Natural Resource Accounting and Budgeting in the Yamuna sub-basin: An Alternate Methodology

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Photograph on the cover is of the Indraprastha Estate, New Delhi, in the early 1980s

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EXECUTIVE SUMMARY

1. The primary objectives of this study are two:
   - To develop a methodology for the accounting of natural resources, appropriate to India.
   - To apply this methodology for some selected aspects in the Yamuna sub-basin and in the Delhi National Capital Region.
2. This study has been jointly conducted by the Indian Institute of Public Administration and Kalpavriksh.
3. The first task of developing an appropriate methodology needs to be prefaced by a survey and critique of the existing methodologies.

   Apart from various inherent weaknesses in the existing methodologies, they were found to be inadequate especially in terms of:
   - Meeting the objectives of (sustainable) development.
   - Meeting the requirements of conservation, especially biodiversity conservation.
   - Meeting the requirements of equity, especially in countries like India.
4. In order to establish this, it is important to understand the notion of development and its evolution. Evolving from the historical understanding of development as just economic growth, today development is understood as economic growth that is both equitable and sustainable (environmentally).
5. The notion of sustainable development can best be understood as being the rate and form of growth which does not transgress the carrying capacity of nature. The carrying capacity of nature can be understood as both its productive capacity and assimilative capacity.
6. In the current understanding of development, both sustainability and equity must be seen as absolute values. However, in the prevailing methodologies of NRA the value of a component of nature is determined by what the market forces indicate. Therefore, the absoluteness of sustainability and equity values cannot be maintained.
7. If an effort is made to maintain them through manipulations of the market, then the values ascribed are arbitrary. Besides, market forces *per se* militate against the poor and the economic process of discounting future value militates against sustainability.

8. The answer, therefore, is to evolve a new system that does not have the weaknesses of the current systems. The suggested new methodology is a mix of both physical budgeting and economic valuation.
9. The new methodology first determines the minimum quantity (of a resource) required to ensure its ecological integrity and, consequently, its renewability. This is determined in physical terms and put apart as the requirement for sustainability.
10. From what remains, the amount required for meeting the basic needs of the people dependent on the resource is then determined, in physical terms, and again put apart as the requirement for equity.
11. Any surplus that remains is then valued using the available market instruments.
12. The specific methodology to be used depends on the resource and other objective conditions.
13. Such an approach not only has the advantage of safeguarding the environment but also of meeting the requirements of social equity. It also focuses attention on methods of enhancing scarce resources.
14. Therefore, if there is a shortage of a certain resource in the market, the market demand will not be met by either degrading the environment or depriving the poor.
15. The excess demand will translate into rising prices, which will start making it economical to either invest in alternatives or to develop ways of using the resource efficiently. Where possible, it will also translate into investments for increasing the supply of the resource.
16. If we take the example of water, it would encourage technologies which use less or no water and which recycle water. It would also encourage investments in the regeneration of catchments and in other water conservation methods.
17. A similar scenario will develop for other resources, like biomass.
18. To test out this approach, three detailed methodologies have been developed:
    - For river waters
    - For forests, and
    - For allocation of land for green cover to control air pollution in cities.

19. The methodology related to river waters involves the assessment of the minimum flow of water required is a river in order to safeguard the riverine ecology, including its environmental functions and its biodiversity.

20. Various existing methodologies are available. These include:

- Hydrological index methodologies
- Hydraulic rating methodologies
- Habitat simulation methodologies
- Holistic methodologies.
- Various Other methodologies

21. A mix of elements of these various methodologies is developed for testing on the river waters of Yamuna. The flows are determined for maintaining the biodiversity of the river, for assimilating the pollutants, for ecologicalrestoration, and for meeting the drinking water needs of the dependent populations. The results are:

Budget

Total mean year availability has been assessed as		**13.000BCM**
Quantum of water not available due to flood spills BCM		0.068
Quantum of water needed for ecological restoration with a flow of 10 cumec BCM		0.032
Quantum of water required to support apex species of fish which requires a flow of 90 cumec		2.88
Total water required for Drinking purposes BCM		2.562
Quantum of water required for pollution abatement BCM		7.100
Total		**13.254 BCM**
Deficit	**(-)**	**0.254 BCM**

22. A methodology for budgeting for forests is also developed. As forests cannot be conserved everywhere, first the methodologies for prioritising among forest areas are discussed. The best scientific methodology is what is known as the iterative methodology. In this methodology, the area with the highest number of species is taken as the first priority. The next area is that which adds the highest number of species to those already found in the first priority area, and so on.

23. Unfortunately, such a methodology, though scientifically correct, is not usable in India as the sorts of data it requires are not available. Therefore,

a compromise methodology is evolved using the data available in India. It is a methodology that is appropriate to data deficient situations.

24. This methodology involves using remote sensing imagery of forest cover and first demarcating those areas that are relatively undisturbed. It then involves the local forest officers and other knowledgeable people in developing an area profile to assess the real biodiversity and socio-economic profile of each of these areas. Prioritisation is then done on the basis of these inputs and separately for each forest type and for each biogeographic zone.
25. The existing protected areas are also assessed and prioritised on the basis of their biodiversity value, their management effectivity and the level of threats.
26. The priorities for the Yamuna sub-catchment are then identified.
27. The existing and required conservation status is assessed in terms of the requirements of its ecological viability in terms of size and the minimum viable population of carnivores and ungulates.
28. The forest area required to sustainably meet the requirements for fuelwood and grazing are then discussed and a methodology developed and applied.
29. A methodology is also developed for calculating the green cover required to maintain the air quality in Delhi, especially for SPM, within acceptable levels. The methodology involves determining the capacity of different species of trees to trap suspended particulate matter. Then the green cover of Delhi is calculated and, based on SPM emissions, the required cover is contrasted with the actual cover. The results are as follows.

Area needed to be under tree cover	= 333532 acres
Area under green cover by municipalities	= 55225 acres
Deficit	= 278307acres

Delhi's area is estimated as 1483 sq. Km.

1 sqkm=1000000 m. So 1483 sqkm is 1483000000m or 1483000 hectares or 3663010 acres
591 sqkm is 591000000 m or 591000 hectares or 1459770 acres

Green Area Table

Delhi's area (Total)	3663010 acres
Green area available	55225 acres (1.51% of total)
Green area essential	333532 acres (9.105%of total)
Deficit area to be greened	278307 acres (7.597%of total)

30. This determines the principles by which land use has to be determined in order for green areas to be allowed to play their ecological functions. The choices are either to increase the green areas or to otherwise reduce SPM emissions. The costs of both alternatives can be worked out. However, the absolute principle of having SPM within the prescribed limits cannot be compromised.

INTRODUCTION

Objectives

The objectives of study, as jointly carried out by The Indian Institute of Public Administration (IIPA) and Kalpavriksh (KV), and as specified in the memorandum of understanding, were:

IIPA, New Delhi *shall be responsible for the following studies for NRA:*

* *Development of methodology, social, legal and policy issues and biodiversity studies*
* *Supporting **CISMHE** in resource accounts and valuation studies of biological resources*
* *Supporting **IEG** in resource accounts and valuation studies of forest resources and integration with income accounts and supporting **NEERI** in overall integration*

The data available, and generated by the participating institutions in the project shall be made available to the coordinating institution for analysis and preparation of interim and final reports to be submitted to MEF.

KALPAVRIKSH, New Delhi *shall be responsible for the following studies for NRA:*

* *Supporting **IIPA** in biodiversity studies The data available, and generated by the participating institutions in the project shall be made available to the coordinating institution for analysis and preparation of interim and final reports to be submitted to MEF.*

Apart from support to other institutions and the provision of data, the remaining tasks were:

1. Development of a methodology for natural resources accounting (IIPA);
2. Identifying the social, legal and policy issues (IIPA);
3. Conducting some biodiversity studies (IIPA);
4. Supporting the biodiversity studies of IIPA (KV).

Structure

Chapter 1 of this report lays down the context within which the assessment of a methodology for natural resource accounting needs to be done. It also deals with the methodological issues and, apart from critiquing existing methodologies, suggests an alternate, optimal, methodology.

Chapter 2 develops and applies a detailed methodology for aquatic ecosystems and biodiversity. It examines the uses of water as a resource and as an ecosystem, reviews existing methodology for assessing the minimum required flows in rivers, and then applies this methodology to the Yamuna River. It develops a natural resources budget for the Yamuna River based on the requirements for ecological functions, biodiversity, assimilation of pollutants and drinking water requirements.

Chapter 3 developes and applies methodologies for terrestrial ecosystems. It discusses the need for prioritising among sites, zones and areas and for determining the function that a site or area has to play. It then lays down some of the basic principles on the basis of which sites and species can be prioritised for conservation. It then goes on to develop and apply methodologies for prioritising and budgeting forest areas for ecological functions, for biodiversity conservation, for sustainable extraction of fuelwood and use as grazing lands, and as green cover in urban areas for controlling airpollution

I ENVIRONMENT AND ECONOMICS

1.1 The Background

The advent of modern civilisation has brought about many changes in society: some considered good, and others bad. One of the less desirable changes is the increasing tendency to see everything in the world as a commodity which can be brought or sold, or at least 'priced' in financial and economic terms. As a result, there is a complimentary tendency to value things only if they have a financial or economic value. This has led, in the last two hundred years, to the single minded pursuit of "goods and services" at the cost of all else. Human suffering, because it is not quantified in monetary terms, has not been considered a cost when establishing the financial and economic viability of projects and activities producing marketable "goods and services". So has been the fate of social and moral values, of culture and tradition, of art and aesthetics and, of course, of nature and the natural environment.

Nature has increasingly been seen as a 'resource' and, for many years, as an endless (or free) resource. Till the middle of the twentieth century, there was little concern about 'harvesting' the produce of nature in increasing quantities, to feed our appetites for 'goods and services'. The waste that the production and provision of these 'goods and services' generated was again dumped back into nature. However, as the cost of environmental degradation started being felt, both in terms of the reduction of resources and the impacts on the health, well being and even the life of the citizens, there was a renewed demand for protecting the environment.

The need to start caring for the environment was interpreted by various sections of the society in different ways. For the environmentalist it meant that, finally, it was being recognised that we could not continue to ignore the environment. Therefore, the carrying capacity of nature must now be determined and we must curb our consumption levels and the consequent level of waste, to be within the carrying capacity. There was no question that nature must be conserved.

To the social activist it meant that, within the carrying capacity, nature must be equitably used and conserved so that all segments of the society benefited from nature, and sacrificed for its conservation, equitably. To the animal rights activist it meant that perhaps now the right of other, non-human, living creatures to live, and live well, would be recognised and not be linked to, and limited by, their utility to humankind.

In short, one view and perhaps the enlightened view, was that it was necessary to ensure that the wants of one class of human beings did not compromise the rights of others to share and enjoy nature (intra generational justice). Similarly, the wants of one generation should not compromise the rights of others (inter generational justice), and the wants of one species (the human species) should not be allowed to override the rights of all others.

<u>A Short History of "Sustainable Development"</u>

But 'development' has continued to be the predominant preoccupation of most societies and that too, understood almost exclusively as economic growth. Initially, there was an assumption that the basic lot of human beings would be bettered by development. Development would exterminate hunger and disease and, consequently, put an end to violence and war. It would free people from the drudgery of working long hours at low productivity, in order to fill their stomach. These freed individuals would then have the time and freedom for the higher pursuits of life, like the arts, music, poetry and philosophy. These hopes were soon belied. Though many of the old diseases did get controlled or even exterminated, development itself brought about new ones that were just as pernicious as the ones it got rid of. Even where the overall life expectancy of individuals started rising, it was not that they were now living distinctly happier lives or were living long enough to die happily. Certainly, in many parts of the world, hunger started disappearing, but in other parts of the world it got aggravated. Violence increased and so did wars, and now they became even more vicious and destructive. Added to the historical problems of disease, hunger and violence were now the additional problems of poverty and inequity, globally and within nations.

One side effect of development was the ease by which different societies, sometimes separated by thousands of kilometres, could interact with each other. Though not necessarily a bad thing in itself, it unfortunately also led to the ability of some societies, the more ruthless ones, to exploit the natural environment of others. One credible view of the history of world development is that it was initially fuelled by the human and natural resources that the 'developed' countries expropriated from those that they exploited. The technological superiority that is often virtuously claimed to be the reason why some countries developed faster than others was really a result of this initial exploitation and, in any case, played a much smaller part in the differences in the pace of development between different countries.

The exploitation of natural resources was carried out in different ways. It was achieved through inequitable trade relations, through the spoils of battle, through colonialism and through external, but proxy, economic and political control over countries. The important point was that the costs of the increasingly high standards of living of some countries, especially the environmental costs, were transferred to other countries who, of course, had little share in the benefits.

This pattern of exploitation was not only between countries but also within countries. Elite classes within countries, either indigenous or created by the external masters, also began enjoying high standards of living and transferring the environmental costs to other parts of the country or other segments of the society.

It is in this backdrop that the growth of environmental consciousness must be understood.

In the 1960s, environmental concern started growing in the 'developed' nations of the west primarily because of the adverse impacts of 'development' on their own societies. The two issues that caught the attention of the western public were pesticide poisoning and pollution, especially air pollution in major cities like London and the contamination of many rivers like the Thames. There were also major scares, especially in the USA, about carcinogenic substances in water, air and food, and other hidden causes of cancer and a host of deadly diseases. The concern was less for the environment and what was happening to it and more for what the impacts of a polluting environment were on the health and well being of the people. Even then, the governments of the world and other social institutions were loath to act. However, public opinion grew rapidly and, especially in democracies, it could not be ignored for long. A series of stringent laws were enacted, regulatory mechanisms set up and the industry, municipalities and other polluters were warned. Where the goodwill of the public was concerned, especially as it translated into votes, there were no other options.

Sustainable Development

It was in this context that the concept of sustainable development came into existence. "*Development*" is a major objective of governments and societies across the world. Countries and societies have, for many years, been classified in terms of their state of development: as underdeveloped and developed, and then as developing and developed. More recently, the terms "south" and "north" are being used to categorise "developing" and "developed" countries respectively. Nevertheless, whatever the language, the primary preoccupation is with the status of development.

The term development actually refers to a process rather than a state of reality, and even the term developed is misleading for it suggests that the countries so described have reached a stage such that no further development is required. However, this is not true and all societies and nations, however developed, can develop further and are only developed in comparison to those less developed than them.

The notion of development has had an interesting history. When it first began being used to describe countries, it referred almost exclusively to the levels of economic development or growth that had been achieved. Therefore, countries were considered developed in direct proportion to how rich they were in economic terms. European countries, with many colonies and, consequently, with large revenues and surpluses, were described as more developed than those which did not have colonies and, consequently, were economically poorer.

However, at the turn of the century and especially after the First World War (1914-1918), many people began to question this understanding of 'development'. It was felt that economic growth alone could not be considered development unless it promoted equity. Consequently, a country that had, as a part of its 'empire', colonies that were impoverished, could not be considered developed. Similarly, if within a country the wealthy were few and the many poor, then again such a country could not be considered developed, even if its wealth was very great.

In recent times such thinking has been translated into what are known as *social or human development indicators*, which include education, health, sanitation, access to drinking water, nutritional levels, and civil rights. The United Nations now brings out a Human Development Report that ranks countries in terms of their development status concerning these various social and human indicators.

In the 1960s, another type of concern started being expressed about the definition of development. With the growing realisation of what we were doing to our natural resources, people started questioning whether a country could be considered developed if its economic growth was based on the destruction of nature and natural resources. Considering natural resources are the most fundamental of resources, even more fundamental than financial resources, any process of growth which destroyed these resources was bound to fail in the medium to long run. Such a development strategy was not likely to be sustainable. Out of such a realisation grew the notion of *sustainable development.*

Development therefore was redefined to mean only that economic and social growth that was equitable and that could be sustained over time. The term "sustainable development" began to be used to distinguish between the old idea of development and the new, sustainable, one.

Sustainable development has been described as development which:

> *"...meets the needs of the present without compromising the ability of future generations to meet their own needs."* (Our Common Future 1987)

Carrying Capacity

To fully understand what sustainable development means, we must first understand the notion of *carrying capacity.* The carrying capacity of an organism or a system is its ability to meet demands and withstand pressures without doing permanent damage to itself or compromising its ability to meet future demands and withstand future pressures.

For an ecosystem, this could mean its ability to tolerate extraction (its productive capacity) and withstand pollution (its assimilative capacity) without getting degraded.

To understand this better, consider that even human beings have a carrying capacity. We can produce a certain amount of blood in a month and, as such, we can donate x litres per month without damage to our health. Similarly, we can assimilate a certain amount of caffeine or other pollutants, without permanently damaging our health. However, if our body was drained of blood or if we were exposed to the type and quantity of pollutants that were beyond our ability to assimilate, then we would not only seriously injure ourselves, but in extreme cases also die. In any case, our ability to produce and function would be impaired.

A similar thing happens in nature. For example, take a river. The river has an ability to function without permanent damage even if a certain amount of water is withdrawn from it and taken for human consumption. However, if we drain the river of most or all of its water, then the river, as an ecosystem, dies or gets permanently damaged. Also, a river has the ability to assimilate some pollutants and to *biodegrade* them so that they do not damage the ecosystem. However, if we dump the types or quantities of pollutants that are beyond the assimilative ability of the river, then the river gets seriously damaged and even dies.

The diagram below shows how we interact with nature and excercise its carrying capacity:

CARRYING CAPACITY

NATURE

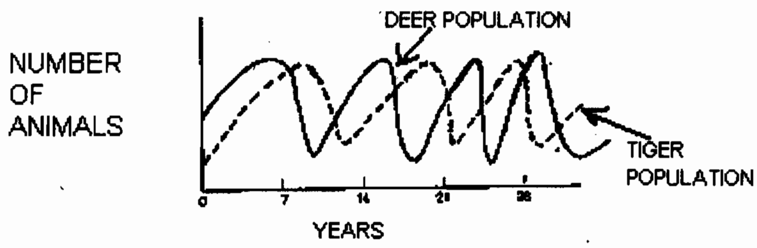
Using the produce of nature	Releasing waste into nature
THE PRODUCTIVE CAPACITY OF NATURE	THE ASSIMILATIVE CAPACITY OF NATURE
forests	*water pollution*
biodiversity	*air pollution*
water	*land pollution*
soil	
minerals	

Therefore, one way of ensuring sustainable development is to ensure that the process of economic growth does not take from nature more than it is able to regenerate, and does not pollute nature beyond its ability to assimilate.

The carrying capacity of a resource is not finite. Through better management and technology, the carrying capacities of various natural ecosystems can be enhanced. For example, through the application of genetic engineering, mainly in the form of better seeds and faster growing strains of crops, the productivity of cultivated plants and of the land on which they grow can be increased. The application of fertilisers and irrigation can also enhance the productivity of land. Similarly, the assimilative abilities of an ecosystem can also be enhanced. Recently there have been successful experiments with earthworms - called wormiculture - where the introduction of earthworms in compost pits can significantly enhance the ability of the ecosystem to break down the waste matter and assimilate the biodegradable substances, consequently enhancing the quality of the soil.

Human beings are perhaps the only living creatures on Earth that have the ability to exceed the carrying capacities of ecosystems to a point where these ecosystems get degraded or destroyed. In the rest of nature there are in built checks and balances to prevent the over utilisation of natural resources. The consumption of resources by animals is determined by the availability of such resources.

So, for example, if the number of deer in a particular area increase to a point where they start consuming more grass then can be regenerated, then the availability of grass goes down and this, in turn, adversely affects the population of deer. Similarly, if the number of tigers in an area increase to a point where they eat up the other *prey* animals faster than these animals can reproduce then, very soon, there is not enough food for these tigers and their population begins to decline. Their population rapidly reaches a point where the balance between their populations and the population of the prey animal is restored without any permanent damage being done. This cycle is endlessly repeated. The diagram below explains this relationship.



PREY PREDATOR DIAGRAM

Also, in nature, nothing is wasted. The 'waste' of one creature is the food of another or is finally an input into one part or another of the ecosystem. Therefore, a whole host of insects and micro-organisms live in and off the excrement of various animals. These insects and micro-organisms break down this excrement to a point where it becomes nourishment for the soil. Similarly, dead plants and trees and even the carcasses of animals, become homes and food for other creatures that, in the process, help them to be assimilated by the ecosystem.

Only human beings, because of the rate at which they consume, the technologies that they have developed for facilitating consumption, and the nature and quantum of the waste they throw out, have a tendency of exceeding the carrying capacity of the ecosystems they depend on. The problem is aggravated by the fact that human beings have the ability to immunise themselves from the consequences of degrading their immediate environment by transferring their attentions to other, remote, ecosystems, once their immediate ones are destroyed. Therefore, it is important to devise ways and means by which the interaction of human beings with the rest of nature is kept at sustainable levels.

Sustainable development is not something that can be achieved overnight. The path to sustainability is through ensuring that every project, every activity, every scheme and every policy is progressively made environmentally friendly till it itself becomes sustainable and promotes over all sustainability.

So, for example, sustainable development within and through the forestry sector means that we should harvest from forests only that much of timber and non timber produce that it can regenerate. So, for example, if a forest grows at the rate of 2 % a year, our harvest should never be greater than the *increment*. This is similar to the principle of judicious financial management where people are expected to not eat into the capital of their savings but live off its interest. *Take not from the capital of nature, but only from its interest.*

What we take and how we take is also important. For example, if we harvest the young and growing trees, then in the long term the forest will die. Similarly, if we concentrate our harvesting on only one part of the forest, then even though overall we might not have extracted more than what is regenerated, the area from which we have over harvested might become barren.

Similarly for biodiversity. Biodiversity or biological diversity is defined as the variability of ecosystems, species and genes. It is now recognised that the maintenance of biodiversity is critical for human wellbeing and survival.

Conservation of biodiversity implies ensuring that the variability among ecosystems, species and genes does not become less than what is natural and that, in any case, no ecosystem or species becomes extinct. There are many reasons why it is important to conserve biodiversity. Some of the major ones are described below.

Medicine: a large proportion of the medicines that are used in the world, especially the non-allopathic ones, are derived from plants and animals. Yet, we have only investigated about one percent of the known species for their medicinal and other values. And of the species likely to exist on earth, perhaps only twenty percent have so far been discovered and identified. If a species that has either not yet even been identified, or whose medicinal and other uses have not yet been investigated, becomes extinct, then the cure to some of the diseases that are currently plaguing the world, like AIDS and cancer, might be lost for ever.

Even if a species that we have already investigated and found to be of no use, becomes extinct, there are grave dangers. For, though this species might be of no use in curing the ailments we know about today, what is the guarantee that some new diseases might not appear in the future, just as AIDS did some years back. And then we might discover that its cure died with the extinction of the species that we thought was valueless. Therefore, in order to ensure that our options are not foreclosed we need to ensure that each species is conserved. This is the *option value* of biodiversity.

Agriculture: All the plants we cultivate or the animals we domesticate, are derived from wild species. In order to keep open the option of developing new strains for cultivation and domestication, we have to ensure that wild species are conserved. Also, if cultivated or domestic strains have to be immunised against pests or diseases, then most often wild species have to be used to create such immune strains.

Biotechnology: This is a new area which perhaps offers the greatest promise, among all technologies, to provide answers to some of the major problems facing the world: those of poverty, hunger and disease. However, the 'raw materials' of biotechnology are wild plants and animals. It is from the various plants and animals that genes can be found which, through genetic engineering, give new hope of solving many of the old problems. For example, the green revolution in India was a result of genetic engineering and, whatever might be the problems with it, has certainly raised the productivity of food grains in India. However, if species in the wild became extinct, then this 'raw material' of genetic engineering would no longer be available. We, therefore, must keep this option open also.

Web of life: All life is interconnected like the web of a spider. Each species is directly or indirectly dependent on all others. Therefore, if one species becomes extinct, then this affects all the species. The effect might not be felt immediately, but eventually the chain reaction starts.

For these and other reasons, it is important that biodiversity is conserved if development has to be sustained. Therefore, sustainable use of biodiversity implies that the natural diversity of ecosystems, species and genes be maintained.

Another relevant resource is water. Water is, after air, perhaps the most critical human resource. The location of human settlements, throughout history, has more often been determined by the location of water sources than by any other single factor. And historically many societies and cultures have perished because they could not manage their water resources properly.

Water is essentially a renewable resource, much of it subject to yearly or half yearly cycles. The water (or hydrological) cycle moves water from one place to another and changes some of it from one form to another. The monsoon winds pick up moisture from the Indian Ocean and distribute it, as precipitation, throughout the country. In this process, they also convert salt water into fresh water. There is also the melting of snows and glaciers, in the Himalayas, which feed many of our rivers.

To ensure that water is sustainably used it has to be ensured that the hydrological cycle does not go awry. This involves, to start with, ensuring that rainfall patterns do not get disrupted. Though the relationship between deforestation and macro climatic changes is not yet well understood, there is good evidence to believe that deforestation can cause serious disruption in micro rainfall patterns.

But, more important, the degradation of vegetative cover in the catchments seriously disrupts the water cycle and causes floods and droughts. Deforestation and degradation of the upper reaches of the Himalayas also causes micro climatic changes which affect the ice and snow melt regimes, thereby disrupting the hydrological cycle.

So, the first task is to ensure that water is available where required, in the right quantity and at the right time. The second task is to ensure that this water is clean and wholesome. Ordinarily, the water that comes down as rain or through ice or snow melt is pure and not polluted. However, certain types of air pollutants can contaminate rainwater even before it reaches the ground. A common result of such pollution is called 'acid rain'. Acid rain occurs when the atmosphere is polluted with sulphur dioxide (So2) which mixes with rainwater (H2o) to form sulphuric acid (H2so4). Such rain, instead of nourishing the soil and vegetation, destroys them. Thousands of hectares of forests in Europe and North America have been 'burnt' by acid rain. The soil there has become acidic and lost much of its productivity.

Apart from atmospheric pollution, water is also subjected to pollution on the ground. Silt, domestic wastes, agricultural run off and industrial wastes pollute our lakes, streams, rivers and even the ocean. Such polluted waters become unfit for most human uses. Due to rampant water pollution in India, most of the surface water is unfit for human consumption. Much of it is also unfit for bathing and some of it even for agricultural use. When polluted water is fed into industries, there is a danger that it would damage the machinery or otherwise adversely affect the industrial process. Polluted water also degrades the environment, particularly affecting the fauna and flora that either live in that water or partake of it.

Water is stored or conveyed on the surface of the earth in or through various water bodies. These natural bodies have an ecological process of their own and include lakes, ponds, seas, oceans, springs, streams and rivers. These are not mere receptacles or passages of water but also habitats for hundreds of living creatures: fish, insects, plants, snakes, reptiles and crustaceans. These water bodies also energise the water, just as they are energised by it. Water, as it rests in or passes through them, is oxygenated, cleaned and mineralised. If there are pollutants in the water, the ecological processes act to biodegrade them and to clean up the water again. Rocks and rapids in the streams and rivers help mix oxygen in the water, which the fish and other creatures living in the water then breathe for their survival.

When the water is polluted beyond its capacity to assimilate the pollutants, then these various functions of the *aquatic* and *marine* ecosystems get compromised. Similarly, if large quantities of water are extracted from such water bodies, then again the ecosystem gets affected and cannot perform normally. Where excessive pollution or extraction continues over time, the ecosystem gets irretrievably damaged, sometimes becoming incapable of supporting even the most basic life forms. Apart from the loss of fish and other life forms, this means that the water body is no longer able to cleanse the water and the water either becomes useless for human use. It has to be subjected to an expensive process of artificial cleansing before it can again be used.

Polluted water also poses a threat to its users. The threat to the environment has already been explained. It also threatens human health and it is estimated that 10,000 children die every day in India due to water related diseases. Also, water that contains large quantities of silt does damage to human made structures, silting up dams and tanks and damaging hydroelectric turbines.

Given the growing human population and the consequent increase in the demand for water, controlling the use and wastage of water, especially 'treated' water, is a high priority. What is required is 'demand side management' of water. The current patterns of water use are not only inequitable but also wasteful and unsustainable. While the well to do in a city throw away 12 to 16 litres of 'treated' water every time they flush their cistern, the poor in the same city have to line up for hours to get even one bucket of water. Our houses and industries are not designed to be water efficient and millions of litres of water are wasted because of leaking taps or outdated industrial processes.

1.2 EXISTING NRA METHODOLOGIES[1]

The need for economic valuation is seen to arise either because the market prices are not available or that they are inappropriate (i.e. they do not reflect the costs and benefits of using environmental resources). Such failures to completely or adequately reflect the opportunity cost are conventionally classified as arising from two sources:

1) Market Failures : Due to market imperfections, e.g. monopolies, or due to missing / incomplete markets (e.g. a market to pollute the atmosphere, which in turn arises due the lack of well-defined property rights). Another important omission in the context of environmental resources is the lack of future markets. The existence of Pareto Optimality, (a particularly desirable outcome in neo-classical economics) requires that a market exist for all goods and services at all times including in the future.

2) Government Failures : Due to the imposition of taxes and subsidies (both explicit and implicit) which may distort relative prices and therefore lead to misallocation of resources. A failure to take corrective action in the presence of market failures may also be classified as a government failure.

Without the need to document specific cases, it suffices to say that market prices need adjustment. Such non-market prices may be termed accounting / shadow prices. This need to adjust market prices is a relatively non-controversial issue, the difficulties arise in choosing a specific methodology and, of course, in selecting the prices.

While the price of many resources need adjustment, the case of biological and flow resources is unique due to one or more of the following reasons:

1) non-substitutability (e.g. the atmosphere)
2) irreversibility (e.g. extinction of a species)
3) uncertainties as ecological processes are imperfectly/ inadequately understood
4) provision of critical life-support functions
5) the threat of potentially catastrophic changes (e.g. global warming)
6) relationship between economic systems and the environment is unclear in many instances
7) open access nature of the resource (e.g. the oceans)
8) option and existence value of such resources

[1] This section was contributed by Mr Chiranjeev Bedi of Kalpavriksh, New Delhi.

Before discussing specific approaches to economic valuation a short summary of the various kinds of value, which together make up total value, is given below.

1) USE VALUE : made up of Direct Use Value involving provision of goods and services for direct consumption and production activities, and usually exchanged in the market, and Indirect Use Value involving provision of functional services.

2) OPTION VALUE : value which is not related to present use but where a potential use may exist in the future.

3) EXISTENCE VALUE : the intrinsic value of a resource

Two ways of classifying the various methods for economic valuation are presented below : The first is based on Munasinghe (1993)

	Conventional market	**Implicit market**	**Constructed market**
Based on actual behaviour	Effect on market Effect on Helath Defensive Cost Preventive Cost	Travel Cost Wage Differences Property Values Proxy Marketed Goods	Artificial Market
Based on potential behaviour	Replacement Cost Shadow Project		Contingent Valuation Other

The second is from Pearce and Moran (1994)

DIRECT APPROACHES	**INDIRECT APPROACHES**
(techniques that elicit preferences, directly by asking respondents to state them) a) Experiments b) Questionnaires (Surveys)-contingent ranking and contingent valuation	(techniques that obtain preferences from actual observed market-based information) a)Surrogate Market i) Hedonic price and wage techniques ii) Travel cost approach b) Other Approaches i) Dose -response techniques ii) Replacement cost

ACCOUNTING FOR THE DEPLETION OF NATURAL RESOURCES (RESOURCE STOCKS) - NATURAL RESOURCE ACCOUNTING

METHOD	SHORT DESCRIPTION	ADVANTAGES	DISADVANTAGES	SUITABILITY
Present Value Method	The value of an asset is the discounted sum of the stream of income that the asset will generate	theoretically sound	information intensive, needs future costs, prices, production levels and discount rates. Most of the future markets are missing. Even otherwise the method is expensive and time-consuming	
Land Value Method	Land (Nature) values ought to reflect the value of natural resource contained.	No need to calculate income streams, comparison of land values suffices.	Land markets are not competitive	
Net Price Method	Calculate changes in physical resources and multiply them by the net price	Simple and easy to calculate and inexpensive	Based only on current prices	
Replacement Cost	Calculate the cost of using another alternative resource to provide the same service /good		An Inadequate method since replacement may be impossible.	May be used where the earlier methods cannot be used
User Cost Methods	That total receipts from sale of mineral stocks consist of two components user cost and true income. The former should not be included in GDP.			

ENVIRONMENTAL ACCOUNTING (ACCOUNTING FOR THE DEGRADATION OF THE ENVIRONMENT)

METHOD	SHORT DESCRIPTION	ADVANTAGES	DISADVANTAGES	SUITABILITY
contingent valuation	The method involves asking respondents to reveal : a) WTP : willingness to pay for the provision of a good/service or to avoid a damage b) WTA : willingness to accept to forgo a change or tolerate it Relies on interviews personal or telephonic	theoretically sound and appealing	expensive and needs trained manpower, great care needs to be taken while sampling and in formulating questions to avoid misrepresentation. There is a danger of strategic answering.	A controversial method. Many argue that answers are unreliable and that replies are not borne out by actual behaviour.
Travel cost method	Value of an asset is determined / derived from the expenditure incurred on travelling to the site		data intensive, theoretical basis is questionable, econometrically difficult to handle due to multiple site-visits and site characteristics.,	popular for recreational sites.
Wage cost method	implicitly values characteristics such as morbidity and risk of mortality in labour market		labour markets are not perfect and in particular lack mobility	
Hedonic pricing	estimate implicit price by looking at real markets in which characteristics are traded such as noise and peace in the housing market		data intensive and often the assumption of competitive market is difficult to justify	

METHOD	SHORT DESCRIPTION	ADVANTAGES	DISADVANTAGES	SUITABILITY
Abatement/ replacement/ preventive/ maintenanc/ restoration costs or defensive expenditure	These are variations on the theme of keeping the natural environment intact. Two broad categories can be made : a) cost of avoiding damage b) cost of restoring the environment	abatement costs are simple to estimate		There can be large difference between abatement and replacement costs, the latter is usually much greater and can be a very high multiple of the former.
Dose - response relationships	Relationship between pollution (dose) and damage (response) is established and then valued at market prices.	Simple exercise where physical effects are well documented.	Can be expensive where relationships are complex and difficult to unravel	

Valuing Biodiversity

Before valuing biodiversity, we need to define it precisely. For the present, biodiversity refers to the variation that exists between plants and animals. Mere stocks of natural resources do not comprise biodiversity, since the operative word here is diversity. For example, a monoculture would be valued less then a mixed forest as far as biodiversity is concerned, irrespective of use value of the forest.

The valuation methods discussed earlier (especially the land-based methods) are not suitable since a market where the biodiversity or its products are exchanged has not developed. Even replacement cost is unsuitable since creation of life is not possible. Where, however, chemical compounds have been synthesized as substitutes for natural ones, replacement cost techniques would become appropriate. Maintenance costs - the costs of establishing and maintaining gene-banks (both in situ and ex situ) - are a possible way of estimating the value of biodiversity. For instance, the payments necessary to indigenous people / governments for them to protect tropical rain forests would comprise the costs of maintaining such forests.

Some estimates of biodiversity have been reproduced (provided earlier). However, what has been termed biodiversity is no more than the value of biological stocks.

The methods discussed earlier are discussed in some detail below.

Present value method

The value of an asset is the discounted sum of the stream that the asset will generate. Discounting refers to the process of calculating present values of future cash/ income flows at a given rate of interest and over a specific period.

To understand discounting it is useful to consider the more familiar notion of compounding. For example, at 15% rate, the value of Rs 1,000, one year from now is Rs 1,150. Now if one were to be asked the question --What is the present value of Rs 1,150, received one year from now, the answer would be Rs 1,000.

Or alternatively, the present value of Rs 1,000 (received one year from today), is Rs 869.6, i.e. Rs 869.9 would grow to Rs 1,000 at the end of one year if compounded at 15%.

The formula for present value is

$$NPV = \frac{Y1}{1+r}$$

where NPV = net present value

Y1=income

r is the rate of discount

Usually an asset will yield income over a period of time. Therefore the formula above would be modified to

$$NPV = \frac{Y1}{1+r} + \frac{Y2}{(1+r)^2} + \ldots\ldots\ldots\ldots + \frac{Yn}{(1+r)^n}$$

where Yi is the annual income accruing from the asset

n is the number of years the asset is expected to yield income

Y here refers to the net income . Alternatively, where income and expenditure (or more commonly benefit and cost estimated are made available), the formula can be written as

$$NPV = \frac{(B-C)_1}{1+r} + \frac{(B-C)_2}{(1+r)^2} + \ldots\ldots + \frac{(B-C)_n}{(1+r)^n}$$

where B and C refer to benefits and costs, respectively.

