	9.26	21.06	17.31	3.60	17.17	7.17	17.77	5.12	6.23	13.34	55.38	33.34	22.81	8.31	31.36	5.54	320.04

Using these computations, one may say that the actual area under land resource region B is equal to 11.87 million hectares; that under LRST **B17** is 11.63 million hectares and that the area of the entire country is equal to 320.04 million hectares. The actual area of the country (excluding the two major archipelagos) being 327 m ha, the above calculation suffers from an error of 2.16 %, a figure lies well within acceptable limits.

The proportions of area under various LRSTs may be determined by using either Table 2 or Table 3. The results are as follows.

Table 4: The proportion of areas under various soils for different Land Resource Regions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				0.29	0.21	0.17		0.11	0.48	0.01	0.78	0.43	0.06	0.04		0.13			0.02
2												0.05		0.00			0.71		0.49
3		0.02	0.11	0.60	0.36	0.45				0.00			0.01		0.00				
4			0.07		0.22	0.15													
5																0.02			0.07
6												0.01		0.06	0.06			0.02	
7											0.05	0.25	0.11	0.74	0.13		0.05	0.23	
8														0.06	0.03				
9					0.03	0.00							0.42	0.01	0.07			0.04	
10						0.05								0.03		0.84		0.36	0.15
11						0.03		0.42	0.29								0.03		
12														0.01				0.17	
13				0.01	0.07			0.00	0.01		0.16	0.26	0.27	0.02	0.47				
14						0.03		0.13	0.18					0.02	0.12	0.01	0.19	0.15	0.27
15				0.08	0.09					0.99	0.01		0.13						
16														0.01	0.12				
17	1.00	0.98	0.72	0.02		0.06	1.00	0.34	0.04						0.00		0.02	0.03	
18			0.10		0.02	0.06													
Col sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

As can be checked from the table above, the proportion of area under LRST **B17** is 98% (11.63/11.87).

The information provided by Narayan and Babu relating the soil erosion in different LRRs is tabulated below.

Table 5: Erosion occurring in land Resource Regions

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
0.00	1.57	28.36	33.41	306.64	133.67	0.60	187.93	249.13	0.00	0.00	41.48	29.38	3407.40	175.80	0.00	234.82	112.41	367.46

This data can subsequently be used to compute the erosion occurring in each LRST

Table 6: Erosion occurring in LRSTs

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				9.69	64.39	22.72		20.67	119.58	0.00	0.00	17.84	1.76	136.30		0.00			7.35
2												2.07		0.00			166.72		180.06
3		0.03	3.12	20.05	110.39	60.15				0.00			0.29		0.00				
4			1.98		67.46	20.05													
5																0.00			25.72
6												0.41		204.44	10.55			2.25	
7											0.00	10.37	3.23	2521.48	22.85		11.74	25.85	
8														204.44	5.27				
9					9.20	0.00							12.34	34.07	12.31			4.50	
10						6.68								102.22		0.00		40.47	55.12
11						4.01		78.93	72.25								7.04		
12														34.07				19.11	
13				0.33	21.46			0.00	2.49		0.00	10.78	7.93	68.15	82.63				
14						4.01		24.43	44.84					68.15	21.10	0.00	44.62	16.86	99.21
15				2.67	27.60					0.00	0.00		3.81						
16														34.07	21.10				
17	0.00	1.54	20.42	0.67		8.02	0.60	63.90	9.97						0.00		4.70	3.37	
18			2.84		6.13	8.02													
Col sum	0.00	1.57	28.36	33.41	306.64	133.67	0.60	187.93	249.13	0.00	0.00	41.48	29.38	3407.70	175.80	0.00	234.82	112.41	367.46

The erosion in LRST B17 is estimated to be 1.54 million tones per annum (1.57 * 0.98).

The following table shows the nutrient content of various soils[15].

Table 7: Nutrient content of the soils of India

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
N	0.0	0.0	-	0.0	0.0	0.0	0.1	0.0	0.0	-	0.0	0.2	0.0	-	0.1	0.0	-	0.1
K2O	1.2	0.1	-	3.1	9.0	1.8	0.2	2.0	4.4	-	1.1	0.1	0.9	-	0.7	0.2	-	3.1
P2O5	0.1	0.0	-	0.3	0.2	0.2	0.1	0.1	0.1	-	0.0	0.1	0.1	-	0.2	0.1	-	0.1

The nutrient losses, as computed through the methodology described above are as shown.

Table 8: Nitrogen losses in LRSTs (million tones)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				0.000	0.000	0.000		0.000	0.000			0.000	0.000	0.000					0.000
2												0.000		0.000			0.000		0.000
3																			
4			0.000		0.000	0.000													
5																0.000			0.000
6												0.000		0.000	0.000			0.000	
7											0.000	0.010	0.003	2.521	0.023		0.012	0.026	
8														0.000	0.000				
9					0.000	0.000							0.000	0.000	0.000			0.000	
10																			
11						0.000		0.000	0.000								0.000		
12														0.068				0.038	
13				0.000	0.000			0.000	0.000		0.000	0.000	0.000	0.000	0.000				
14																			
15				0.003	0.028								0.004						
16														0.000	0.000				
17																			
18			0.003		0.006	0.008													
Col sum	0.000	0.000	0.003	0.003	0.034	0.008	0.000	0.000	0.000	0.000	0.000	0.010	0.007	2.589	0.023	0.000	0.012	0.064	0.000
Total nitrogen loss in the country																			**2.753**

[15] Source: Das and Chatterjee (1982).

Table 9: Phosphorus losses in LRSTs (million tones)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				0.009	0.064	0.023		0.021	0.119			0.018	0.002	0.136					0.007
2												0.000		0.000			0.000		0.000
3																			
4			0.006		0.202	0.060													
5																			0.051
6												0.001		0.409	0.021			0.004	
7												0.010	0.003	2.521	0.023		0.012	0.026	
8														0.204	0.005				
9					0.009	0.000							0.012	0.034	0.012			0.004	
10																			
11						0.000		0.000	0.000								0.000		
12														0.034				0.019	
13				0.000	0.021			0.000	0.002			0.011	0.008	0.681	0.826				
14																			
15				0.005	0.055								0.008						
16														0.034	0.021				
17																			
18			0.003		0.006	0.008													
Col sum	0.000	0.000	0.009	0.014	0.357	0.091	0.000	0.021	0.121	0.000	0.000	0.040	0.033	4.053	0.908	0.000	0.012	0.053	0.058
Total phosphorus loss in the country																			**5.761**

Table 10: Potassium losses in LRSTs (million tones)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				0.116	0.773	0.273		0.248	1.435			0.214	0.021	1.635					0.088
2												0.002		0.00			0.167		0.180
3																			
4			0.061		2.091	0.621													
5																			0.208
6												0.007		3.679	0.189			0.041	
7												0.021	0.006	5.043	0.046		0.023	0.052	
8														4.089	0.105				
9					0.405								0.543	1.499	0.542			0.198	
10																			
11						0.044		0.868	0.795								0.077		
12														0.034				0.019	
13				0.003	0.193				0.022			0.097	0.071	0.613	0.744				
14																			
15				0.019	0.193								0.027						
16														0.068	0.042				
17																			
18			0.003		0.190	0.248													
Col sum	0.000	0.000	0.064	0.138	3.845	1.186	0.000	1.116	2.252	0.000	0.000	0.341	0.668	16.66	1.668	0.000	0.267	0.310	0.476
Total potassium loss in the country																			**28.991**

The preceding tables reveal some extremely interesting (and alarming) statistics. First, an extremely large fraction of nutrient loss is occurring in the LRST N7[16]. The nitrogen loss in this region is equal to more than 90% of the national loss and more than 43% of the national loss of phosphorus. However, the figure for potassium is relatively small (less than 20%). Second, the estimates of annual average loss of nutrients lie between 5.37 and 8.40 million tones[17]. Our estimates of losses of nitrogen and phosphorus seem to be in consonance with these. However, according to our study, the annual loss of potassium is astronomical. This is probably because, in general, Indian soils are rich in potash.

[16] The LRR N largely comprises the black soils region. Soil type 7 is medium black soil.

[17] Source: Government of India (1971). Indian Agricultural Atlas.

Valuation of nutrient loss

The physical losses presented above can be valued for various years in that years prices of the fertilizers that must be applied to recover the loss in productivity. This is done by using the information on prices of fertilizers in terms of nutrients.

Table 11: Prices of fertilizers in terms of nutrients (Rs per kg) inclusive of subsidy and exclusive of excise[18]

	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94
UREA	2.35	2.35	2.15	2.15	2.15	2.35	2.35	2.35	2.35	2.35	3.06	2.76	2.76
SSP	0.94	0.94	0.85	0.85	0.85	0.95	0.95	0.95	0.95	0.95	1.34	1.86	1.80
MOP	1.30	1.30	1.20	1.20	1.20	1.30	1.30	1.30	1.30	1.30	1.75	3.10	3.60

Table 12: Adjustment to be made (Rs Crores)

	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94
UREA	646.95	646.95	591.89	591.89	591.89	646.95	646.95	646.95	646.95	646.95	842.42	759.83	977.32
SSP	542.38	542.38	490.45	490.45	490.45	548.15	548.15	548.15	548.15	548.15	773.18	1073.22	1269.40
MOP	3768.70	3768.70	3478.80	3478.80	3478.80	3768.70	3768.70	3768.70	3768.70	3768.70	5073.25	8986.90	10900.24
Total	4958.03	4958.03	4561.14	4561.14	4561.14	4963.80	4963.80	4963.80	4963.80	4963.80	6688.85	10819.95	13146.96

The value of nutrient loss shows a long-run secular increase. However, in our analysis, this is a reflection of only nominal changes. The estimation of physical changes becomes difficult due to the absence of an earlier piece of work.

[18] Source: Fertilizer Statistics 1992-93

Sediment deposition in reservoir

The data on catchment area and average annual silt load of 17 reservoirs are presented in Table 13. The data show that major reservoirs like Bhakra, Hirakud, Tungabhadra and Mahi have the highest annual sedimentation, ranging from 24,000,000-46,000,000 tones.

Table 13: Sediment data of selected reservoirs of India[19]

Reservoirs	Catchment area (sq km)	Annual average silt load (mt)
Bhakra	56.980	35.1
Matatila	20.720	11.0
Maithan	5.206	7.6
Panchet	9.920	11.9
Hirakud	82.880	46.0
Gandhisagar	22.533	11.0
Nizamsagar	21.694	14.7
Shivajisagar	892	1.5
Ramganga	3.134	7.3
Mayurakshi	1.792	4.1
Girna	4.729	5.3
Lower Bhawani	4.200	1.5
Tungabhadra	28.179	23.8
Machkud	1.956	0.6
Dantiwala	2.862	12.6
Mahi	25.330	31.9
Tawa	5.983	6.8
Average	17587.65	13.70

[19] Source: Dhruva Narayan & Ram Babu (1983).

