Potential distribution of woody bamboos in South, South-East and East Asia, Papua New Guinea and Australia

Working Paper 42

Ms. Nadia Bystriakova, Researcher,
International Network for Bamboo and Rattan (INBAR)

Dr. Valerie Kapos, Senior Advisor (Forest Ecology),
UNEP World Conservation Monitoring Centre (UNEP-WCMC)

Dr. Igor Lysenko, Conservation Analyst,
UNEP World Conservation Monitoring Centre (UNEP-WCMC)

SUMMARY

This study was designed to produce a regional distribution map of all species of woody bamboos occurring in the Asia-Pacific region (South, Southeast and East Asia, Papua New Guinea and Australia). Qualitative data on distribution of woody bamboos were combined with data on existing forest cover. In the course of the study, 998 individual bamboo species and 60 genera of Bambuseae were mapped. The highest figures of potential species richness (144 spp per square km) were recorded in the South China. More than 80% of forest potentially containing bamboo species might have from 1 to 20 different species per square km.

INTRODUCTION

Despite their economic and social significance, statistics on bamboo resources, especially in natural stands, are very limited. Classified as a "non-timber forest product", bamboo is not routinely included in resource inventories. A good, transparent estimate of bamboo resources has yet to be developed.

As a first step to improving the information available, the International Network for Bamboo and Rattan (INBAR) and the Word Conservation Monitoring Centre (UNEP-WCMC) have jointly initiated a project to estimate the magnitude and distribution of bamboo resources within natural stands. The first stage of the project is to combine information on the distribution of bamboo species with the global data on forest cover to determine distribution and estimate the total area of forest containing bamboo. The study was confined to woody bamboos, as these are most important from the socio-economic point of view, and the present section focuses only on those species that naturally occur in the Asia-Pacific region.

SCOPE OF THE STUDY AND METHODOLOGY

The subfamily Bambusoidaeeae (of the family Poaceae, or Gramineae) comprises both woody and herbaceous bamboos with altogether 1575 species. It is divided into 1 tribe of woody bamboos (Bambuseae) and 5 tribes of herbaceous bamboos (Ohrnberger, 1999).

The tribe of woody bamoos, Bambuseae, comprises 10 subtribes with 1447 individual species. 7 of these subtribes could be found in North America, Africa, Asia, New Guinea and Pacific Islands, and Australia. The remaining subtribes (Guaduinae, Chusqueinae and Arthrostylidiinae) with 358 species naturally occur only in Central and South America (Ohrnberger, 1999).

Only the 7 subtribes and 60 genera occurring in the Asia-Pacific region were selected for the present study (Table 1). Only those species that occur naturally (i.e. could be associated with the existing forest cover) in 23 Asian countries and Russia (Sakhalin and Kuril Islands) were included. The project gathered data on 1012 species in total.

Table 1
Subtribes and genera of woody bamboos that naturally occur in Asia

Subtribe	Genera
Arundinariinae	Arundinaria, Acidosasa, Bashania, Ferrocalamus, Gelidocalamus, Indocalamus, Metasasa, Oligostachyum, Pleioblastus, Sasa, Sasaella, Vietnamocalamus
Thamnocalaminae	Ampelocalamus, Borinda, Chimonocalamus, Drepanostachyum, Fargesia, Himalayacalamus, Sinarundinaria, Thamnocalamus, Yushania
Racemobambosinae	Neomicrocalamus, Racemobambos, Vietnamosasa
Shibataeinae	Brachystachyum, Chimonobambusa, Hibanobambusa, Indosasa, Phyllostachys, Semiarundinaria, Shibataea, Sinobambusa
Bambusinae	Bambusa, Bonia, Dendrocalamus, Dinochloa, Gigantochloa, Holttumochloa, Kinabaluchloa, Klemachloa, Maclurochloa, Melocalamus, Pseudobambusa, Pseudoxytenanthera, Sinocalamus, Soejatmia, Sphaerobambos, Thyrostachys
Melocanninae	Cephalostachyum, Davidsea, Dendrochloa, Melocanna, Neohouzeaua, Ochlandra, Pseudostachyum, Schizostachyum, Teinostachyum
Hickeliinae	Nastus, Temburongia

For each species bibliographic sources were searched to acquire data about its distribution. These data were principally political units (country, province, locale), altitudinal range and forest type. They were entered into an Access database containing 13 fields (Table 2) and multiple records for each species (a total of 2190 records). For some species and locations the information available in the bibliographic sources was more detailed than for others: only 980 records (45%) contain information about altitudinal range, while 1846 records (84%) have data about species distribution on the provincial level.

Table 2. Data fields in the Access and GIS databases

Field	Description	Access Database	GIS Database
Genus	Species name at generic rank	All records	Not used
Species	Species name at subgeneric rank (subspecies, varieties, forms and cultivars are not included)	All records	Not used
Name	Unique combination of generic and subgeneric species names	All records	All records
Country	Defined as in the UNEP-WCMC data source	All records	All records
Province	Defined as in the UNEP-WCMC data source	If available	If available
Location	Geographic name other than province	If available	If relevant
Type	Explanation of data in location field	If available	Not used
Almin	Minimum altitude	If available	If available
Almax	Maximum altitude	If available	If available
Direction	Additional information about species distribution, e.g. within a certain forest type	If available	Not used
Abundance	Information about species occurrence	If available	Not used
Origin	Native, endemic, introduced, cultivated, grown in botanical gardens species	If available	Only native, endemic and introduced species selected
Source	Bibliographic source of data	All records	Not used

Initially, the data were stored in an Access table, which was then converted into a DBF file. Only 6 fields of the original data spreadsheet (Table 2) were used to generate individual grids in the Arc View format. For each species listed in the initial table, a singe grid (potential distribution) was generated. Individual grids were shaped according to the information about species natural distribution on the country and province levels and altitudinal range (minimum and maximum altitude) available in bibliographic sources. The information about the distribution of existing forest cover provided by UNEP-WCMC (Annex I) was used as a mask to eliminate areas not forested. In cases where there was no information about distribution of a species within the country, the whole country was regarded as a smallest distribution unit. When multiple data on altitudinal range existed for the same species, the broadest range was applied.