Land value method

This is a straightforward method involving obtaining and comparing the value/price of land. Differences in such valuation would reflect the value of the resource. For instance, depreciation in the rate of capital assets can be computed by calculating the value of the asset at the beginning of the period of comparing it to the value at the end of the period. The difference is a measure of economic depreciation.

The value of the asset is available from the market, where such an estimate is not available, the sum of discounted rentals (net receipts) from the asset can be used (which would make this method equivalent to the present value method).

Let the value of an asset at time i be given by vi. Hence, the change in value between two time periods Vt and Vt is given by

Vt - Vt-1

Now the value of an asset is the sum of discounted future income from the asset, to be calculated as in the section above.

Net price method

This method involves the following steps.

First , the calculation of changes in physical stocks.

Two, the calculation of the net price. Net price is defined as the market price minus the cost of discovery, extraction and marketing.

In the final step, the net price is multiplied by the change in physical stock of the resource to provide an estimate of resource depletion.

Strictly speaking the net price is the rent/profit in the marginal ton. But assuming costs as constant, this method is equivalent to the two mentioned above.

User cost method

This method is a radical departure from the ones outlined above. In all the previous methods, the value of depleted resources is deducted from measures of national income just as depreciation of manmade capital is deducted. However, El-Serafy, has argued that this method involves an error.

He suggests that the proceeds from the sale of natural resources should not be included the GDP to begin with. According to him, total proceeds (receipts) include two components user cost and true income. User cost is the amount that has to be set aside as an investment to generate a perpetual income stream.

True income thus is the difference between total receipts (less extraction costs) and the user cost.

1.3 NRA AND SUSTAINABLE DEVELOPMENT

The imperative for natural resource accounting seems, on the face of it, to flow from an urge to integrate natural resource parameters into the national accounting systems. This means that the GNP calculations of a country would reflect, each year, the use and accrual of natural resources. For specific projects and activities, a system of natural resource accounting would mean that the financial and economic costs of natural resources will be reflected in the cost benefit analysis carried out to assess the viability of the project.

Unfortunately, the methods currently being used by many countries of the North for generating natural resource accounts, have many problems. Some of them are outlined below:

Some shortcomings[2]

The existing methodologies (see Box I for an outline) rely heavily on the conceptual bases of neo-classical economics. The concept of value here is market price. Of course, this market, it is implicitly assumed, is an uncontrolled capitalist market where the actors can be neatly segregated into `demanders' and `suppliers' who haggle in some unspecified way to reach a market-clearing price. The problem with environmental goods is that there may not exist such markets for these goods. The neo-classical solution is to look for proxy markets or create hypothetical markets to try to value for environmental attributes from existing market prices.

This immediately raises two preliminary questions : (a) Is market price (whether from a modified, proxy or hypothetical market) the only or the best method of valuation of environment ? In other words, is economic value to present generation human society the standard by which value must and ought to be measured? (b) Since the methodologies implicitly assume a

[2] This section was contributed by Mr Pranab Banerjee of the Indian Institute of Public Administration, New Delhi

particular type of `market,' should value be in reference to only that type of society? For example, in a primitive tribal economy or a subsistence agricultural economy or even in a partially commercialised economy the market prices, if the exist at all, will differ due to underlying institutional differences. How are we to value goods in such cases even if we decide to value goods from human society perspective.

To give examples, private property in land may be absent in some tribal societies (sometimes land measurement concept may even be absent). A question regarding the willingness to pay for land may therefore be incomprehensible and any answer must be accepted with more than a pinch of salt. Similarly, in caste-based village economies exchange of produce may substantially be based on custom and therefore market prices will be different from that in a free-market society. The literature on market-interlocking in developing countries also points to the serious problem in using market prices. Even in a full market economy market prices will differ depending on the institutional mechanism and information available as game-theoretic approaches have amply demonstrated. The fact that valuation differs in different societies can have serious problems for methods such as contingent valuation. The tribal's willingness to pay or to accept compensation for land taken away cannot be compared with the value that an entrepreneur places on the land. The two `values' are not comparable categories: Market values, and hence any approximation to it, cannot be independent of institutional assumptions.

A second set of problems arises from the psychological assumptions behind neo-classical market value. The `demanders' are visualised as independent (i.e. ignores inter-dependence) individuals with given scales of preferences (which can be measured by utilities) with fixed incomes, exogenous market prices and motivated by the sole desire to act in such a way that the preferences (utilities) are maximised. There are also small assumptions like' local insatiability' - more consumption will be preferred (will give more utility) than less. (Local insatiability at each point is, of course, global insatiability). The higher the preference for a commodity, other things remaining the same, the higher would its value be.

If there are two identical groups of people with the one sole difference that one is concerned about increased CO^2 in the air whereas the other, not aware of its consequences, is least bothered by it, valuations will differ. Toxic wastes can therefore be dumped on the least informed as their willingness to accept compensation, based on their subjective preferences, will be the least. The theory legitimises such action even though the damage may be the greater to the ignorant.

But should subjective preferences be the basis for valuation of environmental goods? If an environmental resource is useful and scarce the willingness to pay for its use will always be greater than the willingness to pay for existence. To use fashionable terminologies, use values will always exceed existence values of fossil fuels, minerals and other non-renewable resources. Therefore, although these resources can be `valued' the implications of such valuations from the environmental view point are completely divergent. Option values and existence values are measures of conservation whereas use values put a premium on depletion. With advancing technologies and unabated consumption (local instability) higher will be the use values of environmental resources leading to greater degradation. Valuation of environmental goods based on subjective preferences therefore provides no guarantee against resource depletion.

Finally, preferences, contrary to the neo-classical assumption, are often interdependent. My preference for security gadgets will increase if I stay in a neighbourhood where people have preference structures of criminals. In environmental matters preferences of one generation to deplete resources and emit pollutants is very likely to lead to preferences of future generation against these acts. But the future generations are absent in today's market and therefore existence values of environmental resources are likely to be low today.

If all human beings had perfect knowledge and placed high values on what is right and not on what is selfish, subjective preferences would serve as a good basis for values. But in our day-to-day lives we are blundering idiots driven by greed (checked by societal fear) catering to small egos. Whether values based on the preferences of such individuals should be the standard is a debatable question.

BOX 1

VALUATION APPROACHES / METHODS FOR ENVIRONMENTAL GOODS

1.	**Effect of Production (EOP) :**	e.g. to value of erosion on the direction-site of the land at risk, or, alternatively, direct costs of conservation at risk, or, schemes (wood, fruit, etc.,) valuing off-site productivity effects is problematic.
2.	**Preventive expenditure (PE) :**	It is the expenditure necessary to avoid or mitigate damage. EOP and PE are alternate ways of valuing conservation benefits, though they can complement each other in the same appraisal. EOP can be used when the relevant effects can be predicted and valued with confidence, and when they are less than the costs of preventive measures.
3.	**Replacement cost (RC) :**	Used sometimes to value non-commercial species, e.g., birds or rare fish. In an estimate of the environmental damage of an oil-spill in Chespeake Bay, the replacement costs of birds quoted by commercial breeders and biological supply firms was used, averaging $ 30 per bird.
4.	**Travel cost (TC) :**	Inferring recreational values from travel cost data. But what about inaccessible regions?
5.	**Contingent Valuation (CV) :**	Based on `willingness to pay' or on `willingness to accept compensation' for existence loss of an environmental good.
6.	**Human Capital Approach (HCA) :**	The value of health effects can be inferred using this approach or cost of risk method derived mainly from wage differentials. This method infers the value of life from the amount that individuals or governments are apparently willing to spend to save a statistical life, i.e., to reduce the probability of death or serious injury. It is customary to value short periods of illness or restricted activity days (RADs) according to direct medical expenses incurred and the average loss of earnings.
7.	**Environmental Surrogates (ES) :**	Certain ES are widely marketed, and serve as a proxy for the value of the environmental services they replace (a variant of RC) e.g., privately sold water, private sewerage and garbage collection.
8.	**Hedonic Methods (HM) :**	Observed differences in property values attributable to clean air, wage differential attributable to occupational safety and health etc.

NRA and Biodiversity

From the earlier debate it is clear that essentially economic value is being attached to elements of nature in accordance with market determined value. The market value is being determined either directly or indirectly. There are many obvious shortcomings of such approaches. Some of them have been described earlier. However, when such methodologies are used to ascribe economic value to elements of biodiversity, and not just natural resources, then the problem becomes even more acute. Some of the major problems with trying to apply the existing methodologies to biodiversity are described below.

Classification of Nature: The first problem relates to classification of nature into that which has economic value or, as economists sometimes describe it, has alternate uses, and that which has no economic value for it has no alternate use. The belief that some elements of nature have no alternate use and therefore no economic or financial value seems misplaced. Perhaps, if one takes a very narrow definition of "value" and "use", then one could argue this. However, it is well established that each individual living organism represents a unique element of biodiversity. Therefore, it is difficult to imagine even a single plant or creature that has no use.

Attaching Value: Even more difficult is the method by which economic and financial value is attached to elements of nature. Unfortunately, economics as a science can only put a replacement value to those goods and services, which are inputs into, or outputs of, an economic process. Much of nature, critical as it is to human survival, is not an input or an output of an economic process. Therefore, for economists, it is either invaluable or valueless. As economics cannot handle the notion of invaluable, it tends to consider much of nature as valueless.

As an example, how can economics ascribe a realistic financial or economic value to the last surviving pair of a species of a bird, which currently might have no known economic function? Given the present methodology, such a pair would ordinarily be considered without economic value. Yet, this very species might, if it survives, become of very great economic value in the future. Nevertheless, as there is no way of predicting with any certainty whether this would happen or not, ascribing value becomes an impossible task.

The North-South Divide: Though the difficulties in ascribing economic value to elements of nature are common all over the world, their implications are far greater for countries of the South. Whereas in countries of the North most people have enough surpluses after meeting their immediate basic needs, to be willing to pay for recreation and long term needs like environmental conservation, this is not so in countries of the South. Therefore, if the economic value of the environment was to be determined through market forces, as is envisaged in many of the prevailing methodologies, it is unlikely that in countries like India the poor people would be in a position to choose long term needs over their immediate ones. Market forces would, consequently, make it difficult to conserve and protect anything.

Also, given the vast differences in the buying power of different segments of society in countries of the South, and between the North and the South, it is difficult to ensure socially just utilisation of natural resources. This is especially so if decisions were to be made solely or primarily on an economic basis.

Undervaluing Nature: There is also a tendency of governments, dominated by imperatives for economic growth, to systematically undervalue the contributions of natural ecosystems to the economy and to human welfare in general. For example, a forest can be contrasted with a human made industry. Whereas the human made industry requires inputs of capital, energy, raw materials, maintenance, replacement, and a labour force to make it productive, the forest, as an industry, produces goods and services critical to humanity without requiring any of these. It generates its own energy, produces its own raw materials, maintains and replaces itself, and goes on for eternity without needing any human input. However, the economic value attributed to forests never reflects this miracle of productivity and renewability.

1.4 ALTERNATE METHODOLOGIES: AN OVERVIEW

The task, therefore, is to develop a methodology which is appropriate for India, which is workable given the socio-economic conditions in India and which is in consonance with the principles of sustainable development.

The term sustainable development is mostly used in the context of natural resources and is understood to imply that the extraction of such resources must be sustainable in the sense of renewability. In other words, sustainability or renewability has come to mean that if a particular resources is being used or extracted, the rate of use or extraction must not exceed the rate at which the resource can renew or regenerate itself. However, such an understanding does not adequately take into consideration concerns about biodiversity conservation.

For one, many species that are not being specifically used or extracted can get adversely affected by the use or extraction of other species. Whereas the renewability of the primary (target) species may be safeguarded under 'sustainable use patterns', mostly the secondary (non target) species are not even considered. For example, the sustainable use of timber usually means that the amount of timber extracted from a forest does not exceed, in that time frame, the capacity of the forest to grow timber. Therefore, only the increment and not the capital is extracted. However, there would be many species of plants, insects, birds, reptiles and mammals that are dependent on the species of trees being extracted. There is rarely, if ever, an assessment to see whether the extraction is at a rate where their populations do not get depleted or adversely affected. Similarly with the sustainable use of grasslands, or rivers and oceans.

Of course, it can be argued that if other species in the ecosystem are being adversely affected then, sooner or later, this will have an adverse impact on the target species and their renewability will be threatened. Therefore, in so far as their renewability is being safeguarded, all the species linked to hem are also being safeguarded. However, the adverse impacts of the depletion of a particular species on another can take many years, sometimes even centuries, to manifest itself and, in any case, is not always obvious and is even now poorly understood. Therefore, if biodiversity has to be protected, just ensuring the sustainable use of the target species is not enough.

Even where the populations of other (non target) species are not depleted, there can still be a change in the populations and in the ecological processes. Such a change might itself be undesirable, especially as adequate representative populations and areas need to be maintained as genetic reference points. Therefore, there must be some areas which are entirely or substantially free from human use and disturbance. Proper sustainability must, then, include these concerns and considerations.

Keeping all this in mind and keeping in mind the earlier discussion on the contemporary meaning of 'development' (Chapter 1), any methodology for natural resource accounting which is to be in consonance with the notion of development must:

- Promote economic growth that is
- environmentally sustainable and
- equitable.

Judging from this standpoint, the current (market based) methodologies fail miserably.

For one, 'development' as defined above accepts sustainability as an absolute value, as it does equity. In fact, it constraints economic growth by prescribing sustainability and equity. However, current NRA methodologies do not accept any absolute values. Therefore, if the unsustainable use of a resource has greater market value than its sustainable use, then current NRA methodologies will prescribe unsustainable use as rational. By not accepting sustainability as an absolute value and, in fact, by discounting future value, current NRA methodologies actually militate against development in the real sense.

Similarly, current NRA methodologies have no absolute value for equity. In fact, market valuation will ordinarily militate against equity for the capacity of the poor to pay for resources would ordinarily be much less than that of the rich. Therefore, the current methodologies would invariably favour the rich and where there was competition between the poor and the rich for a resource, invariably prescribe that the rational thing is to give it to those who can pay more. An interesting example of this was a World Bank internal note that was leaked some years back. In this, a World bank economist had recommended that as the income levels of people in third world countries was very low it made economic sense to shift all polluting and hazardous industrial units to the third world. In the 'third world' it would be cheaper to pollute than to control pollution and certainly much cheaper to compensate injuries and deaths caused by hazardous effluents.

Artificial measures to introduce sustainability values in terms of option values and equity values in terms of government controls also do not work for, as these values are arbitrarily ascribed, they reflect the political power of the environment and the poor, which is usually not very much. What, then, is the solution.

The best way out seems to be to adopt a dual approach of both budgeting and accounting. This means that natural resources (and nature) are accounted for and decided upon on the basis of a system which first budgets, in physical terms, and then allocates the surplus on the basis of economic value. The elements of this approach are described below.

First, a natural resource, say water, needs to be budgeted in physical terms and allocations made to meet the basic ecological and social requirements. This means that, in a river, the minimum flows required for maintaining the ecological balance of the river and consequently its ability to cleanse itself and support life, must be assured. It must be assured that the river is not only able to perform all its ecological functions and renewably supply clean and wholesome water for human uses, but also that its biodiversity profile is not adversely affected. This would meet the absolute value of sustainability in the larger sense of including biodiversity conservation.

Once this is done, then the surplus water must next be allocated for meeting the basic needs of the human populations dependent on the river. This includes their drinking water requirements and other basic needs. Therefore, once sustainability is assured, then the next absolute value, that of equity, must be met. After water has been physically budgeted for these two requirements, the surplus, If any, can then be subjected to market forces and its use determined based on the paying capacity of the various contenders and the economic benefits of the various uses. In such a model, where there is industrial demand for water over and above the surpluses available, there the industrial sector must pay for enhancing lean season flows by, for example, regenerating catchments, in order to produce larger surpluses. There is also, then, an economic incentive to invest in water saving technology, as the real cost of water is being charged.

A similar approach can be applied to other types of ecosystems and resources. Take, for example, forests. Here, also, the area required to maintain the biodiversity and ecological functions of forests must first be physically demarcated and budgeted. Once this is done then the areas required to meet the basic social needs, like firewood, must be physically demarcated. Once this is done, then the surplus can again be ascribed economic value and made available to the highest bidder.

It must, however, be remembered that environmental resources are location sensitive in the sense that apart from ensuring overall availability it must also be ensured that they are available at the right place. So, for example, the ecological functions of forests would not be served if the total area of forests required all occurred in one part of the country while the rest of the country became devoid of forests. Similarly, for a river it is not enough that the total water flow required occurred in one part of the river while other parts became bone dry. Therefore, apart from calculating the area and resources needed totally, there also has to be an assessment of the distribution of these areas and resources. This is also important from the equity angle.

Therefore, apart from determining the carrying capacity of ecosystems there also has to be prioritisation of sites where conservation and utilisation needs to be regulated and where resources need to be earmarked for ecological and social functions. The detailed methodologies for developing natural resource budgets and for prioritising sites are described in the following chapters.

II AQUATIC ECOSYSTEMS AND BIODIVERSITY

INTRODUCTION

Of all the ecosystems and natural resources in India, perhaps the most abused are the fresh water bodies. These include lakes, ponds, streams, rivers and other wetlands. We have, over the years, drained them dry, filled them with earth, converted them into agricultural fields, destroyed their catchments, diverted them, dammed them, and polluted them. Even today, there is little concern for them as ecosystems. For example, the National Water Policy (1987) mentions the hierarchy of priorities for allocating water and lists all sorts of human uses, but there is no mention of allocating water for the ecological requirements of the water body.

This is partly due to the lack of understanding that is prevalent about water as a resource. However, part of the reason is also the high and increasing demand for water in India, foe industrial, agricultural and municipal purposes. It is, therefore, apt that water, especially riverine water, should be treated as a priority in the development of a methodology for natural resource accounting and budgeting.

In this chapter we look at water as a multifaceted resource (Section 1) and then focus on developing a methodology for assessing the minimum water flows required in a river to meet the basic ecological and social functions (Section 2). In Section 3 the developed methodology is applied to the Yamuna River, especially as it passes through Delhi.

1. WATER AS A RESOURCE

Before we develop a methodology for budgeting water, especially river water, it is important to review the various uses and functions of water.

1.1 The Nature of Water

Water can be seen to have atleast three distinct, though possibly overlapping, functions.

- As a human resource
- As an ecosystem, especially as a habitat for flora, fauna and micro-organisms.
- As an element of the larger ecosystem.

i. Water as a Human Resource:

Broadly speaking, water is used by human beings for at least the following five purposes:

- For Domestic and Municipal Use

  This includes drinking, cooking and washing, watering of lawns and gardens, and for other sanitation purposes. The major environmental concerns regarding this form of water use relate to:

  a) Maintenance of sustained supply for human use, appropriately spread over seasons and populations.

  b) Maintenance of water quality to within acceptable levels both at the input and output stages.

- For Industrial Use

  This involves the use of water for industries, including power projects, either as raw material or more often as input into the industrial process. Such use of water also involves the same two environmental issues, namely sustainable supply and maintenance of water quality.

- For Agricultural Use

  Water as an agricultural resource involves the storage, extraction or diversion of water to support agricultural activities. For such use, apart from the earlier two issues of sustainable supply and water quality, there is an additional issue regarding the impact of water management or storage projects on the rest of the environment, and on elements of the human society. Certain water storage projects, like multipurpose dams, are the means of managing water not just for agricultural use but also for domestic, municipal and industrial use.

- For Recreational Use

  Water bodies like rivers, lakes and artificial reservoirs are important centers of tourism and recreation. The important environmental issues associated with such use include sustainable supplies, water quality and, additionally, the ability to maintain these water bodies as holistic ecosystems, which are aesthetic.

- For Inland Water Transport

  This involves using rivers and other large water bodies for transportation of goods or people. The major environmental issues related to such use are sustained availability of water flows in rivers, and the maintenance of water quality.

II. Water as an Ecosystem

Water in itself is a habitat for aquatic flora, fauna and microorganisms. These are not only important as a socio-economic resource, but their maintenance is in itself important to maintain water quality and to keep water bodies and courses healthy and functional. This function of water can be adversely affected by poor water quality, fluctuations in flows or levels, and by other disturbances.

iii. Water as an Element of the Larger Ecosystem

Apart from water being a habitat itself, it is essential for the maintenance of other habitats, including terrestrial and marine habitats. Some of the fish and other fauna and flora that exist in watercourses and bodies are food for terrestrial creatures, and a part of the web of nature. Similarly, influx of fresh water is essential for maintenance of coastal ecosystems and for the prevention of salt water ingress. Fresh water is also essential to maintain the brackish water ecosystems in the coastal regions. Pollution and erratic flows and levels are issues here also.

1.2 Major issues

- The maintenance of water levels and flows, spread appropriately over seasons and areas.
- Prevention and mitigation of the impacts of water management projects on biological diversity.
- Prevention and mitigation of other environmental impacts.

i. Maintenance of water flows and levels

Natural ecosystems, if any such remain, have in-built regulatory mechanisms to maintain water levels (in water storage bodies) and flows (in waterways like rivers and streams) to an optimum level. It has been established that careless or uncontrolled intervention into the processes of nature can have serious adverse impacts on human societies, both directly and indirectly.

Studies have shown that dams and other projects that alter flows and levels have at least the following impacts on aquatic ecosystems:

- HYDROLOGY: Altered – temperatures, water chemistry and nutrients, sediment transport and deposition, and the big one reduced flow patterns (hydrographs) – substitutes daily and hourly fluctuations for seasonal ones;
- AQUATIC BIOLOGY: Altered – habitats (reduced), species composition (favours introduced species at the expense of native ones and reduces species composition and diversity and dried up spawning areas;
- AQUATIC ECOLOGY: altered-primary production and nutrient cycling, reduced species diversity and simplified food chain and reduced primary production in the long term
- TERRESTRIAL HABITAT AND SPECIES: altered – riparian habitat, generally reduced species diversity or replacement by non-natives. The old riparian community is left high and dry and replaced by a new one at a lower elevation due to "reduced flows and lack of seasonal flood flows". Terrestrial species that were dependent on the habitat and food sources associated with the old flows (pre-impoundment or diversion) are generally adversely effected and reduced in population and habitat distribution or replaced by non-native species.

Consequently, it is important to carefully understand the limits to the manipulation of water levels and flows, without triggering off, sometimes irrevocably, undesirable consequences.

Essentially there are at least three ways in which human beings can manipulate water flows and levels.

a) <u>At the source</u>

The source could be snow and ice melt, underground aquifers, or rainfall. Both directly and indirectly, human actions can change the nature of the first two sources, namely snow and ice melts, and aquifers. Such areas are found mostly within India and Nepal, and form an important source for much of the water that flows through these countries and into Bangladesh. Estimates suggest that between 40% to 60% of the waters in the Himalayan rivers are derived from glaciers. According to one estimate, the ice volume of Himalayan glaciers is approximately 1400 cu. km. of ice, or 175 frozen dams of the size of Bhakra.

However, glaciers and snow bound regions have, in recent years, been threatened by various human activities, especially by the construction of roads. As these areas are also usually along the international borders of these two countries, especially along the border with China, there are understandable security compulsions. However, the manner in which road networks are being built needs to be changed so that the source of some of the major rivers are not unduly disturbed. Deforestation and the consequent changes in microclimate have also taken their toll of glaciers. Current trends at global warming would also adversely affect glaciers.

Human action can also interfere with rainfall patterns, though to perhaps a lesser extent.

b) <u>By diverting or otherwise modifying water run offs</u>

Where the patterns of rain fall, snow melt or aquifer recharge remain the same, the degradation of catchments and the independent or consequent modification of river beds and streams, can affect the patterns of run off from the catchments into major rivers and other water bodies. This can have at least two results:

- A seasonal change in water flows where, though the annual run off remains the same, the run off in some seasons go up and in other seasons go down. Where the seasonality matches human requirements, for example by enhancing dry season availability at the cost of wet season availability then, as long as it does not have adverse ecological impacts, it can be considered a desirable outcome. However, very often degradation of the catchments and other unplanned modifications of natural ecosystems leads to the opposite, with heavy human and environmental costs.
- An absolute change in water flows where the amount of water flowing down the river system decreases (or increases), in absolute terms. In such cases the desirability of the change would depend on the impact it has on the environment and whether it better meets the social requirements. However, to properly assess the impact of such a change, the environmental impact of enhancing or reducing the water must be comprehensively looked at. For example, if water is withdrawn from a watershed and diverted to another, or allowed to evaporate, then the impact on the receiving watershed, or on microclimate, must also be assessed.

Road building activities, quarrying, mining, other construction activities and deforestation are also affecting the watercourses that criss-cross the Himalayas and feed the great rivers of the plains. Most significantly, the silt and debris coming down these watercourses are increasingly leading to destruction of the aquatic ecosystem.

Another threat to water flows is diversion. Such diversion might not involve the transfer of water to some other ecosystem but only its 'interception' for human use, putting it back into the same ecosystem, after use. Such interception' often results in fluctuating flows and levels, and also in an adverse change in water quality. In some cases, like in diversion tunnels for `run-of-the-river' projects, it can mean the drying up of whole stretches of the riverbed.

Apart from water flows, changes in run-off patterns also mean changes in the silt and nutrient loads of a stream or a river. The consequences of this also need to be studied.

c) By artificial storage

For many years now, human societies have endeavored to optimize water flows by building artificial storage structures like dams. In their design they are supposed to optimize water flows to suit human requirements. The storage is also used to generate electricity and divert water through channels for irrigation and other purposes. Where such projects are well planned and executed, they can contribute to an optimization of water use by humans, through often with adverse environmental impacts. However, where they are inappropriate, their impact on the human society and on the environment can be disastrous.

II. Conservation of Biodiversity

The impact of river valley and other water management projects on biodiversity needs to be assessed at the following three levels:

a) At the level of **genes**. This means assessing the impact on the variability of genes within species, in terms of each population being large enough to be genetically viable. It also involves assessing what would be the impact of the project on populations of various species of flora and fauna, and consequently its impact on the genetic viability of each species.

b) At the **species** level. This means assessing the impact on the variability of species: assessing what would be the impact of the project on the existence of each of the species in the area, and consequently its impact upon the diversity of species.

c) At the **ecosystem** level. This means assessing the impact on the variability of ecosystem types : assessing what would be the impact of the project on the existence and viability of various ecosystem types in the region, and consequently its impact upon the variability of ecosystems.

Where the species and ecosystems affected are not endemic to the region, or otherwise threatened or endangered, the impacts might be restricted to the specific region. However, if any of the species or ecosystem types are either endemic or generally threatened or endangered, the impact of the project would be felt nationally, regionally and possibly globally.

In assessing the impacts on populations, species and ecosystem types, it is not only the primary impact that is important but equally important is the secondary impact. When any one species or ecosystem is affected, it has an impact on other species and ecosystems which are interlinked or dependent on it. Consequently, no impact assessment is complete unless it is a holistic one.

2. ASSESSING MINIMUM FLOW REQUIREMENTS

2.1 Introduction

Till recently, water pollution was considered the main adverse impact on rivers by human beings. However, new concerns are now being expressed of other impacts of human activities on rivers and other natural water ways and bodies, that seem unrelated to pollution. The first of these changes to be observed and protested about was the loss of commercial fisheries. Since then, it has been recognised that the manipulation or disruption of river flows could cause many adverse impacts which include 'the collapse of river banks, loss of agricultural land, reduction in life of a downstream in-channel reservoir due to increased sediment loads from the eroding land and banks, collapse of a river fishery, loss of an internationally-acclaimed estuarine wetland and decline of a marine fishery dependent on that estuary as a nursery area for juvenile fish' (McCully 1996).

An environmental flow assessment (EFA) is aimed at determining how much of the original flow of a river should continue to flow down it in order to maintain its ecological functions and its biodiversity. It is required whenever there is a proposed diversion of water from the river or interference in the flow of the river. For a river that is already degraded without adequate flows, the EFA can indicate how much of its original flow needs to be restored in order to rehabilitate the river.

Till recently, EFAs were used, when they were used at all, to determine the minimum flow required to safeguard a particular ecological function or a commercially important species of fish. However, it is now being recognised that it is essential to provide adequate water flows in all seasons to ensure that the aquatic ecosystem as a whole and all the species in it are safeguarded. Consequently, methodologies are being developed and tested which comprehensively study flow requirements in terms of biophysical parameters.

There is also a growing realisation that the social functions of a river, especially those related to the poor segments of society, must be safeguarded. Consequently, current methodologies take into consideration social parameters.

Also studied are the economic implications of reduced or disrupted flows. These not only determine the economic costs of environment related impacts but also the cost of depriving communities of adequate water and of adversely affecting downstream water availability. There are efforts to capture the less tangible costs like those of lost tourist revenues and of loss of naturalness and beauty.

What is an environmental flow requirement?

A flow assessment produces one or more descriptions of possible future flow regimes for a river, each linked to an objective which this achieves in terms of the condition or "health" of the riverine ecosystem. Each possible future flow regime is called the environmental flow requirement (EFR) for achieving that objective. For instance, the requirement may be stated as simply as "a water depth of at least 50 cm throughout the year, to provide adequate wetted habitat areas for fish species A". Alternatively, it may be described with much greater complexity, detailing a comprehensive flow regime, with specified magnitudes, timing and duration of low flows and floods at both intra-annual and inter-annual scales of variability, all designed to maintain fundamental functioning of all ecosystem components (e.g., fish, riparian trees, water chemistry) at a specified level of condition.

The linking of "condition" with "flow regime" indicates that rivers may be maintained in a range of conditions. Rivers maintained close to natural require more of their natural flow regime than those for which extensive modification is acceptable. Recognising this, the EFA and resulting EFR can be viewed and used from two perspectives. Firstly, the assessment can be made, and the flow requirement stated, by any stakeholder group, in order to present in a negotiating forum their aspirations for the river. Secondly, as other stakeholders may have different aspirations and thus different EFRs for the river, compromises may be sought and agreed upon. In this situation, an agreed compromise solution reflects the eventual EFR and condition for the river. If no compromise can be agreed upon, a decision-maker would have to make a decision on the future river condition and associated flow regime (EFR), and be accountable for that decision.

The flow-related roles of various disciplines in a water-resource development or re-allocation process are still evolving. Good practice regarding their involvement would be:

- *river scientists provide expert input on the expected condition of the river under a range of different flow conditions;*
- *water engineers provide expert input on possible kinds of flow-manipulation structures, and the costs of constructing or altering, and operating these;*
- *social and anthropological consultants provide expert input on the social implications of possible options;*
- *other specialists may provide expert input on such aspects as land use or agricultural potential of the area of concern;*
- *economists provide expert input on the economic implications of all potential options, including the costs of compensation, mitigation, development of infrastructure and so on;*
- *a range of stakeholders provides input on their water requirements and aspirations for the river; their aspirations may reflect the need for rehabilitation of a degraded river;*
- *water managers identify the need for water-resource development or re-allocation, and manage the process of acquiring the above inputs; this role should preferably not be handed on to any of the parties with a vested interest in the water-resource development;*
- *government, in some form, makes the final decision on future river condition and water allocations for offstream users and the environment, and is accountable for that decision (King et al 1999).*

Essentially the methodology involves assessing the water requirements and the requirements of other water related elements, like silt, nutrients, oxygen, etc., for each of the species in the river and for different aspects of the riverine ecology. The biological and physical characteristics of water are also linked to the requirements of species and ecosystems, for example the force of flow, the bulk, the physical and biological quality and the quantity at different times of the day and in different seasons.

Depending on the quantum of water to be withdrawn, on the complexity of the riverine ecology, and on the state of the river and the time and resources available, the EFA can be of differing complexity and detail. For example, earlier studies might have established that riverine ecology and ecosystems are not adversely sensitive to changes in flow of between five (dry season) and ten (rainy season) percent. Therefore, if all that is proposed is to change the flows within this limit then a very limited desk study might suffice which would establish the normal flows and lay down the limits of extraction or diversion. However, it is not acceptable, as has often been done in the past, to peg the minimum required flow at the minimum dry weather flow.

Where the intervention into the river is more drastic or where there is a proposal to withdraw more water than the empirically established safety margins permit, then a more detailed study has to be done to establish the impact and assess the viability. Where a river is sought to be extensively interfered with, there might be a need of an interdisciplinary, long term study to assess all the different impacts.

Four basic types of methodologies currently available for EFA are:

- **Hydrological index** methodologies
- **Hydraulic rating** methodologies
- **Habitat simulation** methodologies
- **Holistic** methodologies.

There are also some other methodologies which do not fall under any of these four heads. Given below is a description of each of these types of methodologies (King et al 1999).

2.2 Hydrological index methodologies

Hydrological index methodologies mainly use historical river-flow data for determining the optimum and minimum permissible flows. The simplest type of environmental flow methodologies use hydrological data in the form of long-term, historical monthly or daily discharge records. Based on these, either a fixed percentage or some other derived flow index is used to define the minimum accepted flows. The recommendations for minimum flows are for annual, seasonal and even monthly flows.

Perhaps the most commonly used hydrological methodologies are the Montana Method (or Tennant Method; Tennant 1976). In the Montana Method, percentages of the average annual flow (AAF) of the river are used to formulate baseflow regimes on a seasonal basis, to satisfy environmental flow needs. This is done by linking AAF to different categories of instream habitat conditions. For example, 10% AAF could represent the minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic biota, and 60% AAF could be considered to provide optimum habitat. Flood requirements are only considered in terms of a single allocation of 200% AAF for flushing.

Another variant of such a methodology is the Range of Variability Approach (RVA), developed by Richter *et al.* (1996, 1997). The RVA uses a comprehensive statistical characterisation of ecologically-relevant features of the flow regime. It recognises that hydrological variability is critical for sustaining riverine ecosystems. This method appears particularly suited for application to rivers where protection of natural ecosystem and conservation of biodiversity are a primary concern. The methodology comprises six basic steps, the first of which is the characterisation of the natural range of hydrological variation using 32 hydrological indices, termed Indicators of Hydrologic Alteration (IHA) (see Richter *et al.* (1996) for IHA methods). The IHA statistics are grouped into five categories based on virgin regime characteristics:

1) magnitude of monthly water conditions, e.g., mean value for each calendar month;
2) magnitude and duration of annual extreme water conditions, e.g., annual minima 1-day means;
3) timing of annual extreme water conditions, e.g., Julian date of each annual 1-day maximum;
4) frequency and duration of high/low pulses, e.g., number of high pulses each year;
5) rate/frequency of water condition changes, e.g., means of all positive differences between consecutive daily values.

Ranges of variation are set for each of the 32 IHA parameters, for example mean ± 1 Standard Deviation, as flow management targets. A set of management rules based on the RVA targets as guidelines are devised, that will enable attainment of target flow criteria in most, if not all, years. Re-characterisation of flow variation at the end of each year using the 32 indices, and comparison of values obtained with the RVA target values, as well as ongoing research and monitoring, allows for iterative refinement of the EFRs.

Data and expertise requirements for hydrological methodologies: The essential data required for the above methodologies are undisturbed and natural historical flow records. The flows should preferably be observed, daily average discharges, and should cover the longest period of record possible. Approaches like RVA require at least 20 full years of daily data

Weaknesses and limitations of hydrological methodologies: From an ecological perspective, these types of methodologies are inadequate especially as they do not capture the ecological relationships within the riverine ecosystem or the ecological variations along the course of a river. They also do not consider the various species and the cyclic functions of seasons. Such methodologies are also handicapped by the absence of ecological information as input. The above disadvantages render hydrological methodologies appropriate only for preliminary assessments.

Hydraulic rating methodologies

Hydraulic-rating methodologies determine the minimum levels of flow required in a river by assessing the relationship between simple hydraulic variables and discharge. The hydraulic variables usually considered include wetted-perimeter or maximum depth of water and are usually measured along a single cross-section, across the river section. These methodologies generally require some observed stage-discharge data for at least a single cross-section that is deemed representative of each of the river. Measured hydraulic data, specifically water depth and average velocity, at intervals across the transect, at the observed discharge(s) are required, while additional hydraulic data can be simulated along with wetted perimeters and cross-sectional areas.

Habitat simulation methodologies

Habitat simulation, also known as habitat modelling or rating methodologies, also make use of hydraulic-discharge relationships, but provide more detailed analyses of the quantity and suitability of instream physical habitat available to target biota under different flow regimes, on the basis of integrated hydrological, hydraulic and biological response data.

Over time, numerous, increasingly sophisticated methodologies have been developed in an attempt to address the EFRs of a river on the basis of biotic responses to incremental changes in flow at the level of physical habitat. Instream habitat is assessed in terms of hydraulic variables, most commonly depth, average column velocity and benthic shear stress. Generally, modelled changes in the availability and suitability of combinations of hydraulic habitat over time and space, are combined with information on the suitability of microhabitat conditions for particular species, lifestages or assemblages, to predict optimum discharges as environmental flow recommendations.