Sediment load of rivers

The characterstics of 18 river basins are summarized in Table 14. This table includes data on catchment area and sediment loads. The total sediment loads of Ganga and Brahmaputra are the highest (586,000,000 and 470,000,000 tones) and more than 1/3 of these 18 rivers carry sediment loads of 100,000,000 tons or more.

Table 14: Salient hydrological details of river basins of India[20]

River basin	Catchment area (m ha)	Sediment load (mt)
Ganga basin	86.15	586.00
Brahmaputra basin	18.71	470.00
Barakar & other rivers (DVC)	7.82	210.00
West flowing rivers below Tapi	11.21	252.22
Tapi including Kim	6.69	101.98
Narmada	9.88	61.37
Mahi including Dhadhar	3.76	22.10
Sabarmati	2.17	8.39
Luni and others of Saurashtra & Kutch	32.19	22.88
Indus	32.13	105.7
East flowing rivers between Ganga & Mahanadi	8.10	65.69
Mahanadi	14.16	98.5
East flowing rivers between Mahanadi & Godavri	7.97	30.2
Godavri	31.28	79.1
Krishna	25.00	96.8
Pennar & other east flowing rivers between Krishna & Cauvery	14.49	41.7
Cauvery	8.79	32.3
East flowing rivers below Cauvery	3.51	18.4

From the information given above, we know that 2936.59 million tones of silt needs to be removed annually from various reservoirs and water bodies. Given that the cost of removal of a tone of silt is (approximately) Rs 14.30[21], it is easy to see that the annual desiltation costs are slightly under Rs 4200 crores.

[20] Source: Dhruva Narayan & Ram Babu (1983).

[21] Chopra, Kanchan (1990). Agricultural Development in Punjab: Issues in Resource Use and Sustainability.

Concluding remarks

As our analysis shows, the annual amount lost during 1993-94 is more than Rs 13000 crores, a figure that is equal to 7.2% of our GDP. Clearly, current soil use practice are unsustainable. Day by day, we are, unknowingly and unwittingly, destroying a very vital resource base. Certain estimates put the value of national soil loss at Rs 700 crores in 1972 at that years prices[22]. The corresponding loss today is of a much higher order, with higher fertilizer prices and a greater intensity of erosion. This implies that (in nominal terms) the figure has gone up by nearly 20 times during the last two decades.

Additionally, the problem seems to be acute in two senses. First, the black soils region (especially LRST N7) is undergoing an extremely high rate of degradation. In value terms, the losses in this region are nearly equal to Rs 1941 crores which is 15% of the national loss. This clearly indicates that countervailing measures must be conceived and implemented on a war footing in this region which is responsible for providing some of the very important and valuable crops cultivated in our country. Second, the loss of potash is alarming. Even if this may not be of immediate concern (since Indian soils are potash rich), the implications for the coming decades are of extremely serious nature. Therefore, this issue too must be addressed with utmost urgency.

The national loss caused by siltation is also extremely high. The actual rate of sedimentation is three times than the expected rate. Reduction in a reservoir's capacity to hold water diminishes its capacity to hold back heavy flood waters as well as the amount of land it can irrigate in addition to imposing a very heavy cost on society in terms of silt removal.

Clearly, there is an urgent need for a national debate on how India's land ought to be managed. We are basically engaged in a race against time. This is especially because problems in the tropical and underdeveloped countries contain complex human and physical factors which undermine not only development but also present day subsistence. Fortunately, however, it is also widely believed that these countries require strategies which are qualitatively different from 'western' conservation methods. The LDCs need techniques that harmonize with existing systems, which combine existing ethics into effective than their western counterparts, there may be cause for concern. But it is known that, for instance, crop cover provides potentially the most effective means of conservation — that good cover is entirely consistent with good economics. Above all, the re-alignment of strategies of soil conservation must retain the respectability of the small farmer who must implement the conservation.

[22] State of India's Environment (1992).

APPENDIX I

Universal soil loss equation

The most popular method of estimating water erosion (i.e. soil erosion caused by water) involves the use of the Universal Soil Loss Equation (USLE). This equation is used widely not only to predict soil loss due to water erosion but also to evaluate soil conservation measures. The calculations demanded by the USLE are simple once the values of its variables have been established. Average annual soil loss is estimated as a function of six variables. The equation is multiplicative and is written as

$$A = R.K.L.S.C.P$$

where

A is the computed soil loss per unit area.

R is the rainfall erosivity factor. It is obtained through the number of erosion index units (EIUs) in the period of consideration. The erosion index is a measure of the erosive force of rain.

K is soil erodibility factor. This is defined as the erosion rate per unit of erosion index for a specific soil in a cultivated continuous fallow on a 9% slope that is 22.1 meters long.

L is the slope length factor. This is defined as the ratio of soil loss from the field slope length to that from a 22.1 meters length on the same soil type and gradient.

S is the slope steepness factor. This is the ratio of soil loss from a field gradient to that from a 9% slope on the same soil type and slope length.

C is the crop management factor. This is defined as the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated.

P is the erosion control practice factor. This is the ratio soils loss with contouring, strip-cropping or terracing to that with straight-row faring, up-and-down slope.

Inspite of its popularity, the USLE cannot be applied without reservations. First, despite three decades of study, its validity in the tropics is still a matter of controversy. Second, the USLE was developed specifically for small field plots and therefore cannot be used for regional surveys. This is a more important issue for the present study since the USLE ignores soil movement. Displaced soil may get deposited on another land mass (as often happens in the case of wind erosion) or it may get carried away by river waters. A part of the sediment load of the rivers gets deposited downstream as silt. Another fraction fills up reservoirs or raises the bed of the river/stream itself. The rest is emptied into the sea. Clearly, it is possible that such deposits have a significant mitigating effect.

Williams' (Williams, 1975) Modified Universal Soil Loss Equation (MUSLE) is an innovative modification designed to estimate soil loss on a regional scale. However, it requires estimates of run-off volume and peak flow rates, data regarding neither of which is available. Therefore, inspite of the constraints acting upon the choice of the USLE, it remains the best bet. Secondly, and most importantly, the only available country-wide estimates are based on it.

APPENDIX II

1. Alluvial (undifferentiated) soils
2. Coastal alluvium soils
3. Grey-brown soils
4. Gangetic alluvial soils
5. Deltaic alluvium soils
6. Deep black soils
7. Medium black soils
8. Shallow black soils
9. Mixed red & black soils
10. Red loam soils
11. Peat soils
12. Red gravelly soils
13. Red & yellow soils
14. Laterite soils
15. Desert soils
16. Skeletal soils
17. Sub-montane soils
18. Foot-hill swampy soils

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4. *Accounting for coal depletion in the national income accounts of India*

Meeta Mehra, Vikram Dayal and Preety Bhandari

Introduction

The goal of this paper is to develop both physical and monetary accounts for coal in India. While the physical accounts are reported in units of reserves, valuation for the monetary accounts uses the net price method.

Economically workable coal deposits are wealth assets and not merely "free gifts of nature" as they are currently treated by conventional methods of national accounting. The motivation for proposing a new treatment of coal resources within the National Accounts is that the national accounts do not measure the depreciation of coal resources. In this exercise, coal deposits are treated as natural capital, and the depreciation of coal deposits is used to adjust GDP at factor cost.

Coal in the Indian economy

The coal industry plays a critical role in the Indian economy. Coal meets about 60-62% of the total primary energy requirements, mainly through electricity generation. It is also a vital input for a number of core sector industries like iron and steel, cement, fertilizers, chemicals, textiles etc. The principal uses of coking coal are in ore reduction in steel plants, and of non coking coal in power generation and process heating in industries. Some major areas of concern in the coal sector in India are the declining quality of coal in India, the growing dependence on imports of coking coal for the steel industry, coal transportation bottlenecks, and environmental concerns.

India is fairly well endowed in terms of coal resources. The total geological reserves of India are estimated at about 194 billion tonnes, of which 33% are in the proven category. At 1991-92 rates of extraction and technology, the resource base of coal will last for over 250 years. Not all coal in the ground can be mined. It is assessed that only 30-35% of the reserves are recoverable, given the large surface and technical constraints, implying that for each tonne of coal mined, about 2 tonnes would be lost under the prevailing techno-economic conditions.

Moreover, the quality of coal reserves has been on a decline. particularly in the last two decades. The official statistics on coal resources is incomplete. in that the time series data on geological reserves neither indicate the historical depletions through extraction nor do they make any reference to the amount of recoverable reserves available on hand.

Conventional accounting for coal

In the conventional system of national accounts (SNA). activities carried out at the mine site are included in the measurement of income from coal mining - extraction, beneficiation, etc. Coal is taken as a major mineral. The gross value added from coal uses the "production method":

Gross value added = value of output - value of input (both are evaluated at the state level)

The value of output is computed with

(i) Statewise quantity and value of output of coal as published in "Financial Year Aggregates of Mineral Production". Indian Bureau of Mines.

(ii) Pit-head prices are used to value the resource. The value of input uses the cost of inputs like fuel, sand. repair and maintenance. other materials. etc., from the Office of Coal Controller. Calcutta.

The conventional national income accounts do not measure the depreciation of coal resources.

Scope

All coal resources of India have been considered. Lignite has been excluded from the present study. The accounts were prepared for the fiscal years 1983-84 through 1991-92. Computations were done for coking and non-coking coal separately (estimation of recoverable reserves. calculation of average costs of production etc.). Accounts were constructed at the state level for seven states: Andhra Pradesh. Bihar. Maharashtra. Madhya Pradesh, North-eastern states. Orissa and West Bengal. GDP at factor cost at 1991-92 constant prices was adjusted to take note of annual coal depletion.