Individual grids for each species were sorted and merged by genus. Integration of 998 species in a single grid generated a potential species richness map for the whole region. Integration of all genera in a single grid provided a regional potential generic richness map.

Information from the attribute tables associated with the species richness maps was used to calculate the total area potentially containing bamboo species and the potential species richness per square km.

RESULTS

In total, the final regional database covers 1012 individual bamboo species. The largest national complement of species was for China, which had 626 described species, followed by India (102 species) and Japan (84 species) (Table 3).

Table 3. Number of Bambuseae species in the countries of the Asia-Pacific region.

Country	Number of species that naturally occur in the country	Country	Number of species that naturally occur in the country
Australia	3	Myanmar	75
Bangladesh	18	Nepal	25
Bhutan	21	North Korea	2
Brunei	6	Pakistan	3
Cambodia	4	Papua New Guinea	22
China	626	Philippines	26
Hong Kong	9	Russia (Sakhalin and Kuril Islands)	1
India	102	Singapore	3
Indonesia	56	South Korea	6
Japan	84	Sri Lanka	11
Laos	13	Thailand	36
Malaysia	50	Vietnam	69
		Total species in all countries	1012

The potential current distributions of 1007 individual bamboo species were mapped using Arc View tools. Each map shows the distribution of an individual species as it was described in the available bibliographic sources and derived from the geographic and forest cover data available at UNEP-WCMC. Due to space limitations individual species distribution maps are not provided in the report.

In addition potential distribution maps were generated for the 60 genera of the subfamily Bambusoideae that occur within the region. The genera range from widely distributed (e.g. Bambusa, Map 1) to nationally endemic (Sasaella, Map 2). Most genera were distributed across several countries but no the whole region (e.g. Acidosasa, Map 3 and Peioblastus, Map 4).

The regional map of potential bamboo species richness (Map 5) shows a total of 6,315,764 km^2 of forest in the Asia-Pacific region that potentially contains bamboo. The maximum potential species richness in the region, 144 species/km^2, was recorded

for a total area of 915 km^2 in Southern China. More than 38% (2,430,032 km^2) of the total area of forest potentially containing bamboo has potentially from 1 to 5 species per km^2 (Chart 1), while potential species richness of more than 51 species per km^2 was recorded for 221,061 km^2 (3.5% of the regional total).

The regional map of potential generic richness (Map 6) shows that the potential distribution density of 60 genera of subfamily Bambusoideae in the region follows a similar pattern to that of potential species richness, with a maximum generic richness of 22 genera per km^2 found in Southern China. About a quarter of the bamboo-containing forest of the region potentially contains 1-2 genera (Chart 2).
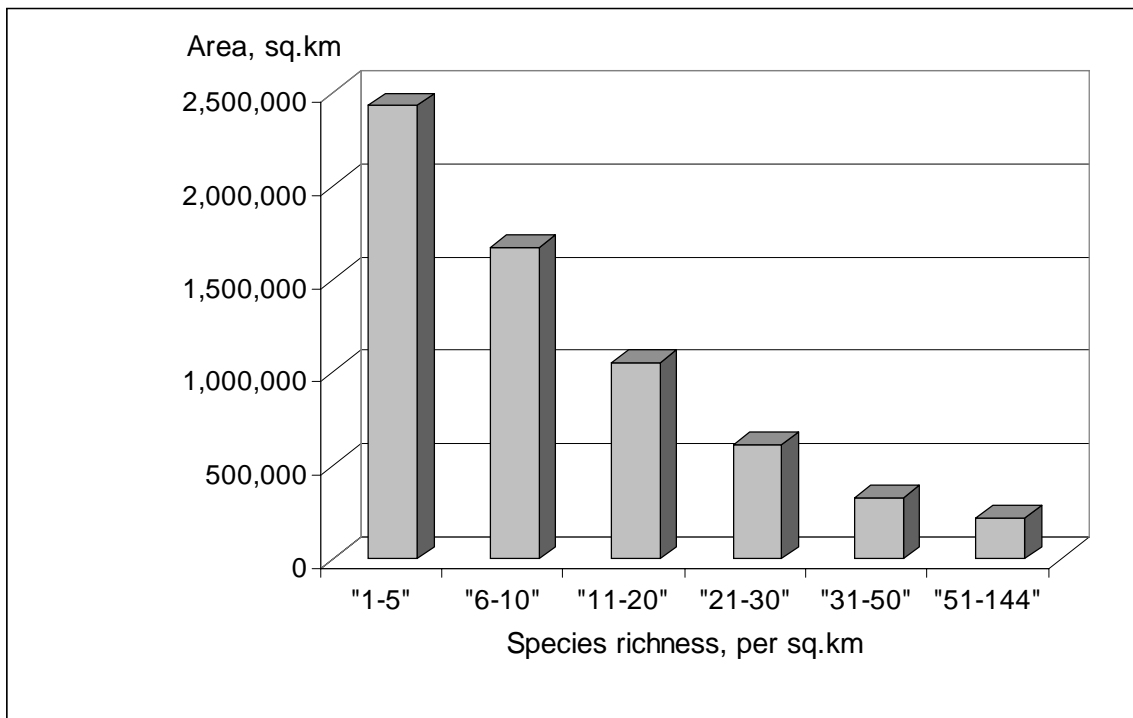

