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National and Regional-Level Human-Environment (Ecosystems) Interactions: Some Empirical Evidence from China

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ABSTRACT *The state of human-environment (ecosystems) interactions—ecosystems (land cover classes), population, biodiversity hotspots and protected status—is examined in the eastern coastal zones, the eastern region, the middle region, the western region and the whole of China. The analysis is based on consistent, comprehensive, geo-referenced and recent datasets and advanced analytical Remote Sensing and Geographic Information System (GIS) techniques. A comparative national and regional priority ranking of the provinces was conducted using the total score of eight indicators, for the four dimensions of human-environment (ecosystems) interaction. Using, these ranks, all the provinces were grouped in low, high and medium priority provinces. The comparative ranking and categorization of provinces will be useful for designing policies and management operations for spatially-differential scientific planning and management of environment (ecosystems) at the regional and national levels in China.*

Introduction

Environmental resources are as critical as human or capital resources for economic development. Agenda 21, during the Earth Summit in Rio de Janeiro 1992, clearly recognized this interdependence of environmental resources and economic development by accepting: "peace, development, and environmental protection are interdependent and indivisible" (UN, 1992, p. 147). However, human activities are the greatest direct threat to environmental resources, and the adverse effects of increasing population and human activities on the environmental resources are accumulating dramatically, which is threatening the very foundation of sustainable development (Singh *et al.*, 1999). Human-environment (ecosystems) interactions have attracted the attention of a wide variety of scholars, and some of the noticeable outputs of this discussion have been the identification of 'biodiversity hotspots', which identify threatened areas of rich biological diversity (Myers *et al.*, 2000;

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Brummitt & Lucghadha, 2003), and 'red data maps', which designate areas of 'critical environmental situations' (Mather & Sdasyuk, 1991).

The issues related to environmental resources are global and national, as well as local, and these issues require attention at all levels. Environmental issues are more critical for sustainable development of developing countries, specifically in China (an emerging economic giant of this century) due to multi-dimensional—highest economic growth and highest population—pressure on environmental resources. As a result, these issues have received a great deal of attention at both regional and national levels in China (Zhao, 1998; *China Daily*, 2000a). With increasing globalization, economic power and membership of the World Trade Organization (WTO), the environmental issues have come to the forefront of global discussions on economic development in China. Various scholars (e.g. Qu, 1984; Qu & Li, 1992; Wang, 1993; Chen, 1996; Liu & He, 1996; Lu, 1997, 1998; Wang, 1997; CERN, 1998; Sun *et al*., 1998; SEPA, 1998; Liu *et al*., 2003) have discussed multiple dimensions of environmental issues in China. However, most of these studies have generally dealt with 'site specific issues' examining small areas or focusing on individual issues. Consequently, extrapolation of the results of such studies to large areas has been limited in scope. Some studies (such as CAS, 1989; Qu & Li, 1992; Liu, 1996; Lu, 1997; Zhao, 1998) have attempted a broader picture, but these are based on the aggregation of data from different administrative units compiled by different sources that provide data with differing precision and accuracy. Some of these datasets are often old and based on different definitions and classifications, and therefore are not compatible. Hence the overall precision and accuracy of the results, based on non-compatible datasets, is questionable.

This paper focuses on human interactions with the environment (ecosystems), an important dimension of environmental issues in China, and four aspects of these interactions are addressed: distribution of different ecosystems or land cover classes, population pressure on these ecosystems, biodiversity hotspots in these ecosystems and protection status of ecosystems and biodiversity hotspots. The main objective of this study is to provide a comparative picture of these four dimensions at national and four regional levels: the eastern coastal zones, the eastern region (including eastern coastal zones), the middle region and the western region of China. It is expected that this comparative picture, based on consistent and reliable data, will provide basic inputs for environment (ecosystems) planning and management at national and regional levels.

The analysis is based on a consistent, comprehensive, geo-referenced, multi-band and recent dataset, collected through the Advanced Very High Resolution Radiometer (AVHRR) and obtained from the National Oceanic and Atmospheric Administration (NOAA). The same data source is used for all analyses in this study. In addition, the advanced analytical Remote Sensing and Geographic Information System (GIS) tools such as temporal image composting, multiple-spectral analysis, modified mixture analysis, geographical stratification and multiple layer overlaying analysis are used for the digital data analyses of different ecosystems. Such data sources and analyses provide a scientifically credible environmental (ecosystem) assessment covering large areas.

The next section describes the selected regions of China. Details of data, sources and methodology of data analysis are then provided. The following section gives a

comparative picture of the four dimensions of human-environment (ecosystems) interactions and a comparative rank of environment (ecosystems) at national and the four regional levels. This discussion highlights the importance for the study of these four aspects, and a comparative empirical overview of the four dimensions at national and the four regional levels is provided. The final section discusses the significance of these outcomes for environmental (ecosystems) planning and management.

The Eastern Coastal Zones, the Eastern Region, the Middle Region and the Western Region of China

The eastern coastal zones are defined as any land within 100 km of the buffer from coastline (Figure. 1). Fifteen provinces (or area and municipality under the Central Government) have coastal zones, which are Anhui, Fujian, Guangdong (including both of Hong Kong & Macau Special Administrative Region), Guangxi Zhuang Autonomous Region, Hainan, Hebei, Heilongjiang, Jiangsu, Jilin, Liaoning, Shandong, Shanghai, Taiwan, Tianjin and Zhejiang, and this area of 15 provinces is known as the eastern region (the geographic area including the eastern coastal zones). The western region includes Loess Plateau, Northwest Desert, Inner Mongolian Grassland and Tibetan Plateau, and in terms of administrative units it includes Shaanxi province, Gansu province, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region, Inner Mongolia Autonomous Region, Qinghai province and Tibet Autonomous Region (see Figure 1). In the study, the remaining provinces, Beijing, Guizhou, Henan, Hubei, Hunan, Jiangxi, Shanxi, Sichuan (including Chongqin) and Yunnan, are called the middle region.

