ENVIRONMENT AND WELLBEING
ISSUES IN CONSTRUCTION OF STATE LEVEL INDICES

Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Philosophy in Applied Economics of the Jawaharlal Nehru University

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ENVIRONMENT AND WELLBEING

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I hereby affirm that the work for the dissertation ***Environment and Wellbeing – Issues in Construction of State Level Indices***, being submitted as part of the requirements of the M.Phil Programme in Applied Economics of the Jawaharlal Nehru University, was carried out entirely by myself and has not formed part of any other Programme and not submitted to any other institution / University for the award of any Degree or Programme of Study.

June 30, 2003

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Certified that this study is the bonafide work of Aparajita Bakshi, carried out under my supervision at the Centre for Development Studies.

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For

Mamoni

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CDS has been quite an enriching experience for me. It was my first venture beyond the protective walls of my home and family and it helped me mature as a person. In this sojourn, I have met many people who have enriched my life in many ways. I have also rediscovered old relationships in new ways. I would take this opportunity to extend my gratitude to all those who have contributed to my work and life and made me successful in my endeavor.

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Abstract of the Dissertation

Environment and Wellbeing – Issues in Construction of State Level Indices

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The environment has profound impact on the wellbeing of population. But the number of index numbers that have been developed since the Human Development Index to assess the different aspects of wellbeing and quality of life does not take into account the environmental factors. This thesis tries to focus on some aspects of the environment and its relationship with wellbeing of people. It tries to develop state level index numbers for the sixteen major Indian states to capture the environment-wellbeing linkages.

For a country like India with dualistic features, the problems related to the environment in rural and urban areas are generically different and thus the analysis is classified in two parts. In rural areas, the relation between environment and wellbeing works through the resource base and resource use path. Agricultural activities directly affect the environment through its impacts on soil quality and water resources. The degradation of the resource base on the other hand adversely affects the productivity and sustainability of the production system. These issues are highlighted in the first part of the analysis. State level indices are constructed to assess the state of the resource base and the long-term sustainability of agricultural production. To avoid problems of double counting, two sets of indices are constructed – outcome index and process index. The outcome index looks at the overall degradation related to land and water resources while the process index looks at sustainable production practices. It was found that the major producers of food, namely Punjab and Haryana, are the most degraded states and their sustainability position is also precarious. There is a very high correlation between high yield and production unsustainability. This brings to the foreground the question of an *optimal tradeoff*, that is, how much environmental degradation we can accept for the sake of increased production.

Urban environments suffer from ever increasing pollution levels and this has immediate impacts on the health of urban population. The second part of the analysis focuses on the problem of air pollution and its consequent health impacts. Again state level indices are constructed at two levels; the outcome index and process index. The outcome index measures the incidence of respiratory illness while the process index tries to concentrate on the ambient air quality and the pollutant levels. It was found that urbanization in itself is not the cause of growing air pollution in cities. It was the middle-urbanized states like Bihar, Punjab, Haryana with the highest incidence of respiratory diseases and also urban air pollution. This reveals an *Environment Kuznets Curve* kind of concave relationship between urbanization and pollution. The emerging urban agglomerations call for immediate attention for pollution control measures, much more than the metropolises.

Apart from inquiring into the environment wellbeing nexus and assessing the positions of the states to draw attention to the areas, which require immediate measures, a major thrust of the thesis is also related to the methodological issues in construction of index numbers which incorporates environmental parameters.

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Chapter 1

INTRODUCTION

1.1 The Background

The concept of human development has gained popularity in the recent years as an alternative to the income-based approaches to assessment of development or wellbeing. Human development is conceptualized as the process of enlarging people's choices. The most critical of these wide ranging choices are, to live a long and healthy life, to be educated and to have access to resources needed for a decent standard of living. Additional choices include political freedom, guaranteed human rights, and personal self-respect. Development enables people to have these choices. Human development thus concerns itself with various dimensions of capabilities and their realization.

The organic link between human development and environment, though sometimes acknowledged, is not reflected in the conventional indicators of human development. It is unanimously agreed that environment has far-reaching impact on overall development of the mankind. If we take the broader definition of human development, we see that the degrading environment and the depleting natural resources leave much less scope for the expansion of choices of the present generation as well as the generations to come. The negative health impact of the environmental problems certainly affects the capabilities of human beings. Thus it is very necessary to integrate environment with the overall assessment of wellbeing.

The role of environment has been ignored much in the mainstream development and growth economic literature. Meadows et.al (1972) developed a growth model and made dire predictions about the economy and survivability of mankind due to exhaustion of non-renewable resources and 'overshoot and collapse'. Their model did not take into account technological development, changing needs and availability of substitutes. Throughout the seventies the discussions on environment mainly contemplated a contradictory relationship between environmental concerns and economic growth. But in the eighties the emphasis was on a complementary relation between the two, that is, the process of development will gradually help to build a better environment.

The topic gained much attention with the World Commission on Environment and Development, more popularly known as the Brundtland Commission in 1987. The commission for the first time showed concern over the insensitiveness of the development process to the deteriorating environmental conditions accompanying it. The purpose of this commission was to promote policies, which are more environment-friendly and to forge out a growth path, which is compatible with the overall environment. In its much celebrated report 'Our Common Future' it explicitly stated that, "Our Common Future is not a prediction of ever increasing environmental decay, poverty, and hardship in an ever more polluted world among ever decreasing resources. We see instead the possibility for a new era of economic growth, one that must be based on policies that sustain and expand the environmental resource base." Thus a new concept of development came into being – sustainable development.

Sustainable development, according to the Brundtland Commission may be defined as '...development that meets the needs of the present without compromising the ability of future generation to meet their own needs.' To achieve such development, the commission emphasizes two aspects. The growth process has to face limitations imposed by the current state of technology and social organizations on environmental resources and by the ability of the environment to absorb the effects of human activities as well as the rate at which it can regenerate itself. Secondly, poverty is given much importance, as sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for a better life. A world where poverty perpetuates is vulnerable to ecological and other disasters.

On the whole, the commission aimed at acknowledging the two-way relationship between environment and development and tried to bring environment into the conceptual framework and policy framework of development economics.

The World Development Report, 1992 also concentrated on issues related to environment and development. However, it stressed the fact that highest environmental priorities are those that directly affects the welfare of a large number of people. Environmental hazards directly affect wellbeing in two ways – through health effects and effect on productivity. Environmental pollution causes death and morbidity and thus affects the quality of life. On the other hand, it may reduce productivity through its complex and widespread linkages, which directly affects income.

One of the main conclusions of the report is that the current environmental debate has paid very less attention to the problems of sanitation and clean air, urban air pollution, indoor air pollution, and severe land degradation. It draws attention to the high incidence of waterborne diseases in developing countries, which can be prevented through clean water and sanitation facilities. A large part of the urban population worldwide face the threat of respiratory disorders, cancer, risks of higher blood pressure, heart attack and hypertension, all caused by air pollution. The world's poorer citizens face health risks posed by smoke and fumes from indoor use of biomass fuel. Soil degradation, waterlogging and salinization, agricultural intensification – all these processes have adverse effects on productivity.

The report also stresses on the fact that the growing population is putting much pressure on already scarce resources. Population growth must be checked. Poorer sections of the population are more exposed to the negative environmental effects. Poverty should be dealt with effectively to safeguard the vulnerable population.

The interrelationship between poverty and environment is now well recognized. Dasgupta (1993) argues that poor countries are biomass based subsistence economies where the rural poor eke out a living from products directly obtained from plants and animals. Thus any kind of environmental problem affects the poor more than the non-poor.

The link between environment and poverty is complex. While agricultural production has a straightforward relationship with the population dependent on agriculture; the government policies, market signals, access to credit, insurance and capital markets and many such things affect the linkages between poverty and environment. It is necessary to understand these linkages while making policies. A good balance must be struck between resource need and carrying capacity, that is the amount that can be naturally sustained.

1.2 Accounting for the Environment

While we can widely accept the generic connection between development and the environment, the difficulty of mainstreaming the environment mainly lies in the problems of commensuration. How do we measure the environmental parameters? That is the main question faced by economists. The paths followed by economists have broadly taken two routes. While one route concentrates on making adequate allowances for environmental degradation into complex accounting schemes, the other route concerns itself with constructing environmental indicators.

Many countries have been developing concepts and methods of resource and environmental accounting. The adoption of Agenda 21 at the Earth Summit in 1992 strengthened such efforts. Agenda 21 called for the establishment of integrated environmental and economic accounts as a complement to UN System of National Accounts (SNA). Resource and environmental accounts are being developed in a variety of forms. It will be worthwhile at this stage to mention a few accounting frameworks that have been developed.

There are mainly four kinds of accounts. The first category is Natural Resource Accounts, which follows the principle of balance sheet accounts and focuses on the opening and closing stock of various natural resources, and the flows that add to and subtract from the balance sheet position. These accounts are in quantities or values and may or may not be linked to SNA. These types of accounts try to build up measures of physical scarcity (resources to production ratio), depletion and environmental degradation. Hence, these natural resource accounts along with their counterparts in the national balance sheet accounts can have wide use with regard to resource management policies.

Next, the Resource and Pollutant Flow Accounts embody considerable sectoral detail and are often directly linked to the input-output account of SNA. For each production and final demand sector in the input-output tables, these accounts associate a physical flow of natural resources, typically as resources such as energy to production processes, and a physical flow of wastes and emissions in the form of SO_2 (Sulphur dioxide), NO_X (Oxides of nitrogen), BOD (Biological Oxygen Demand), etc. These accounts are therefore de facto satellite accounts in physical quantities. Of all the accounts under consideration, resource and pollution flow accounts have links to the widest variety of policy issues.

Environmental Expenditure Accounts are measured in values and generally consist of detailed data on capital and operating expenditures by economic sectors for the protection and enhancement of the environment. It should be noted, however, that measuring environmental expenditures might have their own methodological problems. If some expenditure increases productivity and reduces pollution at the same time, defining environmental expenditure would pose enormous difficulty.

Finally, the alternative national account aggregates tries to design aggregates for national products and wealth. These are also known as Green Aggregates. The Green National Accounting aggregates try to overcome the deficiencies of the SNA by defining the assets more broadly. By including both marketed and non-marketed resources, the system of green accounts offers possibility of bringing the environment into the mainstream economic discourse. Green Accounting aggregates are the most integrative measures of resource depletion and environmental degradation. The weighting provided for different aspects of depletion and degradation is based on costs and benefits at the margin. But assessment of such costs and benefits still has some methodological problems.

The first step towards standardizing the multitude of accounting approaches is provided by the UN Integrated System of Environmental and Economic Accounting (SEEA). The SEEA is designed to be a satellite account to the SNA. It is an adjunct to the SNA, as it does not modify the core accounts. The SEEA is highly complex, involving disaggregation of the standard accounts to highlight environmental relationships, linked physical and monetary accounting, imputations of the environmental costs and extensions of the production boundaries of the SNA.

Since no uniform accounting scheme like the SNA has been developed yet which also accounts for the environmental parameters, it is easier to construct environmental quality indicators to facilitate comparisons across countries and also within a country. There have been a number of studies in many countries with the aim of environmental quality indices, or EQI as they are commonly referred to as. The attempt by the Netherlands Ministry of Housing, Physical Planning and Environment, to develop indicators, is by far the most sophisticated study undertaken at the national level. In the United States, the Green Index was designed by the Institute of Southern Studies (Hall and Kerr, 1991). It was an effort to assess environmental quality across states in the US. The GI collects information on as many as 256 indicators in 8 environmental sectors. All indicators for each state are taken in some ratio form, for example per capita or per acre, because of the disparity in geographical area and population across states. The GI ranks all 50 states by Borda method.

There have been many attempts to make international comparisons as well. The National Center for Economic Alternatives (NCFEA, 1995) has developed a composite index of environmental quality known as the Index of Environmental Trends (IET). The index is an aggregate of 21 environmental change indicators for six categories – air, water, chemicals, waste, land and energy; since the 1970s. The index is compiled for four periods: 1970-75, 1970-80, 1970-85, 1970-90. For each period, the percentage change for each indicator was calculated. The sign of the change is determined by the nature of the indicator. The aggregate index for each sector as well as the overall environmental quality is the simple unweighted average of all the indicators in each category. The NCFEA report presents indicators for 9 countries.

Since the Brundtland Commission and its emphasis on sustainable development, the inadequacy of traditional indicators such as GNP in measuring sustainable development has increasingly been felt. The World Bank in 1995 developed a new measure of a country's wealth. A nations wealth contains four ingredients; natural capital (soil, atmosphere, forest, water, wetland, minerals), man-made capital (houses, roads, factories, ships), human capital (people, their education, health and capacity) and social capital (institutions, cultural cohesion, collective information, knowledge). The total wealth of a nation at any point of time is the sum of all kinds of capital in a unified unit, i.e. dollars. As it is an index finally represented in terms of monetary value, it has to face all the valuation problems faced by the accounting framework.

In the context of Asia, the Asian Development Bank undertook an effort to develop environmental indices. Building EQIs for Asian countries had been especially difficult, given the poor quality of data that were obtainable in most of these countries. In spite of all the difficulties, quite a few indices could be developed, which were able to throw some light.

It developed 'Environmental Diamonds' for sixteen countries taking the idea from the World Bank's 'Development Diamonds'. In its publication on social indicators of development (WB, 1994), the World Bank defined a Development Diamond of a country constructed for four indicators: per capita GNP, life expectancy, gross primary enrolment and access to safe drinking water. By plotting the four values in four axes, the resulting diamond shape can be compared to the best or the average of that country grouping. This is an interesting graphical tool for cross-country comparisons without the need for any aggregation method. The indicators chosen for the environmental diamonds were: per capita energy consumption for air quality, population with access to safe drinking water to represent the water component, fertilizer use per hectare of arable land for land and forest cover as an indicator for the ecosystem. The reason why air quality indicator was chosen to be energy consumption per capita was, the statistical analysis indicated that total air emissions of a country including SO_2 and NO_X are closely related to its commercial energy consumption. This index was interesting in the simplicity of its presentation as well as bypassing effectively the problems related to aggregation. Though the indicators chosen for each component can be questioned, but it does indicate clearly for each country which area requires immediate priority in environmental policies.

To capture the direction and pace of changes in the environmental qualities, the ADB study also designed a measure of Environmental Elasticity. Environmental Elasticity is the percentage change in an environmental aggregate as a result of one-percent change in an economic aggregate. Or, $E_t = N_t / D_t$

Where E_t: Environmental elasticity

N_t: Percentage change in environmental index

D_t: Percentage change in economic index

While measures like environmental diamonds are static measures showing the state of the environment at any point of time (in a relative sense), environmental elasticity on the other hand is a dynamic measure, which focuses on the rate of environmental degradation. It has the merit of putting together economic components and environmental components and also reveals the nature of relationship between the two.

The study computed environment elasticity over the period between 1980 and 1990 for 16 countries. The economic indicator employed was the average annual change rate (AACR) of GDP. For the environment, the AACR of four indicators – commercial energy consumption, population with safe drinking water, fertilizer use per hectare of arable land and forest cover – were taken into consideration. The simple (unweighted) average gives the aggregate environmental AACR. It was seen that except Myanmar and Sri Lanka, all other Asian countries showed a negative environmental elasticity. That means in all countries growth has been achieved with some environmental degradation. However in all countries except Vietnam, environmental elasticity is less than one. In these countries the deterioration rates are lower than the growth rate of the economy. These countries may be classified as weakly sustainable. But Vietnam with elasticity greater than one is unsustainable.

There is a problem in classifying the few countries as 'weakly unsustainable' depending only on the percentage change and not taking into account the levels of degradation. Because of non-linearity, a small percentage change from a very high level of degradation may turn out to be unsustainable. It is thus very important to take the initial conditions into consideration.

However, all these index numbers that are computed and used in specific contexts are environmental quality indicators. They are not wellbeing indices. To transform environmental quality indicators into wellbeing indices, some ideas on the inter-linkage between the environmental indicators and their effects on wellbeing have to be developed. This relationship has to be captured in a functional form, if our aim is to form a wellbeing index. The environmental quality indicators are at best partial indices, as far as the focus of our study is concerned.

1.3 Integrating Environment and Human Development

While the problems of environmental accounting and building environmental quality indicators are debated at different levels, a more fundamental debate that has taken place is whether there is any need to integrate the environmental indicators with the wellbeing indicators at all? It can be argued that, since environmental quality is one of the major factors that have influences on wellbeing, the effects of poor environmental quality are implicit in the outcome based wellbeing indicators. So there is no need to integrate them with the human development indicators as this will only result in double counting. The opposite argument to this is that, human development indicators do not reflect environmental quality and so wellbeing is either overstated or understated if environmental indicators are not included.

Desai (1995) had compared the rankings of countries according to HDI with various Green rankings. According to Desai there should not be much difference between HDI rankings and some indices relating to environmental concerns. Income is heavily discounted in the HDI. This smoothes out the effects of current composition levels on wellbeing of future generations. He also lists the important linkages between human development and environmental degradation, particularly the impact on health and mortality. So, countries performing well on environmental dimensions will also perform well on the human development front.

However, while considering the environment human development linkages, it is important to recognize the fact that direct intervention or the lack of it may weaken this linkage considerably. Desai did not consider such aspects. For example, even if there is considerable air pollution, it may not get reflected in the health indicators in developed countries due to high levels of health status already achieved in those countries and high quality of health care facilities. An equal level of pollution will affect a poor country badly with a high proportion of the population living in 'marginal health conditions' and also very low quality health care facilities. Even with regard to the processes involved, a rich country can afford better preventive measures for pollution control, which a poor country cannot. Under such circumstances it will be difficult to establish a direct statistical relation between environmental and human development indicators unless we control for other intervening factors.

Desai ranks 141 countries according to three environmental indicators:

a) greenhouse gas emissions per capita,
b) water withdrawal as percentage of annual renewable water resources,
c) energy consumption and total requirement per US $ of GDP.

Data relates to late 1980s. Data reveals that some of the poor countries are among the best in environmental concerns, although no general pattern emerges. As we had indicated earlier, this is expected, as it is difficult to establish the statistical relationship. Some poor countries may be showing poor human development indicators just because they are poor. And they are poor because they do not use their resources optimally. And again, they cannot use their resources optimally because they are poor! There is a vicious circle operating here which does not really make them paradise in poverty.

Since it is often argued that environmental problems that rich industrial countries and poor countries face are qualitatively different and hence the same set of indicators cannot be used for both, Desai makes separate comparisons for rich and poor countries. For 22 industrial countries he uses indices of green house gas emissions, efficiency in energy use, air quality and bio-diversity. He notes a few rank reversals but again no general pattern emerges. For poorer countries he used five indicators – proportion of population with access to safe drinking water, annual rate of deforestation, change in fuel wood since 1979, green house gas emissions per capita and energy use per unit of output. He then builds an ordinal green index

(OGI) from these values and compares the ranks with HDI ranks. Out of the 85 countries, 13 countries had large rank differences, exceeding 60 places. In 8 of these countries OGI was higher than the HDI. Desai named these countries 'paradise in poverty'. However he concludes that there is a "broad coherence between environment and human development levels."

One should not come to such a conclusion without trying to look into the matter in a little more detail. The "broad coherence between environment and human development levels" may emerge from the very fact that high human development countries are in a position to afford the preventive measures that low human development countries cannot.

Qizilbash (2001) criticized Desai's methodology on several grounds. Firstly, it is more appropriate to use Borda ranking than ordinal ranking used by Desai. Secondly, there is a link between poverty and environment, so it is justified to compare poverty indicators with environmental ones rather than the HDI. Thirdly, he questions Desai's selection of indicators. He asserts that if an alternative set of indicators also supported Desai's conclusion that would give some insight about the robustness of his results.

Thus Qizilbash first designs a new set of indicators. For wellbeing he includes the UNDP suggested human development as well as poverty indicators. They are: people not expected to live beyond age 40, adult literacy rate, underweight children under the age 5, proportion of population with access to sanitation, combined enrolment ratio, and consumption (US $ PPP). The first four are poverty indicators while the six taken together measures overall wellbeing. For environmental concerns the indicators are: annual water withdrawals as percentage of renewable water resources, internal renewable water resources per capita, proportion of population with access to clean drinking water, percentage change in forest and woodland, carbon dioxide emissions per capita, commercial energy and traditional fuel consumption per unit of per capita GDP (US $).

First, Qizilbash compares the rankings in terms of poverty and overall wellbeing. The orderings are not identical but there is no large discrepancy. Next, he compares the Borda rankings of the environmental indicators and that of the poverty and wellbeing indicators. The comparison brings a striking result. Most countries doing well on the environmental front are doing badly in terms of improving wellbeing of the current generation. The rank order differences do follow a pattern. The differences (E-W, E-P) are large and negative at the top (high wellbeing, worst environment), become positive in the middle and large at the end (low wellbeing, clean environment). The rank correlation coefficient between environment and wellbeing ranks is –0.67. This result clearly questions Desai's conclusion.

Qizilbash argues that Desai obtained the results mainly because of the type of indicators he used. For example, he used per capita energy consumption and accessibility of clean water as indicators of environmental concerns when these indicators directly affect wellbeing. Use of such indicators narrow down the gap of ranks. One way of looking into such problems of recognizing the right indicators is to see the inter-relationships. Some environmental indicators may be functions of development itself. The relationships between the variables are also important.

This debate does not resolve the problem whether environmental quality indicators should be merged with human development indicators to get a more comprehensive picture of wellbeing. The problem takes a complicated form because environmental quality is believed to have a somewhat clear relationship with the level of development itself. This relationship is articulated in terms of the 'Environmental Kuznets Curve'. At the developing phase countries often make a trade-off between economic growth and environmental degradation to achieve higher standards of living using natural resources to attain this growth. If we believe a higher level of development will take care of everything then there is no need to be so concerned about the environment. But if we believe that some environmental damage is irreversible and there should be some limit to how much an economy can afford to grow at the expense of the environment, then a closer look at the environmental parameters is required.

Moreover, it is futile to debate this issue with indices constructed in an ad-hoc manner and trying to prove or disprove a statistical relationship. A more constructive approach would be to make our wellbeing indicators sensitive to environmental changes. Instead of attempting to construct a 'universal wellbeing index', which is supposed to capture everything under the sun, we should identify the areas that need some attention and try to build indices for those areas. A systematic study of the environment and wellbeing inter-linkages should be conducted to identify the areas where the linkages are strongest. The purpose of the index should be to quantify these inter-linked phenomena in the best possible manner in order to gain some insights on the problem at hand. The role of indicators is to show the direction. So, indicators should be designed to identify priority areas for strategic planning and also show the direction of change.

1.4 Objectives of this Study

The focus of this study is on the developmental aspects of environmental quality and its impact on human wellbeing. We do not treat environmental quality as an end in itself. Rather, we prefer to look at environmental quality as a means and wellbeing as the end. Sometimes the relation between the two is antagonistic and sometimes they work in the same direction. Environmental degradation may be triggered by the very need to increase the material wellbeing of the people at the cost of the environmental resources. On the other hand, the degrading environment may have adverse impact on the wellbeing of the mankind. The interplay of these two phenomena is the crux of our analysis.

In the developing countries context where data on the environment is hard to come by but environmental problems are on the rise, the power of environmental indices as a tool for quantification is well recognized. It is very difficult to design environmental accounts in these countries with the scanty data they possess. So, environmental indices become a more practically feasible choice. But an environmental index becomes a reliable tool only when it is constructed with some discretion and understanding of the underlying phenomenon. This is what we intend to do. We have tried to build indices in this study, which will throw some light on the wellbeing effects of the degrading environment. The indices are computed for the sixteen major states of India.

In our analysis we have tried to build two types of indices, *outcome indices* and *process indices*. This differentiation has been made to avoid the problem of double counting. Also such a distinction gives us some important insights on the cause and effect relationships. Our ultimate objective is to allow for state level comparisons of the sixteen major states of India. We are here not entering into the debate on whether any such thing as 'environmental quality of a state' exists or not. As environment is a common resource, its causes and effects are not always limited within the boundaries of the state. To avoid any such contradictions, here we have concentrated on local level indicators. The state level index itself may not be very important but the insights it reveals are of far more importance.

Another important reason for constructing state level index is that most of the times the wellbeing indicators are computed at the state level. This enables comparisons between the wellbeing indicators and the environmental indicators. Though regional comparisons may be more meaningful in some cases, especially in the analysis of agriculture, data classified according to regions are not available. Most data are available at the state level and regrouping state level data into regions is almost impossible. In most cases even district level data are not available. District level data could have enabled us to pool data at the regional level[1]. However, since such classifications are not possible, we have decided to adopt the state as the unit of analysis.

The emphasis of our analysis is as much on the methodological aspects of indexing as on the interpretation of results. There is an urgent need to quantify the environmental affects of development. With limited and imperfect data, we have tried to explore the possibilities of how this data can be utilized to give us some revealing insights. This type of analysis is useful in two ways. First it throws some light on the data gaps and what kind of data can enable a fuller analysis. Secondly, the results of the analysis reveal the immediate concern areas where immediate intervention is required for overall development.

1.5 Conceptual Framework

While conceptualizing the environmental impacts on wellbeing, since the emphasis is more on the underlying processes, it was felt that the dual character of the economy in India brought two sets of problems, and these two problems had to be treated separately. In the rural economy, the problem is not so much of pollution as it is of a sustainable livelihood. The agricultural practices followed in India are increasing the possibilities of land degradation, groundwater pollution and contamination, and a host of related problems. The stress of growing population on the agricultural resource base is the subject of analysis in the first part. The problems faced in urban areas are more directly related to pollution and its immediate health impacts. The issue of air pollution has been taken up while analyzing the urban problems related to the environment.