1) The Instream Flow Incremental Methodology

The Instream Flow Incremental Methodology comprises a collection of analytical procedures and computer programs, including the Physical Habitat Simulation Model, PHABSIM II, which, as a collection of some 240 separate programs, is its best known component (Milhous et al. 1989). In its entirety, IFIM is said to evaluate, for selected riverine biota, the effects of incremental changes in river flow on the *macrohabitat features of channel structure, water quality, and temperature, as well as on the availability of physical microhabitat within a study reach (Bovee 1982). However, time series of changes in the quantity of suitable physical microhabitat for a target species or group of species, lifestage and activity, with flow, per unit length of river, simulated using PHABSIM II, tend to be the only routine product.*

2) Other recent methodologies based on habitat simulation

Over about the past decade, a number of habitat-modelling methodologies of similar character to IFIM, considered by several authors to be of considerable future potential, have been developed and applied in various countries. These include:

- *River Hydraulics and Habitat Simulation Program*
- *Riverine Community Habitat Assessment and Restoration Concept*
- *Computer Aided Simulation Model for Instream Flow Requirements*
- *Evaluation of Habitat Method*
- *River System Simulator System*

Holistic methodologies

Holistic methodologies (sensu Tharme 1996) form a clearly separate group of methodologies that are geared towards addressing the flow requirements for an entire riverine ecosystem, and which may incorporate subroutines derived from methodologies of the first three types.

Holistic methodologies, in particular, are amenable to identifying the flows linked to issues of human use and interest, such as maintenance of aesthetic quality, social dependence on the riverine ecosystem, protection of features of cultural or scientific interest, and river-related recreation.

Briefly, the conceptual foundation of these methodologies hinges on riverine ecosystem theory, particularly disturbance theory (Resh et al. 1988). It is assumed firstly, that the natural hydrological regime of a river dynamically maintains all the instream biota, channel geomorphology, and riparian, floodplain and wetland systems, as well as any estuarine and offshore coastal systems affected by river flow (i.e. the entire riverine ecosystem) (Arthington 1998a). It is further assumed that some baseflows and floods within the complete flow regime are more essential than others for maintenance of the riverine ecosystem. Adequate description of these flows in terms of magnitude, duration, timing, and frequency, and their incorporation in the regulated flow regime should allow the extant biotic characteristics and functional integrity of the river to persist (King and Tharme 1994; Arthington 1998a).

Other Methodologies

Methodologies geared towards specific ecosystem components

Although ecosystem components such as riparian vegetation, the channel and its sediments, wetlands, including floodplains and estuaries, groundwater, water quality, and wildlife can be considered within holistic methodologies, several alternative methods exist that have diverged from an emphasis on the relationship between physical habitat and flow, to explore other kinds of information suited to these particular components.

Methodologies for the maintenance of channel form, and fluvial geomorphological and sedimentological processes

Flows to maintain channel morphology and associated habitats, and to provide for transportation of sediments, commonly referred to as flushing flows, are critically important for riverine ecosystems and their biota. However, the recommendation of such flows is one of several facets of EFAs that has not been adequately investigated to date (Wesche et al. 1987; Tharme 1996; Reiser et al. 1989a). Historically, most flushing flow methodologies have been focused on maintenance of fish habitat (Reiser et al. 1989b), while more recently, there has been a move towards addressing geomorphological and sedimentological flow needs as one component of a more comprehensive EFA.

Environmental flow methodologies for water quality purposes

Historically, environmental flow methodologies have tended to focus exclusively on flow quantity, and water quality has often been disregarded, this despite its obvious importance (Tharme 1996). Currently the three most commonly used approaches for assessing environmental flows for water quality purposes are water quality models, IFIM, and holistic methodologies (Tharme 1996).

Several sophisticated, state-of-the-art water quality models, such as CE-QUAL-RIV1 (Bedford et al. 1983, cited in Dortch and Martin 1989) exist for application to regulated rivers. However, links between model outputs and final recommended EFRs are often not explicit. Malan et al. (1999 in prep.) provide a review of current models and discusses approaches geared towards dynamically linking water quality and flow data. IFIM has been used to assess environmental flows for water quality by linking various water quality and temperature models, for instance QUAL-2E (Brown and Barnwell 1987, cited in Armour and Taylor 1991) with other components of IFIM. Within IFIM, SI curves can also be constructed for temperature and various chemical variables in relation to biotic activities like fish incubation and spawning that can be incorporated directly into PHABSIM II. Finally, all the holistic methodologies make provision for the inclusion of water quality criteria for ecological and, sometimes social needs, to various degrees.

Methodologies addressing the ecological flow requirements of riparian vegetation

Despite widespread recognition of the ecological importance of riparian zones and their numerous functions (Kondolf et al. 1987), and the development of a considerable body of research on sources of water that sustain riparian vegetation (Stromberg and Pattern 1990, 1996), there is a notable lack of formal methodologies for addressing the EFRs of riparian vegetation. The various approaches that have been developed to determine the flow needs of riparian vegetation, appear to have evolved only since the 1980s, mostly within specific case studies (Tharme 1996).

Currently, there are three major, often partly integrated, ways in which EFRs for riparian vegetation are assessed. The first entails the linkage of stream discharge and associated hydrological variables with variables associated more directly with the riparian belt, particularly the riparian groundwater table. An indirect link is then sometimes established between the latter variables and the vegetation. Kondolf et al.'s (1987) Hydrogeomorphic Site Characterisation Methodology is an example of this type of approach. Flow-vegetation growth models represent the basis of a second set of techniques (Stromberg and Patten 1990, 1996). Data requirements, and applications, advantages and disadvantages of the two approaches are summarised in Tharme (1996). Thirdly, holistic methodologies are used in the Southern Hemisphere for assessing EFRs for riparian species and/or communities, and are probably the best structured methodologies as yet for this purpose.

Methodologies addressing ecological flow requirements of wildlife

Inadequate emphasis is being placed worldwide on research into ecological flows for wildlife, with assessments appearing to be recent and restricted to New Zealand, South Africa and the USA. Information on the topic is scarce, and Kadlec (1976), Tharme (1996) and Ferreira (1998) provide the only reviews.

There are no reconnaissance-level methodologies or guidelines for assessments of environmental flows for wildlife, yet the majority of information necessary for this level of assessment probably already exists.

Currently, the emphasis is on habitat simulation methodologies, with case-specific development of predictive models (see Tharme (1996) for examples of wildlife models), or most commonly, application of IFIM through the development of SI curves describing habitats on which various wildlife species are dependent. Mosley (1983) provides a case study on the influence of environmental flows on the availability and quality of riverine habitats used by birds, while Gore et al. (1990) used IFIM to assess EFRs for a semi-aquatic mammal. Environmental flow assessments using holistic methodologies, specifically the BBM and DRIFT, have included EFRs for herpetofauna and water-dependent birds, as well as some considerations of use by terrestrial wildlife (see Ferreira (1998) for an example). However, although holistic methodologies have the potential to include environmental flows for wildlife in a structured manner, this is not routinely done at present (King et al 1999)

Given the variety of methodologies available, it would seem that the task of assessing the required minimum flows is a simple one. However, in the Indian context, such assessments have been rarely carried out, if at all, especially in any comprehensive manner. Also, the data and support studies required to conduct a comprehensive assessment are rarely available.

For the purpose of this study we have examined the available data sets and devised a somewhat simplistic methodology. Essentially, minimum river flow required has been calculated on the basis of what is required for ecosystem integrity and for the apex fish species, plus what is required for assimilating the pollutants put into the river, plus what is required for drinking purposes. The detailed methodology and its application is given in the next section.

The assertion is that the water in the river needs to be first allocated physically in this manner and, if any surplus flow is available, then it can be subjected to market based systems of natural resource accounting and accordingly allocated.

REFERENCES

ARMOUR, C.L. and TAYLOR, J.G. 1991. Evaluation of the instream flow incremental methodology by U.S. Fish and Wildlife Service field users. *Fisheries* 16(5): 36-43.

ARTHINGTON, A.H. 1998a. Comparative evaluation of environmental flow assessment techniques: review of holistic methodologies. *Land and Water Resources Research and Development Corporation Occasional Paper No.* 26/98. Canberra, Australia.

BOVEE, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. *Instream Flow Information Paper* 12. U.S.D.I. Fish Wildl. Serv., Office of Biol. Serv. FWS/OBS-82/26. 248 pp.

DORTCH, M.S. and MARTIN, J.L. 1989. Water quality modeling of regulated streams. In: Gore, J.A. and Petts, G.E. (eds). *Alternatives in regulated river management.* CRC Press, Inc., Florida.

FERREIRA, S. 1998. Mammals and Birds. *Task 2 Report Series. Report No. LHDA 648 (Volume 1). Unpublished report by Metsi Consultants to Lesotho Highlands Development Authority.*

GORE, J.A., LAYZER, J.B. and RUSSEL, I.H. 1990. A non-traditional application of instream flow techniques for conserving habitat of biota in the Sabie river of southern Africa. *Congress on the Conservation and Management of Rivers.* University of York, 10-13 September 1990.

KADLEC, J.A. 1976. Methodologies for assessing instream flows for wildlife. In: Stalnaker, C.B. and Arnette, S.C. (eds). *Methodologies for the determination of stream resource flow requirements: an assessment.* U.S. Fish and Wildlife Services, Office of Biological Services Western Water Association. 199 pp.

KING, J.M. and THARME, R.E. 1994. Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa. *Water Research Commission Report No.* 295/1/94. Water Research Commission, Pretoria. 590 pp.

KONDOLF, C.M., WEBB, J.W., SALE, M.J. and FELANDO, T. 1987. Basic hydrologic studies for assessing impacts of flow diversions on riparian vegetation: examples from streams of the eastern Sierra Nevada, California, USA. *Environmental Management* 11(6): 757-769.

MALAN, H.L., DAY, J.A. and BATH, A.B. 1999 in prep. Development of numerical methods for assessing water quality in rivers: synthesis of relevant literature. Water Research Commission Technology Transfer Report.

MCCULLY, P. 1996. *Silenced rivers: the ecology and politics of large dams.* ZED books, London and New Jersey. 350 pp.

MILHOUS, R.T., UPDIKE, M.A. and SCHNEIDER, D.M. 1989. Phsical habitat simulation system reference manual - version 2. *Instream Flow Information Paper* 26. U.S.D.I. Fish Wildl. Serv. Biol. Rep. 89(16).

REISER, D.W., WESCHE, T.A. and ESTES, C. 1989a. Status of instream flow legislation and practise in North America. *Fisheries* 14(2): 22-29.

REISER, D.W., RAMEY, M.P. and WESCHE, T.A. 1989b. Flushing flows. In: Gore, J.A. and Petts, G.E. (eds). Alternatives in regulated river management. *CRC Press, Inc., Florida.*

RESH, V.H., BROWN, A.V., COVICH, A.P., GURTZ, M.E., LI, H.W., MINSHALL, G.W., REICE, S.R., SHELDON, A.L., WALLACE, J.B. and WISSMAR, R.C. 1988. The role of disturbance in stream ecology. *J. N. Am. Benthol. Soc.* 7(4): 433-455.

RICHTER, B.D., BAUMGARTNER, J.V., POWELL, J. and BRAUN, D.P. 1996. A method for assessing hydrological alteration within ecosystems. *Conservation Biology* 10(4): 1163-1174.

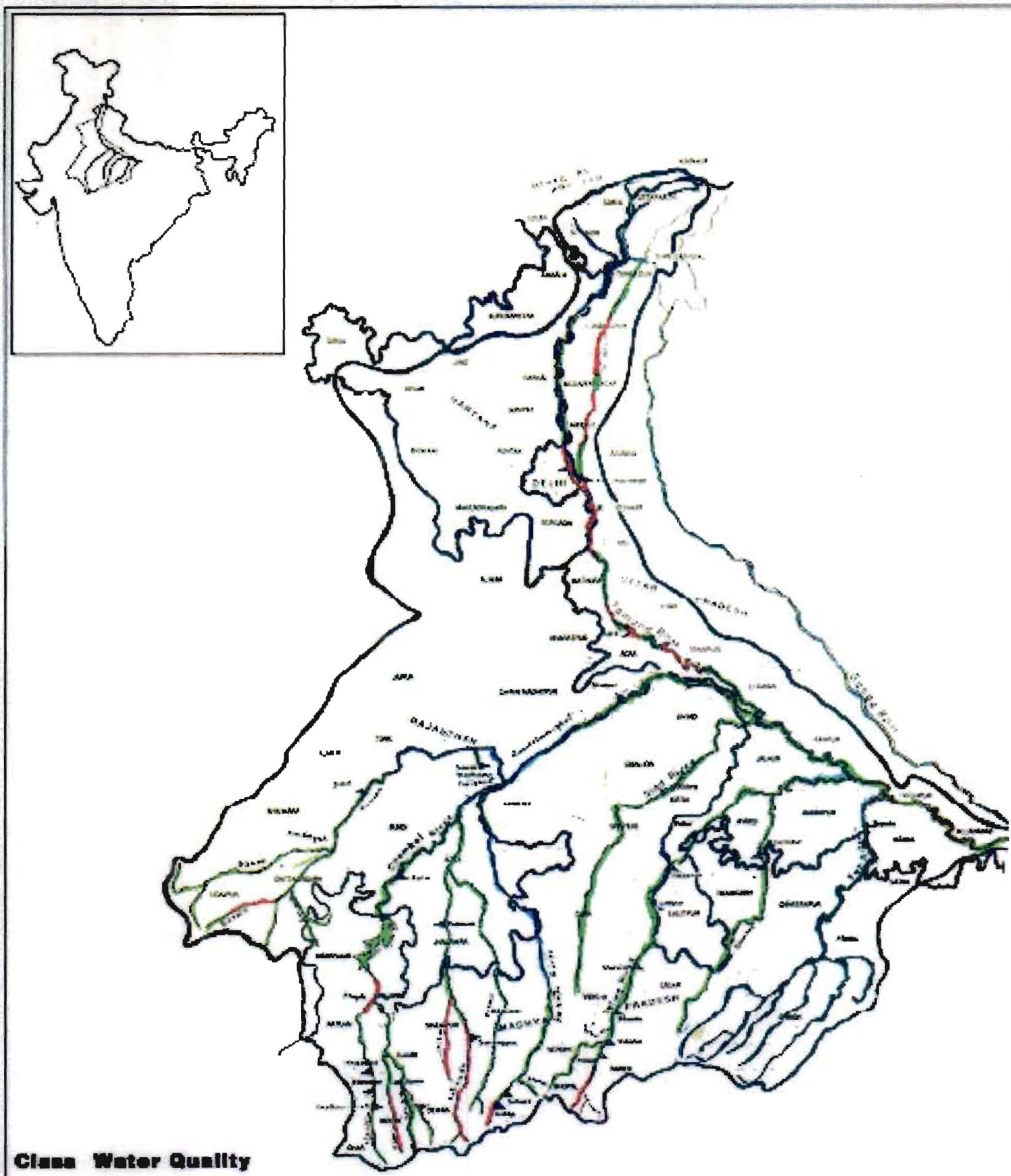
RICHTER, B.D., BAUMGARTNER, J.V., WIGINGTON, R. and BRAUN, D.P. 1997. How much water does a river need? *Freshwater Biology* 37: 231-249.

STROMBERG, J.C. and PATTEN, D.T. 1990. Riparian vegetation instream flow requirements: a case study from a diverted stream in the eastern Sierra Nevada, California, USA. *Environmental Management* 14(2): 185-194.

STROMBERG, J.C. and PATTEN, D.T. 1996. Instream flow and cottonwood growth in the eastern Sierra Nevada of California, USA. *Regulated Rivers: Research & Management* 12: 1-12.

TENNANT, D.L. 1976. Instream flow regimens for fish, wildlife, recreation and related environmental resources. *Fisheries* 1(4): 6-10.

THARME, R.E. 1996. Review of international methodologies for the quantification of the instream flow requirements of rivers. Water law review final report for policy development. For the Department of Water Affairs and Forestry, Pretoria. Freshwater Research Unit, University of Cape Town. 116 pp.



Class Water Quality

- A • Clean
- B • Slight Pollution
- C • Moderate Pollution
- D • Highly Polluted
- E • Severe Pollution
- • Water Intake Points
- • States

Fig.2 Bio Mapping of River Yamuna Basin

Source:

3. RESOURCE BUDGETING OF YAMUNA RIVER WATER*

3.1 Introduction

Natural resources have ecological functions to fulfill, so a certain amount of a resource has to be set aside to carry out the ecological function before the start of physical accounting and the valuation of the resource. This is a policy decision of the Government of India (GoI); **Policy on Conservation and Sustainable development - 1992**. The accounting and budgeting of natural resources will be based on certain ecological and social assumptions; that of safeguarding the basic needs of the poor and that of sustainable use. For example, the resource of water will fulfill the assumption of sustainable ecological use, when each year the waterflow in the river is sufficient for the regeneration of the riverine ecosystem before it is taken up for other uses. Based on the norms for supplying the minimum needed drinking water, a further amount of river flow is set aside which fulfills this basic socal need. The total amount under these two heads will form the budget which will be the absolute minimum quantum required for the ecological and social functions. These environmental concerns have been built into the budgeting of the river water for sustainable use.

3.2 Yamuna River System

The Main River: The Yamuna river originates from the Yamunotri glacier in the Tehri Garhwal district of Uttar Pradesh. In its upper reaches it draws water from the Rishiganga. Ultaganga and Hanuman Ganga Tributaries. After flowing in the hills for about 200 kms, it emerges into the Indo-Gangetic plains in Saharanpur district of U.P. Flowing further down, it reaches Tajewala where the western and eastern Yamuna canals take off from the Tajewala Headworks. Before Tajewala, Tons is the main tributory of the Yamuna. River Giri joins the Yamuna downstream of Dakpathar (see map).

From Faizabad near Tajewala the river flows 104 km in a south westerly direction and receives the Maskara stream on its left bank. Near Biauli in Muzaffarnagar district of U.P. the river turns south wards for a distance of 128 km to reach Delhi.

From the Okhla headworks in the U.T. of Delhi, the Agra canal takes off from its right bank. Beyond Delhi the river flows towards Mathura for a distance of about

* This section has been contributed by Dr (Mrs.) Vasumathi Sankaran of the Indian Institute of Public Administration, New Delhi

205 km. From Mathura onwards it flows in a south-easterly direction through Agra, Etawah, Kanpur and Allahabad districts before joining the Ganga near Allahabad.

On this course, the main tributaries joining on the left bank are the Hindon and Sengar. The Sind, the Betwa, the Chambal and the Ken join it on its right bank. [Report CWC 1989]

The catchment of the Yamuna river system covers parts of Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan and Madhya Pradesh States and the entire Union Territory of Delhi

TABLE I : RIVER SUB-BASIN AND STATEWISE CATCHMENT AREAS

Name of State	Total Area in the Yamuna Catchment sq km.	% of catchment area	Hindon
Uttar Pradesh	74,208	36.08	7,083 (3.44 of total catchment area)
Himachal Pradesh	5,799	2.81	---
Haryana	21,265	10.34	---
Rajasthan	102,883	50.03	---
Delhi U.T.	1,485	0.72	---

[Report CBPCWP 1978]

(For physiographic details of the river basin, seen Annexure I)

3.3 River Flows in the Yamuna and its Tributaries

The Yamuna system is a part of the Ganga-Braharnputra system and all data on flows are classified as secret. Hence the figures given here are only indicative.

For the purpose of examining the stream run-offs with respect to their relationships with the contributing catchment and its characteristics, the year may be divided into four periods :

i) monsoon season (June to September) - when there is frequent precipitation and stream flows comprise of direct storm run-off;

ii) Post-monsoon period (October-November) - when the stream-flows decline sharply and essentially comprise of deferred storm run-off from pools, accumulations and from water-logged and surcharged soils;

iii) Winter season (December to February) - the stream flows are base flows derived from underground reservoir, agricultural drainage and waste-water inflows, and continue to decline with time except for spurts due to winter rainfall; and

iv) Summer season (March to May) - The source of flows is same as in case of winter but for additional contribution from snow-melt in case of snow-fed Himalayan streams.

The catchment areas, mean annual rainfalls, and the run-offs with a periodwise break-up as above, for Yamuna, Hindon and there tributaries are given below in the Table :

TABLE II : MEAN STREAM RUN-OFFS AT VARIOUS POINTS IN THE YAMUNA SYSTEM

River	Station	Area of Catchment contributing, sq km	Mean Annual Rainfall, mm	Mean Run-off, Billion Cubic Meter (BCM)				
				Total	Monsoon	Post-monsoon	Winter	Summer
Yamuna	Tajewala	9,572	1,430	10.5	6.8	1.4	0.9	1.4
	Delhi R.B.	28,988	875	7.9	6.5	0.8	0.2	0.4
	Okhla	30,013	867	8.2	6.7	0.8	0.3	0.4
	Etawah	81,997	720	8.8	7.3	1.0	0.3	0.2
	Pratappur	345,848	810	76.0	61.6	9.3	3.4	1.7
Hindon	Galata	7,083	830	1.1	0.7	0.1	0.2	0.1

[Report CBPCWP 1978]

3.4 River Water Issues

A number of medium and large scale irrigation projects, some based on storage and some on mere diversion, draw water from the Yamuna and its tributaries. While water drawn for municipal and industrial purposes is largely, if not entirely, returned to the river system itself in the form of waste-water, the water drawn for irrigation is mostly consumed in evapo-transpiration.

During the non-monsoon period, almost the entire stream run-off is withdrawn for irrigation with little flow, if any, allowed to escape downstream of the headworks. The storage projects on the other hand do not generally reduce fair-weather flows and may even increase them through seepage and intentional release.

Cattle Bathing and Cattle Watering

Wherever a flowing stream exists closely, it is but natural that cattle are driven to it for drinking rather than being provided with well-water, which involves significant labour. It can be assumed that at least 70 per cent of the total cattle in the basin are getting their drinking water directly from the flowing streams and irrigation canals, and another 30 per cent from pools, ponds and tanks storing surface run-off. Assuming on an average water intake of 40 liters per cattle per day, the water consumed by 70 percent of the 47 million total cattle (according to 1971 cattle census) in the basin would come to about 0.49 Billion Cubic Meter (BCM) annually. This is by no means an insignificant amount when compared to the total discharge in the Yamuna system. The reachwise and sub-basin-wise consumptions of water for cattle watering assumed on the above basis is given in Table III. Besides cattle watering, which though is an in-situ use is nevertheless abstractive in nature, flowing streams are also used for cattle bathing. Buffaloes, which form around 40 per cent of the total cattle population in Haryana and Northern UP and 20 percent in the rest of the basin, particularly enjoy wading through water. Besides direct discharges of dung and urine and washed off organic and inorganic dust, wading cattle churn up the bottom/inorganic sediments of the stream and significantly affect the physical state as also the water quality in the stream.

TABLE III : STREAM-WISE AND REACHWISE WATER-USE IN YAMUNA BASIN

River and Reach	Abstractions for Use, MCM/year						In-situ, Non-abstractive Uses				
	Irrigation	Industry	Organised Municipal Supplies	Un-organised Community Supplies	Cattle Watering	Total Abst.	Fish Farming	River Bathing	Recreational	Cattle Wading	Hydro Power
Yamuna											
U/s of Tajewala	6,000	NA	10	5	10	6,025	M	X	M	L	H
Tajewala-Wazirabad	1,500	NA	275	10	65	350	L	M	X	H	X
Wazirabad-Okhla	1,500	NA	20	2	5	1,527	L	M	M	M	X
Okhla-Etawah	50	NA	30	10	60	150	L	M-H	L	H	X
Etawah-Allahabad	100	NA	20	8	45	173	M	M-H	L	M	X-P

Index : H- High M-Moderate L-Low X-Absent
M - Moderate but high at some points L-H : Low but high at some points
X-H : Generally absent but high at some points X-P : Currently nil, but planned
N.B. No data for industrial use of water were available. Hence column 3 indicates NA (not available). [Report - CBPCWP - 1976]

Note : This data is based on 1971 census, presently the water use must have increased but the flow data is not likely to vary much as this is a national figure based on average rainfall.

Community Bathing and Washing

All flowing streams in the basin are used extensively by the communities for daily bathing and washing. Besides, on particular religious and cultural occasions, special fairs are held on the banks of some of these streams/rivers. The Central Board For Prevention and Control of Water Pollution is of the view that a certain minimum flow in the river at some of the important locations like Delhi, Mathura, Agra and Etawah should be maintained to provide a minimum water front for community bathing and washing.

3.5 Pollution Outfalls in river Yamuna from various towns

The Central Board for Prevention and Control of Water pollution (CBP&CWP) has ben periodically monitoring the water quality of the river Yamuna at 13 locations on the 1200 km stretch from Hathnikud to Allahabad since 1977.

The Yamuna receives major pollution loads mainly from Panipat, Sonepat, Bagpat, Delhi, Mathura, Agra, Etawah and Allahabad. All the outfalls in the above cities/towns have been monitored for their contribution to the pollution load. A brief outline about the sewage outfalls in each of these places is given below.

> **BOX 1 : Requirement For Community Bathing And Washing**
>
> There is as yet no criterion to decide the minimum flows to be maintained in a river near important cities and towns for such purposes.
>
> The Committee on training of River Ganga at Kanpur appointed in January 1988 by the ministry of Environment & Forests was required, among other things to go into the requirement of flowing water at the ghats of Kanpur. The committee after considering the minimum available flows at Kanpur, the minimum river training requirements, a minimum bathing depth 1.5 meters, the safety of existing ghats etc. recommended, as an interim measure a minimum discharge of 10 cumec to be maintained along the ghats.
>
> In view of this a flow of 10 cumec with depth of 1.5 m and flow velocity of 0.6 to 0.7 m/sce. Is considered adequate. In the absence of any criterion or norms it appears reasonable to adopt this as a broad guideline for all major alluvial rivers.
>
> [Report CWC 1989]

PANIPAT : The Yamuna receives very little pollution in the Himalayan stretch. It receives its first outfall near Panipat town through drain no. 2, which is not a continuous discharge. Drain no. 2 receives industrial and domestic waste waters from Panipat, and discharges into the river Yamuna, about 15 km away from the town, near Samalkha village. On the way most of the effluent is used for irrigation. Most of the time no residual water reaches the Yamuna except during monsoon or other periods when the water is not required for irrigation.

SONEPAT : The domestic and industrial effluents from Sonepat, Kundli and Gohana are discharged into drain no. 8, which joins the Yamuna near Palla village at the Delhi Border. The drain carries lot of chloride which originates from the ground water in the basin of drain no.8.

BAGHPAT : There is only one small drain from Baghpat which is seasonal and mainly receives effluent from Sugar industries. The sugar industry runs 3-4 months a year from October to February.

DELHI : The pollution load assessment in Delhi is being done quite intensively as the Yamuna is most polluted in Delhi. There are 17 major drains which directly discharge waste water of domestic and industrial origin (93% and 7% respectively) into the Yamuna.

MATHURA : In Mathura there are 8 main drains directly discharging into the river. Mathura Refinery also discharges its effluents into the Yamuna. Sometimes the total flow from Mathura Refinery is 3.5 cubic meter per sec. However, the waste water is treated to the level prescribed by the CBP& CWP.

AGRA : There are 10 waste water drains directly joining Yamuna at Agra.

ETAWAH : There is only one drain joining the Yamuna, carrying domestic waste water from Etawah town. This drain joins the Yamuna near the town.

Un-polluted segments

The Himalayan segment and upper segment show almost normal characteristics. These segments contain low organic loading, low biomass and less nutrients with dissolved oxygen always at saturation level. The length of Himalayan segment from origin to Hathinikund is 172 km while the upper segment is 224 km long. The water quality of these segments is fit for the designated uses.

Polluted segments

The Delhi segment and the subsequent eutrophicated segment, 22 km and 490 km in length respectively, are the worst polluted segments in the entire Yamuna river. Entry of Najafgarh drain carrying about 50-60 tons of pollution load just downstream of Wazirabad barrage in Delhi sets off a progressive series of chemical and biological events in the downstream water. The Delhi segment receives further about 73 tons of pollution load per day through 17 drains. This segment is characterised by high bacterial population, cloudy appearance, high BOD and strong disagreeable odour-all indicating general depletion of oxygen. Masses of gaseous sludge rising from the bottom are often noticed floating near the surface of the water.

Though there are a number of bathing ghats along the river in the Delhi segment, the quality of water is quite below bathing standards. The quality is only fit for irrigation, industrial cooling and controlled waste water disposal.

The segment downstream of Delhi upto the Chambal confluence is designated as eutrophicated segment. The bio-degradation products of Delhi's pollution load and additional pollution from Mathura and Agra enrich this segment with nutrients. The nutrients loading cause excess growth of algae and cause large fluctuation in diurnal dissolved oxygen and other typical eutrophication symptoms. The water quality standards from the point of view of BOD, DO and other bacteriological conditions is not fit for designated best use.

Flows required at Delhi for dilution of BOD loads after different levels of waste water treatment are therefore as follows :

The dilution requirements at Mathura and Agra cannot be met entirely from the flow as there is a shortfall of atleast 14 cumec and 19 cumec of water respectively, in the river, at these towns. The requirement at these towns could be met if the required augmentation in flow at Delhi is managed and this water is allowed to flow down the river.

3.6 Additional storages required

For 1988 situation : The total annual water requirement at Delhi for dilution of waste water at 30 mg/ltr, 20 mg/ltr and 10 mg/ltr BOD are 5484 MCM, 3104 MCM and 1050 MCM respectively. Making allowances for 35% conveyance losses in the river, the requirements at the outlet of future dam/dams will be 8437 MCM, 4576 MCM and 1615 MCM respectively.

It may, however, be pointed out that though on an annual basis the flow at all the places except Delhi, appear to be adequate to meet the various requirements, on monthly basis the flows are inadequate for several months at Mathura, Agra and Etawah. There is, therefore, need for augmentation of flow at these places.

For Delhi, the requirement is mainly for the city water supply and for dilution of pollution loads (BOD). There is an acute shortage of water at Delhi which will increase sharply in future. At Mathura, Agra, Etawah, Auraiya, Kalpi and Hamirpur the requirement is mostly for maintaining minimum water front.

It would be seen that the additional flow requirements in the river over and above the available flows are the highest for Delhi. This requirement, if fully met, could meet the flow requirements at other towns/cities situated downstream.

3.7 Stream Water Quality Requirements

The water quality requirements for the various streams and for the different reaches of each stream would depend on the beneficial uses derived from the water in these streams or reaches. From the point of view of water quality criteria the various beneficial uses of the Yamuna river system can be classified as follows :

Classification	Beneficial Uses
A	Drinking water and domestic supplies without treatment, but with disinfection
B	River bathing, swimming and water contact sports
C	Source of raw-water for municipal supplies - consumed only after conventional water treatment
D	Propagation of wild life, animal husbandry and fisheries
E	Agriculture, industrial cooling and washing, hydro-power generation and controlled waste disposal

The water quality parameters relevant to each of the above beneficial use classification and the quality criteria as adopted by the Central Board in its report entitled "Scheme for Zoning and Classification of Indian Rivers Estuaries and Coastal Waters (Part - I - Sweet Water) - Assessment and Development Study of River Basin Series : ADSORBS/3/1978-79, are given in Table IV

Designated Best Use Classification of Streams

It is observed that almost all along the entire lengths of all but the very tiny streams in the Yamuna basin, the river water is being put to a mixed pattern of beneficial uses. River bathing and use of water for washing clothes, utensils and sometimes even for cooking and drinking are intensively practised by the rural communities and even by the poorer sections of the nearby urban communities, on all stretches of the streams. If these uses were to be adequately protected, the *Designated Best Use* Classification of all streams in the basin will have to be B, if not A. This would be an extremely costly if not impracticable task to achieve and maintain. The Designated Best Use Classification criteria are give in the table below.

TABLE IV : WATER QUALITY CRITERIA FOR THE VARIOUS DESIGNATED BEST USES

Classification	Parameters affecting the stated use	Quality Criteria proposed
A. Drinking water source without conventional treatment but after disinfection	1. Coliform MPN	Less than 50/100ml.
	2. Turbidity	Less than 10 units
	3. Colour	Less than 10 units
	4. BOD	Less than 2 mg/l
	5. DO	More than 6 mg/l
	6. Toxicants (including pesticides etc.)	No acute toxicity to be present
	7. Plate count	Less than 50/100 ml
	8. Floating Matter	Not noticeable
	9. Taste and odour	Not perceptible
B. Bathing, Swimming and Recreation	1. Coliform MPN	Less than 500/100 ml
	2. Turbidity	Less than 25 units
	3. Colour	Less than 10 units
	4. BOD	Less than 3 mg/l
	5. DO	More than 5 mg/l
	6. Toxicants (including pesticides etc.)	No acute toxicity to be present
	7. Floating Matter	Not noticeable
	8. Taste and odour	Not perceptible
C. Drinking water source after conventional treatment	1. Coliform MPN	Less than 5,000/100ml
	2. Colour	Less than 25 units
	3. BOD	Less than 3 mg/l
	4. DO	More than 4 mg/l
	5. Toxicants (including pesticides etc.)	No acute toxicity to be present
D. Propagation of wild life, fisheries etc.	1. Coliform MPN	Less than 5,000/100 ml
	2. BOD	Less than 6 mg/l
	3. DO	More than 4 mg/l
	4. Toxicants (including pesticides etc.)	No acute toxicity to be present
	5. Temperature	Range : 5^0C to 25^0C
E. Irrigation, Industrial Cooling and Controlled wastes disposal	1. TDS	Less than 1,000 mg/l
	2. (Ca+Mg)	Less than 100 mg/l
	3. Sodium Ratio	Less than 0.5
	4. Chlorides	Less than 250mg/l
	5. Boron	Less than 2.0 mg/l

3.8 Methodology

It is presumed that for ecological integrity of the riverine ecosystem [Ecological Integrity is defined as the maintenance of natural bio-diversity and energy flow at natural status - pers. Comm. Trivedi R.C.] a minimum flow of water even in the lean season is required. This minimum flow has been calculated by the Central Pollution Control Board (CPCB) of the Ministry of Environment and Forests. The methodology followed by the CPCB has been given in anexure III. The total water requirement for the minimum flow, an amount equal to 0.32 BCM will have to be deducted from the total annual flow. The minimum flow can also be indicated by the unit of cumec or cubic meter per second. The minimum flow requirement of Yamuna river is $10m^3$/sec(which when converted to volume of water per annum, amounts to 0.32 BCM). However after discussion with various resource persons it was found that the Biological monitoring section had adopted the standard for minimum flow from the standard calculated for maintaining the water front (See box 1 for details). The biologists reasoned that a healthy riverine ecosystem depended on a healthy benthic community of organisms which were indicators of unpolluted water. 10 cumec flow of `A' or `B' category of designated use (See Table IV) would support such a healthy benthic community, therefore a 10 cumec flow could be accepted as the minimum flow required for ecological integrity. If the flow was more the food web built up and larger animals started colonizing. Such species like turtles and alligators existed near Mathura earlier. Therefore according to their calculations 10 cumec is accepted as the minimum flow. However on peresonal communication Dr. Trivedi suggested that a column of 1 Mt. standing water was required for fish (the apex species) to carry on normal behaviour and reproduction.

BOX 2 : BENTHIC ECOSYSTEM

CBCP during development and testing of bio-monitoring methodology alongwith Dutch experts, has established the fact after a three-year exercise on Yamuna river. The benthic macro-invertebrates were found to be best suitable among all other living systems present in aquatic ecosystem due to the following facts :

- Visible to the unaided eye;
- Stretches having different quality support diverse macro-invertebrate communities;
- Taxonomy is well developed;
- Sampling and observations are comparatively easy;
- Demonstrate an integrated effect of pollution;
- Provide good experimental possibilities;
- Useful in assessing the impact of municipal industrial, oily and agricultural wastes; and

Community response is sensitive to organic loading, substrate alteration and toxic pollution.

Source : PARIVESH, Sept.1995

3.9 Minimum flow required for Ecological integrity

National Water Policy has prioritized water used for the purposes of drinking, irrigation, and community bathing and washing. A thumb-rule of maintaining a flow of 10 cumecs with a depth of 1.5 mts has been evolved (see box 3 for details). CPCB has been conducting the biomonitoring of river Yamuna under an Indo-Dutch Collaboration Programme initiated in 1988. Extracts of information from Parivesh (Sept. 1995), CPCB newsletter are given in annexure VII. A list of benthic orgnisms, zooplanktons and phytoplanktons found in Yamuna river are given in the Annexure VIII. A map showing the ecological condition of the river has also been given. The designated water use table (Table IV) indicates that the parameters given under grade D are sufficient for biodiversity preservation. However, the scientists affirm that the water quality grade should be A or atleast B for a healthy ecosystem. The accepted minimum flow is 10 cumecs.

