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Environmental and Economic Issues in Forestry

Selected Case Studies in Asia

Edited by Susan Shen and Arnoldo Contreras-Hermosilla

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Susan Shen is Senior Ecologist in the East Asia Country Department I of the World Bank. Arnoldo Contreras-Hermosilla is Senior Natural Resources Economist in the Latin America and Caribbean Country Department II of the World Bank.

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Foreword

In 1990, when the papers that make up this volume were commissioned, World Bank lending for forestry in Asia stood at nearly $2 billion. In fiscal 1994 alone, more than $300 million in lending was devoted to Asian forestry issues. As part of its responsibility for this level of investment, the World Bank has assisted the borrowing countries in their efforts to slow the rate of deforestation in the region, estimated at 3.5 million hectares a year during the 1980s, while expanding economic growth. This work has been hampered, however, by a lack of analyses of the key weaknesses in the sector—for example, low administrative capacity, inappropriate forest and other development policies, and limited knowledge of silvicultural and management systems for (tropical) forests and of the social, cultural, and environmental dimensions of forest management.

Over the last few years, the World Bank and the Asia Technical Department have provided significant guidance on reassessing and adapting approaches to these issues. The World Bank policy paper *The Forest Sector* (1991), Operations Evaluation Department Review of Forestry Lending (1991), *Strategy for Forest Sector Development in Asia* (1992), and various country-specific forest sector analyses provide the broad parameters for Bank work in forestry in Asia.

The papers presented in this volume were planned to support specific forestry programs at the country level. Toward that end, the Asia and Pacific Country Departments were invited to identify the priority issues to be studied and collaborated throughout the process of preparation and review of the reports. The resulting studies provide an overview of some of the more important forestry issues facing countries in Asia, and this volume is presented in support of all concerned policymakers, foresters, and development organizations as they balance the pressures of population and economic growth with protection of the region's critical forestry resources.

Harold W. Messenger
Director
Asia Technical Department

Abstract

Forests in Asia are under intense pressure to grow construction timber, provide trees and underbrush for fuel or leaves for crafts, and supply medicinal plants, game, fruits, nuts and so on—for one of the fastest growing populations in the world. The number of people living in South Asia alone is expected to grow by two-thirds during the next two generations, and governments across Asia are justifiably concerned about the degradation or loss this growth may mean to their forest resources and to their people. The poor in Asia particularly depend on forests as a source of protein and shelter.

But beyond the obvious, immediate causes of deforestation, it is generally recognized that other interrelated forces—economic, institutional, and technical—contribute more to forest loss. For instance, the underpricing of timber, or subsidies, will probably lead to overuse of wood and eventually to deforestation.

Recognizing that many of the immediate pressures on Asian forests were caused by the needs of growing populations and economies, in 1991 the World Bank commissioned a series of studies funded by a grant from the Government of Norway to incorporate environmental considerations into economic analyses of forestry operations. The Environment Division of the Asia Technical Department (ASTEN) coordinated the process of preparation and review, and the World Bank Country Departments for Asia were invited to identify the specific issues of concern to operations.

Each of the chapters presented in this volume represent one of those research topics—from analysis of the logging ban in Thailand to technical advice on tree improvement programs to analysis of the effect on forests of economic policy in India. Because the topics represent the interests of the Asia Country Departments, the volume provides an overview of the environmentally related priority issues in Asian forestry and contributes to the critical work of understanding their complex dynamics.

Preface

History of process

Forests are a major resource of nearly every country and provide many services such as cleaning the air, stabilizing the soil, and moderating runoff. But in Asia they also have important second and third jobs—growing construction timber, providing trees and underbrush for fuel or leaves for crafts, and supplying medicinal plants, game, fruits, nuts and so on—for one of the fastest growing populations in the world. The number of people living in South Asia alone is expected to grow by two-thirds during the next two generations, and governments across Asia are justifiably concerned about the degradation or loss this growth may mean to their forest resources and to their people. The poor in Asia particularly depend on forests as a source of protein and shelter.

The growing population in Asia is expected to exacerbate the usual causes of deforestation—conversion to agricultural uses, demand for fodder and fuelwood (four-fifths of Asia's timber demand), and logging. The Food and Agriculture Organization of the United Nations has estimated that forests disappeared in Asia at the rate of 3.5 million hectares a year during the 1980s, and already this historically wood-exporting region is showing a wood deficit. In fact, imports of timber and forest products will cost the region an estimated $20 billion annually by 2000.

But beyond the obvious, immediate causes of deforestation, it is generally recognized that other interrelated forces—economic, institutional, and technical—contribute more to forest loss. For instance, the underpricing of timber, or subsidies, will probably lead to overuse of wood and eventually to deforestation.

Environmental economists, extending these lines of argument, are now recognizing that an even more basic factor than any of these may be what lies behind those forces—that is, what happens, or does not happen, in the economic valuation of natural resources or the services they provide. What is the economic chain of cause and effect that is set in motion when, for example, a lake is polluted and the loss of its fish or surrounding vegetation is ignored as a cost and the service is considered "free"? It is now recognized that the destruction of environmental resources or services is never without cost. One of the main messages of this publication is that when forest resources are destroyed, whether through logging, agricultural activities, or exploitation for fuelwood, the loss is not free and if the full costs of the use—erosion, loss of biodiversity, or release of carbon dioxide into the atmosphere—are not borne by the private or public user, they will be paid by society as a whole, or future generations.

The social, political and economic dynamics that cause the environmental costs of overuse, degradation or destruction to be overlooked by national planners are of course very complex. But this report describes a number of common interlinked actions (or results of inaction) that can be identified and addressed. For instance, when degradation or depletion is not reported in national income indicators, policymakers receive a badly skewed picture of income generation (chapter 2). And as noted earlier, the institutional and policy structures of many countries muddle the environmental management picture even further and create conflicts in objectives (as when programs for intensifying agriculture production encourage the clearing of forests) or unwanted incentives (usually through subsidies) to overuse natural resources (chapters 3 and 4).

Recognizing that many of the immediate pressures on Asian forests were caused by the needs of growing populations and economies, in 1991 the World Bank commissioned a series of studies funded by a grant from the Government of Norway to incorporate environmental considerations into economic analyses of forestry operations. The Environment Division of the Asia Technical Department (ASTEN) coordinated the process of preparation and review, and the World Bank Country Departments for Asia were invited to identify the specific issues of concern to operations. A steering committee selected proposals for funding, and after the research topics were refined through discussions within the departments, the papers were submitted to rigorous peer review and revision. Several seminars were held to allow further discussion and to make tighter application to Bank experience.

Another part of the exercise funded by the Norwegian grant and participated in by Bank staff was a multilateral effort under the direction of the Food and Agriculture Organization of the United Nations. Two publications have already been published from that effort, *Economic Assessment of Forestry Project Impacts* and *Assessing Forestry Project Impacts: Issues and Strategies*.

In the Foreword to *Strategy for Forest Sector Development in Asia*, published by the World Bank in 1992, Daniel Ritchie wrote, "More than perhaps any other sector, forestry captures the interrelationships between economic growth, environmental preservation, and poverty alleviation." This volume that is based on research developed and carried out by World Bank staff and consultants—and representing the interests of Asia Country Departments—is presented here to provide an overview of the environmentally related priority issues in Asian forestry and contribute to the critical work of understanding their complex dynamics.

Tools, policies and institutions, and technologies

Chapter 1 addresses the economic issues in conserving biodiversity in West Kalimantan, the third largest Indonesian province, which is rapidly losing many of its highly diverse ecosystems—an estimated 50 percent of the original forest, for example—and the rich biodiversity they support. Conserving biodiversity in West Kalimantan, or anywhere else, is an economic proposition because alternative land uses are considered economically attractive. The authors, William B. Magrath, Charles M. Peters, Nalin Kishor, and Puneet Kishor, describe their preliminary work in organizing data on these costs in the form of a schedule of the marginal costs of habitat preservation, or a *biodiversity supply curve*. The supply curve is then used in a preliminary exploration of a number of policy issues such as biodiversity valuation and the justification for international compensation for biodiversity compensation. These experiments give rise to additional questions, which will be explored in future work.

In chapter 2, Claudia W. Sadoff addresses the issue of not reflecting the cost of environmental degradation or resource depletion in national income indicators. While recognizing that measurement of the interdependence of economics and ecosystems is complex, the author nevertheless considers the exercise critical to sound environmental management if, as the celebrated economist

J.R. Hicks suggested, income is a "guide for prudent conduct." The author applies two natural resource accounting methodologies, user cost and depreciation, to Thailand's forestry-related income between 1970 and 1990 to assess the effect of the country's logging ban on its forests. According to Sadoff's estimates of forest depletion-adjusted income, the average annual cost of deforestation in Thailand over the past two decades has been roughly 2 percent of the country's real gross domestic product (GDP). The annual losses of forest assets have been, on average, equivalent to more than 20 percent of the total manmade capital depreciation that is currently recorded in Thailand's national income accounts. None of these costs are reflected in the standard calculations of GDP. Clarifying what the variables mean to the computation, the author discusses the policy implications of these and other results of the application of the two natural resource accounting methodologies for Thailand and for environmental economics in general.

Government policy that has negative impacts on forests in India is the focus of chapter 3. The author, Arnoldo Contreras-Hermosilla, sets the discussion in a worldwide context, however, by describing the policies of other governments that have unintended negative impacts on forestry, such as the policies in Costa Rica on livestock and trade that have encouraged the conversion of forests. In India government policy has an especially powerful effect on forests, because they are mainly the property of the state. This and the following chapter on institutions together provide a clear analysis of how policies and the procedures of government agencies can inadvertently work at cross-purposes to the goal of sound management of India's forest resources.

In chapter 4 Augusta Molnar, Malcolm Jansen, and J. Gabriel Campbell analyze the current status of India's forests and wastelands (defined according to the National Wasteland Development Board as lands that are used far below their productive potential). The authors describe the potential for developing these resources and discuss the key environmental and economic issues underlying various alternatives. Institutional arrangements that show promise for the development of forests and wastelands by user groups are examined. And finally the authors outline a potential strategy for biodiversity conservation. The chapter was one of three background papers for India for the World Bank Forest Sector review (1991). There are overlaps among the three background papers, and the complementarity between this chapter and another of the papers, included here as chapter 5, is particularly strong.

Vast areas of forest land worldwide have been degraded and are unproductive, and many countries raise forest plantations on these sites. The Food and Agriculture Organization of the United Nations reports an increase in plantation forest in the tropics of 18 million–44 million hectares over the decade 1980–1990. Not all of these plantations, however, are as productive as they could be. G. Sam Foster, Norman Jones, and Erik D. Kjaer point out in chapter 5 that although people have reaped enormous benefits from domesticating annual plants such as wheat and rice and perennial plants like apples, mangoes, tea, and coffee, they have not made much headway with the process of domesticating tree species. The authors describe how domestication might be attempted through careful attention to germination and nursery practices and through genetic identification and manipulation, or tree "improvement." They outline the basic components of a tree improvement program, describe various common trade-offs necessary when these programs are established or redesigned, and examine the opportunity costs when stock quality is compromised in an attempt to economize on nursery or seed stock. This practical discussion is expanded further by an examination of how the appropriate intensity of a tree improvement program is decided by comparing the value of quick, medium results with the larger but delayed gains that can be achieved through a more intensive and systematic program. Fortunately, as the authors point out, this is not necessarily an either/or decision as there are some simple steps that can be taken to generate gains quickly and these can be followed by a more-sophisticated, yet economically viable, improvement program.

Structure of publication

To prepare the papers for this combined volume several adjustments were required. Where an appendix was attached to the papers, it has been included as the last section to the chapter, followed by the endnotes. The authors had different methods of citing literature and these are reflected as either references or a bibliography at the end of each chapter. Otherwise, except for chapters 2 and 5, the chapters are as they appeared as papers. Chapter 2 was originally two papers that were rewritten into one draft by the editor and substantially updated by the author. Chapter 5 was revised significantly by the authors to reflect advancements in technology.

Acknowledgments

Many World Bank staff were instrumental in bringing this volume to publication. As Division Chiefs of the Environmental Division of the Asia Technical Department, both Gloria Davis, who spearheaded the initial project, and Maritta Koch-Weser, who supported the publication of the findings in this volume, recognized the significance of the close collaboration with the Country Departments this research represents. The contributions of the Country Departments in identifying issues and sharpening the focus is greatly appreciated for helping to make the research and this publication more practical and useful.