The eastern coastal zones and the western region were highlighted on the map and also emphasized in the analysis because of their unique features of human and environmental (ecosystems) interactions. The boundary of the eastern region and the

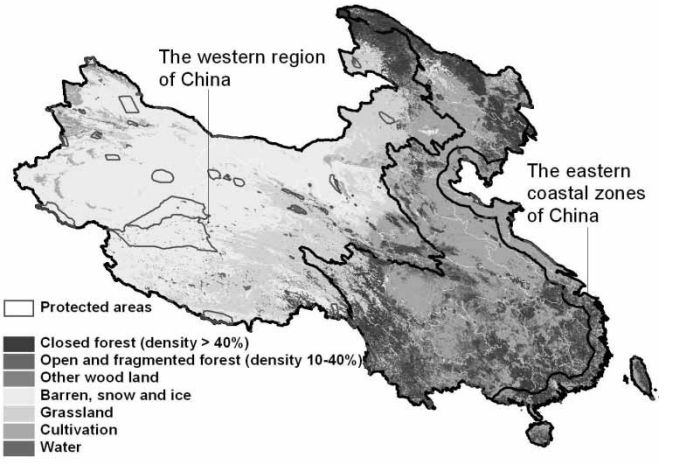

Figure 1. Land cover distribution of China with protected areas

middle region were not shown on the map. The eastern coastal zone is one of the most crowded and developed areas of China. Many parts of this area have had the fastest growth in population over the last 20 years, due in part to rapid economic growth. In comparison, the western region of China has fallen behind economically and is ecologically fragile due to various historical factors, the inland geographical location and a dry or cold environment (cold, arid and semi-arid ecosystems) (Hu, 1997; Zhao, 1998; Shi, 1994).

Data Sources and Methodologies of Data Analyses

The study has four components: an estimation of the area of different ecosystem (land cover) types including forests and other vegetation cover; an estimation of the pressure from the human population; an estimation of biodiversity hotspot areas, and an estimation of protection status of ecosystems and biodiversity hotspots. Next there is an overview of five data sources used in this study.

Political boundary data, including regional (or provincial) boundaries data within China, was taken from the US National Imagery and Mapping Agency's (NIMA) Vector Map Level 0 series CD-ROM. The International Geosphere-Biosphere Programme Data and Information System's (IGBPDIS) global land cover database (Loveland *et al*., 2000) was used as a base source for data on land cover classes. The geographically referenced population database was provided by the United Nations Environment Program UNEP/GRID which is based on the World Resources Database of 2000 (WRI, 2000). The UNEP-World Conservation Monitoring Center provided the protected areas database.[1] The Conservation International provided the data for biodiversity hotspots.[2]

The IGBLDIS global land cover database has been built on characteristics of vegetation seasonality determined in terms of the weekly composite of Normalized Difference Vegetation Index (NDVI) derived from the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (AVHRR) sensor data. In the database, unique NDVI signatures and associated attributes, such as terrain and eco-regions, characterize large area forest cover patterns (Singh *et al*., 2001; Zhu & Waller, 2003). The database were used to develop a map of forest cover in China, for the year 1995, according to the Food and Agriculture Organization (FAO) forest classification system (FAO, 1995). During the preparation of the forest cover map, the data were processed using several Remote Sensing and GIS software systems (ESRI; ERDAS).[3] Most of the data analysis was done in the GRID module of ArcGIS. Raster and vector data layers were in an Interrupted Goode Homolosine Projection, which is an equal area projection. This map of forest cover in China for 1995 was used to calculate areas under three forest classes, namely closed forests (density $> 40\%$), open and fragmented forests (density $10-40\%$), and other woodland, whereas the area under other land covers—grassland, cultivation and water—was taken directly from the IGBP DIS global land cover database.

In the next stage, the different data layers were analysed jointly in order to examine possible interrelations or possible spatial relationships among them. For example, the political boundaries grid of the western region, the eastern coastal zones and all of China, were combined with the population grid. The number of

people were counted for the focus regions and the whole of China, and the areas having a population density of less than 25 people/km^2, 25 to 100 people/km^2, and $>$ 100 people/km^2 were classified as low, medium and high population pressure areas. Similarly, land cover, hotspots and distribution of protected areas in the four regions and over the entire country were estimated by combining the political boundaries grid with the land cover distribution grid, hotspots grid and the protected areas grid, respectively.

A comparative ranking of human-environment (ecosystem) interactions is essential to assign regional and national priorities and provide bases for policy makers. The four critical dimensions of human-environment (ecosystem) interactions in a given geographical area are: (1) the status of habitat in the area which can be represented by the extent of closed forests and other vegetation cover in the area; (2) the human population pressure on the area; (3) biodiversity hotspots; and (4) the human efforts made to protect the habitat and other land use. Therefore, a method was used for comparative ranking that included all the four dimensions.[4]

The identification of suitable indicators for each dimension was the first step in comparative ranking. It was decided that at least two indicators were essential for the measurement of each dimension. However, as far as protection efforts are concerned, it may be useful to examine the protection status of land areas other than closed forests and other vegetation cover. Biodiversity hotspots only have one indicator due to lack of information. Hence, a total of eight indicators were identified:

(1) closed forest as a percentage of total land area;
(2) other vegetation cover as a percentage of total land area;
(3) protection status of closed forest as a percentage of closed forest that is protected;
(4) protection status of other vegetation cover as a percentage of other vegetation cover that is protected;
(5) protection status of other land in percentage of other land that is protected;
(6) population density in the areas;
(7) percentage of the area that is under high population pressure; and
(8) biodiversity hotspots as a percentage of total land area.

The suggested method was for relative ranking, and therefore the mean values of each indicator were calculated separately for the four regional levels and the national level. In the case of comparative ranking at the regional level, the value of each indicator for a given province was compared with the mean value of the indicator for the region. In this comparison, if the value of an indicator for a given province, for items (1), (2), (3), (4) and (5), was less than its mean value for the region, the indicator was scored as 1, otherwise 0; similarly, for the indicators of items (6), (7) and (8), if the value of an indicator of a given province was greater than its mean value for the region, the indicator was scored as 1, otherwise 0. In the absence of any creditable criteria of assigning different weights for these eight indicators, equal weight was assigned for each indicator. On the basis of each indicator's score for a given province, the total score was calculated for each province, and the provinces, within a region, were ranked on the basis of the total score of the eight indicators.

The same procedure was used for the comparative ranking of provinces at the national level. However, in the case of comparative ranking at the national level, the value of each indicator for a given province was compared with the mean value of the indicator for the national average. As a special case, the method of comparative ranking was also used for eastern coastal zones within 15 provinces in China. Hence, this comparative ranking method provided a relative ranking of the human-environment (ecosystem) interactions at regional and national levels and not an absolute ranking.

The Four Dimensions of Human-Ecosystem Interactions and a National and Regional View of these Dimensions in China

This section discusses the general importance of the four dimensions of human-ecosystem interactions and gives a comparative view of the four dimensions, across the eastern coastal zones, the eastern region, the middle region, the western region, and throughout China.

