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Natural Resources in the National Income Accounts

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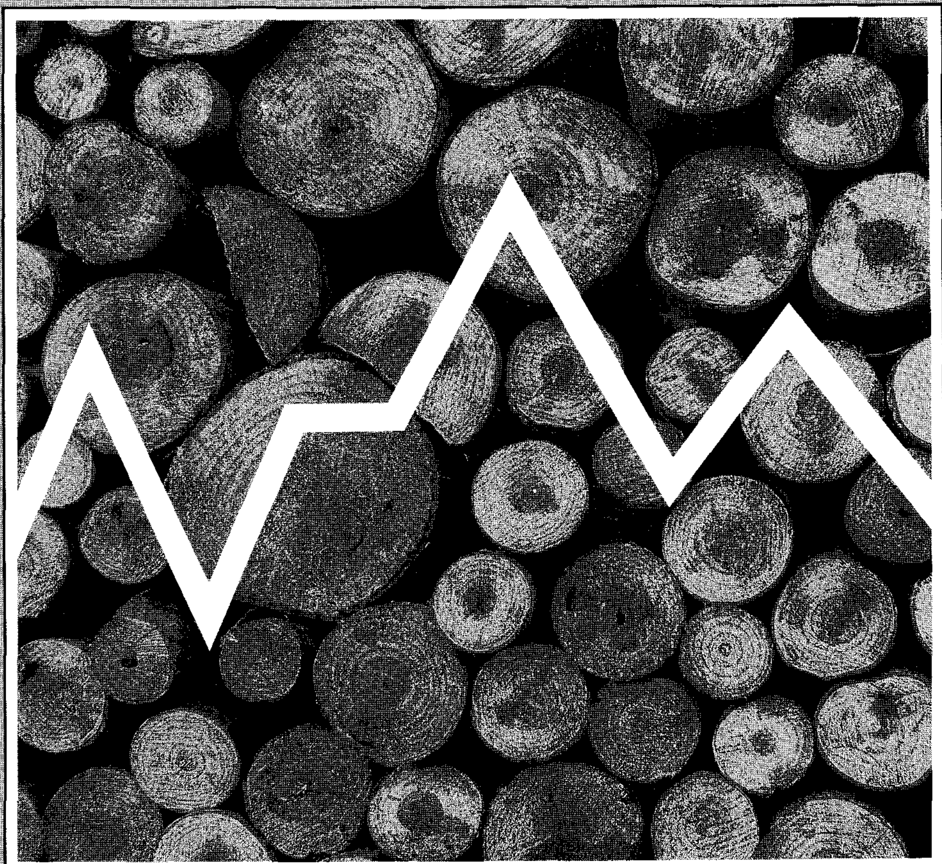

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Foreword

"Sustainable development" has been defined variously as living on the planet's income instead of depleting nature's capital, as meeting the needs of today's population without compromising the ability of future generations to meet theirs, and as the management of natural, human, and financial assets so as to increase long-term wealth and well-being. By whatever definition, sustainable development is clearly an important objective for societies.

National income accounts, the information framework that countries use to analyze the performance of their economies and to determine gross and net national product, ought to encompass the concept of sustainability. And, indeed, they do in certain respects. Man-made assets, including plant and equipment, are valued as productive capital, and their depreciation is charged against the value of national production. But this treatment of capital depreciation in national income accounting does not extend to natural resource depletion. The result is what Robert Repetto and his co-authors refer to in this report as a "dangerous asymmetry." As he notes, "A country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared."

When the index by which we try to measure improvements in living standards ignores the loss of natural resources and the services they provide, policymakers can get very misleading signals, as the results reported here for Indonesia show. Temporary improvements in consumption can be purchased by permanent losses in wealth and productive capacity.

Few people who aren't economists even know what the accounts are, much less how they are calculated. And yet, whenever quarterly GNP figures are released, policymakers invariably find themselves on the line: constituents, reporters, and financial analysts all want to know why the economy's performance is up, down, or unchanged. No economic law says that natural resources and the services they provide can't be included in national income accounts. Indeed, principles of both economics and ecology argue that they should be. But how?

Wasting Assets: Natural Resources in the National Income Accounts demonstrates that natural resources can be treated similarly to capital in national accounts, and it argues convincingly that these accounts should be revised. Repetto and his co-authors don't stop at building a tight theoretical case. Using data from Indonesia, they provide a concrete example of how the revised accounts would work and what signals the new results would give to those who make decisions about economic development.

This report complements several others that WRI has conducted that seek to bring economic and environmental thinking together in a new synthesis. *The Forest for the Trees: Government Policies and the Misuse of Forest Resources* (Robert Repetto, WRI, 1988), *Money to Burn? The High Costs of Energy Subsidies* (Mark Kosmo, WRI, 1987), *Skimming the Water: Rent-Seeking and the Performance of Public Irrigation Systems* (Robert Repetto, WRI, 1986), *Paying the Price: Pesticide Subsidies in Developing Countries* (Robert Repetto, WRI, 1985), and *Public Policies and the Misuse of Forest Resources* (Robert Repetto and Malcolm Gillis, Cambridge University Press, 1988) all show how misguided economic incentives cost governments huge sums and distort investment decisions while inviting environmental abuse and wasting natural resources. In addition, related work is now under way at WRI on the economics of sustainable agriculture and international conservation financing options.

For support for all these studies and WRI's research program in general, we are deeply grateful to the John D. and Catherine T. MacArthur Foundation. Additional much-appreciated support for this study also came from the World Bank.

James Gustave Speth
President
World Resources Institute

I. The Need for Natural Resource Accounting

A. Overview and Recommendations

Whatever their shortcomings, and however little their construction is understood by the general public, the national income accounts are undoubtedly one of the most significant social inventions of the twentieth century. Their political and economic impact can scarcely be overestimated. However inappropriately, they serve to divide the world into "developed" and "less developed" countries. In the "developed countries," whenever the quarterly gross national product (GNP) figures emerge, policy-makers stir. Should they be lower, even marginally, than those of the preceding three months, a recession is declared, the strategies and competence of the administration is impugned, and public political debate ensues. In the "developing" countries, the rate of growth of GNP is the principal measure of economic progress and transformation.

The national accounts have become so much a part of our life that it is hard to remember that they are scarcely fifty years old. They were first published in the United States in the year 1942. It is no coincidence that the period during which these measures have been available, with all their imperfections, has been the period within which governments in all developed and most developing countries have taken responsibility for the growth and stability of their economies, and during which enormous investments of talent and energy have been made in understanding how economies can be better managed. Forecasting the next few quarterly estimates of these statistics has become, with no exaggeration, a hundred million dollar industry.

The aim of national income accounting is to provide an information framework suitable for analyzing the performance of the economic system. The current system of national accounts reflects the Keynesian macroeconomic model that was dominant when the system was developed. The great aggregates of Keynesian analysis—consumption, savings, investment, and government expenditures—are carefully defined and measured. But Keynes and his contemporaries were preoccupied with the Great Depression and the business cycle; specifically, with explaining how an economy could remain for long periods of time at less than full employment. The least of their worries was a scarcity of natural resources. Unfortunately, as Keynesian analysis largely ignored the productive role of natural resources, so does the current system of national accounts.

In fact, natural resource scarcity played little part in 19th century neo-classical economics, from which traditional Keynesian and most contemporary economic theories are derived. Gone were the dismal predictions of Ricardo, Malthus, Marx, and other earlier classical economists that industrial economies would stagnate or collapse because of rising rents and subsistence wages. In 19th century Europe, steamships and railroads were markedly lowering transport costs while foodgrains and raw materials were flooding in from North and South America, Australia, Russia, and the imperial colonies. What mattered to England and other industrializing nations was the pace of investment and technological change. The classical economists had regarded income as the return on three kinds of assets: natural resources, human resources, and invested capital (land, labor, and capital, in their vocabulary). The neo-classical economists virtually dropped natural resources from their model and concentrated on labor and invested capital. When these theories were applied after World War II to problems of economic development in the Third World, human resources were also left out on the grounds that labor was always "surplus," and development was seen almost entirely as a matter of savings and investment in physical capital.

There is a dangerous asymmetry today in the way we measure, and hence, the way we think about, the value of natural resources.

As a result, there is a dangerous asymmetry today in the way we measure, and hence, the way we think about, the value of natural resources. Man-made assets—buildings and equipment, for example—are valued as productive capital, and are written off against the value of production as they depreciate. This practice recognizes that a consumption level maintained by drawing down the stock of capital exceeds the sustainable level of income. Natural resource assets are not so valued, and their loss entails no debit charge against current income that would account for the decrease in potential future production. A country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared. Ironically, low-income countries, which are typically most dependent on natural resources for employment, revenues, and foreign exchange earnings are instructed to use a system for national accounting and macroeconomic analysis that almost completely ignores their principal assets.

A country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared.

Underlying this anomaly is the implicit and inappropriate assumption that natural resources are so abundant that they have no marginal value. This is a misunderstanding. Whether they enter the marketplace directly or not, natural resources make important contributions to long-term economic productivity and so are, strictly speaking, economic assets. Many are under increasing pressure from human activities and are deteriorating in quantity or quality.

Another misunderstanding underlies the contention that natural resources are "free gifts of nature," so that there are no investment costs to be "written off." The value of an asset is not its investment cost, but the present value of its income potential. Many companies valued by the stock market as worth many billions of dollars have as their principal assets the brilliant ideas and inventions of their founders: the Polaroid Camera, the Apple Computer, the Lotus Spreadsheet, for example. These inspired inventions are worth vastly more than any measurable cost to their inventors in developing them and could also be regarded as the products of genius—free gifts of nature.

Common formulas for calculating depreciation by "writing off" investment costs (e.g., straight line depreciation) are just convenient rules of thumb, or artifacts of tax legislation. The true measure of depreciation, which statisticians have tried to adopt for fixed capital in the national accounts, is the capitalized value of the decline in the future income stream because of an asset's decay or obsolescence. (Usher 1980, pp. 104–105) Thus, in the same sense that a machine depreciates, soils depreciate as their fertility is diminished since they can produce only at higher costs or lower yields.

This difference in the treatment of natural resources and other tangible assets reinforces the false dichotomy between the economy and the "environment" that leads policymakers to ignore or destroy the latter in the name of economic development.