Pollution of water in the Yamuna is a major problem affecting the ecological and social needs. The levels of pollution in Yamuna and the flow required to dilute it at various urban centers are given in the following table. This will bring the water quality to grade A. The minimum flow of 10 cumecs at this level of purity will keep the riverine ecosystem in healthy condition.

TABLE VII

Delhi			
BOD of waste water after treatment (mg/l)	**Waste water flow (cumec)**	**Flow required for dilution of BOD to 3 mg/l**	**90% dependable minimum flow (cumec)**
30	12.36	223	2
20	12.36	140	2
10	12.36	58	2

TABLE VIII

Town	**BOD of waste water after treatment mg/l**	**Waste water flow (cumec)**	**Flow required (in cumec) for dilution of BOD to 3mg / l**	**90% dependable minimum flow(cumec)**
Mathura	30 20 10	0.596 0.596 0.596	16.05 10.12 4.17	2.31
Agra	30 20 10	0.812 0.812 0.812	21.93 13.84 5.7	3.40
Etawah	30 20 10	0.12 0.12 0.12	3.24 2.04 0.84	4.23
Allahabad	30 20 10	1.797 1.796 1.796	32.33 20.35 8.38	112.79

The BOD of waste water being let into the river at Delhi is 69 mg/l. Assuming that 70% of the BOD load is non settleable, this will be brought to 10 mg/l after treatment, minimum flow required for dilution will be 58 cumec. To ensure this flow a total storage of 1776 MC will be required to be reacted upstream.

BOX : BIODIVERSITY

Jhingran has recorded that river Yamuna spreads about o.8 to 1.6 km laterally during monsoon. [Jhingran 1982]. The average flow velocity in Yamuna is 0.2 - 0.3 m/sec. Fish require minimum of one meter depth of water for normal behaviour and reproduction. Summer water channel can be taken to be approximately one third of the average lateral spread of 1km which will be approximately equal to 300 mts. [Trivedi Pers. Comm.].

Flow = Area (A) x velocity (V) I

Taking the minimum required flow to be 10 cumec and the velocity of Yamuna to be 0.3m / sec the depth of water for a minimum flow of 10 cumec can be worked out.

Flow of 10 cumec = A x 0.3 m/sec.

Area = Average width of water x average depth (D)

A = 300 D

flow = A x V

10 = (300 x D) x 0.3

10 = 90 x D

D = 10/ 90

= 0.11 mt.

10 cumec flow = width of 300 mt x depth of 0.11 mt.

So, if the width of water remain the same }
and the depth is to be raised to 1 mt. } = 1.0 / 0.11
the flow will be }

= 9 x 10 cumec

= 90 cumec

The river requires a flow of 90 cumec(2.88 BCM) at a velocity 0.3 m/sec and having a spread of 300 mts to have an average depth of 1 mt to support the fish species. But the minimum flow budgeted presently is 10 cumecs.

Fish species found in Yamuna : *Cirrhinus mrigala, Catla catla, Labeo rohita, Labeo calbasu, Mystus aor, M. Seenghala, Wallago attu* and *Hilsa ilisha.* Of these species *Labeo calbasu* and *Hilsa* are most sensitive . *Hilsa* is an upstream species. The post monsoon flow has cleaner water and larger quantity at this time the *Hilsa* is found upto Agra. *Labeo calbasu* is also found in larger quantity at this time [Jhingran 1982].

3.10 Drinking Water Requirements of Yamuna Basin States

Basis

1. The percentage area of districts of each state falling in Yamuna basin have been considered.
2. Population projections, both urban & rural, have been made for the year 2001 A.D. The 1971 & 81 census figures of various districts have been utilized as base data. The growth rate for 71-81 have been applied to the population figures of 1981 to arrive at projection of 2001 A.D.

3. The rate of water required per capita/day for urban population is 140 liters and rural population it is 100 liters (70 liters for a human 30 liters for cattle). For urban population it is considered that the net consumptive use would be 140 lpcd and the actual withdrawal minus this consumptive use would return to the system. The standards are based on the calculations of Public health Engineering Department of GOI.

BOX 3 : DOMESTIC AND NON-DOMESTIC WATER REQUIREMENT

The manual on water supply and treatment prepared by the Ministry of Urban Development Govt. Of India lays down the following minimum rates per capita per day for domestic and non domestic needs.

I)	For communities with population upto 10,000	70 to 100 litres
ii)	For communities with population 10,000 to 50,000	100 to 125 litres
iii)	For communities with population above 50,000	123 to 200 litres

For communities with populations above 50,000 a rate of 140 litres/head/day is usually adopted. This rate has therefore, been adopted for working out the water requirements of cities/towns with population more than 50,000. For towns with population 10,000 to 50,000 a rate of 100 litres has been adopted.

Statement showing projected population/Drinking water requirements in 2001 A.D. of Basin States of Yamuna River. Urban - 140 litrs/capita/day Rural -100 ltrs/capita/day

TABLE V

	Population 1971	**Population 1981**	**Projection 2001**	**Drinking H_2O requirement for 2001 A.D. (BCM)**
Himachal Pradesh				
Rural	256307	379957	832532	0.030
Urban	37068	47971	80112	0.003
Total	293375	427928	912644	0.033
Uttar Pradesh				
Rural	3255299	4729789	9970395	0.364
Urban	957251	1995912	8636311	0.441
Total	4212550	6725701	18606706	0.805
Haryana				
Rural	6682013	8098794	11335508	0.413
Urban	1333422	2191270	6542724	0.334
Total	8015435	10290064	17878232	0.747
Delhi Urban [1]			128 lakhs	0. 526
Rural	4182877	5203837	8039928	0.293
Urban	777862	1222533	3063168	0.156
Total	49541739	6426370	11103596	0.449

[2]

1 Though water requirement for urban Delhi works out to be 0.666 BCM , it is given as 0.526 BCM because 0.138 BCM of water is drawn from other sources like Bhakra and Ramganga.

On the above basis drinking water requirements for the basin states in 2001 A.D. have been worked out.

Himachal Pradesh	:	0.033 BCM
Uttar Pradesh	:	0.805 BCM
Haryana	:	0.747 BCM
Delhi	:	0.516 BCM
Rajasthan	:	0.449 BCM
Total	:	**2.562 BCM**

On an average 3.39 BCM is available downstream of Okhla, of which about 2.11 BCM is likely to be utilized on completion of three storages, namely Renuka (0.46 BCM), Kishan (1.32 BCM) and Lakhwar Vyasi (0.33 BCM). The balance of say 1.28 BC (3.39 - 2.11 BCM) would still be available during three months as contribution from catchment area below the sites of above storages. It is expected that states would be able to draw 25% of their requirements of 2.56 BCM or say 0.6 BCM from the flow supplies available during these three months leaving a balance of 1.28-0.60 = 0.68 BCM which would continue to escape down Okhla unutilized.

(Rajasthan has demanded more water including water for Bharatpur Bird Sanctuary 0.43 BCM (See Table VI for breakup)

TABLE VI

1. Population/Drinking water requirement of Rajasthan in 2001 A.D. projected by State Govt.

Population	**1971**	**1981**	**2001**
Rural	41.83 lacs	52.04 lacs	80.40lacs
Urban	14.43 lacs	22.467lacs	50.115 lacs

2. Drinking water requirement in 2001

Rural (100 lpcd) 0.293 BCM
Urban (15-0-200 lpcd) 0.339 BCM
Total 0.632 BCM

3. Carrier canal losses @ 30% of 2 above 0.190 BCM

4. Net water requirement for drinking water (2+3) 0.322 BCM

5. Water requirement for wildlife Bharatpur Bird Sanctuary0.043 BCM

Total water requirement (4+5) 0.865 BCM

[**Source :** Data supplied by CWC]

Budget

Total mean year availability has been assessed as	**13.000[3]BCM**
Quantum of water not available due to flood spills	0.068 BCM
Quantum of water needed for ecological restoration with a flow of 10 cumec	0.032 BCM
Quantum of water required to support apex species of fish which requires a flow of 90 cumec	2.88 BMC
Total water required for Drinking purposes	2.562 BCM
Quantum of water required for pollution abatement (Based on Table X given in the Annexure)	7.100 BCM
Total	**13.254 BCM**
Deficit	**0.254 BCM**

This leaves a deficit of 0.254 BCM of water. However this figure is arrived at after presuming that the waste water flowing into the river is being treated to the levels such that BOD is at 30 mg/l and 10 mg/l whereas the desired level is 3 mg/l. In reality it may be much more.

The budget has been worked on the data given in the Yamuna Accord. However the data given in the` Report of the Interdisciplinary Working Group on Study of the Requirement of Minimum Flows in the Yamuna River' shows a much larger quantum of water. Yamuna Accord does not indicate how they arrived at this figure, but the CWC Report (1988) , does indicate that the data was based on calculations of water balance taking note of the average rainfall. All calculations should be based on the lowest figures, therefore the budget has been worked on the figures given in the Yamuna accord.

[3] This is the figure given in Yamuna Accord of 1994.

ANNEXURE I

Physiographic and Geological Features of the Basin

Topography :

The ground levels in the basin vary from about 6,320 m above MSL near the Yamunotri Glacier to around 100 m above MSL near the confluence of the Yamuna with the Ganga at Allahabad.

Topography Classification in Yamuna Basin
(approximate areas of each class in sq km)

Classification	Hilly	Foot Hills & Plateau Region	Plains & Valleys
State	**600m Above MSL**	**300m-600m Above MSL**	**100m - 300m Above MSL**
Uttar Pradesh	4,900	4,400	64,908
Himachal Pradesh	5,200	599	---
Haryana	---	800	20,465
Rajasthan	1,600	55,610	45,673
Delhi U.T.	---	---	1,485

Thus of the total basin about 3 percent area would be classified as hilly, and the remaining is almost equally divided between plains and plateau regions.

Lithology

Almost 60 percent of the Yamuna Basin comprises consolidated formations of various age groups while the remaining 40 percent in the plains and valleys and small part in the plateau and foot-hill regions of Rajasthan and UP comprises of unconsolidated formations of relatively recent age.

Climatic Features of the Basin

Temperature

Peak temperatures occur in the middle or latter part of May and the lowest temperatures in the late December or early January. Peak temperatures range from 40^{0}C at 6 of the stations studied. Corresponding temperatures at Dehradun and Simla are 36^{0}C and 25^{0}C respectively. The minimum temperatures similarly range between 5^{0}C and 9^{0}C for the 6 stations in the non-hilly region, but are somewhat lower in the hilly region of Dehradun and Simla. The difference between day and night temperatures is also observed to be of the same order, around 15^{0}C during extreme summers and winters, and between 6^{0}C and 10^0 C during the monsoons at all stations except at Simla. Thus, it might be said that from the point of view of temperatures, the entire Yamuna basin, leaving the hilly region, is almost similar, with rather severe summers and winters, the maximum summer temperatures being around 40^0 C and the winter minimum around 6^0 C.

Mean Annual Rainfall

The maximum precipitation in the basin, 1,600 mm or more, occurs along a narrow strip running from Solan via Sirmur towards Tehri town. From this intensity the rainfall steeply decreases both towards the North as also towards the South to reach 800 mm (barely half of the maximum) within a distance of about 100 kms. The minimum annual rainfalls occur in the western -most parts of the basin : 400 mm or even less in Mohindergarh and Bhiwani districts, and 500 mm or even less in Ajmer, Jaipur, Gurgaon and Rohtak districts. The rainfall intensity increases gradually as one moves towards the East, and more steeply as one moves towards the South East. [Report CBWPCWP 1978]

ANNEXURE II

National Water Policy and Designated Water Uses

In the National Water Policy adopted by the Government of India in 1987 following priorities for allocation of available water for different uses have been laid down :

- Drinking Water
- Irrigation
- Hydro-Power
- Navigation
- Industrial and other uses

The importance and urgency for providing water for drinking and irrigation has been highlighted in the National Water Policy document relevant extracts from which are reproduced.

The drinking water needs of people and livestock have also to be met. In keeping with the objectives of the International Drinking Water Supply and Sanitation Decade Programme (1981-1991), adequate drinking water facilities have to be provided to the entire population in both urban and rural areas and sanitation facilities to 80% of the urban population and 25% of rural population by the end of the decade. Domestic and industrial water needs have largely been concentrated in or near the principal cities, but the demand from rural society is expected to increase sharply as the development programmes improve economic conditions in the rural areas.

Water uses in the basin:The important water uses in the Yamuna basin, as elsewhere is most of the other basins, fell in two main categories viz. Abstractive uses and non-abstractive uses

Abstractive uses: The different identified abstractive uses of water in the basin are:

Domestic Water Supply : In some large towns located on the river banks or in areas where suitable ground water is not available, water from the flowing streams or from stored surface run-off is utilised for municipal supplies after treatment. However ground water is also used either exclusively or to supplement the supplies from surface water sources. A population of around 24.26 million is served from surface water and 32.88 million from ground water.

Irrigation: Irrigation is practised in the basin both from surface water as well as ground water. In the Yamuna basin states of Himachal Pradesh, Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh and the Union territory of Delhi, a net area of about 12.3 million hectares is under irrigation out of a net sown area of 17.8 million hectares. About 49% of this is irrigated exclusively from surface water.

Industrial uses: The industrial water requirement of Delhi is about 7% of the total requirement. However at other towns/cities where the water supply requirements for domestic purposes are much less, the industrial were requirement as percentage of domestic requirement is likely to be much higher. A uniform rate of 10% has therefore been adopted to work out the industrial water requirement at different locations where actual figures are not available. In the absence of any observed data or any criteria to assess the industrial water requirement the above percentage has been uniformly adopted to arrive at industrial water requirement at different important locations along the Yamuna river.

***Community Bathing and Washing*:** All flowing streams in the basin are used extensively by the communities for daily bathing and washing. Besides, on particular religious and cultural occasions, special fairs are held on the banks of some of these streams/rivers. The Central Board For Prevention and Control of Water Pollution is of the view that a certain minimum flow in the river at some of the important locations like Delhi, Mathura, Agra and Etawah should be maintained to provide a minimum water front for community bathing and washing.

Cattle bathing and watering: It is estimated by the Central Board for Prevention and Control of Water Pollution (CBP & CWP) that about 70% of the 40 million cattle in the basin get their drinking water directly from flowing streams and irrigation canals and the rest from pools, ponds and tanks. Though this is an in-situ abstractive use, it has a large number of abstraction points and assessment of quantities of water abstractions at each point is not possible. The streams are also used for cattle bathing especially during summer months.

ANNEXURE III
Interstate River Disputes

CWS has been providing technical assistance to Ministry of Water Resources, in its efforts in resolving the interstate water disputes amicably. During the year, assistance has been rendered in respect of the following :

Dispute	Party States
Yamuna (Upto Okhla)	Utter Pradesh, Himachal Pradesh, Haryana, Rajasthan, and Delhi
Sone	Madhya Pradesh, Uttar Pradesh, Bihar
Cauvery	Tamil Nadu, Karnataka, Kerala and Pondicherry

Yamuna Dispute (upto Okhla)

Long pending dispute on sharing of Yamuna water among the co-basin states has been finally resolved with the signing of a Memorandum of Understanding (MOU) on 12 May, 1994 regarding allocation of mean annual flow of 13.0 BCM at Okhla, by the Chief Ministers of concerned states. The MOU recognised the need for specified allocation of the utilisable water resources of river Yamuna (upto Okhla) and the need for the agreement in respect of identified storages to maximise the utilization. Considering the requirements of basin states for irrigation and drinking, the following allocation was agreed to, with interim seasonal allocation of the annual utilisable flow of 11.983 BCM allowing for a minimum flow in the river from ecological consideration* and also a quantum of 0.68 BCM not utilisable due to flood spills.

State	Seasonal Allocation of Yamuna Waters (BCM)			
	July-October	Nov.-February.	March-June	Annual
Haryana	4.107	0.686	0.937	5.730
Uttar Pradesh	3.216	0.343	0.473	4.032
Rajasthan	0.936	0.070	0.086	1.119
H.P.	0.190	0.108	0.080	0.378
Delhi	0.580	0.068	0.076	0.724
Total	**9.056**	**1.275**	**1.652**	**11.983**

- The interim seasonal allocation shall be progressively modified as storages are constructed, the annual allocation remaining the same. It was also agreed that the allocation of available flows will be regulated by the Upper Yamuna River Board within the over all frame work of the agreement.
- A Memorandum of Uderstanding for the construction of additional parallel channel for Delhi has also been signed between the Governments of Haryana and National Capital Territory of Delhi.

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* States have agreed that a minimum flow in proportion of completion of upstream storages going upto 10 cumec shall be maintained downstream of Tajewala/Hathnikund and downstream of Okhla Headworks throughout the year from ecological considerations as upstream storages are built up progressively in a phased manner.

- Draft Memorandum of understanding has also been signed by the Chief Ministers of Himachal Pradesh, Uttar Pradesh, Haryana and Delhi in respect of :
  - Construction of Renuka Dam in Himachal Pradesh
  - Construction of Hathnikund Barrage in Haryana and
  - Construction of Kishau Dam in Uttar Pradesh
- The states have also agreed on the setting up of an Upper Yamuna River Board for coordinated development and management of the River Yamuna.

The Board was constituted in March, 1995 with Member (WP&P), CWC as Chairman and members from all co-basin states apart from members from the central organisations of the Central Electricity Authority and Central Pollution Control Board to regulate allocation of surface flow of river Yamuna upto Okhla. Chief Engineer (BPMO), CWC is functioning as the Member-Secretary of the Board till regular arrangements are made.

Upper Yamuna River Board

After prolonged efforts and studies of the problems of sharing of yamuna waters by co-basin states of Haryana, UP, Rajasthan, Himachal Pradesh and Delhi, a Memorandum of Understanding (MOU) was signed for sharing of the Yamuna waters on 12.5.94. Upper Yamuna River Board (UYRB) was constituted in accordance with the provisions under para 7 of the MOWR Resolution no.10(66)/74-IT dated 11.3.95 Member (WP&P) is the Chairman and Chief Engineer (BPMO), CWC is in-charge Member-Secretary of the Board. Basin Planning Date. Of BPMO is functioning as the Secretariat of the UYRB in the absence of regular arrangements.

The Board has held ten meetings in all including three meetings during the year. In these meetings, the board took decisions on seasonal distribution of Yamuna waters upto Okhla, framed rules of business, finalised staffing pattern, its condition of service and norms for the selection committees for recruitment of different category of posts. Recruitment rules, functions and duties of the Board Personnel were also framed.

Status of the Board, operation of its funds and seasonal distribution of water to cobasin states were discussed in the 10th meeting held in March, 1997. The first annual report of the Board for they year 1995-96 has been brought out.

The analysis of the data indicates that the flows available in the river Yamuna with 90% dependability at different locations are adequate to meet the requirements of domestic, non-domestic and industrial water supply for the important towns and cities on the banks of the river Yamuna, except the capital city of Delhi. For Delhi, where the water available at 90% dependability is 2 cumec, the shortfall in the natural river flow at present is assessed to be at 29.5 cumec (1048 cusec) to meet the demands of the domestic, non-domestic and industrial uses as per the standards assumed and this quantity is almost being met from imports from other basins as also from ground water. The shortfall is likely to increase to 50 cumec by 2000 AD and 90 cumec by 2025 AD. Measures will, therefore, have to be taken to augment of lean season flow in the river by upstream storages and additional imports from other basins.

For maintaining a minimum water front near all the towns and cities, situated on the banks of the Yamuna, a minimum flow of 10 cumec is considered necessary. It is seen that from Tajewala to the Chambal confluence such an additional flow is not available during the lean season though adequate quantity to meet domestic, non-domestic and industrial water needs of all towns except Delhi is likely to be available upto 2025 AD.

At present 17629 MCM of water is imported from other basins, during the lean season.

From the point of view of minimum flows and river water quality. Delhi is considered the most critical place where a minimum flow of about 223 cumec is required in the present situation for dilution of pollution loads of river water even after treatment of waste waters to a BOD level of 30mg/1 downstream of the present pumping station. Even with more rigorous treatment upto a BOD level 10 mg/1, a flow of 58 cumec will be required. To maintain this flow a storage of 1776 MCM will be required at a capital investment of Rs.1580 crores and an additional annual maintenance cost of about Rs.256 crores. [Report CWC 1989]

ANNEXURE IV

Augmentation of Flow Required in the Yamuna River at Delhi and Tajewala for Maintaining Desired Water Quality (BOD-3mg/1)

Sl.	Water BOD	Flow required at Delhi for dilution	Range of dependable flows at Delhi on monthly basis			Range of Augmentation Required at Delhi on monthly basis			Range of Augmentation required at Tajewala on monthly basis considering 35% losses		
			50%	75%	90%	50%	70%	90%	50%	70%	90%
Unit	mg/1	Cumec	Cumec	Cumec	Cumec (MCM/yr)	Cumec (MCM/yr)	Cumec (MCM/yr)	Cumec (MCM/yr)	Cumec (MCM/yr)	Cumec (MCM/yr)	Cumec (MCM/yr)
1.	30	223	21-1204	8-652	2-347	0-0202 (4373)	0-215 (4823)	0-221 (5484)	0311 (6727)	0-330 (7420)	0-340 (8437)
2,	20	140	21-1204	8-652	2-347	0-117 (2415)	0-132 (2765)	0-138 (3104)	0-184 (3715)	0-203 (4163)	0-213 (4576)
3.	10	58	21-1204	8-652	2-347	0-37 (584)	0-50 (830)	0-56 (1050)	0-57 (898)	0-76 (1278)	0-87 (1616)

ANNEXURE V

Minimum Flow Requirement at Different Locations for Designated Uses (Considering treatment of waste water to BCD 10 mg/1) UNIT CUMEC

Location	Minimum flow required in the Yamuna river for											
	Water supply			Pollution abatement			Minimum water Front			Total minimum requirement		
	1998	2000	2025	1998	2000	2025	1998	200	2025	1998	2000	2025
Delhi	31.52	32.02	92.70	58	103	250	10	10	10	89.52	155.02	342
Mathura	0.31	0.365	0.48	4.17	NA	NA	10	10	10	10.31	10.36	10.43
Agra	1.478	1.782	2.42	3.7	7	10	10	10	10	1.48	4.78	12.42
Etawah	0.249	0.409	1.14	0.84	NA	NA	10	10	10	10.25	10.25	11.14
Auraiya	0.0598	0.128	0.303	--- Negligible ---			10	10	10	10.06	10.13	10.3
Kalpi	0.048	0.126	0.534	--- do ---			10	10	10	10.05	10.12	10.534
Hamirpur	0.035	0.09	0.285	--- do ---			10	10	10	10.02	10.09	10.29
Allahabad	10.336	1.728	2.602	8.38	10.54	13.87	10	10	10	11.34	12.27	12.6

Note :

I) At Auraiya, Hamirpur and Kalpi there is no problem of pollution of river water.

ii) Requirement of water for pollution abatement have been worked out on the assumption that the waste water will be treated to bring down theBOD-10 mg /1.

ii) BOD of river water upstream of Delhi and Allahabad has been taken 1.5 mg/1 and at all other places as 2 mg/1. It is assumed that after augmentation of flow at each place the 3CD will gradually irnproved as the water moves along the river.

Iv) CBP & CWP has indicated that 70% of the BOD load let into the river could be considered as non-settled in for working out the dilution water required.

v) The figure pollution abatement are based on Figures given in Annexure VII.

ANNEXURE VI
What is Bio-Monitoring ?

Monitoring is an important tool for water quality management. It can be defined as "the process of repeated observations and measurement for defined purposes of one or more `indicators of the physical, chemical or biological state of an environmental element or medium.

Bio-monitoring is the introduction of biological variables for assessment of the structural and functional aspects of aquatic ecosystems. Bio-monitoring can be used as a cost-effective means for supplementing the physico-chemical techniques. Bio-monitoring can help in determining the impacts on aquatic ecosystem due to various reasons including the following :

- Non-availability of water in non-monsoon periods;
- Low oxygen conditions and eutrophication;
- High faecal coliforms content;
- Presence of heavy metals;
- Elimination of sensitive species; and
- Damage due to autochthonous and allochthonous pollution.

Why to do Bio-monitoring ?

Generally, the water quality management is related to identified beneficial uses of water in terms of primary water quality criteria parameters. `Designated-best-use' concept was evolved on the same basis. Five major uses of river water have been conceived. If a water body is put to multiple use, then the use which demands the highest quality of water is called designated-best-use and accordingly the water body or its part is designated. Measurement of chemical and physical characteristics have been used so far either to detect pollution or to control it. Biological monitoring of water quality could be useful for assessing the overall health of water bodies because of the following :

- The list of chemicals to be monitored is unending.
- Biological effects often occur at concentrations below analytical capabilities. Many of the pollutants are present in such low concentrations that instrument sensitivity is too poor to determine the microquantity of pollutants.

- The toxicants and other traces may act quite differently in mixture than individually. Such toxicants affect the ecosystem in a synergistic manner which cannot be detected by chemical analysis alone.
- Chemical nature of toxicant is highly dynamic in environment with time and space, whereas biological system can integrate all environmental variables over a long period of time in terms of effects which can be easily measured and quantified.

When to Do Bio-monitoring ?

Bio-monitoring needs to be performed during biologically matured period of a year to get fruitful results. In India due to tropical climate, monsoon occurs for a limited period (average rainy days are 40 in a year), but with high intensity. The entire biological system established during non-monsoon period is flushed because of floods. After the monsoon recedes, the biological system starts re-establishment. After gradual succession "mature" ecosystem establishes. This is the right time for biological sampling.

The sampling time for bio-monitoring is preferably selected either in the morning or before the sunset because some of the benthic animals avoid extreme solar intensity and temperature, and seek refuge under the rocks or in the interstitial sediments. For the measurement of functional biological parameters, such as photosynthesis and respiration, sampling is performed round the clock.

Methods of Bio-Monitoring

Three main types of aquatic bio-monitoring have been recognised, and depending upon the objective, type of bio-monitoring is selected (Fig. 1). These are :

I. Toxicity Testing : For all toxic effluents, standard on toxicity is established by the regulatory authorities and the effluents are monitored for compliance with standard through toxicity test using fish, daphnia or other suitable organisms. Toxicity tests are also performed for setting the standards for various industries as a part of risk assessment.

II. Early warming system : To warn the water supply authorities for sudden change in water quality, and also to the industries for mal-functioning of their treatment plant. This method is used in Western countries.

III. In-stream biomonitoring : This is a measurement of change in structural and functional integrity of the aquatic ecosystem in response to pollution.

Under the Indo-dutch collaboration, a project on development of bio-monitoring methodology for Indian river water quality evaluation was initiated in 1988. The Central Pollution Control Board carried out a pilot study on the river Yamuna. With monthly intervals, a number of biological and physico - chemical parameters were determined at 15 stations, which were later reduced to 11 locations along the river Yamuna from Delhi up-stream to Etawah downstream. The main objective for this study was to formulate strategic methods which can be accepted in scientific and legislative framework for water quality evaluation. The outcome of the study was a generally applicable yardstick for indication of actual water quality, and can be used in water quality management programme in the country.

Amoeba Presentation

The proposed yardstick consists of an "AMOEBA" (A Method of Ecological & Biological Assessment) presentation of 8 different indices :

Pollution Load (Stress) Indces

- Bacterial Pollution Index (BPI)
- Nutrient Pollution Index (NPI)
- Organic Pollution Index (OPI)
- Industrial Pollution Index (IPI)
- Pesticides Pollution Index (PPI)

Effect (strain) Indices

- Benthic Saprobity Index (BSI)
- Biological Diversity Index (BDI)
- Production Respiration Index (PRI)

Each of these indices are derived from a set of one or more monitoring parameters and may very according to regional requirements. The detail methods of derivation is presented in a manual, jointly prepared by the CPCB and RIVM, Netherland.

ANNEXURE VII
Benthic Organisms Phytoplankton and Zooplanktons in Yamuna River
BENTHOS

Aeshna sp
Agabus sp
Amphibia frog
Amphibia tadpoles
Anuraeopsis sp
Aphelocheirus sp
Arachnida
Atherix sp
Baeis sp
Beetis sp
Beetle larvae
Bithynia sp
Colymbetes sp
Corbicula sp
Crustacea
Crustaccean Shrimps
Diptera Chironomus Larvae
Diptera Ephedra Pupa
Diptera Mosquito Larvae
Dragonfly larvae
Enochrus sp
Ephemerella sp.
Gammarus sp.
Gyraulus sp
Hagenius sp.
Hydrobia sp
Hycorius sp
Hydrous sp
Hydropsyche sp
Lestes sp
Lymnaea sp
Mayfly larvae, Ephemeroptera
Mollusca Glessus
Mollusca Helix
Mollusca Pila
Mollusca Polymesoda
Nais sp
Nematoda
Nepa Cinerea
Neuroptera, Dopsonfly larvae
Notonecta sp
Oligochaeta worm
Onychogamphus sp.
Orectochilus sp
Pachydrilus sp
Physa sp
Pisces Fish
Pisidium sp
Plea leachi
Plecoptera Stonefly Larvae
Ranatra sp
Scorpion sp
Sigara sp
Sphaerium sp
Trichoptera, Caddies fly larvae
Trichoptera Helicopsychae
Unio sp
Valvata sp
Viviparus sp

PHYTOPLANKTON

Ablabesmyia monilis
Achnanthes sp
Actinastrum hantzschii
Actinastrum sp
Amphiprora sp
Amphora sp
Anacystis sp
Ankistrodesmus falcatus
Ankistrodesmus longispira
Ankistrodesmus minutissimus
Ankistrodesmus sp (Komarkova-Legnerova)
Anabaena sp
Anabaenopsis sp
Aphanocapsa sp
Aphanothece nidulans
Arthrodesmus sp
Arthrospira sp
Bnuclearia sp
Brebisonia sp
Bumilleria sp
Cocconeis sp
Ceratoneis sp
Centritractus belenophorus
Centritractus sp
Chlorobotrys sp
Chodatella sp
Chodatella crassiseta
Chodatella quadricella
Characiopsis sp
Chlorella sp
Chroococcus limneticus
Chroocooccus minimus

Characium sp
Clathrocystis aeroginosa
Closterium moniliferum
Closterium sp
Coelastrum sp
Crucigenia sp
Cosmarium granatum
Cosmarium sp
Cylindrocystis sp
Cymbella sp
Cymatopleura sp
Cyclotella sp
Diatoma sp
Docidium sp
Elakatothrix sp
Elakotothrix lacustrix
Enujonema sp
Eremospheaera sp
Euglena sp
Fragilaria sp
Glaeotanium sp
Gloeocapsa sp
Gloeothece sp
Gomphonema sp
Golinkiniopsis solitaria
Gomphosphaeria sp
Gyrosigma sp
Hydrodictyon sp
kKirchneriella sp
Lagerheimia chodata
Lyngbya sp
Lyngbia chlorospira
Lyngbya contorta
Lyngbya limnetica
Mastogloia sp
Melosira sp
Merismopedia sp
Merismopedia glauca
Merismopedia marsoonii
Merismopedia minima
Merismopedia minutes
Merismopedia tenuissima
Mesotaenium sp
Microcystis sp
Navicula sp
Netrium sp
Nitzschia sp
Oedogonium sp
Oocystis sp
Orthrospira sp
Oscillatoria sp
Pediastrum boryanum
Pediastrum clathratum
Pediastrum duplex
Pediastrum tetras
Pediastrum sp
Penium sp
Phacus pleuronectes
Phacus sp
Pinnularia sp
Planctomyces sp
Pleurosigma sp
Podohedra sp
Protosiphon sp
Rhoicosphenia sp
Romeria elegans
Rhizoclonium sp
Scenedesmus acutus f. Alternans
Scenedesmus acuminatus v. Bernardii
Scenedesmus acuminatus f.
Globosum
Scenedesmus acuminatus
Scenedesmus apiculatus
Scenedesmus apiculatus var. Indices
Scenedesmus arcuatus
Scenedesmus bicellularis
Scenedesmus carinatus
Scenedesmus columnatus var. Indicus
Scenedesmus dispar
Scenedesmus ecornis v. Disciformis
Scenedesmus ecornis
Scenedesmus sps
Scenedesmus ellipsoideus
Scenedesmus granulatus
Scenedesmus incrassatulus
Scenedesmus intermedius
Scenedesmus jamunai f. Granulatus
Scenedesmus jamunai
Scenedesmus lefevrei
Scenedesmus longispira
Scenedesmus longipra var.
Capricornis
Scenedesmus nanus
Scenedesmus opoliensis
Scenedesmus ovalternus
Scenedesmus ovalternis var. Indicus
Scenedesmus pescensis
Scenedesmus platidiscus
Scenedesmus polydenticulatus
Scenedesmus protuberans

Scenedesmus protuberans
Scenedesmus punctatus
Scenedesmus quadricauda
Scenedesmus l,ongispina
Scenedesmus qadr. V. Mirificus
Scenedesmus sowi
Scenedesmus tetradismiformis
Scenedesmus judayi
Scenedesmus setigera
Scenedesmus spiralis (Printz) Kors.
Sphaerocystis sp
Siderocelis kolkwitzii
Siderocelis ornata
Spirogyra adnata
Spirulina sp
Strombomonas sp
Stephanodiscus sp
Stichococcus sp
Stauroneis sp
Staurastrum sp
Surirella sp
Synedra sp
Synechocystis salina
Tabellaria sp
Tetracyclus sp
Tetradron caudattum
Tetraedron minimum
Tetraedron pentaedricum
Tetraedron proteiforme v. Granulatum
Tetraedron sp
Tetraedron triangulare
Tetraedron tumidulum
Tetraspora sp
Tetrastrum elegans
Tetrastrum punctatum
Tetrastrum sp
Tetrastrum staurogeiaeforme
Tetmemoorus sp
Verheurchia sp
Volvox sp
Zygnema sp
Zygogonium nivale

ZOOPLANKTON

Aedes sp
Amoeba sp
Antocha sp
Anuraeopsis sp
Arcella sp
Asplanchna sp
Aspidisca sp
Atherix sp
Berosidae
Beetle larvae
Brachionus angularies
Branchionus calyciflorus
Branchionus caudatus
Branchionus falcatus
Branchionus forficula
Brachionus sp
Brachionus larvae
Brachionus quadridentatus
Brachionus rubens
Calanous nauplius
Cephalodella sp
Cariodaphnia sp
Chironomidae
Chironomus sp
Chromogaster sp
Cletotidae
Colurella sp
Conochilus sp
Copepoda
Colpidium colpoda
Colpidium sp
Cupelopagis sp
Cyclopoida
Cypridae
Cyclops sp
Daphniidae
Dicranophorus sp
Digochalte sp
Diphnosoma sp
Epiphanes sp
Euchlanis sp
Euglena sp
Exuvae
Filinia spec
Fontanelis sp
Hexarthra sp
Keratella sp
Lecane sp
Leptodora sp
Mayfly larvae, Ephemeroptera
Microcodides sp
Micronecta sp
Moina sp
Monostyla sp
Moraella

Mosquito larvae
Mysis sp
Mytilina sp
Cyclops sp nauplia larvae
Nematoda
Nereidae
Nothalca sp
Odonata Damselfly Larvae
Oligochaeta worm
Opercularia sp
Paramaecium sp
Philodina sp
Platyias sp
Plecoptera Stonefly Larvae
Polyarthra sp
Polychaeta
Rotaria sp
Sylonchia sp
Synchaeta sp
Synura sp
Termite larvae
Testudinella sp
Tradizeda sp
Trichocerca sp
Trichoptera Helicopsychae
Vermatode sp
Vorticella sp
Westells botryoides

REFERENCES

Report CBPCWP 1978 `Basin Sub-basin Inventory of Water Pollution, Part - I, The Yamuna Sub-basin' *Central Control Board for the Prevention and Control of Water Pollution, New Delhi*

Report CWC 1989 *`Report of the Interdisciplinary Working Group on Study of the Requirement of Minimum Flows in the Yamuna River' Central Water Commission RM Directorate, New Delhi.*

Report, CPCB, 1991 *`Annex 3 to report no. 768602008, Raw data stored for the Yamuna River Biomonitoring pilot study'* by D. Zward, CPCB, Delhi, June 1991.