The Habitats (Land Cover Distribution)

Diverse land resources and productive habitats are important for human settlement, development and local subsistence. Despite efforts at varying levels, current approaches to the management of land resources have not always proved capable of achieving sustainable development while land resources and the environment are rapidly being degraded and eroded (Singh *et al.*, 1999). One of China's greatest economic successes has been the export of labour-intensive products (Hu, 1997; Lu, 1997). Large export activities require access to coastal zones. Hence, the eastern coastal zones will be the most threatened by human pressure in order to gain access to markets if this trend continues. Sustainable development practices must be undertaken to ensure the vitality of coastal zones and a particular protection status must be provided to avoid an excessive concentration of industrial development activities in coastal zones at the cost of other areas. Many existing ecological issues and environmental problems such as water shortages, land degradation, biodiversity and its lost habitats, natural hazards, and heavy potential pressures from population growth and resources exploitation, result in increased vulnerability that may be aggravated by an increased pace of development (Shi, 1994; Zhao, 1998). In order to develop a suitable strategy for sustainable development in China, it is vital to assess the distribution and pattern of land cover and, its protected status.

Land cover in China has the following distributions: 12.1% closed forest (density $> 40\%$), 10.6% open or fragmented forests (density $10-40\%$), 3.8% other wooded land, 33.7% barren, snow and ice, 17.1% grassland, 21.7% cultivation and 1.2% water. It is estimated that the eastern coastal zone occupies about 6.4% of the total land area in the country; the land cover distribution in the region is 19.9% closed forest (density $> 40\%$), 14.6% open or fragmented forests (density $10-40\%$), 2.9% other wooded land, 4.38% barren, snow and ice, 1.2% grassland, 55.2% cultivation and 2.3% water. The western region occupies about 56.2% of the total land area of the country; the land cover distribution is 3.6% closed forest (density $> 40\%$), 3.5% open or fragmented forests (density $10-40\%$), 1.1% other wooded land, 56.9%

barren, snow and ice, 26.9% grassland, 7% cultivation and 1% water. The eastern region (including the eastern coastal zones) occupies about 20.7% of the total land area of the country; the land cover distribution is 27.9% closed forest (density $> 40\%$), 17.5% open or fragmented forests (density $10-40\%$), 3.3% other wooded land, 4.9% barren, snow and ice, 1.8% grassland, 42.6% cultivation and 1.9% water. The middle region (including the eastern coastal zones) occupies about 22.1% of the total land area of the country; the land cover distribution is 19.1% closed forest (density $> 40\%$), 21.5% open or fragmented forests (density $10-40\%$), 11.6% other wooded land, 2.3% barren, snow and ice, 7.8% grassland, 35.9% cultivation and 1.1% water.

A pictorial overview of China's land cover patterns is shown in Figure 1. Several broad areas of forested land cover can be seen in the Northeast, Southeast and Southwest of China and barren, ice and snow cover exists in the extreme Northwest region and Tibet. Cultivated land is primarily located in the eastern part of China. Most grassland can be seen in the Northern region and Tibet. In general, the eastern part of China (the eastern region and the middle region) has a high percentage of land under closed forest, open forest and cultivated land compared to the western region, and the proportions of these three categories of land cover, as of total land, in the eastern part are higher than the national proportions while these three proportions for the western region are lower than the national proportions.

Population Distribution and Pressure

China's population has increased from 600 million to 1300 million in the last 50 years (Engelman *et al*., 2000; WRI, 2000). Throughout much of the world, coasts are over-developed, over-crowded and over-exploited (Hinrichsen, 1995; Lu, 1997; Shi & Singh, 2003). In many parts of China, coastal zones are among the areas with the fastest population growth (Qu & Li, 1992; Singh *et al*., 1999). Global climate changes may compound other pressures on the coastal zones through the additional effects of warmer ocean temperatures, altered ocean circulation patterns, changing storm frequency and rising sea levels (Kleypas *et al*., 1999). Rising sea levels associated with climate change are likely to affect virtually all of the world's coasts. During the past century, the average sea level has risen at a rate of $1.0-2.5$ mm per year (Watson *et al*., 1996). The Intergovernmental Panel on Climate Change (IPCC) has projected that the average global sea level will rise $15-95$ cm by 2100, due principally to thermal expansion of the ocean and melting of small mountain glaciers (Watson *et al*., 1996).

Future environmental change is likely to affect the eastern coastal zone of China more than any other inhabited region in the country. The eastern coastal zone is under increasing pressure from population growth and related development. Hence, a comparative study of population distribution and population pressure is critical for environmental planning and management in China.

The data analysis here shows that the population density of the eastern coastal zones (509 people/ km^2) is almost four times that of the average population density of the whole country (133 people/km^2) in 2000. With regard to population distribution in the eastern coastal zones, 1.2% of the area has a low or non-existent

population pressure, 6.2% has medium population pressure, and the remaining 92.6% is under high population pressure (Figure 2).

About 319 million people, or about 25% of China's total population, live within this narrow fringe, about 6.4% of the total land area of China. In some island provinces such as Taiwan and Hainan, coastal zones with 100 km buffers occupy most of the land area, thus harbouring most of the population. More than 18 cities with a population of over 1 million are located in the eastern coastal zones of China. About 660 million or 51.7% of China's total population live within the eastern region (including the eastern coastal zones) which occupies about 20.7% of the land area of China.

About 505 million people, or about 40% of China's total population, live within the middle region, which occupies about 22.1% of the total land area of the country. The population density in this region is about 238 people per km^2, which is above the national average. With regard to population distribution in this region, 17.4% of the area has a low or non-existent population pressure, 22.2% has a medium population pressure, and the remaining 60.4% has a high population pressure.

About 106 million people or 8.3% of China's total population, live within the western region, which occupies about 56.2% of the total land area of China. The population density of western China is approximately 20 people per km^2, which is far less than the eastern coastal zones or the rest of the country. With regard to population distribution in the western region, 86.4% of the area has a low or non-existent population pressure, 8.5% has a medium population pressure, and 5.1% has a high population pressure.