The authors of the chapters also wish to acknowledge special contributions to their work: Andrew Parker, Wayne Luscombe, Pietr Nyborg, John Dixon, Kenneth Chomitz, and Susan Shen of the World Bank (chapter 1); Michael Ward and Arnoldo Contreras-Hermosilla of the World Bank and Albert Fishlow and Jeff Romm of the University of California, Berkeley (chapter 2); N.C. Saxena of the Oxford Forestry Institute and Hans Gregersen of the University of Minnesota (chapter 3); Ben Van De Poll and Ann Clark of the World Bank (chapter 4); and J. Williams, a private consultant, and Arnoldo Contreras-Hermosilla of the World Bank (chapter 5).

Finally, a number of people have helped prepare the papers for this publication. Charlotte Maxey edited the volume and coordinated its production. George Parakammanil designed the cover, and Cynthia Stock produced the desktopped version.

Abbreviations and Data Note

AC1	LANDSAT satellite
BI	Biodiversity Index
CPI	Conservation Priority Index
CPR	Common property resources
ENDAF	Endemism Adjustment Factor
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
f.o.b.	Free on board
FAO	Food and Agriculture Organization of the United Nations
FIO	Forest Industries Organization (Thailand)
FPC	Forest Protection Committee (India)
G&E	Genotype x environment (interaction)
GDP	Gross domestic product
GIS	Global Information Systems
GNP	Gross national product
IPAS	Integrated protected areas system
IRR	Internal rate of return
LANDSAT	Type of U.S. satellite
NDP	Net domestic product
NGO	Nongovernmental organization
NNP	Net national product
NTFP	Non-timber forest products
NWDB	National Wasteland Development Board (India)
ODA	Overseas Development Administration (United Kingdom)
PA	Protected area
PNW	Present net worth
RFD	Royal Forest Department (Thailand)
ROI	Rate of return
SEEA	System of Economic and Environmental Accounts (United Nations)
SNA	System of National Accounts (United Nations)
SPRICH	Index species richness
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WRI	World Resources Institute

Note: *Dollars* are U.S. dollars unless otherwise specified.

1

The Economic Supply of Biodiversity in West Kalimantan: Preliminary Results

William B. Magrath, Charles M. Peters, Nalin Kishor, and Puneet Kishor

West Kalimantan, the third largest Indonesian province on the island of Borneo (see inset map 1), with a total land area of almost 147,000 square kilometers, is facing the rapid disappearance of many of its highly diverse ecosystems and the biodiversity they support. Although reliable data on forest clearing are difficult to obtain, recent estimates suggest that almost 50 percent of the original forest has already been lost and the destruction of lowland dipterocarp forests and mangrove areas has been especially pronounced. Extensive logging, establishment of large-scale industrial crop plantations, and increasing agricultural demands of a growing rural population appear to be the major factors responsible for this alarming reduction in forest area. The environmental impacts of these developments will come under increasing scrutiny in the future.

Conserving biodiversity is an economic proposition. Alternative land uses are being pursued aggressively in West Kalimantan because of their financially attractive returns. Efforts to introduce land use policies aimed at biodiversity conservation would benefit from explicit information on the size of these rents. This chapter describes preliminary work in organizing data on these costs in the form of a schedule of the marginal costs of habitat preservation, or a *biodiversity supply curve*.

The protection of natural areas implies foregoing other socially valued land uses and may require additional resources to ensure that protected areas are actually protected. Exploration of these opportunity costs can provide crucial data to policymakers and others interested in biodiversity loss or degradation. Building on the opportunity cost concept, this chapter uses Geographic Information Systems (GIS) technology to illustrate estimation of the economic supply of biodiversity in West Kalimantan.

West Kalimantan presents an interesting and important opportunity to study the costs of conserving biodiversity. It offers both the availability of fairly detailed information on the economics of various land uses and reasonably well-documented biological resources. The natural vegetation of the region is characterized by a variety of forest types including mangroves, peat forest, freshwater swamp forest, heath forest, and lowland or hill mixed dipterocarp forest. Some of these forests are reputed to be the oldest and most species-rich in all of Southeast Asia (FAO 1981). Floristic studies of the province suggest that the forests of this region are exceptionally rich in edible fruits, rattan, oil seeds, medicinal plants, resins, and other useful plant products (Padoch and Peters 1993). Leighton (1990), for example, reports that the forests at Gunung Palung in the Ketapang district contain 21 species of wild mangosteen (*Garcinia* spp.), 8 species of rambutan (*Nephelium* spp.), 7 species of durian (*Durio* spp.), 4 species of mango (*Mangifera* spp.), and a host of lesser known fruits such as rambai (*Baccaurea*, 23 species) and cempedak (*Artocarpus*, 13 species). Small tracts of forest may also exhibit a high abundance of useful plants. A 1.0 hectare plot of hill dipterocarp forest inventoried in the Sambas district was found to contain 3 species of illipe nut (*Shorea* spp.), 25 species of edible fruits and nuts, 35 timber species, 5 species producing damar (oleo-resin) or other useful exudates, 2 species of rattan, 3 species whose leaves or bark are used medicinally, and 1 species used locally as a fish poison (Peters 1991).

The chapter begins with a brief and selective review of literature on biodiversity, calling attention primarily to the relative neglect, despite its conceptual and methodological appeal, of an opportunity cost approach and to some specific problems of definition that hamper its use. Several pioneering studies of conservation that do apply an opportunity cost approach are reviewed providing a basis for their extension in later sections.The paper then turns to a detailed discussion of the estimation of the economic supply of biodiversity in West Kalimantan.

An index of biodiversity quantity is proposed to link data on ecosystems with data on alternative land uses. Because some of these data are spatially related, the use of GIS techniques to generate the supply curve is then described. Finally, the estimated supply curve is used to explore a number of policy issues including biodiversity valuation, the justification for international compensation for biodiversity conservation, and an assessment of the impact of various economywide variables such as interest rates and foreign exchange rates on biodiversity. These experiments give rise to additional questions, and possible directions for further work are explored.

Economic perspectives on biodiversity

Biodiversity refers to the totality of biological life. The term includes plants, animals and microorganisms together with the ecosystems and ecological processes to which they belong (see, for example, Ehrlich and Wilson 1991; Wilson 1988; McNeely and others 1990) and even extends to the genetic information from which this diversity results. From a conceptual standpoint, the term is an eloquent expression for highlighting the rapid and irreversible species loss now occurring throughout the world, and it provides a useful framework for orienting and promoting conservation activities. From a practical perspective, however, the term remains essentially undefined, and there is probably no spot on earth—certainly no spot lying between the Tropics of Cancer and Capricorn—for which all the constituent biodiversity has been quantified. So poor is knowledge of the biome that current estimates of the number of species on the planet can only be narrowed to a range of 2–100 million (Reid 1992). Fewer than 1.5 million of these species have been named, much less studied, counted or described in terms of their ecology or ecosystems requirements (see table 1.1).

While in principle species can be counted, it is not clear that species number is an appropriate measure of biodiversity. Other quantification schemes have been attempted varying from simple subjective description to complex multivariate assessment. The desired result is usually a single value that can be used to rank different habitats in terms of their potential, predicted or relative biological diversity. Essentially all available measures are imperfect as they may reflect only a small de-

Table 1.1 Estimates of species number by taxa

Group	*Number of described species*
Bacteria and blue-green algae	4,760
Fungi	46,983
Algae	26,900
Bryophytes (moses and liverworts)	17,000
Gymnosperms (conifers)	750
Angiosperms (flowering plants)	250,000
Protozoans	30,800
Sponges	5,000
Corals and jellyfish	9,000
Roundworks and earthworks	24,000
Crustaceans	38,000
Insects	751,000
Other arthropods and minor invertebrates	132,461
Mollusks	50,000
Starfish	6,100
Fish (Teleosts)	19,056
Amphibians	4,184
Reptiles	6,300
Birds	9,198
Mammals	4,170
Total	1,435,662

Source: McNeely and others 1990.

Table 1.2 Estimates of species extinction

Estimate of species loss	*Percentage of global loss per decade*	*Method of estimation*
1 million species 1975–2000	4	Extrapolation of past exponentially increasing trend
15–20 percent of species 1980–2000	8–11	Species area curves
25 percent of species 1985–2015	9	Loss of half of species in area likely to be deforested by 2015
2–13 percent of species 1990–2015	1–5	Species area curves

Source: Reid 1992.

gree of biological reality, may be based on weak assumptions, or may give undue weight to certain habitats or species while ignoring others.[1] Were it not for the conflicts that arise over the measures taken to preserve biodiversity, the difficulties in expressing quantitative dimensions would mainly be of academic interest. However, assessment schemes are needed to provide a means of identifying areas of particular conservation importance, and some have been used effectively in planning and establishing protected areas in many tropical regions.

The need for protected areas derives from the pressures being placed on natural habitats by population growth, open access to land resources, development demands from other sectors and other sources.[2] Estimates of the resulting species extinction vary widely (see table 1.2), but it is generally agreed that the rate of loss is high and is primarily due to destruction of habitat. Only to a very limited extent—for example, as required by legislation on endangered species protection—are biodiversity concerns explicitly considered by policymakers. The world's current stock of biodiversity is thus not the result of carefully weighed valuation of the consequences of alternative land uses. It is rather the result of myriad market-based and other demands for land that aggregate to the observed rates of extinction.

While numerous attempts have been made to estimate the local and global values of biodiversity (see the appendix table),[3] only a relatively few studies have explicitly and systematically addressed the values of alternative land uses. This is somewhat surprising in view of the relatively greater tractability of costs compared with benefits, as well as the conceptual appeal of a cost-based approach.[4] These advantages are well demonstrated by studies conducted by Hyde (1989) on the redcockaded woodpecker, by Montgomery, Brown and Adams (1994) on the northern spotted owl, and by Ruitenbeek (1992) on the Korup National Park in Cameroon.

In his study of mechanisms for promoting rainforest conservation, Ruitenbeek (1992) developed the notion of rainforest supply price (RSP) and applied it to estimate the requirements for international transfers to protect the Korup National Park. Conceptually, RSP is essentially the annual rental value of 1 hectare of rainforest. Ruitenbeek treated the entire park as a project, calculated the present value of the project, and estimated the compensation needed to offset the present value of net losses associated with conservation. He developed scenarios for conversion of park land to secondary forest through agriculture and for timber harvests in the absence of park development and considered the possible benefits from park development, including tourism, fisheries protection, flood control, and soil fertility maintenance. His model estimated that park development would cost CFAF 5,051 million (communauté financière Africaine franc, approximately US$1=524 CFAF), return direct benefits of CFAF 3,199 million, and provide protection, in present value terms, to 513,800 hectares. This generated an estimated RSP of CFAF 3,605 per hectare per year, which compared favorably with values implied by actual debt for nature swaps and other international transactions for compensating for natural area protection.

Ruitenbeek's work treated the existing park and its surrounding areas as an indivisible unit. Hyde (1989), in his consideration of the marginal costs of managing the red-cockaded woodpecker in forests in the southern United States treated habitat area as a choice variable and examined the opportunity costs of different levels of protection. The woodpeckers nest in cavities they build in live pine trees, and their protection requires maintenance of adequate old growth trees. Biologists recommend average age stands of 75–90 years for woodpecker habitat, as opposed to standard multiple use criteria that specifies rotations of 70 years.[5] Each colony of birds requires approximately 4.8 hectares (12 acres) of territory. Therefore, Hyde considered two management alternatives: (a) permanent cessation of harvesting on currently occupied sites and (b) extended rotations and harvests on a sequence of timber stands recruited as colony sites.

By assembling data on land quality (site index), growth rates, costs of operations and timber prices, Hyde was able to determine that the costs, in terms of annual rents, of preserving existing nesting sites varied from $10 to $2,261 per site and that expansion of habitat would result in costs of $473–$4,734 per site. However, when the costs of access (road construction) were taken into account, because the existing nesting sites were generally undeveloped for logging, for much of the area under consideration there was essentially no conflict between logging and woodpecker habitat.

Montgomery, Brown and Adams (1994) extended the use of opportunity cost concepts to analyze species preservation by relating area protected to the probability of species survival. Focusing on a single species, the northern spotted owl (*Strix occidentalis caurina*), they characterized forest tracts in the United States Pacific Northwest by their potential contribution to owl habitat capacity, which they denote c_i, and by their potential contribution to annual public stumpage supply, q_i. The ratio, c_i/q_i, provided an estimate of the physical (wood volume) "price" per owl nesting pair for each tract. Ranking the tracts by physical price and summing give them habitat capacity as a function of the area allocated to protection and the reduction in annual stumpage supply associated with a particular level of protection.