Codified in the United Nations system of national accounts closely followed by most countries, this difference in the treatment of natural resources and other tangible assets provides false signals to policymakers. It reinforces the false dichotomy between the economy and the "environment" that leads policymakers to ignore or destroy the latter in the name of economic development. It confuses the depletion of valuable assets with the generation of income. Thus it promotes and seems to validate the idea that rapid rates of economic growth can be achieved and sustained by exploiting the resource base. The result can be illusory gains in income and permanent losses in wealth.

Indeed, natural resource assets are legitimately drawn upon to finance economic growth, especially in resource-dependent countries. The revenues derived from resource extraction finance investments in industrial capacity, infrastructure, and education. A reasonable accounting representation of the process, however, would recognize that one kind of asset has been exchanged for another, which is expected to yield a higher return. Should a farmer cut and sell the timber in his woods to raise money for a new barn, his private accounts would reflect the acquisition of a new asset, the barn, and the loss of an old asset, the timber. He thinks himself better off because the barn is worth more to him than the timber. In the national accounts, however, income and investment would rise as the barn is built, but income would also rise as the wood is cut. The value of the timber, less that of any intermediate purchases (e.g., gas and oil for the chainsaw) would be credited to value added in the logging industry. Nowhere is the loss of a valuable asset reflected. This can lead to serious miscalculation of the development potential of resource-dependent economies by confusing gross and net capital formation. Even worse, should the proceeds of resource depletion be used to finance current consumption, then the economic path is ultimately unsustainable, whatever the national accounts say. If the same farmer used the proceeds from his timber sale to finance a winter vacation, he would be poorer on his return and no longer able to afford the barn, but national income would only register a gain, not a loss in wealth.

Many countries now heavily burdened with debt are resource-dependent: Mexico, Venezuela, and Nigeria are oil exporters, for example. Their national balance sheets before the debt crisis deteriorated substantially as they drew down natural resource assets and piled up external debt, using the proceeds of both to finance consumption and subsidize investments of little or no economic value. A national accounting system that drew attention to their deteriorating asset positions might have alerted policy-makers to the need for policy changes and international lenders to the growing risks of further exposure.

The fundamental definition of income encompasses the notion of sustainability. In accounting and in economics textbooks, income is defined as the maximum amount that the recipient could consume in a given period without reducing the amount of possible consumption in a future period. (Edwards and Bell 1961; Hicks 1946) Business income is defined as the maximum amount the firm could pay out in current dividends without reducing net worth. This income concept encompasses not only current earnings but also changes in asset positions: capital gains are a source of income, and capital losses are a reduction in income. The depreciation accounts reflect the fact that unless the capital stock is maintained and replaced, future consumption possibilities will inevitably decline. In resource-dependent countries, failure to extend this depreciation concept to the capital stock embodied in natural resources, which are such a significant source of income and consumption, is a major omission and inconsistency.

This is not academic hairsplitting. For resource-based economies, evaluations of economic performance and estimates of macroeconomic relationships are seriously distorted by failure to account for natural resource depreciation. In this report, Indonesia is used as an example. Over the past 20 years, Indonesia has drawn heavily on its considerable natural resource endowment to finance development expenditures. Revenues from production of oil, gas, hard minerals, timber, and forest products have offset a large share of government development and routine expenditures. Primary production contributes more than 43 percent of gross domestic product, 83 percent of exports, and 55 percent of total employment. *(Table I.1.)* Indonesia's economic performance over this period is generally judged to have been successful: per capita GDP growth averaging 4.6 percent per year from 1965 to 1986 has been exceeded by only a handful of low and middle-income countries, and is far above the average for those groups. Gross domestic investment rose from 8 percent of GDP in 1965, at the end of the Sukarno era, to 26 percent of GDP (also well above average) in 1986, despite low oil prices and a difficult debt situation. (World Bank 1988)

Estimates derived from the Indonesian country case study, presented in more detail in Part II of this report, illustrate how much this evaluation is affected by "keeping score" more correctly. Table I.2 and Figure 1 compare the growth of gross domestic product at constant prices with the growth of "net" domestic product, derived by subtracting estimates of net natural resource depreciation for only three sectors: petroleum, timber, and soils. It is clear that conventionally measured gross domestic product substantially overstates net income and its growth after accounting for consumption of natural resource capital. In fact, while GDP increased at an average annual rate of 7.1 percent from 1971 to 1984, the period covered by this case study, our estimate of "net" domestic product rose by only 4.0 percent per year. If 1971, a year of significant additions to petroleum reserves, is excluded, the respective growth rates from 1972 to 1984 are 6.9 percent and 5.4 percent per year, for gross and net domestic product.

The overstatement of income and its growth may actually be considerably more than these estimates indicate since only petroleum, timber, and soils on Java are covered. Other important exhaustible resources that have been exploited over the period, such as natural gas, coal, copper, tin, and nickel have not yet been included in the accounts. The depreciation of other renewable resources, such as non-timber forest products and fisheries, is also unaccounted for. When complete depreciation accounts are available,

Table I.1. Direct Contribution of Primary Production (%)

	Share of GDP 1983–1987	Growth Rate 1983–1987	Share of Merchandise Export 1987/88	Share of Employment 1985
Renewable Resources	**24.2**	**3.2**	**30.4**	**54.6**
Agriculture	21.3	3.5	13.7	
—Food crops	(14.8)	(2.2)	(0.6)	
—Other crops	(4.0)	(6.4)	(12.3)	
—Livestock	(2.5)	(6.6)	(0.8)	
Fishing	1.7	0.6	2.3	
Forestry[a]	1.2	2.5	14.4	
Exhaustible Resources	**19.7**	**3.0**	**53.3**	**0.8**
Oil & natural gas[b]	18.5	2.9	47.7	
Other mining	0.8	5.6	5.6	
Total Primary Sectors	**43.9**	**3.1**	**83.7**	**55.4**

a. Logs, sawn timber and plywood.
b. Includes crude oil and condensates, natural gas, LNG and LPG, but excludes other oil products.

Source: Central Bureau of Statistics and Bank Indonesia.

they will probably show a greater divergence between the growth in gross output and net income.

Other important macroeconomic estimates are even more badly distorted. Table I.3 and Figure 2 compare estimates of gross and net domestic investment, the latter reflecting depreciation of natural resource capital. This statistic is central to economic planning in resource-based economies. Countries such as Indonesia that are heavily dependent on exhaustible natural resources *must* diversify their asset base to preserve a sustainable long-term growth path. Extraction and sale of natural resources must finance investments in other productive capital. It is relevant, therefore, to compare gross domestic investment with the value of natural resource depletion. Should gross investment be less than resource depletion, then, on balance, the country is drawing down, rather than building up, its asset base, and using its natural resource endowment to finance current consumption. Should net investment be positive but less than required to equip new labor force entrants with at least the capital per worker of the existing labor force, then increases in output per worker and income per capita are unlikely. In fact, the results from the Indonesian case study show that the adjustment for natural resource asset changes is large in many years relative to gross domestic investment. In 1971 and 1973, the adjustment is positive, due to additions to petroleum reserves.[1] In most years during the period, however, the depletion adjustment offsets a good part of gross capital formation. In some years, net investment was negative. A

Table I.2. Comparison of GDP and "NDP" In 1973 Rupiah (billions)

Year	GDP[a]	Net Change in Natural Resource Sectors[b] Petroleum	Forestry	Soil	Net Change	NDP
1971	5,545	1,527	−312	−89	1,126	6,671
1972	6,067	337	−354	−83	−100	5,967
1973	6,753	407	−591	−95	−279	6,474
1974	7,296	3,228	−533	−90	2,605	9,901
1975	7,631	−787	−249	−85	−1,121	6,510
1976	8,156	−187	−423	−74	−684	7,472
1977	8,882	−1,225	−405	−81	−1,711	7,171
1978	9,567	−1,117	−401	−89	−1,607	7,960
1979	10,165	−1,200	−946	−73	−2,219	7,946
1980	11,169	−1,633	−965	−65	−2,663	8,506
1981	12,055	−1,552	−595	−68	−2,215	9,840
1982	12,325	−1,158	−551	−55	−1,764	10,561
1983	12,842	−1,825	−974	−71	−2,870	9,972
1984	13,520	−1,765	−493	−76	−2,334	11,186
Average Annual Growth	**7.1%**					**4.0%**

a. In constant 1973 Rupiah, billions. From the Indonesian Central Bureau of Statistics.
b. The flow of resources in each sector is elaborated in the sections on the specific resource later in the text. Positive numbers imply a growth in the physical reserves of that resource during the year.

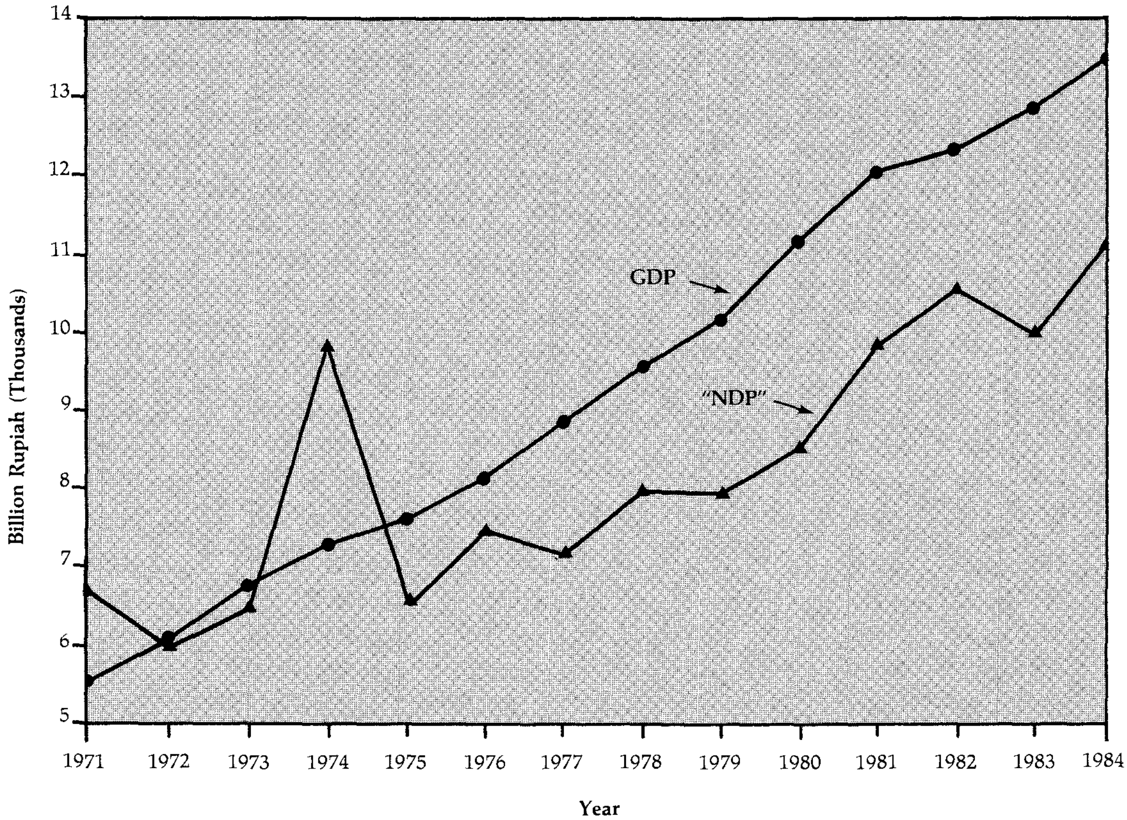
fuller accounting of natural resource depletion might conclude that in many years depletion exceeded gross investment, implying that natural resources were being depleted to finance current consumption expenditures.