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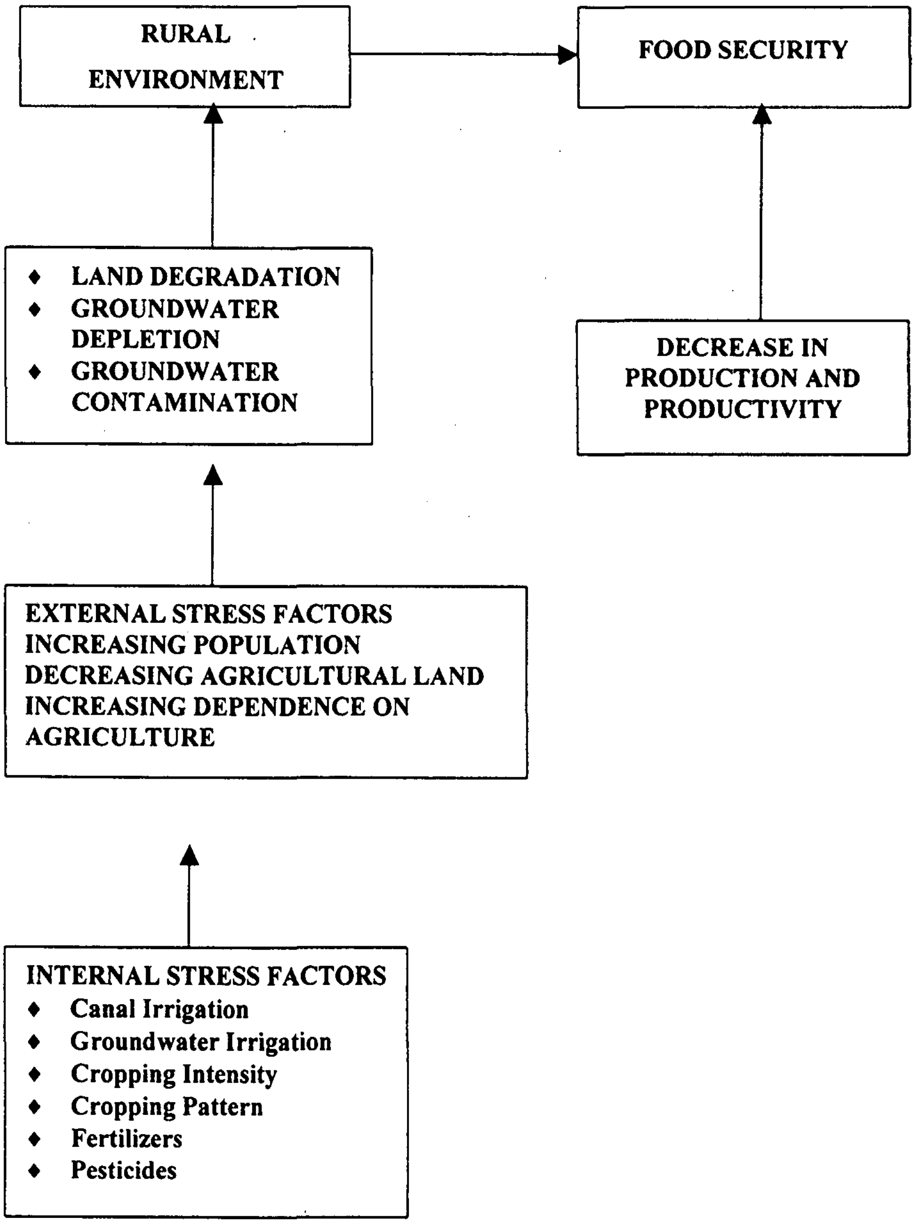
[1] The Planning Commission divides the country into 15 agro-climatic zones. These agro-climatic zones are mainly demarcated on the basis of districts.

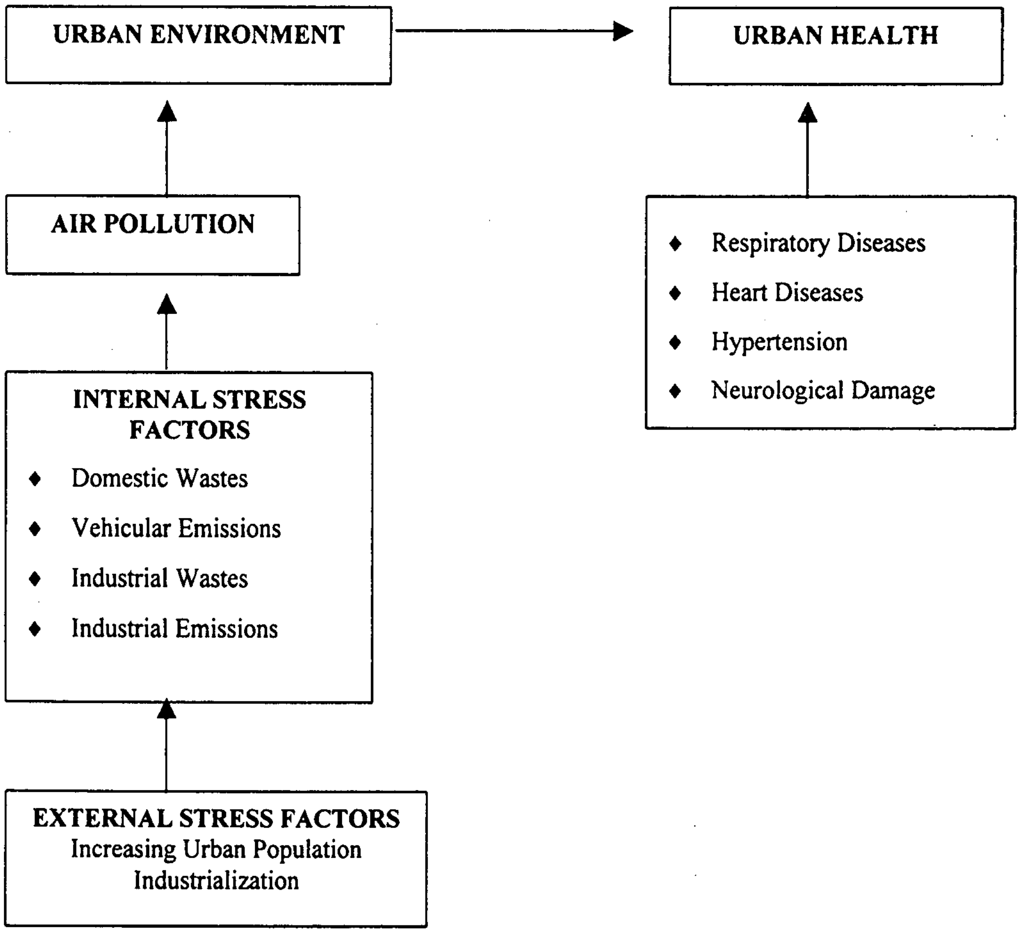
At the very beginning of the analysis it was very important to be absolutely clear about the interlinkages between the final wellbeing indicators and the process indicators. The understanding of such causal relationships will help us in prudent selection of variables. Hence, cause and effect schemes were developed for both the cases – rural and urban, before the computation of indices.

The scheme for the rural environment is as follows:



The left hand side boxes indicate the agricultural processes and the right hand side boxes indicate the wellbeing outcomes. External stress factors lead to intensification of agricultural processes. These agricultural processes again have negative impacts on the environment through land degradation and groundwater problems. The degrading environment affects human wellbeing through productivity losses and the sustainability of the agricultural processes is at risk. We have tried to capture these linkages in our first analytical section on agriculture and the environment.

In case of the urban environment, the causal relationships are much simpler. As we have mentioned earlier, the problems faced in the urban areas are more related to pollution and its health impacts. This impact is much more immediate and direct. We have mainly concentrated on urban air pollution and its effects. The scheme of events here is as follows:



In both the cases, there is no simple one-to-one relationship between the processes and outcomes, that is, a single process having only one kind of outcome. This makes the job of calculation of index numbers complicated. Such issues are dealt with in some detail in our chapter on methodological issues.

The scheme designed by us has been built keeping the Pressure-State-Response (PSR) framework in mind. This framework is originally developed by OECD and is now adopted by, or is being considered by a number of institutions, including the United Nations Commission on Sustainable Development. The PSR model assumes that the state of the environment is linked to the state of the economy. Human activities impose pressures on the environment, but also depend on it for natural resources. As a result of feedback mechanisms, there is human response to the state of the environment. However, we have not considered the response component in our analysis. The policy issues that crop up from the results have been discussed to some extent but that is not the main focus of our thesis.

When one looks at our scheme of things, one finds a very important factor missing. And that is the role of institutions. We have kept the role of institutions outside the purview of our analysis. But it should be asserted that there is no intention at undermining the role of institutions as the ecological school often does. In fact we are very much aware of how critical a role institutions play and that has come up again and again in our discussion of results. But it has been kept outside this scheme because these schemes had been developed to facilitate the computation of indices, the quantification part of the analysis. Even though institutions literally mould the processes, it is too vast an area to explore in detail at this level. We thus chose to exclude it from the core of our analysis, which is mainly focused of quantification issues.

1.6 Chapterization

With such a conceptualization of the problem at hand, we have structured our thesis in the following way. The second chapter deals with the methodological issues on construction of index numbers in the specific context of the index numbers that we have built. Chapter 3 is the first analytical chapter and it deals with the agriculture related and environmental issues. Chapter 4 is on urban air pollution and health related issues. Finally we have a concluding chapter highlighting our main findings and issues that could be taken up for further analysis.

Chapter 2

A METHODOLOGICAL DISCUSSION ON COMPUTATION OF ENVIRONMENTAL INDICES

2.1 Introduction

The task of environmental accounting is a complex one. Environmental non-marketed resources as well as the costs related to pollution, degradation etc have to be valued in monetary terms. This valuation is done using various techniques of project evaluation like shadow pricing, contingent valuation, etc. However, these techniques are based on a variety of assumptions and there are a number of problems in applying these techniques. Most importantly, to apply such techniques, the type of data that is required is difficult to obtain, especially in the developing countries. Many developed countries have made commendable efforts in developing such a database and have succeeded in accounting for the environment, partially at least. The Netherlands, UK are the forerunners in this case. But developing countries are still not in a position to build up such a database with their limited resources.

Another way of getting some information on environmental quality is through the use of indicators, which may be merged up in a composite index. Such kind of indexing has gained much popularity and attention since the seventies. Human Development Index is one such index, which is immensely popular and extensively used. These indices are widely accepted for their simplicity and usefulness in taking policy decisions.

However, when it comes to composite indexing and when the purpose is to relate environment to wellbeing, we should first address the issue that whether we need a separate index or the existing wellbeing indices are sufficient. One extreme view that can be held is that, since the environmental quality affects wellbeing in two ways, through reduction in income and through health effects, both these components will be reflected in the HDI. So we do not need to include environment as a separate component. There may be several counter-arguments to this as well. Both human development indicators and environment parameters do not work in the same direction. For any country a high and improving human development may not reflect improving environmental quality. This is especially true for the developing countries. Another argument put forward by Stehling (1988) is that, all efforts of repairing and protecting the environment leads to an increase in GNP, if these devices are sold in the market. Under such circumstances, the inflated GNP will reflect an increase in welfare rather than a decaying environment.

In the following sections we will first try to set up a general framework to understand the methodological issues pertaining to the construction of indices for the environment. We have largely drawn from Drewnowsky (1970) in these sections. Before going into the detailed functional forms and problems of aggregation and other technical aspects of indexing, we should emphasize on a few desirable properties that our indicator should have.

2.2 Features of an Ideal Environmental Index

Pertinence: An index should be well defined at the very outset so that it is understood without ambiguity what the index represents. If we want to build an index of environmental quality, then the index should represent environmental quality only and all the indicators chosen should reflect environmental quality. We should not include indicators that do not reflect environmental quality. The objective of the index number should be very clear to avoid misinterpretations.

At this point it is necessary to differentiate two kinds of indicators, outcome indicators and process indicators. Outcome indicators represent the final outcome of the phenomenon we are trying to represent. For example, we are assessing the affect of air pollution on the wellbeing of people. The ultimate effect of air pollution on mankind is the risk of respiratory diseases. So incidence of respiratory diseases will be the outcome-based indicator of air pollution. Of course, choice of the final outcome indicator will depend on the purpose and definition of the index. If the purpose is to assess environmental quality, the air pollutant level itself may be the outcome indicator. But if the purpose is to assess wellbeing, health effects become the outcome indicators.

Process indicators, on the other hand, represent the underlying processes. In the example mentioned earlier, if we are trying to assess health impacts of air pollution, the pollutant levels or the pollutant sources are the process indicators. The process indicators quantify the causes of the outcome. The distinction between process and outcome indicators is very important to avoid problems of double counting.

Comprehensiveness: An index should cover as fully as possible all the variables related to the phenomenon that it tries to quantify. In case of environmental variables, it is very difficult to do so. First, the various components of the phenomenon that we want to quantify (e.g. environmental quality, wellbeing) have to be defined. There may be problems defining the components of environmental quality and that may also require value judgement. Next, the variables to be included in each component have to be identified. An ideal environmental quality index should include all variables affecting the environment. But that is hardly feasible. Thus a set of representative variables have to be selected for the purpose. The selection process will lead to further complications, as it will depend not only on the selector's value judgement but also on the production process, consumption behavior, etc. However, a judicious selection of limited number of variables is required to be included in the index.

Even Coverage: The coverage of all the components of the quantified phenomenon should be as even as possible. There should be no scope for double counting and each component should be represented only once.

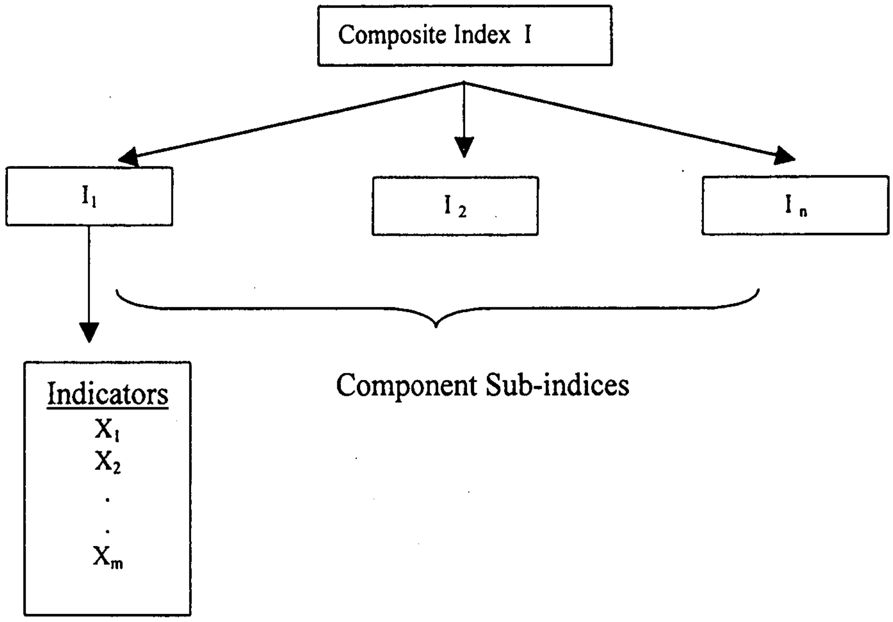
Simplicity: The structure of the index should be made as simple as possible. It should be easy to understand and could be computed with the minimum data.

Flexibility: The index should be computed in such a way as to allow for further elaboration in future as and when data is available. We should leave it open ended, further variables can be included, and some variables can be excluded according to future needs without violating the basic structure of the index.

Measurement in Real Terms: It is better to be able to measure all the components in real terms rather than in monetary units. If we want to measure everything in monetary units, it is better to adopt the accounting route and the significance of indexing is lost.

2.3 General Design of the Index

The general structure of the Index can be represented in the following chart.



2.3.1 Components

The environmental quality or wellbeing may be divided into various components. A component of the overall composite index represents a specific category of the phenomenon in question. For example, suppose we are indexing for the health effects of pollution. This can be divided into two categories, health effects of air pollution and health effects of water pollution. These two independent categories represent the two components of the composite index. The classification of components can be done on the basis of the outcomes. All the components taken together may represent all aspects of the composite index, that is, the components should be exhaustive. At the same time there should not be any overlapping between the components. The components should represent different processes and there should not be any dependence among them.

2.3.2 Indicators

Once we have defined the components, it is necessary to find a quantitative expression for all the components. Each component covers a great number of facts referring to that specific component. Many of these facts can be quantified. These quantifiable facts (which can be called variables) can be used to get a numerical value for the components. These selected variables are called indicators for the components.

While selecting the indicators a few things should be borne in mind[1];

a) *These variables should be representative of the component, i.e. contain information about the most important quantitative basic characteristics of the component.*
b) *The indicators that are selected should aim at a full and even coverage of all the various elements that make up the component. The coverage will be more complete when the number of indicators are increased; but even a limited number of indicators may assure a fair coverage if the selection is judiciously made. An even coverage means that no elements of the component have been covered doubly, i.e. represented in two or more indicators.*
c) *The number of indicators per component may vary depending on how elaborate we want the index to be. It is possible to conceive of only one indicator for each component. This would be the simplest form of the index.*

Once the variables are chosen, we need to find a functional form that will transform the variables into a sub-index. That will depend on the relationship of the variable and the phenomenon we are trying to represent. For example, we are trying to represent the effect of air pollution on wellbeing. We choose the level of certain pollutants as the variable. Now we have to explore how the levels of pollutants affect wellbeing. If it is a straightforward direct relationship, that is, as pollutant levels increase wellbeing decreases proportionately, we can adopt a simple linear transformation. Most of the wellbeing indices commonly in practice use a linear transformation. In fact, using a distance function like that in the HDI has become an unwritten rule for constructing index numbers without being sensitive to the mathematical properties of this function. Apart from the linear relationship depicted in the distance function, which may not be appropriate in the case of environmental indexing, there is another reason why the use of distance function should be avoided. The role of the distance function is not only of aggregation but also to show the distance of each state from the environmentally least affected state. In this way, the distance function measures how much each state has to achieve to catch up with the best state. In the context of environmental problems, such comparisons between the best and the worst are inconsequential. In this context we are more concerned about the threshold levels. The threshold level of any parameter is that level of environmental exploitation that is permissible; it is within the self-healing capacity of nature. Exploitation beyond that level may cause irreversible damage to the environment. In this case if the best

[1] This section is reproduced from Drewnowsky (1970)

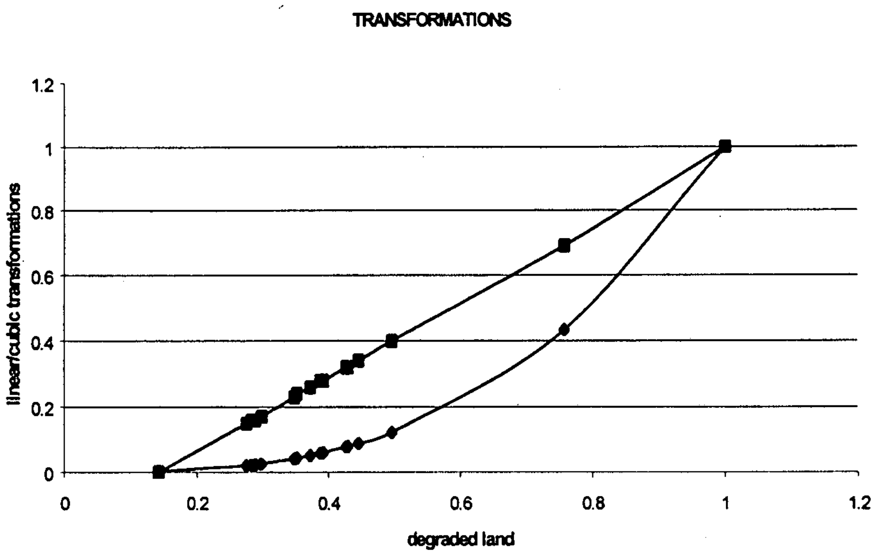
state lies beyond the threshold level, it does not become environmentally sustainable just by the virtue of being the least affected state. Similarly, if the worst state is below the threshold it does not become unsustainable. So if at all any reference points are fixed to measure sustainability, it should be done on the basis of more serious considerations rather than comparisons with maximum and minimum values. We have discussed at length in our Chapter-3 how indiscriminate use of a distance function can lead to meaningless orderings in our criticism of the MSSRF Agricultural Sustainability Index.

If there are adequate reasons to believe that the phenomenon in question is not a linear function of the variables, we can try other functional forms. We can use convex or concave functional forms to make the indicator more suitable. In case of environmental indicators, a convex functional form becomes very relevant because of the very nature of the problem. Nature has its own regenerative properties. At initial levels of pollution or other forms of natural degradation, the effects may not be acutely felt because of the resilience and regenerative properties of nature. But at higher levels the intensity of the impact keeps on increasing as nature gradually loses its resilience. At the extreme case, the degradation may be permanent due to irreversibility of the process.

One example will clarify the situation. Let us take the example of mining of any mineral, coal for instance. When coal is mined at the initial stage, its ill effects like depletion of the resource and land degradation may not be acutely felt. If the rate of mineral extraction is low relative to its stock, it may well be within the regenerative powers of nature. But as mining increases the problems related to mining intensifies until one day when the whole resource is depleted. Humans can deplete a resource in a century, which Nature has taken thousands of years to produce.

Such examples make us believe that in case of environmental indicators an increasing convex functional form becomes more appropriate than a simple linear one. The figure below shows the comparative picture of the two types of functional forms using the same data. The data relates to land degradation, which is later used in our Chapter – 3.

Figure 2.1 Linear and Power Transformations



The linear graph shows a linear transformation of the indicator, degraded land. This is the most commonly used linear transformation of the form,

I = (X – Xmin) / (Xmax – Xmin)

The convex curve is the power transformation of the form,

$I = X^3$ (in both cases X is the value of the indicator).

In case of the linear transformation, an increase in the indicator value proportionately increases the index value. But in case of the convex function, an increase in indicator value brings a more than proportionate change in the index value. The impact on environmental quality is higher if land degradation increases from 20 percent to 30 percent of geographical area than if the level of degradation was from 10 percent to 20 percent.

Another concept that becomes very relevant in case of environmental indexing is that of 'thresholds'. Just as human action on nature causes irreversible damage after a certain level, which sets the upper limit to degradation, there is also a lower limit below which human actions do not cause any damage at all. It signifies that level of action, which is perfectly within the regenerative capacities of nature.

Let us again explain with an example. Let us consider the case of air pollution and its impact on health. The Central Pollution Control Board (CPCB), India categorizes the pollutant levels into four groups: low, moderate, high and critical. Let us assume the cut-off points at every level to be specified by l, m and h respectively, so that the range 0 to l is low concentration, l to m is defined as moderate concentration, m to h as high concentration and above high is critical level. Now, the minimum acceptable limit of air pollution is upto the moderate level, according to CPCB. So, for the categories low and moderate, the index value may be 0 implying that below this threshold level there is no health impact. After that it can be assumed to increase at an increasing rate. The index will thus take the functional form,

$$I = g(x)$$
$$= 0 \text{ for all } x \leq m.$$
$$g'(x) > 0 \text{ for all } x > m.$$

We can also assume that at every level the impact of pollution on health intensifies. In that case, we will get a convex step function as our index value. Since the health impact gets intensified at every step, the curvature of the function also gets steeper at every step. The function thus obtained has to satisfy the following properties.

$$I = g(x),\ g'(x) > 0$$
$$g(x) = 0 \text{ for all } x \leq m$$
$$\text{and, } 0 < g''(x_H) < g''(x_C),$$

Where $m < x_H < h$

$x_C > h$

These two kinds of functional relationships are shown in Figures 2 and 3 using data on SPM levels. The same data is used in Chapter 4 and an application of this functional form can be found in the same chapter.