Biodiversity Hotspots and Protection Status in China

Biodiversity, the variability among living organisms and the environment in which they occur, is important to maintain life-sustaining systems of the biosphere (WCMC, 1992). Many human activities are reducing overall biodiversity (UNEP,

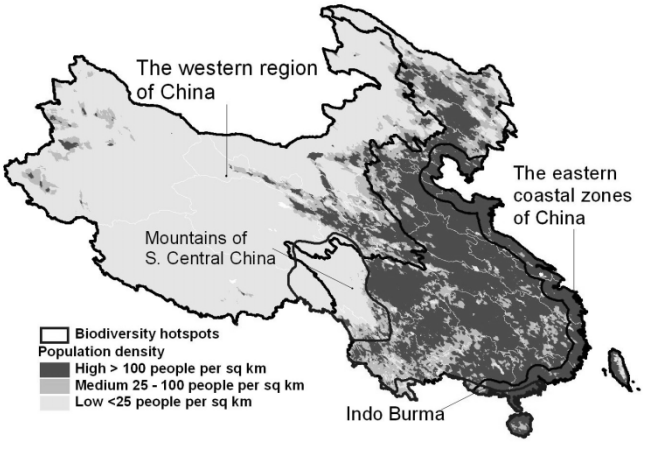

Figure 2. Population pressure in China

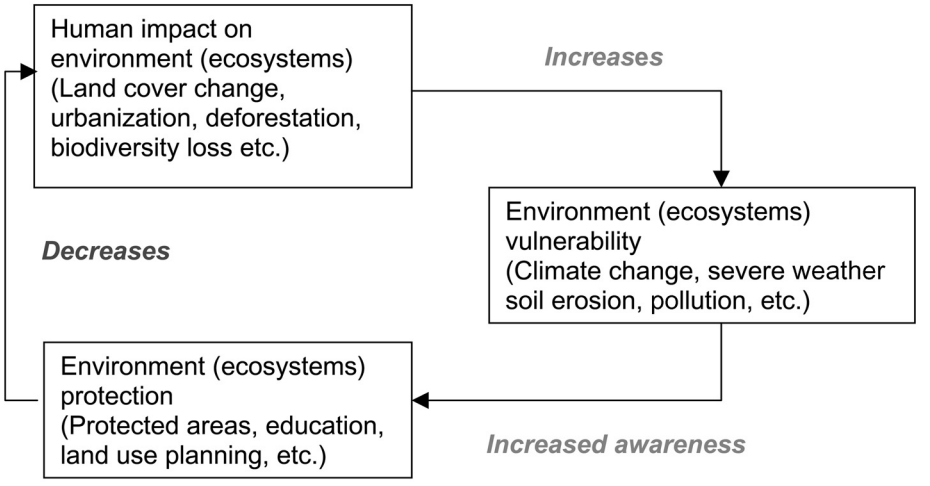

Figure 3. An overall framework for interconnections between humans and the environment

2002). The total number of species that inhabit the planet is unknown and it is feared that the extinction of many will occur even before they have been named and described. It is estimated that 85–90% of all species can be saved by identifying and protecting areas of high biodiversity before they are further degraded (Watson *et al.*, 2000). Realistically, only a relatively small proportion of total land areas is likely to be devoted to biodiversity conservation, so it is important to identify areas rich in a diversity of species and endemism for priority-setting purposes (Singh *et al.*, 1999). In the past, areas have been set aside as protected, often without regard to the biodiversity within their boundaries, As a result, many designated protected areas have little significance in terms of biodiversity, and, conversely, many areas of habitat with significant biodiversity lack protection.

The next half-century could be called the 'last chance decades' (Mittermeier *et al.*, 1999). These could be some of the most dangerous years ever for the Earth's species and ecosystems. Yet this is also a time in which there will still be a chance to make a difference. Already there are only a relative handful of fragile places where biodiversity is still robust. These biodiversity 'hotspots' are remote, they are spectacular, and, without expectation, they are in danger of being destroyed. To protect the diversity of life on the Earth, these invaluable hotspots must be protected (Mittermeier *et al.*, 1999).

China has very rich biodiversity and is one of only 17 'mega diversity countries' in the world (McNeely *et al.*, 1990; SEPA, 1998). China has some of the world's most interesting and best-known flagship species, of which the giant panda, perhaps the world's number one wildlife symbol, is the most famous. Throughout China, every bit of available land is occupied by and under the influence of humans, even in areas above the timberline. All of the biodiversity hotspots and protected areas in China are not exempt from this influence. Mangroves and coral reefs are representative of the types of threatened species in the coastal zone. Some 112 countries and territories have mangroves within their borders (Spalding *et al.*, 1997), but it is estimated that

half of the world's mangrove forests have been destroyed (Kelleher *et al*., 1995). The mangroves and coral reefs in the eastern coastal lines of China are some of the most seriously threatened in the world (SEPA, 1998). In order to address the comparative picture of biodiversity hotspots and protection status, this study was also designed to assess and analyse the status of biodiversity hotspots and protected areas in the four regions and the entire country.

Of the 25 total hotspots around the world, two are totally or partially within China. The mountains of Southern Central China are totally located in China and part of the Indo-Burma hotspot lies within China. Approximately 3.4 % of the total area under biodiversity hotspots is concentrated in China (see Figure 2). These hotspots cover 15.5% of the total land area of the eastern coastal zones, 3.1% of the western region, 4.9% of the eastern region (including the eastern coastal zones), and 19.3% of the middle region.

Population pressure is high in parts of two of these hotspots in China. Approximately 26.6 million people live in and around the Indo-Burma hotspot, 62.3% of the area has a high-population density, 27.7% has a medium-population density and only 10% a low-population density. About 10.9 million people live in and around the mountains of the Southern Central China hotspot, about 5% of the area has a high-population density, 11.3% has a medium-population density, and 83.7% a low-population density.

Designated protected areas in the eastern coastal zones occupy roughly 2.8% of the total land area; about 3.6% are closed forests, 3% open and fragmented forests, 3.9 % other woodland, 9.6% barren, snow and ice, 8.5% grassland, 1.8% cultivation and 1.2% water. In eastern region (including the eastern coastal zones), designated protected areas occupy roughly 3.3% of the land area; about 4.6% are closed forests, 4.4% open and fragmented forests, 2.2 % other land. In the western region, designated protected areas occupy roughly 7.8% of the land area; about 2.7% are closed forests, 3% open and fragmented forests, 2.7 % other woodland, 11.7% barren, snow and ice, 1.9% grassland, 1.3% cultivation and 22.2% water. In the middle region, designated protected areas occupy roughly 1.7% of the land area; about 3.6% are closed forests, 1.7% open and fragmented forests, 0.8 % other land.

The lack of designated protected areas within China is alarming. On average, only 5.6% of the total land area in China, and only 4.2% of the hotspots in the entire country, 3.5% of the hotspots in the eastern coastal zones, 4.3% of the hotspots in the eastern region (including the eastern coastal zones), 5.6% of the hotspots in the middle region, and 3.1% of the hotspots in the western region are designated as protected areas. Only 3% of the land area within the mountains of Southern Central China hotspot has any type of protected status, and the hotspot in Indo-Burma has only 5.4% of the total land in China under designated protected status.