This approach was used to estimate the marginal costs of protecting the northern spotted owl and to evaluate protection proposals. In addition to showing that serious proposals varied in their marginal costs of protection from $0.6 billion to $3.8 billion per percentage point increase in survival probability, Montgomery, Brown and Adams were also able to analyze the distributive impact of owl protection on local communities and producers.

West Kalimantan case study

Extending the opportunity cost approach to West Kalimantan required five basic steps: (a) modelling biodiversity quantity; (b) modelling opportunity costs; (c) spatially associating the distribution of biodiversity with that of alternative opportunities to rank specific areas by both parameters; (d) arraying the results in the form of a supply curve; and (e) utilizing the formulation to evaluate selected policy problems. The essential techniques underlying the methodology used in this study is well established in applied economics. First developed in classic studies in economic theory by Marshall (1947) and Viner (1932), they have been used in forestry by Hyde (1980), in studies of air pollution in Mexico City by Eskeland (1994), and in numerous other applications. In all these studies, average costs and outputs for discrete production units are observed and supply is modelled as an increasing function of average cost.[6]

Modelling biodiversity quantity

The conservation problem faced in West Kalimantan differs significantly from the work described above. Unlike Hyde (1989) and Montgomery, Brown and Adams (1994), who were concerned with the protection of a single species, or Ruitenbeek (1992), who was concerned with a discrete land unit, anyone concerned with biodiversity protection in West Kalimantan must choose both how much land area should be preserved and what kind of land. This problem of which ecosystems and which diversity may actually be the most common form of biodiversity conservation problem, but it has largely been ignored. Consequently, it is necessary to develop a quantitative measure of biodiversity that can be used to rank and compare different units of land. Although there is no entirely satisfactory method for this kind of modelling, there is broad scientific agreement on the essential parameters for developing biodiversity priorities.[7]

A procedure was developed to use insights from the field of island biogeography,[8] and data from the Regional Physical Planning Project for Transmigration (RePPProT) (1987) Land Use map series (scale 1:250,000) for West Kalimantan to calculate a Biodiversity Index (BI) value for specific land units covering the entire province. This series of eighteen maps, which was prepared to assist the Indonesian Ministry of Transmigration in land development site selection, provides the most comprehensive representation of the distribution and extent of land use, land capability, habitat and other features. The vegetation and land use determinations are based largely on interpretation of satellite imagery (LANDSAT-MSS) and aerial photography with limited ground truthing and are therefore subject to considerable margins of error. The eighteen map sheets describe 2,610 geographic units (polygons in GIS parlance) pertaining to forty-five different habitats or land use types. These types conform to the classification scheme proposed for Indonesia by Malingreau and Christiani (1981) and are summarized in table 1.3.[9] A simplified version of the RePPProT data is shown in map 1 in which land use categories have been aggregated for clarity of illustration.

The Biovalue Index used in this work incorporates data from the RePPProT series on (a) the area of each of the 2,610 land use

Table 1.3 Biogeographic description of Indonesia by habitat or land use type

Habitat or land use	*Code*[a]	*Area (ha)*	*SPRICH*	*ENDAF*	*Notes*
Lowland forest	Hh	5,091,950	16	1	Mixed dipterocarp forest 100 meters above sea level (masl)
Swamp forest	Hr	269,080	12	1	Variable flooding by freshwater, *rawa*
Riparian forest	Hs	6,671	11	1	Gallery forest along river meander
Heath forest	Hk	462,645	10	1.02	Forest on white sand; *kerangas*
Peat forest	Hg	1,617,477	6	1	Forest on peat of variable depth; *gambut*
Tidal forest	Ht	208,641	5	1.02	Saltwater tolerant mangroves, palm species
Coastal forest	Hc	23,603	5	1	Beach and/or dune vegetation
Submontane forest	Hf	397,829	5	1.02	Mixed dipterocarp forest; 1,000–2,000 masl
Logged primary forest	Hx	445,998	4	0.9	Selective timber harvest of variable intensity
Lowland forest+Bush	HhB	88,566	3.5	0.8	Forest mixed with secondary vegetaion
Peat forest+Bush	HgB	47,001	3.5	0.8	Forest mixed with secondary vegetation
Lowland forest+Swidden	HhL	1,409	3.5	0.6	Forest mixed with shifting cultivation; *ladang*
Bush	B	875,138	3.5	0.7	Secondary vegetation of varying age
Swamp vegetation	Rr	66,606	3	1	Swamp grassland with sedge and *Pandanus*
Rubber+Lowland forest	PkHh	974	3	0.6	Rubbler plantation mixed with forest
Bush+Rubber	BPk	23,276	3	0.6	Secondary vegetaion mixed with rubber
Rubber+Bush	PkB	36,887	3	0.6	Rubber mixed with secondary vegetaion
Bush+Swidden	BL	1,403,252	2.5	0.6	Secondary vegetation and swidden plots
Bush+Wetland rice	BS	543	2.5	0.6	Secondary vegetation with rice; *sawah*
Tree Crops	P	118,644	2	0.5	Mixed tree crops
Plantation	PLNT	14,346	2	0.5	Unidentified estate crops
Coconut plantation	Pc	74,827	2	0.5	Mostly coconut monocultures
Rubber plantation	Pk	11,793	2	0.5	Mostly rubber monocultures

polygons, (b) habitat type of each polygon, (c) number and type of different habitats adjacent to each polygon, and (d) adjustment to account for rarity, exhaustion rate and protection status. The Biodiversity Index is a weighted measure that integrates information about the species richness, endemism (or number and kind of species that are unique to the region), and heterogeneity of the landscape surrounding a site. The Biodiversity Index provides a representation of the total variety of plants and ani-

Habitat or land use	*Code*[a]	*Area (ha)*	*SPRICH*	*ENDAF*	*Notes*
Oil palm plantation	Pp	11,032	2	0.5	Intensively managed monocultures
Grassland	R	134	2	0.5	Unidientified grassland
Alang-alang	Ra	343,620	2	0.5	Imperata grassland
Wetland rice	S	38,438	2	0.5	Permanent rice cultivation; sawah
Rainfed rice	Sr	139,200	2	0.5	Permanent rice cultivation; no irrigation
Swidden	L	839,929	2	0.5	Shifting cultivation; ladang
Tree crops+Settlements	PK	2,737	2	0.5	Agroforestry fields mixed with villages
Reforested areas	Fr	20,203	2	0.5	Replanted forestry concessions
Settlements+Swidden	KL	1,275	2	0.5	Villages mixed with swidden plots
Swidden+Bush	LB	1,355,453	2	0.5	Swidden plots and secondary vegetation
Swidden+Settlements	LK	1,064	2	0.5	Swidden plots mixed with villages
Swidden+Rubber	LPk	37,031	2	0.5	Swidden plots and rubber plantations
Coconut+Rubber	PcPk	4,918	2	0.5	Coconut and rubber plantation
Coconut+Rainfed rice	PcSr	5,365	2	0.5	Coconut plantation mixed with rice planting
Coconut+Swidden	PcL	3,981	2	0.5	Coconut plantation and swidden plots
Alang-alang+bush	RaB	3,452	2	0.5	Imperata grassland and secondary vegetation
Alang-alang+Swidden	RaL	737	2	0.5	Imperata grassland mixed with swidden plots
Wetland rie+Swidden	SL	48,717	2	0.5	Sawah and swidden plots
Rainfed rice+Coconut	SrPc	279,676	2	0.5	Rice plantings and coconut plantations
Unvegetated	T	427	1	0.5	River bed, rock outcrops, etc.
Settlements	K	18,989	1	0.5	Cities, towns, villages, etc.
Transmigration Area	TRMI	180,947	1	0.5	Existing or planned transmigration site

a. RePPProT map code.
Source: Adapted from Malingreau and Christiani 1981.

mals in a given habitat and is only part of what should be considered in selecting areas for conservation. Since the overall goal of biodiversity conservation is protection of a representative sample of the indigenous flora and fauna of an area (Soulé 1991), a Conservation Priority Index was therefore calculated to avoid a bias toward large species-rich tracts at the expense of smaller but rarer areas.

Arithmetically, the Biodiversity Index (BI) value of polygon i is expressed by equation 1:

$$BI_i = (HD_i + ND_i) \times ENDAF_i \quad (1)$$

where,
HD_i = Habitat Diversity of polygon i
ND_i = Neighborhood Diversity, around polygon i, and
$ENDAF_i$ = Endemism Adjustment Factor of the habitat of polygon i.

The Habitat Diversity (HD_i) value is calculated as:

$$HD_i = \log_{10} (SPRICH_i, A_i) \quad (2)$$

where,
$SPRICH_i$ = Species Richness of Habitat i, and
A_i = Area of Polygon i in hectares.

Data on the distribution and abundance of tree species in different forest habitats were used as the basis for estimating SPRICH (the values are summarized in table 1.3). While data on which to estimate SPRICH are limited, important sources of general information include Ashton (1964) and Whitmore (1984). A basic assumption, which has a strong empirical basis, is that tree species richness is a reliable surrogate for the total biological diversity of a given site. Cranbrook (1982), for example, reports that the richest assemblage of birds (171 species) at Gunung Mulu in Sarawak occurs in lowland dipterocarp forest. Only about half this number were found in the less peat forests. Whitmore's data (1984) suggests that the relatively diverse lowland dipterocarp forest contains about twice the amphibian species found in heath forest. Similarly suggestive data on mammalian diversity can be found in Payne and others (1985) and Marsh and Wilson (1981). These, and many other reports, suggest that habitat type is a useful and easily defined surrogate for the indirect assessment of total biological diversity.[10] Table 1.4 summarizes the diversity of tree species found in different forest types on the island of Borneo.

Because area is perhaps the single most important consideration in ranking sites for biodiversity preservation, equation 2 also factors polygon size into the calculation. As

Table 1.4 Summary of diversity of tree species found on Borneo

Site	*Sample area (hectares)*	*Number of tree species*	*Source*
Lowland dipterocarp forest			
Lempake East Kalimantan	1.6	209	Riswan (1987a)
Wanariset, East Kalimantan	1.6	239	Kartawinata and others (1981)
Lambir, Sarawak	1.0	283	Ashton (1984)
Andulau Resesrve, Brunei	2.0	222	Ashton (1964)
Sandakan, Sabah	2.0	198	Nicholson (1965)
Gunung Mulu, Sarawak	1.0	225	Proctor and others (1983)
Hill dipterocarp forest			
Raya-Pasi, West Kalimantan	1.0	148	Peters (1991)
Kuala Belalong, Brunei	2.0	125	Ashton (1984)
Andulau Reserve, Brunei	2.0	144	Ashton (1964)
Heath forest			
Gunung Mulu, Sarawak	1.0	125	Proctor and others (1983)
Badas, Brueni	1.0	72	Ashton (1984)
Samboja, East Kalimantan	0.5	24	Riswan (1987b)
Peat forest			
S. Durian, West Kalimantan	0.2	26	Anderson (1976)
S. Durian, West Kalimantan	0.2	37	Anderson (1976)
S. Durian, West Kalimantan	0.2	55	Anderson (1976)

was first observed by Arrhenius (1921) and Gleason (1922) large areas have more species than smaller ones. This pattern has been found to hold at almost every scale, whether comparing arthropods in caves (Culver, Holsinger, and Baroody 1973), small tracts of tropical forest (Gentry 1988), or islands of increasing size (Diamond and Mayr 1976). Although the slope and intercept of the species-area curve can vary with habitat, the relationship between these two parameters usually takes a logarithmic form (McGuinness 1984).

Numerous hypotheses have been advanced to explain the species-area effect. Williams (1943) suggested that species numbers increase with area because larger areas usually contain more habitats or available niches. MacArthur and Wilson (1967) theorize that larger areas have more species because populations increase and species interactions decrease with increasing area.