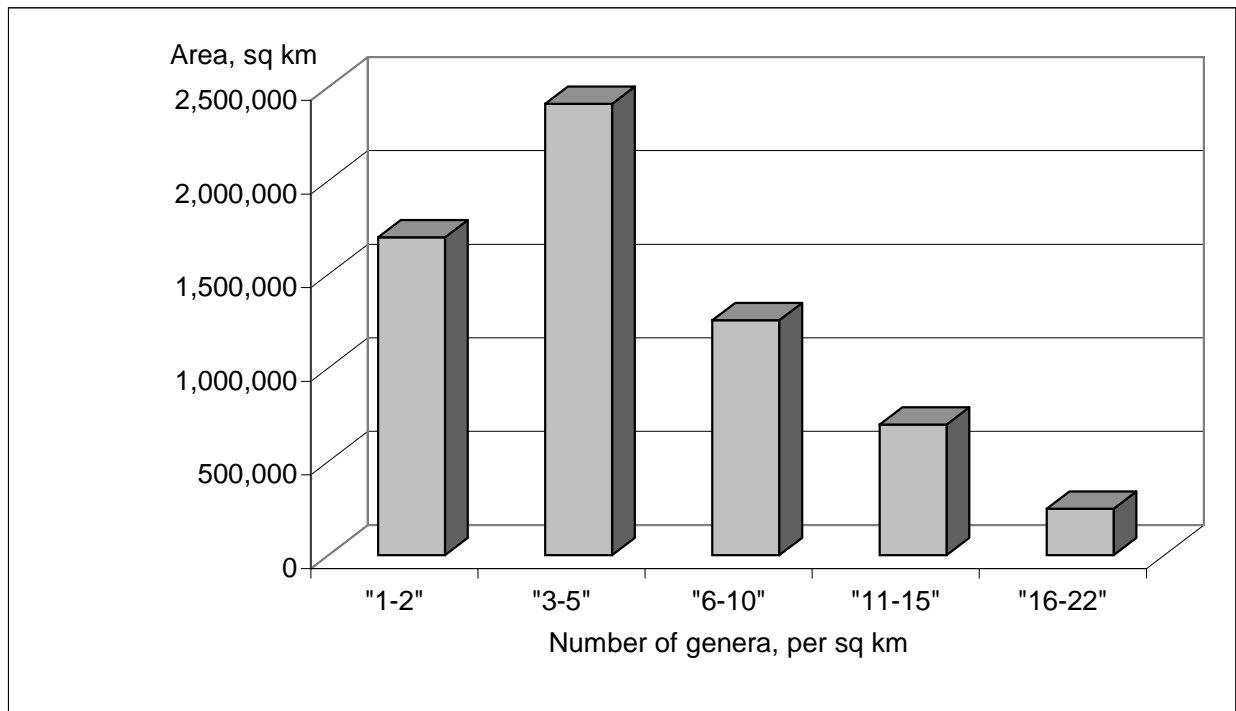Chart 1. Total area covered by bamboo species richness classes in the selected region.

Chart 2. Distribution density of 60 genera in the selected region.

DISCUSSION

The results of the study should be regarded as a first approximation of the regional distribution of bamboo species in natural forests. Since the study was largely based on the existing bibliographic sources of data[*], it reflects the present stage of knowledge about taxonomy and distribution of subfamily Bambusoideae in the Asia-Pacific region.

The results support the existing theories of bamboo species distribution:

- the main centres of diversity of the bambusoid grasses are the monsoon-belt of Southeast Asia with Southern China (Ohrnberger, 1999);
- the highest diversity of bamboos could be found in Southern China (Guangxi, Guangdong, Hainan).

Although the absolute figures of species richness are rather high, the area with very high richness is correspondingly small.

The results contribute to an understanding of where bamboo is most likely to be a significant contribution of biodiversity. They also provide a basis for developing models of bamboo abundance and socio-economic importance.

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[*] Ohrnberger, D. The bamboos of the world: annotated nomenclature and literature of the species and the higher and lower taxa. Elsevier, 1999, 585 pp.

The interpretation of the absolute richness data and the distribution patterns is subject to a number of limitations, including:

- Due to the lack of ecological information and location details in the species descriptions, the boundaries of (sometimes rather large) administrative units were used for species mapping. This resulted in somewhat artificial boundaries of species distributions and in high estimates of species richness per square km.

- Due to the lack of information about species distribution in some countries and inconsistency of taxonomic approach used in different countries rather sharp differences in species richness levels on opposite sides of national boundaries were reflected. For example, maximum species richness in the province Cao Bang (Vietnam) is 38-40 species per square km, and in the adjacent province Guangxi (China) it is up to 70 species per square km.

- Due to the time limitations no crosschecks of the results have been done. This has resulted in inadequate reflection of the distributions of some species, especially those reported from more than one country.