A Comparative Priority Ranking of the Provinces on the Basis of National and Regional Status of Human-Environment (Ecosystems) Interactions

The total score of eight indicators was used for the four dimensions of human-environment (ecosystems) interaction to rank different provinces. First, all the provinces were ranked comparing the values of each indicator with the national average of that indicator, and were called 'national ranks'. Second, all the provinces

in a region were ranked by comparing the values of each indicator with the respective regional average, and were called 'regional ranks'. Using these ranks, all the provinces were grouped in three categories: low priority provinces—score ranging from 0 to 2, medium priority provinces—score ranging from 3 to 5, and high priority provinces—score ranging from 6 to 8. The national and provincial scores of all the provinces are given in Table 1.

On the basis of national ranks, six out of 15 (Guangdong, including both Hong Kong & Macau Special Administrative Region, Hebei, Tianjin, Jiangsu, Shanghai, Tianjin and Zhejiang) provinces of the eastern region which have the eastern coastal zones, none of the provinces of the western region, and four out of nine (Beijing, Hubei, Shanxi and Sichuan) provinces in the middle region were identified as the high priority areas. In addition, the remaining nine provinces of the eastern region, four out of seven (Nei Mongol, Ningxia, Qinghai and Shaanxi) provinces of the western zone, and five provinces (Guizhou, Henan, Hunan, Jiangxi and Yunnan) in the middle region were identified as the medium priority areas.

In regional ranking, within the eastern region, four out of 15 provinces (Guangdong, Hainan, Jiangsu and Tianjin) were ranked as high priority areas, and eight provinces (Anhui, Fujian, Hebei, Heilongjiang, Liaoning, Shandong, Shanghai and Zhejiang) as medium priority areas. It is interesting to note that in national ranking, three provinces (Hebei, Shanghai, Zhejiang) were high priority areas while in terms of regional ranking these provinces became the medium priority areas. Similarly, Hainan was a medium priority area on the basis of national ranking while it became a high priority area in regional averages. Within the western region, the four provinces (Nei Mongol, Ningxia, Qingha and Shaanxi) remained in the medium priority areas as they were based on national ranking, while two provinces (Gansu and Xinjiang) which were low priority areas based on national ranking became medium priority areas. Nei Mongol slipped from a medium priority area to a low priority area. In the case of the middle region, three of the provinces (Beijing, Hubei and Shanxi) were in the same category of priority as they were based on national ranking (high priority). Jiangxi became a high priority category area while it was a medium category area on the basis of national ranking, and Sichuan became a medium priority category area while it was a high priority area on the basis of national ranking.

In order to get a more detailed picture of the eastern coastal zones, the different provinces of the eastern region of China were compared on the basis of the features of human-environment (ecosystems) interactions in the areas of these provinces that fall within the boundaries of the coastal zones (100 km from the coastline). The results are given in Table 2, and on the basis of these results, at least two distinguishing features can be identified of the status of human-environment (ecosystems) interactions in the provinces of the eastern region. First, the two priority rankings, based on the status of human-environment (ecosystems) interactions in the total geographical area of the province and in the geographical area of the province within coastal zones, of most of the provinces, except Hainan, Hebei, Jilin, Liaoning and Shanghai, are the same. Second, for most of the provinces, except Hebei, Heilongjiang, Jilin, and Shanghai, the total score of the eight indicators based on the total geographical area is higher or equal to the total score of the province based on geographical area within the boundary of coastal

Table 1. Comparative national and regional ranks of different provinces (areas) based on the status of the four dimensions of ecosystems -human interactions

Dimensions indicators		Habitat status (% of land area)		Protection efforts (% of the area protected)			Human population		Biodiversity hotspots (% of land area)		
		Closed forest	Closed forest	Closed forest	Other vegetation	Other land cover	Density (people/km²)	High pressure (%) [a]		Score 1[b]	Score 2[c]
Province	**Area (km2)**										
Eastern region											
Anhui	140232	14.42	12.13	14.52	17.57	4.53	420.30	91.99	0.00	4	4
Fujian	119723	41.18	39.84	2.77	0.36	0.06	261.20	77.79	0.00	4	5
Guangdong [d]	174960	51.12	20.04	0.05	0.01	0.02	368.97	92.38	18.88	7	7
Guangxi [e]	236690	37.59	31.96	10.05	8.94	3.01	183.09	72.26	10.84	2	4
Hainan	33434	16.00	34.76	4.24	1.46	0.30	206.49	82.57	100	6	5
Hebei	105664	11.50	24.83	2.37	0.14	0.00	622.62	61.24	0.00	5	7
Heilongjiang	450634	37.71	26.13	2.20	1.36	1.65	83.96	24.87	0.00	3	4
Jiangsu	98971	0.51	4.71	0.00	4.09	2.10	747.69	94.82	0.00	7	6
Jilin	191250	26.46	19.80	6.53	5.90	2.84	137.52	42.65	0.00	2	4
Liaoning	79706	5.39	24.00	4.16	3.30	2.73	510.81	59.37	0.00	4	5
Shandong	154287	0.26	3.86	31.33	18.01	2.29	609.03	98.79	0.00	4	5
Shanghai	5720	0.00	15.42	0.00	91.38	3.41	2238.50	99.97	0.00	5	6
Taiwan	35355	28.69	34.25	22.71	7.57	5.79	588.70	68.03	0.00	2	3
Tianjin	11178	0.12	7.69	0.00	0.00	0.00	822.27	100.00	0.00	7	7
Zhejiang	66346	46.19	28.68	2.64	1.47	0.69	664.03	80.54	0.00	5	6
Regional average	1904150	27.94	22.66	4.64	4.14	2.17	331.11	64.39	4.85		4

(*continued*)

Table 1. (*continued*)