In addition to size and habitat type, the heterogeneity of different habitats (edges or ecotones) surrounding a site has also been shown to have a notable influence on diversity (see, for example, Noss 1983; Harris 1988; Yahner 1988). This effect apparently is because sites contain species from all the adjacent habitats, as well as those species specifically adapted for growth and survival at the edge itself. In addition, the constituent species diversity of the adjacent habitats plays a role as well. A site adjacent to highly diverse communities will usually be subjected to a larger degree of species immigration and colonization than one surrounded by species-poor habitats (MacArthur and Wilson 1967, Stamps and others 1987, Shafer 1990). To account for all of this, a second parameter, Neighborhood Diversity (ND_i) attempts to account for landscape heterogeneity and edge effect by summarizing the variety and biological richness of the different habitats adjacent to each polygon. The parameter is derived by:

$$ND_i = \log\left(\sum SPRICH_j\right) \qquad (3)$$

The last parameter included in the Biodiversity Index is the Endemism Adjustment Factor (ENDAF). This value serves a dual purpose: (a) it provides a rough estimate of the level of endemism characteristic of each habitat, and (b) it serves to adjust or "fine tune" the habitat and neighborhood diversity parameters by accounting for the degree to which the original vegetation in each habitat has been disturbed. This adjustment is needed because of the strong influence that forest type and land use appear to exert on the specificity or endemism of local species. Although the entire island of Borneo is thought to contain a large percentage of endemic species,[11] heath forests, tidal or mangrove forests and submontane forests have been found to be especially rich in endemism (Brunig 1974; Kartawinata 1980; Anderson and Chai 1982; Whitmore 1984). Intensively used, highly disturbed, or artificially revegetated habitats may exhibit a very low level of endemism. Forest habitats with high levels of endemism, such as heath forest (Hk) and mangrove swamp (Ht) were assigned a value of 1.02. Undisturbed forest habitats were given a score of unity, mixtures of secondary vegatation received scores of 0.9 or 0.8, and intensively managed habitats from which natural vegatation has been completely removed were assigned an adjustment factor of 0.5. ENDAF values are shown in table 1.3.

The Conservation Priority Index (CPI) is intended to add consideration of the relative abundance of a particular habitat, rate at which habitat is being destroyed or transformed, and extent to which similar representatives of similar habitat have already been selected for protection (PROTAREA). The derivation of this index requires information about the original area (ORIGAREA), the remaining area (REMAREA), and the area currently protected in reserves of different forest habitats. ORIGAREA data were taken from MacKinnon and Artha (1982) or estimated based on average rates of deforestation in West Kalimantan (FAO 1989). REMAREA and PROTAREA were obtained directly from RePPProT. Based on these data,

Table 1.5 Derivation of Conservation Priority Index for selected forest types

Habitat	*Code*	*Original area (hectares)*	*Remaining area (hectares)*	*Protected area (hectares)*	*Rarity*	*Exhaustion rate*	*Protection status*	*CPI*
Lowland forest	Hh	7,020,000	5,091,950	901,200	0.146	1.139	0.892	0.148
Swamp forest	Hr	1,305,000	269,080	110,800	0.164	1.686	0.385	0.106
Riparian forest	Hs	12,060	6,671	1	0.245	1.257	3.824	1.178
Heath forest	Hk	1,845,000	462,645	13,600	0.160	1.601	1.532	0.391
Peat forest	Hg	2,201,000	1,617,477	58,500	0.158	1.134	1.442	0.258
Tidal forest	Ht	425,000	208,641	7,600	0.178	1.309	1.439	0.335
Coastal forest	Hc	42,697	23,603	3,100	0.216	1.257	0.882	0.239
Submontane forest	Hf	1,800,000	397,829	252,800	0.160	1.656	0.197	0.052

coefficients of rarity, exhaustion rate and protection status were calculated for each forest habitat according to the following:[12]

$$\text{Rarity} = 1/\log(ORIGAREA) \tag{4}$$

$$\text{Exhaustion Rate} = \log(10 \times ORIGAREA/REMAREA) \tag{5}$$

$$\text{Protection Status} = \log(ORIGAREA/PROTAREA) \tag{6}$$

The results of these calculations are summarized in table 1.5, which gives CPI as the product of equations 4–6. CPI is then added to the Biodiversity Index to calculate the final Biovalue for each polygon. CPI is set at zero for deforested or otherwise altered polygons and can thus be interpreted as a premium given to rare, threatened or unprotected habitats.

$$\text{Biovalue}_i = BI_i + CPI_i \tag{7}$$

The resulting Biovalue Index produces a score for each polygon ranging from 10.4 for a large tract of lowland forest to 0.84 for a small swidden plot among human settlements. While it is difficult to quantitatively test the validity of this modeling procedure, the results and other considerations of the relative scores of specific polygons yield a surprisingly accurate reflection of biological realism. In the absence of quantitative forest inventories and detailed species counts, the index seems to provide an acceptable interim criteria for ranking different habitats and types of land use in terms of their potential biological richness.

Table 1.6 Input and output prices and economy-wide variables

	Unit	*Rp*
Interest Rate	%	0.1
Exchange Rate	Rp/US$	2,000
Wage Rate	day	2,000
Rice	kilogram	200
Coconut	kilogram	250
Oil Palm	kilogram	60
Rubber	kilogram	1,350
Chemicals	unit	1
Rice Seed	kilogram	384
Rubber Stock	unit	296,000
Rubber Tax	per hectare	20,000
Oil Palm Stock	per hectare	184,000
Oil Palm Tax	per hectare	20,000
Coconut Stock	per hectare	531,000
Coconut Tax	per hectare	20,000

Note and source: Basic information used in preparing the rice budget came from the most recently available edition of the annual provincial statistics (BPS 1990: 1589). Modification of these data was needed to properly account for family labor, which is a major source of labor but which is generally excluded from Indonesian official statistics. Information for the three tree crops (coconut, palm, and rubber) was derived from World Bank project and sector work, revised according to information from the provincial office of the Directorate-General of Estate Crops.

Table 1.7 Net revenue from selected alternative products

Inputs	*Upland rice*	*Lowland rice*	*Rubber*	*Oil palm*	*Coconut*
Labor	258,000	278,000	90,266	64,474	39,239
Chemicals	—	11,450	43,393	73,364	40,024
Seeds/planting material	13,056	13,056	8,970	5,576	17,066
Machinery rental	—	—	3,931	5,536	5,647
Other	21,000	17,000	1,811	0	0
Taxes	—	—	6,051	6,158	6,107
Cost of production	292,056	319,506	151,786	155,156	105,768
Value of output	320,000	513,600	278,522	166,633	135,121
Net return per hectare	27,944	194,094	126,736	11,477	29,353

— Data not available.
Source: BPS 1990 and World Bank project and sector studies.

Modelling opportunity costs

Much of the area of West Kalimantan has the potential of supporting a variety of commercial uses. Modelling the opportunity costs of land involved the construction of a series of budgets for various land uses and spatially referencing this data with respect to the potential of sites for supporting alternative uses. This potential was assessed by RePPProT (1987) on the basis of technical criteria that considered the requirements of different crops, soil type and other site factors such as slope, rainfall and elevation. In all, the RePPProT system identified thirty-seven "Land Systems" on the basis of different combinations of limiting factors and matched these with the requirements of twenty-two industrial and estate crops.[13] The Land Systems version of the RePPProT data identifies 1,682 polygons each associated with a set of limitations and suitabilities. A simplified version of the Land Systems data is given in map 2 in which land uses have been aggregated for clarity.

Budgets for alternative land uses were compiled by reference to literature, project proposals and other sources. Based on a common set of input and output prices (see table 1.6) scaled to 1991 prices, input and output coefficients were reconciled to generate the budgets for dryland rice, wetland rice, oil palm, coconuts, and rubber. Although an exhaustive list of activities was not undertaken, the table does cover the most important crops in terms of areal extent and production.

While most smallholder cultivation of the oil palm, coconuts, and rubber has been carried out, to date, on a relatively informal basis in West Kalimantan, future expansion of production is likely to be more organized. Palm oil and rubber production is being developed increasingly along the nucleus estate and smallholder model, and hybrid coconuts are being encouraged for copra production. The budgets for the three crops summarize present valued (at 10 percent) annual cash flows for a 31-year period on a per hectare basis. Thus, they represent the annualized flows from the equivalent of one representative hectare in a fully established plantation.

Net revenues of Rp. 28,000 and Rp. 194,000 per hectare per year for dryland and wetland rice, respectively (see table 1.7), do not appear out of line with returns to rice in some of the less advantageous rice-growing regions in Indonesia reported in Pearson and others (1991). Similarly, estimated returns for rubber, oil palm and coconut, also appear reasonable. The range of crops and land uses is somewhat limited, and a priority for further development of the model is specification of additional alternatives and introduction of transport costs and forest management options (see below). Despite these weaknesses, these five crops do provide an economic option for a significant portion of the total area of the province and also correspond well to observed land uses.

Geographic analysis and supply curve construction

After the modelling of the magnitude and distribution of both biodiversity and land development opportunities in West Kalimantan, the next step in the analysis was to determine the spatial correspondence between the two. This was calculated by using a the Arc-Info GIS system (Environmental Systems Research Institute, Inc.). Digitized versions of the Land Systems and Forest/Land Use Map were superimposed on each other to generate a new map. This new map, generated by the 2,610 Forest/Land Use polygons and the 1,682 Land Systems polygons, consisted of 22,656 polygons representing 1,761 combinations.

Because the Biovalue Index was calculated from the physical parameters of the Forest/Land Use polygons, they were treated as indivisible "biodiversity production unit." Each Forest/Land-Use Polygon was then assessed on the basis of its Biovalue and the sum of the profits of the different land uses it was capable of supporting.[14] Because Biovalue is an index and therefore not an additive value, each polygon area was adjusted by a factor equal to its Biovalue divided by the area weighted average Biovalue for the entire 2,610 polygons. This yielded a Biodiversity Adjusted Area for each polygon and a total adjusted area equal to the real area of the province. The total opportunity cost for each polygon was then divided by its Biodiversity Adjusted Area to yield an average cost per biodiversity adjusted hectare. Average costs varied from zero for 555 polygons totaling about 500,000 hectares to a maximum of Rp. 12,000 per hectare per year. Arraying polygons from the lowest average cost to the highest and mapping out the running total generated a "particular expenses" approximation to a biodiversity supply curve (map 3). The supply curve maps out the areas that would be preserved as a function of the amount that would need to be paid as an annual rent, or price. The cartographic equivalent to figure 1.1 is presented in map 3, showing spatially conservation priorities as a function of price.

The supply curve suggests that for a considerable portion of the area of West Kalimantan there is little or no trade off between economic development of land and protection of biodiversity. Nearly 3.7 million hectares of land in the province could be set aside for biodiversity conservation purposes at a cost or price of less than Rp. 400 per hectare per year (approximately $0.20). This is quite consistent with the aggregate results of the planning process of the Indonesian Forest Land Use by Consensus, which allocated 3.71 million hectares to conservation and protection status. Since considerations other than biodiversity preservation figured into this allocation, it is suggestive of a relatively low valuation of biodiversity. The curve also suggests that if a market existed for the province's biodiversity, a relatively small increment in the current implicit willingness to pay for biodiversity could make competitive the allocation of a significant additional amount of land away from alternative uses. Examination of additional policy questions are taken up in greater detail in the next section.