Future work in this area will need to focus on a number of ways forward:

1) Expanding the potential species distribution and richness work beyond the Asia-Pacific to global coverage;
2) Identifying the few forest inventory data sets that include bamboo and investigating their application in estimating bamboo abundance and extrapolating overall resource quantification;
3) Identifying ways to attach economic value to the resource;
4) Identifying information gaps, for instance in taxonomy of subfamily Bambusoideae and sources of improved information to fill them.

Annex I.

Source documentation for the Current Forest Cover map compiled for the WCFSD.

WCMC, March 1998

The map/GIS datasets sources that were used in the compilation of the Current Forest Cover map are listed below by country, within each region.

SOURCES FOR ASIA:

BANGLADESH:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

For Bangladesh, the map in the above publication was interpreted from (a and b):
(a) *Bangladesh-General Vegetation* (1981) Sheet No. G8 at 1:500,000 scale, prepared by the Resource Planning Unit, Agriculture and Rural Development Department, World Bank, Washington. This is derived from updated and ground-truthed 1977 Landsat satellite imagery. (Categories used for the main map in this atlas were numbers 25 and 26, main land use *Forest and Forest or Forest Reserve*).
(b) data were modified by manual digitising from recent Landsat images.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangroves: Information for the Sundarbans was derived from World Bank (1981), derived from updated and ground-truthed 1977 Landsat satellite imagery. Additional areas are largely plantation forest, taken from a detailed sketch map prepared for this work by N.A. Siddiqi, Bangladesh Forest Research Institute, drawn onto a 1:1,000,000 base map.

References:
World Bank (1981). Bangladesh-General Vegetation. Sheet No. G8, 1:500,000. Prepared by the Resource Planning Unit, Agriculture and Rural Development Department, World Bank, Washington.

BHUTAN:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

For Bhutan, the map in the above publication was interpreted from: *Wildlife Habitat classification for Bhutan* - Satellite interpretation of TM images (1993) by J MacKinnon for WWF Bhutan. Partially ground-truthed. Boundaries partly modified to match WCMC Biodiversity Map Library Botanical Reporting Units.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

BRUNEI DARUSSALAM:

MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

For Brunei, the map in the above publication was interpreted from the *Brunei Forest Resources and Strategic Planning Study* prepared by Anderson and Marsden (1988), consultants to the Brunei Forest Department.

Mangrove data were extracted from a 1:25,000 coastal sensitivity map that has been prepared as part of a written report on the same issue (Fisheries Department/Shell, 1992), including coastline and shoreline type (rock, sand, mud, mangrove, urban), and mangrove polygons. Source data includes field survey work and data gathered as part of an ASEAN-US Coastal Resources Management Project.

References:
Fisheries Department/Shell (1992). Coastal Environmental Sensitivity Mapping of Brunei Darussalam. A joint project of Fisheries Department, Ministry of Industry and Primary Resources and Brunei Shell Petroleum Company Sdn Bhd. Unpublished report, August, 1992. 40pp + 1:250,000 map

CAMBODIA:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map, ASB and WCMC, Canterbury, UK.

For Cambodia, the map in the above publication was interpreted from a version originally digitised in AUTOCAD by the Asian Bureau for Conservation. Based on three available maps, Mebray Commission Vegetation Map, FAO study and then pulled into ARC/INFO through DXF format.

Managove data were digitised from the Mekong Secretariat (1991) which is based on 1988/9 Landsat TM images interpreted without ground-truthing. More recent maps (Mekong Secretariat, 1994) showing mangroves (c. 1:400,000 to 1:1,000,000) are now available.

References:
Mekong Secretariat (1991). Reconnaisance Landuse Map of Cambodia. 1:500,000, Mekong Secretarait, Bangkok, Thailand.

Mekong Secretariat (1994). Cambodia Land Cover Atlas< 1985/87 - 1992/93 (including national and provincial statistics). remote Sensing and Mapping Unit, Mekong Secretarait, United Nations development Programme; Food and Agriculture Organisation, Cambodia.

CHINA:
Mackinnon, J., Chung and Mengsha (1992) Biodiversity Review of China Forested Areas, scale unknown. Chinese Academy of Sciences.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangrove coverage was gathered from sketch maps drawn over 1:500,000-1:1,000,000 base maps, prepared for this work by Professor Lin

Peng, Xiamen University.

HONG KONG:
WWF Hong Kong (1994) Hong Kong Vegetation Map, scale 1:1,20,000.

Coastline and mangrove data from a digital dataset provided by WWF HK
(1994), prepared at 1:20,000 from 1989 aerial photographs taken at the same
scale. Details of the dataset are provided in Ashworth et al. (1983).

References:
Ashworth, J.M., Corlet, R.T., Dudgeon, D., Melville, D.S. and Tang, W.S.M.
(1983). Hong Kong Flora and Fauna: Computing Conservation, Hong Kong
Ecological Database. World Wide Fund for Nature Hong Kong. 24pp.

WWF HK (1994). Hong Kong Vegetation Map. 1:20,000 GIS on ARC/INFO prepared
by World Wide Fund for Nature Hong Kong.