Dimensions indicators		Habitat status (% of land area)		Protection efforts (% of the area protected)			Human population		Biodiversity hotspots (% of land area)	Score 1[b]	Score 2[c]
		Closed forest	Closed forest	Closed forest	Other vegetation	Other land cover	Density (people/km²)	High pressure (%) [a]			
Province	**Area (km2)**										
Western region											
Gansu	380593	4.54	33.21	8.75	4.42	6.30	61.38	20.92	5.05	4	2
Nei Mongol [f]	1148553	9.84	40.70	0.02	2.16	1.23	19.47	4.64	0.00	2	4
Ningxia [g]	52013	0.01	34.11	100	4.43	4.55	91.79	33.19	0.00	4	3
Qinghai	734057	0.69	49.98	1.17	0.44	1.36	6.10	1.48	4.56	5	4
Shaanxi	203367	12.31	49.57	7.00	0.77	0.19	172.80	44.66	0.00	4	4
Xinjiang [h]	1604516	0.21	9.82	10.36	3.16	10.73	9.59	1.13	0.00	3	2
Xizang [i]	1130045	2.40	37.64	5.08	2.34	27.42	1.57	0.04	9.55	2	2
Regional average	5253144	3.63	31.64	2.66	2.03	10.86	20.42	5.15	3.06		4
Middle region											
Beijing	16560	32.77	24.14	2.34	0.45	0.00	706.77	93.38	0.00	6	6
Guizhou	176069	7.64	44.61	4.99	1.03	0.26	193.26	73.24	0.00	4	5
Henan	165977	2.78	13.15	8.53	5.01	0.33	544.97	95.00	0.00	5	5
Hubei	186120	11.26	43.73	3.44	0.96	0.23	312.18	81.65	0.00	6	6
Hunan	211455	15.03	43.56	6.11	2.27	2.44	297.82	87.77	0.00	3	3
Jiangxi	167938	30.07	32.51	0.96	0.39	0.65	239.33	78.47	0.00	6	5
Shanxi	156134	7.55	32.09	0.00	0.00	0.00	201.15	61.75	0.00	6	6

(*continued*)

Table 1. (*continued*)

Dimensions indicators		Habitat status (% of land area)		Protection efforts (% of the area protected)			Human population		Biodiversity hotspots (% of land area)	Score 1[b]	Score 2[c]
		Closed forest	Closed forest	Closed forest	Other vegetation	Other land cover	Density (people/km^2)	High pressure (%) [a]			
Province	**Area (km2)**										
Sichuan	563537	20.97	46.20	2.23	1.35	0.56	206.78	40.78	52.26	4	6
Yunnan	384216	34.22	48.55	5.29	2.79	3.18	96.06	32.93	25.36	1	3
Regional average	2028006	19.14	40.90	3.59	1.65	0.81	237.82	60.36	19.33		6
National average		12.10	31.83	3.93	2.24	7.69	132.83	29.68	7.02		

[a] High pressure: % of the area under high population pressure (human population density > 100 people/km^2).

[b] Regional rank: if the value of the indicators for vegetation cover, closed forest, protection status of vegetation cover, protection status of closed forest, and protection status of other land was less than its regional mean value, the indicator was scored as 1 and marked with an asterisk, otherwise 0; similarly, for other three indicators, population density, high population pressure and biodiversity hotspots, if the value of an indicator was greater than its regional mean value, the indicator was scored 1 and marked with an asterisk, otherwise 0; on the basis of the indicator scores, the total score was calculated for provinces (areas), and the provinces (areas) were ranked on the basis of the total score.

[c] National rank: if the value of the indicators for vegetation cover, closed forest, protection status of vegetation cover, protection status of closed forest, and protection status of other land was less than its national mean value, the indicator was scored as 1 and marked with an asterisk, otherwise 0; similarly, for other two indicators, population density, high population pressure and biodiversity hotspots, if the value of an indicator was greater than its national mean value, the indicator was scored 1 and marked with an asterisk, otherwise 0; on the basis of the indicator scores, the total score was calculated for provinces (areas), and the provinces (areas) were ranked on the basis of the total score.

[d] Including both of Hong Kong and Macau Special Administrative Regions.

[e] Guangxi Zhuang Autonomous Region.

[f] Inner Mongolia Autonomous Region.

[g] Ningxia Hui Autonomous Region.

[h] Xinjiang Uygur Autonomous Region.

[i] Tibet Autonomous Region.

Table 2. A comparative rank of eastern coastal zones within different provinces (areas) based on the status of the four dimensions of ecosystems - human interactions

Dimensions indicators		Habitat status (% of land area)		Protection efforts (% of the area protected)			Human population		Biodiversity hotspots (% of land area)	Score [b]
		Closed Forest	Other vegetation	Closed forest	Other vegetation	Other land cover	Density (people/km²)	High pressure (%) [a]		
Coastal zones	**Area (km²)**									
Anhui	1179	13.99	16.12	95.76	95.79	99.03	308	100.00	0.00	3
Fujian	49995	29.25	39.15	0.14	0.06	0.00	417	91.81	0.00	4
Guangdong [c]	94087	49.50	14.57	0.00	0.00	0.01	504	97.08	35.11	6
Guangxi [d]	34914	38.59	16.73	6.52	16.42	3.26	232	83.65	73.52	2
Hainan	33316	16.06	34.85	4.24	1.46	0.29	205	82.49	100.00	4
Hebei	30657	1.29	7.21	0.00	0.00	0.00	491	98.85	0.00	6
Heilongjiang	697	94.55	5.45	0.00	0.00	0.00	4	0.00	0.00	4
Jiangsu	77502	0.46	4.72	0.00	3.09	2.54	777	94.75	0.00	6
Jilin	7405	71.91	17.64	0.00	0.00	0.00	43	11.92	0.00	4
Liaoning	67849	4.54	22.77	3.70	2.92	3.03	336	87.68	0.00	2
Shandong	85027	0.21	4.83	19.89	19.02	3.23	550	98.87	0.00	4
Shanghai	4951	0.00	16.99	0.00	0.00	0.00	2388	100.00	0.00	7
Taiwan	35266	28.77	34.20	22.71	7.60	5.80	584	67.89	0.00	1
Tianjin	8390	0.00	6.94	0.00	0.00	0.00	908	100.00	0.00	7
Zhejiang	66684	28.22	38.72	1.20	0.47	0.20	543	96.66	0.00	5
Average		19.93	19.57	3.32	3.17	2.25	510	91.13	15.45	

[a] High pressure: % of the area under high population pressure (human population density > 100 people/km²).

[b] Comparative rank: if the value of the indicators, for vegetation cover, closed forest, protection status of vegetation cover, protection status of closed forest, and protection status of other non-vegetated land was less than its regional mean value, the indicator was scored as 1 and marked with an asterisk, otherwise 0; similarly, for other three indicators, population density, high population pressure and biodiversity hotpots, if the value of an indicator was greater than its regional mean value, the indicator was scored 1 and marked with an asterisk, otherwise 0; on the basis of the indicator scores, the total score was calculated for provinces (areas), and the provinces (areas) were ranked on the basis of the total score.