Such an evaluation should flash an unmistakable warning signal to economic policy-makers that they were on an unsustainable course. An economic accounting system that does not generate and highlight such evaluations is deficient as a tool for analysis and policy in resource-based economies and should be amended.

The same holds true with respect to evaluation of performance in particular economic sectors, such as agriculture. Almost three-quarters of the Indonesian population live on the fertile but overcrowded "inner" islands of Java, Bali, and Madura, where lowland irrigated rice paddies are intensively farmed. In the highlands, population pressures have brought steep hillsides into use for cultivation of maize, cassava, and other annual crops. As hillsides have been cleared of trees, erosion has increased, now averaging over 60 tons per hectare per year, by our estimates.

Erosion's economic consequences include loss of nutrients and soil fertility from thin soils, and increased downstream sedimentation in reservoirs, harbors, and irrigation systems. Increased silt concentrations affect fisheries and

Figure 1. GDP and "NDP," in Constant 1973 Rupiah



downstream water users. Although crop yields have improved in the hills because farmers have used better seed and more fertilizers, the estimates presented in Part II imply that the annual depreciation of soil fertility, calculated as the value of the lost farm income, is about 4 percent of the value of crop production, which is as large as the annual production increase. In other words, these estimates suggest that *current* increases in farm output in Indonesia's uplands are being achieved almost wholly at the expense of potential *future* output. Since the upland population is unlikely to be smaller in the future than it is now, the process of soil erosion represents a transfer of wealth from the future to the present. By ignoring the future costs of soil erosion, the sectoral income accounts significantly overstate the growth of agricultural income in Indonesia's highlands.

Current *increases in farm output in Indonesia's uplands are being achieved almost wholly at the expense of potential* future *output.*

Table I.3. Comparison of GDI and "NDI"

Year	GDI[a]	Resource Depletion[b]	NDI
1971	876	1,126	2,002
1972	1,139	-100	1,039
1973	1,208	-279	929
1974	1,224	2,605	3,829
1975	1,552	-1,121	431
1976	1,690	-684	1,006
1977	1,785	-1,711	74
1978	1,965	-1,607	358
1979	2,128	-2,219	-91
1980	2,331	-2,663	-332
1981	2,704	-2,215	489
1982	2,783	-1,764	1,019
1983	3,776	-2,870	906
1984	3,551	-2,334	1,217

a. In constant 1973 Rupiah, billions. From the Indonesian Central Bureau of Statistics.
b. In constant 1973 Rupiah, billions. Includes depletion of forests, petroleum and the cost of erosion on the island of Java. These figures are explained fully in Part II.

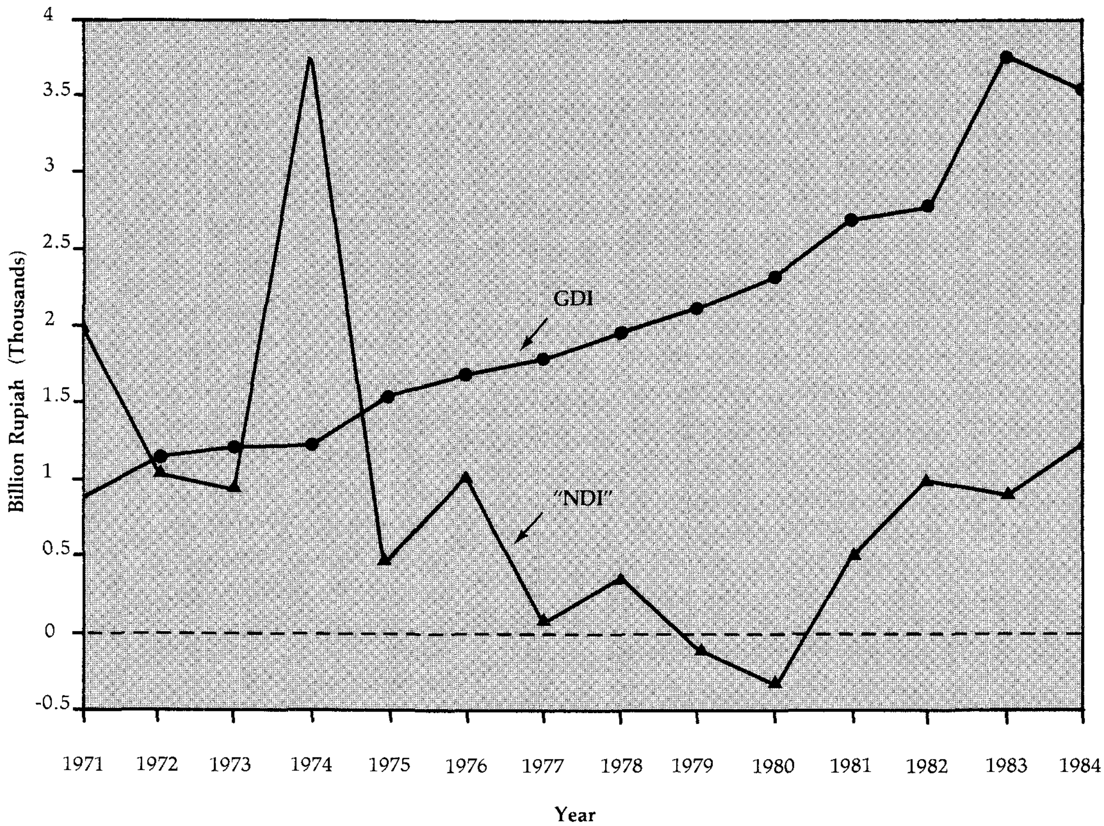
A considerable and growing body of expert opinion has recognized the need to remove this anomaly from the accounting framework by accounting for depreciation of natural resource assets like depreciation of other physical capital. In the words of a recent treatise on the measurement of economic growth, "Policymakers need, among other types of information, a set or sets of accounts which describe the significant dimensions of the system for which they are responsible ... a cogent argument can be made for the view that the present set of national accounts provides an increasingly deficient representation of the substantive economic activities taking place within the system, and that many of these deficiencies are capable of being remedied by using available data." (Juster 1973, pp. 26–27)

In June 1985, the member governments of the OECD adopted a "Declaration on Environment: Resources for the Future." They declared that they will "ensure that environmental considerations are taken fully into account at an early stage in the development and implementation of economic and other policies by ... *[inter alia]* ... improving the management of natural resources, using an integrated approach, with a view to ensuring long-term environmental and economic sustainability. For this purpose, they will develop appropriate mechanisms and techniques, including more accurate resource accounts." (OECD, 1986)

Our Common Future, the 1987 report of the World Commission on Environment and Development, stated, "Thus, figuring profits from logging rarely takes full account of the losses in future revenue incurred through degradation of the forest. Similar incomplete accounting occurs in the exploitation of other resources, especially in the case of resources that are not capitalized in enterprise or national accounts: air, water, and soil. *In all countries, rich or poor, economic development must take full account in its measurements of growth of the improvement or deterioration in the stock of natural resources." (Our Common Future,* p. 52)

Similarly, academic experts (Stauffer, 1983) and such international agencies as the OECD have recommended that capital consumption allowances be extended to natural resource assets, such as mineral deposits (OECD, 1986). The World Bank and the United Nations Environment Programme have emphasized the deficiencies in the current accounting system and have sponsored work on improvements. According to a recent Bank publication, "GDP is essentially a short-term measure of economic activity for which exchange occurs in monetary terms. It is of limited usefulness to gauge long-term sustainable growth, partly because natural resource depletion and degradation are being

Figure 2. GDI and "NDI," in Constant 1973 Rupiah



ignored under current practices." (Lutz and El-Sarafy 1988)

A number of OECD member governments, including Canada, France, Netherlands, Australia, and Norway, have carried on substantial statistical work programs to compile accounts on natural resource stocks and stock changes. France and Norway have made perhaps the most extensive official estimates, France's patrimony accounts have emphasized the development of physical accounts. (Weber 1983) Norway's resource accounts for energy and other significant economic resources have stressed integration with macroeconomic models and budgets. (Alfsen, Bye and Lorentsen 1987) There is a detailed estimate of the national balance sheet of the United States that includes values for timber and subsoil assets, and an important study of national balance sheets covering twenty countries by the same scholar. (Goldsmith, 1982, 1985)

Within the last few years, governments in developing countries, recognizing their natural resource dependence, have become interested in a more adequate accounting framework. The World Resources Institute is collaborating on pilot studies with government research institutes and statistical agencies in Indonesia, Costa Rica, and the People's Republic of China. Other governments considering new work programs in natural resource accounting include Thailand, the Ivory Coast, and Argentina. Policy-makers in these countries recognize the need for a planning tool that more effectively integrates economic and ecological considerations.

In filling this need, the United Nations Statistical Office has an important role to play. The U.N. System of National Accounts provides a standard and model that, at least in its core flow accounts, is closely followed by most countries. The U.N. Statistical Office is also a worldwide source of expertise and guidance in the development of national income and other statistical systems.