Figure 2.2 Convex transformation with a threshold limit

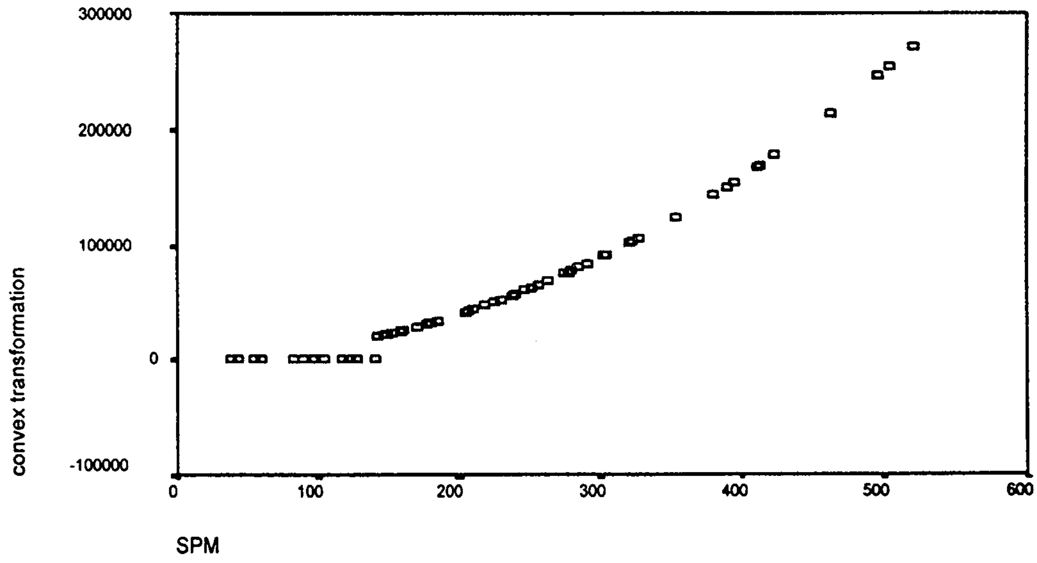


Figure 2.3 Convex and step transformation with threshold limits

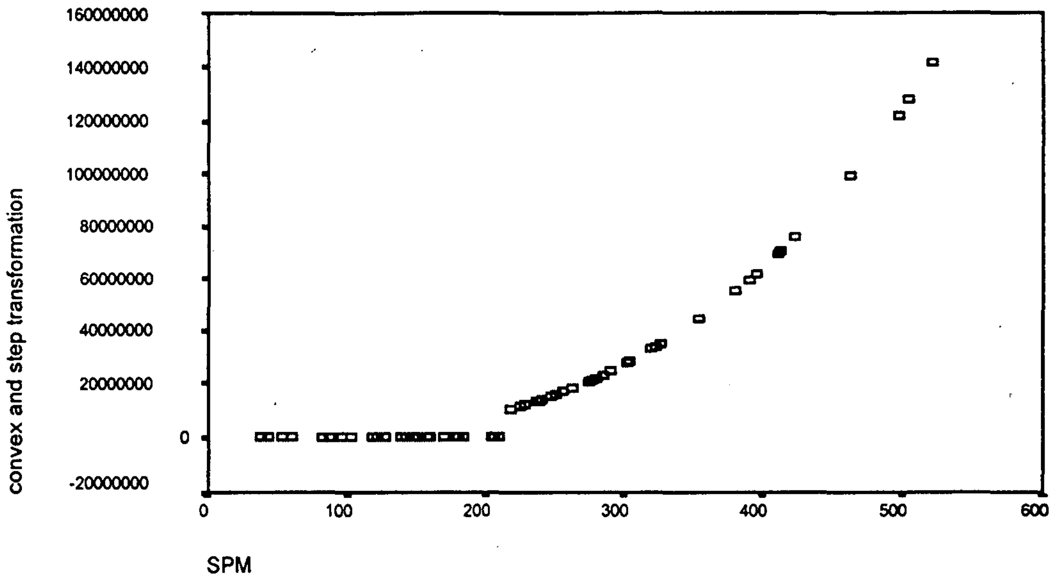


Figure 2 uses the specific functional form,

$I = x^2$, for all $x > m$ (here, x is the average annual concentration of SPM and m = 140 μg.)

$= 0$, for all $x \leq m$.

Figure three uses the specific transformation,

$I = 0$, when $0 < x \leq m$

$I = x^2$, when $m < x \leq h$ ($h = 210$ μg)

$I = x^3$, when $x > h$.

However, all these transformations that we are proposing can be criticized on the argument that they are quite ad-hoc in nature without adequate empirical or theoretical justification. We do not have adequate information to assess the exact relationship between pollutants and health. So we leave our methodological discussion here, hoping that such issues can be taken up for further research.

2.3.3 Aggregation

The indexing framework illustrated in the previous sections requires aggregation at two levels. At the initial stage we have to aggregate the variables into its component sub-index. At the final stage, we have to aggregate the sub-indices into a composite index. But before we go into the nitty-gritty of aggregation rules, let us ask a very basic question, is aggregation necessary?

Aggregation transforms a multidimensional phenomenon into a single scalar value. It is not always necessary to have a scalar representation of the phenomenon. In fact, there is a substantial loss of information when we do such transformations. The only merit in such scalar transformations is that it facilitates comparisons across the observations. But if comparison is not the objective, we can go for a vector representation as well. In Chapter 1 we have mentioned about the World Bank's Development Diamonds and ADB's Environmental Diamonds. These Diamonds are examples of such vector representation. Each axis of the Diamond (or it can be any polygon for that matter) represents a vector – a dimension of the problem at hand. We may have cut-offs at every axis denoting the threshold or desirable levels. Then we can have a clear picture in which dimensions a state requires improvements.

Aggregation brings with it a variety of complications. To aggregate a group of variables in a single value, we first have to standardize all the variables into a common standard unit. So the first step is standardization. This can be done in a variety of ways. We can express the variables in unit free ratios. An example of this kind of standardization is the Human Poverty Index of the UNDP. This index standardizes all its variables, population below poverty line, population without access to sanitation facilities, population not expected to live beyond the age of 40, etc. by taking the variables as percentage of total population. This makes the variables comparable across countries and also being pure numbers they can be aggregated into a single HPI. Another method that is very much in use is the construction of distance functions. The distance function is used in the Human Development Index. It standardizes the variables in a zero to one scale by measuring the relative distance of each value from the maximum or minimum value.

Once we have a group of variables in comparable units, we have to aggregate them into a component index. Aggregation gives rise to two problems. The first problem is the problem of attaching weights. All variables do not affect the environmental quality in the same intensity, so uniform weights cannot be attached. Let us again go back to our example of the health effects of air pollution. Do all the pollutants affect human health in the same intensity? Or does a single pollutant cause more harm than others do? If so, we have to assign more weight to this more harmful pollutant than the other pollutants. But again the relative importance of each pollutant has to be substantiated by epidemiological studies.

While aggregating the variables into a sub-index for any one component of environmental quality (say, air, water and land), it is necessary to look into the relationship between the variables in the way they affect environmental quality. Stehling (1988) quotes three kinds of relationships that may exist between the variables from Ott (1978) – synergism, antagonism and superposition.

Let us suppose two variables, x_1 and x_2, affect the environmental quality. $D(x_1, x_2)$ is the damage function, that is, the function showing how much environmental quality is affected. Synergistic relationship between the variables x_1 and x_2 is said to prevail if the overall damage caused the simultaneous influence of x_1 and x_2 is greater than the sum of damages caused by individual effects of x_1 and x_2. That is,

$D(x_1, x_2) > D(x_1, 0) + D(0, x_2)$.

Similarly, if the overall damage is less than the individual effects, antagonism is said to exist between the variables. In case of antagonism,

$D(x_1, x_2) < D(x_1, 0) + D(0, x_2)$.

Superposition is said to exist if, $D(x_1, x_2) = D(x_1, 0) + D(0, x_2)$.

The environmental quality sub-index should reflect such relationships. For example if CO_2 and SO_2 show synergistic relationship, we cannot simply add them to get a sub-index of air quality. We have to adopt a function that reflects this desired property.

The next problem arises in the process of aggregation. Once we have built sub-indices for different components, these must be integrated into a single composite index. The relationship between the components and the degree of substitutability among them is subsumed in the aggregation rule adopted. There are several aggregation rules, cardinal and ordinal. Cardinal aggregation rules require the use of simple arithmetic mean, geometric mean or power mean formula. Ordinal aggregation is associated with Borda ranking method.

Environmental quality indicators are seldom substitutable among themselves. For example, enhancing air quality cannot compensate for soil degradation. To solve this problem, we can adopt an aggregation formula that does not allow for substitutability or for which the elasticity of substitution is low.

Let us elucidate further how the idea of substitution elasticity is implicit in the aggregation formula adopted for the index. Given the functional form of the index, we can calculate the value of the elasticity of substitution between the components. The elasticity of substitution (ε) between two components, say I_1 and I_2 along an iso-I curve (the curve on which the value of the composite index I remains constant for various combinations of I_1 and I_2) is defined as the percentage change in (I_1/I_2) for a unit percentage change in the slope of the tangent along this curve[2]. If we adopt a simple unweighted arithmetic mean of the form $I = \frac{1}{2}(I_1 + I_2)$ to aggregate the various components of the index, as in the HDI, the elasticity of substitution (ε) becomes infinite. If we use an unweighted power mean of degree $\propto$ of the form $I = \{(I_1^{\propto} + I_2^{\propto}) / 2\}^{1/\propto}$, then the elasticity of substitution becomes, $\varepsilon = 1/(1-\propto)$. Using various values of $\propto$ we can depict the elasticity of substitution, as we perceive the relationship to be. Using higher values of $\propto$, we get lower values of ε. As ε approaches ∞, I takes the form of a maximum value function such that, $I = \max(I_1, I_2)$. In this case, the maximum component overwhelms all other components and only this component determines the ranks of all the cases. The elasticity of substitution of the maximum value function is zero. This issue has been dealt with at length in our critical appraisal of the MSSRF Sustainability Index and an application of this concept can be found in our construction of our Degradation Index (Chapter 3).

Apart from the use of a maximum or minimum value function, even Borda ranking method also implies zero substitutability among the components. This method assigns ranks to each individual component and rank of the composite index is the sum of all the ranks of the sub-indices. In this way it bypasses the complexities of choosing a functional form for aggregation. Dasgupta (1992) has used this method to integrate indicators of political freedom and civil rights into the Human Development Index. Though this method does not assume any substitutability, it violates Arrow's assumption of "Independence of Irrelevant Alternatives". [3] Having discussed in general about the various issues related to aggregation, we would like to discuss a little bit more in detail about the power mean and its properties. In our view, this form of aggregation is more appropriate in case of environmental indices. In our analysis we have used this functional form. So it is important at the very outset, to clearly illustrate the properties of the power mean and why it becomes more meaningful while constructing an

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[2] The mathematical form and the derivation of elasticity of substitution for the various aggregation formulas are discussed at length in Mathematical Appendix.

[3] For a detailed discussion on Borda method, please refer to Dasgupta, P (1990) and Dasgupta, P (1992). The same method has also been applied in Qizilbash (2000).

index for the environment. While a more rigorous mathematical derivation of the properties of the power mean is illustrated in Mathematical Appendix for the more interested reader, we restrict our discussion in the next section to the implications of these properties.

2.3.4 Properties of the Power Mean

i) *The power mean like any other mean lies between the highest and lowest values of the distribution.*

This property is a very useful one in case of building indices. Especially, if we express the variables as a proportion (or even a distance function) the values of the subindices lie within some specified limits, say 0 and 1 or 0 to 100. The composite index constructed using the power mean formula also lies between the same specified limits.

ii) *For a power mean of order α, as α tends to infinity $P(\alpha)$ tends to the maximum value of the sub-indices.*

In case of two indices I_1 and I_2,

As $\alpha \to \infty$, $P(\alpha) \to \max \{I_1, I_2\}$

This property has special significance in case of environmental indicators. If the environmental quality in a certain component has a very large value, the composite index will also take a very high value even if the other components have small values. It somehow resists the 'smoothing out' operation which a simple average does.

Suppose we are constructing a composite index representing two components – water quality and air quality. The final index, of course, denotes wellbeing as a function of these two components. If a certain observation has a very high value in air quality, denoting very polluted air quality, but a relatively better position in terms of water quality, what will be the ultimate effect on wellbeing? The relatively low risk of water borne diseases cannot decrease the risk of respiratory diseases and neither can it compensate for the morbidity conditions (measured by say, number of productive days lost). Due to the independent character of the components, the smoothing out feature of a simple average does not carry much meaning in the case of environmental indicators. The power mean, with a high value of α thus becomes more meaningful.

iii) P(α) is an increasing convex function of each sub-index.

This is also a very important property with regard to environmental problems. The composite index reflects the environmental quality. As the value of the indicator increases, its effect on environmental quality gets intensified. A power transformation can capture this idea in its functional form. The significance of a convex functional form in case of environmental indicators has already been discussed in the previous section.

iv) The elasticity of substitution between any two sub-indices of P (α) is constant and is equal to 1/(1- α).

This implies that the components are not perfectly substitutable among themselves. Using various values of α we can get the desired elasticity of substitution. This property has also been discussed in the previous section. Here we present just a few more corollaries to this property.

a) If $\alpha = 1$, then elasticity of substitution $\varepsilon = 1 / (1-1) = \infty$. Hence, there is infinite elasticity of substitution between the component indices, that is, they are perfectly substitutable. It is worth mentioning here that when $\alpha = 1$, the power mean becomes the simple arithmetic mean. So, arithmetic mean is a special case of the power mean. Since most composite indices are based on the arithmetic mean formula, the assumption of perfect substitutability is implicit in their computation.

b) If $\alpha > 1$, $\varepsilon < 1$. Thus higher values of α gives us lower values of the elasticity of substitution. As α increases from 1, the elasticity of substitution decreases monotonically from ∞ to 0.

c) When $\alpha = \infty$, there is no substitutability among the components. The aggregate index tends to the maximum value of the sub-indices, max $\{I_1, I_2\}$. Again, maximum value function can also be treated as a special case of the power mean.

Due to these properties, we hold the view that the power mean formula, where the power α is greater than unity, is more appropriate for the purpose of an environmental index. As we have stated repeatedly, this formula in its variant forms have been applied in our analysis in the chapters that follow.

2.4 Conclusion

This chapter can be treated as a theoretical prelude to our following chapters, which form the core of this thesis. In this chapter, we have tried to clarify some methodological aspects of indexing. All these methodological issues have come up repeatedly in our analysis.

In this chapter, we have first laid down the desirable properties of a composite index and generally discussed the design of index that we have followed in our analysis. As a part of this discussion, we have dealt at length with the problems of using appropriate functional forms and aggregation formulas while constructing the index. The choice of the right functional forms and aggregation formulas are very crucial to indexing. Ultimately, any composite index is a numerical value attributed to a phenomenon. Only when we use the correct specifications relating to this phenomenon, will the numerical value we assign to the phenomenon be really representative.

Composite indexing has become so commonplace a technique that the theoretical basis of indexing is often neglected. This negligence gives rise to ad-hoc rankings, and in the process the strength of this very powerful yet simple tool is often trivialized. The entire discussion in this chapter tries to explain the logic behind every step of index building. It is to emphasize that constructing a truly representative index is not a trick of mere data compilation but a job requiring much more insight.

MATHEMATICAL APPENDIX

Properties of the Power Mean

Let us consider an unweighted power mean $P(\alpha)$ of three components P_1, P_2 and P_3, of power α. Hence,

$$(1) \quad P(\alpha)=\left[\frac{1}{3}P_1^{\alpha}+\frac{1}{3}P_2^{\alpha}+\frac{1}{3}P_3^{\alpha}\right]^{1/\alpha}$$

$$(2) \quad P(\alpha)^{\alpha}=\frac{1}{3}P_1^{\alpha}+\frac{1}{3}P_2^{\alpha}+\frac{1}{3}P_3^{\alpha}$$

The mean of order 1 ($\alpha = 1$) is thus the simple unweighted arithmetic mean of P_1, P_2 and P_3.

Property 1: *The power mean like any other mean lies between the smallest and largest values of Pi for i = 1,2,3.That is,* $\min\{P_1, P_2, P_3\} \leq P(\alpha) \leq \max\{P_1, P_2, P_3\}$

Proof: By definition of $P(\alpha)$ in equation (2)we have,

$$P(\alpha)^{\alpha}=\frac{1}{3}P_1^{\alpha}+\frac{1}{3}P_2^{\alpha}+\frac{1}{3}P_3^{\alpha}$$

But for each i = 1,2,3,

$\min\{P_1,P_2, P_3\} \leq P_i \leq \max\{P_1, P_2, P_3\}$

Therefore, since $\alpha > 0$,

$[\min\{P_1, P_2, P_3\}]^{\alpha} \leq P_i^{\alpha} \leq [\max\{P_1, P_2, P_3\}]^{\alpha}$

using the right hand side of the above inequality in equation (2) gives,

$P(\alpha)^{\alpha} \leq [\max\{P_1, P_2, P_3\}]^{\alpha}$

[This expression is obtained by substituting the relationship $P_i^{\alpha} \leq [\max\{P_1, P_2, P_3\}]^{\alpha}$ for each P_i in equation (2)]

Similarly,

$P(\alpha)^{\alpha} \geq [\min\{P_1, P_2, P_3\}]^{\alpha}$

Hence,

$[\min\{P_1, P_2, P_3\}]^{\alpha} \leq P(\alpha)^{\alpha} \leq [\max\{P_1, P_2, P_3\}]^{\alpha}$

Since $\alpha > 0$, it follows that,

$\min\{P_1, P_2, P_3\} \leq P(\alpha) \leq \max\{P_1, P_2, P_3\}$ □

Property 2 : *As α tends to infinity, the limiting value of $P(\alpha)$ is max $\{P_1, P_2, P_3\}$. Or, as $\alpha \to \infty$, $P(\alpha) \to \max \{P_1, P_2, P_3\}$.*

Proof: Let P_k be the largest Pi for i = 1, 2, 3. Thus,

$P_k = \max \{P_1, P_2, P_3\}$

From Property 1 we have,

$P(\alpha) \leq \max \{P_1, P_2, P_3\}$

Therefore,

(3) $P(\alpha) \leq P_k$

Now,

$P(\alpha)^\alpha = 1/3\, [P_1^\alpha + P_2^\alpha + P_3^\alpha]$

$\therefore P(\alpha)^\alpha \geq 1/3\, P_k^\alpha$, since P_k is one of P1, P2, P3.

Since $\alpha > 0$,

$P(\alpha) \geq (1/3)^{1/\alpha} P_k$

As $\alpha \to \infty$, $(1/3)^{1/\alpha} \to 1$

so that, $\lim_{\alpha \to \infty} P(\alpha) \leq P_k$

hence, $\lim_{\alpha \to \infty} P(\alpha) = P_k = \max \{P_1 + P_2 + P_3\}$ □

Property 3: *$P(\alpha)$ is monotonic increasing in each Pi, for i = 1, 2, 3. Or, for each i = 1, 2, 3,*
$$\frac{\partial P(\alpha)}{\partial P_i} > 0$$

Proof: From the definition of $P(\alpha)$ we may rewrite equation (1) as,

$$3\, P(\alpha)^\alpha = P_1^\alpha + P_2^\alpha + P_3^\alpha$$

Differentiating partially with respect to P_i,

$$3\alpha\, P(\alpha)^{\alpha-1} \frac{\partial P(\alpha)}{\partial P_i} = \alpha\, P_i^{\alpha-1}$$

(4) $$\frac{\partial P(\alpha)}{\partial P_i} = \frac{1}{3}\left[\frac{P_i}{P(\alpha)}\right]^{\alpha-1}$$

since P_i and $P(\alpha)$ are positive,

$$\frac{\partial P(\alpha)}{\partial P_i} > 0 \; □$$

In case of $\alpha = 1$, so that P(1) is simply the arithmetic mean of P_i, we have

$$\frac{\partial P(1)}{\partial P_i} = \frac{1}{3}$$

Property 4: *P(α) is increasing at an increasing rate in P_i – in other words, P(α) is convex with respect to P_i. For each i – 1, 2, 3,* $\frac{\partial^2 P(\alpha)}{\partial P_i^2} > 0$

Proof: From equation (4),

$$\frac{\partial^2 P(\alpha)}{\partial P_i^2} = \frac{\partial}{\partial P_i}\left[\frac{\partial P(\alpha)}{\partial P_i}\right]$$

$$\Rightarrow \frac{\partial^2 P(\alpha)}{\partial P_i^2} = \frac{\partial}{\partial P_i}\left[\frac{1}{3}\left(\frac{P_i}{P(\alpha)}\right)^{\alpha-1}\right]$$

Therefore,

$$(5)\quad \frac{\partial^2 P(\alpha)}{\partial P_i^2} = \frac{1}{3}\frac{\partial}{\partial P_i}\left[\frac{P_i}{P(\alpha)}\right]^{\alpha-1}$$

Now, $$\frac{\partial}{\partial P_i}\left[\frac{P_i}{P(\alpha)}\right]^{\alpha-1} = (\alpha-1)\left(\frac{P_i}{P(\alpha)}\right)^{\alpha-2}\left[\frac{P(\alpha) - P_i\frac{\partial P(\alpha)}{\partial P_i}}{P(\alpha)^2}\right]$$

Substituting $\frac{\partial P(\alpha)}{\partial P_i}$ from equation (4) we have,

$$\frac{\partial}{\partial P_i}\left[\frac{P_i}{P(\alpha)}\right]^{\alpha-1} = (\alpha-1)\frac{P_i^{\alpha-2}}{P(\alpha)^{\alpha}}\left[P(\alpha) - \frac{1}{3}P_i\frac{P_i^{\alpha-1}}{P(\alpha)^{\alpha-1}}\right]$$

$$\Rightarrow \frac{\partial}{\partial P_i}\left[\frac{P_i}{P(\alpha)}\right]^{\alpha-1} = \frac{(\alpha-1)P_i^{\alpha-2}}{P(\alpha)^{\alpha}}\left[\frac{3P(\alpha)^{\alpha} - P_i^{\alpha}}{3P(\alpha)^{\alpha-1}}\right]$$

Hence,

$$\frac{\partial^2 P(\alpha)}{\partial P_i^2} = \frac{(\alpha-1)P_i^{\alpha-2}}{9P(\alpha)^{2\alpha-1}}\left(3P(\alpha)^{\alpha} - P_i^{\alpha}\right) > 0$$

Because, $\alpha > 1$ and

$$3P(\alpha)^{\alpha} - P_i^{\alpha} = \sum_{i=1}^{3} P_i^{\alpha} - P_i^{\alpha} = \sum_{j\neq i} P_j^{\alpha}\ \square$$

Property 5: *The elasticity of substitution σ between any two sub-indices of P(α), that is between any two sub-indices of P_1, P_2 and P_3, is constant and equal to 1 / (α-1).*

Proof: Consider the elasticity of substitution between P1 and P2, holding P3 constant. The slope of the tangent along an iso-P(α) curve in P1-P2 space is given by,

$$x = \frac{\partial P(\alpha) / \partial P_1}{\partial P(\alpha) / \partial P_2}$$

By definition, the elasticity of substitution σ between P_1 and P_2 is,

$$\frac{\partial \log (P_1 / P_2)}{\partial \log x}$$

From equation (4) we have,

$$\frac{\partial P(\alpha) / \partial P_1}{\partial P(\alpha) / \partial P_2} = \left(\frac{P_1}{P_2}\right)^{\alpha-1} = x$$

Therefore,

$$\frac{P_1}{P_2} = x^{1/\alpha-1}$$

$$\therefore \log\left(\frac{P_1}{P_2}\right) = \frac{1}{\alpha-1} \log x$$

Hence the elasticity of substitution,

$$\sigma = \frac{\partial \log (P_1 / P_2)}{\partial \log x} = \frac{1}{\alpha - 1} \quad \square$$

It ought to be mentioned in this context that the un-weighted power mean is the simplified version of the weighted power mean of the form,

$$P(\alpha) = \left(\frac{w_1 P_1^{\alpha} + w_2 P_2^{\alpha} + w_3 P_3^{\alpha}}{w_1 + w_2 + w_3}\right)^{1/\alpha}$$

where, w_i denotes the weights. Since we have not used this type of function in our analysis, we do not include the properties of this generalized mean in our appendix. However, a detailed mathematical discussion on the properties of the power mean can be found in the Mathematical Appendix of Human Development Report 1997.

Chapter 3

AGRICULTURE AND THE ENVIRONMENT

3.1 Introduction

Agriculture is by far the dominant sector in most developing economies. In the transitional phase of development, the agricultural sector faces disproportionately high pressures in these countries. These pressures mainly originate from the growing population, since population growth has not yet stabilized in these countries. The basic task before these economies is to achieve food security, as well as to heighten its standard of living. In order to accomplish this dual task, agricultural sector has to grow at a faster pace than the growing population.

However, with increased demand for land for non-agricultural activities, the agricultural sector is left with the only option of boosting up its productivity to very high levels with very intensive farming practices. Along with the technological changes that have taken place in the agricultural sector, the questions of sustainability of the system as a whole and the environmental impacts of such a system have emerged time and again. It is now recognized that sustainable agricultural production not only involves identification and application of improved technologies but also ecological and socio-economic concerns (Pookpakdi 1993). The Food and Agricultural Organization (FAO) has defined sustainable agricultural development as, "The management and conservation of the resource base and the orientation of technological and institutional changes in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations. Such sustainable development is environmentally non-degrading, technically appropriate, economically viable and socially acceptable." (FAO, 1991)

These objectives can broadly be grouped under four properties of agro-economic systems – productivity (measured in terms of yield or net income or food value, etc.), stability (measured as coefficient of variation of yield or income), sustainability and equitability (in terms of income distribution) (Conway et al 1987). These objectives are not complementary to each other and there are internal contradictions among them, which gives rise to a trade-off at the policy level. In fact, productivity and stability are short run goals which may, more often than never, clash with the long run goals of sustainability and equitability. In such situations the question of trade-off appears and in most cases it is seen that the immediate concerns gain priority over the not so obvious long-term concerns. Hence in most developing countries, environmental problems take a back seat and are not dealt with unless and until its repercussions become too apparent to neglect further.

Indian agriculture is a classic case of such dilemma. Since the inception of Green Revolution technology in the mid-sixties, it has successfully addressed to its problems of food security. But the environmental consequences had been left unattended till the eighties when the major agricultural region in the Indus basin began showing signs of land degradation and groundwater depletion. However, no major changes in policy have been formulated so far to address the issue at a national level. Neither have their been enough macro-level studies to assess the impact of agricultural practices on the environment. Due to the nature of the problem and also problems of ready availability of reliable data, most of the literature in this sphere has confined itself to micro level studies, depending mostly on primary or unpublished official sources of information. Such literature has its own merits in the sense that environmental problems are very much specific to geographical location and macro level analysis may not be able to capture many elements and underplay the severity of the problem. But macro level analysis is necessary all the same, at least for the sake of drawing attention to the issues. In this chapter, we attempt to make a state level analysis of the Indian agricultural scenario vis-à-vis the environment.