[c] Including both of Hong Kong and Macau Special Administrative Regions.

[d] Guangxi Zhuang Autonomous Region.

zones. Hence, in the eastern coastal zones, environment (ecosystems) stresses are comparatively higher outside coastal zones in these provinces.

Environment (Ecosystems) Planning and Management and Conclusions

In general, the nature of human-environment (ecosystems) interactions are highly complex. However, common trends indicate that human population growth and economic growth in early phases will increase environment (ecosystems) vulnerability, but economic growth, in later phases, will increase human awareness about environmental issues and scientific management of environment and that will stimulate human efforts to protect the environment (ecosystems). These interactions between human and environment (ecosystems) are shown in Figure 3. The realization of the two-way interaction between economic growth and the environment is necessary for environmental planning and management. In addition to these interactions, current status of environmental (natural) resources, human resources and economic resources will also be critical inputs for environmental planning and management in any given area.

In the case of China, all three resources are unequally distributed over its land surface. The largest concentration of population and economic resources can be found in the eastern part of China, especially in the eastern coastal zones, and these areas are also home to pristine habitats such as wetlands, mangroves, wild life, and marine life. At the same time, these areas are the centres of China's economic growth. The western region of China has fallen behind economically and recently it has become the focus of the Chinese government and international funding agencies for accelerating economic growth. The western region development strategy has been much talked about in recent years and has been placed on the main agenda (*China Daily*, 2000b). However, at the same time, there has been alarm about environmental issues in eastern China, and some economically rich provinces, such as Zhejiang, Jiangsu and Guandong, have been focusing their efforts on environmentally-sensitive development efforts. The experiences of economic growth in eastern China provide enough evidence to show the cost of environmentally-non-sensitive economic growth. The environmental costs of economic growth can be reduced drastically by integrating environmental management with economic growth. Hence, it is suggested that, in future, China should use an Integrated Approach to economic growth rather than a two-stage approach of economic growth and environmental management.

The integrated approach, as suggested above, will vary across the regions depending upon their resources and human population. An overview of forest resources, biodiversity, ecosystems protection and human population of the four regions is provided in Figure 4. Some of the main features of these resource distributions are: (1) the western region is well below the national average in terms of forest resources, cultivated land, biodiversity hotspots, population density and high population areas; (2) the eastern coastal zone is well above the national average on all factors except the protection of closed forests; (3) the biodiversity hotspots are concentrated in the eastern coastal zones and the middle region.

These observations, as well as the regional and national ranks of different provinces, discussed in the previous section and details given in Table 1 and 2, provide information on different aspects that are necessary for environmental

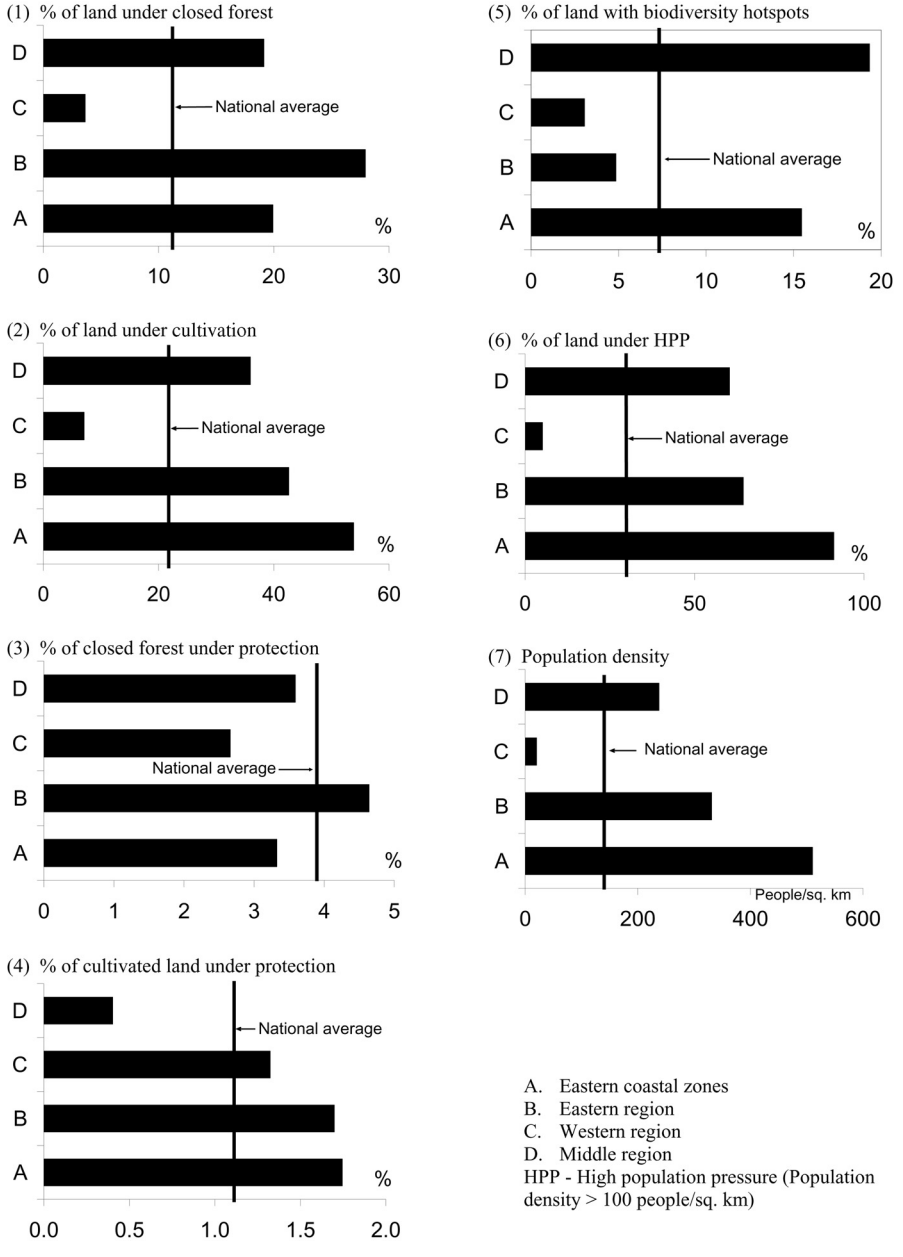

Figure 4. A comparative overview of forest resources, biodiversity and human population in the four regions

(ecosystems) planning and management. The analyses bring the diversity among regions and provinces to the forefront. It is thought that this information will be very useful for designing province and region specific integrated approaches of economic

development. This study does not aim to provide an environmental management plan for China which is also not possible within the space of one journal paper. However, it is possible to emphasize several aspects that should be seriously considered in any environmental (ecosystems) planning and management in China.