The system of national accounts (SNA) published by the United Nations Statistical Office (United Nations 1968) is more complete with respect to natural resource accounting than are the accounting systems actually implemented by most national governments. The SNA provides for balance sheets that record opening and closing stocks, and sources of increase and decrease. Such accounts are included for reproducible tangible assets, such as tree plantations, and non-reproducible tangible assets, such as agricultural land and subsoil minerals. The criterion for inclusion in the SNA is whether the assets are privately owned and used in the commercial production of goods and services so that economic values can be established. Natural resources in the public domain, such as surface waters, atmosphere, and wilderness, are excluded on the grounds that the SNA deals with the market economy and that the economic values of natural resources outside the market system cannot readily be established.

For natural resource assets included in the SNA, the accounting framework provides for "reconciliation accounts" that link balance sheet and flow accounts. These revaluation accounts encompass changes in opening stocks due to changes in prices during the period, and due to physical changes such as growth, discoveries, depletion, extraction, and natural losses. The valuation principle endorsed by the United Nations for use in these accounts is market asset value, when possible. When direct asset value cannot be established, the U.N. guidelines endorse the economic asset-valuing principle discussed above: the present value of the expected future income stream obtainable from the resource is the measure of the resource's asset value.

The U.N. Statistical Commission, advised by a number of expert working groups, is currently considering changes in the SNA, as it does periodically. Dissatisfaction stems from many inconsistencies and omissions in the current system. For example, production of goods and services outside the enterprise sector, notably by households, is largely omitted. Also, along with natural resources, other kinds of capital assets, such as knowledge and the stock of skills possessed by the workforce are ignored. Furthermore, in the government sector, the goods and services produced are not directly measured, but are valued at their factor cost. These and many other deficiencies have led to a long agenda of suggested improvements.

Although deliberations will continue until 1991, the U.N. Statistical Commission has evidently already reached the decision that there should be no fundamental changes in the existing SNA. The existing accounting methodology is protected, in a sense, by its very inadequacy: wholesale reform is a large task, and improvement limited to just one aspect is hard to justify when so many other problems would still remain. Moreover, both at the national and international level, decisions regarding the accounting system are in the hands of the *producers* of statistics, not the users. The national income accounts are like sausages: there are many consumers, but few who want to know how they are put together. Partly for this reason, decisions are dominated by the concerns of national income statisticians, who are typically handicapped by shortages of staff, budgets, and raw data. These statisticians are resistant to recommending changes when so much work remains to be done before the *existing* SNA can be fully implemented.

National income accounts are like sausages: there are many consumers, but few who want to know how they are put together.

With respect to depreciation accounts for natural resources, therefore, the expert committees of the U.N. Statistical Office have taken the position that countries should be encouraged to implement balance sheet accounts for reproducible and non-reproducible tangible assets and link those to conventional national income measures through "satellite accounts," as indicated in the present system. In other words, their position is that depletion accounts for natural resources should be calculated, but kept apart from the main tables. The measure of depreciation in the national income accounts should not be extended to include natural resources, and the present misleading indicators of economic performance should be maintained.

The rationale for this position is pragmatic: until more national statistical offices are capable of estimating depreciation accounts for natural resource assets, the core national income accounts should not be modified. Any estimates of natural resource balance sheets and depreciation should be displayed in ancillary tables, so that users can make their own evaluations.

Therefore, from the statistician's perspective, the amount of effort required to implement natural resource accounts is important. The Indonesian country case study was implemented partly to obtain first-hand information about the level of effort needed to prepare numerical estimates. The accounts presented in this report were prepared almost entirely by predoctoral and master's level graduate students. Enough information to make reasonable estimates was found to be already available, so that compilation and reorganization of data were the main tasks. In this pilot study, without prior experience, working solely with existing data (no fresh field surveys were conducted), without the access to data a government statistical office would have, researchers spent approximately 12 person-months mostly in the United States. This modest input generated estimates that shed substantial new light on Indonesia's growth performance over more than a decade.

Only if the basic measures of economic performance, as codified by the official national accounting framework, are brought into conformity with a valid definition of income will economic policies be influenced toward sustainability.

The importance of bringing such estimates into the main national income accounts, rather than relegating them to "satellite" or "reconciliation" accounts, is demonstrated by events of the past decade. While virtually all countries calculate national income accounts, few have implemented the United Nation's recommendations with respect to ancillary tables in the SNA because with limited resources they have had to "stick to the basics." Similarly, despite their recognized deficiencies, politicians, journalists, and even sophisticated economists in official agencies continue to use GDP growth as the prime measure of economic performance. (In the first statistical table of the World Bank's annual *World Development Report,* for example, entitled, "Basic Indicators," the economic indicators are GDP, GDP growth per capita, and the rate of inflation.) Only if the basic measures of economic performance, as codified by the official national accounting framework, are brought into conformity with a valid definition of income will economic policies be influenced toward sustainability.

There is ample time before the revisions to the SNA are announced for the U.N. Statistical Office to explore fully the implications of extending the concept of depreciation to natural resource assets. It should use this time to prepare for that change. At the same time, key international economic institutions, such as the World Bank, other multilateral development banks, the IMF, and the OECD, should begin to compile, use, and publish revised estimates of net national product and national income, as this report has done. All these institutions should ready themselves to provide technical assistance to the growing number of national statistical offices that wish to adopt these changes and make such estimates for themselves.

B. Current National Income Accounting

1. Imputations and the Treatment of Depreciation

The market economy—goods and services exchanged for financial consideration—broadly limits the scope of national income accounts. For this reason, intra-household production and exchanges are excluded, except for subsistence agricultural production. Nonetheless, the accounts often do impute values to important economic activities that take place without any market transaction. For example, the rental value of owner-occupied housing is treated as if the owner rented the premises to himself. The criteria used to judge whether nonmarket activities should be included in national accounts are (1) whether they are directly comparable to production taking place in the market, and (2) whether their value can be reliably measured, given the statistical resources.

An imputed value of particular concern here is for the consumption of capital stock. The value of capital goods, such as structures and equipment, declines over time with use because of physical wear and obsolescence. This gradual decrease in the future productive potential of capital goods is reflected in the national accounts by a depreciation allowance that amortizes the asset's value over its useful lifetime. There are markets for some used capital goods, such as vehicles, from which depreciation factors can be estimated. Otherwise, amortization is a surrogate measure for the loss of income-generating capacity of older assets. Straight-line depreciation and other formulas are imputations for this loss of value.

Depreciation of tangible reproducible capital is subtracted from gross national product (GNP) in calculating the net national product (NNP) and national income. A nation must invest enough in new capital goods to offset the depreciation of existing assets if the future income-producing ability of the entire capital stock is to be preserved. Therefore, according to the definition of income given above, this capital consumption allowance must be excluded from total production. However, this procedure is applied only to structures and equipment, not to natural resources or other types of assets. NNP should provide a more useful measure of economic performance than GNP but generally receives less attention in economic policy planning. As currently defined and estimated to include only buildings and equipment assumed to depreciate at fixed rates, gross and net product tend to move closely together. However, ignoring or underestimating the deterioration or depletion of the capital stock can lead to economic policy errors with serious, long-term consequences.

2. Income Statements and Balance Sheets

A complete system of financial accounts consists of two parts, one (the *income statement*) dealing with transaction flows over a period of time, and the other (the *balance sheet*) with stocks of tangible and financial assets at different points in time. The concepts of production, consumption, revenues and costs relate to transaction flows within accounting periods. The national economic accounts in which they appear are comparable to income statements in business accounting. In contrast, balance sheets comprise stocks or levels of assets, liabilities and net worth at the end of accounting periods. Flows and stocks are linked, in that flows are equal to differences between stocks, and that stocks are equal to accumulated past flows.

National balance sheets provide a picture of a country's tangible and financial wealth at different points in time, facilitating intertemporal and international economic structural comparisons. The evaluation of a nation's future potential for sustained income generation can be enhanced by the detailed analyses of national assets and liabilities, through the preparation of national balance sheets. In the United Nations' SNA, the importance of balance sheets and wealth estimates for economic analysis, are fully recognized, and the SNA includes models and an explicit recommendation to construct national balance sheets. However, while neither business firms nor households would ignore significant changes in their balance sheets, few national governments even calculate theirs.

At least in concept, the United Nations has endorsed accounting for certain natural resources. SNA specifically includes forests and subsoil assets (e.g., oil and gas reserves) in model national balance sheets. Two principal approaches to valuing assets have been endorsed for application to natural resources. These are (1) the use of values derived from market transactions in assets, and (2) the use of the discounted present value of estimated future income flows derived from the assets to be valued. For example, the SNA guidelines (United Nations 1977) suggest that the value of timber tracts should be based upon market data if available, taking account of timber type and the situation and character of the land. If there have been insufficient market transactions in timber to provide estimates, standing timber should be valued by discounting the future proceeds of selling the timber at current prices after deducting management and harvesting costs. An identical approach is suggested with respect to subsoil assets, using as a discount rate a rate of return "expected by investors in mining or quarrying enterprises."

Neither the United Nation's SNA nor the national income accounts of any country now integrates the treatment of natural resource between income and balance sheet accounts. Final sales to consumers are included on the product side; on the income side, the value added from resource extraction is included in wages and salaries, in rental incomes and in company profits. In other words, the *total* value of current production, net of purchased inputs, is imputed to current income.

There are no accounting entries in the flow accounts for depletion, growth (in the case of forests), discoveries (in the case of subsoil assets) or asset revaluation due to price changes. Only capital investments in durable structures and equipment used in the industry are subject to depreciation, not the resources themselves. There is no depreciation factor in the flow accounts to represent the loss of forests, the depletion of minerals, the erosion of soils, or the deterioration of water resources, even though these user costs impair the future income-generating capacity of those assets.

The U.N. recommends instead that these balance sheet valuation adjustments should flow through reconciliation accounts and not the current income accounts. The SNA guidelines suggest, for example, that reductions in the market value of land due to erosion be reflected in the reconciliation accounts. (United Nations 1977) An expert group of the United Nations has expressed general support for a calculation of the change in the value of proven subsoil mineral reserves that would include allowances for both depletion and new finds, as well as the effects of price changes. This group recommended that the resulting adjustments also flow through the reconciliation accounts (United Nations 1980), leaving GNP and NNP unadjusted.