INDIA:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining
Habitat Map. ASB and WCMC, Canterbury, UK

For India, the map in the above publication was interpreted from (a and b):
(a) forest cover data were digitised from the National Forest Vegetation Map (FSI, 1986) published by the
Forest Survey of India in 26 sheets at 1:1,000,000 scale. Map sheets used in this analysis were 2.
Arunachal Pradesh, 3. Assam, 5. Gujarat, 9. Karnataka, 10. Kerala, 12. Maharashtra, 13. Manipur,
14. Meghalaya, 15. Mizoram, 16. Nagaland, 21. Tamil Nadu, 22. Tripura, 24. West Bengal, 25.
Andaman and Nicobar Islands, and 26. Union Territories (Goa only). For each map, the two
categories dense forest (crown density above 40 per cent) and mangrove forest were extracted.
Monsoon and rain forests were further delimited using Champion (1936), Champion and Seth
(1968) and, in particular, the Atlas of Forest Resources of India (Das Gupta, 1976). Map sheets
16-20 from the atlas, showing forest types of India, were digitised, harmonising forest categories as
follows: 'tropical wet evergreen', 'tropical semi-evergreen', 'subtropical broadleaved hill' and
'montane wet temperate' forests were combined into rain forests. The categories 'tropical moist
deciduous' and 'tropical dry evergreen' forests were used to delimit monsoon forest. Montane sectors
were delimited using a 3000-ft (914-m) contour taken from JNC (Jet Navigation Charts) 36, 37 and
53. Further information on the mangrove forest of the Sundarbans was taken from Department of
Forests, Government of West Bengal (1973). Forest Map of South India (Pascal, 1986), published
by the Karnataka and Kerala Forest Departments and the French Institute, Pondicherry, in three
sheets at 1:250,000 scale with an explanatory booklet by J. P. Pascal was a valuable reference, but
was not used in the preparation of this dataset. The islands of Lakshadweep have not been mapped
as FSI (1986) and Das Gupta (1976) indicate no tropical forests exist there. In addition the following
maps were used in preparing generalised coverage of the monsoon forests: 1. Andhra Pradesh, 4.
Bihar, 11. Madhya Pradesh, 11B. Madhya Pradesh, 12. Maharashtra, 17. Orissa, 23. Uttar Pradesh,
24. West Bengal. Where monsoon forests abut onto the rain forests, these have been mapped as part
of the closed moist forest dataset. However, there are extensive monsoon forests in central and
eastern India, in northern India along the foothills of the Himalaya, and to the west of Bangladesh,
as well as in the western and north-eastern areas digitised in the closed moist forest dataset. These
monsoon forests have also been generalised and digitised.

(b) also combined with data for arid forests digitised from a diazo map at 1:3,500,000 of vegetation of
India from Remote Sensing of the Himalayas (M.A. Kawasa, 1988) and four separate sheets
covering the Himalayan region.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangroves: Some data were obtained from FSI (1986). Further information on the mangrove forest of the Sundarbans was taken from Department of Forests (1973). Gaps in these data holdings were filled using Blasco and Bellan (1995), prepared from Landsat MSS, Landsat TM and SPOT data. Further approximate areas were added from edits provided by Francois Blasco.

References:
FSI (1986). National Forest Vegetation Map. 1:1,000,000. Forest Survey of India.

Department of Forests (1973). Forest Map of South India. Department of Forests, Government of West Bengal.

Blasco, F and Bellan, M.F. (1995). A Vegetation Map of Tropical Continental Asia. 1:5,000,000. Institut de la Carte Internationale de la Vegetation, Toulouse, France.

INDONESIA:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

For Indonesia, the map in the above publication was interpreted from (a and b):
(a) Data produced by the Regional Planning Programme for Transmitigation (RePPProT) at a scale of 1:2, 500,000. The data was compiled over a number of years, commencing in 1984.
(b) Parts of Sumatra, Kalimantan and Irian Jaya were revised on basis of newer plots of AVHRR data provided by the TREES project.

Mangrove data have been taken from WCMC held coverages which are based on the Regional Physical Planning Programme for Transmigration (RePPProT) work begun in 1984 in association with the National Centre for Co-ordination of Surveys and Mapping (BAKOSURTANAL). Surveys were based on existing reports, air photographs and satellite or radar imagery with selective field checking. Areas covered, dates and scales varied greatly and full details are available from BAKOSURTANAL and RePPProT's regional reviews. Data were generously provided to WCMC by the RePPProT team in the form of hand-coloured draft maps at 1:2.5 million scale: Sumatra (1988), Java and Lesser Sundas (1989), Lesser Sundas (1989), Kalimantan (Central, 1985; South, West and East, 1987), Sulawesi (1988), Moluccas (1989), Irian Jaya (1986). WCMC are especially grateful to the Director General of Settlement Preparation, Ir. Djatjanto Kretosastro for use of data from the RePPProT project; to BAKOSURTANAL for their support; and to Dr David Wall, the RePPProT team leader, and his cartographers, for their cooperation in providing draft maps. The total area of mangrove for Indonesia based on these coverages is: 44,189 sq km

These maps have been further updated from a series of maps provided by Wim Geisen of the Asian Wetlands Bureau showing key mangrove areas, notably on Sumatra and Irian Jaya. Most maps are from unpublished reports (see list below). The information was transferred to eight A2 maps before digitising. Where these data differed from the data described above they were assumed to

be more accurate and the latter removed from the present coverage. Areas marked as "disappeared or very disturbed" were not included. A small number of original edits were provided by Dr Jim Davie, University of Queensland, Australia and Francois Blasco.

References:
AWB (1992). Proposal: Buffer Zones Development of the Berbak National Park. Final Draft. Asian Wetland Bureau, October, 1992.