The next section of this chapter lays out the interlinkages between agriculture and the environment. These interlinkages are established with the help of the existing literature and micro level studies. Section 3.4 is the core analytical section of the chapter. With a critical appraisal of the MSSRF Environmental Sustainability Index in section 3.3, we proceed to construct alternative indices in the next section. Two sets of indices are constructed, an outcome based degradation index and a process based sustainability index. Each of these indices is compared with food security indicators to get a complete picture.

3.2 Interlinkages between Agriculture and the Environment

Before going into the analysis, it is necessary to set up a structure in which we prefer to address the issue. Given the complicated nature of the problem at hand, it is very important to arrive at a simplified structure to make the analysis comprehensive. For this, it is important to understand the linkages between agriculture and the environment. Agriculture is one human activity that directly affects and is directly affected by the environment. For agricultural activities, human beings crucially depend on the natural resource base. The proper usage and maintenance of this resource base is very important for the sustenance of the activity itself.

There are two way links between the natural environment and agriculture. Environmental problems can act as a serious hindrance to agricultural development through their effects on productivity. Similarly, unscientific and environment insensitive farm practices may damage the environment and this may in turn reduce agricultural productivity. However, empirically it is very difficult to capture the two kinds of linkages separately. Given the limited and inadequate data available and especially the absence of reliable time series data on different environmental aspects in India, it is very difficult to establish any kind of cause and effect relationship. But at a conceptual level such linkages can be established.

3.2.1 External Stress Factors

Agriculture is subject to lots of external stress factors. These stress factors have intensified in recent years leading to intensification of agricultural activities. Intensification of agriculture has accentuated environmental degradation.

Population is a major stress factor on the resource base. The entire population of the country depends on the agricultural sector for their food requirements. In spite of the fact that production of foodgrains has increased manifold since the green revolution, the question often faced is that how far this increase can be maintained given the dwindling resources. All major agricultural regions have reached a plateau in productivity, and profitability of farming has started falling, though these regions still continue to be highly productive compared to other regions and hold the key to meeting future food demands (Vyas and Reddy, 1993). The green revolution technology has been concentrated to a few irrigated regions and to a few crops. So the country has put undue pressure on the resources of a few states to meet the increasing food demands. These states have to over-exploit their resources, much more than the amount necessary to meet their own food demands, which make them all the more environmentally vulnerable. On the other hand, the states that cannot produce their own food have been vulnerable in terms of food security. This especially has effects on the rural poor and the equitability dimension of the system.

Land is a non-renewable natural resource. Agricultural land (Net Area Sown) in India has shown an increase in the sixties and has remained almost constant since the seventies. Agriculture is losing land to non-agricultural uses as well. There have been substantial changes in the land use in the recent years. Decreasing agricultural land and multi-cropping practices have put much pressure on the natural quality of soil.

The changes in the land use affect the ecosystem of an area in terms of vegetation, local weather effects, land quality itself and the quality of life that can be sustained. The changes in the land use pattern and the associated ecological changes are generally long drawn. The gravity of these consequences can only be captured through long run analysis. In a developing country like India, immediate concerns for agricultural growth had undermined the importance of the long run consequences on the ecological balance. But increasing problems of land degradation, water logging, salinity, soil erosion are gradually surfacing and in need of immediate attention.

While agricultural land has declined, there has been a steady increase in the agricultural workforce. Due to lack of employment opportunities in other sectors, a large part of the population has to depend on the agricultural sector for their livelihood. This has also exerted considerable pressure on agriculture.

3.2.2 Internal Stress Factors

Such external stress factors compelled the intensification of agricultural activities. What have been overlooked so far are the environmental repercussions to such agricultural intensification. The different types of environmental damages that may emanate from the present form of agriculture are discussed below.

The demerits of canal irrigation are a much debated issue. The major negative effects of surface irrigation are the problems of soil salinity/alkalinity, waterlogging and canal seepage. During the post independence period, many of the major projects witnessed waterlogging and consequent soil salinity problems. However information availability on these aspects are limited.

The direct effect of land degradation is loss of agricultural production. As the concentration of salt in the soil and water table increase, production declines in two ways: the yield in the problem area declines and sometimes the affected area cannot be cultivated and has to be kept fallow. Soil salinity has indirect effects as well. The resource use is severely affected in the presence of soil salinity in farms.

Joshi (1987) tried to examine the impact of mismanagement of surface irrigation on land degradation and also tried to assess the direct and indirect socio-economic losses of land degradation.

Since data on land degradation and its consequences is hard to come by, Joshi based his analysis on data collected through primary surveys. A survey conducted in village Demol in Kheda district of Gujarat showed that the productivity of important crops like rice and wheat declined as salt concentration increased. Same results were obtained for Gauriganj block of Sharda Sahayak command area.

To examine the short-term economic losses in the presence of soil salinity, a study was carried out in four villages of Gohana region of Sonepat district of Haryana in 1984-85. It was observed that farms with soil salinity problem had considerable fallow land and this reduced their net-cropped area. The farms with salinity problems also had a lower cropping intensity of 149 percent as against 192 percent in problem free farms.

The resource use is adversely affected in the presence of soil salinity in farms. It was estimated that for two crops, rice and wheat, there is a negative relationship between resource use and salinity. The use of fertilizer decreases by 9.78 percent in case of rice and 16.38 percent in case of wheat as the extent of salinity increases by one hectare. Similarly, the use of irrigation declines by 2.86 percent in case of wheat and 26.8 percent in case of paddy, as the extent of salinity increase by one hectare in the farm. The corresponding figures for labor utilization are 5.73 and 6.29 in case of paddy and wheat respectively.

To examine the effect of salinity and response of different factors namely fertilizer, labor, irrigation and other expenses on the productivity of paddy and wheat, a Cobb-Douglas production function was estimated. It was observed that productivity of wheat declines by 8.57 percent and that of paddy by 4.83 percent in farms witnessing salinity. It was assumed that the responses of different factors of production would remain the same in both the categories of farms as the estimated production function represents normal soils.

The recommended strategies for avoiding salinity are horizontal drainage, conjunctive use of irrigation water, canal lining, on-farm water management and organizational change. Dhawan (1995) also tried to assess the amount of land degradation due to problems related to canal irrigation. His findings were as follows. Land degradation due to salinity and waterlogging is small compared to other forms of degradation. It is hardly one-tenth of total degraded land. At least half the land affected by waterlogging and salinity is due to natural reasons. Among the manmade factors, the development of canals, roads, railways and flood protection embankments along rivers are the major factors, though canal is a pre-dominant factor. Nearly one-fourth of the Culturable Command Area (CCA) of all canal projects taken together is suffering from land degradation. That is, a little under 6 million hectares out of total CCA of 24 million hectares are degraded and need remedial action. For reclaiming 6 million hectares of already affected area, we need at least Rs.6000 crores.

Chopra (1987) studied the interrelation between, irrigation, fertilizer use and land degradation in a district level analysis for the state of Punjab. In his analysis, the dependent variable was saline and waterlogged land as percentage of geographical area, while the explanatory variables were volumetric supply of canal water per unit of cultivated area, rainfall, number of tubewells per hectare of NSA and consumption of fertilizer per hectare of cropped area. Two linear regression models were set up to test the hypothesis that land degradation depend on the variables listed above. The models pooled time series data for three sets of years, 1969-70 to 1971-72, 1977-78 to 1979-80 and 1982-83 to 1984-85. In the first instance an OLS model was set up for each set and an F-test is conducted to ensure that the pooling is in order. Later, a WLS regression was run by defining the weights as,

$w_i = y_i (1 - y_i)^{½}$ and then regressing y_i/w_i on x_i/w_i,

where, w_i = weights used as defined above

y_i = estimated values of yi from OLS estimates

y_i, x_i = dependent and independent variables respectively.

The results of both specifications were reasonably acceptable. While the variables rainfall, volume of canal water and level of fertilizer use, lead to increases in land degradation, the number of tubewells per hectare reduces land degradation by lowering the water table. In the OLS specification, the volume of canal water per hectare and fertilizer use are significant at 5 percent level and number of tubewells is significant at 10 percent level.

From the results Chopra concludes that new agricultural technology characterized by water fertilizer intensive agriculture had second round effects. It was just circumstantial that the accelerated investment in tubewells has offset some of these effects. One cannot however in planning for large irrigation systems depend on such fortuitous happenings. Detailed projections of environmental impacts should form a part of planning exercise.

In India canal irrigation is now giving way to groundwater irrigation. Although groundwater is a mineral resource it has some unique characteristics not possessed by other minerals. The uniqueness lies in its dual dimensionality of having both stock and flow aspects. While the stock is equal to the volume of water available underneath the land at any point of time, the flow dimension is the annual change that occurs in the groundwater stock. In hydrological parlance, this replenishment is known as groundwater recharge, which stems essentially from rainwater infiltration. There are two components of rainwater infiltration. By force of earth's gravity the infiltrated water moves downward the soil. A good deal of water remains in the crop root zone (about 1.5m of soil profile) and is known as soil moisture needed for meeting water needs of crops. This soil moisture is not counted as ground water resource for irrigation purpose. Only that portion of infiltrated water, which travels or percolates down to the groundwater table is deemed as groundwater resource or recharge which can be extracted for irrigation and non-irrigation purposes. Rainfall itself being a periodic phenomenon, groundwater recharge also becomes a periodic phenomenon.

Technically, groundwater resource can be deemed to be in a depleted state when groundwater stock in a region diminishes in volume. This would arise if groundwater use or withdrawals in a year exceed groundwater recharge of the year. In the reverse situation, the stock may not increase if the excess of recharge over withdrawal gets dissipated through natural discharge from groundwater aquifers, say through subterranean outflow to a nearby river.

Dhawan (1995) assessed the groundwater situation using the volumetric measure data. He found out that groundwater depletion had affected hardly 4 percent of our districts. If we consider variation in the size of these districts, as reflected by their groundwater endowment, we find that the combined share of groundwater recharge of the dozen over exploited districts to be hardly 3 % of the utilizable groundwater recharge. However, the state of Punjab has full exploitation of groundwater resources. Six districts of Punjab are facing groundwater depletion.

An increase in the cropping intensity and production leads to continuous drainage of soil nutrients. Loss of soil nutrients, if not substituted by other means leads to further land degradation. It has been calculated that in Indian agriculture, the consumption of fertilizers is not in tune with the loss in soil nutrients.

On the other hand, there has been increased concern over the use of chemical fertilizers, especially nitrogen-based fertilizers. One of the effects of extensive use of fertilizer is the contamination of groundwater supplies.

Only nitrogen fertilizers are harmful as far as groundwater contamination is concerned. Nitrogen fertilizers, applied in any form are rapidly converted to nitrates by soil organisms. Nitrates are highly soluble in water and move down along with it up to the groundwater. According to WHO standards, water containing more than 10 ppm (parts per million) of nitrogen is unfit for infants. When human beings or animals drink this water, nitrate readily gets reduced to nitrite, which converts hemoglobin in the red blood cells into methaemoglobin. The latter complex cannot transport the needed oxygen to the blood tissues and a condition similar to asphyxiation occurs which can even cause death. Convincing evidence that nitrate originating from fertilizers accumulated in shallow groundwaters is available in studies carried out in the developed countries (Nightingale, 1972; Miller and Nap, 1971).

In Punjab, Singh and Sekhon (1976) found that in Ludhiana district, where nitrogen fertilizer rates are the highest in the country, nitrate concentration in well water decreased significantly with the depth of the water table and correlated positively with the amount of nitrogen added per unit area per year. Although they found a very low mean rate of nitrate-nitrogen level in the groundwater, it was predicted that with the existing fertilizer application rates and management practices in Punjab, very high nitrate levels in the groundwater may occur in the coming years.

Singh, I. P, Singh, B., Bal, H.S. (1987) analysed the status of nitrate pollution of groundwater vis-a-vis the pattern of fertilizer use in Punjab. The data is collected for rice and wheat only as these are the major crops in the state. Only Central Punjab is taken as the sample since data on nitrate pollution is available for this area. The data pertaining to fertilizer nitrogen use and production of wheat and paddy were collected under "The Comprehensive Scheme to Study the Cost of Cultivation of Principal Crops in Punjab" for agricultural years 1971-72, 1981-82 and 1985-86.

The results obtained from the study showed that per hectare use of fertilizer nitrogen for both wheat and rice had increased much in the given period. The use of fertilizer in these two crops had been consistently higher than the average consumption of fertilizer for the state as a whole. From the values of the coefficient of variation it was clear that the differences in fertilizer use by different farmers had narrowed down by the passage of time. The mean fertilizer nitrogen use in paddy was much higher than the dose recommended by Punjab Agricultural University scientists in the region.

The Nitrate level in the water samples collected from wells in the cultivated area of the study zone was determined both in 1975 (Singh and Sekhon, 1976) and 1982 (Singh and Sadana, 1987). In these studies it was indicated that mean values for nitrate-nitrogen contents during the year 1982 had increased to 2.36 ppm (parts per million) before the advent of monsoon season over its corresponding value of 0.99 ppm in 1975. This increase was still more after the monsoon rains and growing of paddy. It was 3.88 ppm in 1982 as against 1.02 ppm in 1975. The range of actual values show that in 1975 there was no groundwater sample in which nitrogen nitrate contents were more than 10 ppm. But in 1982 roughly 10 percent of the samples contained the chemical above the permissible standard. This trend coupled by the two to four fold increase in the mean nitrate-nitrogen level showed the seriousness of the problem of groundwater pollution as it is linked to the use of nitrogen fertilizer in coarse textured irrigated agricultural lands of Punjab.

According to the authors, increasing trends in bringing land under paddy cultivation and applying higher doses of nitrogen fertilizer to wheat and paddy are not likely to change. Paddy requires frequent irrigation in coarse textured soils of the study area resulting in intensive leaching of nutrients beyond the root zone of crops leading to still higher levels of nitrogen in the groundwater. Efforts should be made to judiciously use fertilizer so that leaching beyond the crop root zone is minimized. Otherwise the consequences of groundwater being polluted can be imagined from the statement of Viets and Hageman (1971): "The rate of water recharge from deep percolation is so slow that the possible nitrate pollution of aquifers from our modern technology will take decades. However, once nitrate gets into aquifer, decades will be required to replace the water with low nitrate water." [As quoted in Bal and Singh (1987)]

Increased and indiscriminate use of pesticides also poses the risk of health hazards. The pesticides may leach into the soil and pollute waterbodies. Cropping pattern and crop rotation may also have adverse environmental effects. Cropping pattern is getting more and more biased towards crops which uses up more and more soil nutrients. This may be due to the institutional impetus provided for such crops. Cropping patterns are now determined by the profitability and marketability of crops and are not naturally determined according to agro-climatic situations. For example increasing production of paddy in the irrigated lands of Punjab and Haryana are accentuating problems of waterlogging and soil salinity. Paddy cultivation has also picked up in Tamil Nadu, in spite of the semi-arid agro-climatic conditions of the state.

Decreased crop cycle has also decreased the fallow period of land. Continuous cropping does not allow for natural rejuvenation of soil nutrients. Faulty and unscientific crop rotation practices add up to the problem.

3.3 The M. S. Swaminathan Research Foundation (MSSRF) Environmental Sustainability Index: A Methodological Appraisal

The MSSRF has computed an environmental sustainability index for agriculture and ranked the sixteen major Indian states accordingly. This is part of their study on food security, and environmental problems are discussed in that context. Environmental degradation, soil salinity and climate change are long term threats to sustained productivity and hence are potential causes for food insecurity. "Potential food insecurity may arise out of unsustainable livelihood and production practices. These lead to deforestation and degradation, soil erosion, desertification, etc. Sustainability is not limited to food production but includes environmental sustainability, which is essential for long term viable crop and animal production." [Food Insecurity Atlas of Rural India, pp. 16]

They define the term sustainability as "the use of natural resources or the application of a practice or technology in a manner in which the long-term net impact on natural resources is not negative. In other words, we must use only as much natural resources as can be replenished." [pp. 17] On the basis of this definition they construct four sustainability indices each represented by a single indicator. The four indices are:

1. Sustainable land use index represented by the indicator area under forests as a percentage of the geographical area of the state.
2. Sustainable water use index measured by the level of groundwater exploitation represented by net draft as percentage of net available groundwater for irrigation.
3. Sustainable cropping pattern represented by area under leguminous crops as percentage of gross cropped area.

4. Sustainable technology indicator measured as total degraded land as percentage of the geographical area.

To make the indicators unidirectional, the area under non-forest and non-leguminous crops are taken in the indicators.

First, individual indices are computed for each indicator. Individual indices were calculated as a distance function measuring the distance of the individual states

$I_s = \Sigma_i \{(X_{ij} - X_{imin}) / (X_{imax} - X_{imin})\} * 100$

Where, I_s : Index of sustainability

X_{ij}: ith sustainability index for the jth state

X_{imax}: ith sustainability index for the maximum state

X_{imin}: ith sustainability index for the minimum state

i = 1,2,3,4 sustainability indices

j = 1,2,....,16 major states

The composite index is the simple unweighted average of the four sub-indices.

According to the values of the sustainability index, the states are ranked. The higher the value of the composite index, the worse is the condition of the state in terms of environmental quality.

However, this index can at best be called a partial index for environmental sustainability of agriculture. The main reason for this is that one major component is missing in this index: the component of agricultural production. What we mean by environmental sustainability in the context of agricultural production is that, in the process of production, the states should not deplete or over-use their natural capital. Put in other words, there should be efficient use of natural capital. So it is very important to bring in agricultural output in the frame to get a complete picture. This index does not say anything about production. Let us take the example of Rajasthan and Gujarat for instance. These states rank third and fifth respectively in terms of environmental sustainability index. But if we take agricultural production or yield into account, they are not the major producers in terms of foodgrains. Hence these two states are depleting their natural resources even without any production. So how do we place them now against Punjab and Haryana who are producing foodgrains at the expense of their environment? The common sense judgement would say Rajasthan and Gujarat are more unsustainable than Haryana and Punjab. Such nuances cannot be captured in terms of this index. That is why we argue that this index is at best a partial index of sustainability.

It needs a more technical discussion to point out the weaknesses of this ordering. There is substantial amount of confusion in the selection of indicators. When we choose some variables to reflect a component of the overall phenomenon under the analysis, we should be careful about a few things. As mentioned in the previous chapter, a good indicator should be pertinent and should cover evenly all aspects of the phenomenon in question.

The task of selecting the component indices and the representative variables becomes very difficult in the case of environmental problems. There are a lot of inter-connectivity and inter-dependence among the variables which makes it extremely perplexing to arrive at independent components represented by a set of independent variables. So, in the case of environmental indicators it is essential to distinguish between the process indicators and outcome indicators. If we tend to put them in the same basket, the problem of double counting is bound to arise. Let us take the sustainable technology indicator – land degradation. Does land degradation actually give a complete picture of the technology in use? Canal irrigation is a major cause of waterlogging and salinity, but appropriate land use also affects land degradation. That is why we see a significant positive linear correlation between the two variables, non-forest area and degraded land (both as percentages of geographical area). These two indicators are thus not independent and hence the components become linearly dependent. On the basis of this result we may further argue that sustainable land use is a component of sustainable technology and so sustainable land-use, as a separate indicator is redundant. The indicator non-forest area and level of groundwater extraction are also highly correlated though there may not be any scientific reasoning behind it. But it all the more validates our view that non-forest area should be dropped as an independent component. Next we come to the indicator of sustainable cropping pattern. The same thing can be said about this indicator, it is in fact a component of sustainable technology. Ultimately, unscientific cropping pattern also leads to land degradation. Though this correlation is not clear statistically mainly because these processes may take a long time to manifest themselves, but intuitively it is pretty convincing.

Ultimately we can thus zero down to two components: degraded land and the level of groundwater extraction. Instead of defining them as ambiguous process indicators, we would prefer to define them as the two sustainable resource use outcome indicators. Any discrepancies in the processes will be reflected in these outcome indicators. But this index will also suffer from the weakness of stationarity, which is also pertinent in the MSSRF index. It will reveal the state of the environment at a particular point of time, it cannot quantify the direction of change. It can be said that taking the values of the indicators at two time periods can indicate the direction of change, which is of course true. But the problem lies in the fact that, environmental problems take a long time to become visible and in most cases, when they do become visible, it is too late. When land is already degraded or water table has already fallen, remedial measures become expensive and the reversal process is equally slow. So it is essential to identify environmental problems fast and take preventive measures. Here lies the importance of the process indicators.

Once the ambiguity regarding the choice of indicators is resolved, we deal with the next question, that of computing the sub-indices. We have to bring the indicators to a common denominator so that they can be aggregated into a composite index. The MSSRF has used a distance function to do so. Here all the indicators chosen are in percentages, which being pure numbers within a definite uniform range did not require any further transformations to club them into a common index. If the use of distance function is to show the distance from the best state, we have already discussed in our Chapter 2 that such relative rankings are not appropriate in case of environmental indicators. We should rather look at the distances from some threshold values.

Taking a look at the indicators chosen by MSSRF, for three of the four indicators can have some sort of threshold levels. In case of forest cover, officially 33 percent forest cover is taken as desirable and is the planned target of the Ministry of Environment and Forests. But, the data shows that only three states (Orissa, M.P and Assam) show forest cover of 33 percent, the rest of the states are all thus in the unsustainable zone. In case of groundwater exploitation, an upper limit of 65 percent extraction is considered as safe by the Central Groundwater Board. Any extraction beyond 65 percent is termed semi-critical while that beyond 85 percent is termed critical. Except Punjab and Haryana, no other state shows any sign of danger in this context. In case of land degradation, any amount of land degradation is a severe problem and so the maximum and minimum limits should be 0 percent to 100 percent. In case of cropping pattern it is difficult to arrive at such a cut-off point. In any case, the crux of our argument is that if formulation of a distance function is necessary, the cut off points should be on some theoretical basis. Sustainability, after all is not a relative concept. So there is no meaning in making relative comparison among the observation points.

Also, the distance function is a linear function. As we have discussed in Chapter 2, in case of environmental indicators, a convex function may be more relevant.

Once the individual index numbers are calculated, the problem of aggregation arises. In the index we are discussing, a simple average is used to transform the individual indices to a composite form. The assumptions behind such aggregation are as follows. All the components are equally important so that they have equal weights and the components are perfectly substitutable among themselves. The second assumption may have far reaching implications in case of environmental indicators. Let us consider the indicators degraded land and groundwater exploitation. Perfect substitutability implies that land and water are substitutable. But that is not the case. We cannot have agriculture on degraded soil even if we have adequate water and neither can we have agriculture without water even when the soil is fertile. So this assumption is not valid in case of environmental indicators. In terms of productivity there may be some substitutability in the sense that we may get some yield in degraded land when there is adequate supply of water or a fertile area can yield crops even when irrigation is low. In either case the elasticity of substitution is likely to be low, lower than unity but never infinite.

So keeping these things in mind, the next logical step in our analysis would be to try to develop an alternative index.

3.4 Building up Alternate Indices

At the outset let us first distinguish between two phenomena – outcome and process. Because of the inter-relationships involved, if we do not differentiate between the two there may be a risk of double counting. So it would be a good idea to work out two indices, a process index and an outcome index.

The outcome index here would be the total degradation index. It shows how bad the environmental quality is at this point of time. It does not say much about the sustainability of the agricultural process. A region may not be very degraded at present but it may be using its resources in way that may accentuate the degradation problem in the near future. Such a system is not degraded but it is unsustainable. So while the degradation index shows the current level of degradation, the process index or sustainability index will indicate the direction of change for the region.

3.4.1 The Degradation Index

Selection of Indicators: The degradation index consists of two components: land and water. The land component consists of only one indicator, area of degraded land. There are two types of data related to land degradation. The Ministry of Agriculture estimates total degraded area at the state level. Degraded land, as defined by the ministry is land susceptible to water and land erosion and these estimates are based on the data on rainfall, humidity, terrain, soil type, wind movements etc. These are referred to as problem areas, which are likely to be degraded in the future, even though they may be in productive use at present. The Ministry of Rural development, on the other hand, collects data on wastelands. Not all wastelands are degraded land. Uncultivated area, lands left with natural habitat are also referred to as wastelands. So wasteland refers to area not in use, while degraded land may still be in some use. For this reason the estimates of degraded area are higher than estimates of wasteland. The ministry of agriculture data, till very recently, did not exactly specify the type of problem faced; it just specified two categories - soil erosion and land degradation. Attempts are being made now to classify this data further according to various types of degradation. Wasteland data on the other hand, gives a much more detailed break-up. The two data sets are highly correlated. In the formation of indices we are much more concerned about the rankings than the actual value of the variables. Hence, whichever data we take is not going to change the rankings by substantial amount.

The water index comprises of two components: the stock of water and the flow. The stock index tries to throw light on the state of the water stock in the region. Data is available on the number of districts that have experienced a fall in the water table for each year. The data is categorized in two classes, districts with a fall in water table of 2 metres to 4 metres, and districts where water table has fallen below 4 metres. It would be interesting to bring in some type of weighing factor to capture the varying intensities of water table depletion, but here we have only taken the total number of districts that have experienced fall in water table beyond 2 metres.

The data on the flow aspect of groundwater are compiled by Central Groundwater Board. It offers two estimates: 1) Volume of annual groundwater recharge or replenishment and 2) volume of annual groundwater draft or withdrawals. Over-exploitation arises when withdrawals tend to exceed replenishment. This data is available at the block level and the state level. At the state level, the volume of groundwater withdrawal as a percentage of volume of annual groundwater recharge is termed as the level of groundwater development. This gives a widely aggregated picture of the use of water resources by the states. At the block level, a block is said to be 'critical' if it withdraws over 85 percent of its replenishable water resources and 'over-exploited' if it withdraws over 100 percent of its replenishable water resources. This block level data helps to capture the local dimension of water use. Agriculture may be concentrated only in a few districts in a state where water is used intensively. At the overall state level the intensity of water use in these few districts may not be reflected by the level of groundwater development. But the number of over-exploited and critical blocks will reflect the water use pattern. The following table gives a comparison of the two figures.