In arguing for keeping such asset revaluations in satellite accounts, the U.N. guidelines pointed out that large and sudden revaluations of subsoil asset values as a result of (1) extensive new discoveries; (2) changes in technology increasing the range of exploitable reserves; or (3) changes in market conditions could markedly affect estimates of current income if admitted into the flow accounts. This position ignores the fact that changes in technology or market conditions can equally affect the reproducible capital stock. Energy price shocks, for example, first made most older heavy industrial equipment economically worthless because at high energy prices those plants could not produce at a profit. The same fluctuations in energy markets led to drastic inflation, then deflation, in real estate values in oil-producing regions, such as Texas. The income accounts were insulated from these changes in asset values only because depreciation rates are estimated at constant "book" values, a procedure equally applicable to natural resource assets. The impact of capital consumption allowances for natural resources on the national income accounts would depend, as it should, entirely on the importance of natural resources to the particular economy.

In essence, reconciliation accounts provide a means of recording changes in the value of net assets between successive measurement dates *without having to show any effect on the income of the intervening period.* Recording these adjustments in reconciliation accounts is likely to minimize their consideration in national policy analysis. Therefore, while it is significant that the United Nations has specifically endorsed the principle of valuing natural resource assets and asset changes in the system of national accounts, the procedure they have recommended would still leave the income account seriously biased as an estimate of economic performance.

C. The Scope of Natural Resource Accounting

A number of developed countries have proposed or set up systems of environmental accounts, including Norway, Canada, Japan, the Netherlands, the United States, and France. These systems have been reviewed in detail and evaluated for the United Nations Environment Programme by Weiller (1983) and Friend (1983). While natural resources take priority in Norway and France, pollution and environmental quality have been the focus in the United States and Japan. The approaches of Canada and the Netherlands combine elements of both approaches.

In both Norway and France, extensive systems of resource accounting have been established to supplement their economic accounts. The Norwegian system of natural resource accounting and the past decade's experience with it has recently been described. (Alfsen, Bye, and Lorentsen, 1987; Garnasjordet and Saebo, 1986) Accounts have been compiled for "material" resources, such as fossil fuels and other minerals, such "biotic" resources as forests and fisheries, and such "environmental" resources as land, water, and air. The accounts are compiled in physical units of measurement, and not integrated with the national income accounts. However, resource accounts, especially those for petroleum and gas, have been expressed in value terms for use in macroeconomic planning and projection models maintained by the Central Bureau of Statistics.

The French natural patrimony accounts are intended as a comprehensive statistical framework to provide the authorities with the facts and data they need to monitor the state and changes in "that subsystem of the terrestrial ecosphere that can be quantitatively and qualitatively altered by human activity."

(Corniere, 1986) They are conceptually broader than the national income accounts: material and energy flows to and from economic activities form only a subset of the accounts. (Commission Interministerielle des Comptes du Patrimoine Naturel, 1983) Methodology and empirical estimates have been under development since 1971, and they now cover the same range of resources as Norway's: non-renewables, the physical environment, and living organisms. The basic accounting units are physical, with provision for monetary valuation of stocks and flows that are marketed or contribute directly to market production. (Weber, 1983)

The construction of such frameworks for the compilation of environmental statistics may well encourage decision-makers to consider the impact of specific policies on the national stock of natural resources. However, a physical accounting approach *by itself* has considerable shortcomings. On the one hand, it does not lend itself to useful aggregation. Aggregating wood from various species of trees in physical units (cubic meters) obscures wide differences in the economic value of different species. Aggregating reserves of a mineral in physical units (tons) obscures vast differences in the value of different deposits, due to grade and recovery cost. On the other hand, maintaining physical accounts in disaggregated detail results in a mountain of statistics that are not easily summarized or used.

A further problem is that accounts maintained in physical units do not enable economic policy-makers and planners to understand the impact of economic policies on a nation's natural resources and thereby to integrate resource and environmental considerations into economic decisions—presumably, the main point of the exercise. While the information from the physical resource accounts undoubtedly facilitates the assignment of monetary values to balances and transaction flows (as will be described in this paper) from the perspective of *economic* policy, it is only an intermediate step. (Theys, 1984) Yet, there is no conflict between accounting in physical and economic units because, as the Indonesian case study shows, physical accounts are necessary prerequisites to economic accounts. If the measurement of economic depreciation is extended to natural resources, physical accounts are inevitable by-products.

There is no conflict between accounting in physical and economic units because physical accounts are necessary prerequisites to economic accounts. If the measurement of economic depreciation is extended to natural resources, physical accounts are inevitable by-products.

Notwithstanding these points, there are limits to monetary valuation, set mainly by the remoteness of the resource in question from the market economy. Some resources, such as minerals, enter directly. Others, such as subsurface water, are extensively used as inputs to market production, and although they are rarely bought and sold, values can be readily imputed. Others, however, such as noncommercial wild species, do not contribute directly to production and can be valued in monetary terms only through quite roundabout methods involving numerous, somewhat questionable, assumptions. While methodological and empirical research into the economic value of resources that are remote from market processes is to be encouraged, common sense suggests that highly speculative values should not be included in official accounts.

In industrialized countries experiencing increasingly acute problems of pollution and congestion while becoming less dependent on agriculture, mining, and other forms of primary production, the focus of attention has been on ''environmental'' rather than natural resource accounting. Since Nordhaus & Tobin (1973) proposed their ''measure of economic welfare'' as an alternative to GNP, several different approaches to the development of more comprehensive systems of national income accounting have been described that go well beyond the scope of natural resource accounting described above. An excellent recent survey of these approaches is available. (Eisner, 1988) Each reflects their authors' particular concerns (e.g., Daly, in press; Hueting 1980, 1984; Peskin 1980; Peskin & Peskin 1976, 1978). For example, Herfindahl & Kneese (1973) considered how GNP might be modified by the costs and benefits associated with pollution and its abatement. Others have proposed general systems to account for the impacts of economic activities on the quality of the environment more broadly defined.

Problems with the current framework are obvious since they lead to bizarre anomalies. If toxic substances leak from a dumpsite to pollute soils and aquifers, measured income does not go down, despite possibly severe impairment of vital natural resources. If the government spends millions of dollars to clean up the mess, measured income rises, other things equal, because such government expenditures are considered to be purchases of final goods and services. If industry itself undertakes the cleanup, even if under court order, income does not rise because the same expenditures are considered to be intermediate production costs if carried out by enterprises. If the site is not cleaned up, and nearby households suffer increased medical expenses, measured income again rises because household medical expenses are also defined as final consumption expenditures in the national income accounts.

Although the system that gives rise to such results is widely regarded as faulty, there is little consensus on the remedy. Suggested approaches can initially be classified into those involving physical accounting and those that attempt to establish monetary values. The physical approach rests on a straightforward extension of input-output analysis to keep track of ''deliveries'' of various material from various resource stocks to producing and consuming sectors, and ''deliveries'' of materials from producing and consuming sectors to various receiving bodies in the environment. (Leontief, 1970; Kneese, Ayres, & d'Arge, 1970) Thus, for example, each industrial sector's discharges of waste materials to water, land, and air are estimated, along with each sector's use of water, primary raw materials, land, and other natural resources.

This approach conceptually straightforward and empirically feasible, has the virtue of bringing common economic models of ''production'' and ''consumption'' into approximate accord with the physical laws of nature. Moreover, the data thus organized provides an important intermediate step toward approaches that do involve estimation of monetary values. However, the plausible assumption of approximate linearity in the relation of waste generation to production and consumption activities cannot be carried over to the effects of emissions on environmental quality, or to the effects of environmental quality on human welfare. Both of these linkages are often highly non-linear, due to thresholds and chemical or biological interactions.

Establishing monetary accounts for changes in environmental quality is by no means so straightforward. While all would agree in principle that a good environment yields a continuing flow of beneficial goods and services, valuing those benefits is complex. For one thing, the existing accounts already reflect some of those values, but not others, so that there is the danger of double-counting along with that of omitting important elements of income. Agricultural output, yields, and income, for example, already reflect the environmental inputs of sunshine and precipitation, which make purchased inputs more productive. Increased concentrations of ozone and other air pollutants reduce agricultural yields and thus diminish measured income in the existing accounts. Environmental deterioration, insofar as it raises current production costs or reduces productivity, is already reflected in the accounts of the enterprise sector.

The glaring omission is the direct value of environmental quality or quality changes to the household. In principle, the damages to individuals from increasing pollution, congestion, and noise can be estimated by measuring willingness to pay, lost productivity, or needed defensive expenditures. Despite a large body of research literature on methodological and statistical problems, the task would be formidable if attempted on a national scale and remains in the realm of research rather than accounting.

The notion of "defensive" expenditures is elusive, since spending on food can be considered a defence against hunger, clothing a defence against cold, and religion a defence against sin.

On the other side of the ledger, there are problems—although perhaps not so serious—in improving the accounting of expenditures undertaken to prevent or remedy environmental damages. These problems can be brought into focus by assuming that households and enterprises are forced to spend more and more as the economy grows to maintain a constant level of environmental quality. (Juster, 1973) One anomaly might be addressed by treating such expenditures as intermediate purchases when undertaken by households and governments, as they now are when undertaken by enterprises. However, this immediately raises the broader question of treating as intermediate expenses a wide range of outlays by governments and households that have the basic function of maintaining productivity (including, for example, traffic control, health maintenance, and so on). The notion of "defensive" expenditures is elusive, since spending on food can be considered a defence against hunger, clothing a defence against cold, and religion a defence against sin.

Another difficulty is in establishing the boundary between outlays to maintain environmental quality and those undertaken for other purposes. A household's purchase of a water filter, or a firm's installation of a water treatment plant, might be readily identified. However, a household's move to another region with a superior environment, or a firm's adoption of an intrinsically low-residuals process technology would probably not.

There has been little consensus on the principles or quantification of proposals for broader environmental quality accounting so far, though the discussion has helped highlight the importance of incorporating environmental protection and effective natural resource management in national economic planning. However, for most developing countries and other resource-based economies, it is more relevant to think of natural resources as productive assets than as consumer goods. The first priority is to account for those disappearing assets in a way that gives due emphasis to the costs.

D. Setting Up Natural Resource Accounts

1. Physical Accounts

Natural resource physical stocks and any changes in those stocks during an accounting period can be recorded in physical units appropriate to the particular resource. The basic accounting identity is that opening stocks *plus* all growth, increase or addition *less* all extraction, destruction, or diminution *equals* closing stocks. Although the following discussion refers to oil and gas reserves and timber stocks as examples, the principles are applicable to many other resources.