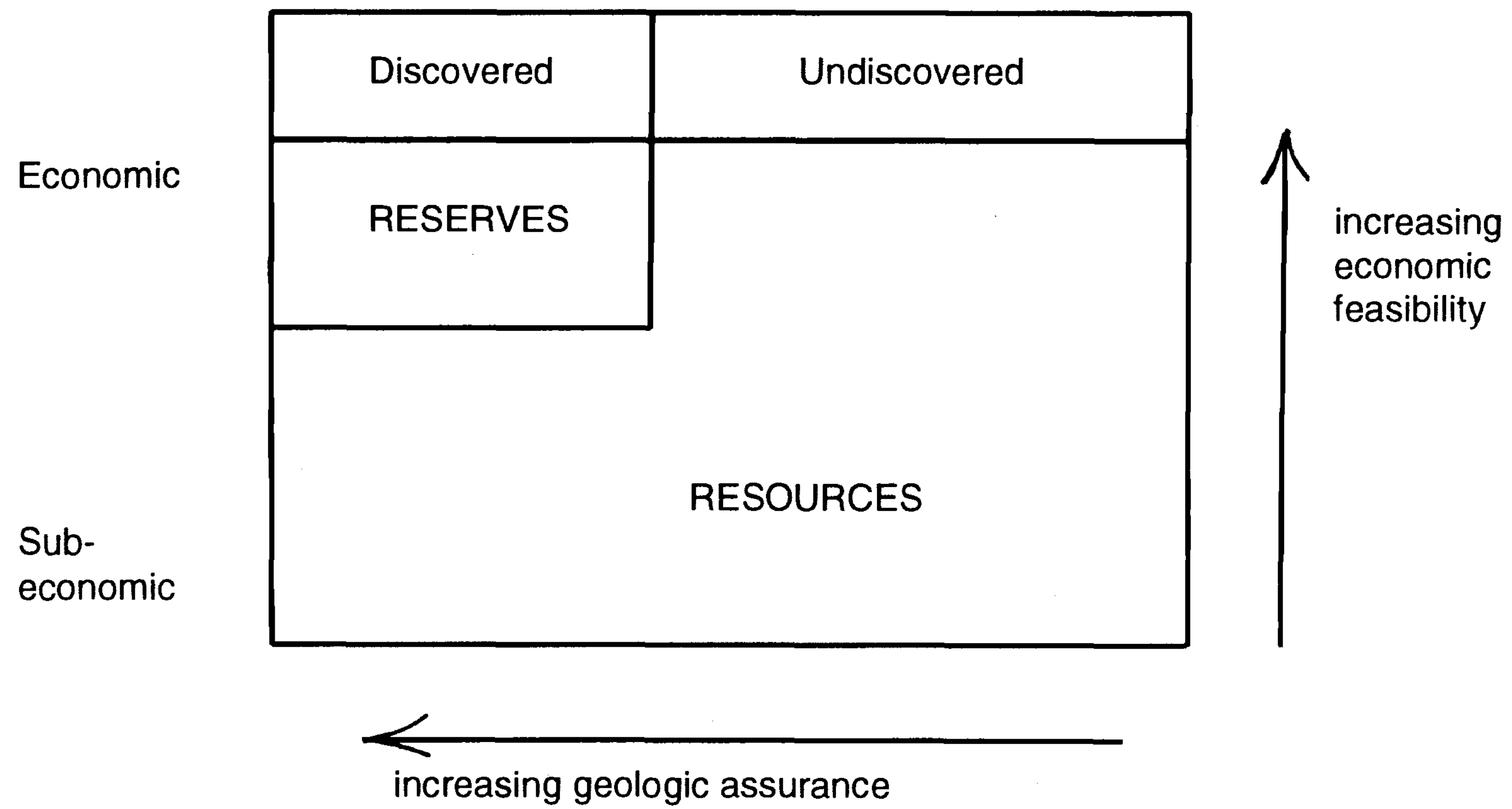
Methodology

Three steps characterised the methodology:

i) Preparation of physical accounts of the resource.

This used the fundamental identity:

McKelvey's Box



Source: modified from McKelvey

Closing stock = Opening stock + reserve accretion - production (depletion)

ii) The economic valuation of the resource depletion/change in stock. This used the net price method.

iii) Finally GDP at factor cost was adjusted by the value of coal depletion.

Data Sources

Reserves:	Geological Survey of India
Minability and recoverability factors:	Sub-group II on Coal Exploration, Mine Planning and Design and Development and Environmental Management
Production:	Directory of Coal, Coal Controller's Organization
Cost of production:	Operational Statistics, Coal India Limited
Cost of imports:	Monthly Statistics of Foreign Trade in India, Volume on Imports, Directorate General of Commercial Intelligence and Statistics, Ministry of Commerce

Compilation of physical accounts

Definition of Reserves and Resources:

The McKelvey Box illustrates the classification of mineral reserves and resources. The vertical axis represents the degree of economic recovery and the horizontal axis measures the degree of geologic certainty of mineral reserves and resources. The boundary between identified (discovered) and undiscovered resources fluctuates as the result of a mining company's investment in exploration and development, and differing geological conditions. The boundary between economic reserves and sub-economic resources is affected by the relationship between prices and extraction costs, and technological improvements.

Measurement of reserves is an imprecise science at the best of times, with frequent revisions in recoverability during a coalfield's life. The exact size of the economic resource is known only when the coalfield has ceased to produce.

In India, coal resources are termed proved, indicated and inferred according to the method of coal exploration and estimation, with proved reserves being the most reliable and inferred reserves being the least reliable. Geological reserves are the sum of proved, indicated and inferred reserves. Minable reserves include reserves which could be exploited under favourable surface and underground conditions. Recoverable reserves are those reserves which can be actually brought out of the mines taking into account the losses during mining, and it is only these which were valued.

Estimation of recoverable reserves

We estimated the recoverable reserves for coal for different years, coalfield wise, and then estimated the drawing down of reserves which production each year represents.

We have used Planning Commission statistics for recoverable reserves for 1991, to calculate the proportions of recoverable to geological reserves for different coalfields. For example:

Godavari Valley coalfield, non-coking coal, upto 600 metres

Geological	Minable	Recoverable
9054.15	7097	2501

from which we have calculated the following fractions:

Minable/Geological : 78.38%

Recoverable/Geological : 27.26%

Our assumption is that these fractions are unlikely to change drastically from year to year. These fractions were then applied to the coalfield-wise geological reserves published for different years to obtain minable and recoverable reserves. Past production was calculated and subtracted from the recoverable reserves.

Reclassification of coal production statistics

In order to match production and reserves data, mine-wise data was summed up to the coal field level, and grade-wise data was reclassified to get broad categories of coal quality

Monetary valuation

The concept of economic rent is central to natural resource valuation. Economic rent is defined as the return to any production input, its market price (MP) over and above the minimum amount required to retain it in present use or cost of production (CP)

ER = MP - CP

Economic rent constitutes the difference between the international commodity price and all factor costs of extraction, including a normal return to capital but excluding taxes, royalties and other costs that are not part of the cost of physical extraction.

Economic rent is the return accruing to investors over and above those necessary to sustain:

1. ongoing production from existing fields
2. the further development of discovered fields
3. new exploration

These are the marginal costs necessary to replace the existing stock of the natural resource in the long-run. Measurement of these rents requires knowledge of the costs of finding, developing and operating coal fields, production profiles, coal prices and discount rates.

In accounting for non-renewable resources in the extractive industry, it is important to determine the net value-added from the resource. The return to this factor of production is economic rent. It is also important to distinguish the value added from the resource from that value added associated with the physical (man-made) capital used to extract the resource. The value added from the resource is defined as the net revenue from the resource less all factor payments including a normal return to capital. That is, the value of the natural resource stock is the discounted present value of the net revenue.

Economic rents from natural resources consist of Hotelling rents (scarcity or exhaustability) and Ricardian rents (differential or varying quality) as well as locational rents (arising from transportation costs) and rents arising from unexpected price variations. While much of the literature on monetary valuation of natural resource stocks has focused on aggregate economic rent or Hotelling rents, there is little discussion on how to treat these different rents in the context of developing natural resource accounts. In most models, it is assumed that stocks are homogeneous and that there are no differential or Ricardian rents.

Most of the literature suggests that it is the Hotelling or scarcity rent that should be used to measure depletion of the resource.

Net price method of Repetto et. al:

Repetto used the net price method to value petroleum stocks in Indonesia. In this method the change in the stock of the resource is multiplied by the current unit net price to arrive at a monetary value of the depletion of the resource. The unit net price is equal to the market price less the cost of discovery, extraction and marketing. The use of this method requires current data on costs and prices. Although competitive equilibrium conditions are rare, the convenience of this method may compensate for its theoretical inadequacies. The net price method provides a relatively simple alternative to use when the information needed to calculate the present value and transaction values of resource stocks is not available.

Value of coal depletion = Net price * Amount of depletion

Discussion of the physical and monetary accounts

All India (Table 1):

The stock of coal reserves has been increasing quite steadily from 46776 million tonnes in 1983-84 to 63485 million tonnes in 1991-92, due to large additions in reserves of about 2000 million tonnes each year. These large additions to the reserves are far larger than the depletion of coal reserves by a factor of ten. If we were to value the change in reserves due to both depletion and addition to reserves, then there would be a substantial upward revision in the gdp figure. We have chosen to value only the depletion of the resource.

The reserves to production ratio, or the life of the resource, decreases from 367 years in 1983-84 to 284 years in 1991-92. This rather high life of the resource rules out the use of a method such as that due to El-Serafy[1], since the user cost comes to zero over such a long life span of the resource.

Madhya Pradesh (Table 2):

The stock of coking coal in this state increased four-fold from 1983-84 to 1991-92. The reserves to production ratio also saw a sharp increase from its 1983-84 levels to its 1991-92 levels. The economic rent on coking coal in current prices increased steadily due to a low

[1] According to El Serafy, the proper approach is to estimate that portion of the receipts from mineral extraction that represents capital depletion (user cost) and exclude this entirely from the GDP. The value of the user cost is just that amount that must be invested in some alternative activity at a given rate of discount that will generate a steady income flow equal to that earned from the mine. This income flow should commence in the period following the end of production in the mine. If the life of the mine is a hundred years or more, the user cost is very small and almost zero, since the time when the invested user cost begins to yield a return is very distant.

increase in the cost of production and a high increase in the cif price. Production of coking coal fell from 3.35 million tonnes in 1983-84 to 1.69 million tonnes in 1984-85 and then to 0.45 million tonnes in 1985-86 and stayed at about that level till 1991-92.

The stock of non-coking coal increased less dramatically from 9319.38 million tonnes in 1983-84 to 12362.72 million tonnes in 1991-92.

Andhra Pradesh (Table 3):

In 1988-89 there was a sharp downward revision in reserves estimates. Yet, the stock of non-coking coal increased overall from 1745 in 1983-84 to 2174 in 1991-92. The reserves to production ratio fell from 153 in 1983-84 to 108 in 1991-92.

Maharashtra (Table 4):

The stock of non-coking coal in this state increased almost two-fold from 1073 in 1983-84 to 2068 million tonnes in 1991-92. The production of coal in this state more than doubled from 8 million tonnes in 1983-84 to 19 million tonnes in 1991-92.

Bihar (Table 5):

The stock of coking coal decreased in Bihar from 6510 million tonnes in 1983-84 to 5763 million tonnes in 1991-92. The value of depletion increased from Rs 16525 million in 1983-84 to Rs 45017 million in 1991-92. Interestingly the value of depletion of coking coal is far higher than the value of depletion of non-coking coal in this state.