Map 3 shows how the production schedule implied by the supply curve translates into priorities for land management. As discussed below, because this preliminary application has not considered transportation costs, forestry options, and other concerns, the geographic priorities shown in the map cannot be recommended for actual land use planning. They do serve to illustrate the economic dimensions of biodiversity policy. The white and pink areas indicate the areas where the opportunity costs of biodiversity conservation are lowest. These areas, largely in the northeast corner of the province, are predominantly forested areas with relatively high levels of biodiversity and limited capacity to support alternative land uses. Even if forestry alternatives were considered, as is planned for future investi-

Figure 1.1 Marginal costs of conservation

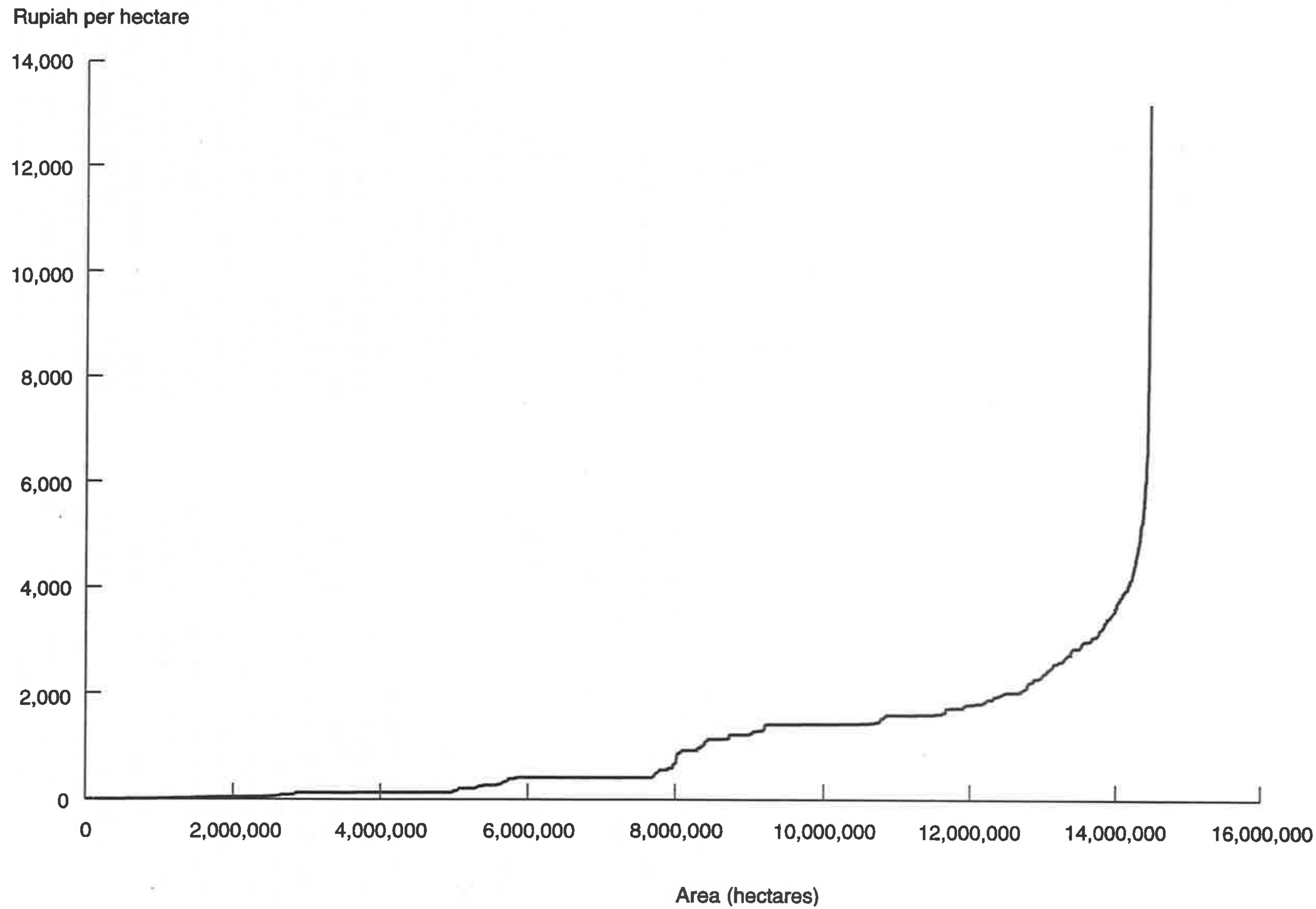

Table 1.8 Spearman's Rank Correlation Coefficient (alternative scenario against base case)

Scenario	*Base value*	*Alternative value*	*Correlation coefficient*
Devaluation	US$1 = Rp. 2,000	US$1 = Rp. 4,000	0.934167*
Low Wage	Wage = Rp. 2,000/day	Wage = Rp. 0/day	0.789914*
Increased Wage	Wage = Rp. 2,000/day	Wage = Rp. 4,000/day	0.909885*
Low Discount Rate	i = 0.10	i = 0.03	0.915311*
High Discount Rate	i = 0.10	i = 0.13	0.966867*

* Indicates significance at the p = 0.90 level.
Source:

gations, because these areas are remote from transportation infrastructure, it is likely that a similar result would be obtained.

On the other hand, the darker areas, along the west coast and in the southern corner of the province, indicate areas where biodiversity can only be preserved at relatively high cost. This includes areas already heavily altered by human activity, such as developed agricultural lands and tree crop plantations, urban development around the capital of Pontianak, and human settlement along the major rivers.

Policy experiments

With an explicit estimate of biodiversity supply, it is possible to quantitatively explore a number of biodiversity policy issues. In view of the preliminary nature of this model and the need to extend and deepen the model in a number of directions, only two questions were explored, but these indicate the range of questions appropriate. First, because there is significant interest in the question of how relative prices and economywide policies can influence environmental concerns, a sensitivity analysis was conducted to illustrate the impacts of these variables. Among the key prices that seem to influence pressures on natural environments are interest rates, wages and foreign exchange rates. To examine the effects of changes in these variables, the model was recalculated with values given in table 1.8. The results of these trials are summarized in figure 1.2. Qualitatively, the results are highly intuitive. Changes in prices that make land development more profitable (decreases in wages) shift the supply curve up and to the left, while cost increases shift the curve down and to the right.

The movements shown in figure 1.2 could be the result of changes in relative prices with essentially the same land use priorities or the result of changes in the underlying conservation production schedule that result from a different constellation of prices. To explore this question, it is possible to employ Spearmans Rank Correlation Coefficient. In this test, the rank of each of the land use polygons in the base case is compared with its rank in an alternative scenario. If the order of the polygons is identical, the rank correlation coefficient between the two scenarios will be equal to 1, lower values indicate that the ordering of polygons is affected by the change in prices. As shown in table 1.8, there are significant differences between the orderings for all scenarios. This preliminary finding provides quantitative support for arguments that macroeconomic policy can have strong influence on incentives affecting biodiversity.

A second use of the model is for exploring possible compensation needs if, for example, international willingness to pay for biodiversity exceeds the implicit preferences of Indonesian policymakers. In the absence of an estimate of local and interna-

Figure 1.2 Impact on biodiversity supply of economy-wide variables

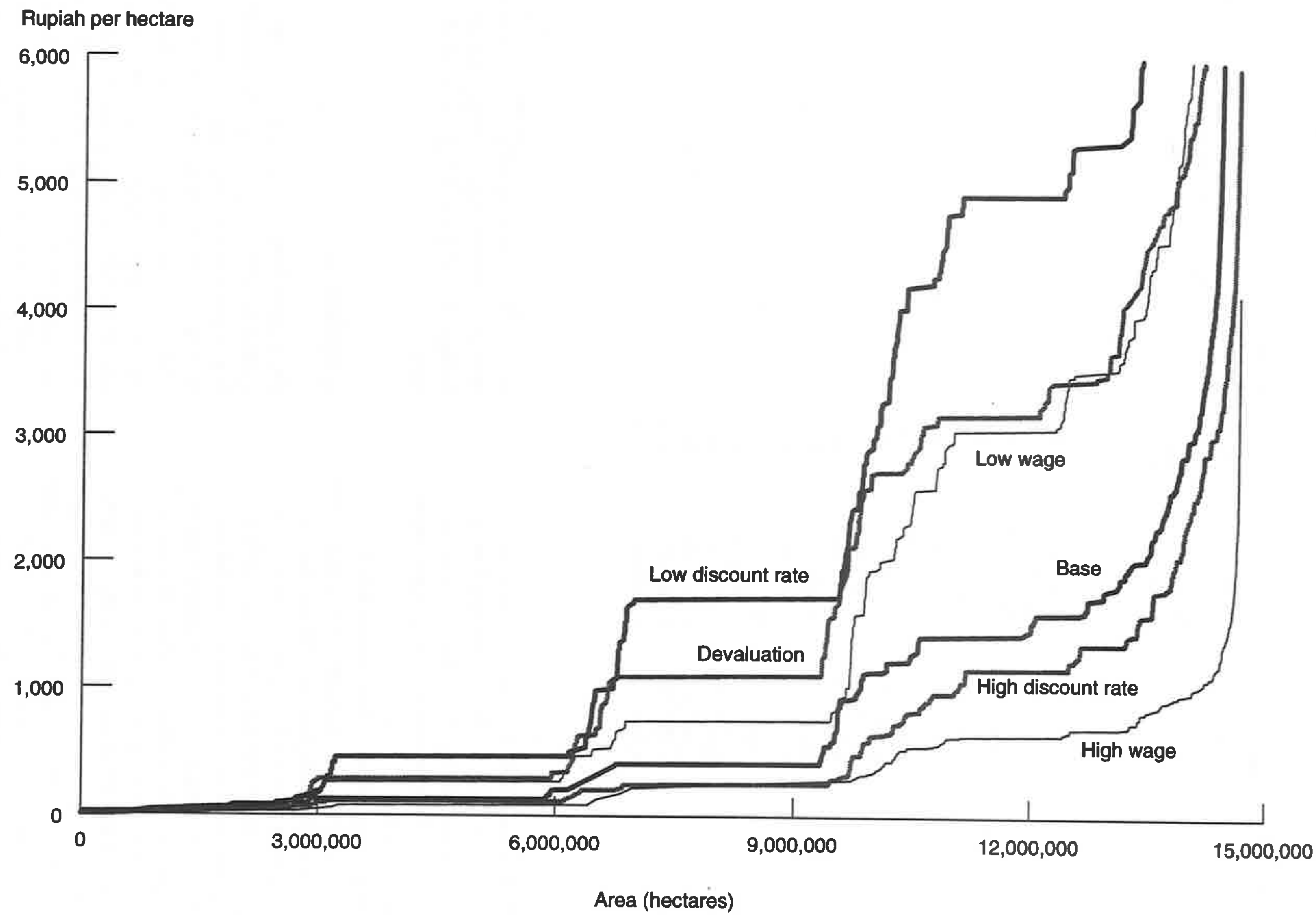

Table 1.9 Model calculation of total costs for conservation of biodiversity

Price	*Cummulative real area (hectares)*	*Cummulative biodiversity adjusted area (hectares)*	*Total cost (Rp/biodiversity adjusted hectares)*	*Producer surplus (Rp. millions)*	*Opportunity cost (Rp. millions)*	*Elasticity of supply (Rp. millions)*
0	296,305	184,105	0	0	0	
102	2,830,425	2,881,993	295	220	75	0.88
200	5,065,796	5,955,636	1,193	734	459	1.08
300	5,649,910	6,550,414	1,965	1,364	601	0.24
398	5,868,301	6,749,167	2,689	2,014	674	0.11
499	7,747,200	9,367,899	4,675	2,926	1,749	1.45
598	7,957,424	9,518,301	5,688	3,855	1,833	0.09
697	8,006,919	9,554,714	6,662	4,804	1,858	0.02
800	8,014,577	9,559,539	7,650	5,789	1,861	0.00
900	8,080,394	9,610,120	8,653	6,748	1,905	0.04
989	8,334,372	9,821,066	9,714	7,613	2,101	0.23
1,100	8,416,536	9,878,905	10,865	8,704	2,161	0.06
1,187	8,709,314	10,171,765	12,071	9,578	2,494	0.38
1,301	9,178,106	10,563,501	13,742	10,766	2,976	0.41
1,404	9,209,162	10,587,106	14,866	11,858	3,008	0.03
1,500	10,770,176	12,008,637	18,012	12,991	5,022	1.91
2,001	12,455,375	13,304,515	26,629	19,423	7,206	0.36
3,000	13,647,487	14,092,916	42,273	33,164	9,109	0.14
4,001	14,157,280	14,343,791	57,391	47,421	9,970	0.06
5,002	14,323,063	14,409,670	72,072	61,813	10,259	0.02

tional demand for biodiversity in West Kalimantan, the analysis presented here took a number of prices and to calculate costs, producer surplus and compensation requirements.

Total costs were calculated (table 1.9) as the product of the average cost or price and the corresponding biodiversity adjusted area (from figure 1.1). Producer surplus is the area above the supply curve and below the price, and opportunity cost is the area beneath the supply curve. A conservation compensation system could be structured in a variety of ways that can be linked to these values. Total cost, for example, corresponds to a conservation advocate setting a target for conservation and acting as a price taker. Under such a system, the rent, or producer surplus, accrues to the land owner. Alternatively, the conservation advocate could attempt to discriminate along the particular expenses curve, offering only the actual marginal cost to each land owner. In this system, surplus accrues to the conservation land owner, and a given conservation budget could yield a higher level of protection.

Conclusions

Because of benefits that may accrue to the global community, many tropical developing countries are being asked to undertake special efforts to conserve biodiversity. There are costs, however, to the land use restrictions that conservation implies, and a conceptually sound approach to the estimation of these costs is needed to aid in the design of land policy and in the negotiation of compensation and side payments. The methodology discussed in this chapter can contribute to better understanding of the economic consequences of biodiversity policy and provide specific and quantitative insights into land use policy.