Oil and natural gas resources, the former measured in barrels and the latter in barrel-equivalents, consist of identified reserves and other resources and identified reserves can be divided into proven reserves and probable reserves. Proven reserves are the estimated quantities of oil and gas that geological and engineering data indicate with reasonable certainty to be recoverable from known reservoirs under existing market and operating conditions—that is, prices and costs as of the date the estimate is made. Probable reserves are quantities of recoverable reserves that are less certain than proven reserves. Thus, one limit on the stock of reserves is informational. Additional proven reserves can usually be generated by drilling additional test wells or undertaking other exploratory investments to reduce uncertainty about the extent of known fields. The boundary between reserves and other resources is basically economic. Vast quantities of known hydrocarbon deposits cannot be extracted profitably under current conditions. They are thus known resources, but cannot be counted as current reserves, though price increases or technological improvements might transform them into reserves in the future.

For other mining industries, geological characteristics tend to be known with more certainty, so there is less distinction between proven and probable reserves but a sharp division between economic reserves and total resources. Many minerals are present at very low concentrations in the earth's crust in almost infinite total amounts. (Goeller & Weinberg, 1984) Technological changes in mining and refining processes have markedly reduced the minimum ore concentrations that can profitably be mined, correspondingly expanding mineral reserves.

A similar framework is applicable to sub-soil deposits of water in available aquifers, except that accounting for changes in stocks must take into consideration the annual recharge. Accounting for water *quality* changes encounters problems that illustrate the limitations of physical accounting. Quality changes can be reflected in economic valuation rather readily, if they affect treatment costs or the economic uses to which water can be put. However, the numerous dimensions of quality, reflecting contamination by many other substances in varying concentrations and combinations, makes the construction of discrete physical categories difficult.

Changes in oil and gas stocks may be classified under various headings. Landefeld & Hines (1982) include under additions to reserves: "discoveries," the quantity of proven reserves that exploratory drilling finds in new oil and gas fields or in new reservoirs in oil fields; "extensions," increases in proven reserves because of subsequent drilling showing that discovered reservoirs are larger than originally estimated; and, "revisions," increases in proven reserves because oil or gas firms acquire new information on market conditions or new technology. Extensions of and revisions to oil and gas reserves have historically been significantly larger than new discoveries. Landefeld & Hines (1982) point out that reserve statistics generally produce very conservative estimates of the total resource stocks that will ultimately enter the economic system. Soladay (1980) estimated that actual production from new U.S. fields and reservoirs was over seven times the amount initially reported as discovered.

Reserve levels fall because of extraction and downward revisions. In the United States, oil and gas companies are required by the Securities and Exchange Commission to disclose net annual changes in estimated quantities of oil and gas reserves, showing separately opening and closing balances; revisions of previous estimates (from new information); improved recovery (resulting from improved techniques); purchases and sales of minerals in place; extensions and discoveries; and, production. (FASB 1977)

The accounting framework for timber resources in physical units could be expressed in hectares, in tons of biomass, or in cubic meters of available wood (Weber 1983), though the last is probably the most important economic measure. As in the case of minerals, the total resource is larger than the economic reserve since a substantial part of the total stock of standing timber in any country cannot be profitably harvested and marketed with current technologies and market conditions.

Additions to the timber stock can originate from growth and regeneration of the initial stock, and from reforestation and afforestation. Reductions can be classified into production (harvesting); natural degradation (fire, insect infestations, etc.); and, deforestation by man. Separate accounts might be established for different categories of forests—for example, virgin production forests, logged (secondary) forests, protected forests, and plantations. In temperate forests, where species diversity is limited, timber stocks are further disaggregated by species.

Physical accounts can be constructed along similar lines for agricultural land. Land and soil maps and classification systems are used to disaggregate land into productivity categories. Changes in stocks of each land category within a period reflect various phenomena: conversion to non-agricultural uses; conversion to lower productivity classes through physical deterioration by erosion, salinization, or waterlogging; and conversions to higher productivity classes through physical improvements by irrigation, drainage, and other investments. A set of physical accounts for agricultural land would record stocks of land at each accounting date by productivity class, and flows among classes and to other land uses according to cause.

Similarly, physical accounts can be set up for other biological resources, such as wildlife or fish populations. The principles are essentially those of demography. Additions to initial populations are attributed to fertility, estimated from reproduction rates and the size of the breeding population, and inmigration. Subtractions from stocks are attributed to natural mortality, estimated from age-specific or general mortality rates, harvesting operations, other special sources of mortality, and outmigration.

2. *Valuation Principles*

The concept of economic rent is central to natural resource valuation. Economic rent is defined as the return to any production input over the minimum amount required to retain it in its present use. It is broadly equivalent to the profit that can be derived or earned from a factor of production (for example, a natural resource stock) beyond its normal supply cost. For example, if a barrel of crude oil can be sold for $10 and costs a total of $6 to discover, extract, and bring to market, a rent of $4 can be assigned to each barrel.

Rents to natural resources arise from their scarcity and from locational and other cost advantages of particular stocks. These rents are distinct from monopoly rents, which increase returns to a factor of production beyond its opportunity cost by restricting supply through market power or government action. In principle, rents can be determined as the international resource commodity price less all factor costs incurred in extraction, including a normal return to capital but excluding taxes, duties and royalties. Thus, the economic rent is equivalent to the net price.

This is the same concept of rent that appears in a Ricardian scarcity model, which assumes that resources from different "deposits" will be supplied at a rising incremental cost until profit on the marginal source of supply is completely exhausted. In this Ricardian model, rents arise on relatively low-cost, infra-marginal sources of supply.

It is also equivalent to a user cost in a Malthusian scarcity model, which assumes that a homogeneous exhaustible resource is exploited at an economically efficient rate, such that the profit on the marginal amount brought to market is equal to the expected return derived from holding the asset in stock for future capital gain. (Hall & Hall 1984) In such a Malthusian model, if the resource is being extracted at an efficient rate, the current rent on the last unit of resources extracted is thus equal to the discounted present value of future returns from a unit remaining in stock.

As Ward (1982) has pointed out, the gross operating surplus of the extractive sector in the SNA, represented by the sum of the profits made by all the different enterprises involved in resource extraction activities, does not represent true rewards to factors of production alone but also reflects rents from a ''one time only'' irredeemable sale of a non-renewable natural asset. By failing to measure an appropriate depletion allowance, conventional national accounting procedures allocate a disproportionate share of current income flows to present generations at the expense of future generations. The basic definition of income as the amount that can be consumed without becoming worse off is clearly being infringed as the value of the asset base declines.

Ward presents the sad exemplary tale of Kiribati, the small atoll republic of the Solomon Islands, which depended throughout the 20th century on its phosphate mines for income and government revenues. While the mines ran, gross domestic product was high and rising, but the mining proceeds were treated as current income rather than as capital consumption. When the deposits were mined out in the 1970s, income and government revenues declined drastically because far too little had been set aside for investment in other assets that would replace the lost revenues.

It would seem reasonable to apply this argument, not only to all soil and subsoil assets, but also to tropical forests which, though theoretically renewable, are being removed without adequate provision being made for their replacement in many areas. In forest economics, the concept of ''stumpage value'' is very close to that of economic rent. Stumpage value represents timber sale proceeds, less the costs of logging, transportation, and processing. Better quality and more accessible timber stands will command a higher stumpage value.

Asset transactions in natural resources, such as competitive auction sales of rights to extract timber or minerals, closely follow estimated stumpage values or rents, with allowance for risk. Because holders of those rights can usually hold the resources in stock or bring them to market immediately, the current rent or stumpage value tends to reflect the present value of expected future net income that can be derived from them.

This principle is readily extended to other resources: agricultural land can be valued directly on the basis of its current market worth, or indirectly as the present value of the future stream of net income, or annual rent, that can be derived from it. The value of subsurface irrigation water deposits can be estimated from market transactions in ''water rights,'' or by comparing the value of agricultural land overlaying a usable, known, aquifer with that of otherwise equivalent land without subsurface water. Alternatively, it can be estimated as the present value of future rents, calculated as the difference between the costs (per cubic meter) of supplying the water for irrigation and the incremental net farm income attributable to the use of the water for irrigation. The value of a fishery could be estimated, in principle, as the maximum amount of revenue that a government authority could collect in bids from potential fishermen for the rights to participate in the catch. Alternatively, it could be estimated as the present value of the net income fishermen could derive from the catch under optimal regulation. In a world of frictionless, competitive markets, these valuation methods would yield the same results.

If adjustments to national income accounts for natural resource stock changes are to attain broad acceptance, a credible standard technique for valuing natural resources must be adopted that can be applied to various resources by statisticians in different countries.

If adjustments to national income accounts for natural resource stock changes are to attain broad acceptance, a credible standard technique for valuing natural resources must be adopted that can be applied to various resources by statisticians in different countries. That method must be as free as possible from speculative estimates (about future market prices, for example) and must depend on underlying data that is reasonably available to statistical agencies.

Landefeld & Hines (1985) have recently compared the three principal methods discussed above for estimating the value of natural resource stocks: 1) the present value of future net revenues; 2) the transaction value of market purchases and sales of the resource *in situ;* and 3) the net price, or unit rent, of the resource multiplied by the relevant quantity of the reserve.

The present value method requires that future prices, operating costs, production levels, and interest rates be forecast over the life of for example, a given oil field, after its discovery. The present value of the stream of net revenue is then calculated, net revenue representing the total revenue from the resource less all extraction costs. Soladay (1980) extends the present value method by attempting to take into account the upward revisons in estimates of reserves that typically occur subsequent to the initial discovery. The United Nations Statistical Office has recommended use of the present value method when market values for transactions in resource stock are not available. (United Nations 1979)

The net price method applies the prevailing average net price per unit of the resource (current revenues less current production costs) to the physical quantities of proved reserves and changes in the levels of proved reserves. Landefeld and Hines make the important point that while the net price method requires only current data on prices and costs, it will be equivalent to the other two methods if output prices behave in accordance with long-run competitive market equilibrium. "Equilibrium in natural resource markets (where the net price rises in accordance with the rate of return on alternative investments) produces the interesting result that depletion as measured by changes in the present value of the resource equals depletion as measured by the net price method." (Landefeld & Hines 1985, p.14) The assumption here is derived from the theory of optimal depletion of exhaustible resources, that resource owners will tend to arbitrage returns from holding the stock into future periods with returns from bringing it immediately to market, adjusting current and future supplies until price changes equate those returns. (Dasgupta, 1982) When expected future increases in the net price take place at a rate equal to the return on alternative investments, these increases would therefore be eliminated in the calculation of the net present value of future cash flows. (Miller & Upton, 1985)

A number of recent studies (Boskin et al. 1985; Landefeld & Hines 1982, 1985; Soladay 1980; Ward 1982; Lutz and El-Sarafy 1988, Devarajan and Wiener 1988) have considered the issues associated with valuing the discovery and use of depletion of exhaustible natural resources in measures of national income and wealth.