PARIVESH, 1995 *`Parivesh'* Newsletter, Central Pollution Control Board, Sept. 1995, New Delhi

Jhingran 1982 *' Fish and Fisheries of India'* - Hindustan Publishing Corporation; Delhi

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III TERRESTRIAL ECOSYSTEMS AND BIODIVERSITY

Introduction

The allocation of forests and forestland, and of other types of terrestrial ecosystems, needs to be done keeping in mind the twin principles of sustainability and equity. Therefore, the amount of land to be kept under forest cover and the uses permitted in the forests need to be calculated. The main ecosystem types include forests, deserts and grasslands. Unlike aquatic (fresh water) ecosystems which are naturally demarcated, there is a need to demarcate and prioritise terrestrial ecosystems on the basis of their ecological, biodiversity and socio-economic values. As these ecosystems are put to various uses, as are all other ecosystems, it is also important to specify their uses and accordingly demarcate zones and sites.

For example, landscapes could be demarcated in terms of the following functions or intended uses:

- Genetic reference areas – with no human manipulation, use or disturbance.
- Biodiversity conservation areas – with minimal human use and disturbance and manipulation only where required to promote biodiversity conservation.
- Ecological function areas – like watersheds, where management is aimed at promoting and maintaining the designated ecological functions.
- Sustainable use areas – where resources are extracted or used in a sustainable manner.
- Other use areas – where other human uses, like urban use or industrial use, take precedence.

Of course, a site, zone or area could well have more than one of the above functions. For example, a genetic reference point would also be a biodiversity conservation area and also an ecological function area, though the converse might not be true.

Therefore, in the process of physically budgeting and allocating terrestrial area, the first task is to prioritise those areas that need to be kept apart for one or more of the functions above. In order to do this, it is necessary to determine how much of the area is required as a genetic reference area, as a biodiversity conservation area and as an ecological function area. Next, the area needed for sustainable extraction of resources for the poor is taken out. The remaining area is then allocated according to market determination.

In section 1 of this chapter the principles to be used for prioritising sites (and species) for conservation are described and discussed. In section 2, a methodology is developed, using these principles, to budget and prioritise for ecosystem functions of forests. In section 3, a methodology is developed to budget and prioritise for biodiversity conservation areas and a prioritisation is attempted for the Yamuna Sub Catchment (YSC). In section 4, a methodology is developed, described and used, for budgeting for some socio economic functions of forests in the YSC. In section 5, a methodology is developed for allocating land for urban forests for pollution control in Delhi.

1. PRIORITISING FOR CONSERVATION*

1.1. INTRODUCTION

The need to prioritise conservation sites arises because of the various limitations and constraints that operate in the real world. Ideally, perhaps all biodiversity everywhere would be conserved. However, there are financial, institutional and human resource constraints which limit conservation efforts. There are also multiple demands on land and ecosystems. To meet all these demands and yet also adequately conserve biodiversity is not easy and, if it is to be achieved at all, it becomes critical to focus efforts on priority sites and species.

Prioritisation of strategies is again important to ensure that efforts at conservation yield the best possible results and that undesirable side-effects, especially the alienation and impoverishment of local communities, is avoided.

1.2 VALUES FOR PRIORITISING SITES AND SPECIES

Prioritisation of sites and species, for conservation, needs to be done with reference to certain well defined values. These include biodiversity and socio-economic values, and values determining the feasabilitity of conserving a site.

1.2.1 ***Biodiversity Values***

The importance of a site in terms of its biodiversity value can be assessed on the basis of its :

- # Biological representativeness
- # Biological uniqueness
- # Naturalness
- # Biodiversity richness
- # Support functions for other sites and for species
- # Potential value of an area where an area might potentially be of high biodiversity value (for one or more of the earlier mentioned reasons) but its biodiversity value has not been studied or established.

Though these different basis for determining biodiversity value are not ranked, in determining the final priority a judgement would have to be made about their relative importance. For example, there might have to be a choice made between unique ecosystems and representative ecosystems, or between ecosystems where the biodiversity value has already been established and those where it is suspected but not yet studied.

* This section is jointly authored by Mr Shekhar Singh of IIPA and Ms Bansuri Taneja of Kalpavriksh.

Described below is each of these proposed values in detail.

1.2.1.1 *Representativeness*

Strictly speaking, a site is representative only of itself. However, as there are limits on how disaggregated conservation efforts can be, eco-system and habitat types have to be identified and representation sought therein. The level of biological similarity of a particular site with other similar sites or with an ecosystem type, in terms of the number and percentage of defining characteristics of that eco-system (or of similar sites) the site has, would determine its representativeness. Since it is impossible to find a site identical to an entire eco-system, sites can be prioritised on the basis of levels of similarity. The level of disaggregation at which eco-systems can and should be represented is dependent on the scale at which the exercise of selecting representative sites is being carried out. Small scale studies will distinguish between ecosystems in greater detail. Albeit, a representative site must be large enough to reflect the integrity of ecosystem processes and not just ecosystem species.

An additional criteria for prioritising representative sites, especially when deciding between ecosystem types, is the <u>coverage</u> in terms of protected representative sites that each ecosystem type already has an ecosystem with no or relatively few already protected representative sites would have a higher priority than one with many such sites.

1.2.1.2 *Uniqueness*

Strictly speaking, each site is unique. However, in terms of practical conservation, areas that are markedly different in their habitat, ecosystem processes, species combination from all other areas, are classified, through admittedly somewhat arbitrarly, as unique ecosystem. This criterion has the twin components of distinctiveness and rarity. Distinctiveness of a community would mean how far separated the unit is from its nearest neighbour in terms of combinations and processes. With regards to species, this translates into the relatedness of the specie with other levels of the taxonomic hierarchy e.g. a specie that is the only members of its genus or family would be a greater loss to diversity than one which is part of a large genus. `Rarity' signifies the occurrence, in a site, of species, combinations of species, which are rare in nature or processes. Rarity may be a natural occurrence or due to human intervention.

This criterion can be seen as, in a sense, opposite to that of representativeness, since its defining quality is distinctiveness.

1.2.1.3*Naturalness*

This captures the extent to which a system has been free from human intervention and therefore has been allowed to exist and evolve in its natural state. Such sites are likely to be examples of relatively unmodified ecological processes. (e.g. Major Wilderness Areas identified by McCloskey and Spaulding based on the absence of permanent/continuous human presence over a specified area [Johnson, 1995]).

There are two difficult questions related to this criterion. First, is all human intervention negative in terms of naturalness values? Second, is any ecosystem on Earth "natural"? Conceivably, human activities leading to pollution and climate change, among other, might arguably have modified even those wilderness patches never actually visited by humans.

1.2.1.4*Richness/diversity*

This refers to the number (and density) of species contained in an area. Measurement of species per unit area is perhaps the most objective measure of this criterion. In the context of ecological communities, it could mean diversity of habitats.

However, this criterion should be used to prioritise between sites belonging to the same ecosystem type only. Species richness cannot be used to prioritise between ecosystem types.

Diversity is an additional value insofar as the less the genetic relatedness of constituent species, the greater the value of diversity.

1.2.1.5*Endemism*

An endemic entity is one whose occurrence is restricted or particular to a locality or area. In this review, its implications are restricted to endemic species since endemicity of ecosystems is covered under Uniqueness. The measure most often used is the number/percentage of species endemic to a site. The problem of scale arises here as well, since the question of local endemism is dependent on the size of the area under consideration. Also, if limits on the extent of area are set for characterisation of a specie as endemic, species with larger ranges but endemic within those may be overlooked e.g. birds endemic to the Mediterranean rim are not considered restricted range species because of the 50,000sq. Km. limit on EBAs [ICBP, 1992].

1.2.1.6*Significance for other areas of biodiversity value*

This involves valuation of an area based on its importance for the health of other eco-systems, though it may not be biologically rich in itself. These inputs could be constant, cyclic (repeatedly in a known cycle) or periodic (at unknown intervals).

(a) Constant inputs could be functions such as water catchments for wetlands, or genetic corridors. With regards to species, constant services would mean their role in maintaining processes such as pollination or their status as keystone species.

(b) Cyclic significance to an area of biodiversity value is
a function of an area occurring at regular intervals e.g. nesting/wintering grounds, stopovers on migratory routes.

(c) Periodic inputs could include refuge provided to species in times of crisis (e.g. flood) in their natural habitat. This would often be at unknown intervals.

1.2.1.7 *Containing valuable or important species*

The value of the constituent species could be ecological, economic, as a conservation symbol or because of its threatened status. Apart from conserving ecosystems, biodiversity conservation would also involve the conservation of specific species. Prioritisation between species could be made based on endemism, of how rare they are, how fragile they are, threatened they are and their importance to other species (the keystone function).

1.2.1.8 *Potential for High Biodiversity Value*

Unexplored areas whose potential biodiversity value is high, e.g. unexplored island in the Andaman and Nicobar group.

1.2.1.9 *Size of site*

The need to conserve biological viability usually translates into a minimum size requirement for sites.

1.2.2 ***Socio-economic Values***

In deciding priority sites for conservation it is important to assess and take into consideration the socio-economic value of the site. In one sense, all biodiversity values are also socio-economic values as, directly or indirectly, individually or collectively, biodiversity resources are also socio-economic resources. However, more specific socio economic values also need to be taken into consideration in the prioritisation process.

There are indirect socio-economic values where biodiversity rich sites perform catchment, seed bank, climate regulation and other such functions that contribute to the social and economic welfare of humanity. There are, in addition, direct socio economic benefits where local communities, especially the tribal and forest dwelling communities, use plants and animals for food, medicine and to meet other basic needs. Consequently, a river, or a bay, or a part of the sea which, apart from having rich biodiversity, also functions as a seed bank in support of the fisheries of the region, has added priority for conservation. If the area also directly supports fisher folk or other local people (even from tourism based activities) then its priority goes up further.

Social and economic values can be classified as follows.

- # Direct economic value
- # Indirect economic value
- # Option value
- # Socio-cultural value
- # Scientific value

1.2.2.1 *Direct economic value*

The direct economic value of a site (or species) is the economic value of those goods and services it directly provides (or can provide) that are generally acknowledged to have a market price and perhaps a replacement cost or an exchange value. Such goods could include timber, fuelwood, and medicinal and edible plants. Such services could include tourism.

1.2.2.2 *Indirect economic value*

The indirect economic value of a site (or species) is the (notional) economic value of those goods and services provided (or providable) that are not ordinarily bought or sold (or even exchanged) and, consequently, do not have an acknowledged economic value. Such goods and services are, however, critical for human well being and for the continued availability of other goods and services which have direct economic value. Examples would include carbon sink, climate and hydraulic regulation, seed bank, and soil and oxygen replenishment functions.

1.2.2.3 *Option value*

Option value is the (notional) value, economic, cultural or scientific, that a site or a species might have in the future, but which is not yet recognised.

1.2.2.4 *Socio-cultural value*

Socio cultural value is the non-economic value that human beings attach to sites and species, as a part of sentiment, culture, aesthetics, history or religion. This is especially true of rural and forest based communities.

1.2.2.5 *Scientific value*

Scientific value is indicated by the potential of a site or species to contribute to our knowledge of the world. This could include sites of long standing research value and others where new studies could prove fruitful, e.g. the Antarctica.

1.2.3 *Conservation Feasibility Values*

Given the need to prioritise because of the constraints already mentioned, it is important to assess the conservation feasibility value of an area, in terms of how easy or difficult it is to conserve. Essentially this involves on the one hand an assessment of the threats and pressures on the area and, on the other hand, the capabilities and institutional structures available to conserve the area. Clearly if a choice has to be made between two areas which are otherwise of equal biodiversity and socio economic value, that which is easier to conserve must be chosen.

An exception to this rule might, however, need to be made in the case of an area which, if something is not urgently done, would loose all its unique biodiversity value. In such cases priority may be given to such an area even when it is difficult to conserve, over other areas which are easier to conserve but can well wait for a while.

Some of the important concerns could be:

- # Protection status
- # Level of threats
- # Management Capability
- # Size and ecological vulnerability

1.2.3.1 *Protection Status*

The legal or social protection status a site enjoys is an important factor for determining the conservation feasibility value. For example, a duly notified national park would have greater feasibility value than a sanctuary. Similarly, a sanctuary would have higher conservation feasibility than a reserved forest, and all three would have a higher status than a site which has no special conservation status. Conservation feasibility value can also be enhanced by the non-legal social status of a site, like a sacred site.

1.2.3.2 *Level of threat*

The level and type of human pressures that an area is subjected to is also an important criterion for determining the feasibility value. For example, constant pressures might be far more damaging than infrequent, cyclic, ones. Similarly, pressures emanating form the legitimate needs of the local population might be far more difficult to control than those from elite tourist activities.

1.2.3.3 *Management Capability*

The ability and willingness of the government and other institutions, including local community institutions, to conserve the site is an important criterion for determining feasibility value. Mere legal status does not guarantee proper protection.

This involves not only having the capability of managing the site but also of influencing larger policy and action which has a bearing on the conservation of the site. It also involves being able to get the participation and the support of local communities in conserving the site.

1.2.3.4 *Size and ecological vulnerability*

The damage that specific pressures can cause to a site often depends on size and ecological vulnerability of the area. Smaller sites are often less able to absorb pressures and threats. The layout and extent of a site, its shape and relationship with other sites, also has a bearing on its viability as a conservation unit.

1.3 SURVEY OF PRIORITISATION VALUES

An attempt was made to study various biodiversity conservation prioritisation exercises undertaken in different parts of the world with the purpose of extracting the prioritisation values used in these exercises. For the purpose, 47 prioritisation exercises were studied, 33 through primary sources and 14 through secondary sources. The list is at Annexure I.

The summary of findings, in terms of the different types of prioritisation values preferred, is given below.

SUMMARY OF FINDINGS

VALUES	SCORE			RANKING	
	Primary Studies	Secondary Studies	Total	Within Section	Overall
Biodiversity Values					
1a Representative	16	4	20	5	7
1b Gaps in PAs	12	2	14	6	10
2 Uniqueness	21	5	26	3	4
3 Naturalness	11 1/2	2 1/2	14	6	10
4 Richness/ diversity	27 1/2	10 1/2	38	1	1
5 Endemism	26	10	36	2	2
6a Significance for other areas	10 1/2	1	11 1/2	7	12
6b Cyclic significance	10 1/2	1	11 1/2	7	12

VALUES	SCORE			RANKING	
	Primary Studies	Secondary Studies	Total	Within Section	Overall
7 Important Species	14	6 1/2	20 1/2	4	6
8 Potential Value	3	-	3	8	14
SOCIO ECONOMIC VALUE					
9 Direct	18 1/2	5	23 1/2	1	5
10 Indirect	14	5	19	2	8
11 Option	8	-	8	4	13
12 Socio cultural	11 1/2	3	14 1/2	3	9
13 Scientific	7	1	8	4	13
CONSERVATION FEASABILITY VALUES					
14 Protection Status	17	9	26	2	4
15 Level of Threat	27	3	30	1	3
16 Management capacity	11	2	13	3	11
17 Size	5 1/2	2 1/2	8	4	13

NOTES:
One point was given to a value for each exercise that it was fully used in. Half a point was given for partial use.

* Role with other areas of biodiversity significance is sometimes indistinguishable from indirect economic value (i.e. functions such as catchment areas).
* Cyclic significance is the most obvious of the roles that a site could perform with reference to an area/species. It is therefore usually more explicitly stated.
* Valuable/Important species are again a highly visible criterion for conservation. It is perhaps widely used also because it helps in obtaining institutional support.
* Potential for high biodiversity value is not much looked into, though perhaps it should be because it can include the criterion of naturalness as well.
* Direct economic values are often not explicitly mentioned perhaps because there is a demand that biodiversity should be conserved for its own sake and not just because it is of value to humans. Sometimes, direct economic are implicit in the decision to conserve.
* Option value again seems to be implied in many studies, but not directly considered perhaps because of the difficulty of quantification.
* Scientific value usually seems to refer only to existing research and usefulness of biodiversity to science.
* Valuation based on the feasibility of conservation often assumes that adequate conservation action will be taken subsequent to the site being prioritised.

ANNEXURE I

Documents reviewed are as follows :

Gdls: Anon, Guidelines for Preparation of National Biodiversity strategies and Action Plans, Draft copy, 1994, UNEP.

Indo: Anon, Biodiversity Action Plan for Indonesia, Project profile (selected), 1993, National Development Planning Agency, Jakarta

Mckn: Mackinnon, J. - Introduction to the Indo - Malayan Realm and Methods of Current Review, paper prepared for discussion at First Regional Workshop of Review of PA system of Indo-Malayan Realm, Kathmandu, Nov 1994.

SSA: Anon, Biodiversity in Sub-Saharan Africa and its Islands, 1990, IUCN papers of the Species Survival Commission.

NBP: Anon, National Biodiversity Planning - Guidelines based on early experiences around the world, 1995, WRI, Washington DC.

Cha: Maxey & Lutz ed., China - Biodiversity Conservation Action Plan, 1994, National Environmental Protection Agency.

LAC: Anon, A Regional Analysis of Geographic Priorities for Biodiversity Conservation in Latin America and the Caribbean, 1995, BSP, Washington D.C.

WRI: Reid, W.V & Miller, K.R- Keeping Options Alive : The Scientific Basis for Conserving Biodiversity, 1989, WRI, Washington D.C.

ICBP: Bibby et. al - Putting Biodiversity on the Map - Priority Areas for Global Conservation, 1992, Cambridge.

CWBV: McNeely et.al, Conserving the World's Biological Diversity, 1990, IUCN, Gland, Switzerland.

Phipns : Republic of the Philippines - Conservation of Priority Protected Area Project, 1994, World Bank/GEF. Washington D.C.

SBSTTA: Alternative ways and means in which the Conference of Parties could start the processes of considering the components of Biological Diversity, particularly those under threat. Identification of action which could be taken under the Convention. First Meeting of Subsidiary Body on Scientific, Technical and Technological Advice, Sep`95, Advance copy.

UNEP-CS: Anon, Guidelines for the Preparation of Country Studies on costs, benefits and unmet needs of Biological Diversity conservation within the framework of the planned Convention on Biological Diversity, 1991, UNEP.

Ter LAC : Dinerstein E., Olson, D.M., et.al. A conservation assessment of the Terrestrial Eco-regions of Latin America and the Caribbean 1995, World Bank.

Stanf: Sisk, et.al- "identifying Extinction Threats", Bioscience 44 (9).

Mckn(2) : Mackinnon, J. - A Method for Evaluating and classifying Habitat Importance for Biodiversity conservation- Paper for discussion at WCMC/MCI meeting on Identification of Habitat criteria, Oct `94, Cambridge, England.

U.Kan: Ranjit Daniels, Chandran & Gadgil - A strategy for conserving the Biodiversity of Uttara Kannada , A district in south India.

GIS: Bawa, K., National Resource Monitoring using Geographic Information Processing Software (GIPS) workshops in India- Proposal to World Bank Small Grants Program. 1995, TERI/UMass.

Mt PAs: Poore, D. - Guidelines for Mountain Protected Areas, 1992, IUCN.

BSI: Nagar M P, In-situ conservation of Wild Flora Resources,1987,BSI

Indic: Reid et al, Biodiversity Indicators for Policy Makers, 1993, WRI/IUCN

CNA: Alcorn J. (ed), Papua New Guinea -Conservation Needs Assessment., 1993, BSP/Govt. of Papua New Guinea

Mary: Proceedings of Methods Workshop I on Geographic Priorities Project for Biodiversity conservation in the Asia and Pacific Region, April 1995, Mary land.

Wn Ghat: Ghate, Basis for conservation of western Ghats in Maharashtra, 1993.

Mck PAR: Mackinnon & Mackinnon - A Review of the Protected Area System in the Indo-Malayan Realm, 1986, IUCN/ Cambridge.

GBA: Anon, Global Biodiversity Assessment, 1995, Cambridge.

ODA : Flint, M., Paper in Biological Diversity and Developing Nations : Issues and options, 1991, ODA.

R & P: Rodgers W.A. & Panwar H.S., Planning a Wildlife Protected Area Network in India, Report for Department of Environment, Forests and Wildlife, 1988, WII, Dehradun.

2. BUDGETING AND PRIORITISING FOR ECOSYSTEM FUNCTIONS OF FORESTS

2.1 Introduction

When budgeting for forests, initially we need to determine the forest area required for various ecosystem purposes. Then, in order to optimise the sites and locations, we need to prioritise from among the various forested sites. Given below, first, is an assessment of the forest area required in the YSC for performing basic ecosystem functions. This is followed by the description of a methodology to prioritise from among forest areas.

2.2 Forest Area Requirement

Though it is possible to determine the area required separately for various ecosystem functions, like watershed and catchment functions, soil binding functions or functions related to he atmosphere and climate, a comprehensive measure can be adopted by using the norms prescribed in the National Forest Policy.

The National Forest Policy stipulates that the forest cover in the country should be a minimum of 33%, with 20% cover in the plains and 60% cover in the hills. The actual and required area in the Yamuna Sub-Catchment (YSC) is as follows.

FOREST COVER IN THE PLAINS AREA OF THE YSC in sq. km

1 State	2 Total area of ysc	3 Total forest area required 20% of 2	4 Existing forest area	5 4 as % of 2	6 Shortfall 3-4	7 6 as % of 2
Haryana	40071	8015	1030	2.57	6985	17.43
Uttar Pradesh	38709	7742	1931	4.47	5811	15.53
Rajasthan	92199	18440	2308	2.56	16132	17.44
Total	170979	34196	5269	3.01	28927	16.99

FOREST COVER IN THE HILL AREAS OF THE YSC in sq. km

1 State	2 Total area of ysc	3 Total forest area required 60% of 2	4 Existing forest area	5 4 as % of 2	6 Shortfall 3-4	7 6 as % of 2
Haryana	1756	1054	23	12.99	1031	47.01
Uttar Pradesh	19946	11968	13276	66.56	Excess of 1308	6.56
Himachal Pradesh	9892	5935	1304	13.18	4630	46.82
Total	31594	18957	14603	46.22	4353	13.88

2.3 Prioritising From Among Forest Areas

1. The task is to prioritise, for conservation action, forest sites based on their biodiversity and socio-economic value, separately for each of the biogeographic zones in the country.
2. Biodiversity value could ideally be ascribed as follows:
    a. The site (in each biogeographic zone) with the greatest number of species would have the top priority.
    b. The site, which adds the largest number of species to the top priority site, would be the next priority, and so on.
    c. After priorities had been given on this basis, the list of prioritised sties would be checked to ensure that other relevant biodiversity values are also appropriately reflected in the list of priority sites. These values would include:
        i. Representativeness
        ii. Uniqueness
        iii. Naturalness
        iv. Link with other valuable areas
        v. Potentially valuable but unstudied areas
3. The resultant list would be reordered taking into consideration 'socio-economic' and 'ease of conservation' values.
4. However, in order to meaningfully ascribe the relevant values what is required is:
    a. A list of species, both fauna and flora (ideally even microorganisms), for all the various forest 'sites'.
    b. An assessment of the socio-economic uses and various pressures on each of these forest areas.
5. A major constraint in ascribing biodiversity value is the non-availability of a comprehensive listing of fauna and flora species for forests across the country[i].
7. The required listing of species needs not only to be comprehensive but the data base used should be comparable across the country, as prioritisation between sites would depend on the number of species found in each site. Consequently, lists of species prepared for different sites using different methodologies are likely to result in significantly different levels of authenticity and comprehensiveness, and can not be used for the purpose. In fact, only

three databases seem to exist in the country, which could be considered for the prioritisation exercise. These are :

a. Lists of fauna and flora in forest working plans for a large proportion of the forest divisions in India.

b. Lists of fauna and flora, compiled by the Zoological Survey of India (ZSI) and Botanical Survey of India (BSI) respectively for many of the districts in India.

c. The inventories done by the Forest Survey of India (FSI).

8. The limitations of these databases are:

a. **Forest Working Plans:** They rarely have a comprehensive listing of flora as usually the lists focus on trees and other larger plants or species of economic importance. Even with fauna, the lists rarely go beyond large mammals and some species of birds.

Though the rest of the working plan is written according to strict guidelines and can therefore be considered comparable across the country, this is not true for flora and fauna lists in the working plan. Often the comprehensiveness and authenticity of the lists depend on the personal interest, expertise and competence of the officer writing the plan, and these tend to vary significantly across the country.

Also, the fauna and flora lists in working plans are often not updated comprehensively when new plans are prepared. This problem becomes even more critical when old forest divisions are broken into smaller ones, or reorganised into new divisions. Often the list of the original division gets repeated in the working plans of all these new divisions.

Also, listings in working plans are usually for whole divisions and it is not easy to segregate the lists at a smaller scale of a circle or a reserved forest.

b. **The ZSI and BZI Lists:** Though they perhaps have greater comparability across the country, the lists are only disaggregated to a district level. Also, as they are based on collections from specific sites and not based on surveys, the status of the species and its distribution in the district is often difficult to deduce.

c. **Inventories of the FSI:** Though with greater comparability, these have not yet been computerised and are also not ready for the whole country.

9. The time and resources available do not usually permit a fresh listing of species and, as such, existing data, with all its shortcomings, has to be used.

Alternate methodology for data deficient conditions

10. Keeping these factors in mind, a modified strategy for prioritising forest sites has been developed. Its salient features are given below:

    a. **Step 1:** The optimal crown cover density for different forest types and sub types, as specified by Champion and Seth (revised classification), would be determined, using existing 1:250,000 remote sensing forest cover maps.

    b. **Step 2:** Crown cover density maps would be prepared separately for each state indicating only those areas which have optimal crown cover for each of the forest types. These maps will mark out the different forest types and sub types and the different biogeographic zones.

    c. **Step 3:** Based on these maps, those forest divisions will be demarcated which have forest areas of optimal crown cover density.

    d. **Step 4:** The maps of these divisions, showing the patches of forests with optimal density, will be sent to the local forest officer (Divisional Forest Officer), for identifying those that are actually undisturbed.

    e. **Step 5**: Based on the responses from these officers, a preliminary marking of the priority areas would be made.

    f. **Step 6:** These will then be discussed with experts in, and for, each state, including with knowledgeable NGOs, to demarcate those areas which are actually undisturbed or minimally disturbed, and have high biodiversity value.

    d. **Step 7:** Detailed list of fauna and flora species will then be compiled for the demarcated areas, using various sources including forest working plans, FSI inventories, listings of the Botanical and Zoological Surveys of India.

    e. **Step 8:** Based on the compiled lists, preliminary priorities will be allocated to the sites, using the method outlined in 2a and b above.

f. **Step 9:** This preliminary prioritisation would then be checked against the list of other values, as indicated in 2c above, and revised, as required.

g. **Step 10:** The revised prioritisation would then be analysed in terms of socio-economic and ease of conservation aspects and a further revised list developed. Data on these aspects are being collected separately.

h. **Step 11:** This list will then be discussed at state levels and with selected local communities, and again revised, if required, to accommodate the views expressed in such discussions.

i. **Step 12:** The list that emerges from this process will then be discussed at a national seminar and finalised.

11. The size of the `site' identified for prioritisation would be determined by its ecological boundaries. On the one hand, as far as possible, the site must be of a viable size for conservation. On the other hand, it must not be so large that it is unmanageable as a single unit.

12. The chosen site must be clearly demarcated and its location identified within an administrative unit like a protected or reserved forest, or a forest beat, range or division. Where it is on non-forest land, the district and *taluk* must be identified.

13. The final priorities would be listed nationally, state wise, biogeographic zone wise, and by forest types. The priority sites will be illustrated through maps separately for each type of listing.

3. BUDGETING AND PRIORITISING FOR BIODIVERSITY CONSERVATION AREAS*

3.1 Introduction

If one assesses the requirement of forest area from the perspective of biodiversity conservation, the picture that emerges is described below. One of the approaches to biodiversity conservation is that of conserving flagship species. It is assumed that the effort to conserve a flagship species, which normally happens to be at the apex of the food chain, would also result in the conservation of the habitat of the species along with all other species that are a part of the ecosystem.

3.2 Assessing Minimum Viable Areas

One of the concepts used in managing a flagship species is that of a Minimum Viable Population (MVP). For the plains part of the Yamuna Sub-Catchment, the Tiger can be considered the apex species. Conservation biologists have estimated that for populations of large carnivores, like the Tiger or Leopard, to have a reasonably certain (around 95% or more) chance of survival, without there being progressive inbreeding, there must always be atleast 50 breeding pairs in each population. This would mean that each population must always have a 100 or more individuals. Newmark (1986) talks of median population as 108 (range 70-146) for large carnivores. However, Leyhausen (1986) says with specific reference to Tigers that the MVP is 300. This might be too high for mere survival but too low for genetic variability. For maintaining genetic variability in the long run, each population must have atleast 500 breeding pairs or 1000 or more individuals. In order to ensure that the species does not get wiped out by epidemics or other natural calamities, there would be a need for multiple populations.

Studies on the Tiger carried out in India and Nepal have concluded that each individual may need to have a territory that ranges between 10 sq. km. (Karanth (1997)) to 100 sq. km (estimated during studies carried out at the Royal Chitwan National Park). For example, a study conducted by Karanth (1997) in Nagarahole, Pench, Kanha and Kaziranga concluded that in sites having high prey densities, populations of Tigers could reach densities of 10-15 Tigers/100 sq. km. Another study conducted by Chundavat *et al* (1997) concluded that in sub-optimal habitats like the ones that exist in the semi arid areas of the plains of the Yamuna River Sub Basin, densities of Tiger could be around 15 individuals/ 300 sq. km. Another study

* This section has been contributed by Mr Raman Mehta of Kalpavriksh

conducted by Franklin *et al* (1997) in Sumatra concluded that 100 sq. km. of habitat can support around 4 Tigers. Therefore, if one takes a mean, each individual would need about 60 sq. km. to survive in the wild. This would imply that each protected area (PA) or cluster of connected PAs, which are in the natural range of the Tiger would have to be a minimum of 6,000 sq. km. and have a population of at least 100 individuals for the Tiger to survive. Presently, no such PA or cluster of PAs exists in the Yamuna River Sub Basin. The largest population of Tigers in the Yamuna River Sub Basin is found in Sariska Tiger Reserve. However, even here the population is estimated to be less than 100 individuals and is mainly confined to an area of around 300 sq. km.

To maintain genetic variability, the minimum population required is 1000 individuals. Given that the area required per Tiger is 60 sq. km. one would need a PA or a cluster of connected PAs of at least 60,000 sq. km. with a population of at least 1000 individuals. However, it is not essential that such a population be contained within the Yamuna sub-region, but could extend beyond it while covering a part of it.

The Tiger range does not extend to the hilly areas of the Yamuna River Sub Basin where the Leopard can be considered the apex species. Since it is a smaller animal than the Tiger, the Leopard can be assumed to survive in the wild on an average area that is half that of the Tiger (though no empirical study to confirm this was found). Each MVP of the Leopard would, therefore, need an area of atleast 3,000 sq. km. to survive and 30,000 sq. km. to maintain genetic variability. Again, at present, there is no PA or cluster of PAs in the hilly areas of the Yamuna sub-basin with such a huge size. The tables below list the various PAs in the Yamuna River Sub Basin where Tigers and Leopards could or are known to occur and also gives the deficit or additional area needed to achieve conservation objectives in the short as well as long run.

Tiger Range Protected Areas (excluding pure wetlands) in the

Yamuna River Sub Basin

Sno.	Name	Area of the PA (sq km)	Additional area needed for survival of the Tigers in the short run (sq km)	Additional area needed for survival of the Tigers in the long run (sq km)
1.	BIR BARABAN JIND SANCTUARY, HARYANA	4.19	5995.81	59995.81
2.	BIR SHIKARGARH SANCTUARY, HARYANA	7.60	5992.40	59992.40
3.	CHILCHHILA SANCTUARY, HARYANA	0.28	5999.72	59999.72
4.	KALESAR SANCTUARY, HARYANA	46.28	5953.72	59953.72
5.	KHAPARWAS SANCTUARY, HARYANA	0.81	5999.19	59999.19
6.	NAHAR SANCTUARY, HARYANA	2.09	5997.91	59997.91
7.	SARASWATI SANCTUARY, HARYANA	49.98	5950.02	59950.02
9.	RENUKA SANCTUARY, HP	4.00	5996.00	59996.00
10.	SIMBALBARA SANCTUARY, HP	19.03	5980.97	59980.97
11.	KEOLADEO GHANA NATIONAL PARK, RAJASTHAN	28.73	5971.27	59971.27
12.	SARISKA TIGER RESERVE, RAJASTHAN	587.80	5412.20	59412.20
13.	BANDHA BARATHA SANCTUARY, RAJASTHAN	192.76	5807.24	59807.24
14.	JAMWA RAMGARH SANCTUARY, RAJASTHAN	300.00	5700.00	59700.00
15.	KELADEVI SANCTUARY, RAJASTHAN	676.38	5323.62	59323.62
16.	VAN VIHAR SANCTAURY, RAJASTHAN	59.93	5940.07	59940.07
17.	HASTINAPUR SANCTUARY, UP	2073.00	3927.00	57927.00
	Totals	4052.86	91947.14	955947.14

Leopard Range Protected Areas (excluding pure wetlands and Tiger Range PAs) in the Yamuna River Sub Basin

Sno.	Name	Area of the PA (sq km)	Additional area needed for survival of the Leopards in the short run (sq km)	Additional area needed for survival of the Leopards in the long run (sq km)
1.	CHURDHAR SANCTUARY, HP	56.15	2943.85	29943.85
2.	TALRA SANCTUARY, HP	40.49	2959.51	29959.51
3.	GOVIND PASHUVIHAR NATIONAL PARK AND SANCTUARY, UP	953.12	2046.88	29046.88
	Totals	1049.76	7950.24	88950.24

A look at the tables given above makes it clear that no single PA in the Yamuna River Sub Basin is at present capable of supporting a MVP for either the Tiger or the Leopard. Also, the total area needed to make each and every PA listed above a viable habitat for either the Tiger or the Leopard would exceed perhaps even the area of the Yamuna River Sub Basin. Therefore it is clearly impractical to suggest that each and every one of the PAs listed above should support MVPs of either the Tiger or the Leopard. What needs to be done is to start looking at existing populations within and around PAs, and start making efforts to connect them through forest corridors which would ensure cross breeding in order to avoid problems like inbreeding. For example, for Leopards, the cluster of PAs including Govind Pashuvihar, Talra, Churdhar, Renuka and Simbalbara, if connected through forest corridors, might prove to be adequate, with some enlargement, for supporting a viable population. Similarly, the cluster of PAs in Rajasthan which includes Sariska and Keladevi with existing Tiger populations, could also be connected through forest corridors to provide a habitat for a viable population of Tigers. It may be noted here that a habitat that can support a MVP of Tigers would also allow Leopards to survive.

Protected Areas located in the Yamuna River Sub Basin

3.3 Preliminary Prioritisation of National Parks and Sanctuaries

This section outlines a methodology for prioritising national parks and sanctuaries. It is recognised at the outset that national parks and sanctuaries are in themselves a priority because these protected areas (PAs) are among the last repositories of India's wild biodiversity. Much of India's vast faunal and floral wealth is now contained only within PAs which offer, arguably, the only viable strategy for *in-situ* conservation of most wild species. As such, we would like to assume that the biodiversity occurring in all PAs needs to be conserved with the same degree of efficacy and urgency. However, this may not be possible for the following reasons:-

1. The resources available for conservation are scarce, and can not be used to protect the entire PA network of the country with the same level of effectiveness and efficiency.
2. There are certain PAs which harbour species or communities which are rare or threatened. It is necessary to identify these and take steps for their conservation before taking up other sites for conservation. While efforts have been made by the government to do this through initiatives like the Project Tiger, there are many more sites which need to be prioritised, and action taken for their immediate conservation.
3. There are also certain PAs which face a high level of threats or pressures. These PAs, especially the ones which harbour rare or threatened species or communities, need to be identified so that the necessary steps can be taken for their conservation.

It is for all these reasons that a prioritisation exercise for PAs is needed. An added benefit of carrying out a prioritisation exercise is that it helps in making an assessment of the information needed for prioritisation. This in turn is helpful in making an assessment of the gaps which exist in information about PAs. Once these gaps are identified, action can be taken to collect information to try and fill them, so that the correct priorities for conservation can be identified.

Methodology

The PAs can be prioritised on the basis of their:-

1. **Biological Value**: This can be ascertained through identifying the diversity of forest types and subtypes occurring in the PA and looking at whether any of them are rare or threatened, the species occurring in the PA and whether any of them are endemic, rare, or threatened, the

size of the PA, its proximity or connectivity to other PAs, whether the PA is located in a biogeographic province which does not have an adequate area under protection or whether it is located in a biogeographic province where the total number of PAs is inadequate etc. The details are given in Annexure A.