Erftemeijer, P., Allen, G.R. and Zuwendra (1989). Preliminary resource inventory of Bintuni Bay, Irian Jaya, and recommendations for conservation and management. AWB-PHPA. Bogor, November 1989.

Geisen, W. (1991). Hutan Bakau Pantai Timor Nature Reserve, Jambi Survey Report. PHPA/AWB Sumatra Wetland Project Report No. 17. December, 1991.

Geisen, W. (1991). Bakung Island, Riau (Pulau Bakung, Pulau Basu) Survey Report. PHPA/AWB Sumatra Wetland Project Report No. 11. December, 1991.

Geisen, W., Baltzer, M. and Baruadi, R. (1991). Integrating Conservation with Land-use Development in Wetlands of South Sulawesi. PHPA/AWB, Bogor, October, 1991.

PETA (1992). Profil Lingkungan Hidup Daerah Lahan Basah Propinsi Jambi Sumatra, Indonesia. PHPA/AWB Proyek Lahan Basah Sumatera, Laporan No. 20b. February, 1992.

Silvius, M.J. and Taufik, A.T. (1990). Conservation and land use of Pulau Kimaam, Irian Jaya. PHPA - AWB/INTERWADER, January, 1990. Unpublished Report.

Zieren, M., Yus Rusila Noor, Baltzer, M. and Najamuddin Saleh (1990). Wetlands of Sumba, East Nusa Tengarra: an assessment of the importance to man, Wildlife and conservation. PHPA/AWB-Indonesia, Bogor, August, 1990.

JAPAN:
Environment Agency, Japan (1987) Actual Vegetation Map, scale 1:3,000,000.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangroves of Iriomote Island digitised from 1:50,000 map appended to Aramoto (1986) (map title: Map of Land Utilisation of Iriomote Island). Mangroves for the remainder of the islands around Okinawa were digitised from the Environment Agency (1981-87), whilst location of mangrove areas not covered on these maps were gathered from approximate distribution maps provided by Dr Shigeyuki Baba (June, 1995).

References:
Aramoto, M (1986). Iriomote-jima wo chusin to shita shigen shokubutsu huzon genkyo (Bio-resources distribution in Iriomote Island, Okinawa. Published by Chiiki-sanjyo-gijyutsu-shinko-kai, Okinawa Japan. 97pp.

Environment Agency (1981-87). Actual Vegetation Map, Okinawa 1-29. 1:50,000.
The Third National Survey on the Natural Environment (Vegetation).
Environment Agency, Japan. (29-map series on 26 sheets).

KOREA, DEMOCRATIC PEOPLE'S REPUBLIC:
World Forestry Atlas (1956) Korea, scale 1:5,000,000.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics
database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly
AVHRR images, analysed for NDVI.

KOREA, REPUBLIC:
World Forestry Atlas (1956) Korea, scale 1:5,000,000.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics
database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly
AVHRR images, analysed for NDVI.

LAO PEOPLE'S DEMOCRATIC REPUBLIC:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining
Habitat Map. ASB and WCMC, Canterbury, UK.

For Laos, the map in the above publication was interpreted from digitised tracings of TM interpretations
by J. MacKinnon and TREES data with reference to land cover map supplied by UNEP GRID
Bangkok. The 'scrub' category was added from data digitised from plots of TREES data. This
information was then superimposed on to the original map and deciduous and evergreen types
reclassified.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics
database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly
AVHRR images, analysed for NDVI.

MALAYSIA:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining
Habitat Map. ASB and WCMC, Canterbury, UK.

For Malaysia, the map in the above publication was interpreted from (a and b):
(a) The forest area, at a scale of 1:1,000,000 a hand-coloured map obtained from the Forest Department
in Kuala Lumpur in May 1989. Although undated, this unpublished map is the latest mapped
information available. It is an amended version of the published Peta Khazanah Hutan
Semenanjung Malaysia (Forest Map of Peninsular Malaysia), based on 1981-2 data and published
in 1986 at 1:750,000 scale.

(b) Peninsular Malaysia: The forest area shows hill, montane, swamp and mangrove forests. We have
only used the mangrove category directly. The original hill and montane forests have been
combined and separated again at a lower contour, 3000 ft (914 m), to comply with *The Vegetation
Map of Malaya, 1962* (Wyatt Smith 1964). The distribution of swamp forest in the south-east of
the country has also been adjusted slightly to comply with that work.

Reference:
Wyatt Smith, J. (1964) A preliminary vegetation map of Malaya with descriptions of the vegetation
types. Journal of Tropical Geography 18: 200-13.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangrove data for Sabah were taken from Sabah Forestry Department (1989). This provides a useful representation of forests within the protected and gazetted forests in the Permanent Forest Estate, but gives no indication of the extent (if any) of additional natural stateland forests. For Sarawak the main source was Lands and Surveys (1979). The data for Peninsula Malaysia are taken from Forest Department (n.d.). Although undated, this unpublished map is an updated version of a map published in 1986.

References:
Sabah Forestry Department (1989). Sabah Malaysia, Natural and Plantation Forests. 1:1,270,000. Sabah Forestry Department, Malaysia.

Lands and Surveys (1979). Sarawak: Forest Distribution and Land Use Map. 1:1,000,000. Director of Lands and Surveys, Sarawak, Malaysia.

Forest Department (1989). Peninsular Malaysia: The Forest Area. 1:1,000,000. Hand-coloured map obtained from the Forest Department, Kuala Lumpur in May 1989.