In the private sector, financial accounting and reporting for petroleum- and mineral- producing companies has been debated for many years in the United States by the accounting profession, regulatory agencies, industry groups, and the companies themselves. The U.S. Securities and Exchange Commission (SEC) and Financial Accounting Standards Board (FASB) have given extensive consideration to the appropriate accounting and financial reporting for publicly traded corporations involved in extractive activities. The debate was initially focussed on the two widely different methods of reserve valuation used by companies, the full cost method and the successful efforts method. (FASB 1977) Each was based upon the costs of exploration and development actually incurred, but without reflecting the market value of reserves or annual changes in reserves to which the company has rights of ownership. Believing with ample justification that neither method provided sufficient information to stockholders, the SEC proposed a new method of reserve recognition accounting (SEC 1978) that valued proven oil and gas reserves according to the discounted present value of the stream of future income at current prices and costs. Following further debate on the issue, however, SEC abandoned this method of accounting since the burden of producing the information was considered to outweigh its usefulness to users of financial statements. (SEC 1981)

The FASB recently considered means by which companies could provide information about future cash flows from oil and gas reserves as supplemental information, outside the financial statements. (FASB 1982) They evaluated the alternatives of fair market value, discounted future net cash flows, and a "standardized measure" of discounted net cash flows. Fair market value was rejected on the basis that relatively few exchanges of oil and gas mineral interests take place, and the geological characteristics of each property are unique and thus incomparable. The use of discounted future net cash flows, based on estimated future prices and costs, production timing, and an enterprise-specific discount rate as a surrogate for fair market value, was also rejected since such subjectively based calculations could not provide sufficiently comparable and verifiable information for financial reporting. The Board settled on a standardized measure of discounted net cash flows. Future net cash flows result from subtracting future development and production costs (and tax expenses) from future cash inflows relating to proved oil and gas reserves, using prices and unit costs as of the end of the reporting year. A discount rate of 10 percent is specified. The FASB points out that the standardized measure cannot be considered an estimate of fair market value but should reflect some of the key variables that affect fair market value—such as changes in reserve quantities, selling prices, production rates, and tax rates. Thus, the private accounting profession, after lengthy consideration, has adopted a valuation method based on the net price approach.

E. Integrating Natural Resources into the National Accounts

Income accounts for natural resources can be developed directly from accounts expressed in physical units by assigning appropriate monetary values to stock levels and changes. Net changes in the value of stocks are attributed to current year additions (discoveries, net revisions, extensions, growth or reproduction) less deductions (degradation, deforestation, or depletion) plus any price changes of the resource during the year, as illustrated in Table I.4. This framework is applicable with suitable specification to a wide variety of resources.

If the primary objective were only the national balance sheet presentation of natural resource accounts, the example shown in Table I.4 would be relatively straightforward. The net value of the resource increased by $155 ($255-$100) during the year and net national wealth also increased by $155.

To adjust gross national product to a net basis, economists have a number of options. If the only desired adjustment to income were to reflect resource *depletion*, then net national product would be reduced by $32, using the average valuation rate of $1.60 per barrel. If *all* the physical changes in the resource base were netted, yielding a decrease of 15 physical units, NNP would be reduced by $24, at the same average valuation. However, if the gain in value of the opening stock due to price changes were also treated as current income, NNP would be increased by $155, the difference between the two balance sheets.

In other words, alternative adjustments are possible, depending on the objective. Treating unrealized capital gains and losses due to price changes as income is consistent with the definition of income given above, since the capital gain during the year could be consumed without reducing future potential consumption below what it would have been at the original price level. However, accounting conventions

Table I.4. Example of Resource Inclusive National Acounting System

	Physical Units	Unit Value	Value ($)	Basis of Calculation
Opening Stock	100	1.00	100	
Additions:				
Discoveries	20	1.60	32	
Revisions (Net)	(30)	1.60	(48)	
Extensions	15	1.60	24	
Growth*	0	1.60	0	
Reproduction*	0	1.60	0	
Reductions:				
Production	(20)	1.60	(32)	
Deforestation*	0	1.60	0	
Degradation*	0	1.60	0	
Net Change	(15)	1.60	(24)	
Revaluations:				
Opening Stock	—	—	200	100 × (3.00 − 1.00)
Transactions	—	—	(21)	15 × (3.00 − 1.60)
Closing Stock	85	3.00	255	

Note: Example of a natural resource account as it might appear in national economic accounts. The resource unit value (based on international commodity prices less factor costs incurred in extraction or production) is assumed to be $1.00 at the beginning of the year, $3.00 at the end of the year, and to average $1.60 during the year.

The total increase in the value of the resource over the period shown is equal to $155 ($255 − $100). The methodology recommended in this paper would result in a downward adjustment to net national product of ($24). The remaining net change in total value of $179 ($155 + $24 or $200 − $21) would be recorded in a revaluation reserve and have no impact on income of the current period.

Items marked * are specific to forest resources; all other categories are applicable to subsoil minerals, e.g., oil and gas.

now in use for physical plant and equipment value assets at "book value" rather than replacement cost: they *do not* reflect changes in asset values in current income accounts.

The United Nations (1977, 1980) has suggested that all changes in the value of natural resource stocks due to new finds, price changes, and depletion should be excluded from the income accounts. At the opposite extreme, Eisner (1980, 1985) has argued that capital revaluations in excess of those generated by general price rises should be included in measures of income and capital accumulation.

Accordingly, the money value of all capital gains in excess of those necessary to keep the real value of capital intact should be included in income. Eisner (1980) extends this argument to propose the inclusion of capital gains arising from the discovery of new resources in income, and the exclusion of resource depletion from income.

International resource commodity prices are subject to dramatic fluctuations over comparatively short time periods because price elasticities of demand and supply are often small in the short run. Including unrealized capital gains from natural resource price changes in current income could lead to significant swings in income between successive periods in resource-dependent countries. However, natural resource price swings (such as the energy price shocks) also markedly affect the value of plant, equipment, and real estate that are specific to those natural resource sectors.

The procedures illustrated here, which incorporate the net price method (Landefeld & Hines 1982, 1985), include only the value of *physical* resource stock changes in national income. This procedure is consistent with current asset-accounting practices. In addition, it is more readily implemented since, for most natural resources, information on stock changes due to extraction or discovery is more accurate than information on the size and composition of the total stock. At the end of each accounting period, the physical units comprising the opening balance of natural resource stocks have been revalued at the net price prevailing at the end of the period. The revaluation adjustment (which, in the example shown in Table I.4, equals $200) has been recorded in a revaluation reserve and therefore has no effect on the current period's income. The net physical change (15 units) is valued at the average net price prevailing during the period and is used to adjust NPP downwards by $24. The remaining revaluation adjustment, which arises from the difference between average and closing prices applied to the net physical change in resource stocks ($21) is recorded in the revaluation reserve as an unrealized capital gain, with no impact on income.

If national accounts are adjusted to show income at constant prices, thereby eliminating the effects of general inflation, the adjustment to income ($24) should be deflated by an appropriate price index. As a result, only real wealth increases or decreases will be reflected in measured national income.

Preliminary resource accounts in physical and value terms for tropical timber, petroleum, and soil resources in Indonesia from 1970 to 1984 illustrate this methodology. The net changes in resource values from physical sources (for example, excluding price revaluations) implied by these tables were reflected in the summary tables and figures presented earlier to illustrate the usefulness of such calculations in macroeconomic evaluation. The resource accounts are preliminary, in that they have not been endorsed by official Indonesian statistical or economic agencies, but represent a non-governmental research effort that drew on published and some unpublished statistical sources. Efforts are currently under way in cooperation with the Ministry for Environment and Population and a consortium of universities in Indonesia to revise these accounts and to extend the methodology to other resource sectors.

Details of the estimates are provided in Part II of this report.

Note

1. It may seem anomalous that in 1971 and 1973 depreciation was a negative number, that is, net capital consumption was *added* to gross domestic product and investment. The reason for this is that the value of additions to petroleum reserves in these years were considerably larger than all categories of depletion combined, leading to "negative" depreciation.

   One way of resolving this apparent anomaly would be to account separately for additions and subtractions from natural resource assets. Real capital gains (as distinct from those resulting from price changes) can be accounted for as gross income and gross capital formation. This is consistent with our earlier definition of income, because additions to resources during the current year augment the amount that *could* be consumed currently without reducing potential consumption in future years. This is obvious in the case of forest growth, but less obvious for mineral discoveries, since current discoveries may leave less to be discovered later on. However, insofar as additions to mineral reserves reflect advances in the technology of exploration or extraction, the total potential resource base will have expanded.

II. The Indonesian Resource Accounts

A. Timber Resource Accounts, 1970–1984

Preliminary accounts in physical and value terms for Indonesia's timber resources were estimated using the methodology explained in Part I. The accounts do not represent the full value of Indonesia's *forest* resources, which yield such important non-timber commodities as rattan, oils, resins, foodstuffs, and pharmaceutical products, and which also provide important ecological services. In principle, the values of non-timber forest commodities enter into gross domestic product, though in practice they are greatly underestimated. Exports alone of non-timber products reached U.S. $120 million in 1982. Full accounting for deforestation would include the present value of foregone future income from these non-timber forest products and services. Indonesian forests are mostly equatorial rainforests and tropical semi-deciduous *(dipterocarp* and mixed *dipterocarp)* forests, but also include swamp and mangrove forests along the coasts of Sumatra and Kalimantan and small areas of peat forests. Before World War II, timber production was concentrated on Javanese teak plantations, but after 1967 timber extraction increased rapidly from extensive primary lowland rainforests in Kalimantan, Sumatra, Sulewesi, and Irian Jaya. Indonesia joined Malaysia and the Philippines as Southeast Asia's leading log exporters, accounting together for 80 percent of world tropical hardwood exports. Indonesia's share of world exports rose from 1 percent in 1964-66 to a peak of 31 percent in 1979-81, when timber was the country's second largest export commodity in terms of gross receipts. After 1980, government restrictions to promote domestic processing reduced log exports, and replaced them with increasing volumes of lumber and plywood.