2. **Pressures or threats** on the PA due to consumptive human use by local and other people and/or institutions. A large number of different types of pressures or threats are being evaluated. These are detailed in Annexure A.

3. **Management and legal status** of the PA. The details are given in Annexure A.

A detailed explanation of the above is being given in the proposed valuation framework attached at annexure A. The values mentioned above can be further subdivided in order to categorise PAs. These categories are:-

1. In terms of the value of a PA, each area can be subclassified as:-
   a. Either a Very High Value PA, or
   b. A High Value PA.
2. In terms of pressures or threats on the PA, each area can be subclassified as:-
   a. Either a High Pressure PA, or
   b. A Low Pressure PA.
3. In terms of the legal and management status of a PA, each area can be subclassified as:-
   a. Either a Low Legal and Management Status PA, or
   b. A High Legal and Management Status PA.

On the basis of the categories outlined above, PAs should be classified within each biogeographic province. It would be reasonable to assume that the PAs that are of very high value would be the priority areas for conservation. However, those among the very high value PAs that also have a high level of pressures being exerted on them would have a greater priority to those with lower levels of pressure. Further, if a very high value and high pressure PA also has a low legal and management status, efforts for its conservation would have to be taken up before the others. This is because the same level of pressures or threats being exerted on a certain PA would have a greater impact on it if the management and legal status was low and a lesser impact if the management and legal status was high.

Therefore, the highest priority would be those PAs that have a very high value, are threatened due to a high level of pressures, and where the legal and management status is low. Conversely, the lowest priority would be given to high value PAs with low levels of pressure and a high legal and management status. With this in mind, the following is being assumed to be the order of priority of PAs:-

1. Very High Biodiversity + High Pressure + Low Legal and Management Status
2. Very High Biodiversity + High Pressure + High Legal and Management Status
3. Very High Biodiversity + Low Pressure + Low Legal and Management Status
4. Very High Biodiversity + Low Pressure + High Legal and Management Status
5. High Biodiversity + High Pressure + Low Legal and Management Status
6. High Biodiversity + High Pressure + High Legal and Management Status
7. High Biodiversity + Low Pressure + Low Legal and Management Status
8. High Biodiversity + Low Pressure + High Legal and Management Status

A consolidated list of Very High Value and High Value PAs respectively, is being given below. The PAs in this list have been further classified according to whether they are high or low pressure PAs, and sub-classified according to whether they have a low or high legal and management status. The list is sorted within each category as per the biogeographic province. Please note that the PAs that figure in the list given below are the ones for which data was available for applying the valuation framework which is detailed at Annexure – A. The detailed tables of values ascribed to each PA are given at Annexures B, C and D.

CATEGORY OF THE PA	Sno.	BIOGEOGRAPHIC PROVINCE	AREA (sq. km.)	NAME
Very High Value+High pressure+Low management and legal status	1	4B	676.38	KELA DEVI SANCTUARY, RAJASTHAN
Very High Value+High pressure+High management and legal status	2	2B	481.04	GOVIND PASHUVIHAR SANCTUARY, UTTAR PRADESH
	3	4B	635.00	NATIONAL CHAMBAL SANCTUARY, UTTAR PRADESH

CATEGORY OF THE PA	Sno.	BIOGEOGRAPHIC PROVINCE	AREA (sq. km.)	NAME
	4	4B	587.80	SARISKA NATIONAL PARK (Including Sariska Sanctuary), RAJASTHAN
Very High Value+Low pressure+High management and legal status	5	4A	28.73	KEOLADEO GHANA NATIONAL PARK, RAJASTHAN
	6	4A	4.06	BHINDAWAS SANCTUARY, HARYANA
	7	4A	1.43	SULTANPUR NATIONAL PARK, HARYANA
High Value+High pressure+Low management and legal status	8	2B	40.49	TALRA SANCTUARY, HIMACHAL PRADESH
High Value+High pressure+High management and legal status	9	4A	4.00	RENUKA SANCTUARY, HIMACHAL PRADESH
High Value+Low pressure+low management and legal status	10	4B	300.00	JAMVA-RAMGARH SANCTUARY, RAJASTHAN
High Value+Low pressure+High management and legal status	11	4A	19.03	SIMBALBARA SANCTUARY, HIMACHAL PRADESH
	12	4B	59.93	VAN VIHAR SANCTUARY, RAJASTHAN

Limitations of the data: Information for many of the valuation parameters identified in the valuation framework is not yet available.

ANNEXURE - A
PROPOSED FRAMEWORK FOR VALUATION OF PAs

The following is proposed for biodiversity and other positive values:

1. Biodiversity Values:
   a) Occurrence of forest types:
      i) Occurrence of a forest sub type = 2 marks for each forest sub type [source: Questionnaire 1A]
      ii) Occurrence of more than one forest type = 5 marks
      iii) Occurrence of a rare forest type/sub type = 5 marks [source: Rodgers and Panwar]
   b) Occurrence of an under represented biome apart from a forest type e.g. deserts, wetlands etc. = 5 marks [source: Rodgers and Panwar & Forest Survey of India]
   c) Occurrence of a species of flora or fauna listed in schedule – I of the Wildlife (Protection) Act, 1972, in a PA which does not occur in any other PA = 10 marks [source: Questionnaire 1A, WII Database & Rodgers and Panwar]
   d) Occurrence of a species of flora or fauna listed in schedule – I of the Wildlife (Protection) Act, 1972, which is found in more than 1 PAs and less than or equal to 5 PAs = 8 marks [source: Questionnaire 1A, WII Database & Rodgers and Panwar]
   e) Occurrence of a species of flora or fauna listed in schedule – I of the Wildlife (Protection) Act, 1972, which is found in more than 5 PAs and less than or equal to 10 PAs = 5 marks [source: Questionnaire 1A, WII Database & Rodgers and Panwar]
   f) Occurrence of a species of flora or fauna listed in schedule – I of the Wildlife (Protection) Act, 1972, which is found in more than 10 PAs and less than or equal to 15 PAs = 3 marks [source: Questionnaire 1A, WII Database & Rodgers and Panwar]
   g) Occurrence of a species of flora or fauna listed in schedule - I of the Wildlife (Protection) Act, 1972, which do not fall in categories c), d), e) and f) above = 1 mark per species [source: Questionnaire 1A, WII Database]
   h) Value for the size of the PA = Area of the PA(sq. km.)/100 upto a maximum of 10 marks
   i) PA adjoining other PAs or linked through corridors to other PAs = Area of the PA/PAs(sq. km.)/100 upto a maximum of 10 marks [Source: Rodgers and Panwar, IIPA Database]
   j) PA situated within a biogeographic province where total area covered by PAs is less than or equal to 1% = 10 marks [Rodgers and Panwar, List of PAs (MoEF)]
   k) PA situated within a biogeographic province where total area covered by PAs is greater than 1% and less than or equal to 2% = 7 marks [Rodgers and Panwar, List of PAs (MoEF)]
   l) PA situated within a biogeographic province where total area covered by PAs is greater than 2% and less than or equal to 4% = 4 marks [Rodgers and Panwar, List of PAs (MoEF)]
   m) PA situated within a biogeographic province where total number of PAs is less than or equal to 5 = 10 marks [Rodgers and Panwar, List of PAs (MoEF)]

n) PA situated within a biogeographic province where total number of PAs is greater than 5 and less than or equal to 10 = 7 marks [Rodgers and Panwar, List of PAs (MoEF)]

o) PA situated within a biogeographic province where total number of PAs is greater than 10 and less than or equal to 15 = 4 marks [Rodgers and Panwar, List of PAs (MoEF)]

The following is proposed for looking at Legal Status and Management Values:

1. Legal Status:

   A. Intended Sanctuary (if notified after the 1991 amendment of the Wildlife (Protection) Act, 1972) = 0.5 marks [source: Questionnaire 1A]
   B. Intended Sanctuary having a legal status of a Reserve Forest = 1 mark [source: Questionnaire 1A]
   C. Intended Sanctuary having no rights within = 1.5 marks [source: Questionnaire 1A]
   D. Intended National Park = 2 marks [source: Questionnaire 1A]
   E. Intended National Park having a legal status of a Reserve Forest = 2.5 marks [source: Questionnaire 1A]
   F. Intended National Park having no rights within = 3 marks [source: Questionnaire 1A]
   G. Sanctuary notified before the 1991 amendment of the Wildlife (Protection) Act, 1972, but not fully set up = 3.5 marks [source: Questionnaire 1A]
   H. Sanctuary not fully set up but having a legal status of a Reserve Forest = 4 marks [source: Questionnaire 1A]
   I. Sanctuary not fully set up but having no rights within = 4.5 marks [source: Questionnaire 1A]
   J. Sanctuary fully set up = 5 marks [source: Questionnaire 1A]
   K. Sanctuary fully set up and an Intended National Park = 5.5 marks [source: Questionnaire 1A]
   L. Sanctuary fully set up and an Intended National Park as well as having a legal status of a Reserve Forest = 6 marks [source: Questionnaire 1A]
   M. Sanctuary fully set up and an Intended National Park having no rights within = 6.5 marks [source: Questionnaire 1A]
   N. Fully notified National Park = 7 marks [source: Questionnaire 1A]

2. Management Parameters:

   A. PAs which have a management plan = 1 mark [source: IIPA database, Questionnaire 1A & WII database]
   B. PAs which have a separate budget = 1 mark [source: IIPA database, Questionnaire 1A & WII database]
   C. PAs which have zoning = 1 mark [source: IIPA database, Questionnaire 1A & WII database]

The following is proposed for valuation of pressures or negative values:

1. Biotic Pressures [Source: IIPA database and Questionnaire 1A]: Please note that an absence of any of the pressures will result in the PA getting no marks for those pressures which do not exist. In the case of a PA having no pressures at all, its negative value will be equal to zero.

   a) Dam for an irrigation or hydel power project:

- i) Area of the reservoir less than or equal to 5% of the PA = 1 mark
- ii) Area of the reservoir more than 5% or equal to 10% of the PA = 2 marks
- iii) Area of the reservoir more than 10% of the PA = 3 marks

b) Tourism:
- i) Area occupied by the tourism project less than or equal to 5% of the PA = 1 mark
- ii) Area occupied by the tourism project more than 5% and equal to 10% of the PA = 2 marks
- iii) Area occupied by the tourism project more than 10% of the PA = 3 marks
- iv) Density of tourists visiting the PA annually below or equal to the 33 percentile class density of tourists visiting all other PAs annually = 1 mark
- v) Density tourists visiting the PA annually more than 33 or equal to 66 percentile class density of tourists visiting all other PAs annually = 2 marks
- vi) Density of tourists visiting the PA annually more than 66 percentile class density of tourists visiting all other PAs annually = 3 marks

c) Mining/Quarrying
- i) Area occupied by the mining/quarrying project less than or equal to 5% of the PA = 1 mark
- ii) Area occupied by the mining/quarrying project more than 5% and equal to 10% of the PA = 2 marks
- iii) Area occupied by the mining/quarrying project more than 10% of the PA = 3 marks

d) Plantations:
- i) Area of the PA used for plantations less than or equal to 5% of the PA = 1 mark
- ii) Area of the PA used for plantations more than 5% and equal to 10% of the PA = 2 marks
- iii) Area of the PA used for plantations more than 10% of the PA = 3 marks

e) Electrical cables/transmission lines:
- i) Electrical cables transmission lines within the PA = 2 marks

f) PWD Roads/Highways:
- i) PWD Roads/Highways within the PA = 2 marks

g) Habitation:
- i) Area of habitation less than or equal to 5% of the PA = 1 mark
- ii) Area of habitation more than 5% or equal to 10% of the PA = 2 marks
- iii) Area of habitation greater than 10% of the PA = 3 marks
- iv) Density of population less than or equal to 33% of the density of population of the district(s) in which the PA is located = 1 mark
- v) Density of population more than 33% and less than or equal to 66% of the density of population of the district(s) in which the PA is located = 2 marks
- vi) Density of population more than 66% of the density of population of the district(s) in which the PA is located = 3 marks

h) Cultivation:

i) Area of cultivation less than or equal to 5% of the PA = 1 mark
ii) Area of cultivation more than 5% or equal to 10% of the PA = 2 marks
iii) Area of cultivation greater than 10% of the PA = 3 marks

i) Pilgrimage:
  i) Area of pilgrimage spot(s) less than or equal to 5% of the PA = 1 mark
  ii) Area of pilgrimage spot(s) more than 5% or equal to 10% of the PA = 2 marks
  iii) Area of pilgrimage spot(s) greater than 10% of the PA = 3 marks
  iv) Density of pilgrims visiting the PA annually less than or equal to the 33 percentile class of pilgrims visiting all other PAs annually = 1 mark
  v) Density of pilgrims visiting the PA annually more than 33 percentile or equal to 66 percentile class of pilgrims visiting all other PAs annually = 2 marks
  vi) Density of pilgrims visiting the PA annually more than 66 percentile class of pilgrims visiting all other PAs annually = 3 marks

j) Fishing:
  i) Area impacted by fishing less than or equal to 5% of the PA = 1 mark
  ii) Area impacted by fishing more than 5% or equal to 10% of the PA = 2 marks
  iii) Area impacted by fishing greater than 10% of the PA = 3 marks
  iv) Quantum of extraction per sq. km. of fish less than or equal to the 33 percentile class of the per sq. km. extraction of fish from PAs = 1 mark
  v) Quantum of extraction per sq. km. of fish more than 33 or equal to 66 percentile class of the per sq. km. extraction of fish from PAs = 2 marks
  vi) Quantum of extraction per sq. km. of fish more than 66 percentile class of the per sq. km. extraction of fish from PAs = 3 marks

k) Timber Extraction:
  i) Area impacted by timber extraction less than or equal to 5% of the PA = 1 mark
  ii) Area impacted by timber extraction more than 5% or equal to 10% of the PA = 2 marks
  iii) Area impacted by timber extraction greater than 10% of the PA = 3 marks
  iv) Quantum of extraction per sq. km. of timber less than or equal to 33 percentile class of the per sq. km. extraction of timber from PAs = 1 mark
  v) Quantum of extraction per sq. km. of timber more than 33 percentile or equal to 66 percentile class of the per sq. km. extraction of timber from PAs = 2 marks
  vi) Quantum of extraction per sq. km. of timber more than 66 percentile class of the per sq. km. extraction of timber from PAs = 3 marks

l) Fuelwood Extraction:
   i) Area impacted by fuelwood extraction less than or equal to 5% of the PA = 1 mark
   ii) Area impacted by fuelwood extraction more than 5% or equal to 10% of the PA = 2 marks
   iii) Area impacted by fuelwood extraction greater than 10% of the PA = 3 marks
   iv) Quantum of extraction per sq. km. of fuelwood less than or equal to 33 percentile class of the per sq. km. extraction of fuelwood from PAs = 1 mark
   v) Quantum of extraction per sq. km. of fuelwood more than 33 percentile or equal to 66 percentile class of the per sq. km. extraction of fuelwood from PAs = 2 marks
   vi) Quantum of extraction per sq. km. of fuelwood more than 66 percentile class of the per sq. km. extraction of fuelwood from PAs = 3 marks

m) NWFP Extraction:
   i) Area impacted by NWFP extraction less than or equal to 5% of the PA = 1 mark
   ii) Area impacted by NWFP extraction more than 5% or equal to 10% of the PA = 2 marks
   iii) Area impacted by NWFP extraction greater than 10% of the PA = 3 marks
   iv) Quantum of extraction per sq. km. of NWFP less than or equal to 33 percentile class of the per sq. km. extraction of NWFP from PAs = 1 mark
   v) Quantum of extraction per sq. km. of NWFP more than 33 percentile or equal to 66 percentile class of the per sq. km. extraction of NWFP from PAs = 2 marks
   vi) Quantum of extraction per sq. km. of NWFP more than 66 percentile class of the per sq. km. extraction of NWFP from PAs = 3 marks

n) Fodder Extraction:
   i) Area impacted by fodder extraction less than or equal to 5% of the PA = 1 mark
   ii) Area impacted by fodder extraction more than 5% or equal to 10% of the PA = 2 marks
   iii) Area impacted by fodder extraction greater than 10% of the PA = 3 marks
   iv) Quantum of extraction per sq. km. of fodder less than or equal to 33 percentile class of the per sq. km. extraction of fodder from PAs = 1 mark
   v) Quantum of extraction per sq. km. of fodder more than 33 percentile or equal to 66 percentile class of the per sq. km. extraction of fodder from PAs = 2 marks
   vi) Quantum of extraction of fodder more than 66 percentile class of the per sq. km. extraction of fodder from PAs = 3 marks

o) Grazing:
   i) Area impacted by grazing less than or equal to 5% of the PA = 1 mark
   ii) Area impacted by grazing more than 5% or equal to 10% of the PA = 2 marks

iii) Area impacted by grazing greater than 10% of the PA = 3 marks
iv) Density of cattle units grazing in the PA less than the density of cattle units in the district in which the PA is located = 1 mark
v) Density of cattle units grazing in the PA equal to the density of cattle units in the district in which the PA is located = 2 marks
vi) Density of cattle units grazing in the PA less more than the density of cattle units in the district in which the PA is located = 3 marks

p) Forest Fires:
   i) Area impacted by forest fires less than or equal to 5% of the PA = 1 mark
   ii) Area impacted by forest fires more than 5% or equal to 10% of the PA = 2 marks
   iii) Area impacted by forest fires greater than 10% of the PA = 3 marks

q) Weed infestation:
   i) Area impacted by weed infestation less than or equal to 5% of the PA = 1 mark
   ii) Area impacted by weed infestation more than 5% or equal to 10% of the PA = 2 marks
   iii) Area impacted by weed infestation greater than 10% of the PA = 3 marks

2. Poaching:

a) Existence of Poaching of animals = 2 marks
b) Existence of illegal cutting of trees = 2 marks
c) Poaching or illegal cutting of trees being done by organised gangs of poachers = 3 marks

ANNEXURE - B
BIOLOGICAL VALUES OF PAs

CODE	BIOGEOGRAPHIC PROVINCE	NAME	AREHE PA (es)	VALUE ON THE BASIS OF OCCURR-ENCE OF FOREST TYPES/SUB TYPES [Source: IIPA Database]	VALUE ON THE BASIS OF HARBOUR-ING A RARELY OCCURRING FOREST TYPE/SUB TYPE [Source: Rodgers and Panwar]	VALUE ON THE BASIS OF OCCURRENCE OF MAMMALIAN SPECIES LISTED IN SCHEDULE - I OF THE WILDLIFE (PROTECTION) ACT, 1972 [FOR DETAILS, PLEASE REFER TO ANNEXURE - G]	VALUE ACCORDING TO SIZE (Maximum upto 10) [Source: List of PAs by MoEF]	VALUE ON THE BASIS OF EXISTENCE OF FOREST CORRIDORS OR LOCATION OF THE PA ADJOINING OTHER PAs [Source: Rodgers and Panwar]	LOCATION OF PA WITHIN A BIO-GEOGRAPHIC PROVINCE WHERE AREA COVERAGE OF PAs IS INADEQUATE [For details, please see Annexure I]	LOCATION OF THE PA WITHIN A BIO-GEOGRAPHIC PROVINCE WHERE THE TOTAL NUMBER OF PAs IS INADEQUATE [For details, please see annexure I]	VALUE ON THE BASIS OF HARBOUR-ING AN UNDER REPRE-SENTED ECOSYSTEM eg. WETLANDS, DESERTS, GRASS-LANDS [Source: IIPA database, Rodgers and Panwar]	OVERALL VALUE OF THE PA
HAR/N/SUL	4A	SULTANPUR NATIONAL PARK	37	2			0.01		10		5	17.01
HAR/S/BHI	4A	BHINDAWAS SANCTUARY	00	2			0.04		10		5	17.04
HP/S/REN	4A	RENUKA SANCTUARY	53	2		1	0.04		10		5	18.04
HP/S/SIM	4A	SIMBALBARA SANCTUARY	56	2		3	0.19		10			15.19
HP/S/TAL	2B	TALRA SANCTUARY	00	13		2	0.26					15.26
RAJ/N/KEO	4A	KEOLADEO GHANA NATIONAL PARK	00	6		8	0.29		10		5	29.29
RAJ/N/SAR	4B	SARISKA NATIONAL PARK (Including Sariska Sanctuary)	00	4		15	7.66		4			30.66
RAJ/S/JAM	4B	JAMVA-RAMGARH SANCTUARY	00	2			3.00		4			9.00
RAJ/S/KAI	4B	KAILA DEVI SANCTUARY	00	2		12	6.76	7.37	4			32.13
RAJ/S/VAN	4B	VAN VIHAR SANCTUARY	00	6			0.60		4			10.60
UP/S/GOV	2B	GOVIND PASHUVIHAR SANCTUARY	00			9	9.53					18.53
UP/S/NAT	4B	NATIONAL CHAMBAL SANCTUARY	00	11		11	6.35	7.03	4		5	44.38

ANNEXURE - C

VALUES OF MANAGEMENT AND LEGAL STATUS OF PAs

CODE	BIOGEOGRAPHIC PROVINCE	NAME	AREA OF THE PA (Hectares)	VALUE ACCORDING TO LEGAL STATUS	VALUE ON THE BASIS OF EXISTENCE OF A MANAGEMENT PLAN	VALUE ON THE BASIS OF EXISTENCE OF A SEPARATE BUDGET	VALUE ON THE BASIS OF EXISTENCE OF ZONING	VALUE OF THE PA ACCORDING TO LEGAL AND MANAGEMENT STATUS
HAR/N/SUL	4A	SULTANPUR NATIONAL PARK	117.37	4.5	1	1		6.50
HAR/S/BHI	4A	BHINDAWAS SANCTUARY	406.00	4.5	1	1		6.50
HP/S/REN	4A	RENUKA SANCTUARY	407.53	3.5			1	4.50
HP/S/SIM	4A	SIMBALBARA SANCTUARY	1925.56	3.5	1			4.50
HP/S/TAL	2B	TALRA SANCTUARY	2610.00	3.5				3.50
RAJ/N/KEO	4A	KEOLADEO GHANA NATIONAL PARK	2873.00	3.5		1		4.50
RAJ/N/SAR	4B	SARISKA NATIONAL PARK (Including Sariska Sanctuary)	76580.00	3.5	1	1	1	6.50
RAJ/S/JAM	4B	JAMVA-RAMGARH SANCTUARY	30000.00	3.5				3.50
RAJ/S/KAI	4B	KAILA DEVI SANCTUARY	67638.00	3.5				3.50
RAJ/S/VAN	4B	VAN VIHAR SANCTUARY	5993.00	3.5		1		4.50
UP/S/GOV	2B	GOVIND PASHUVIHAR SANCTUARY	95312.00	3.5		1		4.50
UP/S/NAT	4B	NATIONAL CHAMBAL SANCTUARY	63500.00	3.5		1		4.50

ANNEXURE - D

VALUES OF PRESSURES OR THREATS ON PAs

CODE	BIOGEOGRAPHIC PR	NAME	AREA OF THE PA (Hectares)	VALUE ACCORDING TO THE AREA OCCUPIED BY DAMS	VALUE ACCORDING TO THE AREA OCCUPIED FOR TOURISM	VALUE ACCORDING TO THE QUANTUM OF TOURISTS	VALUE ACCORDING TO THE AREA USED FOR MINING	VALUE ACCORDING TO THE AREA USED FOR QUARRYING	VALUE ACCORDING TO THE AREA USED FOR PLANTATIONS	VALUE FOR OCCURRENCE OF TRANSMISSION LINES	VALUE FOR OCCURRENCE OF ROADS/ HIGHWAYS	VALUE ACCORDING TO AREA OCCUPIED FOR HABITATION
HAR/N/SUL	4A	SULTANPUR NATIONAL PARK	117.37	0	2	3	0	1	0	0	0	0
HAR/S/BHI	4A	BHINDAWAS SANCTUARY	406.00	3					3			
HP/S/REN	4A	RENUKA SANCTUARY	407.53	0	0	0	0	0	0	0	2	0
HP/S/SIM	4A	SIMBALBARA SANCTUARY	1925.56	0	0	0	0	0	0	0	2	0
HP/S/TAL	2B	TALRA SANCTUARY	2610.00	0	0	0	0	0	0	0	2	0
RAJ/N/KEO	4A	KEOLADEO GHANA NATIONAL PARK	2873.00	0	1	3	0	0	1	0	0	0
RAJ/N/SAR	4B	SARISKA NATIONAL PARK (Including Sariska Sanctuary)	76580.00	0	1	3	0	1	0	2	2	1
RAJ/S/JAM	4B	JAMVA-RAMGARH SANCTUARY	30000.00	0	0	0	1	0	1	0	2	0
RAJ/S/KAI	4B	KAILA DEVI SANCTUARY	67638.00	1	0	0	0	0	0	2	2	0
RAJ/S/VAN	4B	VAN VIHAR SANCTUARY	5993.00	0	0	3	0	0	1	0	2	0
UP/S/GOV	2B	GOVIND PASHUVIHAR SANCTUARY	95312.00	0	0	3	0	1	1	0	2	0
UP/S/NAT	4B	NATIONAL CHAMBAL SANCTUARY	63500.00	0	0	0	0	3	1	0	2	0

ANNEXURE - D

VALUES OF PRESSURES OR THREATS ON PAs

CODE	BIOGEOGRAPHIC PR	NAME	VALUE ACCORDING TO THE DENSITY OF POPULATION INSIDE THE PA	VALUE ACCORDING TO THE AREA OCCUPIED FOR CULTIVATION	VALUE ACCORDING TO THE AREA USED FOR RELIGIOUS YATRA/ RELIGIOUS MONUMENTS	VALUE ACCORDING TO THE AREA USED FOR FISHING	VALUE ACCORDING TO THE AREA USED FOR TIMBER EXTRACTION	VALUE ACCORDING TO THE AREA USED FOR FUELWOOD EXTRACTION	VALUE ACCORDING TO THE AREA USED FOR NWFP EXTRACTION	VALUE ACCORDING TO THE AREA USED FOR FODDER EXTRACTION	VALUE ACCORDING TO THE AREA USED FOR GRAZING	VALUE ACCORDING TO DENSITY OF CATTLE UNITS GRAZING IN THE PA
HAR/N/SUL	4A	SULTANPUR NATIONAL PARK	0	0	0	0	0	0	0	1	1	1
HAR/S/BHI	4A	BHINDAWAS SANCTUARY										
HP/S/REN	4A	RENUKA SANCTUARY	0	0	0	0	0	0	0	0	1	3
HP/S/SIM	4A	SIMBALBARA SANCTUARY	0	0	0	0	0	0	0	0	1	1
HP/S/TAL	2B	TALRA SANCTUARY	3	0	0	0	1	3	3	1	3	3
RAJ/N/KEO	4A	KEOLADEO GHANA NATIONAL PARK	0	0	0	0	0	0	0	0	1	
RAJ/N/SAR	4B	SARISKA NATIONAL PARK (Including Sariska Sanctuary)	1	2	1	0	1	1	0	0	1	1
RAJ/S/JAM	4B	JAMVA-RAMGARH SANCTUARY	0	0	0	0	0	0	0	0	1	1
RAJ/S/KAI	4B	KAILA DEVI SANCTUARY	0	0	0	0	1	1	0	1	1	1
RAJ/S/VAN	4B	VAN VIHAR SANCTUARY	0	0	0	0	0	0	0	0	1	
UP/S/GOV	2B	GOVIND PASHUVIHAR SANCTUARY	1	0	0	0	1	1	1	0	1	2
UP/S/NAT	4B	NATIONAL CHAMBAL SANCTUARY	0	3	0	0	3	3	1	3	3	

ANNEXURE - D
VALUES OF PRESSURES OR THREATS ON PAs

CODE	BIOGEOGRAPHIC PR	NAME	VALUE ACCORDING TO THE AREA AFFECTED BY FOREST FIRES	VALUE ACCORDING TO THE AREA AFFECTED BY OCCURRENCE OF WEEDS	TOTAL VALUE OF PRESSURES OR THREATS
HAR/N/SUL	4A	SULTANPUR NATIONAL PARK	0		9.00
HAR/S/BHI	4A	BHINDAWAS SANCTUARY		3	9.00
HP/S/REN	4A	RENUKA SANCTUARY	0	2	8.00
HP/S/SIM	4A	SIMBALBARA SANCTUARY	1		5.00
HP/S/TAL	2B	TALRA SANCTUARY	0		19.00
RAJ/N/KEO	4A	KEOLADEO GHANA NATIONAL PARK	0	2	8.00
RAJ/N/SAR	4B	SARISKA NATIONAL PARK (Including Sariska Sanctuary)	1	2	21.00
RAJ/S/JAM	4B	JAMVA-RAMGARH SANCTUARY	0		6.00
RAJ/S/KAI	4B	KAILA DEVI SANCTUARY	0	2	12.00
RAJ/S/VAN	4B	VAN VIHAR SANCTUARY	0		7.00
UP/S/GOV	2B	GOVIND PASHUVIHAR SANCTUARY	1		15.00
UP/S/NAT	4B	NATIONAL CHAMBAL SANCTUARY	0		22.00

References

Ali, Salim and Ripley, Dillon S. (1983): Handbook of the Birds of India and Pakistan, Oxford University Press, New York

Anonymous (Undated): List of National Parks and Sanctuaries in India, Ministry of Environment and Forests, Government of India, New Delhi

Chundawat, R.S., Neel Gogate and A.J.T. Johnsingh (1997). Paper presented in the Zoological Society of London Tigers 2000 Symposium

Daniel, J.C. (1983): The Book of Indian Reptiles, Bombay Natural History Society and Oxford University Press, Bombay

Database on National Parks and Sanctuaries in India, Indian Institute of Public Administration, New Delhi

Dutta, S.K. (1997): Amphibians of India and Sri Lanka, Odyssey Publishing House

Franklin, Neil, Bastomi, Sriyanto, Dwiatmo Siswomartono, Jansen Manansang and Ronald Tilson (1997). Paper presented in the Zoological Society of London Tigers 2000 Symposium

Hilaluddin, M., (Undated): Checklist of Animals Found in the Protected Areas of Jammu and Kashmir (Mimeo)

Karanth, Ullas K., (1997). Paper presented in the Zoological Society of London Tigers 2000 Symposium

Kumar, Ajith: Personal communication received vide. a letter dated Februry 12, 1998.

Lal, R., Kothari, A., Pande, P. and Singh, S. (Editors) (1994): Directory of National Parks and Sanctuaries in Karnataka: Management Status and Profiles, Indian Institute of Public Administration, New Delhi

Leyhausen, Paul, (1986). What is a Viable Tiger Population? Published in Issue No. 04: Spring, 1986, Cat News, IUCN

National Wildlife Database, Wildlife Institute of India, Dehradun

Newmark, W.D., (1986). Mammalian Richness, colonisation and extinction in Western North American National Parks, PhD Dissertation, University of Michigan, Ann Arbor, Mich, as quoted in Michael E. Soule, 'Where Do WE Go From Here?', in Michael E. Soule edited *Viable Populations for Conservation,* Cambridge University Press, 1987

Pande, P. (Editor) (1997): Directory of National Parks and Sanctuaries in Maharashtra: Management Status and Profiles, New Delhi

Prater, S.H. (1971): The Book of Indian Animals, Bombay Natural History Society and Oxford University Press, Bombay

Rodgers W.A. and Panwar, H.S. (1988): Planning a Wildlife Protected Area Network in India, Wildlife Institute of India, Dehradun

Singh, S., Kothari, A., Pande, P. and Singh, S. (Editors) (1990): Directory of National Parks and Sanctuaries in Himachal Pradesh: Management Status and Profiles, Indian Institute of Public Administration, New Delhi

4. BUDGETING FOR SOME SOCIO ECONOMIC FUNCTIONS OF FORESTS*

4.1 Introduction

As already discussed earlier, once forest area has been demarcated, through budgeting and prioritising, for ecosystem functions (section 2) and for biodiversity conservation (section 3), then, from what remains, further demarcation has to be done for sustainable socio-economic uses.

There are many socio-economic uses of forests. However, for the purposes of developing and testing a methodology, we restrict ourselves to the supply of fuelwood and to the grazing of cattle. These are not only the two most widespread uses but also meet the needs primarily of the poorer segments of society. Therefore, by focussing on these two we not only highlight the sustainable use function but also the equity function. Besides, some data are available for these two functions.

Accordingly, in this section an attempt is made to calculate the fuelwood and fodder demand from the forests of the YSC. The forest area required to sustainably meet these demands is then calculated, district-wise, and the surplus/deficit available is indicated. Subsequently, an attempt is made to calculate grazing pressures and to determine what sorts of areas would be required to be demarcated in order to sustainably meet these demands.

4.2 Fuelwood demand and supply in the yamuna river sub basin

The table given below shows the area from where fuelwood in this region is collected.

* This section has been contributed by Dr (Mrs) Vasumathi Sankaran of IIPA

TABLE I : PERCENTAGE OF FOREST AREA IN THE DISTRICTS OF THE HILLS & PLAINS OF YSC

A. PLAINS	**Total area (ha)**	**Forest area (ha)**	**% of Forest area to reported area**
HARYANA			
Gurgaon	276000	15000	5.45
Rohtak	441100	8000	1.8
Sonepat	138500	8000	5.97
Panipat	175400	5000	2.86
Rewari	155900	4000	2.58
Faridabad	210500	6000	2.88
Karnal	196700	7000	3.59
Jind	273600	8000	2.96
Bhiwani	514000	9000	1.95
Mahendragarh	168300	6000	3.09
Sirsa	427600	6000	1.41
Hissar	627900	10000	1.52
Kurukshetra	121700	5000	3.12
Kaithal	279900	6000	2.51
TOTAL	**4007100**	**103000**	**2.57**
UTTAR PRADESH			
Bulandshahar	435300	9370	2.15
Gaziabad	259400	2555	0.98
Meerut	391100	7993	2.04
Mathura	381100	1581	0.42
Aligarh	501900	808	0.16
Muzaffarnagar	404900	7326	1.75
Saharanpur	386000	78298	14.25
Agra	402700	39616	8.31
Mainpuri	275900	6893	1.59
Etawah	432600	38683	8.86
TOTAL	**3870900**	**193123**	**4.47**
RAJASTHAN			
Alwar	838000	16179	2.11
Jhunjhunun	592800	33488	5.65
Jaipur	1406800	64303	4.59
Bharatpur	506600	25941	5.11
Sikar	773200	32675	4.22
Sawai Madhopur	1052700	2370	22.48
Churu	1683000	4916	0.29

Norms:
60% of the hill areas should be covered with forests
20% of the plains should be covered with forests

- *The area reported under forest department the canopy cover is not considered here.*

A. PLAINS	Total area (ha)	Forest area (ha)	% of Forest area to reported area
Ganganagar	2063400	39371	1.91
Dholpur	303400	11576	3.85
TOTAL	9219900	230819	2.56
B. HILLS AND FOOT HILLS REGION			
HARYANA			
Yamunanagar	175600	2300	12.99
UTTAR PRADESH			
Dehradun	308800	220056	60.76
Tehri Garhwal	884200	397322	68.97
Uttarkashi	801600	710268	88.69
TOTAL	1994600	1327646	66.56
HIMACHAL PRADESH			
Shimla	513100	61874	17.55
Sirmour	282500	48958	21.78
Solan	193600	19586	10.86
TOTAL	989200	130418	13.18

This table indicates that the plains of Haryana, Uttar Pradesh and Rajasthan have respectively 2.57%, 4.47% and 2.56% of forest lands, that is about 10% of required area. The quality of the forests is not known.

Hills of Uttar Pradesh, however, have adequate forestlands of 66.56% of the area. But this table is worked out on the basis of reported area under forest department and not on the quality of canopy cover. The hills of Haryana and Himachal Pradesh have only about one fourth of the required area as forest land.