Orissa (Table 6):

The depletion of the coal stock in Orissa is very small relative to the size of the coal reserves, with the result that the reserves to production ratio was as high as 1181 years in 1991-92 though it is bound to fall sharply as production expands.

West Bengal (Table 7):

The experience of this state is quite different from the others in that the stocks of coking coal saw a three-fold decrease from 344 million tonnes in 1983-84 to 111 million tonnes in 1991-92. Even the stocks of non-coking coal decreased substantially, due to downward revisions in the estimates of coal reserves.

North East (Table 8):

In the states of the north-east, the reserves of coal declined from 134 mt in 1983-84 to 123 mt in 1991-92. The rate of extraction was steady at about 1 mt of coal per year. The value of the depletion of coal due to extraction decreased from Rs 339 million to Rs 17 million in 1987-88 and then rose to 282 million tonnes in 1991-92.

Table 1. All India

	Units	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92
PHYSICAL										
Opening stock	*mt*	46776	48912	51033	53248	55794	58230	59532	62301	63485
Additions	*mt*	2270	2268	2375	2707	2614	1496	2969	1392	2181
Depletion	*mt*	133	147	160	162	177	194	201	209	230
Change in stock	*mt*	2136	2121	2216	2545	2437	1302	2769	1183	1951
Closing stock	*mt*	48912	51033	53248	55794	58230	59532	62301	63485	65436
R/P ratio	*year*	367	348	334	345	328	308	310	304	284
MONETARY										
Depletion value	*Rs m*	65782	78184	72990	51599	41112	61522	76525	112634	162458

Table 2. Madhya Pradesh

	Unit	1983-84		1984-85		1985-86		1986-87	
Type of coal		*CC*	*NCC*	*CC*	*NCC*	*CC*	*NCC*	*CC*	*NCC*
PHYSICAL									
Opening stock	*mt*	112.91	9319.38	118.57	9134.73	128.65	8904.40	160.35	8786.01
Additions	*mt*	9.01	-149.52	11.77	-186.31	32.11	-68.51	80.76	450.45
Depletion	*mt*	3.35	35.13	1.69	44.02	0.41	49.88	0.41	48.65
Change in stock	*mt*	5.66	-184.64	10.07	-230.33	31.71	-118.39	80.34	401.80
Closing stock	*mt*	118.57	9134.73	128.65	8904.40	160.35	8786.01	240.70	9187.81
R/P ratio	*years*	35.41	260.05	76.00	202.27	394.36	176.14	580.60	188.86
MONETARY									
cif price	*Rs/t*	690.00	668.00	741.00	713.00	774.00	633.00	709.00	489.00
Cost of production	*Rs/t*	141.81	141.81	144.59	144.59	147.51	147.51	154.95	154.95
Economic rent	*Rs/t*	548.19	526.19	596.41	568.41	626.49	485.49	554.05	334.05
Depletion value	*Rs m*	1835.59	18483.58	1009.60	25023.23	254.74	24216.01	229.69	16250.75

	Unit	1987-88		1988-89		1989-90		1990-91		1991-92	
Type of coal		*CC*	*NCC*	*CC*	*NCC*	*CC*	*NCC*	*CC*	*NCC*	*CC*	*NCC*
PHYSICAL											
Opening stock	*mt*	240.70	9187.81	316.17	9728.67	374.27	10858.41	419.65	11975.69	452.04	12362.72
Additions	*mt*	75.93	592.45	58.55	1188.91	45.81	1185.03	32.89	462.17	17.60	1184.37
Depletion	*mt*	0.45	51.59	0.45	59.17	0.43	67.75	0.50	75.14	0.52	81.75
Change in stock	*mt*	75.47	540.86	58.10	1129.74	45.38	1117.28	32.39	387.03	17.08	1102.62
Closing stock	*mt*	316.17	9728.67	374.27	10858.41	419.65	11975.69	452.04	12362.72	469.12	13465.34
R/P ratio	*years*	696.93	188.56	838.10	183.51	979.62	176.78	902.17	164.53	894.16	164.72
MONETARY											
cif price	*Rs/t*	619.00	422.00	754.00	527.00	908.00	593.00	1004.00	765.00	1363.00	920.00
Cost of production	*Rs/t*	179.95	179.95	198.30	198.30	215.20	215.20	212.78	212.78	211.87	211.87
Economic rent	*Rs/t*	439.05	242.05	555.70	328.70	692.80	377.80	791.22	552.22	1151.13	708.13
Depletion value	*Rs m*	199.18	12488.34	248.16	19449.60	296.78	25594.13	396.45	41494.83	603.94	57887.22

Table 3. Andhra Pradesh

	Unit	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92
Type of coal		NCC	NCC	NCC	NCC	NCC	NCC	NCC	NCC	NCC
PHYSICAL										
Opening stock	*mt*	1745	1753	1879	2105	2109	2352	2016	2153	2174
Additions	*mt*	20	138	241	19	260	-317	154	39	10
Depletion	*mt*	11	12	15	16	16	19	18	18	20
Change in stock	*mt*	8	126	226	4	244	-336	136	21	-10
Closing stock	*mt*	1753	1879	2105	2109	2352	2016	2153	2174	2164
R/P ratio	*year*	153	159	140	134	143	108	121	123	108
MONETARY										
cif price	*Rs/t*	668	713	633	489	422	527	593	765	920
Cost of prod	*Rs/t*	143	146	189	194	208	235	257	258	317
Economic rent	*Rs/t*	525	567	444	295	214	292	336	507	603
Depletion value	*Rs m*	6012	6711	6661	4631	3518	5428	5984	8985	12048

Table 4. Maharashtra

	Unit	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92
Type of coal		*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*
PHYSICAL										
Opening stock	*mt*	1073	1107	1345	1753	1742	1746	1803	1893	2068
Additions	*mt*	42	249	420	-0	19	72	105	191	26
Depletion	*mt*	8	10	12	12	14	15	16	17	19
Change in stock	*mt*	34	238	408	-12	5	57	90	175	7
Closing stock	*mt*	1107	1345	1753	1742	1746	1803	1893	2068	2074
R/P ratio	*year*	141	130	150	147	123	122	120	124	110
MONETARY										
cif price	*Rs/t*	668	713	633	489	422	527	593	765	920
Cost of productio	*Rs/t*	143	146	189	194	208	235	257	258	317
Economic rent	*Rs/t*	525	567	444	295	214	292	336	507	603
Depletion value	*Rs m*	4115	5878	5194	3488	3037	4315	5296	8442	11339

Table 5. Bihar

	Unit	1983-84		1984-85		1985-86		1986-87	
Type of coal		CC	NCC	CC	NCC	CC	NCC	CC	NCC
PHYSICAL									
Opening stock	mt	6510	8828	6427	9337	6077	10334	5553	11722
Additions	mt	-50	523	-316	1013	-489	1403	195	369
Depletion	mt	33	15	34	16	35	15	35	15
Change in stock	mt	-83	508	-350	997	-524	1388	160	354
Closing stock	mt	6427	9337	6077	10334	5553	11722	5713	12076
R/P ratio	years	194	631	181	654	160	771	163	781
MONETARY									
cif price	Rs/t	690	668	741	713	774	633	709	489
cost of production	Rs/t	191	191	203	203	234	234	243	243
Economic rent	Rs/t	499	477	538	510	540	399	466	246
Depletion value	Rs m	16525	7048	18102	8068	18778	6064	16370	3800

	Unit	1987-88		1988-89		1989-90		1990-91		1991-92	
Type of coal		CC	NCC	CC	NCC	CC	NCC	CC	NCC	CC	NCC
PHYSICAL											
Opening stock	mt	5713	12076	5782	12314	5654	12330	5736	12677	5763	13102
Additions	mt	106	261	-87	33	122	367	66	442	-2	284
Depletion	mt	37	23	40	18	40	20	40	17	45	17
Change in stock	mt	69	238	-127	16	82	347	26	425	-46	267
Closing stock	mt	5782	12314	5654	12330	5736	12677	5763	13102	5716	13369
R/P ratio	years	155	545	142	703	144	633	144	759	128	775
MONETARY											
cif price	Rs/t	619	422	754	527	908	593	1004	765	1363	920
cost of production	Rs/t	256	256	288	288	319	319	321	321	352	352
Economic rent	Rs/t	363	166	466	239	589	274	683	444	1011	568
Depletion value	Rs m	13530	3759	18590	4187	23386	5479	27363	7660	45017	9793

Table 6. Orissa

	Units	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92
Type of coal		*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*	*NCC*
PHYSICAL										
Opening stock	*mt*	13388	15321	17218	18969	20436	21742	22679	23654	23787
Additions	*mt*	1937	1903	1757	1473	1311	948	988	150	568
Depletion	*mt*	4	5	6	5	5	11	13	16	21
Change in stock	*mt*	1933	1897	1751	1468	1306	937	975	133	547
Closing stock	*mt*	15321	17218	18969	20436	21742	22679	23654	23787	24334
R/P ratio	*year*	3935	3163	3179	4118	4337	2076	1785	1463	1181
MONETARY										
cif price	*Rs/t*	668	713	633	489	422	527	593	765	920
Cost of production	*Rs/t*	143	146	156	166	201	231	252	253	203
Economic rent	*Rs/t*	525	567	477	323	221	296	341	512	717
Depletion value	*Rs m*	2045	3085	2845	1601	1109	3238	4521	8333	14776

Table 7. West Bengal

	Unit	1983-84		1984-85		1985-86		1986-87	
Type of coal		CC	NCC	CC	NCC	CC	NCC	CC	NCC
PHYSICAL									
Opening stock	mt	344	5322	341	5242	320	4714	280	3831
Additions	mt	-1	-59	-20	-507	-38	-859	-5	105
Depletion	mt	2	21	2	21	2	24	2	27
Change in stock	mt	-3	-79	-21	-528	-39	-883	-6	78
Closing stock	mt	341	5242	320	4714	280	3831	274	3909
R/P ratio	years	159	251	181	222	180	158	175	144
MONETARY									
cif price	Rs/t	690	668	741	713	774	633	709	489
Cost of productio	Rs/t	263	263	281	281	303	303	321	321
Economic rent	Rs/t	427	405	460	432	471	330	388	168
Depletion value	Rs m	918	8462	811	9185	734	8011	607	4547