Table 3.1 Indicators for Groundwater

States	*over exploited & critical blocks[1] (percentage)*	*level of groundwater development[2] (percentage)*
Andhra Pradesh	2.36	23.64
Assam	0	4.48
Bihar	2.04	19.19
Gujarat	15.22	41.4
Haryana	37.96	83.88
Himachal Pradesh	0	18.04
Karnataka	9.14	31.26
Kerala	0	15.28
Madhya Pradesh	0.65	16.49
Maharashtra	3.46	30.39
Orissa	2.55	8.42
Punjab	60.14	93.85
Rajasthan	39.83	50.63
Tamil Nadu	26.82	60.44
Uttar Pradesh	4.88	37.66
West Bengal	0.29	24.18
s.d / mean	1.44	0.74

[1] Data relates to 1998, Source: www.indiastat.com
[2] Data relates to 1992-93, Source: Food Insecurity Atlas of Rural India, MSSRF

There is no direct relationship between the two measures of groundwater use. Let us look at the cases of Rajasthan and Tamil Nadu. Rajasthan with a lower level of groundwater development has a higher percentage of critical and overexploited blocks. Similar arguments can be extended to the case of West Bengal and Orissa. While either of the indicators can be chosen for capturing the phenomenon of water use, we would prefer the percentage of critical and over-exploited blocks as a better indicator for two reasons. Firstly, groundwater depletion is a problem very specific to a locality and this indicator captures this local level effect. Secondly, the variation in this indicator is higher than the variation in groundwater development (the coefficient of variation is given in the last row of the table). So, this will be a more sensitive indicator while we rank the state.

Computation of Sub-indices: Once the indicators are chosen, we can now proceed to develop the sub-indices. For reasons argued in the previous section, we are not in favor of choosing a distance function to transform the indicators into an index. Our objective is not to measure the distance between the best and worst states but to give an absolute figure representing the level of degradation in every state. The figures in our analysis are in percentages and so within a common range 0 to 1. Hence, these percentages themselves can be taken as the index numbers for every component.

In case of water resources, we have two indicators. The index can be taken as an un-weighted average of these two indicators (which are again percentage figures and thus require no transformation). If s and f are the stock and flow indicators, the water resource index is simply,

$I_W = ½ (s + f)$

Aggregation: The aggregation is done using an unweighted power mean of order three. The Resource Degradation index is given by,

$I = [½ (I_L^3 + I_W^3)]^{1/3}$

Where, I_L is the land degradation index, and I_W is the water depletion index.

Power means have some desirable properties which may reflect the environmental problems better than a simple mean. These properties are already discussed in our Chapter 2. We have taken the mean of order three, which is a fairly high value. This brings out two features in the index. If any one of the components (say land) has a very high value, the composite index will also take a very high value even if the groundwater index shows a low value. It supports the intuition that if land quality is too bad, even with adequate water resources we cannot have a high yield in agriculture. The power transformation also reflects an increasing function and the components are not substitutable among themselves. The elasticity of substitution in this transformation is ½, thus the components are inelastic. This implies that land and water are substitutable to some extent but to get the same yield from degrading land, the use of water should be proportionately higher.

Now let us take a look at the rankings of the states according to the resource degradation index.

Table 3.2 Resource Degradation Index

States	*Degraded area*	*Over-exploited and critical blocks (1998)*	*Fall in water table (1998-99)*	*Resource Degradation Index*	*Rank*
1	2	3	4	5	6
Andhra Pr	0.3879	0.0236	0.3043	0.0105	7
Assam	0.3523	0	0.2609	0.0077	6
Bihar	0.283	0.0204	0.1622	0.0039	3
Gujarat	0.4962	0.1522	0.64	0.0307	13
Haryana	0.7568	0.3796	0.2105	0.0765	15
Himachal Pr	0.275	0	0.0833	0.0035	2
Karnataka	0.392	0.0914	0.2222	0.0107	8
Kerala	0.3723	0	0.5	0.0112	9
Madhya Pr	0.348	0.0065	0.7174	0.0149	12
Maharashtra	0.2889	0.0346	0.3143	0.0049	5
Orissa	0.4458	0.0255	0.1667	0.0149	11
Punjab	0.4293	0.6014	0.3529	0.0313	14
Rajasthan	1	0.3983	0.8125	0.2036	16
Tamil Nadu	0.1421	0.2682	0.1724	0.0023	1
Uttar Pradesh	0.2977	0.0488	0.1571	0.0046	4
West Bengal	0.4266	0.0029	0.2632	0.0133	10

Note: For column 2 the data source is Indian Agriculture in Brief, 2000 (Ministry of Agriculture, Government of India)
For columns 3 and 4, the data source is www.indiastat.com. Original Source: Central Water Authority.

Column 5 of the above table gives us the values of the resource degradation index. Column 6 gives the rank of the states. The ranks are so assigned that the state with the lowest level of degradation is ranked first. According to this index, Tamil Nadu stands first, followed by Himachal Pradesh, Bihar and Uttar Pradesh. Rajasthan, Haryana, Punjab and Gujarat are the worst states. These rankings are quite different from the rankings done by MSSRF. Comparisons of the rankings are given in the following table.

Table 3.3 Comparison between Degradation Index and MSSRF Index

States	*rank of degradation index*	*rank of MSSRF index*	*rank difference*
Andhra Pradesh	7	3	4
Assam	6	5	1
Bihar	3	8	-5
Gujarat	13	12	1
Haryana	15	16	-1
Himachal Pradesh	2	10	-8
Karnataka	8	6	2
Kerala	9	3	6
Madhya Pradesh	12	1	11
Maharashtra	5	6	-1
Orissa	11	2	9
Punjab	14	15	-1
Rajasthan	16	14	2
Tamil Nadu	1	9	-8
Uttar Pradesh	4	11	-7
West Bengal	10	13	-3

It is observed that for the states with high values of the index, there is no large difference in ranks. But the differences in ranks occur for the states in the lower and middle range. Madhya Pradesh, which ranks first in the MSSRF index, is ranked 12th in our index. Tamil Nadu which ranks first in our index ranks 9th in the MSSRF index. Rank reversals can also be seen in the case of Orissa, Uttar Pradesh, Bihar, Himachal Pradesh, and Kerala. Now, how do we explain these rank reversals?

3.4.2 Interpretation of Results

The main difference between our index and the MSSRF index is the elimination of two process-based indicators, forest cover and cropping pattern. What we intended to do was to differentiate between the process of degradation and the current level of degradation. The MSSRF index clubs these two aspects together. But the presence of the two process indicators in the index can throw some light on the direction the states are headed towards. For example, let us take the case of Tamil Nadu. Its degradation index is 1, it is the least degraded state. But it ranks 9th in the MSSRF index. This gives us some indication that though Tamil Nadu is not degraded at present, but because of the resource use pattern and other processes adopted by the state, it is in the potential danger of degradation in future. Same interpretations can be made for Madhya Pradesh. It is quite degraded at present but there is a positive resource use pattern, which makes it more sustainable.

The last column of the table shows the differences in ranks between the degradation index and MSSRF sustainability index. The states where the difference is positive are the states where degradation is high but the resource use is sustainable which makes it less susceptible to degradation in the future. The states where the difference is negative are not presently degraded but are in the danger of being degraded in the future. Special attention should be paid to these states in terms of policies to carefully study the practices that are followed in these states and take appropriate measures to correct them. But again, we would like to emphasize that the MSSRF index can only give some indication for the direction of change, it cannot be taken as a complete sustainability index. It takes into account only two factors and both these factors relate to land degradation. To arrive at a fuller and more meaningful sustainability index we have to device some other methods and then the comparisons between degradation and sustainability becomes more accurate and meaningful. All the same, the divergences in these preliminary ranking exercises give support to one of our major arguments that we need separate indices for degradation and sustainability; we cannot put the process and outcome indicators in the same basket. It also justifies our next step of analysis, computing sustainability indices.

So far we have only analyzed the resource degradation index. But we should put the question of resource degradation in the wider context of agricultural sustainability. So it is very important to bring in the third component of our index: production of foodgrains. A legitimate question that may arise at this point is, why only foodgrains? We may extend two explanations for this. In terms of soil degradation and loss of soil fertility, foodgrains are more important than non-foodgrains. Crops like cotton, rubber, tea, coffee remain planted to the soil all year through thus reducing chances of soil erosion. For these crops since the part that is removed from the plant for human use is very minimal, so it does not account for loss of nutrients. But in case of foodgrains, the entire crop is removed from soil after harvest thus removing all soil nutrients along with it and accentuating land degradation. Foodgrains cannot hold on to soil to minimize soil erosion and once the crop is harvested, it loosens the soil making it more susceptible to erosion. The problems related to irrigation are also largely associated with foodgrains. So production of foodgrains fairly well represent the land related problems. Secondly, from the welfare context production of foodgrains is more important in terms of food-security. In the presence of a public distribution system and inter-state trade in foodgrains, it may not be very meaningful to talk about self-sufficiency within the state. In spite of that, we may assume a positive relationship between availability and access. And in any case, is it desirable that the nation's entire food requirement is met by a few states at a very high environmental cost? In our view, may be not. It is time to take a fresh look at our agricultural policies.

Again, for the sake of comparison among the states, it is necessary to standardize the indicator of foodgrains production in a comparable unit. We formulate our index as 'production of foodgrains per unit of geographical area'. This standardization takes into account two types of effects, the productivity effect and the area effect. That is because,

$$\frac{Production}{GeographicalArea} = \frac{Production}{TCA} * \frac{TCA}{NSA} * \frac{NSA}{GeographicalArea}$$

Let us clarify it further. If a state (take the example of Kerala) has high productivity of foodgrains (production per hectare), there is a chance for high soil degradation. But at the same time, the cultivated area as a percentage of geographical area is small. So this degradation will be only in a few pockets of the state. The standardized variable will thus be smaller for a state like Kerala with high yield but low area cultivated than a state with high yield and a high percentage of area cultivated. That is the reason why we chose not to take yield itself as the standardized variable. This would put a state like Kerala at a ranking at par with Punjab, though Kerala is not a major producer, nor is agriculture the dominant activity there.

Due to differences in the nature of the degradation indices and the production index, it is difficult to aggregate them into a single index. The degradation indicators are all in percentages and thus take a value within the range 0 to 1, while the production indicator can take any value. Also, they are characteristically different and work in different directions. So before trying to club them into a single index we should take a more judicious look at the problem. The following table tries to illuminate certain features.

Table 3.4 Degradation Index and Foodgrain Index

States	*Degradation index*	*foodgrains index**	*rank di*	*rank fi*	*rank difference*
Andhra	0.0105	0.5419	7	7	0
Assam	0.0077	0.4378	6	10	-4
Bihar	0.0039	0.7837	3	5	-2
Gujarat	0.0307	0.284	13	14	-1
Haryana	0.0765	2.7421	15	2	13
Himachal	0.0035	0.2678	2	15	-13
Karnataka	0.0107	0.5212	8	8	0
Kerala	0.0112	0.1941	9	16	-7
Madhya	0.0149	0.4398	12	9	3
Maharashtra	0.0049	0.4145	5	11	-6
Orissa	0.0149	0.3721	11	13	-2
Punjab	0.0313	4.5484	14	1	13
Rajasthan	0.2036	0.3782	16	12	4
Tamil Nadu	0.0023	0.7242	1	6	-5
Uttar Pradesh	0.0046	1.3728	4	4	0
West Bengal	0.0133	1.6188	10	3	7

* Data relating to foodgrain production is obtained from Indian Agriculture in Brief, 2000.

In this table the foodgrains index is simply the production of foodgrains per unit of geographical area. The ranks for the foodgrains index are assigned such that the first rank is given to the highest producer. The point to note is that there is no direct relationship between the two indices. This means, it is not necessarily true that all the agriculturally developed states are doing badly on the environmental front. In the absence of a linear relationship, it is difficult to make much sense from the rank differences. To give a clearer picture, we have divided the states into four subgroups.

Table 3.5 Classification of States according to Degradation and Foodgrain Index

	Low FI	*High FI*
Low DI	Assam, Himachal Pradesh	Andhra Pradesh, Bihar, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh
High DI	Gujarat, Kerala, Madhya Pradesh, Orissa, Rajasthan	Haryana, Punjab, West Bengal

In the classification of 'High' and 'Low' we have used the median values of degradation and foodgrains production as the benchmark. High FI states are those for which the foodgrain production index is higher than the median value, i.e. 0.480494; low FI states have a index value below it. Similarly, high DI states have an index value above the median value of 0.0109. Of course, this classification is totally arbitrary and cannot say anything about the absolute degree of degradation or production. It just throws some light on the relative positions of the states.

The most vulnerable states in terms of sustainability are the ones with high degradation but low production, viz. Gujarat, Kerala, Madhya Pradesh, Orissa, and Rajasthan. Even these states are not a homogeneous category, because they fall in different agro-climatic regions. Gujarat and Rajasthan fall in the desert region of India and much of the degradation is natural. Trying to improve production may aggravate the condition further. In fact, technology based intensive farming practices may not be appropriate in these states. The present price policies that induce such kind of practices may be aggravating the conditions in these states.

On the other hand, it may be easier to handle degradation problems in Kerala, Madhya Pradesh and Orissa and there may be greater potential to increase production in these states as well.

The states with low degradation and high production may be called the 'ideal' states. But we cannot be complacent about the fact either. Here again the question about the sustainability becomes very important. We have to study the resource use pattern in these states to assure that they maintain their positions. If they are overexploiting their resources they can become degraded in the near future and that has to be resisted.

The three most productive states, Punjab, Haryana and West Bengal also show signs of high degradation. This fact makes it imperative for us to take a second look at the agricultural policies we have pursued so far from the sustainability perspective.

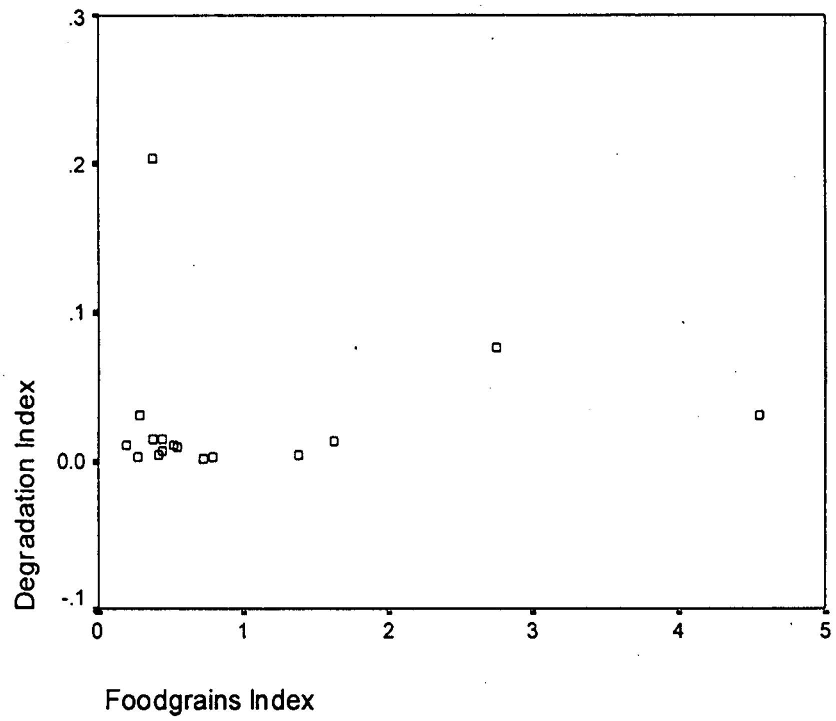
Another way to look at the issue is by looking at the cost benefit ratios. In the next table we have computed the ratio of the two indices; DI / FI. If this ratio is high that means the state is paying too high a price compared to the benefit it receives. The states are ranked according to this ratio and tabulated in ascending order, i.e. the state, which secures the most benefits at least cost ranks top.

Table 3.6 Aggregating Degradation and Foodgrain Index

STATES	*DI / FI*	*RANK I/F*
Tamil Nadu	0.003121	1
Uttar Pradesh	0.003336	2
Bihar	0.004982	3
Punjab	0.00688	4
West Bengal	0.008236	5
Maharashtra	0.011831	6
Himachal Pradesh	0.01299	7
Assam	0.017491	8
Andhra Pradesh	0.019308	9
Karnataka	0.020494	10
Haryana	0.027907	11
Madhya Pradesh	0.033943	12
Orissa	0.040086	13
Kerala	0.057713	14
Gujarat	0.108175	15
Rajasthan	0.538422	16

This table conforms to the general pattern revealed in the previous table. But something interesting also catches our attention. The states Punjab, Haryana and West Bengal have high degradation and high foodgrain production. But when we compute the cost benefit ratio we see that Punjab and West Bengal pay a lower cost (in terms of degradation) for its benefits compared to Haryana and also many other states which actually have a high production and low degradation. Actually, if we see the scatter plot of degradation index versus the foodgrain index we see a heavy clustering of the states with a few outliers like Punjab, Haryana, Rajasthan, Uttar Pradesh and West Bengal. The question of how much degradation we can afford for our production is very crucial here. Where do we draw the line and more importantly, on what basis do we draw the line? The trade-off is very important here and our policies should take note of this trade-off. What are the actual positions of the states – we leave the question open ended here. For some states like Rajasthan, Gujarat, Haryana, we can give a definitive answer – "the situation is bad and requires immediate attention". For some states like Tamil Nadu, UP, Bihar, things look pretty good at present but nothing can be said about the future. States like Punjab and West Bengal leave us confused, while most other states take a middle ground. So how we place a state very much depends on our own judgements, on our own perception to how much trade-off is "optimal".

Figure 3.1 Scatterplot of states according to Degradation Index and Foodgrain Index



3.4.3 On the Process of Building up Process Indicators

The construction of process indicators becomes difficult due to the very complicated channels through which the process of agrarian production interacts with the environment. The complicated form of the relationships as well as the time lag involved in the processes makes it statistically impossible to establish any type of causal relationships. The lack of direct causal relationships makes our task of choosing the indicators to be incorporated in the index all the more difficult. The problem of assigning weights and aggregation into a single index also remains.

As the simplest way out of these complications, we have adopted the factor analysis method to reduce the several process variables into a single composite index. The process is simple and has been applied in various areas of analysis in the social sciences. We run a factor analysis exercise using principle components method. The first principle component, which captures much of the variability in the data, is used as the composite index of sustainable agricultural production. The coefficients of each variable in the first principal component are taken as weights to transform the variables into a single scalar value. The states are then ranked according to the value of this composite index.

Selection of Indicators: Simple as it may sound, there are certain conditions that have to be satisfied in the selection of indicators for factor analysis. Principal component factor analysis method for data reduction is based on the principles of correlation. The variables selected for the analysis have to be correlated to get some meaningful results for the factor analysis exercise. The method tries to club the variables that are most closely correlated into a single component. This component will represent a particular phenomenon. There will be a number of components depending on the variability in the data set.

To proceed with principal component factor analysis with a host of variables requires the variables to satisfy test for sphericity. Initially we had taken all types of data related to agricultural processes and run two tests for sphericity, the Keyser-Meyer-Oklin Measure of sampling adequacy and Bartlett's test of sphericity. The requirements are, K-M-O measure should exceed the value 0.5, while the approximate chi-square value of Bartlett's Test should be high. When all the variables are taken into account, these conditions are not satisfied. So we drop a few variables which are not fairly correlated with the other variables and run the tests again. We select those variables for which the conditions are satisfied. The final list of variables is given in the following table.

Table 3.7 List of Variables for Process Index

VARIABLE	*STANDARDIZED UNIT*
1. Fertilizer use (1997-98)	Kg per hectare of total cropped area
2. Level of groundwater development (1992-93)	% of replenishable water resources
3. Water logged area (2000)	% of geographical area
4. Salt affected area (2000)	% of geographical area
5. Canal irrigated area (1995-96)	% of geographical area
6. Well irrigated area (1995-96)	% of geographical area
7. Area under HYV (1996-97)	% of geographical area
8. Area under leguminous crops (1998-99)	% of geographical area
9. Area under water intensive crops (1998-99)	% of geographical area

Notes: Data on variables 1,5,6,7,8,9 is obtained from Indian Agriculture in Brief, 2000.
Data on variable 2 obtained from Food Insecurity Atlas of Rural India.
Data on variables 3 and 4 are obtained from www.indiastat.com. Original Datasource: Ministry of Agriculture, GOI.
Leguminous crops include groundnut, pulses and soyabean.
Water intensive crops include rice and wheat.

It is observed that only those variables are chosen which have direct bearing on the environmental processes. Some variables, which were chosen by us, for example, area under fallow, forest cover, area under green manure crops, had to be discarded to meet the test criteria. While these factors have important roles to play but since the linkages are somewhat roundabout, and hence the correlations are not statistically strong enough to be included in the analysis.

In this context it should be mentioned that water eroded area was also included in our variable list initially. But surprisingly it was found out that water erosion had a negative relationship with most of our other variables. It meant that, given the cross sectional data, water erosion was low in states where the agricultural processes were more intensive and degrading. Water eroded area also had a negative relationship with salt affected area and waterlogged area, and surprisingly enough, even with forest cover. There may be many reasons for such anomalous behavior, the most obvious being the small sample size. We are only dealing with sixteen major states and so we can expect some results, which may not conform to our intuitive logic. Another reason may be that agricultural processes do not directly cause water erosion, it degrades the quality of land which makes the land more susceptible to water erosion. Again, the weak relationship does not get properly reflected in our data set. To avoid problems of interpretation, we do not include water erosion in our analysis.

The Composite Index: Once the variables are selected, we run the principal component factor analysis exercise. The results give one major component explaining 58.64 percent of the total variation. This component is selected as our composite index for sustainable resource use. The coefficients of the unrotated component are used as weights to convert the variables to a single value. The results of the principal component analysis are given in Annexure (Table A.3.1). The resulting rankings of the states using this composite index are as follows:

Table 3.8 Ranking of States according to Sustainability Index

STATES	*SUSTAINABILITY INDEX*
Assam	21.34
Orissa	35.14
Himachal Pradesh	43.23
Madhya Pradesh	54.03
Kerala	71.07
Rajasthan	71.41
Maharashtra	82.07
Bihar	86.10
Karnataka	95.80
Gujarat	104.92
West Bengal	113.83
Andhra Pradesh	122.75
Uttar Pradesh	124.13
Tamil Nadu	154.91
Haryana	181.79
Punjab	215.51

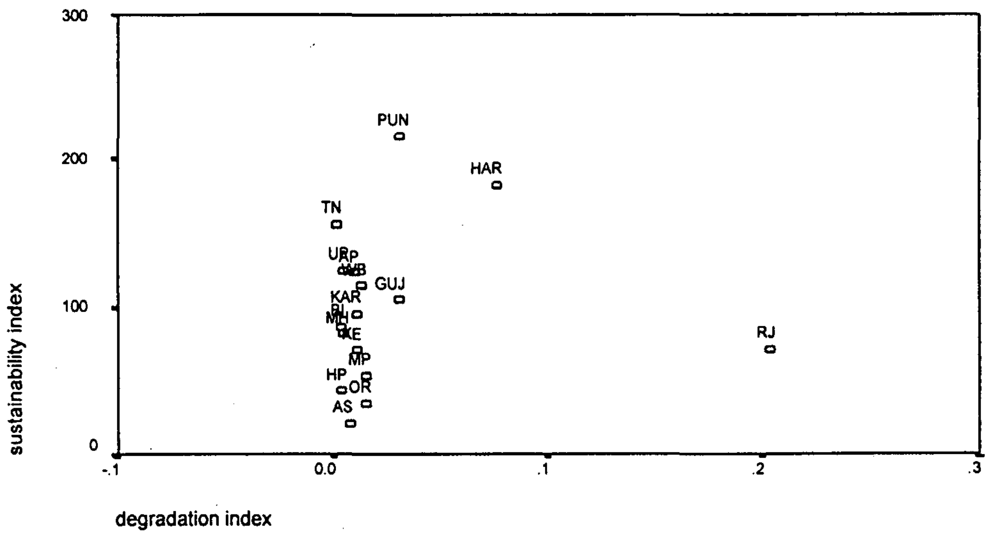
3.4.4 Interpretation of Results

Looking at the values of the composite index, we find three groups among the states. The states of Punjab, Haryana and Tamil Nadu are the highly unsustainable production systems in environmental terms. The next group of states comprises of the states Kerala, Rajasthan, Maharashtra, Bihar, Karnataka, Gujarat, West Bengal, Andhra Pradesh and Uttar Pradesh. These states are fairly unsustainable. The states with the lowest value of the sustainability index are Assam, Orissa, Himachal Pradesh, and Madhya Pradesh. These states can be said to be sustainable in their resource use.

Here it is necessary to make two kinds of comparisons. First we should compare the rankings of the states in terms of the degradation index and the sustainability index. Second, as we had already done in our degradation index, there should be some comparison between production sustainability and environmental sustainability.

Degradation Index and Sustainability Index: Let us first take a look at the scatter plot of the degradation index and sustainability index.