TABLE II: FUELWOOD BUDGET FOR RURAL POPULATIONS IN YSC

(1)	(2)	(3)	(4)	(5)		(6)		(7)	(8)	(9)	(10)
State	[1]Area available for extraction '000	[2]Annual increment of biomass Cu m	Annual increment by weight tons	Population in millions		[3]Fuelwood requirement		Annual deficit (tons) '000	[4]Forest Area required (ha) '000	Scrub forest available (ha) '000	Wasteland available (ha) '000
				Rural	Urban	tons/ day '000	tons/ annum '000				
Haryana	8.4	4474.26	6263.96	10.81	3.54	3.8	1366	1360	64	4	86
H.P.	195	249511.68	349316.35	1.8	.24	1.5	480	130	73	.2	49
RAJASTHAN	30.6	6677.88	9349.05	14.46	4.79	8.5	3035	3024	98	117	350
U.P.	226.9	386564.31	541190.4	18.68	7.82	8.7	3135	2597	11	16	130

Source : *IEG Report, TERI yearbook; per.comm. Shri O.N. Kaul, TERI.* ** *Conversion of annual increment in volume to weight is 1 c.m. = 1.4 tons (TERI).*

Footnotes

1 **Column (a) - (b) in ha.**

2 **Column (a) x (c)**

3. Column (d)

State	**Forest Area adjusted for losses (a)**	**Protected area (b)**	**Rate of annual biomass increment (m3/ha) (c)**	**Per Capita per day Fuelwood Consumption in Kg. (d)**
HARYANA	20984	**12542**	0.53	0.34
H.P.	216343	**21412**	1.28	1.12
RAJASTHAN	156776	**187130**	0.22	0.57
U.P.	274368	**48307**	1.71	0.45

4 Column (8) is calculated as follows: Column (7) ÷ 1.4 = increment in volume which is required for the present population.
Increment in volume ÷ Rate of annual biomass increment in volume (c) = Forest area required to produce the annual increment demand

Procedure for calculating fuelwood requirements

Column (2) gives the area of the forest legally available for extraction of fuelwood in the states within the Yamuna river sub basin. The actual forest area under dense and medium canopy cover was taken from the Institute of Economic Growth NRA Report (IEG report). Areas under national parks and sanctuaries situated in each state were deducted from the total area under forests, as fuelwood extraction is not permitted within them.

The average standard increment of biomass/ha for each state was taken from the IEG report. The standard multiplied by area has given the total increment of biomass in cubic meters for each state as given in column (3).

The annual increment was converted to a weight measurement by multiplying the volume increment in column (3) by a standard supplied by TERI. The results are given in column (4). This gives the total annual fuelwood requirement for each state. Endnote 3 gives the per-capita fuelwood requirement per day for the particular agro-ecological zone. For want of more refined data, it is presumed that all the rural households and 10% of the urban households will use fuelwood for their energy requirements. The total fuelwood requirement per day and per annum is calculated by multiplying the number of people by the standards given in endnote 3. The figures are tabulated in column (6).

Column (7) gives the deficit by weight of the fuelwood requirement for each state. This amount is arrived at by subtracting the annual increment of the forests, in weight measurement given in column (4), from the actual requirement given in column (6).

The deficit fuelwood requirement value given in tons in column (7) is converted to volume measure by dividing the value by 1.4, the conversion factor. This gives the annual increment required in volume. The value indicating the volume increment required for each state has to be divided by the standard increment for each state to arrive at the area of forest required to produce the increment (Please see end note 4 in the table). Column (8) gives the area.

The area under scrub forest was not taken into account while calculating the deficit. It was presumed that scrub forest and wastelands cannot yoeld significant amounts of fuelwood in a sustainable manner. The area under both these categories are given in columns (9) and (10). This is the land considered suitable for afforestation. But even this land will not satisfy the total demand.

4.3 Grazing Demand and Supply in the YSC

TABLE III.1: COW UNITS GRAZING IN THE YSC

State/ District	Rural population	Cow Unit (CU) per Capita	Total Cow Unit (C.U.) in the district
HARYANA			
Gurgaon	913390	0.5	456695
Rohtak	1243130	0.54	671290
Sonepat	576840	0.65	374946
Faridabad	759930	0.52	395060
Rewari	52810	4.5	26405
Panipat	607160	0.5	303580
Yamuna Nagar	544950	0.5	272475
Karnal	642510	0.73	469032
Jind	797560	0.73	582219
Bhiwani	943570	0.64	603885
Mahendra-garh	597230	0.58	346393
Sirsa	712340	0.65	463021
Hissar	1455080	0.61	887599
TOTAL			5852600
HIMACHAL PRADESH			
Shimla	491270	0.9	442143
Sirmour	341620	1.1	375782
Solan	334990	1.0	334990/ 1152915
TOTAL			817925.29
RAJASTHAN			
Alwar	1976290	0.85	1679846
Jhun-Jhunun	1257380	0.56	704133
Jaipur	2855910	0.74	2113373
Bharatpur	1330780	0.53	705313
Sikar	1455390	0.85	1237081
Sawai Madhopur	1671970	1.2	2006364
Churu	1097170	0.95	1042312
Dholpur	620650	2.6	372390
Ganganagar	2070660	0.80	16528
TOTAL			9877340

State/ District	Rural population	Cow Unit (CU) per Capita	Total Cow Unit (C.U.) in the district
UTTAR PRADESH			
Buland Shahar	2257060	0.4	902824
Ghaziabad	1455670	0.3	436701
Meerut	2171360	0.3	651408
Dehradun	510200	0.38	193876
Tehri Garhwal	547260	0.70	383082
Uttarkashi	222450	1.2	266940
Mathura	145930	0.57	841280
Aligarh	1507100	0.54	813834
Muzaffarnagar	2143310	0.56	1200253
Saharanpur	1719380	0.84	1444279
Agra	1639930	0.36	590375
Mainpuri	1142860	0.59	674287
Etawah	1790950	0.57	1020841
TOTAL			9419980

TABLE III.2 : COW UNITS GRAZING IN THE YAMUNA RIVER SUB-BASIN

State	Total Cow Units (CU) in the state	% of cattle grazing in forest	Total number grazing in forest	Forest Area (in ha)	Carrying capacity of forest (@ 1 cu/2 ha) (4) /2	Excess cattle grazing in forests (CU)	Additional grazing land required (ha)	Available wasteland (ha)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HARYANA	58,52,600	N.A.	N.A,	25,246	12,632	N.A.	N.A,	17,06,092
H. P.	8,17,925	85.1	6,96,054	2,38,102	1,19,051	5,77,000	11,54,006	1,20,712
RAJASTHAN	98,77,340	7.7	7,60,555	2,80,239	1,40,120	6,20,435	12,40,870	19,84,713
U.P.	94,19,980	4.1	3,86,219	2,96,941	1,48,470	2,37,749	4,75,498	9,79,057

Sources: Population - Census Handbook (1981) for Haryana H.P., Rajasthan and Uttar Pradesh. Livestock Population 13th Indian Livestock Census 1982 - Ministry of Agriculture, Government of India. Agenda Notes Fifth Meeting of NAEB MoEF, Government of India, December 08, 1995.
Norm for Carrying Capacity for Forest Grazing given by Shri O.N. Kaul (TERI)
Total rural livestock (cows, buffaloes, sheep and goats) were converted to cattle units.
Total rural cow unit (cu) divided by total rural population gives cu/capita
Rural population of districts in Yamuna Basin (IEG Report) x cu/capita gives the total c.u. of the districts in Yamuna Basin.
Value of column (4) divided by 2 = c.u. unit which can be supported by the reported Forest Area.

Procedure of Calculation

The 13th Indian Livestock Census gives the livestock statistics district-wise for the year 1982. There are standards for reducing various types of livestock into cow units. One buffalo is equal to 1.8 cow and one goat or sheep is equal to 0.5 cow. The census figures for all these animals are, accordingly, reduced to cow units and tabulated. Figures of the district level human population for 1981 were extracted from the Population Census Handbook (1981) for the four states. Total cow units of each district divided by total rural population of each district indicated the cow unit (cu) per capita. The actual numbers of cu were available for the entire district but not separately for that part of the district that fell in the YSC. A method was devised to arrive at the probable numbers of cattle within the sub basin, which did not exactly coincide with the district boundary. The per capita cu, multiplied by the actual rural population residing within the sub basin for each district, gave the approximate cu in each district area falling within the sub basin.

Column (1) gives the actual number of cu in each district calculated as explained above. Column (2) gives the percentage of cattle grazing in the forest. These figures are taken from the report of the Policy Advisory Group on Integrated Grazing Policy of the Ministry of Environment and Forests. Column (3) gives the numbers grazing in the forest. This is calculated by multiplying the percentage given in Column (2) by the figures in Column (1). Column (4) gives the forest area of the state including the sanctuaries but excluding the national parks. Grazing is allowed in sanctuaries but not in national parks.

Column (5) gives the carrying capacity of the forest, calclated as per the norms given by Shri O.N. Kaul of TERI, during personal discussions.

Column (6) shows the number of excess cattle units (Column (3) Column (5)). Column (7) gives the additional land required if grazing has to be carried out in a sustainable manner. Column (8) gives the land available for grazing outside the forestland. This is the land categorised as fallow land.

5. BUDGETING OF URBAN FORESTS FOR POLLUTION CONTROL: A CASE STUDY OF DELHI*

5.1 Introduction

In this section, a methodology is developed to determine the green cover required in a city to effectively control air pollution, especially that of suspended particulate matter (SPM). The methodology is then applied to the city of Delhi.

5.2 Air Pollutants

Before discussing air pollutants, it is necessary to define air, particularly that portion of the air that affects the existence of living organisms. Air is an ocean of gases which reaches from the earth's surface to outer surface. Troposphere is a portion of this ocean that is 5-10 miles deep next to the surface of the earth and which is most important to life on earth. It is this layer of air and it's interface with the surface of the earth that we must consider in order to understand the fate of pollutants in the atmosphere.

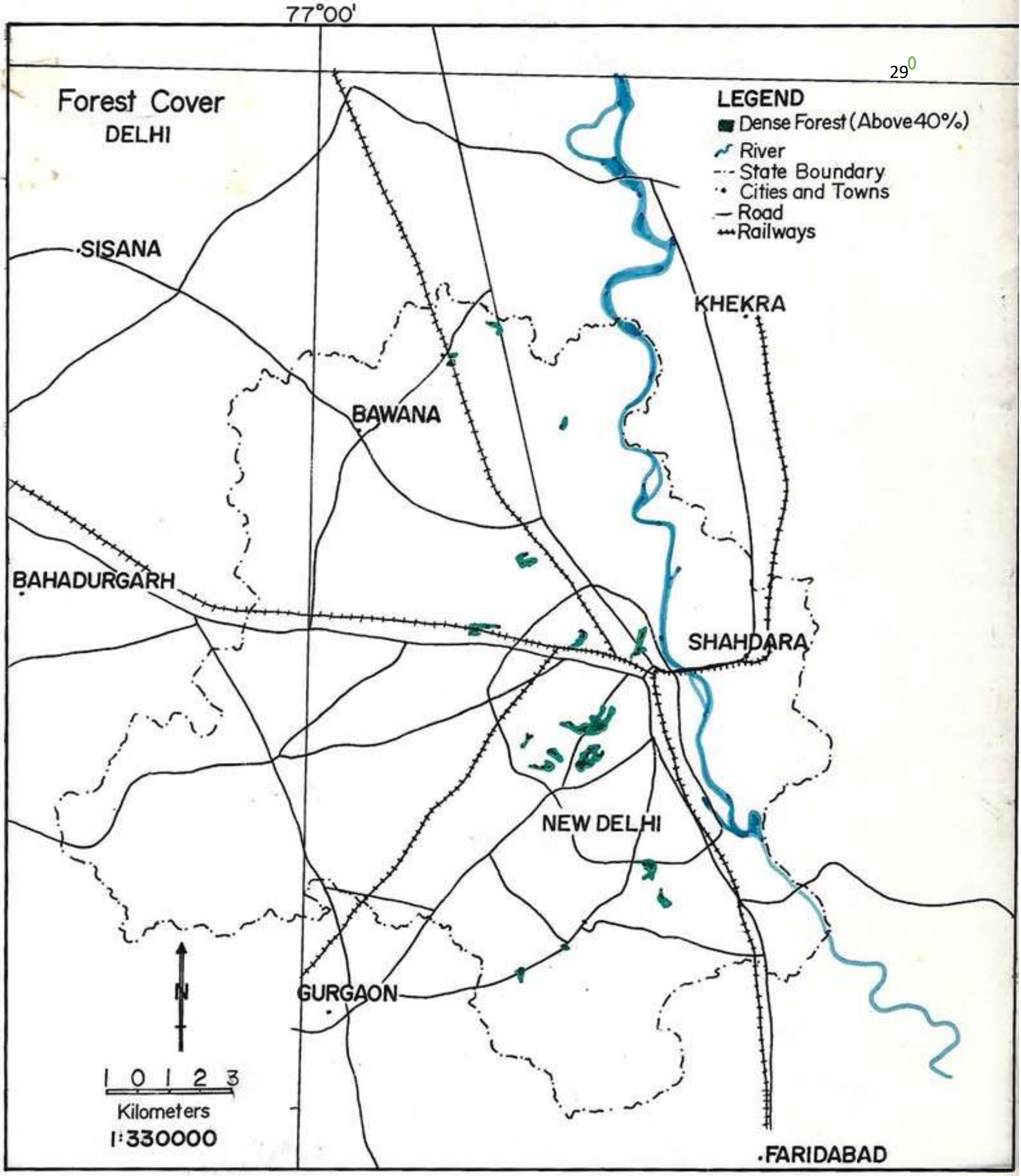
Air as we know consists of 21% O_2, 78% N_2, about 0.03% CO_2, less than 1% argon and traces of other gases plus varying amounts of water vapour. This is the mix in which living organisms of the earth can best function. But air has for millions of years been contaminated by natural products including salt droplets from the sea, ice, soil, dust, plant and animal propagules and parts, oxides of nitrogen and sulphur, methane, ammonia, hydrogen chloride and hydrogen floride, to name just a few. Soil erosion, volcanic eruptions, the wave motion of the ocean and billions of respiring, photosynthesising, dying and decomposing organisms still fill the air with these same contaminants. But of main concern here are human induced pollutants.

At any given time air is a mixture of gases and naturally produced pollutants which coexist with man made pollutants generated by stationary and mobile combustion of fossil fuels, plus the effluents from a variety of processing and manufacturing industries. Factors that affect air pollution include :

(i) Direction and spread of wind

(ii) changes in temperature

* This section has been contributed by Dr Prabhakar Rao, Kalpavriksh


77°00'
29⁰
Forest Cover
DELHI
LEGEND
Dense Forest (Above 40%)
River
State Boundary
Cities and Towns
Road
Railways
SISANA
KHEKRA
BAWANA
BAHADURGARH
SHAHDARA
NEW DELHI
GURGAON
N
1 0 1 2 3
Kilometers
1:330000
FARIDABAD

(iii) maximum mean height

(iv) precipitation

(v) topography.

In case of air, the concern is more with air quality than quantity. In a city context, whenever we talk of lack of air, what we mean is not the lack of air as such but the lack of clean air. In Delhi, air pollution has become a major area of concern. Excessive emissions from automobiles are major reason for this. If we have to manage pollution within tolerable limits we have to take both preventive and corrective steps. The quality of fuel supplied, the type, age and number of automobiles, the conditions of roads, the driving habits, the periodicity of emission checkups and standards thereof are factors that can prevent auto pollutants from contaminating the air. Similar preventive measures are called for in other areas like thermal stations and other industries. But once pollutants are released into the atmosphere, they affect the quality of life of not only humans but also other life forms (both plants and animals) . They also affect buildings and monuments.

5.3 Role of Vegetation in Combating Air Pollution

In Delhi, the consequences of excessive levels of air pollution are manifesting themselves in tangible detrimental forms. The only way to remedy the situation is by checking emissions at source. But if for whatever reasons this is not done the ill effects of polluted air have to be dealt with. Once the air gets polluted, steps that can mitigate the adverse effects have to be initiated. Greenery is a very good means of doing precisely this. Green vegetation is a natural way of cleaning the air by absorption of gaseous and by trapping of particulate pollutants through leaves.

It has long been recognised that trees filter particulates. The larger the particulate and the more stable the atmospheric conditions, the better the tree screen will operate. With small particles and increased turbulence, the effectiveness of the screen diminishes. There are many reasons for ensuring the maintenance of green belt in urban areas: their value as a filter and sink for air pollutants is just one. The sink concept is particularly of interest to atmospheric chemists and meteorologists, who are attempting to develop air pollutant budgets.

It is one thing to find that plants are major pollutant sinks and another to extrapolate this information to the development of greenbelts, primarily for the purpose of decreasing pollutant concentration. We cannot keep emitting pollutants into the air and expect greenery to cleanse it. Pollutant uptake by plants involves many factors, including the inherent variation in potential for uptake by different plant species, the direct effect of the pollutant on the uptake potential of the plant, the effect of other environmental stresses on the uptake potential of the plant, and meteorological factors affecting pollutant distribution.

A major point to remember is that plants do not always respond in a predictable way and are not active throughout the year. The efficiency of greenbelts as air pollution control measures should never be overemphasised. The exact capacity of a green belt to absorb pollutants, and its capacity to absorb these without harm to the plants or to ecological communities, are not known.

Plants are themselves prone to injury due to pollution and the injury may manifest itself in many forms, it can slow the growth rate or in extreme cases can result in the death of plants. Acute damage occurs as a result of the action of high concentrations of gases over a short period of time. When the poisonous gases reach the plant cells, the latters natural physiological and biochemical processes are altered. Accumulation of large quantities of poisonous substances leads to injuries to leaf blades, the formation of necroses, and eventually to the rapid dying of the plant. Chronic damage occurs when low concentrations of polluting gases act for a longer period of time. This results in reduction in growth and development of plants without any initially visible injuries. The phytotoxicity of pollutants usually depends more on the concentration in the foliage, in ug per g or mg per kg dry matter, than on the rate of deposition. Plant damage due to air pollution varies with the plant and the type of pollutant as well as with the time of day of exposure and the concentration of the pollution in the atmosphere. Threshold concentrations which cause damage to plants vary with the length of exposure of the plant to the pollutant. The mechanism by which pollutants are phytotoxic results mainly from altered plant enzyme activity. It appears that the enzyme activity can be inhibited and then increased. This damages the plant by first lowering the respiration then increasing the respiration. The enzyme enolase appears to be affected most by the pollutants.

Leaves have two major functions : to feed the plant and to protect itself. According to Bradshaw, (1976) the different methods by which vegetation canopies interact with environmental pollution are given below :

1. By modifications to cuticles, stomata, plants adapt to pollution,
2. By mixing of pollutants in the internal tissue to make pollution harmless
3. By degradation of pollutant products
4. By development of resistant enzymes.

In typical roadside conditions, plants are subjected to a combinations of pollutants. The chemistry of this mixture, and it's effects on plants are not known precisely. Studies have been attempted only with regard to some specific combinations of pollutants. The threshold limits of pollutants that injure plants are not known precisely. The ambient air quality standards are supposedly fixed in a manner that takes into account plant injuries as well. The determination of criteria for the maximal permissible concentration of injurious substances (i.e. air quality standards) requires improved knowledge of the critical levels for various wild and cultivated plants. Determination of principles on which the protection of air purity has to be based, requires a compromise between results of scientific investigation on the effects of emission on people and plants, the level of industrial technology, and the economy of plants and industrial production.

Not all types of plants are suitable for mitigation of air pollution. Even those that are, need extra special care in order to enable them to grow in stressful roadside conditions. It is to be remembered that plants can act as efficient sinks of air pollutants only as long as they are healthy and metabolising at their optimal rate.

The relative ability of a plant which can tolerate and remove pollutants from the atmosphere is measured by a composite index called the Air Pollution Tolerance Index (APTI). Various studies have identified trees, shrubs, herbs, and grasses that are suitable for pollution abatement based on their APTI. A high ranking on APTI however does not mean that the plant can grow under any condition. Not withstanding their APTI, plants do need the support of necessary abiotic components in order to perform at their potential best. When the air is already severely polluted, it should be seen that atleast the soil and water requirements are adequately met. For example, the dust capturing capacity of plants diminish if they face water stress. Water in the body of a plant helps to maintain the physiological balance specially when transpiration rates are usually high under stressful conditions of air pollution. Similarly, soils should have necessary nutrients that plants need. The soil texture is equally important. But if soils are severely compacted on side walks or completely sealed with concrete tiles, root aeration is severely hampered leading to tree deaths. Thus other conditions have to be as favourable as possible so that the plant can perform its mitigating role in pollution abatement.

More than their role as sinks, plants are good indicators of pollution. That is why industries that care for the environment raise plantations of sensitive species in close proximity to their production facilities, to indicate the efficacy of their clean technologies. Since time immemorial the role of greenery in regulating of CO_2 and supply of O_2 were well recognised. But now they are required to perform greater roles in making the city air better for all living and non-living beings. But once again it should be emphasised that the plant's role as pollution abaters is limited. They cannot be the panacea for air pollution. The combustion of fuels in petrol and diesel engines, for e.g., leads to the emission of such substances as CO_2, CO, SO_2, NO_x, H_2, hydrocarbons and aldehydes. As a result of photochemical reactions, ozone and peroxyacetyl nitrate (PAN) are formed, which are extremely injurious to plants. Designing cleaner engines & changing of basic fuel can reduce emissions drastically. The self purification of poisonous emissions is very slow and so it is essential to eliminate poisonous emissions at the source, before they reach the atmosphere.

5.4 Air Pollution in Delhi

But in a world where many things are topsy turvy, instead of protecting plants from pollution we expect plants to protect us from pollution. Delhi is a typical case. It has a unique place in the most severely polluted cities in the world [third most polluted city in the world].The Central Pollution Control Board has provided data regarding ambient air quality in Delhi. This is shown in Table-I

TABLE-I

Ambient Air Quality - Actual (1995) Figures in ug/m³

Location	Mean SO_2		Mean NO_2		Mean SPM	
	Actual	Std.	Actual	Std.	Actual	Std.
(I) Nizamuddin	15.9	80	37	80	398	360
(I) Ashok Vihar	17.7	80	28.5	80	406	360
(I) Shehzada Bagh	26	80	45.3	80	369	360
(I) Shahdara	22.2	80	27.6	80	437	360
(R) Janakpuri	17.9	60	37.2	60	422	140
(R) Siri Fort	14.5	60	28.9	60	408	140
(R) Netaji Nagar P.O.	23.4	60	57.2	60	308	140
ESI Desp, Najafgarh Rd.	30.5	80	52	80	475	360
Town Hall	43.1	60	110.8	60	472	140

From this table it is clear that concentrations of SO_2, are well within the prescribed standards and also of NO_2 except in one case. However, in specific locations even SO_2 & NO_2 exceed permitted standards.

However, it is with regard to SPM that the concentrations are well above the prescribed standards and the trend is rising. This study shall therefore focus primarily on SPM concentrations and the green cover needed to offset this. The maximum recorded SPM are shown in Table II

TABLE-II

Maximum SPM recorded in the locations (1995) : (in ug/m³)

PLACE	MAXIMUM SPM RECORDED	STANDARD
Nizamuddin	994 (December '95)	360
Ashok Vihar	891 (November '95)	360
Shahzada Bagh	613 (Feb '95)	360
Shahdara	883 (May & June '95)	360
Janakpuri	856 (May '95)	140
Siri Fort	812 (May '95)	140
Netaji Nagar	916 (December '95)	140
ESI Dip. Najafgarh	1321 (January '95)	360
Town Hall	1082 (January '95)	140

Table II indicates that the levels of SPM are really excessive. Urgent steps are needed to control this situation. SPM has adverse effects on the health of humans, plants and animals. It adversely affects inanimate objects like electronic items and buildings, specially monuments of archaeological significance.

In Delhi greater-than-background concentrations of more than one pollutant are introduced into an air mass as a result of atmospheric mixing, the emission of pollutant into an already polluted air, or the simultaneous emissions of more than one pollutant. Such combinations result in impact on vegetation that differ appreciably from those of the single pollutant. Combinations of pollutants affect various individual physiological and biochemical processes and activities such as stomatal functions, photosynthesis, gas exchange, water relations, and the activities of individual enzymes and metabolic pathways. While discussing plant response to pollutant combinations, Tingey and Reinert (1975) noted that the effects can be less than additive (antagonistic interference), greater than additive (synergistic potentiate) or equal to additive effects of individual pollutants. Air pollutants in urban and industrial areas may get adsorbed, absorbed, accumulated or integrated in the plant body and if toxic, may injure them variously.

Pollutant transfer from the atmosphere to plant communities is very complex and an incompletely understood process. Atmospheric contaminants may be removed by both the soil and vegetative compartments of an ecosystem through a variety of mechanisms. The primary process are precipitation scavenging, chemical reaction, dry deposition (sedimentation), and absorption (impaction).

Components of the ecosystems of the earth that remove pollutants from the atmospheric compartment and store, metabolise, or transfer them are termed as "sinks". The transfer of contaminants from the atmospheric compartment to the surface of soil or vegetation is expressed as a flux (pollutant uptake) rate and is given as a weight of pollutant removed by a given surface area per unit of time. Actual determination of flux rates (sink strengths) are extremely complex, and involve an appreciation of atmospheric conditions (wind, turbulence, temperature, and humidity), pollutant nature and concentrations, sink surface conditions (geometry and presence or absence of moisture), and other parameters.

5.5 Effects On Vegetation

A brief discussion of important pollutants and their effects on vegetation are described below :

Ozone is gaseous `secondary' air pollutant formed as a result of a complex reaction between oxides of nitrogen and sunlight. O_3 enters plant leaves via the open stomates during normal gas exchange between the plant and its immediate environment. O_3 injury is usually found on older leaves and not those newly formed. A common symptom of O_3 injury on plants is flecking. It is usually an indication of acute injury. Small necrotic spots or flecks occur due to the death of palisade cells. These flecks are metallic or brown and often bleach to tan or white with age. Flecks may coalesce to form blotches which can result in chlorosis and leaf fall.

There are a number of oxides of nitrogen in polluted air. In addition to being involved in the reactions that lead to 0_3 formation, two of them are thought to be potential phytotoxic air pollutants - nitric oxide (NO) and nitrogen dioxide (NO_2). In general, higher concentrations of NO_x are required to cause plant injury than other pollutants such as O_3 or SO_2. Many ambient concentration of NO_x are too low to cause visible injury. At low concentrations, growth stimulation may occur and plants become darker green in colour. Acute NO_2 injury may resemble acute SO_2 injury. There are no reliable symptoms. But at higher (0.40 to .80 ppm NO) concentrations, growth inhibitions occurs. It is generally believed that a NO_2 concentration of 0.05 ppm (0.1 mg per m^3) for an annual average, or 0.13 ppm (0.244 mg per m^3) as a mean for 24 hours, is below the threshold for visible effects on vegetation.

SO_2 (from power plants, specially thermal) injures leaves. SO_2 enters via stomatas. SO_2 is oxidized to Sulphite (SO_3) and then slowly to Sulfate (SO_4). SO_3 is highly toxic. SO_4 is less toxic. At low concentrations, SO_3 conversion to SO_4 occurs and injury is avoided. At higher concentration for longer durations, SO_2 conversion to SO_3 occurs faster than conversion of SO_3 to SO_4 and leaf injury results. SO_4 concentrations in plants can also increase to phytotoxic levels over prolonged exposure times. SO_2 is known to cause plant injury at dosages of 0.05 to 0.50 ppm for 8 hrs or more. Acute SO_2 injury leads to interveinal bleaching [brown or white] and marginal bleaching. On some leaves, a herring bone effect may be observed, with the veins as the bones. Chronic or SO_4 injury may consist of chlorosis or red-brown discoloration.

Peroxyacyl nitrates: A number of peroxyacyl nitrates are formed in the ambient air. Of these, peroxyacetyl nitrate, or PAN, is the best known and appears to be most phytotoxic. PAN results from a complex reaction between hydrocarbons and sunlight. PAN enters the stomates of the youngest, most actively growing, leaves on plants. Injury often occurs at the apex of the youngest leaves and the base of the older and yet sensitive leaves. Injury occurs most frequently when plants are exposed to PAN at higher temperatures rather than low ones. Injury symptoms vary with the plant type and may be confused with those caused by other pollutants, pollutant mixtures, frost or other factors.

Particulates and heavy Metals [Suspended Particulates] : Particles which are too fine to have an appreciable falling velocity and so tend to stay suspended in atmosphere for a considerable period are called as suspended particulates. Particulates suspended in the air are of different sizes and shapes hence are named differently such as aerosols, flyash, dust etc. Particulate pollutants are a group of solid and liquid aerosols suspended in the atmosphere. Particulate matter comes either from processes involving condensation or dispersion such as erosion, spraying and grinding. Dust refers to solid dispersion aerosols while mist is a liquid aerosol. Dust means small particles in the size range 1 to 200 um in diameter. Particles above 75 um size come into the category of grit. Below 1um, the particles, if air borne, would tend to remain in suspension rather than settle due to gravity. These small, multi-molecular units are measured in microns and sorted out by particle size. Determining size can be difficult as they interact with each other and with water and gases. In themselves, they often tend to be rather inert but, when combined with other substances, they may be phytotoxic. HF (hydrogen floride) and SO_2 are water soluble gases that can become part of water films around particles. SO_2 dissolution can result in acidic particles which burn plant leaves. Besides gases, there are several other matters suspended in air floating all the time. Both clean and polluted air has some particulates. Particulates may be living or non-living. Bacteria, fungal spores and pollen are living and soil dust, coal dust, cement dust are nonliving particulates present in the atmosphere. Particulates include carbon, phosphorous, pottassium, iron, manganese, copper, zinc, calcium, magnesium, antimony, arsenic, asbestos, beryllium, cadmium, lead, mercury, silica or silicon dioxide and sulphuric acid mist. Gaseous pollutants are CO_2, CO, Fluorides, Sox, Nox, gaseous ions, hydrocarbons, hydrogen cyanide, hydrogen sulfide, O_3 and PAN. Urban dust may be considered as a mixture of heterogeneous particulate matter consisting of heavy metal particles, tarry deposits and other kinds of particles related to the day-to-day activities in the area. Particles in the city atmosphere include : soil and road dust, spores and pollen, fly ash, bacteria, lead from vehicles, diesel and other smoke.

Since the phisico-chemical properties of dust samples may differ from area to area, depending on the type of industrial activity carried on there, their injurious effects on plants and animals may also differ. Further, as the chemical nature of particles may be diverse, a series of synergistic reactions may occur among these particles affecting the physico-chemical function of plants. The level of particulate pollution in cities increase due to exhaust from automobiles, emission of large particles from industries and breakdown in the oxygen cycle due to the absence of an adequate green cover.

Particles are deposited on vegetation by several processes viz. sedimentation, impaction, interception and Brownian diffusion.Some of the adverse effects of particulate pollutants are:

- Solid and liquid aerosols are able to scatter and absorb sunlight thus reducing the amount of insolation and visibility.
- Particulate pollutants reduce visibility in the cities.
- Particulate type air pollutants such as ash, dirt and grit , land on the surface of the leaves. They do not enter the leaf but may damage it by mechanical abrasion of the surface of the leaf.
- Particulates may clog stomates and increase SO_2 susceptibility or interfere with flower pollination, leaf size and condition and the composition of vegetation by affecting soil pH. An examination of dusted leaf surface reveals that deposition of particles on the leaf surface is not uniform. The particles are heavily concentrated on the stomatal pores. Such differential deposition of particles on the leaf surface are attributed to the suction created by the stomatal opening. Since a significant quantity of air enters into the plant body through these stomatal pores, particles larger than the pore diameter tend to pile up on the pore opening to interfere with the gaseous exchange and

in turn affecting photosynthesis, water relation, respiration and the ultimate growth of plants.

- Particulates can form physical barriers on leaves that decrease or blockout sunlight, thereby reducing photosynthesis and the food making ability of the plant. Leaf areas damaged by particulate abrasion are more susceptible to attack by chewing bugs.

Air contains many particles which are continuously deposited on plant surfaces. Some are blown or washed off, others enter leaves through stomatas or by injuring epidermal cells. The role of particulates in air pollution effects on vegetation needs a great deal more investigation. In a nutshell, the unfavourable alterations in different plant parameters under the stress of any particulate pollution can be ascribed to the following :

i. Quantitative and qualitative changes in solar radiation impinging on the leaf surface, and alterations in the energy exchange process of leaf due to dust layer.

ii. Decreases in Chlorophyll level and Chloroplant injury.

iii. Interruption in gaseous exchange due to shading of culticle and clogging of stomata by dust.

iv. Dust induced alterations in pH and of other physio-chemical properties of soil supporting the plant growth.

Most heavy metals occur in the atmosphere in some type of particulate form as salts or adsorbed to other particles. Deposition occurs on plant parts and soil surface. There is considerable debate as to whether heavy metals are absorbed by leaves in any appreciable way or whether they are absorbed by roots and stored or translocated upward to leaves, fruits, etc.

Heavy metals that fall on soil tend to accumulate in upper soil layers. Clay or organic matter content will affect the availability of heavy metals. In general, heavy metals are stable and not leached or degraded. When concentrations rise due to continuous application, toxic concentrations may occur. Selection for resistant plants also occurs.

Lead (Pb) is the most common and most abundant heavy metal in air and soil (mainly from leaded gasoline combustion and manufacturing operations). Lead does occur on leaves, but most of it can be removed by washing. Lead is taken up by plant roots, but is thought to be localised in dictysone vesicles and deposited in cell walls. Lead does accumulate in soil, but no clear evidence of lead poisoning in plants grown under natural conditions, has been reported. This is an area which needs greater investigation.

The atmosphere around plants in the field usually contains several potential phytotoxic air pollutants. How these pollutants interact and how this affects the expression of injury on plants has not been extensively explored. Two gases mixed together may cause more or less injury than either of the two alone (synergism). The plants tolerant to air pollution (particulate and/or gaseous) somehow seem to strike a balance between adaptiveness (the physiological capacity to cope with their present environment) and adaptability (the capacity to produce offspring with new combination of genes, combinations that may be better suited to future environments). Research to investigate the mechanisms and levels of adaptiveness and adaptability in plants for short and long terms survival and protection against the stress of air pollution would be of great practical utility.

5.6 Budgeting for Green Cover

Budgeting for green cover implies determining the area to be kept under permanent green cover in order to mitigate or abate the effects of air pollution. The starting point is by examining the extent of air pollution in the NCT [Table I &II]. Since SPM is the major problem, the study shall deal exclusively with it. SPM needs increased attention also because it arises both from human and natural sources. Even if human induced SPM is kept under check, the effects of SPM from natural phenomenon still would require to be offset. Considering only the SPM shall also reduce the complexities involved in dealing with combinations of pollutants. The idea here is to demonstrate the process of budgeting for green cover. The steps are described below:

Step1 : Ascertain the total yearly emission of SPM in Delhi from various sources.

Step2 : From the data on the dust collecting efficiency of the chosen tree species per sq. meter of leaf area, determine the total leaf area required to collect the total SPM emission

Step3: Determine the leaf area of the particular tree species. Assume that the tree is fully grown. The species chosen is a species that has a dust collecting efficiency which is average of many other species

Step4 : Calculate the number of trees by dividing the total leaf area (Step2) by the leaf area of a single tree (Step3)

Step5 : Determine the ground area required to accommodate the number of trees as indicated by step4.

Step6 : Ascertain the total green area existing in Delhi under the jurisdiction of various municipalities.

Step7 : Compare the existing green cover area with the desirable green cover area from step5 and make suitable recommendations.

Step8 : Recommend a mix of species and the design of greenbelts for abating dust.

In case it is found that additional green cover is needed, then the study needs to be extended to determine the optimal locations of individual greenbelts. This is beyond the scope of the present study. But the same methodology as described for the entire Delhi region can be applied to determine area specific greenbelt requirements. This is because when pollution levels are different in different parts of the city, it would not be of much use if the entire green cover needed is provided in a single location . The green belts need to be spread out with concentrations near major traffic intersections, thermal plants and other sources of pollution. This is also because trees can best abate pollution if they are grown near the source of pollution. Therefore, green belts also need to be located in areas from where dust and other particulate pollutants enter the atmosphere. The green belt area required for a particular micro-area needs to be determined keeping in view the pollution levels in that particular area. Since data is available for both total pollution load in Delhi and also pollution loads at important locations therein, necessary calculations can be made. The general possibility of reducing air pollution are outlined.

The search for new solutions is obvious if we are to reduce air pollution sufficiently to maintain recommended air quality standards. A very complex situation has been greatly simplified by assumptions. The aim is to focus attention of city planners to the need to raise green belts with emphasis on pollution control in mind.

There are many agencies and departments in Delhi that maintain greenery under their respective jurisdiction. The area under green cover is summarised in the table III :

TABLE III : GREEN AREA STATUS

AGENCY	AREA
NDMC	1027 acres
DDA	4506 acres
MCD	5500 acres +9923 acres
PWD/CPWD	11800 acres
Dehi Admn (Horti)	700 acres
ASI	270 acres
Cantonment Board	178 acres
Forest Dept	19196 acres+ 2125 acres
TOTAL	**55225 acres OR 22358 hectares (approx.)**

The estimated emission of SPM in Delhi is 1,16,000 tonnes per annum.