First, protection of habitats and environmentally vulnerable areas should be given a high priority, and protected status must be accompanied by effective enforcement measures in the long term to ensure protection of endemic and endangered species. Second, the two hotspots are located in different provinces and some type of co-operation mechanism should be designed for effective planning and management of these areas. Third, education of the public as well as decision makers, about the vital importance of environment (ecosystems), should become an integral component of environmental planning and management.

On the basis of these outcomes, it is suggested that environmental management policies and strategies should consider using the following features of the regions in national level considerations: (1) most of the eastern coastal zones, except within Heilongjiang and Jilin, have a very high population pressure ($> 80\%$) and density, high biodiversity, above the national average of closed forest and other vegetation, and a low protection status; (2) the eastern region (including eastern zones) has a high population pressure, high biodiversity, average protection status and habitats; (3) The middle region has above average closed forest and other vegetation cover, high biodiversity, high population pressure, and low protection status; (4) the western region has very low closed forest and average other vegetation, high biodiversity, low population pressure, and above average protection status. Based on these characteristics, region-specific conservation policies and strategies should be developed. For example, in the eastern coastal zones the emphasis should be on controlling the urbanization (city size and population), and developing effective protected areas for biodiversity and current habitat strategies, while in the western region the emphasis should be on arid, semi-arid and cold environmental (ecosystems) protection and restoration strategies. The basic environmental features and main aspects of environmental policies and strategies for the four regions of China are summarized in Table 3.

The environmental (ecosystems) management policies and strategies should consider using the following categories of provinces at the regional level: (1) high biodiversity but low protection status while population pressure is high (Guangdon and Hainan in the eastern region); (2) low closed forest and other vegetation cover, high population pressure, and low protection status (Jiangsu and Tianjin in eastern region, Beijing and Shaxi in the middle region); (3) high habitat status, medium or high population pressure but protection status is above average (Guangxi, Liaoning and Taiwan in eastern region, Hunan and Yunan in the middle region); and (4) low population pressure, and average other vegetation cover, low closed forests and protection status (most of provinces of the western region). Based on this classification, class-specific and province-specific environmental (ecosystems) policies and strategies should be developed. For example, in the provinces with a high percentage of forests and vegetation cover, high biodiversity and low protection status, the emphasis should be on developing effective protection area strategies, while in the provinces with a low percentage of forests and vegetation cover emphasis should be on restoration strategies.

Table 3. Environmental (ecosystems) features, main environmental issues, social-economic status and environmental polices and strategies

Region	Environment (ecosystems) features	Main environmental (ecosystems) issues	Social-economic features	Environmental policies and strategies
The eastern coastal zones	Coastal ecosystem (tropical, subtropical, temperate); above national average closed forest and other vegetation, and low protection status.	High population pressure, urbanization, coastal biodiversity loss, coastal vulnerability.	Most of developed zones of China.	Controlling population growth and migration; protecting mangroves and coral reefs; reducing urbanization; establishing coastal early warning systems.
The eastern region (including the eastern coastal zones)	Monsoon climate (tropical, subtropical, temperate); high biodiversity, average protection status and habitats.	High population pressure, urbanization, pollution, habitat loss.	Most of developed region of China except northeast part and Guangxi.	Controlling population growth and migration; protecting existing forests and other vegetation; reducing urbanization; developing economic water resources.
The middle region	Most of them have subtropical and temperate climate; above average closed forest and other vegetation cover, high biodiversity.	High population pressure, shortage of water resources in north part of region, biodiversity and its habitat loss, pollution, construction of dams.	Some of provinces are developed; many are medium developed socially-economically.	Controlling population growth; increasing protection of biodiversity and its habitats; establishing monitoring and early warning systems for flood and drought; educating and training local people.
The western region	Arid, semi-arid and cold environment (ecosystem); abundance of natural resources; very low closed forest and average other vegetation, high biodiversity, and above average protection status.	Lower population pressure, shortage of water resources, desertification, salinization of the soil, biodiversity loss.	Developing socially-economically, compared with the eastern region.	Protecting natural vegetation and biodiversity; controlling desertification; strengthen of natural resources planning and management, educating and training the local people and decision makers; increasing awareness; developing economic irrigation systems.

Finally, this paper has provided a broad view showing ways to incorporate the four critical dimensions of human-environmental (ecosystems) interactions, and a comparative priority ranking at both regional and national levels, for all of the provinces and four regions of China. It is suggested that the next step should be to add social-economic dimensions and to conduct an analysis interaction between human, environmental (ecosystems), social-economic and sustainable development for environmental planning and management. The authors strongly emphasize the necessity of a broad view of human-environmental (ecosystems) interaction and a comparative priority ranking at regional and national levels for environmental planning and management.

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Notes

1 In this database, protected area is defined as "An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (WCMC, 2000).

2 The hotspots are considered to be the Earth's biologically richest and most endangered terrestrial eco-regions, these areas are especially rich in endemic species, which are threatened by human activities, and constitute more than 1 million km^2 in the total area. The hotspots' boundaries have been determined by 'biological commonalities'. Each of these areas features a separate biota or community of species that fits together as a bio-geographic unit. Conservation International have identified 25 hotspots: Atlantic Forest Region, Brazilian Cerrado, California Floristic Province, Cape Floristic Region, the Caribbean, Caucasus, Central Chile, Choco-Darien-Western Ecuador, Eastern Arc Mountains & Coastal Forest, Guinean Forests of West Africa, Indo-Burma, Madagascar & Indian Ocean Islands, Mediterranean Basin, Mesoamerica, Mountains of Southern Central China, New Caledonia, New Zealand, Philippines, Polynesia & Micronesia, Southwest Australia, Succulent Karoo, Sundaland, Tropical Andes, Wallacea, Western Ghats & Sri Lanka (Myers *et al.*, 2000).

3 IMAGINE -Version 8.3 (ERDAS, Denver, CO) for stratification and digitizing of vector polygons; ENVI (Research Systems, Atlanta, GA) for image interpretation, graphical analysis and determining models; and Land Analysis System (public domain) for modelling. GIS analysis was performed using software donated by the Environmental Systems Research Institute (ESRI, Redland, CA).

4 The fourth dimension of ecosystem-human interaction is the number of threatened species of fauna and flora. However, due to non-availability of these data at the provincial level, it could not be included in the analysis, and the extent of biodiversity hotspots is used as an indicator in this dimension.

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