Figure 3.2 Scatterplot of States according to Degradation Index and Sustainability Index



The degradation index shows that most of the states clustered together at the same range of values with few outliers like Haryana and Rajasthan. At the most we can subdivide the states into three groups: Rajasthan in the most degraded category; Haryana, Gujarat, and Punjab in the second category; and the rest of the states in the final not so degraded category. The sustainability index on the other hand gives three clusters. This tells us a very interesting story. But before we move into that, let us take a look at the comparative rankings of the states.

Table 3.9 Rank Differences between Degradation Index and Sustainability Index

States	*Degradation Index (DI)*	*Sustainability Index (SI)*	*Rank of DI*	*Rank of SI*	*DI - SI*
Tamil Nadu	0.0023	154.91	1	14	-13
Himachal Pr	0.0035	43.23	2	3	-1
Bihar	0.0039	86.10	3	8	-5
Uttar Pradesh	0.0046	124.13	4	13	-9
Maharashtra	0.0049	82.07	5	7	-2
Assam	0.0077	21.34	6	1	5
Andhra Pradesh	0.0105	122.75	7	12	-5
Karnataka	0.0107	95.80	8	9	-1
Kerala	0.0112	71.07	9	5	4
West Bengal	0.0133	113.83	10	11	-1
Madhya Pradesh	0.0149	54.03	12	4	8
Orissa	0.0149	35.14	11	2	9
Gujarat	0.0307	104.92	13	10	3
Punjab	0.0313	215.51	14	16	-2
Haryana	0.0765	181.79	15	15	0
Rajasthan	0.2036	71.41	16	6	10

When we construct the degradation index, we take the total degraded area, but in the sustainability index we take salt affected and waterlogged areas which are directly related to the agricultural processes. What we are trying to emphasize here is that, in the degradation index the indicators chosen reflect both types of degradation – natural and human induced. But the process indicators are directly related to human activities. The high level of degradation in Rajasthan is mostly because of natural factors, since it is desert area. The high level of degradation makes it difficult to carry on agricultural activities at a sustainable basis in the state. The initial conditions are very important in case of agricultural activities to decide on what sort of a production process to pursue. The degradation index can throw light on such initial conditions. The sustainability index on the other hand, gives us an idea about the type of processes being pursued and hence gives us some insight on the type of environmental impacts that can be expected. Continuing with the example of Rajasthan, it has a highly degraded resource base. Adding to it, the agricultural processes followed in the state are not very sustainable. This places the state in a very precarious position.

In our scatter plot, we have tried to identify the groups of states with similar characteristics. We have mainly two clusters. The first group consists of states, which are not degraded and have sustainable processes. This group consists of the states of Assam, Himachal Pradesh and Orissa. From the environmental front these states can be called the 'ideal states'. The second major group comprises of the states with low level of degradation but fairly unsustainable processes, viz. Kerala, Maharashtra, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, West Bengal, Bihar and Karnataka. Apart from these two major groups, we have Punjab and Haryana standing apart from the rest with medium degradation but with the most unsustainable processes. Gujarat, with medium degradation and sustainability and Rajasthan with high degradation and medium sustainability are more like exceptions than rules. Of course, with the agro-climatic conditions prevailing in these two states, with substantial part of desert area, they are bound to be exceptions (we go back to our argument that initial conditions matter).

This simple scatter can tell us an interesting story regarding the interplay of the processes and outcomes. First, degradation can be natural or human induced. Whatever be the cause of degradation, it affects the sustainability of the system. Agricultural systems should take care of the natural degradation and accept the limitations posed by them.

Next comes the question of human induced degradation. This form of degradation is a direct effect of the agricultural processes adopted by humans. Punjab and Haryana are classic cases for such degradation, which is caused by their unsustainable production structure. Many states like Tamil Nadu, Karnataka, Uttar Pradesh, Maharashtra which are not highly degraded right at this moment are also following such unsustainable production practices which puts them at the high risk of degradation for the future. The ray of hope is the few states with sustainable resource use and low degradation, but we cannot be very optimistic about the path they follow in future. The story said so far cannot be complete unless we link it to production. So the next section tries to analyze the link between production sustainability and environmental sustainability.

Production and Sustainable Resource Use: Sustainable agriculture has two components, sustainability of production and sustainable resource use. These two elements, in the short term, may seem contradictory in nature. To achieve food security in the short run, intensive agricultural practices may be adopted. These intensive agricultural practices may have adverse impact on environmental resource base. In the short run, production sustainability *can* be achieved *at the expense of* environmental sustainability. But in the long run, a degraded resource base cannot support a sustainable agricultural system and the process of production receives a setback. Hence, in the long run, production sustainability *cannot* be achieved at the expense of environmental sustainability. But of course, such arguments are easily brushed aside as 'theoretical jargons'. Let us instead concentrate on the reality.

When we talk about sustainable production, what do we mean? What should be the indicators for sustainable production? One measure could just be the yield or productivity of foodgrains. We can also consider our previous index of foodgrain production. But now since we would like to compare production with the process indicators, it would be a good idea to stick to productivity rather than production per unit of geographical area (as computed in our foodgrain index). But apart from productivity, we would like to introduce two more indicators. The first one would be the percentage share of the states in total foodgrain production. This will reveal the relative importance of the state with respect to domestic production. The other indicator is one computed by the MSSRF; the ratio of consumption to production of cereals[1]. The indicator values are given in the following table.

[1] Food Insecurity Atlas of Rural India, pp-15.
The figures relating to per capita cereal consumption are taken from NSSO 50th Round (1993-94). The production figures are the three year average of cereal production 1991-92 to 1993-94. Per-capita production is computed by dividing through by the projected population of 1994. C/P ratio is per capita consumption/per capita production

Table 3.10 Sustainability of production and consumption

States	*SI*	*Yield of Foodgrains(kg / ha)*[2]	*Share in production of foodgrains (%)*	*C/P ratio*
Assam	21.34	1288	1.69	1.286
Orissa	35.14	1080	2.86	1.126
Himachal Pradesh	43.23	1766	0.73	0.764
Madhya Pradesh	54.03	1113	9.75	0.973
Kerala	71.07	1768	0.34	3.989
Rajasthan	71.41	961	6.37	1.252
Maharashtra	82.07	974	6.28	1.274
Bihar	86.10	1441	6.36	1.791
Karnataka	95.80	1352	4.91	1.11
Gujarat	104.92	1426	2.74	1.745
West Bengal	113.83	2198	7.08	1.182
Andhra Pradesh	122.75	2003	7.09	1.158
Uttar Pradesh	124.13	1957	19.77	0.839
Tamil Nadu	154.91	2278	4.99	1.179
Haryana	181.79	2700	5.97	0.329
Punjab	215.51	3741	11.28	0.156

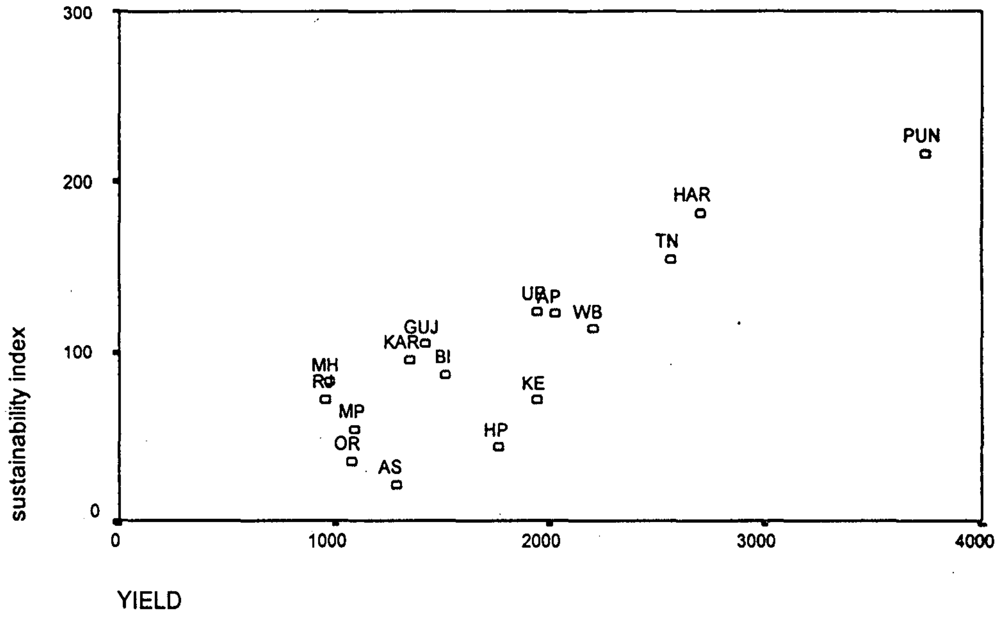
Note: The table is sorted according to the ranks in SI

In this table, the states of Punjab and Haryana stand strikingly apart from the rest. These two states produce the highest surplus, have the highest yield rate and at the same time are the most unsustainable. Apart from these two states, all the states are more or less self-sufficient, neither the deficit nor the surplus being too large. Just one more state draws our attention and that is Kerala. Kerala is the major deficit state, even though the yield is considerably high in this state. It lies in the middle range of the sustainability index.

As a matter of fact, there is significant positive correlation between the sustainability index and yield of foodgrains ($r = 0.857$, significant at 5% level of confidence). This shows that we are indeed trying to achieve production sustainability at the cost of environmental sustainability. But that does not mean that it is necessary to forgo environmental concerns for production sustainability. For example, the states of West Bengal and Andhra Pradesh have a sustainable production process and high yield. These states also have a high share in total foodgrain production and are almost self sufficient in their consumption. So, perhaps there is a lesson to learn from these states.

[2] Figures of yield and production relate to the year 1998-99, source: Indian Agriculture in Brief 2000.

Figure 3.3 Comparison of Yield and Sustainability Index



How Green is our Green Revolution? One of the major limitations with the type of analysis we are doing is that, we are trying to understand a dynamic phenomenon with static indicators. To make more sense out of all these numbers we should keep in mind the transformation of the agricultural production in India. It is well known that in the mid sixties the new agricultural strategy was implemented. This strategy changed the agricultural production system substantially, bringing in a lot of changes in terms of use of inputs (water and fertilizers) and cropping pattern. The introduction of this new technology increased foodgrain production manifold and solved India's food security problem in terms of domestic production and availability. After almost forty glorious years of the "green revolution" it is time to look back and contemplate on a few issues.

The new agricultural strategy evolved from the immediate concerns regarding the fragile food security situation at that time. The aim was to produce the most at the fastest. So, we chose a policy, which concentrated on a few crops (initially only wheat) and a few areas (Punjab and Haryana). Punjab and Haryana developed as the "food bowl" of the country meeting the food requirements of almost the entire nation. Later the new technology gradually spread to a few more crops (rice to be more precise) and a few more areas.

The policies relating to agriculture, as we perceive it, at the initial level of planning was directed to the development of multipurpose irrigation projects to cater to the needs of irrigation as well as electricity. Presently, agricultural policies are concentrated on two areas; (a) price incentives for rice and wheat, and (b) subsidies on fertilizer and electricity. As we have mentioned earlier, these policies mainly emanated from the need to deal with a crisis situation. Hence these policies never took care of environmental concerns. For a vast country like India with such varied agro-climatic situations, a uniform agricultural policy for the entire nation is not a wise decision.

Price incentives for rice and wheat only benefited those regions, which cultivated these two crops. As a response to such incentives, these crops were adopted even in areas not suitable for these crops. Multipurpose river projects and free electricity gave a new boost to irrigated farming. This led to the cropping pattern entirely being shifted in favor of these two crops in all regions, with the help of irrigation. Excess use of irrigation for the cultivation of these water intensive crops accentuated problems of water logging and soil salinity. Use of fertilizers aggravated the problem. As a result of concentrating only a few crops and a few areas, the productivity levels are reaching an upper limit and cannot be increased any further under the prevailing conditions.

This type of policy framework, which does not take account of the agro-climatic conditions and applies uniformly to the country as a whole, is not sustainable. Now that we have a comfortable food availability situation and that our short-term requirements are met, we should now concentrate in evolving a long-term sustainable agricultural policy. The requirements of this policy would be to divide the country into agro-climatic zones and there should be separate goals and targets for these zones. In each zone, there should be incentive for the farmers to profitably grow such crops, which are naturally suitable for the area. The question of pricing and subsidies should be exclusive for every zone, depending on the sustainable cropping pattern and resource use of the place. Such a policy will broaden the scope for diversification and may bring productivity gains in areas and crops yet unforeseen. In short, the policies should aim at optimal resource use, rather than maximizing production of a few crops at present. And such policies can be formulated only through a decentralized policy structure.

3.4.5 Towards a Simpler Index – A Methodological Digression

The type of index we are trying to construct is directly related to policy making. These indices give a picture of the current state of affairs and thus help policy makers to take policy decisions. But any index, which can be used for policy design should have some desirable properties. Indices should be simple to compute and they should make the most with the least amount of data. Data collection is an expensive process and a very difficult task in developing countries. So, an index should only retain the bare minimum amount of data necessary to give an indication to the process involved.

In our sustainability index, we have used nine variables. All these variables are not readily available for all the years. Data relating to several forms of land degradation are especially scarce. Also, the statistical technique used is complicated. If we can arrive at a simpler index without much loss of information, it may be a better option. So, our concern here is to retain the best variables and discard the rest.

One method of selecting the best variables is given by Jolliffe (1972). The number of variables discarded should equal the number of characteristic roots associated with the principal component which are smaller than 0.7. This method retains best subsets of variables in largest percentage. In our case from the principal component results (Table A.3.2) we can see that we can at the most retain 8 variables.

The next step is to choose the best variables. The process is to choose the variables, which have highest correlation with each of the principal components. If we want to choose one variable, we can choose the variable with highest correlation with the first component. To obtain two variables we can take the variables with highest correlation with the first two components, and so on. When we look at the correlation matrix of the principal components and the variables (Table A.3.3), we find that the variable fertilizer use has the highest correlation with the first component. For the second component, groundwater development has the highest correlation. In fact groundwater development has high correlation with most components. So, we can build an index with just these two variables to approximate our sustainability index.

To assign weights we take the clue from the characteristic roots of the first principal component. The characteristic roots for these two variables in the first component are 0.783 and 0.793 respectively. For our index, we thus assign the weights 1/2 and 1/2 for the two components respectively. The composite index is the weighted average of these two variables, i.e our new sustainability index takes the form;

SI = ½ (level of groundwater development) + ½ (fertilizer use)

The index values of our old index and the new one are given in the following table. The correlation (Pearson's correlation and Spearman's correlation) between these two index numbers is 1. They are perfectly correlated!

Table 3.11. Comparison between PC Index and Simple Index

States	*PC1*	*SI*
Assam	21.34	13.21
Orissa	35.14	21.98
Himachal Pradesh	43.23	27.28
Madhya Pradesh	54.03	34.06
Kerala	71.07	45.03
Rajasthan	71.41	45.08
Maharashtra	82.07	51.9
Bihar	86.1	54.15
Karnataka	95.8	60.64
Gujarat	104.92	66.44
West Bengal	113.83	71.35
Andhra Pradesh	122.75	77.82
Uttar Pradesh	124.13	77.99
Tamil Nadu	154.91	98.04
Haryana	181.79	113.99
Punjab	215.51	134.82

3.5 Conclusion

This chapter gives a macro view of the environmental implications of the intensive agricultural practices followed in India, using various indicators and indices. In the process we have made an attempt to develop meaningful indices of outcome and process aspects of sustainability. We observe that our agricultural strategies have been concentrated on only a few states and these states have paid a high price in environmental terms. These states, Punjab and Haryana have shown very high values in both types of indices computed. They are highly degraded and at the same time most unsustainable. These states need to immediately reorient their agricultural strategies.

Among the major producers, the states of West Bengal, UP and Bihar have shown a more sustainable resource use pattern than the other two. However, West Bengal's position is a bit precarious, as its degradation index is high. At another end, we have states like Tamil Nadu, which have very high yield and unsustainable resource use but low degradation. This state should take a lesson from the precursors like Punjab and Haryana and try to avoid degradation in future.

There is very high correlation between yield and un-sustainability. This is an observation, which our policymakers should contemplate on. We have reached a juncture where we should consciously decide on the optimal trade-off between high production and environmental sustainability. The growth rate of yield has also reached an upper limit in recent years. So it is time to look for new strategies, newer avenues. With no plausible food security threat at present but an environmental threat quite visible, a new agricultural policy should definitely include the environment in its ambit.

STATISTICAL APPENDIX

Table A 3.1: Principal Component Results for Agricultural Sustainability Index

VARIABLE	WEIGHT
Fertilizer use	0.7848
Ground water development	0.7933
Salt affected area	0.8132
Waterlogged area	0.8468
Canal irrigated area	0.9371
Well irrigated area	0.92
HYV area	0.9545
Leguminous crops area	-0.3063
Water intensive crops area	0.9399

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.749
Bartlett's Test of Sphericity	Approx. Chi-Square	147.899
	df	36
	Sig.	.000

Table A 3.2: Component Coefficient Matrix

Variables	Components								
	1	2	3	4	5	6	7	8	9
Fertilizer use	0.7848	0.3492	-0.3017	-0.232	0.3196	0.1214	-0.0058	-0.0159	0.0096
groundwater development	0.7933	0.4869	0.1854	-0.1392	0.0028	-0.2801	-0.0314	-0.0168	0.0123
salt affected area	0.8132	-0.1412	0.5183	0.0401	0.1691	0.0898	0.1081	0.0008	0.0124
waterlogged area	0.8468	-0.3363	-0.1371	0.2736	0.2325	-0.1116	-0.04	0.0844	-0.0294
canal irrigated area	0.9371	0.1056	0.2093	0.0026	-0.129	0.1424	-0.1696	-0.0188	-0.0298
well irrigated area	0.92	0.1872	-0.1103	-0.1074	-0.2553	0.0403	0.0887	0.1415	-0.0132
HYV area	0.9545	-0.0597	-0.1795	0.0889	-0.1138	-0.0244	0.0935	-0.147	-0.0376
leguminous crops	-0.3063	0.885	-0.0026	0.3448	0.0188	0.0557	0.0216	0.0057	0.0035
water intensive crops	0.9399	-0.2168	-0.1488	0.1547	-0.1249	0.0195	-0.0317	-0.0179	0.0794

Table A 3.3: Correlation Matrix of Principal Components and Variables

	Fertilizer	groundwater dev	salt affected	waterlogged	canal	well	HYV	leguminous crops	Water intensive
PC1	0.964	0.8892	0.5847	0.5883	0.7807	0.8345	0.765	0.043	0.6666
PC2	0.9467	0.915	0.5926	0.5717	0.787	0.8353	0.7566	0.0638	0.6549
PC3	-0.9535	-0.4983	-0.3409	-0.5402	-0.5246	-0.6285	-0.6246	0.0548	-0.5554
PC4	-0.9835	-0.8467	-0.5531	-0.5843	-0.7513	-0.8148	-0.7512	-0.0357	-0.6536
PC5	0.9999	0.7376	0.4875	0.5828	0.6847	0.7647	0.722	0.0042	0.6323
PC6	0.0342	-0.6509	-0.3961	-0.0474	-0.4091	-0.319	-0.2039	-0.1795	-0.1553
PC7	-0.8404	-0.9855	-0.6324	-0.5247	-0.8099	-0.8275	-0.7275	-0.102	-0.6253
PC8	-0.9624	-0.8921	-0.5878	-0.5911	-0.7837	-0.8361	-0.7697	-0.0414	-0.6705

Chapter 4

URBAN ENVIRONMENT AND WELLBEING

4.1 Introduction

The problem with urban life and the environment is mainly that of pollution. Increasing population in towns and cities, increasing industrialization brings with it increased pollution and its consequent health hazards. Pollution mainly affects human lives through its health impacts and production losses.

To analyze the causes of pollution, the analysis can be classified in two parts: pollution emanating from the domestic sphere and pollution emanating from the industrial sphere. However, it should be noted that in whichever sphere it originates, its effects are felt most acutely by the domestic sphere. The increasing population pressure in the urban areas has been a growing problem in recent years. Indian towns do not have the infrastructure and amenities to support such vast population influx. This has led to unhygienic living conditions and polluted living environments. Another growing concern is the increase in slum areas in the towns and cities. The slum population is the most vulnerable section living in very dirty living conditions, lacking basic amenities like drinking water and toilet facilities and thus are exposed to various health hazards.

Pollution can be of two forms, air pollution and water pollution. Pollution of air through industrial and vehicular emissions is peculiar to urban areas and its effects are rather local in character. Of course, here we leave out the larger issues of global warming and ozone depletion. The effects of water pollution, on the other hand, are more spread out. Effluents let out at some part of the river may pollute the entire stretch of the river and have adverse effect on humans using water from the same river at some other point. So, the problem of water pollution is less confined in space than that of air pollution. In this section, our main thrust is thus on air pollution and its effect on urban health.

The next section discusses the causes and effects of air pollution based on the existing literature in this area. Once the linkages are established, we concentrate on state level analysis using outcome indicators. Section 4.3 deals with the problem of construction of process index. Having constructed a process index we proceed with the discussion of results. In the last section we bring in a discussion on how the index constructed by us could be further strengthened using some other functional forms.

4.2 Air Pollution – Causes and Effects

Air pollution in urban areas of developing countries is a growing concern. Population and output are growing in these cities and along with it pollution levels are on the rise. The number of large cities is also growing. The ambient air quality in many of these large cities violates WHO standards. As a result, respiratory diseases are rising among the population.

The pollutants of potential concern may be classified into conventional air pollutants like sulphur dioxide, particulates, ozone, nitrogen dioxide and carbon monoxide, air toxics like lead, benzene, 1,3 butadiene and others. The regional and global pollutants are acid rain, carbon dioxide and associated atmospherically reactive gases, chloro-fluro-carbons and similar compounds. The conventional pollutants may have a variety of effects on health, productive activities like crop production, economic assets such as building materials and environmental assets such as endangered species and parkland. The primary concern regarding air pollution is its effect on human health. Air pollution has respiratory and other health impacts. Total suspended particulates and PM10 (particles less than 10 microns in diameter) are associated with premature mortality from respiratory illness and cardio-vascular disease and increase in chronic obstructive lung disease, bronchitis, upper and lower respiratory tract infection. Ozone contributes to incidence of respiratory hospital admissions, restricted activity, asthma, eye irritation and heart disease. Carbon monoxide (CO) reduces the amount of oxygen carried by blood. High levels of atmospheric lead contribute to hypertension and neurological damage, including IQ loss in children.

There are three major sources of urban air pollution. Point sources, mobile sources and domestic sources. Point sources are stationary sources like industries and power plants. Coal burning by power plants and industry are the major sources of SO_2. Industry is also the major source of particulates and toxics. Mobile sources are cars, buses, and all other motor vehicles. Automobile is one of the primary sources of CO and an important source of VOCs (Volatile organic compounds) and NOx (Nitrogen oxides) along with toxics. Diesel trucks and buses are major sources of particulates. Diesel engines produce ten times more particulates than petrol engines. In some countries like Mexico, sulphur content in diesel is high creating SO_2 problems. Two-stroke motor cycles and scooters create large quantities of conventional pollutants. These generate twenty two times more VOCs than petrol cars. In developing countries, domestic sources of pollution also carry major importance. Use of coal and other bio fuels for cooking are the chief sources of SO_2 and particulates.

Air pollution from mobile and domestic sources varies largely depending on a variety of factors. For instance, pollution from automobiles depends on type of fuel used, as well as the specific age and make of the vehicle. In case of burning of bio-fuels for domestic use, it depends on the mix of fuels and pollution characteristics of the fuel used.

Krupnick (1997) tries to look at the emerging problem of air pollution in developed as well as developing countries and analyze its impacts. He uses WHO/UNEP Global Environmental Monitoring System (GEMS) data of selected urban areas to assess the ambient air quality situation. This data source only gives information on SO_2 and SPM. Moreover, the published data gives annual averages of all locations – industrial and residential. So there may be an upward bias in assessing the severity of ambient exposures.

Two measures are important for assessing health risks – the annual average concentration is needed to measure chronic health risks and the number of days exceeding the daily ambient standard is needed to gauge risk of acute health response.

Assuming that the residential monitors always register lowest levels of concentration and that residential monitors best characterize population exposures, the annual average concentrations associated with minimum monitor years give the best indication of chronic health risks. According to the figures, the situation of SO_2 is better than that of SPM. All cities except Rio de Janeiro, Seoul, and Milan show at least one monitor-year that does not exceed the WHO annual average guidelines. But with SPM, about half the cities report a minimum monitor-year annual average SPM concentration that exceeds the WHO guidelines.

Considering the number of days exceeding the WHO daily guidelines, only in three cities does the residential concentration exceed the daily SO_2 guideline and out of these only one is in a developing country. For particulates, nearly all the cities in developing countries show minimum monitor year daily concentration above the WHO standard, and that too for a considerable number of days.

Another problem connected to air pollution is that of concentration of lead in blood. Surveys in lead levels in blood in the USA since the lead phase out program began in 1975 show a startlingly clear relationship between lead in petrol and blood lead levels. In most developing countries leaded petrol dominates. Increased use of petrol has increased blood lead levels in such countries. Overall, it has been estimated that 60 percent of the children in developing countries have blood lead content higher than the WHO guideline. But adequate data on lead concentrations are not available for developing countries.

Indoor concentration of SPM in developing countries is 25 percent higher than that of developed countries due to burning of solid fuels for cooking, according to Smith (1987). However, as the country develops, both indoor and outdoor concentration of SPM falls as cleaner fuels are substituted for dirtier ones.