More than the usual disclaimers and cautions are necessary with respect to interpretation of the results of this exercise. In addition to the preliminary nature of these results, the underlying data and assumptions described and used gloss over important gaps in understanding and representativeness. The land resource maps and derived biodiversity indices, for example, are subject to significant margins of error. Additional work is needed before this model can be used to develop implementable policy interventions. In particular, more effort is needed to explicitly incorporate transportation costs, forestry land use options, and multiple use alternatives into the model.

Despite its preliminary nature, this work does make several important contributions to discussions of biodiversity policy. Perhaps most important, it demonstrates the significance of, and scope for, clarity on the objectives of conservation policy. Biodiversity conservation does have costs, and priorities needs to be established on the basis of defined and measurable objectives. This chapter offers one characterization of biodiversity that is soundly based on ecological principles. While other ways of modelling biodiversity quantity can be proposed, and an important priority for further testing and development of this model is sensitivity analysis of the parameters used here, policy will inevitably reflect a set of weights that compare the importance of different elements of the ecosystem. An explicit formulation such as provided here allows for identification of areas of agreement and disagreement on priorities and determination of their policy significance. This work thus has significant scope for replication in other areas by interdisciplinary teams.

With respect to land use and conservation priorities in West Kalimantan, the analysis also makes clear that a significant share of the biodiversity in the province can be conserved at very low opportunity cost. This is an important finding and one that is consistent with the reality of natural areas preservation in many developed countries (see Krutilla and Fisher 1985). With modest levels of additional conservation compensation, the high elasticity of supply over a wide area revealed by this model can be taken by conservation advocates as encouraging evidence of good chances for introducing policies and practices to protect the resources of the province.

Appendix table. Summary of studies on the economic value of biodiversity

Value category:	Direct use	Indirect use	Non-use values option, quasi-option, bequest, existence	Total economic value	Benefit (sustainable use) /opportunity cost ratio
Ecosystem type: **Tropical forest** *Sources:* (1) Peters, Gentry and Mendlesohn (1989) (2) Gutierrez and Pearce (1992) (3) Ruitenbeek (1989a) (4) Mendelsohn and Tobias (1991) (5) Pearce (1991d) (6) Schneider et al. (1991) (7) Mendelsohn and Balick (1992) (8) Pearce (1990) (9) Watson (1988) (10) Kramer et al. (1992) (11) Guttierez and Pearce (1992) (12) Pinedo-Vasquez et al. (1992) (13) Solorzano and Guerrero (1988) (14) Schneider (1992)	(1) Sustainable harvesting in 1 hectare of Peruvian Amazon, (timber, fruit and latex 1987$). NPV hectare[1] $6,820 (local market values) relative to a net revenue $1,000 h[1] from clear-felling which risks uncertain regeneration, $3,184ha[1] plantations for timber and pulpwood or $2,960ha[1] from cattle ranching. (2) Estimated contribution of direct use to Brazilian GNP—$15b (3) Medicinal/genetic Net Present Value $7/ha over 126,000 ha (park area) or 426,000ha (with the additional buffer zone) This represents a minimum expected genetic value. Estimates depend on i) the probability of an area yielding a drug base ii) the method of valuation iii) an assumed extent of rent capture by local authority. Under certain assumptions the genetic/ medicinal NPV of tropical forest could be as high as $420 ha (See Appendix 1). (4) Travel cost valuation of tourist trips to Costa Rica's Monteverde Cloud forest. Average visitor valuation $35 (1988), producing a present value for trips assuming constant flows of $2.5m or extrapolating for foreign visitors, $12.5m. This gives a value per hectare in the reserve of $1,250 relative to the market price of local non-reserve land of $30–$100/ha. (7) Sustainable harvesting of medicinal plants in Belize *(local market values alone)* NPV $3,327per ha compared to $3,184 from plantation forestry with rotation felling. (9) Forest production (Malaysia) $2,455/ha compared with $217/ha from intensive agriculture. (3) Tourism value from the Korup $19/ha (10) Annual value of fuelwood to Malagasy households about $39 per annum	(3) Arising from sustained use of the Korup forest: Existence of Watershed functions affording protecton to Nigerian and Cameroonian fisheries: NPV (1989£) £3.8m (approx $6.8m) or $54ha, assuming that the benefit starts to accrue in 2010 and beyond (2010 represents the time horizon by which the continued use of the forest resources (in the absence of protection) would start to exhaust resources. The imputed benefit stream therefore represents the continued existence of resources. An imputed value of the expected loss from flooding resulting from alternative land use from 2010 onwards: NPV of expected value of loss by 2040 is £1.6m ($2.84m) or $23 ha Soil fertility maintenance. Benefit imputed based on crop productivity decline from soil loss which would take effect from 2010 onwards (the without project scenario) NPV £532,000 ($958,000) or $8ha. (5) (6) Valuing Carbon sequestration; crediting standing forest with damage avoided from adverse climate change: $1.2b–$3.9b/year, depending on assumptions of: i) Damage estimate per tonne carbon estimated range $5–13 tonne. ii) amount released, itself dependant on assumptions of per hectare sequestration and annual deforestation rates. (8)(14) Carbon storage $1,300–5,700/ha/year (11) Total carbon storage value Brazilian Amazon $46b (13) Rio Macho Preserve, Costa Rica. Evaluates the replacement cost in terms of water services and energy generation resulting from reserve conversion to agricultural use.	Lower bound option value may be inferred from the current market value or foreign exchange earning potential of plant based pharmaceuticals, (See Appendix 1) Attempts to gauge existence values in other contexts, rely on CVM to report WTP/willingness to accept compensation (WTA). To date only one study relating directly to tropical forests is available (10), although this does not report any foreign (explicitly non-use) WTP. However (2) set the existence value for the Brazilian Amazon at $30b, calculated using an arbitrary WTP figure (observed from various CVM studies), aggregated across the OECD adult population. Donations to charitable funds may be one possibility to place CV evaluations in context; however, adichotomy exists between the observed reason for giving and actual use of funds. Problem of identifying organizations involved uniquely in forest protection. (3) Value of debt-for-nature swaps may provide an estimation of a WTP, reflecting a non-use value. Varying implicit valuation of different sites is reflected in the price paid by conservation bodies involved. Some swap transactions have aimed to preserve tropical forest ecosystems,(see Appendix 3). (10) Foreign visitor's WTP for the creation of the Mantadia National Park (1991). Bids ranged $75–$118 p.a., with sums being *additional* to existing prices paid. Multiplying these sums by the number of annual foreign visitor s to a neighbouring park (3,900) resulted in an annual WTP of $292,500–460,000, a PV of $3.64m–$5.73m (at 5% and 20 years) or $364–573/ha (10,000ha). These sums might represent use values as tourists were actually in the area.	(2)Brazilian Amazon: ($1991) Direct Use $15b Indirect $46b Existence $30b Total $91b/year NPV (using Krutilla & Fisher) $1,296b (10) CVM survey of villagers' WTA, to forego use benefits in the newly created Mantadia National Park (Madagascar). Implicitly their valuation will reflect a total economic value of the resource foregone. The survey revealed a per household sum of $13.91 per annum, which is aggregated over the affected number of households (347) to give $4,827 per annum PV (assuming payments for 20 years and discounted at 5%) $60,141 or $6/ha over 10,000 ha of park.	(1), Implicit ratios of 6.82, 2.14 or 2.3 depending on alternative use, but subject to qualifications regarding local elasticity of demand for harvested forest products. A similar exercise (12) in another area of Peruvian Amazon contradicts these estimates with a ratio of about 30 in favour of logging and rotation cropping. (2) Total present value $1296bn over 3.6b ha=$360/ha relative to a net revenue from clear felling of $1000/ha. The implied ratio of 0.36 will not be strictly representative since the calculation of Total economic value is not necessarily based on the assumption of sustainable use. (4) Implied for Costa Rica 12.5 which is the ratio of recreation value per hectare of protected area to the highest estimated price of land outside the park. (7) On the basis of local medicinal plant harvesting only, the implied ratio of 1.04 (9) Determination of market prices in this study is uncertain (ie world or local) implied ratio 11.3 (3) 1.07 total project ratio or 1.94 from the perspective of Cameroon when indirect project adjustments are included. These include figures for project related aid flows and value for uncaptured genetic and watershed values. (13) Implied ratio of 2

Value category:	Direct use	Indirect use	Non-use values option, quasi-option, bequest, existence	Total economic value	Benefit (sustainable use) /opportunity cost ratio
Ecosystem Type: **Wetlands (Floodplains, Coastal wetlands, Wet meadows, Peatlands)** *Sources:* (1) Barbier, Adams and Kimmage (1991) (2) Semples et al. (1986) (3) Costanza et al. (1989) (4) Thomas et al. (1990) (5) Bergstrom et al. (1990) (6) Thibodeau and Ostro (1981) (7) Ruitenbeek (1991) (8) Hamilton and Snedaker (eds.) (1984) (9) Hanley and Craig (1991) (10) Van Diepen and Fiselier (1990) (11) Fiselier (1990a) (12) Danielson and Leitch (1986) (13) Turner and Brooke (1988) (14) Mcneely and Dobias (1991)	(1) NPV per acre ($1990) from the preservation of the Hadejia-Jama'are floodplain, Nigeria Agriculture $41 Fishing $15 Fuelwood $ 7 Discounted at 8% Other floodplain benefits: livestock and grazing non-timber forest products tourism, recreation, (including hunting), educational and scientific benefits (genetic and information value) (3) Louisiana. WTP PV at 8% ($1990) per acre. Commercial fishery $400 Fur trapping $190 Recreation $ 57 Storm protection $2,400 Total $3,047 (5) Louisiana. WTP PV at 8% ($1990) per acre Recreation $103 (6) Charles River, Massachusetts PV (1990$) per acre at 8%. Recreation $3400 Water supply $80,000 (8) Present Value per acre (at 8%) of Mangrove systems. Direct use from fisheries, forestry and recreation. Trinidad $15,000 Fiji $11,000 Puerto Rico $13,000	(1) Ground water recharge function for surrounding areas, potentially measurable by either WTP or using costs of ground water depletion on local agriculture—ie a *production function* approach—as a minimum benefit approximation. Other important functions: Flood Control and Storm Protection can in theory be approximated estimating alternative *preventative expenditure* or *replacement costs* for sea defences and dykes. In Malaysia the cost of rock escarpments to replace eroded mangrove fringe is typically around $300,000/km ($1990) (11). The same study quotes a 1987 E.C. estimate of the "inherent" value of mangrove protection to Guyana as $4bn, though there is no indication of how the figure is derived. Nutrient cycling will normally have a measurable effect on fishing and agricultural yields (in deltaic areas) the value of which might also be approximated by *replacement expenditures* on nutrients and compensating technologies. The value of wildlife habitats and life support functions will be reflected in the value placed on the continued existence of dependant species, (see under Existence values for some estimates) (14) Sustainable charcoal production from mangrove (Thailand) generates an annual national income of approx. $22.4m Net profits are nearly $4,000/ha for forests with average productivity of 230m³/ha.	Significant option values fom future tourism, educational and scientific uses. existence values of wetland wildlife probably high although no explicit studies exist. (2) Some non-use values for wildlife (CVM estimates) 1990$/annum/person: brown bear, wolf, wolverine (Norway) 15 bald eagle (US) 12.4 emerald shiner 4.5 grizzly bear 18.5 bighorn sheep 8.6 whooping crane 1.2 blue whale 9.3 bottlenose dolphin 7.0 california sea otter 8.1 (9) Revealed WTP (CVM) for preservation benefits of blanket bog area in Scotland (1990) (once and-for-all payment) PV £164.68/ha (approx. $296.50/ha) implicitly representing the discounted future stream of user and non-user benefits. As such the value is interpreted as an option value. (See Smith [1987]) (12) An average annual amount ($343/acre) paid (by the US Fish and Wildfowl Service in 1980) to owners of wetlands in Massachusetts for *preservation easements*, can be taken to represent a minimum option Value for the ecosystem in an unaltered state. Similar conclusions could be inferred by looking at the average value of *management agreements* negotiated between conservation bodies and land owners in the UK. Such an *alternative cost approach* has revealed a value of £70/ha/per annum for coastal marsh and.	(7) Bintuni Bay mangrove ecosystem, Irian Jaya. NPV of whole system ($1991 discount rate 7.5%) $961–$1,495m, of which direct-use probably $152–534m. This value does not account for the high *cultural value* placed on the bay by the Irarutu tribe (10).	(1) Benefit/cost ratio expressed in terms the relative benefits accruing from alternative water use: $45 per 1,000m³ of water maintained in the floodplain as opposed to *4 cents* per 1,000m³ from diverted water. (4) From a similar analysis of the Ichkeul National Park, Tunisia, direct-use benefits amounted to $134 per 1,000m³ compared to *negative returns* from diversionary use. Given the difficulty of generalizing with respect to alternative uses for wetland areas, informative cost-benefit ratios are difficult to provide. Where non-use values have been inferred from costs of imposing or agreeing land use constraints (the cost of which represent a discounted future benefit stream), the implicit cost-benefit ratio will normally be at least 1, because the compensatory payment from the recipient's perspective will have to be at least equal to the perceived opportunity cost.