	Unit	1987-88		1988-89		1989-90		1990-91		1991-92	
Type of coal		CC	NCC	CC	NCC	CC	NCC	CC	NCC	CC	NCC
PHYSICAL ACCOUNTS											
Opening stock	mt	274	3909	230	3874	121	3575	136	3534	111	3543
Additions	mt	-42	-8	-107	-269	17	-18	-24	33	10	56
Depletion	mt	2	27	2	29	2	24	2	23	1	25
Change in stock	mt	-44	-35	-109	-299	15	-41	-25	10	9	32
Closing stock	mt	230	3874	121	3575	136	3534	111	3543	120	3575
R/P ratio	years	107	144	65	121	76	150	68	155	115	145
MONETARY ACCOUNTS											
cif price	Rs/t	619	422	754	527	908	593	1004	765	1363	920
Cost of productio	Rs/t	318	318	348	348	381	381	381	381	522	522
Economic rent	Rs/t	301	104	406	179	527	212	623	384	841	398
Depletion value	Rs m	650	2803	763	5273	945	4981	1018	8803	880	9832

Table 8. States of the North East

Type of coal	Unit	1983-84 NCC	1984-85 NCC	1985-86 NCC	1986-87 NCC	1987-88 NCC	1988-89 NCC	1989-90 NCC	1990-91 NCC	1991-92 NCC
PHYSICAL										
Opening stock	*mt*	134	131	113	89	107	145	121	123	123
Additions	*mt*	-2	-17	-24	20	39	-23	3	-1	26
Depletion	*mt*	1	1	1	1	1	1	1	1	1
Change in stock	*mt*	-3	-18	-25	19	38	-24	2	-1	25
Closing stock	*mt*	131	113	89	107	145	121	123	123	148
R/P ratio	*year*	162	138	105	118	142	143	162	200	172
MONETARY										
cif price	*Rs/t*	668	713	633	489	422	527	593	765	920
Cost of prod	*Rs/t*	248	334	360	407	405	492	537	539	593
Economic rent	*Rs/t*	420	379	273	82	17	35	56	226	327
Depletion value	*Rs m*	339	312	231	75	17	30	42	139	282

Adjustment of GDP

Finally, GDP was adjusted by the value of coal depreciation to obtain a GDP which takes into account the running down of the stock of natural capital which coal represents (Table 9). In 1991-92, the value of the depreciation of coal is Rs 162 billion, which is 2.94% of the conventional GDP.

Table 9. GDP at factor cost, depletion allowance for coal, and GDP adjusted for coal depreciation

(1991-92 prices, in Rs. billion)

	GDP	Coal depreciation	Adjusted GDP
1983-84	3741	132	3609
1984-85	3885	146	3739
1985-86	4043	126	3917
1986-87	4216	84	4132
1987-88	4398	61	4337
1988-89	4867	85	4782
1989-90	5202	97	5105
1990-91	5455	129	5326
1991-92	5516	162	5353

Future Work

In future natural resource accounting for coal could:

- Refine valuation methodologies. We have chosen the relatively simple methodology employed by Repetto et.al. There is a need to employ methodologies which have gained acceptance. In the context of this paper, one question which needs to be considered is: should the resource extraction be valued or the change in stocks of reserves?
- In a more detailed exercise at the state level, adjust State Domestic Product (SDP).
- Internalize the depletion value in the resource commodity price.
- Build up wealth accounts. Expanded wealth accounts would yield useful information on the relative importance of reproducible wealth and natural wealth for a country, and provide an important enhancement of the balance sheet accounts for the resource sectors.
- Include the environmental costs of coal mining in the valuation of coal depreciation when adjusting national income.

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5. *Evaluating India's forest resources*

Shubhra Bhatia and Rajnish Goswami

Background

Many economic activities require man-made inputs as well as natural resources. As long as the latter are available in plenty, they are considered free and are often exploited recklessly. Though many natural resources regenerate themselves, both the quality and the quantity decline when extraction as a consequence of human intervention exceeds the regeneration capacity of the natural environment. In fact, the so-called renewable resource e.g. forests, cease to be renewable when they are depleted faster than they can regenerate. A depleted resource means less output for the same level of inputs and hence higher cost of production. Often if degradation goes beyond a limit natural replenishment may not take place at all. Positive amelioration measures would then be needed at an additional cost. Thus degradation in the context of natural resources implies that the present generation is borrowing from future generations. It then becomes imperative to know how much of each resource we have used up and how much we leave behind. If we are to avert ecological bankruptcy we must ensure that use of natural resources is properly accounted for.

Even though accounting of natural resources does not take place in the process of economic activities, the effects of environmental resource depletion cannot be outside the profit and loss account of the society. The simple reason for non-accounting of natural resource depletion is that the costs of environmental degradation and resource depletion are not generally borne by the economic actors who cause them. It is, therefore, important for any nation to keep track of its resource base and the state of its natural environment.

India's depleting forest resources

According to the Forest Survey of India, nearly 6,39,182 square kilometres, comprising 19 per cent of the country's geographical area are under forest cover. Of the total forest cover only 60 per cent are dense forests with crown density of 40 per cent and above. Recorded forest area in the country covers 7,70,078 square kilometres. This area is divided under various legal classifications into reserve forests (54 per cent), protected forests (30 per cent) and others (16 per cent). The state has complete and exclusive rights to trees in reserve forests, people have rights of collecting fuelwood and other subsistence items in protected forests, whereas most of the other or unclassed forests comprise village or community forests with various forms of group or community access.

The composition of forests in the country is determined by a wide variety of factors, namely

- climatic factors including rainfall, temperature, relative humidity of the atmosphere
- species characteristics including rate of height growth, ability to endure shade, resistance to fire, general adaptability and life span
- grazing practices of the region
- practices of the local peoples particularly those related to lopping for fuel and fodder.

India's vegetation may be classified on the basis of physiognomy and structure into the following forest types :

- **tropical forests** (including wet evergreen, semi-evergreen, moist deciduous, littoral and swamp, dry deciduous,dry evergreen and thorn forests)
- **montane sub-tropical forests** (including sub-tropical broad-leaved hill forests, sub-tropical pine and sub-tropical dry evergreen forests)
- **montane temperate forests** (montane wet evergreen, himalayan moist temperate and himalayan dry temperate forests)
- **sub-alpine forests**
- **alpine scrub** (including moist alpine and dry alpine scrub)

The National Forest Policy (1952) laid down by the Ministry of Food and Agriculture apart from other features emphasised the fact that atleast one-third of the country's geographical area should be under forests for long term sustainability of forestry and agricultural production in the country. This fact was reiterated in the 1988 revised National Forest Policy by the Ministry of Environment and Forests.

Despite efforts to enhance the development of forest resources in the country, over-exploitation of forests, excessive pressure of grazing on forest lands, and diversion of forest lands for non-forestry purposes like agriculture and construction of dams have depleted India's forest wealth substantially in the past few decades. This is evident from the fact that whereas at the time of independence 33 per cent of the country's land was under forest cover, today only 19 per cent has any forest cover left, of which most are degraded forests or scrub lands.

The need for forest resource accounting

Valuation of forest resources is essential to the appraisal of projects affecting forests and to the development of forest and non-forest policies. Undervaluation of forests, their outputs and their services can bias policy decisions relating to resource allocation, can result in underestimation of the contribution of forests to economic growth and can result in untimely liquidation of forest capital. Many forest products and services are important to the livelihood of the rural poor, a group whose welfare is a major focus of public policy particularly in developing countries like India. Thus valuation of India's forest resources forms an essential ingredient in effective policy formulation.

The value accounts for a forest would pertain to all the products and services that it provides. By defining the forests as a capital asset, its depreciation can be stated as loss or decrease in its income-generating capacity. The depreciation of forest resources in terms of timber or any other tangible forest product can be expressed either in physical terms such as surface area or volume, or in economic terms.

Problems related to forest accounting

One of the most important problems faced while attempting to evaluate forest resources arises from the fact that most of the services that forests provide are intangible and not easily quantifiable. Moreover, forest products, particularly in the form of environmental services like carbon sequestering and watershed protection, are likely to be required by future generations too. Hence demand for forests would emanate from present as well as future generations. Besides, the value of forests are perceived differently at the levels of individual, community and society. In forests, as in the case of many natural resources, there is a marked divergence between private and social costs. One aspect peculiar to forest resources is that they acquire some value on account of the fact that they occupy land which is itself a scarce resource. In fact, a significant portion of deforestation, as in the case of clearing for agricultural or housing purposes, is traceable to this characteristic of forests.

A methodology for evaluating depreciation of forest resources

The basic accounting units for measuring the natural resources of a region are proposed to be split at two levels - a) Framework for measuring the physical units of the given resource and associated changes and the resulting outline is called **Physical Accounts**; b) Framework for monetary valuation of stocks and flows that are marketed or contribute directly to market production called **Economic Accounts**. Physical accounts are infact a necessary prerequisite to economic accounts.

a) *Physical accounts* — Natural resource physical stocks and any changes in these stocks during an accounting period can be reorded in physical units appropriate to the particular resource. The basic accounting identity is that opening stocks plus all growth, increase or addition less all extraction, destruction, or diminution equals closing stocks.

b) *Economic accounts* — The value of forest resources can be broadly classified into two categories : direct value (resulting from products consumed directly — fuelwood, timber and MFPs), and indirect value (related to ecosystem functions, aesthetic value and cultural value). And the value accounts for a forest would pertain to all the products and services that it provides.

In view of the facts that the forests in India are diverse over regions and there is paucity of reliable data at the national level, the accounting work was confined to data collected for the states of Uttar Pradesh, Haryana, Karnataka and West Bengal.

Physical forest resource accounts

The accounting framework for forest resources has been expressed in tons/cubic metres of wood available (both timber and firewood). Additions to the forest stock have been taken to have originated from growth and regeneration of the initial stock, reforestation and afforestation. Reductions have been classified into production (harvesting), natural degradation (fires etc.), and deforestation.

In physical terms the depreciation of a forest resource expressed in the form of timber output is equal to the net increase/decrease in the total volume of timber from the national inventory for the year under consideration. In this sense, the appreciation/depreciation of a forest resource is equal to the final volume of timber in a given period less the volume at the beginning of the period. The final volume includes additions due to natural regeneration, growth of the standing stock, afforestation and reforestation activities on the area under consideration, minus decreases due to harvesting of timber, deforestation, logging damage and fire damage.

In the Indian context, fuelwood is another major product from the forests which indirectly contributes significantly to the Indian economy. Hence, the methodology would be applied to both timber and fuelwood. However, a large portion of the fuelwood consumed in the country comes from illicit gathering/felling. Some estimates state that the unofficial supply amounts to something like 80-90% of the actual consumption. However, for the purpose of our calculation, we have included only the official estimates.

The enclosed tables give an account of change in the physical forest accounts for the the states of West Bengal, Uttar Pradesh and Haryana. These accounts are based on the following assumptions:

1. Potential growth had been estimated for the years 1981-82 for Uttar Pradesh, 1989-90 for Haryana and 1982-83 for Karnataka. No estimates are available for any other

year. These figures have been used for estimating the annual increase in volume of both timber and fuelwood for the years under consideration.