The dust affecting efficiency of plants mostly depends on the morphological traits of leaves, such as epidermal and culticular features, surface geometry, phyllotaxy, orientation, size and area of leaf etc.The following plant species are considered as suitable for plantation in dust polluted areas:

TABLE IV : DUST COLLECTING EFFICIENCY OF PLANTS

Name	Dust collection efficiency g/m^2
Croton sp.	7.74
Mirabilis jalapa	8.13
Thespesia populnea	7.00
Tectona grandis	5.35
Shorea robusta	4.50
Terminalia arjuna	4.49
Polylthia longifolia	4.56
Ficus religiosa	4.15
Mangifera indica	4.05
Lagerstromia flosregeinal	4.04
Bahunia purpuria	3.90
Saraca indica	3.78
Ficus bengalensis	3.59
Ficus infectoria	4.09
Anthocaphalus cadamba	3.57
Butea frondosa	3.05
Azadirachta indica	2.92
Cassia fistula	2.24
Tamarindus indica	2.08
Poinciana regia	1.44

i. As an illustrative example, if Ficus religiosa is chosen for plantation, then for every Square Meter of leaf surface area, the tree can trap 4.15 gms of dust. The leaf area to collect 116000 tons of SPM works out to (116000* 1000*1000)/4.15=27951807228.92 sq. m The total leaf area of a fully grown single ficus tree is 20700000 sqcm or 2070sqm. Therefore the number of fully grown trees to abate the yearly SPM emission works out to 27951807228.92 sqm/ 2070sqm= 1,35,03289 [approx] trees. If 1 hectare can accommodate 100 standing trees, 1,35,03289 trees would need 135033 hectares or333532 [approx] acres.

ii. Area needed to be under tree cover = 333532 acres

Area under green cover by municipalities = 55225 acres

Deficit = 278307acres

Delhi's area is estimated as 1483 sq. Km.

1 sqkm=1000000 m. So 1483 sqkm is 1483000000m or 1483000 hectares or 3663010 acres
591 sqkm is 591000000 m or 591000 hectares or 1459770 acres

TABLE V : Green Area Table

Delhi's area (Total)	3663010 acres
Green area available	55225 acres (1.51% of total)
Green area essential	333532 acres (9.105%of total)
Deficit area to be greened	278307 acres (7.597%of total)

- [Note: The leaf area has been calculated by taking sample ficus trees from different locations in Delhi by a group of college students under instructions from the World Wide Fund for Nature, New Delhi. An average figure has then been worked out. A method of working backwards was used in that the number of leaves in sub-sub-sub branches were counted first. By working backwards the total leaf area was arrived at.]

5.7 Summary

Atmospheric contaminants may be removed by both soil and vegetative components of the ecosystem through a variety of mechanisms. Bare soil is shown as an important sink. Soil can act as a sink for particulate lead, trace metals including zinc, cadmium, copper, nickel, manganese, vanadium, and chromium. Soils remove pollutant gases from the atmosphere via several microbial, chemical, and physical processes. Gases that may be significantly removed by soils include carbon monoxide, sulphur dioxide, ammonia, some hydrocarbons, and mercury vapour. Like soils, vegetation too are sinks for both gaseous and particulate pollutants. The former are transferred from the atmosphere to vegetation by the combined forces of diffusion and flowing air movement. When once in contact with plants, gases may be bound or dissolved on exterior surfaces or taken up by the plants via stomata. If the surface of the plant is wet, and the gas is water soluble, the former process can be very important. When the plant is dry, or in the case of gases with relatively low water solubilities, the latter mechanism is assumed to be more important. Because of high solubility in water, large amounts of sulphur dioxide are absorbed on external tree surfaces when they are wet. In the dry condition, sulphur dioxide is readily absorbed by trees' leaves and rapidly oxidised to sulphate in their mesophyll cells. At low uptake rates, sulphur dioxide is presumed to be oxidised about as rapidly as it is absorbed. Caution must be exercised in extrapolating results of sink functions obtained from labs to trees in natural environments. Uptake under ambient conditions may be less than under experimental conditions. Nitrogen dioxide dissolved in water yields nitrite and nitrate ions in solution. The latter can be reduced to ammonia in leaf cells. The interception and retention of particles by plants depends on the size, shape, wetness, and surface structure of the particles as well as the intercepting plant part. Leaves with complex shape and large circumference- to- area collect particles most efficiently.

Generally it is considered that vegetation can reduce S.P.M. of 12 ug/m^3 over a distance of 200 m. Evergreen trees with simple leaves, having rough and pilose (hairy) surface are better dust collectors than deciduous trees with compound leaves having glaborous (smooth) surface; that Ficus, Mangifera, Tectona and Polyalthia are better dust collectors than Cassia, Poinciana and Sesbania sp. Plants serve as sinks of air pollutants and thus help to reduce air pollution through scavenging, although their capacity to do so varies with species. Leaf area is the main component of canopies and the leaf area index gives quantitative data on the depth of canopies. Leaf area index is defined as the total area per unit ground area and it is used to define canopies. The foliage area index gives both leaf and stem area indexes. Canopy is defined in term of height of supporting systems besides leaf and stem area.

5.8 Stomatal Uptake

Stomatal pores are small openings, typically approximately 10 um in length and 2 and 7 um in width when open, in the epidermal surface of leaves through which plants naturally exchange carbon dioxide, oxygen, and water vapour with the atmosphere. The waxy cuticle of leaf surfaces restricts diffusion, so that essentially all gas exchange carried out by leaves is via stomatal openings. Eventhough these openings make up only approximately

1% of the leaf's surface area, their orientation and mechanics prove to be nearly optimal for maximum gas diffusion in and out of leaf (Salisbury and Ross, 1978). Stomata undergo diurnal opening and closing with the pores of most plants opened within an hour of sunrise and closed by dark. The timing and degree of opening of stomatal apertures, and hence gas diffusion to and from leaves, is strongly influenced by a number of complex environmental factors.

During daylight periods, when plants' leaves are releasing water vapour and taking in carbon dioxide, other gases, including trace pollutant gases in the vicinity of the leaf, will also be taken in through the stomata. When once they are inside the leaf, these gases will diffuse into intercellular spaces and be absorbed on or in the surfaces of palisade or spongy parenchyma cell walls.

The rate of pollutant gas transfer from the atmosphere to interior leaf cells is regulated by a series of resistances. Factors controlling atmospheric resistance include wind speed, leaf size and geometry, and gas viscosity and diffesivity. Stomatal resistance is regulated by stomatal aperture, which is influenced by water deficit, carbon dioxide concentration, and light intensity. Mesophylic resistance is regulated by gas solubility in water, gas-liquid diffusion, and leaf metabolism (Kabel et. al., 1976). Because the rate of pollutant uptake is regulated by numerous forces and conditions, the rate of removal under field conditions is highly variable. If leaf characteristics, wind speed, atmospheric moisture, temperature, and light intensity, are quantified, the pollutant uptake rate can be estimated (Bennett & Hill, 1973; Kabel et al., 1976).

5.9 General Plant Uptake

In general, plant uptake rates increase as the solubility of the pollutant in water increases. Hydrogen fluoride, sulphur dioxide, nitrogen dioxide, and ozone, which are soluble and reactive, are readily absorbed. Nitrogen dioxide and carbon monoxide, which are very insoluble, are absorbed relatively slowly or not at all. The rate of pollutant removal is found to increase linearly as the concentration of the pollutant is increased over the range of concentrations that are encountered in ambient air and that are low enough not to cause stomatal closure.

Under controlled conditions wind velocity, canopy height, and light intensity, are shown to affect the rate of pollutant removal by vegetation. As previously stressed, light plays a critical role in determining physiological activities of the leaf and stomatal opening and, as such, exerts great influence on foliar removal of pollutants. Under conditions of adequate soil moisture, however, pollutant uptake by vegetation is judged as almost constant throughout the day, as the stomata remain fully open. Pollutants are absorbed most efficiently by plant foliage near the canopy surface where light-mediated metabolic and pollutant diffusivity rates are the greatest. Sulphur and nitrogen dioxides are taken up by respiring leaves in the dark, but uptake rates are greatly reduced, relative to rates in the light.

5.10 Recommendations

- Soils should as far as possible be left bare for them to act as pollutant sinks. Indiscriminate tiling of pavements in Delhi is a bad practice that needs to be severely restricted. Tiling also affects trees adversely by cutting off moisture for the roots and suffocating the trees by completely blocking off root aeration. Water stress in particular curtails the efficiency of trees as pollutant sinks. The other environmetal benefits of not tiling include:

  Drastic reduction in demand for cement, brick, gravel requirements which in turn would lessen dust emissions (SPM), lessen quarrying requirements, lessen the damage and degradation of top soil, more space for grass and other green cover, better groundwater recharge, lesser generation of malba during digging operations. If these factors are monetised and added to the cost of tiling, the amount would never justify even minimal tiling let alone indiscriminate tiling being witnessed in Delhi currently by the engineering wings of MCD, NDMC, PWD, DDA in the name of beautification. An enquiry into the cost of tiling a two kilometer stretch of pavements and road divider (central verge) of standard width four years back revealed an astronamical figure of Rs 22 lakhs excluding the cost of labour. The figure must be much higher. On the newly built ITO bridge over the Yamuna river, the pavements have been tiled inspite of the fact that the pedestrian movement is zero. The cost of tiling both sides would be in excess of Rs 50 lakhs. Not a single tree or shrub has been planted. In contrast the same space that has now been tiled could have been used for planting approximately 400-500 trees that could have mitigated pollution effects at fraction of the cost. The same can be said of many other roads in Delhi. Morever the engineering design of Delhi has become a model for other cities like Chennai, Bangalore, and Noida to emulate. The new engineering design has destroyed Noida's greenery without any reason. While corresponding with Delhi municipalities, Kalpavriksh used to provide photographs of green Noida pavements as examples to emulate. Instead of Delhi adopting Noida's green design, to our dismay Noida adopted Delhi's worst designs. Every inch of soil lost to concreting, represents the space lost permanently for greening.

Money saved by greening = Money spent in crores on tiling+ Saving in health cost+ Increased productivity of healthy people+ Savings resulting from prevention of degradation of hills and mountains, pollution of soil + Recharge potential of aquifers+Saving costs in disposal of malba (a form of solid waste)

- Trees should be chosen for their pollution control abilities including dust trapping. A combination of trees, shrubs and grasses should be grown. Grasses play a vital role in making the soil suitable for other vegetation to grow. No patch of soil, however small should be considered worthless. The common practice of uprooting grasses by horticulture departments should be stopped forthwith.
- Trees and shrubs growing under stressful road conditions invest a lot of energy to raise stems and branches. The regular practice of excessive pruning of shrubs in particular appears rather meaningless. Pruning of plants in a well nurtured garden and pruning of roadside plants cannot be equated. In a park that is monitored regularly, water and manure are provided for, whereas most of the roadside plants are left to fend for themselves. When this is the case, pruning makes life more difficult for the plants. Excessive pruning upsets the root:shoot ratio.
- Uncovered ground devoid of trees absorbs and emits more heat (as much as 10-20 times more) than the ground covered with vegetation. The ratio increases with cemented pathways, asphalt or tar roads. Trees are sensitive to the disturbed or altered conditions around them, whether the disturbances are of a physical, or edaphic nature.

- Because trees and bushes are many times more effective than lawns in absorbing CO_2, trees should get a major share in city landscaping. For every cubic feet of wood it grows a tree locks up 17.5 pounds of carbon. If that tree lives for 100 or 200 years, the carbon contained in its wood will not be added to the growing problem of atmospheric CO_2 build-up, the principal cause of global warming. Bringing additional area under trees will also mean availability of soil that can absorb methane and thus help in contributing to reducing the green house effect.
- It is now well recognised that the planting of trees along roadsides increases the perception of the motorists. Besides reducing the temperature of the asphalt surface, they provide shade and act as wind breakers, making car driving a more pleasant task. This is important for Delhi, where the number of automobiles is rapidly growing and the summer months are hot and prolonged
- The big old trees lining some of Delhi's roads indicate the species that can be used for regular planting. Being old trees, they stand testimony of their ability to withstand the variations of heat and limited water availability, due to covered pavements and widening of roads. The nutrient supply to the soil also is restricted due to regular cleaning of streets, preventing the collection of leaf litter near the base of the tree.
- Yamuna river front area should be developed as a green belt and not converted for commercial or other developmental activities.
- The foliage prevents sunlight from directly scorching the tar roads that leads to bleeding of road surfaces. The canopy also breaks the impact of rain drops and prolongs road life.
- Green area requirements have been computed by considering a single species of tree. However, a mix of plants tolerant to air pollution have to be planted. The dust collecting efficiency of a mix of plants would vary from that of a single species. But this should not affect green area requirements because annual SPM has been considered and not monthly or daily emissions. The yearly figure provides a safe buffer.
- Other recommendations to mitigate pollution that are not linked to greenery include early implementation of the Mass Rapid Transport System (MRTS), improving the public transport system to prevent use of

private vehicles, increasing average speeds by better traffic and traffic signal managements. Emissions increase at low speeds consequent to bumper to bumper traffic movements.

The plants suitable to be grown under stress of air pollution are shown in tables VI,VII,VIII.

Table VI : Deciduous Trees arranged in decreasing order of their Air Pollution Tolerance Index (APTI) determined on the basis of leaf extract pH, ascorbic acid, total chlorophyll and relative water contents (RWC)

Plant species	**Total Chlorophyll (mg/g dry Wt)**	**PH**	**Ascorbic acid (mg/g dry Wt)**	**RWC %**	**APTI**
Ficus religlosa	15.21	8.2	10.65	87	34 x 2
Albizzia lebbek	8.22	6.2	18.44	47	31 x 2
Cassia fistula	7.01	5.9	15.84	63	27 x 2
Phyllanthus distichus	8.59	5.7	17.07	27	23 x 2
Zizyphus jujuba	9.95	6.0	9.89	74	19 x 2
Azadirachta indica	7.05	6.2	12.21	74	19 x 2
Phyllanthus emblica	9.37	6.2	8.27	64	19 x 2
Sapindus mukorossi	5.27	7.0	8.21	68	16 x 2
Tamarindus indica	6.85	4.0	6.00	86	15 x 2
Psidium guyava	6.22	6.2	5.10	73	14 x 2
Morus alba	2.96	5.4	6.08	64	12 x 2
Moringa oleifera	6.08	6.1	2.99	87	12 x 2
Anthocephalus cadamba	7.62	5.1	2.95	81	12 x 2
Bombax ceiba	3.79	6.2	2.66	68	10 x 2
Madhuca indica	4.73	5.6	2.51	67	9 x 2
Aegle mormelos	3.05	6.0	1.62	74	9 x 2
Feronia elephantum	2.02	5.8	1.34	75	9 x 2
Cordia myxa	5.51	8.3	2.54	42	8 x 2
Delonix regia	5.96	6.2	2.55	34	7 x 2
Bombusa bombos	12.16	5.7	1.41	30	6 x 2
Butea frondosa	4.72	6.3	1.61	34	5 x 2
Tectona grandis	5.59	7.2	0.35	48	5 x 2
Dalbergia sissoo	5.13	6.6	0.94	18	3 x 2

[Data from : Singh and Rao 1983]

Table VII : Evergreen trees arranged in the decreasing order of their Air Pollution Tolerance Index (APTI) determined on the basis of leaf extract pH, ascorbic acid, total chlorophyll and relative water contents (RWC).

Plant species	**Total Chlorophyll (mg/g dry Wt)**	**PH**	**Ascorbic acid (mg/g dry Wt)**	**RWC %**	**APTI**
Ficus glomerata	**18.89**	**8.4**	**9.41**	71	32
Pithecelobium dulce	**17.21**	**6.0**	**8.35**	87	28
Polyalthia longifolia	**6.56**	**6.0**	**8.75**	78	19
Ficus infectoria	**6.58**	**7.9**	**7.51**	76	19
Nerium odorum	**2.39**	**6.0**	**8.17**	84	15

Plant species	Total Chlorophyll (mg/g dry Wt)	PH	Ascorbic acid (mg/g dry Wt)	RWC %	APTI
Eucalyptus citriodora	4.59	5.2	6.61	85	15
Ficus infectoria	7.81	7.2	5.12	68	15
Leucaena leucocephala	10.41	5.7	4.42	72	14
Mangifera indica	3.89	5.2	4.12	72	11
Anona squamosa	4.66	5.4	4.11	60	10
Syzygium Jambolana	7.07	4.5	2.86	68	10
Acacia arabica	2.54	6.1	3.94	54	9
Artocarpus heterophyllus	6.39	6.2	3.12	48	9
Alstonia scholaris	3.68	6.5	2.89	64	9
Grewia aslatica	1.85	5.6	2.10	74	9
Casuarina equisetifolia	0.75	5.3	1.79	65	7
Nyctanthes arbortristis	6.96	6.8	1.46	34	5
Litchi chinensis	1.74	6.1	0.70	40	5

[Data from : Singh and Rao 1983]

Table VIII : Shrubs and Herbs, arranged in decreasing order of their Air Pollution Tolerance Index (APTI) determined on the basis of leaf extract pH, ascorbic acid, total chlorophyll and relative water content (RWC)

Plant species	Total Chlorophyll (mg/g dry Wt)	pH	Ascorbic acid (mg/g dry Wt)	RWC %	APTI
Shrub :					
Bougainvillea spectabilis	12.64	6.0	13.36	70	32
Calotropis gigantea	13.58	6.3	9.34	63	25
Poinsettia pulcherrima	17.63	5.9	7.41	77	25
Ricinus communis	18.80	6.0	5.35	83	25
Rosa indica	4.75	5.6	9.25	71	17
Calotropis procera	5.07	6.1	8.64	61	16
Duranta plumieri	8.00	5.7	6.10	69	15
Murraya exotica	6.67	6.1	8.64	61	16
Lantana indica	5.52	7.5	2.33	33	6
Lagerstromia indica	2.56	4.3	0.34	42	4
Carissa carandas	2.52	5.7	0.80	63	3
Herb					
Vinca rosea	9.43	5.8	19.5	75	37
Croton tiglium	12.29	6.0	9.33	78	25
Argemone mexicana	22.48	6.2	5.14	63	21
Ageratum conyzoides	23.81	6.6	3.33	64	17
Phyllanthus niruri	5.68	5.5	7.96	78	17
Clerodendron	6.57	5.7	9.34	48	16

Plant species	Total Chlorophyll (mg/g dry Wt)	pH	Ascorbic acid (mg/g dry Wt)	RWC %	APTI
infortunatum					
Ocimum basilicum	6.23	6.1	4.50	73	13
Cynodon dactylon	11.55	6.2	1.50	66	9
Leucas aspera	5.98	6.9	2.93	54	9
Musa sapientum	2.33	6.4	3.14	57	9
Ipomoea cornea	8.54	6.2	1.76	68	9
Euphorbia hirta	12.25	5.9	1.90	55	9
Dichanthium annulatum	10.43	6.2	0.91	50	7
Chrozophora sp.	5.57	5.9	0.31	38	4

[Data from : Singh & Rao 1983]

5.11 Assault On Trees In Delhi

Planting trees is not an environmental panacea; but a step in the right direction. Trees need space to grow and space is scarce in a metropolis. Crowded and congested areas are the ones that need greenery the most. There are two aspects of tree space-- above and below the ground--and both are important. The above-ground space needs are more obvious in that tall trees should not be grown directly beneath power lines or building overhangs. Trees should be kept atleast 10 ft away from building foundations. Below the ground space is difficult for most people to understand. Trees not only have deep taproots; a majority of its roots are concentrated within the top one foot of the soil. The horizontal reach of the roots can be more than twice as much as the height of a tree . The whole tree, when fully grown, has a profile of a wine glass set on a table. This means that roadside trees must be given far more root space than often is the case.

Roots need aeration and moisture. During monsoon, the deep roots are submerged in the rising water table and the tree totally depends on the superficial roots. But when soils on pavements are severely compacted or as in most cases in Delhi, they are completely sealed off with cement and concrete slabs, or with tiles, the superficial roots do not get any oxygen. For this reason, even fully grown trees start withering away during the monsoon when, infact, they should ordinarly be in very good health.

Kalpavriksh has documented tree deaths in the last few years because of indiscriminate tiling of foot paths. It has been documented that, in Delhi, the vehicular traffic is very heavy on most roads whereas the pedestrian load is almost negligible except on certain roads. The logic of having a single design of pavements is therefore beyond comprehension. Without studying the pedestrian load, footpaths on every road including colony roads are being tiled in the same manner as footpaths that are heavily used. The complete sealing of bare soil has taken a heavy toll of the trees. It is true that every road requires a footpath for pedestrian safety, but this does not mean that every footpath needs to be covered with concrete slabs. Even on heavily trampled pavements where tiling is desirable, alternatives like porous tiles may be used. The majority of the pavements can be left green and grassy.

A brief note on tiling brings out clearly the needlessness and the wastefulness of this process. The tiling process starts with making space for tiles to be placed. To create this space, the top soil is removed from around the base of trees, resulting in severe damage to the superficial roots. Many roots stand exposed to the elements. The space created by removal of the soil is packed with a mixture of stones or bricks, cement and badarpur. The surface is then levelled with a mixture of cement and water. Finally the surface is completely sealed with placing concrete cement slabs. On a typical summer in Delhi, when day time temperatures touch 43 degrees Celsius, the tiles absorb heat and become so hot that walking barefoot on them would be impossible. One can only imagine what happens to the tree roots that lie beneath the tiles. Excessive heat, no air and no water for the roots-- the tree stands no chance of survival. Cement dust, that flies off, also affects the leaves, especially of the lower vegetation like grasses and shrubs. Cement dust is a heterogeneous mixture of calcium, potassium, aluminium, silica, and sodium oxides that affects vegetation. Calcium silicate and calcium aluminate present in the cement dust form colloidal gels which, after crystallisation and solidification, develop into a hard crust. Such a crust makes the surface of leaves compact and impervious to water. This upsets their physio-chemical properties, thereby altering the biological activity.

Every material used in the tiling process -- be it stones, bricks or badarpur, is a natural extraction that inflicts ecological damage when it is extracted or made. For example, the stones used are extracted from the nearby Aravallis, where excessive mining has resulted in degradation of the mined sites. The boulders extracted are broken and crushed. Stone crushing is again an activity that leads to excessive air pollution. Instead of stones, bricks are also used. The severe damage to environment from brick kilns are well known. Badarpur extractions create huge craters. The cement industries that provide the cement are known to be polluting industries. Thus, all the materials used in tiling ravage nature since most of them are natural extractions. When such items are mixed and put into the soil, the soil also stands completely ravaged. But since soil has been a neglected area, specially in urban areas, the preciousness of the soil goes unrecognised. Soils cannot be made by humans but certainly we can destroy them.

In Delhi, the demand for items like cement, stones and badarpur is already very high, owing to the large amount of building activities. The effort of urban bodies should be to curtail their use in avoidable constructions like concrete pavements. Pavements add upto a very large area and they are the only spaces available for greenery in a city, besides public parks. But if soils stand destroyed, where is the question of greening Delhi. And tiling ends up in killing trees and depleting water tables by not allowing water percolation.

Finally, in an ever expanding city like Delhi, pavements are constantly dug out/ tiles are uprooted and relaid for some reason or the other. Many a times, the quality of construction is so substandard that pavements disintegrate inspite of low pedestrian load. This presents a very unaesthetic picture. The irregular pieces of solid waste that get generated from the uprooting of tiles add up to a huge and heavy bulk. The disposal of this waste poses a problem for municipalities that are already reeling under pressure for removal of the city garbage. On several occasions the dug out wastes are simply dumped on the existing greenery or used as landfill. They cannot be used for relaying of tiles. For this, fresh materials are once again requisitioned for. In this way, tiling is an activity that kills trees, and is destructive of environment at every stage of production, use and disposal. It is not a once for all activity as it is made out to be. Tiling is also a huge drain on the financial resources. The cost of paving varies between Rs 800 to Rs 1000 per square metre, depending on the work. The cost of making a one-kilometre stretch of pavement of one-metre width works to around Rs 10 lakhs. The end result of such a colossal waste of natural and financial resources is the death of healthy trees. Kalpavriksh has highlighted this issue in the print and electronic media. It has also written letters at many different official levels and raised awareness through education in schools. School children have also participated in direct action in the form of removing tiles from suffocating trees. But, unfortunately, the engineering wings of the various municipalities are continuing to tile relentlessly without any letup.

Concentrating efforts on beautification through concrete constructions in Delhi seems totally inappropriate at a time when living in the city has become unhealthy due to toxic levels of pollution. When people are dying due to pollution, it is criminal to divert funds and resources to beautification rather than initiating steps to mitigate pollution on a war footing.

THE STORY OF A ROADSIDE TREE : *I was bom in a forest nursery and was delighted to leam that I was among the batch of tree saplings being sent to Delhi to adom its roadside. Much of the delight was due to the fact that living and growing up in the forest had become very unsafe now. I lost my parents to the greed of timber contractors. Life in the protected forest had become quite unprotected. Part of the delight was due to the fact that I was being sent to the nations capital city. I had heard of the good city life and it was like a dream come true. I was loaded on to a lorry and landed in Delhi in the early hours of the day. It was peak winter and I had expected that I would be kept in a nursery till the winter months had passed. But the newly built bridge over the river had to be inaugarated by the minister before the elections and so I along with my friends were chosen to be planted on the pavements. By sheer chance I landed up on the road divider. The engineers had not left any space for plantations and had tarred or tiled every inch of bare soil. Small holes were made for our plantation and we landed up one each into designated potholes. We were standing alone with no companions like grass, shrubs and other bushes. For the first few days water was provided and some dried crusted pieces of dung (supposed to be manure for us) were placed near our base. The pieces remained their for some days without disintegrating but one evening the construction workers collected them and made a bomfire to keep the cold away. The day-night temperature difference was not much and we remained without growing in the wintery conditions. Wind scattered leaves from far away trees sometimes landed up in our pothole but they were promptly removed the very next day by the horticulture staff in their effort to keep the place clean. In the forest, leaf litter was our main food but I thought it was a small sacrifice to be made in order to live in the nation's capital. The bridge was inaugurated and thrown open to the traffic. Vehicles in both directions moved past in a never ending chain spewing their exhaust directly on us. During the day it was fumes from petrol driven motors and at night the deisel driven commercial vehicles. Slowly the days started becoming warmer but the nights remained very cold. The variation in day-night temperature of around 12 degrees celsius affected many plants. With the rising daytime temperature, the roots of young saplings like us were subjected to heavy loss of water due to transpiration while the soil rendered very cold during night prevented absorption of water. As a result, many of the seedlings (which naturally have superficial root systems) dried up. By sheer chance some of us survived. The temperatures – both day and night, started soaring. Watering became a totally neglected activity. Luckily for us there were some unseasonal showers that lashed the city periodically. We also thought that how difficult it would be to transport water over long distances in a city just to water some plants. But we were proved wrong. They did transport water over long distances to repair or lay tiles on pavements. After all tiles are more important than trees! But we consoled ourselves by telling each other that when city people remain without water for several days, is'nt it too much expecting water for saplings. After all humans do come first in the scheme of things! Some water did manage to trickle in from the quantity used to wet the cement nearby. But this could not be used by us because* *the soil had become very compacted. Even root aeration was rendered difficult. That is why tree cover is helpful for other tree saplings to grow. The city people dont understand. As far as soil is concerned, they have no idea. It's a fact that the daily variation in ground tempearture is much higher in the denuded areas compared to land under trees; the soil is also less protected from the torrential rains. Soil temperatures remain higher at all depths from 5 to 50cm. in the bare soil, slightly less under grassland and lowest and the least variable under mixed forest. Higher soil temperature increases the rate of mineralisation of the organic matter, impairs the stability of the soil crumb structure, making the soil easily erodable.*

What surprised us was that the landscape approach was only talked of but never implemented. It is a simple approach that has roots in landscape ecology. Landscape may be defined as kilometres wide area with patches of a variety of habitats that get repeated. Landscape ecology itself is considered as the ecology of patches. The landscape approach stands on one basic principle that no patch of habitat is an island'. All habitats are open and as they supply, as well as receive from, other habitats energy and nutrients, they are made ***interactive****. Thus in any landscape all patches of habitats or biological elements* ***interact****. This means that any landscape is to be treated as a unit, how ever heterogeneous it is.*

The basic principle that patches interact in a landscape opens up an entire avenue to environmental planners. The first moral is that no habitat patch, whatever be the size, is to be considered useless. For example, a small grove of trees can shelter a few species of small birds (sunbirds and flycatchers). These birds are not however confined to this patch because they fly about and visit adjacent patches. When a bird species start utilising two different habitat patches in a landscape to satisfy its vital needs, these patches become interactive. Environmental planners must take advantage of such simple habitat patch dynamics.

Habitat patches interact better if linked with each other by corridors (like a set of avenue trees). This is the least expensive and most feasible way. Planting trees in vacant spaces is one of the best strategies. Species of Ficus are some of the longest living keystone species among trees. But in Delhi the obssession with tiling is so much that any patch of bare earth is converted to concrete in the relentless tiling operations that continue throughout the year with no let up. The importance of soil is not known to city dwellers -- how soils are formed, nutrients in the top soil and so on. Within no time free soil is converted to concrete surface. Habitat ecology, soil science, role of greenery in urban areas are topics to be discussed in close door seminars.

But we trees are hardy creatures. We try and battle it out for our survival. Some species do a better job than some others. Some just give up and perish. But all of us suffer as a consequence of human doings. Out of the 400 odd saplings planted, around 80 of us survived the first year. We gained in height and slowly went past the height of the tree guards. Vehicles passing on both sides made us sway in all directions. In the process our bark frequently made contact with the sharp metal rim of the tree guard. The rim slowly cut into the bark and some trees got completely cut and came crashing down with their small crown. Only long stubs were left inside the tree guards. In this way, some trees were as good as perished (but technically not dead). Windy days made matters worse. All of us had injury marks (thinning of tree trunk) at the point of contact with the tree guard. It is a wonder that benign tree guards with appropriate design and material cannot be used. A tree guard meant for our protection became the cause for our death. Some NGO people did complain to the horticulture department and after much persuasion the remaining tree guards were reluctantly removed. But not before many trees perished in the meantime. Some of us who survived this ordeal, grew slowly for want of good soil and nourishment. When our barks became stronger, signboards of various kinds were nailed onto us, including bus route boards. Twentyfour hours non stop highway traffic spewed all kinds of pollutants on to us. No part of us was spared. Thus our bark, our leaves, our stems were all adversely affected. Then one fine morning there was a further assault on our root system, in the form of re-tiling. Assault over the ground *good for humans. Only ten of us survived to tell this story. Our branches were recklessly lopped for some flimsy reason or the other. The hedges planted on the opposite side were also subjected to the same cruelty. They grew painfully slowly by investing their energy in raising branches. But they were seasonally pruned heavily -- for beautification of roadsides. By springtime they could not recover enough. Pruning is no doubt a horticultural practice. But it cannot be done in isolation. In well maintained parks and gardens pruning is done carefully and all other requirements of water, manure, good soil etc. are taken care of. But on neglected roadsides where no other help is given to the greenery (infact negative factors abound), just resorting to pruning is totally ill advised. But then who are we to complain. Humans know best about us. We are supposed to grow from small holes in the midst of concrete. A real miracle indeed.*

At this rate, the slogan of GREEN DELHI can only remain on the thousands of such signboards that dot the city. Perhaps the greening for city people will come through these green painted boards atleast.

A small note on bushes before I finish. Open spaces are not wastelands. Fallow land with thorny bushes and scrub have their own community of birds like warblers, babblers, and so on. They have to be maintained. Bush birds cannot use huge trees for nesting and roosting. Without the thorny bushes such birds will perish. A little care in order that they are not destroyed will make a lot of difference, and for the better, to birds. The birds would in turn enrich our daily life.

If living in protected forest areas had become unsafe, living in a city against all odds has become a cruel experience. We have become topics for seminars and workshops on forestry, biodiversity, wildlife, urban ecology and so on. In forests we are supposed to perform valuable ecosystem functions, and in urban areas we are supposed to cleanse the air of pollutants and beautify the landscape. But just see the conditions provided to us. Trees are not safe in forests; they are not safe in the cities. Where do we go from here.

5.12 CONCLUSIONS

Delhi is a classic example of the biological instability arising from ecosystem simplification resulting from human activity. The productive potential of the life supporting natural resources base of air, water and soil have greatly diminished. Nature's resilience and it's ability to perform the basic functions have been affected. The human demands on Delhi's environment is increasing without limits. Some control must absolutely be set if we are to have a healthy functioning of Delhi's ecosystem.The baseline is that the supporting capacity of an ecosystem should never be allowed to be violated. For example if we desire to have a clean Yamuna flowing in Delhi, the fisrt requirement is to ensure the flow of a certain minimum quantum of water. If we add/release pollutants into the river system, the flow quantum has to be enhanced in order to wash out the effect of pollutants. But we cannot without any limit keep releasing effluents because the flow quantum cannot be raised indefinitely. But if the entire water that flows into Delhi is impounded for human use and simultaneously huge quantities of untreated effuents are released downstream, then we can never have a clean river. This must be clear to one and all. We have to allow water to flow and simultaneously control discharges keeping in mind the assimilating capacity of the river and the water needs of the different species of aquatic living resources. For this to happen, people in the city have to practice harvesting of rainwater, facilitate recharge of acquifers, adopt conservation measures in their offices and homes. But if we go on doing buisness as usual, open the tap and expect water to flow instantly, then indeed we are living in a fools paradise. We will not allow water to flow in the river, we would continue to release untreated effluents --then we have to live with a dead river. The river cannot cleanse itself magically. All talk of river action plans sound hollow if we do not try and understand the river basics.

The interconnectedness in nature and the concept of an integral biosphere should guide the basic designing of cities. If we ruin the countryside to provide resources for the cities, it would be a self defeating process.

References:

Master Plan Delhi 2001, Delhi Development Authority

Rao,D.N, Sharma, J.P & Singh,U.R. Ed. Air pollution-- Problems and perspectives, Environmental Planning and Coordination Organisation, Bhopal, 1983.

Beckham, Nancy (1992) The value of an Urban tree, Indian Bioligist XXIV (1), II.

Krishna Kumar, Sastry, A.R.K., Chatterjee, Sudipto and Usha, M (1996) Air Pollution : Plants as means of Control, Presented at Workshop on Selection of Plant Species for Pollution Abatement by ACF, Oct. 1996, New Delhi.

Singh, S.K. and Rao D.N. (1983) Evaluation of Plants for their tolerance to air pollution. Procs. Symp. On Air Pollution Control Vol I Indian Assoc for Air Pollution Control, New Delhi pp 218-224.

Varshney, C.K. (1985) Air Pollution and Plants. Ministry of Environment and Forests, GOI, New Delhi.

Varshney, C.K. (1996) Greenbelt for Environmental Improvement. Workshop on Selection of Plant Species for Pollution Abatement by AFC, Oct. 1996, New Delhi.

Sigurd Schulte - Hostede, Nancy M. Darrall, Lutz W. Blank, Alan R. Wellburn Ed. Air Pollution and Plant Metabolism. Elsiver Applied Science London and NY. 1988.

Grace J. Ford, E.D. & Jarvis, P.G Ed. Plants and their amospheric environment. 21st Symposium of the British Ecological Society. Blackwell Scientific Publications, London 1981.

Howard E. Hesketh Understanding and Controlling Air Pollution II edition, Ann Arbor Science Publishers INC Incorporated, Michigan 1974.

Methods of Measuring Air Pollution : Organisation for Economic Cooperation and Developmen, Paris 1964.

William J. M. & Feder, W.A. Biomonitoring Air Pollutants with Plants, Applied Science Publisher, London, 1980.

Misra S.G. & Tiwari S.D. Air & Atmospheric Pollutants, Venus Publishing House, New Delhi, 1992.

Agarwal,S.K. Pollution ecology,.Himanshu Publications, 1991

Mudd,J.B. & Kozlowski.Ed. Response of plants to air pollution, Academic Press N.Y. 1973.

Kabel,R.L, O'Dell, R.A, Taheri,M & Davis, D.D. (1976): A preliminary model of gaseous pollutant uptake by vegetation. Centre for Air Environment Studies, Publ. No. 455-76, Pennsylvania State University, Univ Park, Penn. ,USA 96pp.

Bennet J.H & Hill,A.C (1973) Absorption of gaseous air polluants with canopies of vegetation pp 273-306 in Responses of plants to air pollution. Eds Mudd J.B &Kozlowski T.T),Academic Press NY

Tingey,D.T, Reinert,R.A (1975): The effect of ozone and sulphur dioxide singly and in combinations on plant growth. Environmental Pollution, 9, pp117-125.

Salisbury, F.B & Ross C.W(1975): Plant Physiology. Wadsworth, Belmont, Calif. USA 422pp.