Value category:	Direct use	Indirect-use	Non-use value option, quasi-option, bequest, existence	Total economic value	Benefit (sustainable use) /opportunity cost ratio
Ecosystem Type: **Rangelands (semi-arid) and wilderness areas** *Sources:* (1) Brown and Henry (1989) (2) Western and Thresher (1973) (3) Dobias (1988) (4) Child (1984)(1990) (5) Coulson (1991) (6) Dept. of National Parks, Zimbabwe (1991) (7) Jansen (1990) (8) Barnes (1990) (9) Imber (1991)	(1) Wildlife tourism. Viewing value of Elephants in Kenya $25m/per annum. The same study gives an indication of the extent of revenue forgone through sub-optimal park entrance pricing. A rough WTP survey revealed a potential consumer surplus as high as $25m/per annum (a sum almost 10 times the value of poached ivory exports and at least a 10% increase in actual expenditures). Since people were only asked their WTP to preserve elephants, consumer surplus for all wildlife viewing is presumably higher. (4) *Wildlife utilization:* Non-consumptive game viewing, lightly consumptive safari hunting and live animal trade, consumptive meat and hide production. **Zimbabwe:** illustrative examples: *Non-consumptive use:* Direct and indirect income accruing to the Matusadona National Park (1991) US$10.3m, 66% of which foreign currency (5). *Safari hunting:* Value for foreign visitors in 1990 was US$9m of which, trophies accounted for US$4m (6). *Consumptive value* Zimbabwe estimates it makes $4.7m/annum from the sale of elephant goods and services, a return of $75/km^2 over approx 74,000km^2 of elephant habitat. The proportion attributed to sale of goods has fallen significantly since the imposition of an international ban on ivory sales.	Indirect benefits from sustainable wildlife management: *Distribution of benefits to local communities* as a result of sustainable wildlife management schemes. (7) The Nyaminyami Wildlife Management Trust, Zimbabwe channeled approx Z$198,000 (1989) of wildlife revenues into local projects for health, housing, education and recreation. In addition the project was able to compensate local farmers for any damage incurred and offer cropped wildlife products for sale locally at subsidiized prices. Direct and indirect provision of employment. Improvements in local infrastructure and potential increases in land and property values. Significant saving in the hidden costs of land degradation and soil erosion arising from agricultural production in marginal areas. The role of elephants as keystone species diversifying savannah and forest ecosystems. Value added retained in the host country consists of net revenues accruing to: local airlines, tour operators, hotels, transport and cottage industries.	(3) Beneficial use project for Khao Yai National Park surveyed user WTP for continued existence of elephants at approx $7. Under certain assumptions of population and park use, the option and existence value of Khao Yai to Thai residents (for elephant preservation) may be as high as $4.7m/year . The extent of existence values might be approximated from the value of *vicarious tourism*—the consumption of books, films and TV programmes —particularly in developed countries, or from observed *charitable donations* to organizations involved in wildlife preservation. More crudely we might extrapolate on the basis of WTP information of visitors to wildlife sites in substitute countries like Kenya. In 1990 56% of overnight visitors to wildlife areas in Zimbabwe were foreign, of which 26% originated in Europe or North America (approx 151,000 visitors). Assuming 50% of these visitors reveal a similar WTP *in addition to* entry fees (in much the same way as in (1) i.e. a $100 permit for elephant preservation), extra revenue generated might amount to $7.5m per annum. (9) CV study preserve the Kakadu Conservation Zone (from mining development) revealed that Australians were willing to pay A$124/annum for ten years to avoid a major impact scenario and A$53 to avoid the minor scenario. Extrapolated to the whole population produced a total WTP range of A$650m–$1,520m , or a PV at 5% of between A$1m/ha and A$2.3m/ha over 5,000 ha. Both cultural and bequest values are likely to be significant in wildlife valuation although as yet few WTP studies reveal specific motivations.		(2) Ratio of wildlife tourism revenue per ha ($40) to income from extensive pastoralism ($0.80) 50. This ratio has probably increased significantly due to increasing value added in tourism. (4) Ratio of value of wildlife production (Z$4.20/ha) to Cattle Ranching (Z$3.58/ha in Zimbabwe 1.17. Calculation based on *economic rates of return* (as opposed to financial rates), and accounting for the relative environmental costs would in certain areas of the country produce ratios of between 2 and 5. (8) Provides PVs for returns from game viewing combined with some form of elephant cropping and for viewing alone in Botswana (1989). The ratio of the former to the latter range from 2.63 to 1.8 (depending on whether a 5 or 15 year horizon is considered) demonstrating the earning potential of consumptive uses. Comparison with the economic rate of return from cattle production on a per hectare basis could show ratios similar to those in Zimbabwe.

Value Category:	Direct use	Indirect use	Non-use values option, quasi-option, bequest, existence	Total economic value	Benefit (sustainable use) /opportunity cost ratio
Ecosystem Type: **Marine/coastal systems, heritage sites** (1) Carter et al. (1987) Hundloe (1990) (2) de Groot (1992) (3) Marcondes (1981) (4) Posner et al. (1981) (5) Schulze et al. (1983) (6) Hausman, Leonard, McFadden (1992)	(1) Estimating the socio-economic effect of the Crown of Thorns starfish on the Great Barrier Reef. A travel cost approach provided estimates of consumer surplus of A$117.5m /year for Australian visitors and A$26.7m/year for international visitors. The study showed that tourism to the reef is valued (in NPV terms) over and above current expenditure levels by more than $A1b. (2) Total direct use valued at $53/ha/year, comprising ($/ha/year): Recreational use 45 food/nutrition 0.7 Raw materials for construction 5.2 Energy resources 1.5 Ornamental resources 0.4 Biochemical and genetic resource values are also thought to be significant though no estimates are provided. Provision of employment directly or indirectly related to the National Park is a considerable benefit to the Galapagos economy (60% of 2,500 work-force). Tourism is the most important activity, contributing an estimated $26.8m to the local economy. (3) A form of Travel cost appraisal of the recreational value of the Cahuita National Park, Costa Rica. Consumer surplus estimates were derived from observed wage equivalent travel time net of transport costs multiplied over a visitor population. The resulting benefit-cost ratio demonstrated that the park is economically beneficial. (4) Conventional benefit-cost analysis of the Virgin Islands National Park, St John, identified significant direct and indirect benefits associated with the park, particularly tourist expenditures and the positive effect on land values in proximity to the designated area. Little information is available on the environmental effects of alternative land uses or the extent of visitor's consumer surplus. Total benefit ($1980) approx. $8,295/ha over approx 2820ha of National Park on St. John. (6) Recreation demand study to value recreation use loss caused by the Valdez oil spill in Alaska; about $3.8m (1989)	(2) Estimates provided for the Galapagos National Park, Ecuador: $/ha/year Maintenance of biodiversity 4.9 Value of fish breeding (nursery function) (applicable to 430,000 ha of marine zone). 0.07 Watershed and erosion prevention functions (applicable to terrestrial area of 720,000ha) 0.3	(2) Option value for the Galapagos National Park set arbitrarily at $120/ha/year which is the approximate sum of direct and indirect use values from the park. The uniqueness of the Galapagos ecosystem suggests that existence values are likely to be significant. (5) Describes a CV survey to value visibility improvements at the Grand Canyon (from reduced sulphur dioxide emissions). Mean bid ($1990/person/year) $27. A high level of familiarity may explain the high value respondents seem to have been willing to pay in this study (compared to bids for endangered species—see table 5.3). Higher WTP bids in habitat valuation studies have generally revealed a preference for protection of a perceived array of benefits rather than for a targeted species. As with other CV studies the Grand Canyon case has been the subject of much debate, particularly with respect to the levels of information and framing (hypothetical) bias (see Schulze et al. [1981]).	(2) Total annual monetary returns from direct and indirect use approx $120/ha. In present value terms this represents $2,400/ha (at 5% discount rate) or almost $2.8b for the entire study area.	(3) Cahuita National Park ratio 9.54* (4) Ratio of total (direct and indirect) benefits to total cost 11.5* * A conventionally assessed ratio rather than one based on opportunity cost.

Source: Pearce, Moran, and Fripp 1992.

Notes

1. For an interesting discussion of the ways in which conservation policy in the United States has emerged to favor "charismatic megafauna," see Metrick and Weitzman 1994.

2. For a review of the direct and indirect causes of biodiversity loss in developing countries, see McNeely and others 1990 (especially chapter 3).

3. In addition, see de Beer and McDermott 1989; Aylward 1993; Aylward and others 1993; McNeely and others 1990 (especially chapter 2).

4. Attempts to estimate theoretically defensible and policy relevant shadow prices for biodiversity, such as those summarized in the appendix, have shown considerable promise. However, as compared with techniques to measure, say, willingness to pay for recreation or the benefits of watershed management, biodiversity values can be approached from the consumption perspective only with great uncertainty.

5. Age is not the only criterion by which woodpeckers select trees. Heartwood and fungus attack are also factors, but these are also correlated with age and age is the key management variable.

6. Marshall (1947) introduced the term "Particular Expenses Curve" for this approximation of a supply curve.

7. For a recent discussion, which is generally consistent with the formulation proposed here, see Reid and others 1993.

8. The classic work is MacArthur and Wilson 1967.

9. The eighteen map sheets were digitized for this work by the World Bank's Asia Region Information Technology Lab.

10. With respect to tree species: Nicholson (1965), Kartawinata and others (1981), Proctor and others (1983), Riswan (1987a), Ashton (1984) provide data on lowland dipterocarp forests; Ashton (1964 and 1984) and Peters (1991) report on upland or hill dipterocarp forest; and Proctor and others (1983), Ashton (1984), Riswan (1987b) describe kerangas or heath forest. Anderson (1961, 1976) provides thorough descriptions of the ecology and floristics of peat swamp forest, and Corner (1978) reports on freshwater swamp forests.

11. An estimated 33 percent of the plant species, 24 percent of the reptiles, 18 percent of the mammals, and 6 percent of the birds of Borneo are thought to be endemic to the island (MacKinnon and Artha 1982). Similarly, 82 of the 130 local species of *Shorea*, an important genera of timber trees, are found nowhere else in the archipelago (Ashton 1982).

12. These formulas are essentially the same as those used by MacKinnon and Artha to calculate what they called "Habitat Product."

13. The "Land Suitability" methodology employed by RePPProT is limited by both (a) the accuracy and precision with which sites can be assessed and the requirements of different uses established and (b) the neglect of economic considerations such as market size, price, and other considerations.

14. In some cases, a particular land system is capable of supporting more than one land use. Where this occurred, the model allocated land to the option yielding the highest return.