2. For the state of West Bengal, the growing stock has been estimated for the year 1985-86 on the basis of Landsat imagery and forest types in the state.

3. When there is a forest fire, only the young regenerated crop gets damaged. In case of the standing tree crop only the bark and foliage gets damaged (when the fire is mild), which recovers after a brief period. In fact, in some areas a mild fire has been seen to promote regeneration. But such regeneration (promoted by fires) is relatively negligible in India. Hence, for a year when there has been fire only the regeneration volume contributed by the young crop has been deducted from the annual volume budget.

4. In case of diversion of forest areas for dam constructions etc. the entire standing volume gets lost for the year under consideration. Hence the entire standing volume of the year under consideration is deducted from the annual volume budget.

Table 5.1. Forestry Accounts for West Bengal

Physical Units (million cubic metres)

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Opening Stock	30.250	29.683	29.244	28.756	28.550	28.407	28.476	28.643	28.785
Additions									
Annual Increment	0.605	0.594	0.585	0.575	0.571	0.568	0.570	0.573	0.576
Reductions									
Timber	0.303	0.294	0.243	0.234	0.211	0.140	0.144	0.153	0.073
Fuelwood	0.793	0.643	0.779	0.492	0.454	0.305	0.258	0.277	0.286
Deforestation	0.001	0.027	0.001	0.001	0.000	0.014	0.001	0.001	0.003
Net Reductions	1.097	0.964	1.023	0.727	0.665	0.459	0.403	0.431	0.362
Net Change	-0.492	-0.371	-0.438	-0.151	-0.094	0.109	0.167	0.142	0.213
CLOSING STOCK	29.758	29.312	28.807	28.605	28.456	28.517	28.643	28.785	28.998

Table 5.2. Forestry Accounts for Uttar Pradesh

Physical Units (million cubic metres)

	1981	1982	1983	1984	1985	1986	1987
Opening Stock	105.335	103.885	102.849	101.926	101.773	101.644	101.500
Additions							
Annual Increment	1.256	1.236	1.224	1.213	1.211	1.210	1.208
Reductions							
Timber	0.947	0.692	0.663	0.671	0.704	0.686	0.683
Fuelwood	1.750	1.571	1.471	0.638	0.629	0.619	0.611
Deforestation	0.004	0.006	0.007	0.008	0.002	0.047	0.015
Fire damage	0.005	0.004	0.005	0.049	0.005	0.001	0.005
Net Reductions	2.706	2.272	2.147	1.366	1.340	1.353	1.314
Net Change	-1.450	-1.036	-0.923	-0.153	-0.129	-0.143	-0.107
Closing Stock	103.885	102.849	101.926	101.773	101.644	101.500	101.394

Table 5.3. Forestry Accounts for Haryana

Physical Units (million cubic metres)

	1988	1989	1990	1991
Opening Stock	4.819	4.724	4.607	4.503
Additions				
Annual Increment	0.090	0.090	0.090	0.090
Reductions				
Timber	0.071	0.054	0.0612	0.059
Fuelwood	0.115	0.152	0.1331	0.145
	0.185	0.206	0.194	0.204
Net Change	-0.095	-0.116	-0.104	-0.114
Closing Stock	4.724	4.607	4.503	4.389

Economic forest accounts

The concept of economic rent is central to natural resource valuation. Economic rent is defined as the return to any production input, its market price (MP) over and above the minimum amount required to retain it in present use or cost of production (CP)

ER = MP - CP

Economic rent constitutes the difference between the international commodity price and all factor costs of extraction, including a normal return to capital but excluding taxes, royalties and other costs that are not part of the cost of physical extraction.

In accounting for forest resources, it is important to determine the net value-added from the resource. The return to this factor of production is economic rent. It is also important to distinguish the value added from the resource from that value added associated with the physical (man-made) capital used to extract the resource. The value added from the resource is defined as the net revenue from the resource less all factor payments including a normal return to capital. That is, the value of the natural resource stock is the discounted present value of the net revenue.

Economic rents from natural resources consist of Hotelling rents (scarcity or exhaustability) and Ricardian rents (differential or varying quality) as well as locational rents (arising from transportation costs) and rents arising from unexpected price variations. While much of the literature on monetary valuation of natural resource stocks has focused on aggregate economic rent or Hotelling rents, there is little discussion on how to treat these different rents in the context of developing natural resource accounts. In most models, it is assumed that stocks are homogeneous and that there are no differential or Ricardian rents

Most of the literature suggests that it is the Hotelling or scarcity rent that should be used to measure depletion of the resource.

Net price method

Repetto used the net price method to value natural resources in Indonesia. In this method the change in the stock of the resource is multiplied by the current unit net price to arrive at a monetary value of the depletion of the resource. The unit net price is equal to the market price less the cost of discovery, extraction and marketing. The use of this method requires current data on costs and prices. Although competitive equilibrium conditions are rare, the convenience of this method may compensate for its theoretical inadequacies. The net price method provides a relatively simple alternative to use when the information needed to calculate the present value and transaction values of resource stocks is not available.

The relevant measure of economic value to be applied to the changes in the physical resource base is the value of the standing forestry resources prior to any value added by processing. The economic rent of forestry resources corresponds to its "stumpage value," the market value of standing trees. With full knowledge of the resource and competitive bidding, this is the maximum amount potential concessionaires would pay for harvesting rights.

The stumpage values we have used have been taken from the State Forest Departments.

$SV = P_s - [(1 + i) * (C_m + C_t + C_h)]$

where

SV is stumpage value,

P_s is the sale price,

i is the royalty,

C_m is the cost of marketing

C_t is the cost of transportation

C_h is the cost of harvesting

These vary widely from state to state

Table 5.4. Valuation of depletion of forestry resources

Uttar Pradesh

Year	Net change (million m3	Stumpage value (Rs/m^3)	Resource depletion (Rs million)	
			Current prices	1991-92 Stumpage value of Rs 717.03/m^3
1981-82	-1.45	235.14	-340.95	-1039.69
1982-83	-1.04	308.09	-319.18	-742.84
1983-84	-0.92	310.75	-286.82	-661.82
1984-85	-0.15	360.00	-55.08	-109.71
1985-86	-0.13	393.00	-50.70	-92.50
1986-87	-0.14	432.50	-61.85	-102.54
1987-88	-0.11	475.75	-50.91	-76.72

Table 5.4 shows the valuation of the depletion of forestry resources of Uttar Pradesh in current prices. The net change in stocks of forestry resources shows a decrease from 1.45 million cubic metres to 0.11 million cubic metres, with a sharp drop from 1983-84 to 1984-85. The stumpage value of the forestry resources increased from Rs 235.14/cubic metre to Rs 475.75/cubic metre, again fairly steadily. The overall resource depletion valued at current prices decreased throughout the period, but most sharply between 1983-84 and 1984-85. Valued at constant economic rent of 1991-92, the resource depletion is merely a magnification of the net change in forestry resources.

Table 5.5. Valuation of depletion of forestry resources: West Bengal

Year	Net change (million m^3)	Stumpage value (Rs/m^3)	Resource depletion (Rs million)	
			Current prices	1991-92 Stumpage value of Rs 2007.40/m^3
1981-82	-0.49	524.30	-257.96	-987.64
1982-83	-0.37	599.70	-221.89	-742.74
1983-84	-0.44	685.80	-301.75	-883.26
1984-85	-0.15	784.30	-117.65	-301.11
1985-86	-0.09	897.10	-80.74	-180.67
1986-87	0.12	1025.90	123.11	240.89
1987-88	0.17	1173.30	199.46	341.26
1988-89	0.15	1341.90	201.29	301.11
1989-90	0.22	1534.70	337.63	441.63

The valuation of the depletion of forestry resources in West Bengal is shown in Table 5.5. The net change is actually positive from 1986-87 onwards, and so this translates into additions to the gross domestic product. In other words, in natural resource accounting, the measure of national income is inflated with an increase in the stock of natural resources. This addition is a sizeable and significant Rs 337.63 million in 1989-90, valued at current prices. Valued at the stumpage price of 1991-92, this addition to national income due to a net increase in forestry resources is an even higher Rs 441.63 million.

Table 5.6. Valuation of depletion of forestry resources: Haryana

Year	Net change (million m^3)	Stumpage value (Rs/m^3)	Resource depletion (Rs million)	
			Current prices	1991-92 stumpage value of Rs 717.03/m^3
1981-82	-0.07	171.01	-11.97	-61.35
1982-83	-0.15	195.60	-29.34	-131.46
1983-84	-0.14	223.73	-31.32	-122.69
1984-85	-0.08	255.90	-20.47	-70.11
1985-86	-0.06	292.70	-17.56	-52.58
1986-87	-0.14	334.79	-46.87	-122.69
1987-88	-0.17	355.95	-60.51	-148.98
1988-89	-0.10	453.33	-45.33	-87.64
1989-90	-0.12	523.17	-62.78	-105.16
1990-91	-0.10	730.17	-73.02	-87.64
1991-92	-0.11	876.37	-96.40	-96.40

In Haryana, the net change does not show any clear trend, with increases and decreases interspersed (Table 5.6). The variation in the value of resource depletion is more due to the variation in the stumpage value, which increased eight-fold from 1981-82 to 1991-92.

Adjustment of GDP

Finally, GDP was adjusted downwards by the sum of the value of the depletion of forestry resources in Uttar Pradesh, West Bengal and Haryana, both GDP in current prices and GDP in constant prices. In 1981-82, GDP in current prices was adjusted downward from Rs 1432.16 billion to Rs 1431.55 billion and GDP in constant prices was adjusted downward from Rs 3354.11 billion to Rs 3352.07 billion. In 1987-88, the GDP in current prices was Rs 2948.51 billion and the "adjusted" GDP in current prices was Rs 2948.42 billion.

	GDP (Rs billion)		GDP adjusted for resource depletion	
	Current prices	1991-92 prices	Current prices	1991-92 prices
1981-82	1432.16	3354.11	1431.55	3352.07
1982-83	1593.95	3458.08	1593.38	3456.57
1983-84	1867.23	3740.84	1866.61	3739.26
1984-85	2085.77	3884.62	2085.58	3884.19
1985-86	2337.99	4042.99	2337.84	4042.70
1986-87	2600.30	4216.14	2600.29	4216.05
1987-88	2948.51	4398.21	2948.42	4398.01

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6. *Natural resource accounting: an overview of valuation methodologies*

Rajnish Goswami

The present system of national income accounting

National Income Accounts (NIAs) are a set of statistical statements reflecting the value of total final output produced in the various sectors of the economy. They provide details of the distribution of factor incomes among different groups or sectors and the final expenditure of the economy. NIAs provide a tool of analysis for understanding the functioning of an economy and provide various indices - GNP, GDP - that gauge the performance of the economy and the reflect the success/failure of a range of economic policies. These NIAs are structured on the basis of the United Nations System of National Accounts (UNSNA).