From the data available for developing countries, it is difficult to establish causal link between air pollution and the health effects. But such relationships have been seen in developed countries context, linking air pollution to certain types of health effects. Such studies mainly estimate some dose-response functions. Though these functions can be directly applied to the developing country data, it is likely to underestimate the health effects. This is because dose response functions are non-linear and increasing with dose. The baseline concentrations are higher in case of developing countries. Secondly, the marginal effect of dose on response is inversely related to health status. In developing countries a substantial number of people live with poor health status. A minor fluctuation in pollution level can have serious health impacts on these people.

In spite of data limitations to estimate dose response functions for developing countries, it is seen that the incidence of chronic obstructive pulmonary diseases (COPD) and acute respiratory infections (ARI) are much higher in developing countries than developed ones. But the incidence cannot be attributed to pollution alone because smoking is also one of the major causes. In any case, the health effects of pollution cannot be ignored in the developing country context.

According to Krupnick, industrial SO_2 and particulate emissions, diesel particulates, and cooking and heating emissions appear to be of current concern to urban population in developing countries. Car and two-wheeler emissions are of future concern primarily because of their ozone forming potential. Air toxic concentrations, aside from lead are not measured in any country, although risks from lead and risks from indoor fuel burning require current attention. Further growth in demand for electricity in developing countries may also cause this sector to be a major source of SO_2, particulates and NOx. Adequate policy measures are required in this direction.

Brandon and Hommann (1995) computed the health impacts of air pollution in India for 36 Indian cities. If pollutant levels in these could be reduced to WHO standards it could avoid 40,351 premature deaths, 19,800,000 hospital admissions and 1,201,300,000 minor sicknesses, according to them. This would save total costs of \$517 to \$2,102 million US dollars annually. In their estimations of incidence of disease, they have used dose response functions computed for the city of Zakarta developed by Ostro (1994). The monetary valuation of premature deaths is done using value of statistical life approach. The valuation of morbidity is done using two kinds of costs, medical expenses and lost wages.

The authors found out that in the context of India, two pollutants - PM10 and SO_2 account for over 95 percent of the health impact damages. In terms of geographic incidence, the total cost of air pollution is generally correlated with city size. But percapita air pollution costs are significantly higher in some of India's secondary cities.

4.3 State Level Analysis of Urban Air Pollution in India

Conforming to the analytical structure that we laid down for ourselves, we compute two types of indices, outcome index and process index. The outcome index looks at the health impacts of air pollution while the process index tries to quantify the level of air pollution.

4.3.1 Outcome Index of Urban Air Pollution

Selection of Indicators: The major impact of air pollution, as discussed in the previous section, is on the health of the urban population. Though there have been some studies in the context of some Indian cities, Delhi for instance, on the health impact of environmental pollution, a state level analysis has not been done so far. The Ministry of Environment and Forests has initiated environmental epidemiological studies in seven critically polluted areas. A World Bank (1993) study showed that respiratory infections contribute to 10.9% of the total burden of diseases, which may be both due to presence of communicable diseases as well as high pollution levels. Cerebro-vascular disease (2.1%), ischemic heart disease (2.8%) and pulmonary obstructions (0.6%) are much lower. The prevalence of cancer is about 4.1% amongst all the diseases.

Review of Existing Data Sources on Health: The dearth of any state level analysis so far has been mainly due to the unavailability of reliable data on the different broad categories of diseases, at the state level. The Health Information of India published by the Central Bureau of Health Intelligence, Ministry of Health and Family Welfare, Government of India, gives information on different categories of waterborne diseases like cholera and diarrhoeal diseases. But it does not provide much information on respiratory diseases. This information is a very crude estimation because it offers information on notified cases only, that is, cases reported in hospitals and other health care units. Most of the times, chronic respiratory problems go unreported or do not result in hospital admissions, and thus the results can only be an underestimation. Also, rural urban break up of the profile of diseases is not available. The report also gives data on mortality by cause. Mortality statistics carries information on deaths due to disorders of the respiratory system as well as diseases of circulatory system.

The NHFS (National Family Health Survey) conducted in 1992-93 and 1998-99 by the International Institute for Population Studies gives some information on mortality, health and health care apart from its main thrust on fertility, family planning and nutrition. Its sample design includes ever-married women in the age group of 15 to 49 years. Information on children born in three years preceding the survey (i.e. children in the age group of 0-3 years) is also collected. However information on certain kinds of diseases is collected for all members of the household. NFHS-1 collected data on five major morbidity conditions – partial and complete blindness, tuberculosis, leprosy, physical impairment of limbs and malaria. NFHS-2 collected data on Asthma, Tuberculosis, Jaundice (during the past 12 months) and Malaria (during the past 3 months). The data gives a residence wise and sex wise break up. The limitation of this data is its limited coverage of illnesses. It includes only one kind of respiratory disease – asthma – and so is not very useful in assessing the health impact of air pollution.

The NSSO 52nd round conducted from July 1995 to June 1996 concentrates on health care. State level information on health by different types of illnesses at the state level can be obtained from this round and the data can be classified according to rural urban break up. This round takes into account the illnesses suffered by the population in the last fifteen days of the investigation.

4.3.2 Results from NSSO Data and Discussion

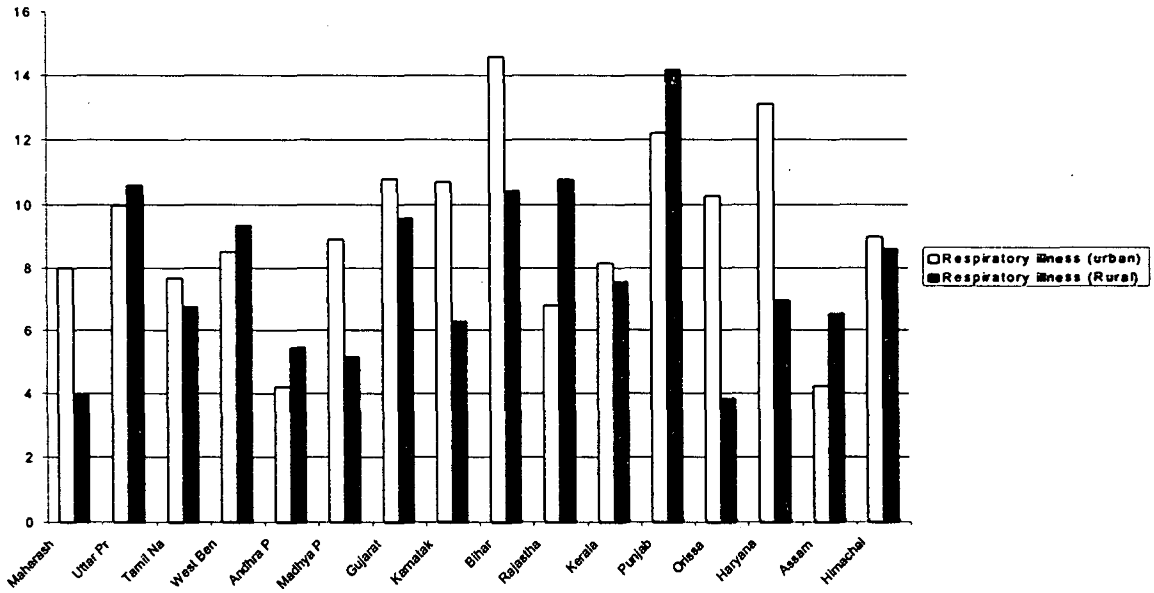
For our analysis we have used NSSO 52nd round data. The air pollution related illnesses selected are; (1) Cough/Bronchitis (2) Acute Respiratory Infection (3) Heart diseases. Table 1 shows the burden of air pollution related diseases as a percentage of total burdens of disease (i.e. population suffering from respiratory disease per 100 ill population).

Table 4.1 Incidence of Respiratory Illness per 100 ill Population

STATES	***RESPIRATORY DISEASES***		***RANK***	
	Urban	Rural	Urban	Rural
Andhra Pradesh	4.2	5.46	16	13
Assam	4.211	6.521	15	11
Bihar	14.58	10.43	1	4
Gujarat	10.8	9.56	4	5
Haryana	13.12	6.971	2	9
Himachal Pradesh	8.97	8.58	8	7
Karnataka	10.705	6.29	5	12
Kerala	8.14	7.54	11	8
Madhya Pradesh	8.878	5.157	9	14
Maharashtra	7.98	3.964	12	15
Orissa	10.28	3.81	6	16
Punjab	12.198	14.17	3	1
Rajasthan	6.78	10.768	14	2
Tamil Nadu	7.66	6.73	13	11
Uttar Pradesh	9.98	10.6	7	3
West Bengal	8.5	9.35	10	6
Median	**8.924**	**7.2555**	-	-

The burden of respiratory disease (including heart diseases) is 8.924 per 100 ill population in urban areas compared to 7.2555 per 100 ill population in rural areas. So, comparatively the burden is higher in urban areas, which is quite in tune with our understanding of the problem. Urban incidence of respiratory disease is highest in Bihar, followed by Haryana, Punjab and Gujarat. This comes as a striking result in the sense that these states are not the ones with the highest urban population. There is no direct link with the urban population and the incidence of respiratory diseases. The bar diagram (Figure 4.1) gives a graphical presentation of the burden of respiratory illness. The states are ordered according to the total urban population (Census, 1991). The states Bihar, Punjab, Haryana have the highest incidence of respiratory illness in urban areas but they are not the states with highest urban population.

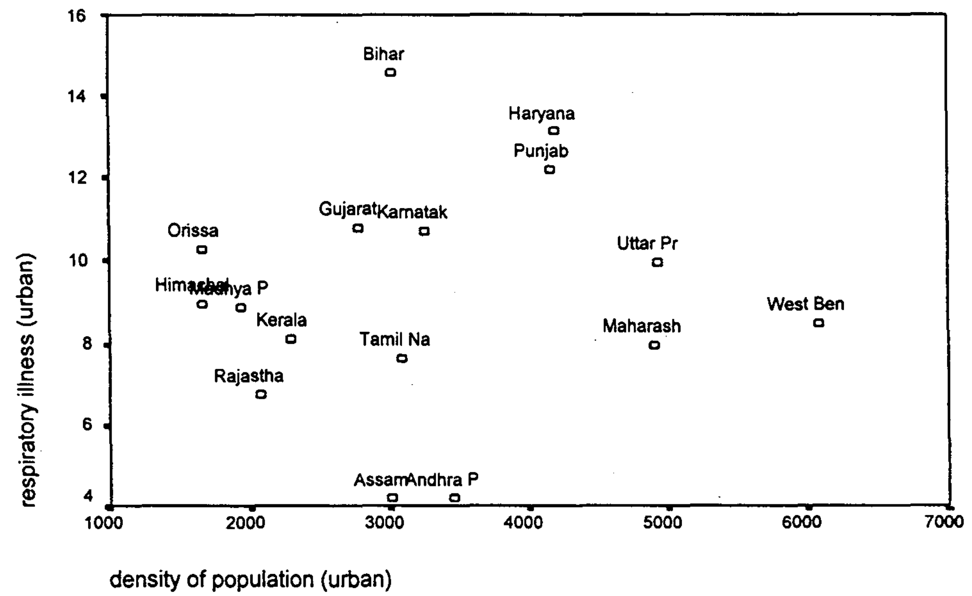
Figure 4.1 Incidence of respiratory illness in rural and urban areas



But more important than the total urban population of a state is the density of urban population. The density of population acts as pollution increasing pressure factor. Also, polluted air is like a common property resource. The denser the population in the polluted environment, the higher will be the population affected by the polluted air. The scatter plot below (Figure 4.2) shows the urban incidence of respiratory diseases on one axis and the density of population on the other axis.

Even in this case we find that it is the middle density states that have highest incidence of respiratory illnesses. These states, especially Bihar, Haryana, Punjab do not even have any metro city in the states but have the highest incidence in respiratory diseases. West Bengal and Maharashtra, which have the highest density of urban population (mainly due to the existence of Kolkata and Mumbai) show medium incidence of respiratory illnesses. Andhra Pradesh seems to be an outlier in the sense that it has a medium level of urbanization and density of urban population but a very low level of respiratory illnesses.

Figure 4.2 Urban incidence of respiratory illness and Density of population



If we look at rural urban differences from Figure 4.1, it is clear that urban incidence is fairly high in all states except Andhra Pradesh, Assam, Rajasthan, and Punjab. In Uttar Pradesh and West Bengal rural incidence is marginally higher than urban incidence. Rural incidence of respiratory illness is highest in Punjab, followed by Rajasthan, Uttar Pradesh and Bihar. Rural incidence of respiratory illness is exceptionally high in Punjab, higher than the urban incidence in most states.

One of the interesting findings from our exercise is that the burden of illness for air pollution related diseases is not the highest in the most urbanized states but is much higher in some medium and low urbanized states. Neither is there any clear relation between total urban population, or urban population density of the state, and the burden of disease. From this we can infer that urbanization defined as the growth of population in urban areas may not be the sole cause of pollution, especially air pollution in urban areas. Urbanization in itself should not be blamed as the cause of all ills. On the other hand, states like Punjab, Rajasthan, UP show that living in rural areas may not be a very blissful experience after all. The rural environment may also be polluted due to many reasons, indoor air pollution due to use of bio-fuels being one of the major causes.

Why do we get such results? To explain this we again have to go back to our previous distinction between processes and outcomes. Burden of disease is the outcome indicator, which we have chosen to represent the problem of air pollution in urban life. Our analysis does not provide any clear relationship between urbanization and air related health problems. To throw some light on the results we get and for a deeper understanding of the problem we have to go back again to the process indicators. Only then can we get a complete picture.

However, one thing that should be borne in mind at this point is that the relationship between the processes and outcomes are very complex. Apart from the environment related factors, the health status of individuals depend on a variety of other factors. Health status depends on individual level characteristics like genetic factors, nutritional status and lifestyles. It also depends on seasonal factors, like temperature, humidity. But when we use NSSO data, to some extent the seasonal factors are taken care of. The data is collected round the year to neutralize season specific incidence of diseases. The individual level characteristics make the processes rather complex. In our analysis, which mainly concentrates on constructing some state level indicators, it is not possible to take into account the individual level characteristics. So, some part of the variation remains unexplained. Sometimes some natural factors also affect the incidence of certain kinds of illnesses. For example, the high incidence of respiratory diseases in rural Rajasthan may have some connection with its geographic conditions. Rajasthan falls in dry desert region, suspended particulates in the form of sand and dust may be very high in the atmosphere causing a high incidence of respiratory illnesses. All these individual, seasonal and geographical factors make it very difficult to establish causal links between the process and the outcome indicators. It is also not possible to bring out any statistical relation between the outcome and process indicators at the state level and that too for only sixteen states. So, much of our explanation has to depend on intuitive reasoning. Saying this, let us proceed with an analysis of the process indicators.

4.3.3 Process Index of Urban Air Pollution

Selection of Indicators: Health effects of air pollution, defined as the incidence of pollution related diseases, are the ultimate outcome based indicators. To build process indicators, we can think of two stages;

Pollutant sources ➔ Air pollution ➔ Health effects.

We can just take the levels of different pollutants in the air as the process indicators. If we want to go back one step further, we can look at the sources of pollution. Ultimately the indicators chosen will depend on the availability of data and the amenability of data to construct aggregate indices. However the stage of the process has to be kept in mind in choosing the indicators to avoid problems of double counting.

When we speak about process indicators, we have to first take a look at the different pollutants, their sources, and their health effects.

Table 4.2 Sources and health outcomes of air pollution

Major Sources of Pollutants	*Air Pollutants*	*Health Effects*
Fuel Combustion, Power Station, Industrial Processes, Chemical Processes, Diesel Vehicles, Solid Waste Disposal, Smelters	Sulphur Dioxide (SO_2)	Respiratory symptoms
Transport (Road, Rail, Passenger and Commercial), Fuel Combustion, Power Station, Industrial Boilers, Chemical Processes, Waste Incinerators, Smelters	Nitrogen Oxide (NO_X)	Respiratory symptoms
Fuel Combustion, Power Station, Construction Activities, Industrial Processes, Diesel Vehicle Exhaust, Resuspended Road Dust, Domestic Refuse Burning, Domestic Wood	Particulate Matter (SPM, RSPM-PM_{10}, RSPM-$PM_{2.5}$)	Respiratory illness, cardio-vascular disease, chronic obstructive lung disease, Bronchitis, Upper & Lower respiratory tract infections
Transport, Combustion, Industrial Processes, Solid Waste Disposal, Refuse Burning	Carbon Monoxide (CO)	Reduces oxygen carried by blood
Secondary Pollutants formed during Photohemical Reaction	Ozone (O_3)	Respiratory illness, asthma, eye irritation, heart disease
Lead Additives in Gasoline, soil Originated Particles	Lead (Pb)	Hypertension, Neurological Damage

When we try to develop some process indicators, these cause and effect relations should be taken into account. We should decide on a definite stage of the process. In our view, the best way is to concentrate on that stage of the process, which is nearest to the outcome. As we move further back on the processes, the impacts on the outcome become more complex and blurred. In this case, it would be wise to select the levels of air pollutants as the indicators, to preserve simplicity. If we try to look at the pollutant sources, the sources are so varied that it will be difficult to capture them all due to data limitations. Even if we do find data on all sources, how do we value the relative importance of each source, or put more simply, how do we assign weights? The most reasonable way to assign weights would be to look at the emission levels of each source. That will again complicate matters further because emission levels of the pollutant sources vary with age of the machine, particular fuel type used and so on. It is simply impossible to capture all these factors in a single composite index.

Data Sources: For data on the ambient air quality the Central Pollution Control Board (an autonomous body under the Ministry of Environment and Forests, GOI) provides with nationwide data on the levels of pollutants in the air under the National Ambient Air Quality Monitoring Programme (NAAQMP). This programme was initiated in 1984. As on March

1995, the network comprised of 290 monitoring stations covering over 90 towns and cities distributed over 24 states and 4 Union Territories. The NAAQM network is operated through respective State Pollution Control Boards and the Central Pollution Control Board and also through National Environmental Engineering Research Institute (NEERI). The pollutants monitored in these stations are SO_2, NO_2 and SPM. NEERI also monitors special parameters like Ammonia (NH_3), Hydrogen Sulphide (H_2S) and Respirable SPM (RSPM) and Polyaromatic Hydrocarbons (PAH). The WHO has 30 monitoring stations in India under the GEMS programme. These stations are operated through CPCB and the parameters measured are SO_2, NO_2, SPM, RSPM, CO, Lead and PAH. There are also 8 monitoring stations under the SPCBs under the World Bank programme which monitor SO_2, NO_2, SPM, RSPM, CO and Hydrocarbons. Ozone is not monitored in India.

In spite of the fact that a large pool of data on pollutant levels is available, the problem arises in making any aggregation with this data for a state level analysis. This data represents the cities and it is difficult to arrive at a composite index at the state level with this kind of data. However, in our analysis we have tried to do some simple aggregation with NAAQM data for the year. Though NAAQM gives data from 90 cities in 24 states, here we have taken only 66 cities from 16 major states.

In case of data on different polluting industries, the Ministry of Environment and Forests has data on seventeen categories of most polluting industries. These industries are the ones with high levels of emissions in the air and/or discharging high levels of effluents in water-bodies. State level location of these industries and their compliance status with the environmental norms is available. But this data may not be very useful for a few reasons. Firstly, we cannot separate out the industries that pollute the air and those, which pollute the water. Even if we do from other industrial data sources, the level of pollution cannot be worked out. Each industry may have separate pollution intensities depending on the factory size, type of pollutants emitted etc. So, just going by the number of units present in each state we may reach erroneous conclusions. These industries are all in the organized sector. The unorganized sector industries have a high potential for pollution because they are generally not monitored. Data from the seventeen polluting industries for the year 2000 show that most industries have the apparatus to deal with pollution. So data from these industries are not very helpful. In case of other pollutant sources, data on the number of registered vehicles in every state is available. This may be helpful in some sense. But to avoid double counting we stick to only one kind of process indicator, the levels of pollutants in the air.

Index of Air Pollution: As we had mentioned earlier in the discussion, the problem with NAAQM data is its aggregation at the state level. We have tried to adopt the simplest route. For our analysis we have taken NAAQM data for the year 1995. NAAQM gives data on three major pollutants, SO_2, NO_2 and SPM. Pollutant level data is reported for three categories, annual and 24 hourly. Again for each category, three sets of data are available, Maximum, Minimum and Average. We have taken the annual data for our analysis. Annual data is the annual arithmetic mean of a minimum of 104 measurements in a year, taken twice a week at uniform interval. The maximum records the maximum concentration of the pollutant in 24 hours, while minimum records the minimum concentration of the day. The average is the 24 hourly average of the pollutant levels. The maximum concentration of air pollutants shows the risk for sudden bouts of respiratory problems while the average concentration shows the risk of chronic respiratory problems. We have just taken the average annual concentration of pollutant as our indicator.

The levels of pollutants are recorded for cities. Our task is to aggregate them at the state level. The simplest way to do it is to club all the cities in the state and take the average as the state level indicator. However, this indicator can only represent the health risk faced by a fraction of urban population in the states. That is, it can only represent the health risk of that part of the population of the state that resides in these cities.

While aggregating, we have used the simple arithmetic mean. But a weighted arithmetic mean could have been more meaningful. The unit of concentration levels is micro-gram per cubic meter (µg/cu.m). So the appropriate weight that should have been used is the geographic area of the cities. However, let us proceed with the simple arithmetic mean.

Table 4.3 gives the state level index of average annual concentration of the three pollutants. In the last column, it also gives the percentage of urban population residing in the cities for which data is taken.

Table 4.3 Index of ambient air quality (µg/cu.m)

State	*SO_2 avg*	*NO_2 avg*	*SPM avg*	*Population*
Andhra Pradesh	17.95	32.7	165.25	21.3
Assam	2.38	18.95	67.5	24.92
Bihar	38.98	35.82	337.4	15.23
Gujarat	54.88	23.34	217.2	43.89
Haryana	36.15	18.4	320.5	18.79
HP	3.7	8.98	210.88	26.99
Karnataka	26.65	21.28	92.75	28.11
Kerala	9.8	21	117.83	23.81
Maharashtra	19.68	25.53	167	27.11
MP	16	24.83	255.33	47.72
Orissa	23.9	23.65	199.38	11.47
Punjab	27.27	51.3	363.6	30.13
Rajasthan	20.68	48.4	298.02	31.6
Tamil Nadu	10.6	13.23	74.63	25.46
Uttar Pradesh	26.34	22.56	357.24	20.34
West Bengal	45.52	93.03	254.03	29.14

Source: State of India's Environment, A Citizen's Report, 1999 (CSIE)
Data relates to 1995

Central Pollution Control Board has some standards of ambient air quality. There are separate standards for residential areas and industrial areas. The common notion is that levels of pollutants below the minimum standards may not have harmful health impacts. When we checked the data of all the pollutants for all the 66 cities, we found that in most cities the problem is mainly of SPM. In case of NO_2 and SO_2, most cities had ambient pollutant levels well below the standards. Here we are accepting the residential standards as the cut-off and residential standards are more stringent than industrial standards. So it was not necessary to aggregate the three types of pollutants further into a composite index. However if we chose to do so, it would not have been too difficult because all the three pollutants have the same units of measurement. But the problem that we would have faced is that of assigning weights. Another aspect that becomes very important in this context is the relationship between the pollutants in their health impact. If synergistic or antagonistic relationship exists between them then the aggregation formula should reflect the existing relationship. A discussion on these issues can be found in Chapter 2.

For the time being we rank the states according to the average annual level of SPM.

Table 4.4 Rank of ambient air quality and respiratory illness.

STATE	*SPM AVG*	*RANK SPM*	*RANK ILL*
Punjab	363.6	1	3
Uttar Pradesh	357.24	2	7
Bihar	337.4	3	1
Haryana	320.5	4	2
Rajasthan	298.02	5	14
MP	255.33	6	9
West Bengal	254.03	7	10
Gujarat	217.2	8	4
HP	210.88	9	8
Orissa	199.38	10	6
Maharashtra	167	11	12
AP	165.25	12	16
Kerala	117.83	13	11
Karnataka	92.75	14	5
Tamil Nadu	74.63	15	13
Assam	67.5	16	15

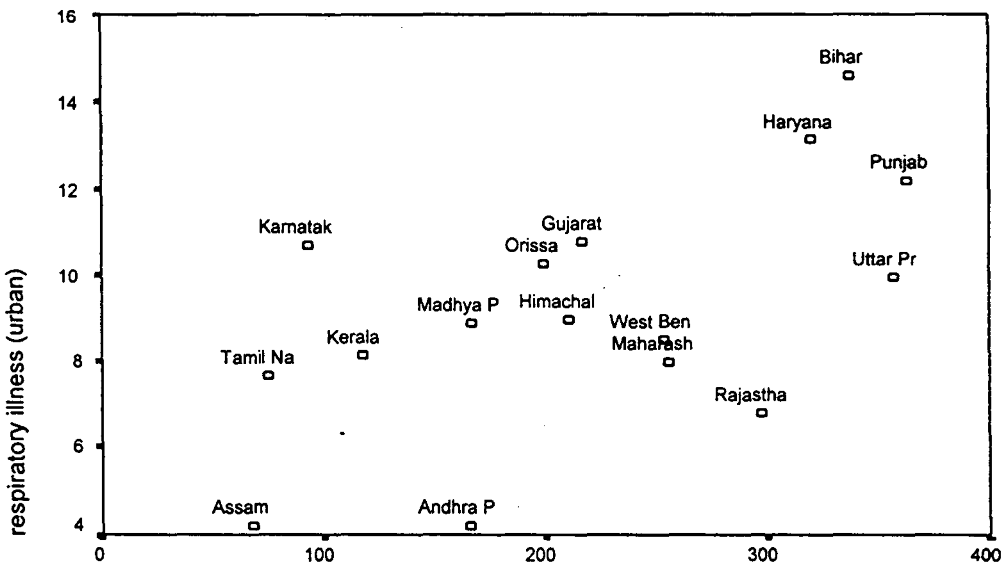
We see even in case of pollution levels Punjab, Uttar Pradesh, Bihar, Haryana top the list. Though Bihar ranks first in terms of respiratory illness, it ranks third in case of level of pollution. However, the data available on pollution in Bihar represents only 15 percent of its urban population while in case of other states it comes roughly around 25 percent. For this there may be an underestimation of the effect of pollution in Bihar. The city of Patna ranks first among all Indian cities in average annual concentration of SPM.