MYANMAR:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

For Myanmar, the map in the above publication was interpreted from a map distinguishing between evergreen and monsoon forest, mangrove and cleared land that was digitised in AUTOCAD by ABC. this was based on A4 maps of the Forestry Department and TREES data. This coverage was then combined with the original habitat map (also in the above publication) and reclassified.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangroves: Data for the Irrawaddy Delta were obtained from Blasco and Bellan (1995), prepared from Landsat MSS, Landsat TM and SPOT data. Further data were added based on the mangrove arcs shown on Petroconsultants SA (1990).

References:
Blasco, F and Bellan, M.F. (1995). A Vegetation Map of Tropical Continental Asia. 1:5,000,000. Institut de la Carte Internationale de la Vegetation, Toulouse, France.

Petroconsultants SA (1990). MUNDOCART/CD. Version 2.0. 1:1,000,000 world map prepared from the Operational Navigational Charts of the United States Defense Mapping Agency. Petroconsultants (CES) Ltd, London, UK.

NEPAL:

MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK. based on 1980-1990's AVHRR and LANDSAT images. Scale 1:1,000,000.

For Nepal, the map in the above publication was interpreted from data in UNEP GRID in Bangkok, derived from 1km resolution AVHRR satellite landuse data 1992-1993. This was combined with *Vegetation map of Himalayas Part IV (Nepal)* scale 1: 1,000,000 showing forests (continuous canopy) and degraded forests (40-60% cover) produced from LANDSAT imagery. Resulting coverage was reclassified into three categories, forest, degraded forest and non-forest according to areas of agreement or disagreement between the two data sources. The coverage was overlain with the original habitat types map (also in the above publication) and reclassified according to original condition.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

PAKISTAN:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

For Pakistan, the map in the above publication was interpreted in the following manner:
(a) Deserts, alpine and glacier habitats were assumed to be remaining.
(b) Remaining forest patches were digitised from two poor quality forestry maps of Pakistan and required transforming to match geographic projection. General reliability of these sources is thought to be poor.
(c) Mangroves were added from spatial data held in WCMC.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangroves for the Indus Delta were extracted from 1:1,000,000 map in Meynell and Qureshi (1993). Remaining areas were added to a 1:1,000,000 base map by S.M. Saifullah, Karachi University.

References:
Meynell, P.J. and Qureshi, M.T. (1993). Sustainable management of the mangrove ecosystem in the Indus Delta. In: Moser, M. and van Wessen, J. (eds.). Wetlands and Waterfowl Conservation in South and West Asia. IWRB Publications, No. 25. Gloucester, UK.

PHILIPPINES:
Forest Management Bureau (1988) Forest Cover Map of the Philippine Islands. Scale 1: 2,000,000.

National Mapping and Resource Information Authority. Landuse map, Scale 1: 5,000,000.

Mangroves: Processed satellite imagery has been kindly provided by NAMRIA (1988), prepared from SPOT images taken in 1987, at a scale of 1:250,000. Some of the smallest islands in the southwest, central and northern parts of the country are not included in the coverage, but are not likely to be make a significant difference to the total area.

References:
NAMRIA (1988). Land cover Maps. National Mapping and Resources Information Authority, Manila, Republic of the Philippines.

SINGAPORE:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK. based on 1980-1990's AVHRR and LANDSAT images. Scale 1:1,000,000.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

SRI LANKA:
Forest Management and Planting Project (1995) Forest map of Sri Lanka. From 1988 Landsat images, interpreted at about 1:50,000.

TAIWAN:
Mackinnon, J., Chung and Mengsha (1992) Biodiversity Review of China Forested Areas, scale unknown. Chinese Academy of Sciences.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangrove coverage gathered from sketch maps drawn over 1:500,000-1:1,000,000 base maps, prepared for this work by Dr Jane Lewis, National Taiwan Ocean University.

THAILAND:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

The Thailand map in the above publication was interpreted from The Royal Forest Department (RFD) Dataset "THFT" (based on 1993 Landsat imagery) which was first projected transformed slightly to account for a small misalignment. The RFD coastlines and international boundaries were removed and replaced with the WCMC Botanical Reporting Units border file.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangrove polygons were prepared from the four-map series (IDRC/NRCT/RFD, 1991) produced as a part of the Remote Sensing and Mangroves Project (Thailand) at a scale of 1:500,000. Sources for these maps were Landsat-MSS data recorded in 1986-1987.

References:
IDRC/NRCT/RFD (1991) Remote Sensing and Mangroves Project (Thailand). Series of four maps prepared at 1:500,000 by the Remote Sensing Division of the

National Research Council. International Development Research Centre, National Research Council of Thailand and the Royal Forestry Department.

VIETNAM:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining Habitat Map. ASB and WCMC, Canterbury, UK.

The map for Vietnam in the above publication was digitised in AUTOCAD by Asian Bureau for Conservation, converted via DXF to ARC and rubber sheeted to fit the DCW boundary more exactly.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Data showing mangrove in the Mekong Delta only are taken from Anon (1987), believed to be the result of a forest inventory in 1987.

References:
Anon (1987). Cac Loai Thuc Vat bi de Doa Dien Hinh va Mot Vung Tap Trung. 1:4,000,000. Publisher unknown.