In spite of their universal application, NIAs, and in particular its aggregates such as the GDP, are widely believed to be a poor measure of the welfare of a nation. Any number of things could make a nation better off without raising its GNP as measured today - peace, equal opportunity, justice to all citizens etc. We may circumvent this issue by claiming that NIAs concern themselves only with economic welfare, as welfare is too subjective a criteria to measure. Still there remain several controversial issues concerning NIAs such as the treatment of leisure, household and subsistence production, expenditure on education, other non-market transactions and the services of long-lived consumer durables.

However over and above these economic aspects, a further glaring omission in the National Income Accounts is related to the treatment of "natural resources". According to the Hicksian definition true income is the maximum amount that can be consumed in a given period without reducing consumption in a future period. This definition of income encompasses the notion of sustainability. Sustainable development should aim at meeting the needs of today's population without compromising the ability of future generations to meet theirs. The depreciation concept reflects the fact that unless the capital stock is maintained and replaced, future consumption will decline. In much the same way if a nation is achieving high rates of growth by running down its natural assets, without concomitant accretion of capital stock, it is future living standards which will be affected in the long term.

There are two shortcomings because of which GDP as measured at present does not adequately represent sustainable income. These concern the treatment of :

i) environmental protection costs ;

ii) costs of degradation/depletion of natural resources.

As these two are not being correctly dealt with under the present UNSNA, the GDP figures do not reflect environmental and natural resource concerns in the manner they should. Anthropogenic activities that deplete or degrade natural resources are not recorded as consuming capital. A nation could run down its natural resources, cut down its forests, erode its soils, over exploit its fisheries, but measured income is not affected as these assets disappear. In fact, NIAs measure the income generated from the sales of these assets as value added, so what happens is that consumption of natural capital shows up as "income" in GDP accounts.

The need for natural resource accounting

Under the UNSNA, man-made assets and natural resources are treated differently. Man-made assets are valued as productive assets and their consumption is written off against their value of production as they depreciate. The loss of natural resources entails no adjustment in the national accounts against current income to reflect the decrease in potential future income. Instead net revenues from overexploiting forests, soils, fisheries are treated as factor incomes, not as capital consumption.

Behind this neglect of the valuation of the natural resources used up is a implicit, incorrect assumption that natural resources are unlimited in quantity or have zero marginal value.

In developing countries like India, natural resources- like forests, soil- are arguably among the most important economic assets. If managed in a way consistent with sustainable development, they can generate a stream of economic benefits. However the UNSNA not only ignores the importance of these assets but their destruction is treated as an increase in income instead of as a loss of wealth. Thus, while natural resources deteriorate rapidly in order to support the pressures of growing population and rapid industrialisation, this depletion is not reflected in the macro economic statistics.

By incorporating the cost of resource depletion we can show in the NIAs, the cost of running down valuable natural assets to achieve high rates of growth of income.

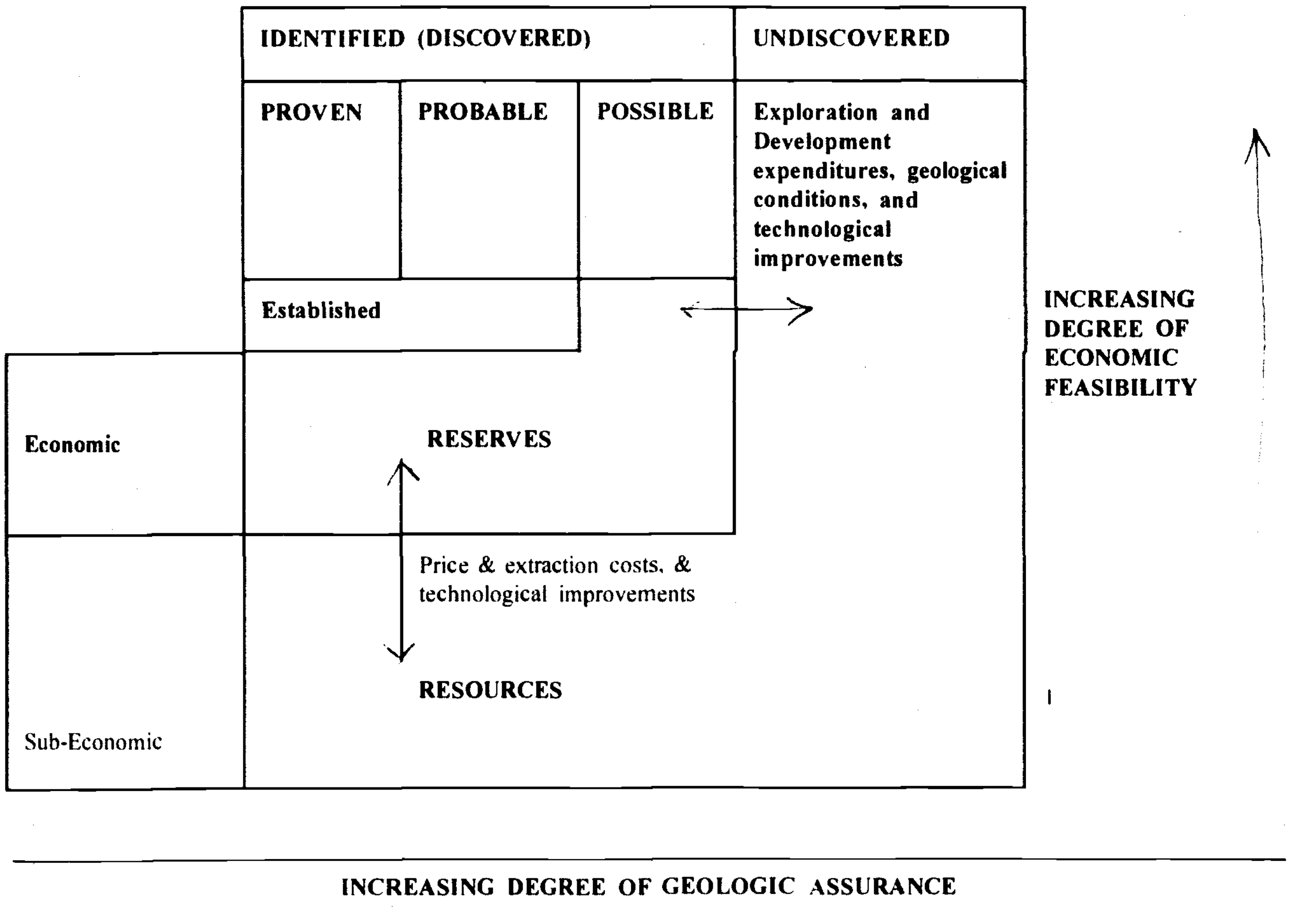
Purpose of natural resource accounting

- They provide an integrated information system for the entire resource flow from natural resource stocks through extraction and processing to end use/disposal.
- They measure resources in physical units and provide material and energy flows and balances.
- They connect physical accounts and measurements to economic valuations.

Natural resource accounting attempts to correct NIAs for the depletion of natural capital. It aims to provide an inventory of major natural resources of the country and their value at the beginning and end of the accounting period. For this we need (i) a definition of natural resources and (ii) a valuation methodology.

Valuation is necessary as physical accounts are prepared in different units. For aggregation and comparisons, these need to be valued in monetary terms.

Definition of mineral resources



The McKelvey Box illustrates the classification of mineral reserves and resources. The vertical axis represents the degree of economic recovery and the horizontal axis measures the degree of geologic certainty of mineral reserves and resources The boundary between identified and undiscovered resources fluctuates as a result of investment in exploration and development, and differing geological conditions. The boundary between economic reserves and sub-economic resources is affected by the relationship between prices and extraction costs, and technological improvements. Identified resources are defined as discovered reserves in producing areas. Undiscovered resources are in non-producing areas or in non-productive strata in producing areas.

Valuation methodology

The precise methodology to be applied will differ across countries as data availability varies depending on the type of accounting practices followed. Methodology will also differ across sectors based on whether resources are renewable or non renewable, marketed or non-marketed. For each category again, the choice of evaluation procedure will be constrained by the availability of reliable data. As an example, the methodology used to depreciate fisheries will be different from that used to depreciate crude oil. The basic approach however is modelled on a set pattern. The first step is the construction of physical accounts of resource stocks and changes in them for each asset under consideration.

Depreciation of the resource: In physical terms, the depreciation of the natural resource is equal to the net decrease in its quantity from the national inventory. In this sense, the appreciation or depreciation of the natural resource equals the final quantity of the resource in a given period less the volume at the beginning of the period. This method satisfies the most basic accounting identity which is ;

Closing Stock = Opening Stock + Additions - Depletions/Extractions

Valuation principle

Natural resource valuation for marketable resources largely hinges on the concept of "economic rent". Economic rent is defined as the return to any production input over the minimum amount required to retain it in its present use. The two main approaches to deal with depletion of Natural resources are :

1. Depreciation approach.
2. User Cost approach.

These approaches are largely applicable to marketable Natural Resources, since markets reflect their value to the consumer.

The depreciation approach

Depreciation approach can be applied to the consumption of renewable and non-renewable natural resources. Since resources are measured in physical units, they have to be valued in monetary terms for making an adjustment to the GDP. Hence all the four methods under the depreciation approach value the depreciation of natural capital and subtract that from the Net Domestic Product (which is GDP net of capital depreciation) to achieve a NDP adjusted for the depletion of natural resources.

i) **The present value method** : This requires that future prices, operating costs, production levels, and interest rates be forecast over the life of the asset under consideration. Once this is done, the present value of the stream of net revenue is calculated. The UNSO has recommended the use of this method when market values for transaction are not available.

$$PV_0 = \sum_{t=0}^{T} \frac{N_t\ Q_t}{(1 + r)^t}$$

where N_tQ_t is the future income flow produced by the asset being valued;
Nt the future price;
Qt the quantity expected;
T the time the asset would last;
r the rate of discount.