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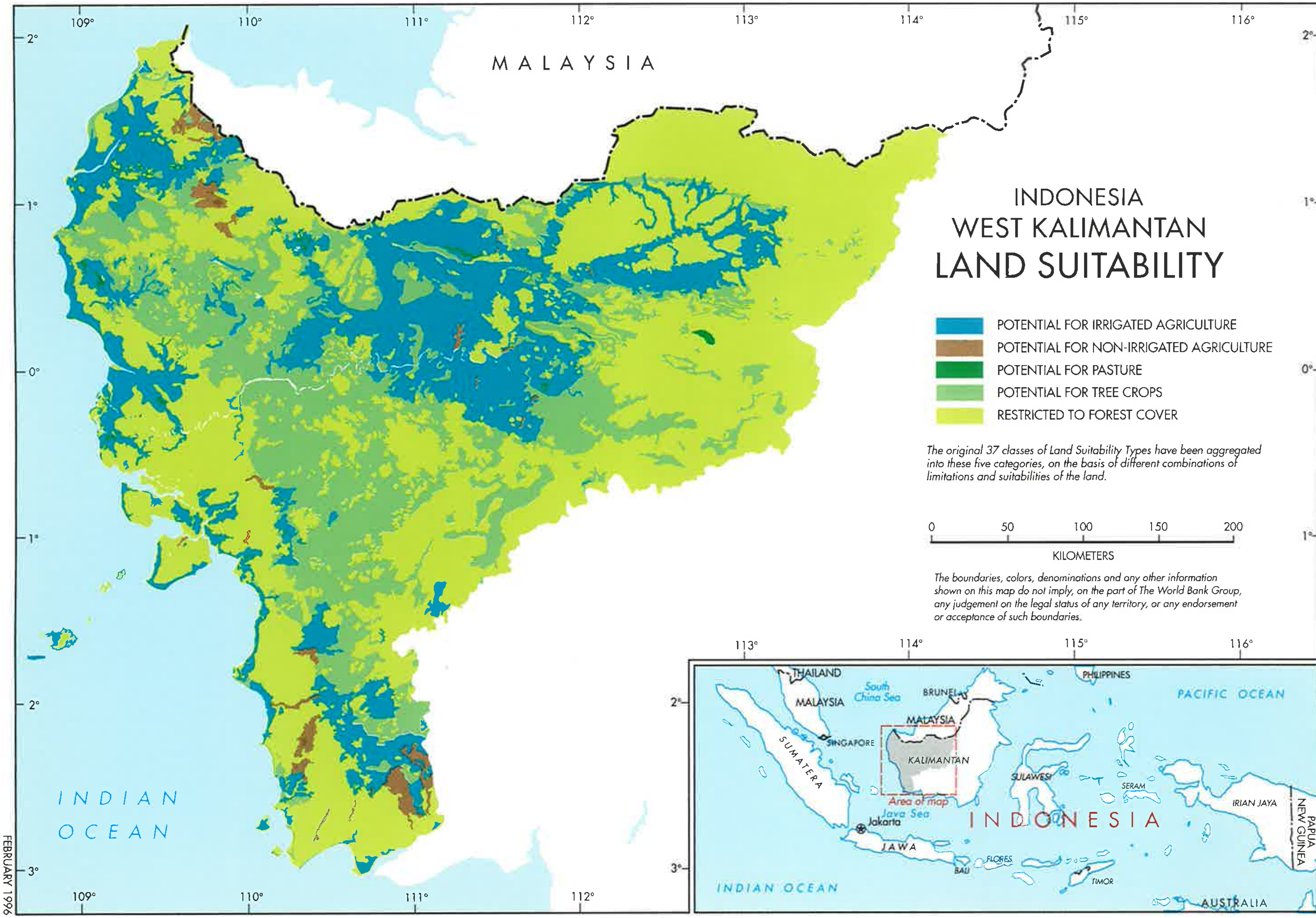

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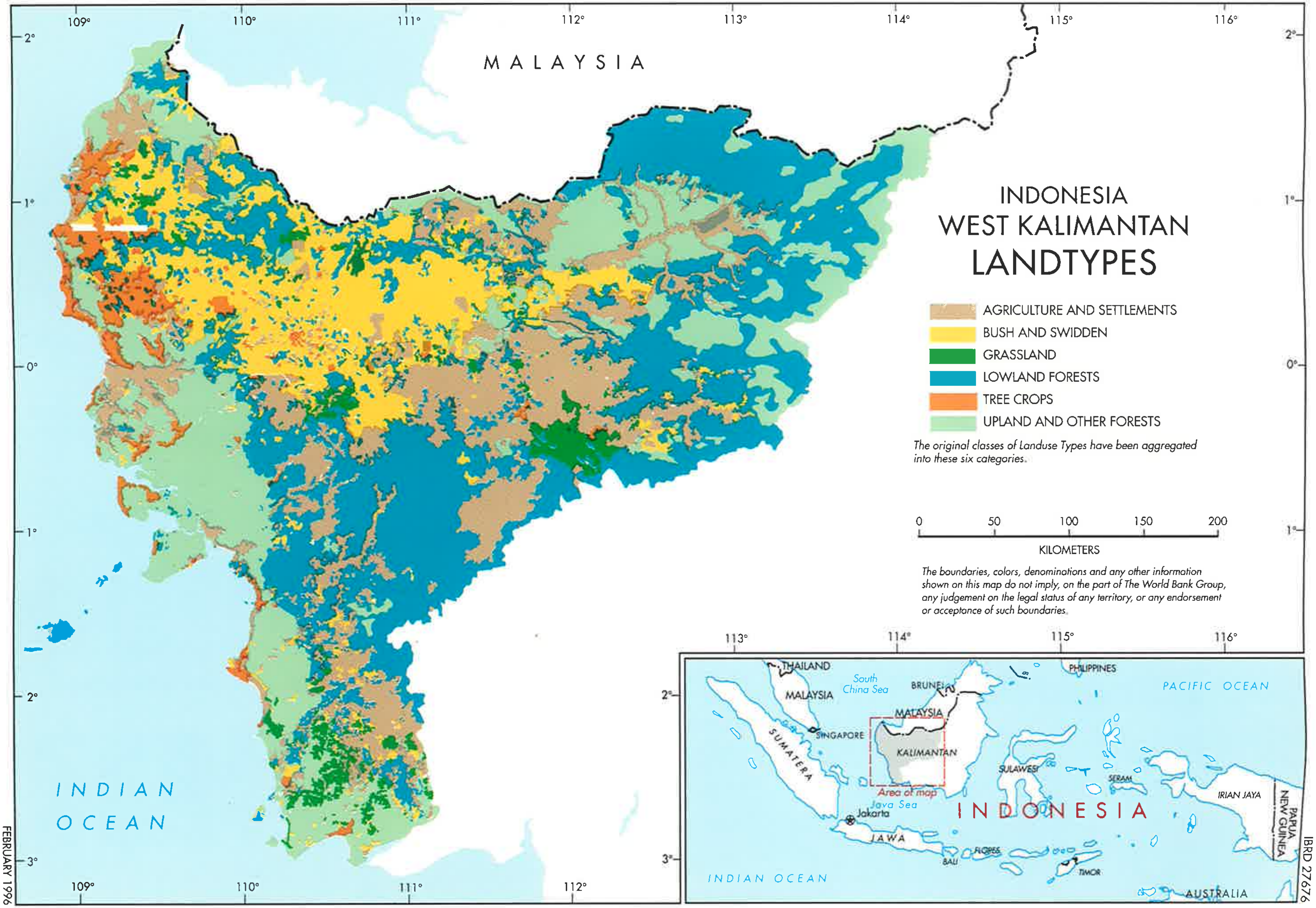
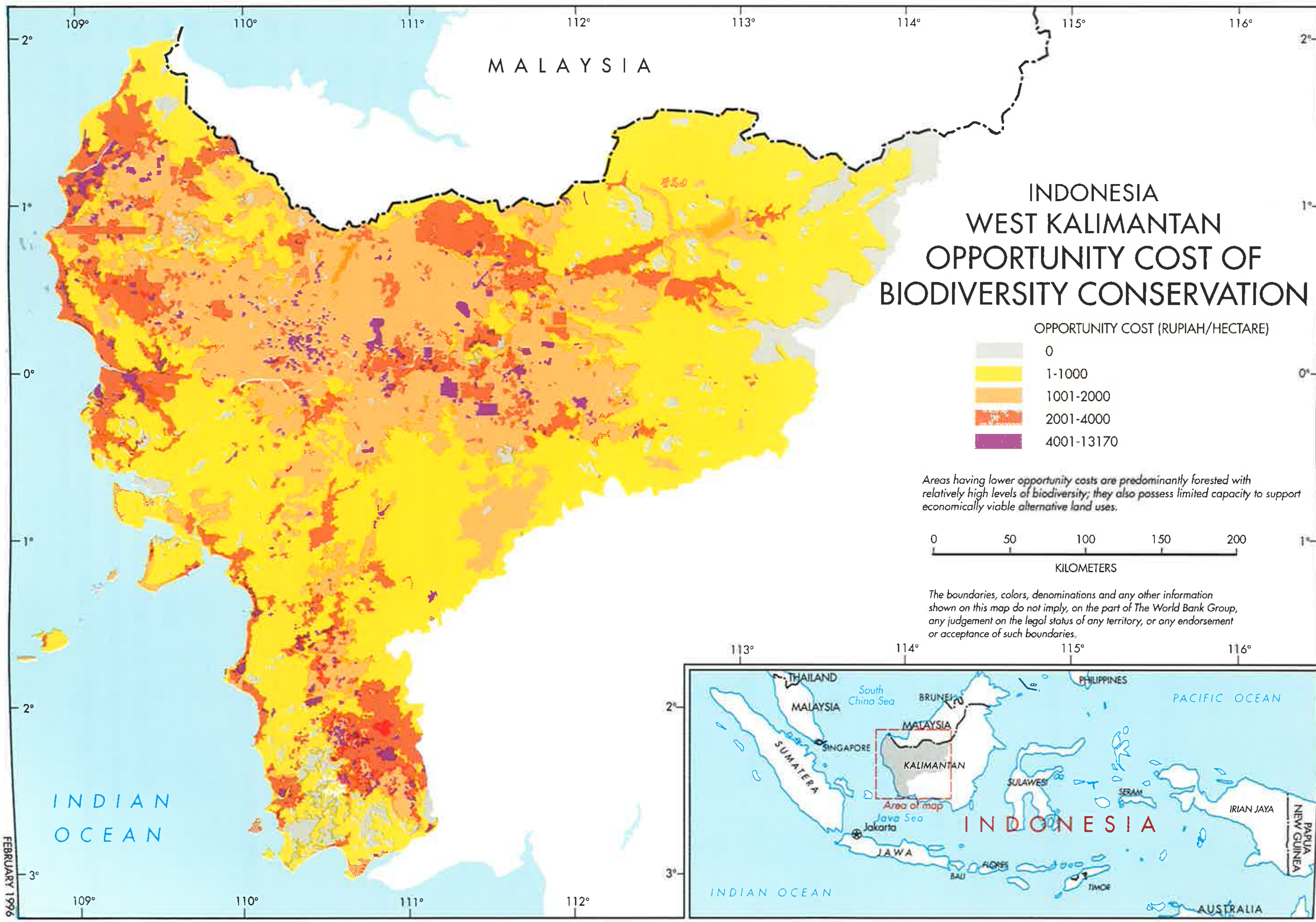


INDONESIA
WEST KALIMANTAN
LANDTYPES
AGRICULTURE AND SETTLEMENTS
BUSH AND SWIDDEN
GRASSLAND
LOWLAND FORESTS
TREE CROPS
UPLAND AND OTHER FORESTS
The original classes of Landuse Types have been aggregated into these six categories.
0 50 100 150 200
KILOMETERS
The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgement on the legal status of any territory, or any endorsement or acceptance of such boundaries.
MALAYSIA
INDIAN OCEAN
109° 110° 111° 112° 113° 114° 115° 116°
2° 1° 0° 1° 2° 3°
THAILAND
MALAYSIA
SINGAPORE
SUMATERA
South China Sea
BRUNEI
MALAYSIA
KALIMANTAN
Area of map
Java Sea
Jakarta
JAWA
BALI
FLORES
TIMOR
SULAWESI
SERAM
IRIAN JAYA
PAPUA NEW GUINEA
PHILIPPINES
PACIFIC OCEAN
INDONESIA
INDIAN OCEAN
AUSTRALIA
IBRD 27676
FEBRUARY 1996


INDONESIA
WEST KALIMANTAN
OPPORTUNITY COST OF
BIODIVERSITY CONSERVATION
OPPORTUNITY COST (RUPIAH/HECTARE)
0
1-1000
1001-2000
2001-4000
4001-13170
Areas having lower opportunity costs are predominantly forested with relatively high levels of biodiversity; they also possess limited capacity to support economically viable alternative land uses.
0 50 100 150 200
KILOMETERS
The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgement on the legal status of any territory, or any endorsement or acceptance of such boundaries.
MALAYSIA
INDIAN OCEAN
THAILAND
MALAYSIA
South China Sea
BRUNEI
MALAYSIA
SINGAPORE
SUMATERA
KALIMANTAN
Area of map
Java Sea
Jakarta
JAWA
BALI
FLORES
TIMOR
SULAWESI
SERAM
PHILIPPINES
PACIFIC OCEAN
INDONESIA
IRIAN JAYA
PAPUA NEW GUINEA
AUSTRALIA
INDIAN OCEAN
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