SOURCES FOR OCEANIA

AUSTRALIA:
Canahan, J.A, and Australian Surveying and Land Information Group (1989) Australia: Present Vegetation . Scale 1:5,000,000, based on standard false colour transparencies of 1980-1985 LANDSAT imagery at 1:1,000,000 scale.

Department of Forestry (1987) Edition 4 North Queensland. Scale 1:500,000. (generalized)

Department of Forestry (1988) Edition 1 Far North Queensland. Scale 1:500,000. (generalized)

AUSLIG (1997) *Australia: mangroves*

USDMA (1989) *Operational Navigation Chart.* 1:1,000,000. Global map series published by the US Defense Mapping Agency.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Australia/Pacific land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Mangrove data taken from ONC charts (1989) at 1:1,000,000 scale and a 1:500,000 scale map (mid 1980's) Australia: Present Vegetation produced by the Australian Surveying and Land Information Group (AUSLIG), Department of Administrative Services. Assistance was received from Max Finlayson at the Alligator Rivers Region Research Institute, the author of the Australian chapter of the IUCN Wetlands atlas and from G.W. Howard, IUCN East Africa, who advised in the classification of the digitised information and the

location of mangal areas.

References:
AUSLIG (198?). Australia: Present Vegetation

USDMA (1989). Operational Navigation Chart. 1:1,000,000. Global map series
published by the US Defense Mapping Agency.

PAPUA NEW GUINEA:
MacKinnon, J. (1997) Protected Areas Review of the Indo-Malayan Realm: Remaining
Habitat Map. ASB and WCMC, Canterbury, UK.

For Papua New Guinea, the map in the above publication was derived from the following works (a and
b):
(a) Collins, N.M., J.A. Sayer and T. C. Whitmore (Eds) (1991). Conservation Atlas of Tropical
       Forests. Asia and the Pacific. Macmillan, London, UK. The map for Papua New Guinea in the
       Conservation Atlas was derived from: a set of 18 maps at 1:500,000 scale dating from 1971: *PNG
       Vegetation and Timber Resources* Edition 2. Compiled by the Australian Department of Defence
       from air photography and radar imagery, these maps show the distribution of major forest types.
       Given the relatively slow rate of change in PNG, they are still of value. However, K . Paijmans's
       (1975) set of four 1:1,000,000 scale maps remains the most useful and recent set of data, and
       formed the basis for the map presented in this dataset. *Vegetation of Papua New Guinea* and the
       accompanying Explanatory Notes show 13 forest categories, mangrove and 10 other categories. In
       the forest categories, lowland rain forests mapped here have been compiled from Paijmans's
       categories large to medium crowned and small crowned forests on plains and farms (FPl, FPs),
       littoral forest (FB), medium, small and large crowned lowland hill forests (FHm, FHs, FHl) and dry
       evergreen forest (Fd). Freshwater swamp forest comprises Paijmans' open forest on plains (FPo),
       swamp forest (Fsw) and moist swamp woodland (Wsw). Montane forest comprises lower montane
       (FL), coniferous lower montane (FLc), very small-crowned lower montane (FLs) and montane
       (FM) forests, and begins at 1400m altitude. Seasonal (monsoon) forest is Paijmans's woodland
       category W. Non-forest comprises Paijmans's categories of scrub (Sc), savanna (Sa), grassland (G,
       Gsw) mixed herbaceous vegetation (Hsw) and gardens (Ga). Areas of secondary forest, indicated
       by an overlay of dots onto the forest type by Paijmans, have not been distinguished in this dataset.
       Pioneer vegetation (Pi) has been included with its neighbouring climax forest type.

(b) Manual classification lines drawn on TREES data plots only where newer data showed changes to
       forest distribution in the Conservation Atlas of Tropical Forests .

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics
database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly
AVHRR images, analysed for NDVI.

Digital Mapped data have kindly been provided by the Research School of
Pacific and Asian Studies, Australian National University, with generous
permission from the Department of Agriculture and Livestock, Papua New
Guinea. These data are taken from the Papua New Guinea Resource Information
System, developed by the Australian Commonwealth Scientific and Industrial
Research Organisation. The source data have been generated from extensive
field studies, extrapolated over the whole country by air photograph
interpretation of 1:50,000 and 1:80,000 images taken in the 1960s and 1970s,
and mapped at a scale of 1:500,000. Although data are old it is thought that
rates of change may not be large in this country, while these data are the
most accurate available for this country.

References:
Bellamy, J.A. (1986). Papua New Guinea Inventory of Natural Resources: Population Distribution and Land Use Handbook. Natural Resource Series No.6, CSIRO Division of Water and Land Resources, Canberra.

Paijmans, K. (Ed.) (1976). New Guinea Vegetation. Australian National University Press and CSIRO, Canberra.

RUSSIAN FEDERATION:
Isaev, A.C., (1990) Forests of the USSR. State committee of the USSR. Scale 1: 2, 500,000.

U.S.G.S. EROS Data Center/GLCCD version 1.2 (1998) Eurasian land cover characteristics database. The data have 1-km nominal spatial resolution, derived from 1992-1993 monthly AVHRR images, analysed for NDVI.

Annex II.

List of maps:

Map 1. Potential distribution of the genus Bambusa
Map 2. Potential distribution of the genus Sasaella
Map 3. Potential distribution of the genus Acidosasa
Map 4. Potential distribution of the genus Pleioblastus
Map 5. Potential species richness of the subfamily Bambusoideae
Map 6. Potential distribution of 60 genera of the subfamily Bambusoideae