The problem in this case is that extraction ceases when Nt equals the price of the resource, and we need to forecast when this happens. Otherwise, Nt may rise without limit and Qt fall exponentially.
A variation of this method was used by the World Resources Institute (WRI), for evaluating

the fisheries sector in Costa Rica.

ii) **The net price method** : This method can be used as an alternative when the information needed to calculate the present value and transaction values of resource stocks is not available. This method is based on the assumption that net price will rise at a rate equal to the rate of return on alternative investments. Landefeld and Hines stress that this method will be equal to the present value method if output prices behave in accordance with long run competitive market equilibrium. (See Appendix 1)

In this method, changes in the reserves are multiplied by the "net price" of the asset - the market price minus the cost of discovery, extraction, and marketing. This method requires only current data on prices and costs. Equilibrium in natural resource markets produces the result that depletion as measured by changes in the present value of the resource equals depletion as measured by the net price method. This assumption is derived from the theory of optimal depletion of exhaustible resources that private resource owners will tend to arbitrage returns from holding the stock into future period with returns from bringing it immediately to market, adjusting current and future supplies until the price changes equate those returns.

iii) **The land value method :** Under conditions of competitive markets, land prices should reflect the present value of the natural assets that they hold. Thus if we know the market values of transactions in resource stocks, we can provide a basis for valuing the resource.

iv) **The replacement cost method:** If the resource under consideration does not directly enter the market, (example environmental assets such as forests) data on current prices will not be available and hence application of the net price method is ruled out. In such cases, the replacement cost method may be used. This considers the cost incurred to replace productive assets which are damaged to be the estimate of minimum benefits of protecting the environment. The replacements costs are not based on the subjective valuation of an economic agent, but on actual cost to be incurred if damage has occurred.

The assumption implicit in this approach is that the magnitude of damage is measurable and that it is economically efficient to make the replacement . If undertaken, it reveals a willingness to pay for environmental improvement. This method measures the cost of restoring

the resources to its previous state and not the actual change in value terms.
Given that it is worthwhile to make the replacement, this method furnishes a lower bound for the value of the asset.
In the WRI Costa Rica case study, soils were valued in terms of replacement cost of fertilizers. This method is at best a good approximation - fertiliser loss, for example, is not really an adequate replacement for loss of soil quality due to erosion.

The user cost approach

El Serafy argues that adjusting NDP by natural capital depreciation entails an error in that the sales of natural assets should not be valued in GDP to begin with, as they do not wholly represent value added. He presents a method to estimate the true income from the proceeds of the natural resource sales by splitting total receipts into income and capital components. The price of a non renewable resource like oil should contain a user cost which represents the depletion of the resource.

Serafy divides the net receipts into a user cost and value added component.

$$X/R = 1 - 1/(1+r)^{(n+1)}$$

where R is the total receipts (less extraction costs);
X is the true income;
n is the reserve life in years;
r is the discount rate and;
R-X is the user cost.

This approach aims at modifying the GDP in that the user cost represents the depletion factor that should be set aside and allocated to capital investment. This investment would create a perpetual stream of income, both during the life of the resource as also after its exhaustion. The user cost is the present value of the net receipts from the resource calculated over the expected life time of the reserves. According to Serafy only the user cost portion of rent should be subtracted from GDP.

This method can handle changing levels of extraction, movements in the discount rate, and alterations in reserve estimates, like new discoveries which would change the reserves to extraction ratio. Total reserves are not valued in this method, only the fraction of the resource being liquidated in the current accounting period are valued at current prices. However this method is quite sensitive to changes in a arbitrarily chosen discount rate.

It also assumes constant user cost, and does not have a mechanism for incorporating changes in terms of trade or technological upgradation. Kirk Hamilton has pointed out that Serafian approach does not measure the depletion but hypothesizes about a constant stream of income from resources. Although Serafian method has been applied as an alternative in the WRI studies, it has primarily remained confined to the realms of text book discussions.

In case of non marketable resources the valuation methodologies which could be used are discussed below :

Surrogate markets techniques

In the absence of market prices to evaluate benefits and costs the choice of projects may be guided by implicit valuation of environmental factors. This is done by looking for an observable market price that reflects an unmarketed environmental impact. The valuation would then include the tangible cost of the product itself and a mark up/down due to the environmental factor.

Three approaches here are:

i) Hedonic price/property value approach where the value of a fixed asset such as land would reflect the utility stream consumers expect from it. Ceteris Paribus, land values in a polluted area will be less than those in an environmentally preferred area. The difference between the two would be an implicit price of their environmental characteristic which consumers are prepared to pay for.

ii) Travel Cost approach :In case the environment good being consumed is a recreational facility that visitors frequent, the transactions price they may be prepared to pay, may not be reflected by the entrance fee charged. The distance traversed to get to the service and the cost therein is a lower bound indication of the value of the recreational service to the visitor.

iii) Wage differential approach : This is based on the presumption that the market for labour is perfectly competitive and that there is free mobility of labour. This will result in wage rates being equalised to the marginal productivity of labour. In order to induce labour to locations with higher pollution risks, wage rates will have to be higher, as that will be the price at which the labour is prepared to expose itself to increased risk. The assumption here is that risk is correctly perceived.

Market creation techniques

In this technique individuals are asked directly about their willingness to pay for a change in environmental quality. Such techniques are known as contingent valuation methods. The problem in this technique is that there may be a bias in the response of individuals.

Dose-response relationships

In this approach, a link is established between, for example, a particular level of pollution and the rate at which the surface of a material decays. We can then value the decay by applying the market price. The thrust of this technique is to identify the link between the dose and the response.

APPENDIX 1

Economics of depletion

As some resources like coal, oil and gas are exhaustible, issues concerning their rates of depletion and the impact on output and prices have sparked off work related to what should constitute optimal use of exhaustible resources.

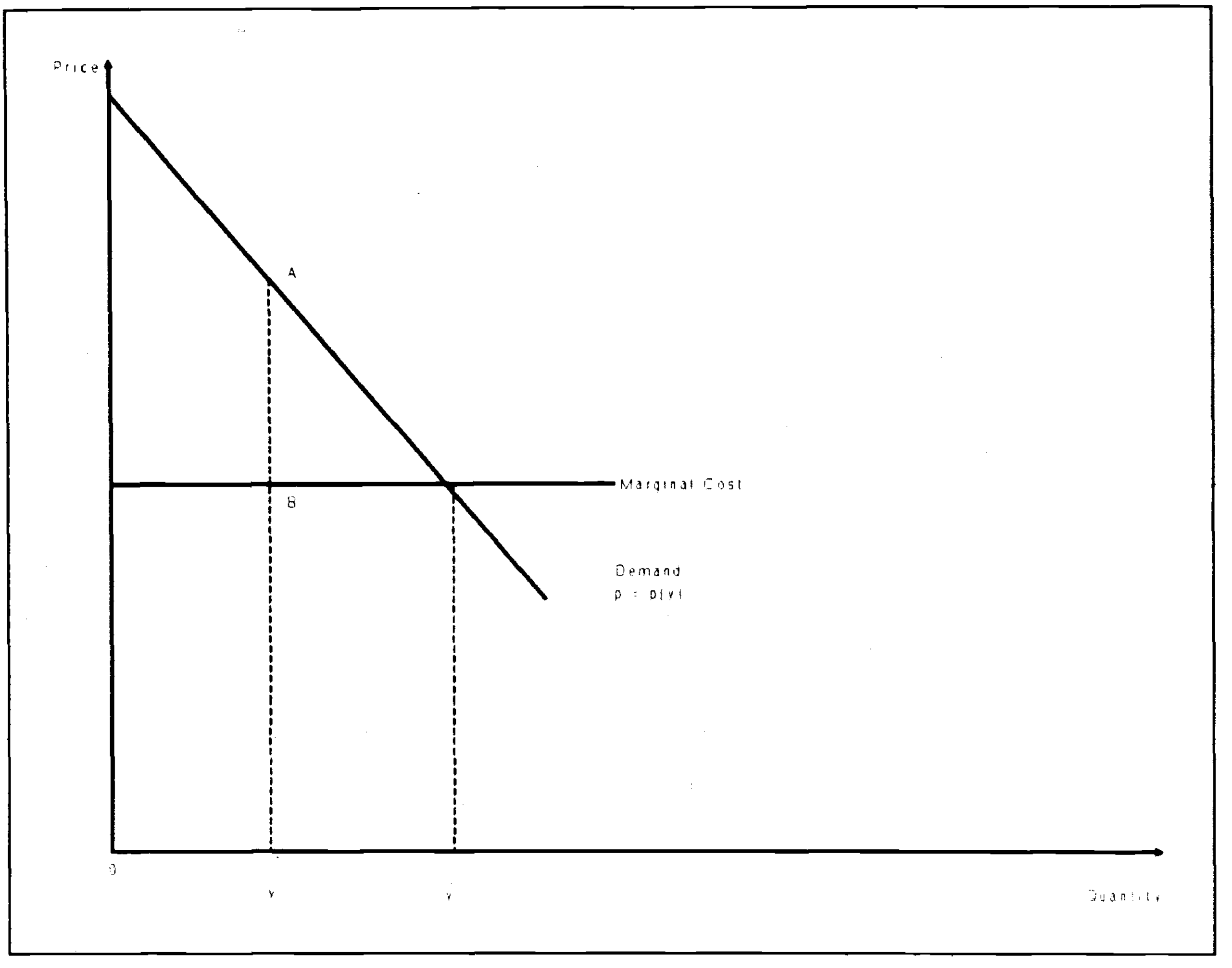
As we know extraction and consumption of a unit of a resource involves an opportunity cost, which has to be accounted for while allocating the resource over time. Thus we arrive at the first condition of optimal depletion ;

Price = Marginal Cost + Opportunity Cost

which ensures that only y* units will be extracted by a person seeking to allocate extraction efficiently over time.

The difference between the price and the marginal extraction cost is shown by AB, and is known as user cost or the opportunity cost to the user of taking a unit of the resource in the present time.

The second condition of optimal depletion is that the present value of royalty remains



the same in all periods or that royalty rises with the rate of interest.

Solow has expressed the intuition behind the theory of optimal depletion very nicely,in the following extract from his lecture "The Economics of Resources or the Resources of Economics".

> A pool of oil or vein of oil or deposit of copper in the ground is a capital asset to society and to its owner much like a printing press or a building or any other reproducible capital asset. The only difference is that the natural resource is not reproducible, so the volume of the existing stock can never increase through time.
>
> A resource deposit draws its market value, ultimately, from the prospect of extraction and sale. The only way that a resource deposit in the ground and left in the ground can produce a current return for its owner is by appreciating in value. Asset markets can be in equilibrium only when all assets in a given risk class earn the same rate of return, partly as current dividend and partly as capital gain. The

common rate of return is the interest rate for that risk class. Since resource deposits have the peculiar property that they yield no dividend so long as they stay in the ground, in equilibrium the value of a resource must be growing at a rate equal to the rate of interest. Since the value of a deposit is also the present value of future sales from it, after deduction of extraction, costs, resource owners must expect the net price of the ore to be increasing exponentially at a rate equal to the rate of interest. This is the fundamental principle of the economics of exhaustible resources.

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