It is also worth mentioning in this context that in the city of Howrah, West Bengal all three pollutants SO_2, NO_2 and SPM exceed the residential standards. This is the only city to do so.

4.3.4 Discussion of Results

The most interesting fact that comes out from the comparison of the process index (average annual concentration of SPM) and the outcome index (incidence of respiratory illness) is that both are positively and significantly correlated. The correlation between the two variables is 0.582 (significant at 5% level of confidence). The scatter plot (Figure 4.3) shows the distribution of the states.

Figure 4.3 Urban incidence of respiratory illness and Index of air quality



The three states Bihar, Haryana and Punjab show a high incidence of respiratory illness and high value of air quality index showing poor air quality. UP and Rajasthan show poor air quality but are in the medium range in terms of incidence of respiratory illnesses. Most of the other states fall in the middle range with medium level of air quality and respiratory illness. The exceptional states are Assam which can undoubtedly be awarded the first place with its low level of air pollution and also low incidence of respiratory illness, and Andhra Pradesh which has very low incidence of respiratory illness but medium level of pollution.

One thing that we would like to re-emphasize here is that the air pollution index constructed and used here is at best a very rough approximation of the real condition. The air quality index only reflects a narrow fraction of the urban population. Besides, the aggregation technique used in the computation of the index is also not very rigorous.

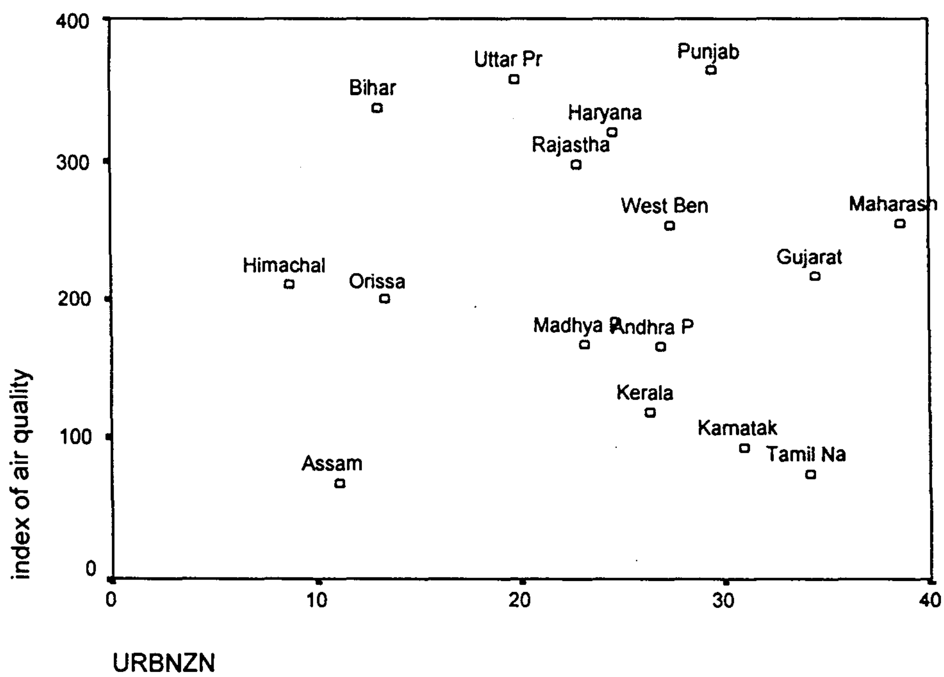
In spite of these shortcomings, what the results reveal is striking. It establishes the fact that even at the macro level we can in fact find a relationship between the pollution related health problems and the level of pollution. Why we had to proceed with such gross approximations is the unavailability of adequate data. The concept of an environmental database is new in India and whatever data is being made available is not yet adequate. So while the nation tries to build up a database, such considerations should be taken account of. Till now the pollution data is available for very few cities. The coverage has to be expanded to include at least 60 to 70 percent of the urban population. Secondly, the CPCB should report data separately for residential and industrial areas. In its annual report, most of the times where it reports pollutant level for industrial and residential areas, it does not report the actual values. It only reports in which range the value falls - low, moderate, high and critical. Such categorical variables are more difficult to handle. If the CPCB wants a wider use of its database, it should take into account such issues. Even the morbidity data does not suit our purpose well. The ideal way to deal with this issue would have been to relate the pollution levels of the cities with the morbidity statistics of that city. But NSSO estimation at the city level is not very robust and thus we cannot proceed on that line.

Now, the results indicate that environmental pollution and its consequent health impact has little to do with urbanization and density of urban population. People by themselves cannot cause urban pollution, they can only be victims of air pollution. Congestion in urban areas, industrial pollution, vehicular load may be the actual reasons for air pollution. In fact when we look at the states and cities with maximum pollution levels, that is the idea we get. As we have mentioned earlier, Howrah exceeds the limits of all pollutant concentration levels. Howrah also has many small-scale factories and foundries. Bihar (presently Jharkhand) again is the core of the coal industry and open cast mines are the highest in Bihar. Punjab has the highest number of vehicles per 1000 population. All these facts give us an indication that the emerging urban areas without adequate infrastructure to contain pollution are creating problems. Of course, studies have shown the immense air pollution in metros, especially Delhi and Kolkata, due to vehicular emissions. But the point that we are trying to make is that often the pollution problems of small cities are neglected and our findings show that more attention should be paid to these cities.

In the medium cities implementations of rules and regulations related to pollution might be slack making them havens of pollution. The infrastructure necessary to avoid such pollution may also be unavailable. For example, let us take the measures taken in order to contain the vehicular pollution. Stringent emission norms along with fuel quality specifications were laid down in 1996 and 2000. Euro-I norms have been applied from April 2000. But many of these norms are followed only in metropolitan cities. Many of the norms, like age of the vehicle, do not apply for medium towns and cities.

Even in case of location of industries, polluting industries especially in the small scale and informal sectors may be located within city limits in case of medium cities. It is less likely to be so in the metropolises. Inspection of polluting industries also may be more careful and regular in the big cities. Anti-pollution devices may not be readily available in small towns and cities, thus increasing the pollution load. In such cases, the issue boils down to urban planning and implementation of laws in growing or emerging cities rather than urban pollution control in the metros. Just like the Environment Kuznets curve, which shows that a concave relationship between development and pollution, the same may be true for urban development and pollution. At one end we have states like Assam with low level of urbanization and low pollution, at the other end we have Maharashtra and Gujarat with high urbanization but medium pollution. The middle urbanized states Bihar, Punjab, Haryana, UP have the highest levels of air pollution (Figure 4.4 shows the relationship between pollution levels and urbanization). This type of a relationship indicates that policy wise more emphasis should be laid on the emerging urban agglomerations in case of pollution abatement, at this moment. As new urban agglomerations emerge proper urban planning is required.

Figure 4.4 Air pollution Index and Urbanization



4.3.5 Alternate Indices

The way we constructed the air pollution index is far from satisfactory. The reason why we had to compromise with a simpler form of index is mainly due to data unavailability. But a more rigorously constructed index can fill up some analytical gaps.

In the context of air pollution, the idea of a threshold becomes very relevant. Below the threshold level, the pollutants may not have much adverse impacts on health. While constructing our air quality index we included only SPM as we found out that for the other pollutants, ambient levels were below the CPCB residential standards. So we implicitly assumed that the CPCB residential standard is the 'threshold'. However, in our SPM index, we did not make any concessions for this threshold level. We simply aggregated all values by using the simple arithmetic mean.

A more careful construction of the index would take into account two things. Firstly, the threshold as already discussed; and secondly the functional relationship between pollutant levels and health impacts. While some studies on such functional relations are available in terms of dose-response functions for developed countries, there have not been many studies in the Indian context. But again, an increasing function seems more appropriate. In fact even dose-response functions indicate that the intensity of the response increases with the dose, that is the pollutant level. If we assume a convex kind of relationship, with thresholds we can construct some alternate indices.

In fact that is what we have tried to do. We have constructed two alternative indices. In the first case, the air pollution indicator for each city is taken to be the convex transformation of the pollutant level above the threshold. More specifically,

$P = x^2$, for all $x > 140\ \mu g / m^3$

$= 0$, for all $x \leq 140\ \mu g / m^3$

In this case P is the pollution indicator while x denotes the pollutant levels. 140 $\mu g/ m^3$ is the CPCB residential standard for SPM. The state level Index of Air Pollution is the simple arithmetic mean of all the city level pollution indices for each state. This index is denoted as I_1 in our analysis.

The second index allows for intensification of the impact of air pollution at different levels. We have used a convex step function to transform pollutant levels to air pollution indicators.

A discussion of such a function can be found in Chapter 2, so we do not elaborate on it further. The functional form we use is as follows:

$P = 0$, for all $x \leq 140\ \mu g / m^3$

$= x^2$, for $140 < x \leq 210\ \mu g / m^3$

$= x^3$, for all $x > 210\ \mu g / m^3$

The aggregate index I_2 is again the simple arithmetic mean of the city level indices.

It is to be borne in mind that using alternative formulae is not going to change the rankings among the cities, as the index P is an increasing function of the pollutant level x. But there may be some changes in the state level index. The Table below gives the comparative picture of the three indices.

Table 4.5 Air Quality Index using Alternate Functional Forms

States	*SPM**	*I_1**	*I_2**	*Rank SPM*	*Rank I_1*	*Rank I_2*
AP	165.25	27491.17	27491.17	12	11	11
Assam	67.5	0	0	16	14	14
Bihar	337.4	133962.2	61099101	3	4	1
Gujarat	217.2	52933.24	15160052	8	7	7
Haryana	320.5	51360.13	16460920	4	8	6
HP	210.88	46116.06	9641277	9	9	8
Karnataka	92.75	0	0	14	14	14
Kerala	117.83	6448.09	6448.09	13	13	13
MP	167	68915.72	16818313	11	6	5
Maharashtra	255.33	25217.81	25217.81	6	12	12
Orissa	199.38	43349.44	6940633	10	10	10
Punjab	363.6	135337.7	51370654	1	3	3
Rajasthan	298.02	95448.45	32631380	5	5	4
Tamil Nadu	74.63	0	0	15	14	14
Uttar Pradesh	357.24	137648.9	56446845	2	2	2
West Bengal	254.03	24217488	8072496	7	1	9

* SPM refers to Index using simple average of SPM levels, I_1 refers to the simple average of the convex transformation and I_2 refers to simple average of the step and convex transformation of SPM levels.

The table shows that in all the three indices the ranks of the states are more or less the same. There are no major rank reversals, except for the case of West-Bengal, which ranks first according to Index-2 but in other forms it assumes the ranks 7 and 9 respectively. This is because in all the three cities of West Bengal pollution levels are high while in case of Bihar UP, Punjab, some cities are critical while in some cities it is low. Having an average concentration in all cities give West Bengal a higher value. But when we start giving more weightage to higher values as in the case of Index 2, West Bengal falls back in the ranks of medium polluted states while Bihar which has very high pollution in some cities (and very low in some) takes the first rank. Altogether the rank correlation coefficients of the three indices are high, above 0.8, ensuring that the alternative formula do not bring any major change in the rankings.

Table 4.6 Spearman's rank correlation between alternative air quality indices

CORRELATION	*SPM*	I_1	I_2
SPM	1	0.820*	0.861*
I_1	0.820*	1	0.882*
I_2	0.861*	0.882*	1

* significant at 1 percent level of confidence.

As we checked the correlations between the air quality indices and the health index, we found that the specification of I_1 does not correlate with the health index. But I_2 strengthens the relationship between health and pollution to some extent. The correlation values are given in Table 4.7.

Table 4.7 Correlation between Health Index and Air Quality Indices

		SPM	I_1	I_2
RESPIRATORY ILLNESS (URBAN)	Pearson Correlation	0.582*	-0.0601	0.584*
	Spearman Correlation	0.550*	0.410031	0.534*

* Significant at 5 percent level of confidence

4.4 Conclusion

In this chapter we have looked into the problem of urban air pollution and its impact on health in the form of respiratory diseases. In our discussion we have initially tried to identify the causes of air pollution and the effects. Air pollution leads to respiratory diseases, heart problems, hypertension and even neurological damage among children. However, there is no one-to-one correspondence in the sense that only one pollutant causing a single disease. Not only that, air pollution is not the sole cause for such diseases. This makes the problem of constructing indicators rather complicated. We have looked at two kinds of indicators, outcome indicators and process indicators.

As outcome indicators we have tried to estimate the incidence of respiratory diseases. We have only looked at the morbidity factors using NSSO data. A brief glance at the incidence of respiratory illnesses in India shows that it is not typically an urban phenomenon. Even in rural areas in some states, respiratory illness is high. However, we have restricted our analysis to the urban processes since our main thrust is on urban air pollution. Since respiratory diseases are not only caused by air pollution, there may be a whole lot of other causalities, so it is important to know how much of this incidence can be attributed to air pollution. This required a further look into the process indicators.

In the next step we have looked into the process indicators of urban air pollution. The city level pollutant level data collected by NAAQMS provided the necessary information to construct process indices. Even though average annual concentrations of three pollutants, NO2, SO2 and SPM are reported, it was found that the main problem facing the Indian cities is that of SPM. The other pollutant levels are below the CPCB residential standards. Hence the index of air pollution could be constructed using only the SPM levels. City level data was aggregated at the state level using a simple arithmetic mean formula.

When the air pollution index was compared with the health index, a positive correlation was found between the two. Air pollution, whether we use the health indicators or pollutant level indicators, does not have a direct relationship with urbanization or size of urban population at the state level. The medium urbanized states like Bihar, UP, Punjab, Haryana face the highest levels of pollution as well as respiratory illnesses. This brings to the foreground very clearly the need for proper urban planning and implementation of pollution control measures in the emerging urban agglomerations. The preoccupation of policymakers with the metropolises may be affecting the other cities adversely.

STATISTICAL APPENDIX

Table A 4.1 Pollutant Levels in Cities (1995) and City Population as % of State Urban Population (1991)

State	*City*	*SO2 (ug/cum)*	*NO2 (ug/cum)*	*SPM(ug/cum)*	*Population*
		Avg Annual	Avg Annual	Avg Annual	% of state urban
AP	Hyderabad	17.1	37.8	178.8	17.1
	Vizag	18.8	27.6	151.7	4.2
Assam	Bongaigaon	0.45	7.4	38	1.43
	Guwahati	4.3	30.5	97	23.49
Bihar	Dhanbad	31.1	39.1	275	1.34
	Jamshedpur	62.8	10.4	118	4.22
	Jharia	40.9	54.2	496	0.61
	Patna	26.1	29	521	8.42
	Sindri	34	46.4	277	0.64
Gujarat	Ahmedabad	32	18.76	251.2	20.74
	Ankleshwar	86.6	25.1	327	0.5
	Baroda	69.7	19.2	280	7.45
	Rajkot	15.5	8.2	59.5	4.3
	Surat	85.8	30.4	263	10.57
	Vapi	39.7	38.4	122.5	0.32
Haryana	Faridabad	38	14	320.5	15.23
	Yamunanagar	34.3	22.8	n.a	3.56
HP	Damtal	n.a	4.6	247	
	Paonta Sahib	4	7.9	225.5	2.94
	Parwanoo		12.1	229	1.3
	Simla	3.4	11.3	142	22.75
Karnataka	Bangalore*	19.8	11.5	89.5	23.74
	Mysore	33.5	31.05	96	4.36
Kerala	Cochin	10.3	14.8	82.2	7.59
	Kottayam	2.4	35.5	140	1.17
	Kozhikode	12.2	11.3	88.5	5.95
	Trivandrum	14.3	22.4	160.6	9.11
MP	Bhilai	19.8	32.9	290.7	2.58
	Bhopal	12	19.2	207	6.93
	Indore	6	10.2	389.6	7.23
	Jabalpur	1.7	61.5	180	4.98
	Korba	10.4	7.8	257	0.81
	Nagda	46.3	31.6	205.3	0.52
	Raipur	16.5	20.7	257	3.02
	Satna	15.3	14.7	256	1.05
Maharashtra	Aurangabad£	19.8	18.6	149.5	1.88
	Mumbai	31.1	34.2	209.8	32.5
	Chanderpur£	21.4	36.4	170.5	0.74
	Nagpur	8.3	14.2	184.7	5.32
	Nashik£	15	26.4	147.5	2.15
	Pune	22.5	23.4	140	5.13
Orissa	Angul	21.2	12.3	159.5	0.58

State	City	SO2 (ug/cum)	NO2 (ug/cum)	SPM(ug/cum)	Population
		Avg Annual	Avg Annual	Avg Annual	% of state urban
	Raygada	18.1	29.3	158.5	1.14
	Rourkela	39.3	38.6	302.5	9.11
	Talcher	17	14.4	177	0.63
Punjab	Jalandhar^	38.7	52.3	285	8.5
	Ludhiana^	21.2	50.9	394.8	17.4
	Patiala^	21.9	50.7	411	4.23
Rajasthan	Alwar	27.3	73.6	380	2.09
	Jaipur	9.6	26.8	218.5	14.49
	Jodhpur	41.3	32	413	6.62
	Kota	7.1	64.1	238.3	5.34
	Udaipur	18.1	45.5	240.3	3.07
Tamil Nadu	Coimbatore	1.7	5.7	42.5	4.28
	Chennai	21.7	17.5	127.4	20.14
	Tuticorin	8.4	16.5	54	1.05
Uttar Pradesh	Agra	18	10.3	423	3.23
	Anpara	48.7	46	229.5	
	Dehradun	28.3	19.8	323	0.98
	Gajroula	22	17.8	320	0.08
	Kanpur	14	15.9	463.2	6.81
	Lucknow	29.8	28.5	504	5.87
	Varanasi	23.6	19.6	238	3.38
West Bengal	Kolkata	35.7	29.9	354.3	15.94
	Haldia	27.95	44.9	103.5	0.54
	Howrah	72.9	204.3	304.3	5.08

n.a Not available
* Data relates to 1991
^ Data relates to 1993
£ Data relates to 1994

Chapter 5

SUMMARY AND CONCLUSIONS

This study aims at constructing some macro-level indicators for quantifying the wellbeing impacts of environmental degradation. It takes off from the debate whether environment indicators should be integrated with human development indicators. We hold the view that instead of trying to construct an all inclusive human development index, it is more appropriate to focus on the environmental issues and the impact on wellbeing and develop indicators of wellbeing, which will represent these environmental problems specifically. Such indicators can also be useful at the policy level.

With that as a starting point, we try to look at the environmental problems related to the sixteen major Indian states and their wellbeing impacts. There are so many environment-related issues to deal with, so it was necessary to focus on a very few issues to be able to do any justice to them. Just as the literature asserts that the environmental problems related to developing and developed countries are different, we argue that in a country like India the problems faced in rural areas are different from that of urban areas. While the urban problem is more pollution related, the rural problem is more livelihoods based. So, we chose to identify the problems in rural and urban areas and dealt with them separately.

The major problem faced in rural areas of India is the sustainability of livelihoods through the sustainability of the agricultural production process. The external and internal pressures on agriculture are large and such pressures are leading to a degradation of the agricultural resource base. Intensive agricultural practices are leading to land degradation in the form of waterlogging and salinity, and also groundwater pollution and contamination. The degradation of the resource base has direct impact on rural livelihoods and it also raises questions on the food security of the country as a whole.

In order to quantify the phenomenon, we have tried to build to two kinds of indices, an outcome index of degradation and a process index for sustainability of production. The degradation index constitutes of two components: land degradation and ground water depletion. The sustainability index is a composite index of nine process indicators. These two indices along with the food security indicators like yield, consumption-production ratio and share in total foodgrain production tells an interesting story.

If we look at the major producing states, it reveals an interesting if threatening pattern. The major producing states[1] where agriculture is a dominant activity are Punjab, Haryana, West Bengal, Uttar Pradesh, Bihar, Tamil Nadu and Andhra Pradesh. These states have different "take-off" periods. It was seen that the two leaders of the green revolution Punjab and Haryana are among the most degraded and have the most unsustainable resource use pattern. Then we have West Bengal, which is degraded but lies in the medium range of sustainability. Bihar has a low value of degradation index and a middle value in sustainability index. But the rest of the states Uttar Pradesh, Tamil Nadu and Andhra Pradesh have highly unsustainable resource use even though they are not so degraded. There is very high correlation between the sustainability index and the yield.

So what do we infer from here? In our opinion, we have to take a second look at our agricultural policy. The orientation of the agricultural policy in India is necessarily a 'short term' one, where the major objective is to be self sufficient in production. To achieve the production goals by the fastest route, we have selected a strategy that concentrates on a few regions and a few crops. This had two types of impacts. The states of Punjab and Haryana, which were developed as the food bowl of the country, have paid a very high price in environmental terms for the food security of the country. The second impact is that, due to price and other incentives, the cropping pattern has shifted in favor of wheat and rice without any consideration on the natural suitability of such a cropping pattern to the agro-climatic conditions of the regions. This has intensified the pressures and lead to unsustainable production structure.

In our view, it is time to usher another New Agricultural Policy – a policy that will look at the long term sustainability of agricultural practices and which will aim at a much more diversified production base. Dividing the country into agro-climatic zones and providing incentives for crops and production systems, which are naturally suitable for each zone may be a good idea. The policy package should not only include subsidized inputs but also comprehensive resource management schemes.

The problem identified for urban areas is that of air pollution and its associated health impacts. The problem of increasing levels of air pollution in congested urban areas of the country has manifested itself in the form of high incidence of respiratory diseases. To quantify

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[1] Here we define major producing state on the basis of our Foodgrain Index in Chapter 3. The foodgrain index is the ratio of total foodgrain production to geographical area.

this, again we have built two types of indices; an outcome based health index and process based air pollution index.

The health index shows the incidence of respiratory diseases. There seems to be no clear relationship between total urban population or urban population density of states and the burden of respiratory diseases. Middle urbanized states like Bihar, Punjab, Haryana have very high incidences of respiratory illness. Since health indicators are influenced by a variety of individual, seasonal and geographical characteristics apart from environmental factors, it was necessary to look at the process indicators.

The air quality index also confirms the general pattern revealed by the health index. Bihar, Punjab, Haryana, UP have very high concentrations of air pollution. In fact, Patna has the highest concentration of SPM, which is the major pollution factor in India.

The pattern revealed in the outcome and process indices brings to the foreground a number of issues. It raises questions on the metro-centric pollution policies and the neglect of the developing townships in terms of urban planning, pollution abatement laws and related issues. Even the few micro level studies that are taking place to estimate the health impacts of air pollution, are concentrated to the metropolises. We do not say that this concern is misplaced. But metros have infrastructure and other advantages to overcome the problem. Delhi is an example how the air pollution problem can be tackled with sufficient measures. However, the problems in other cities with equally polluted environments are obscured by presence of these omnipresent metro cities. It is time that they deserve some attention.

Apart from the strategic questions, the analysis also brings forward some basic methodological issues. To be able to get a true picture of situations, two things are necessary. Firstly, the data we are working with should be of good quality. Secondly, the tools that we use should be used with some discretion. In our analysis we have emphasized a number of times about the data problems. India is yet to come up with a comprehensive environmental database. The process is expensive and time consuming. So it is important to set up priorities. It is imperative that immediate concern areas are identified and data are made available in those areas at the earliest. In our view, the priority areas should be those, which have direct bearing on the wellbeing of people. Of course, steps are already being taken in this direction as the National Workshops on Environment Statistics being held annually suggest.

The second issue has been dealt with in much detail in our discussions. It is regarding the theoretical basis of constructing index numbers. When we construct index numbers, it should not be done in an ad-hoc manner. The type of functional form used, the aggregation formula used – each step should have adequate theoretical backing. There lies the strength of a truly representative index.

The focus of this thesis has been quite limited due to many practical constraints. Even with our limited focus, we have been able to draw attention to some issues. There are many equally important issues, which can be taken up as a continuation of this study. The same type of analytical structure can be adopted to address similar issues.

In our rural scheme, we have restricted ourselves only to the agricultural problems. But equally important are problems of health (indoor air pollution, water-related diseases, and sanitation). Even our analysis of agriculture is incomplete with no mention of shifting cultivation, deforestation and such issues. All these problems can be taken up for further probing.

Our urban scheme also leaves many issues unattended. Waterborne diseases, industrial pollution especially from discharge of effluent wastes into rivers are a few such issues. Some of these issues, for instance those related to water pollution could not be taken up due to data problems. The water quality parameters, which are reported by the Central Water Authority are mostly reported according to river basins and could not be aggregated at the state level. There were also problems of standardization, wherever some data was available at the state level. All this hampered further progress on this line.

As we have mentioned when we defined our objectives, the thrust of this dissertation is as much on methodological issues related to construction of environmental indices as on the interpretation of results. While our results do bring up some policy issues, our methodological discussions also raise some important measurement issues. We believe, both aspects are of equal importance.

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