All Indonesian natural forests are state-owned and administered by the Ministry (formerly Directorate General) of Forestry. While the basic forestry law acknowledges the traditional rights of indigenous communities, in practice these *adat* rights are honored more in the breach than in the observance. On the Outer Islands, management and harvesting of most tracts are contracted to private companies, subject to regulation under the Basic Forestry Act of 1967, which prescribes good timbering and ecological practices. Up till now, the forestry agencies have been unable to enforce these prescriptions effectively. Virtually all concessionaires have nominally adopted the Indonesian Selective Cutting System, which specifies minimum tree sizes harvested and numbers, spacing, and size classes of residual trees per hectare, along with the allowable cut, but few actually follow it faithfully.[1] Forest management and policy in Indonesia have posed difficult development problems.[2]

1. The Physical Accounts

While stock estimates at different points in time provide consistency checks, an estimate of the physical growing timber stock was essential for only one benchmark year during the period. Stocks for the remaining years were computed from the respective annual net additions and reductions, for which estimates (of varying quality) were available.

Estimates of the total forest land area vary considerably among sources. An estimate for 1985 by the Directorate General of Forestry, presented in Table II.1, puts the total forest area at 143 million hectares, nearly three-quarters of Indonesia's total land area. However, this estimate included land within classified forest boundaries designated as "conversion forest," much of which had already been deforested. A 1981 FAO study *(Table II.2)* gives a figure of 158.2 million hectares, of which 113.9 million are closed forests.[3] A more recent assessment by the Land Resources Development Center and the Ministry of Transmigration, using aerial photographs dating mostly from the early 1980s, roughly agree with FAO totals for the islands already covered. A regional breakdown shows that only 1 percent of forest land is in the densely populated Inner Islands of Java and Bali, while Sumatra, Kalimantan, Irian Jaya, and Sulewesi account for 90 percent.

a. *Growing Stock*

Estimates of the total growing stock are derived from concession surveys carried out in the 1970s and from more recent provincial surveys. Although such inventories, carried out at

Table II.1. Indonesian Forest Resources: Department of Forestry Classification 1985 (million hectares)

1. **Total Land Area**		**193.6**
2. **Total Forest Area** *		**143.0**
3. **Elements of Forest Area** *		
a. Protection Forest		30.3
b. Nature Conservation and Tourism Forest		19.0
c. Production Forest (available for commercial harvesting)		64.0
i) Limited Production		(30)
ii) Permanent Production		(34)
d. Production Forest that may be converted to non-forest purposes		30.0
4. **Area Awarded to Concessionaires or in Process of Award**		**65.4**
a. Area under Concession (holders of Forest Exploitation rights)		52.2
b. Areas under Forestry Agreements (last step prior to award of rights)		13.2
* Total Rain Forest Area	82.2	
Total Swamp Forest Area	12.0	
Total Secondary Forest Area	14.6	
Other Forest Area	34.2	

Sources: Forest Area: 1985 Departamen Kehutanan, Draft Long-Term Forest Plan (Jakarta, January 1985, p. 17). Concession Areas: P.T. Data Consult, 1983.

Table II.2. Indonesian Forest Resources FAO Classification, 1980 and 1985 (million hectares)

	1980	1985	Indonesia as % of all Southeast Asia, 1985
Total Area, Natural Woody Vegetation	**158.2**	**157.1**	n.a.
A. **Closed Forests**[a]	**113.9**	**110.9**	61.8
1. Productive Forests[b]	73.7	67.7	58.5
a. Undisturbed Forest	38.9	33.0	56.6
b. Logged Forest	34.8	34.7	68.6
2. Unproductive Forest[c]	40.2	43.2	19.7
a. For Physical Reasons	34.7	n.a.	n.a.
b. For Statutory Reasons (parks, reserves)	5.4	n.a.	n.a.
B. **Open Forest**[d]	**3.0**	**2.8**	n.a.
C. **Fallows**[e]	**17.4**	**19.5**	n.a.
D. **Shrub Formations**	**23.9**	**23.9**	n.a.

a. Closed forests are those that have not been recently cleared for shifting cultivation or heavily exploited. In closed forest formations, tree crowns, underlayer and undergrowth combine to close off most of the ground from light so that continuous grass cover cannot develop.
b. Productive forests are those from which it is both physically and legally possible to produce wood for industry.
c. In unproductive forests, timber is not exploited for statutory reasons, or because harvesting is infeasible due to difficult terrain or stand conditions.
d. Open forest formations are marked by continuous grass cover on the ground.
e. Fallow refers to secondary vegetation following the clearing of forests.

Source: Food and Agriculture Organization of the United Nations, Forest Resources of Tropical Asia, Rome, FAO, Tropical Forest Assessment, 1981, p. 40, pp. 211–237, 277–313, 391–416.

different times and by different methods, aren't fully comparable, they have been made as consistent as possible through cross-checking and adjustment. The measure of stocking volume used is *'volume over bark'* (VOB): gross volume in m^3 per hectare over bark of free bole (from stump or buttresses to crown point of first main branch) of all living trees more than 10 centimeters in diameter at breast height.

Regional VOB values were obtained in the FAO study by comparing results from sample areas with more complete data from the Malaysian national inventory.[4] Stocking rate estimates of 323 m^3/ha for virgin forests (49 percent), 204 m^3/ha for logged forests (17 percent), and 198 m^3/ha for unproductive forests (34 percent) were applied to Sumatra and Kalimantan. These estimates were reduced by 15 percent for Sulawesi, Maluku, and Nusantenggara, and by 25 percent for Irian Jaya. Estimated stocking rates are then applied to data on forested areas by island and category. The total growing stock in natural forests at the end of 1980 comes to 24,248 million cubic meters, an average stocking rate of 212.9 m^3 per hectare.

A 1980 closing stock estimate of 24,248 million m^3, reflecting the VOB measure, has been included in the timber resource accounts for natural forest. This includes 10,311 million m^3 of virgin forests, 6,911 million m^3 of logged forests, and 7,026 million m^3 of unproductive forests.

Another measure, *'volume actually commercialized'* (VAC), describes the "volume under bark of logs commercially exploitable actually extracted from the forest," and it has been estimated only for virgin productive forests where the volume extracted per hectare is generally well-known. The average volume of commercial timber remaining in logged-over forests is difficult to estimate. VAC has been estimated at 20 m^3/ha for Irian Jaya, 25 m^3/ha for Sulewesi, and 45 m^3/ha for Sumatra and Kalimantan. Compared to VAC measures in Malaysia and the Philippines, these rates are low, reflecting the more selective logging practices in Indonesian forests. The value actually commercialized depends in part on the system of forest taxes and royalties, which influences the degree to which concessionaires limit harvesting to the most valuable trees. The average annual commercial production during the years 1974–80 was actually 40 m^3/ha.

Government-sponsored plantation programs implemented by the Directorate for Reforestation, the parastatal timber company, and timber concessionaires now cover significant areas in most provinces. Plantations established by concessionaires in response to financial incentives are largely pine, and many are of questionable commercial value. The Directorate's plantations include fodder and fruit trees and have had a lower survival rate.

Estimates of the area and volume of forest plantations are uncertain, partly due to unreliably reported survival rates on planted areas. The United Nations Food and Agriculture Organization estimated that "successfully established and reasonably stocked" plantations had a total estimated area of 1,918,000 ha (1,446,000 industrial and 472,000 non-industrial) in 1980.[5] The stocking of plantations has been assumed to be at an average rate of 100 m^3/ha, yielding 192 million m^3 of growing stock at the end of 1980. This figure has been added to the natural forest stocks to derive the 1980 resource account closing balance of 24,440 million m^3 of standing timber.

b. *Growth and Reproduction*

An average annual increment in volume of all trees in the forest can be expected only from disturbed or managed forests since undisturbed forests have reached their climax equilibrium. No detailed information on growth rates of disturbed natural forests is available for Indonesia, but estimates for *dipterocarp* forests elsewhere in the region suggest annual growth in commercial species between 1 and 2 m^3/ha/year.[6] Commercial growth in the forests of Sulewesi and Irian Jaya, where stocking rates are relatively low, must be lower. Another FAO study indicates an annual net increment of 1.3 m^3/ha.[7] The 34.6 million ha of logged forests were estimated to carry a timber volume of 6,911 million m^3 at an average stocking level of 200 m^3/ha. This study assumes a growth rate of 1.5 m^3/ha for these forests, yielding an annual increase in volume of 51.9 million m^3, which corresponds to an annual biomass increment of 0.75 percent. This figure has been used in the timber resource accounts.

An estimate of annual increase in plantation timber volume can be developed from the plantation species' growth rates (expressed as the mean annual increment at rotation age) and the distribution of industrial plantation areas by species reported by the FAO, as follows:[8]

Species	Area of Established Industrial Plantation (1980) (thousand ha)	Mean Annual Increment (M.A.I.) (m^3/ha/year)
Tectona grandis	861	8.5
Pinus merkusii	390	18.0
Others	195	n.a.
	1,446	11.5*

*Approximate weighted average M.A.I. based on *Tectona grandis* and *Pinus merkusii* only.

FAO (1981) estimates that 542,000 ha of the industrial plantation area of 1,446,000 ha (i.e., 37.5 percent) was established during 1976–80. The physical stock of industrial plantations at the end of 1976 can therefore be estimated as the remaining 904,000 ha. Assuming the same rate of increase in non-industrial plantations, the 1976 total plantation physical stock can be estimated as 1,199,000 ha (62.5 percent of 1,918,000). The growth in plantation area for the remaining years during the study period (1970–82) has been estimated by assuming a linear growth rate, and the volume change by applying the annual growth rate of 11.5 m^3/ha/year calculated above.

c. *Harvesting*

Figures for the total log harvest are reported by the Directorate General of Forestry in the annual report on Indonesian forestry statistics. They may be underestimates, due in part to considerable log smuggling and underinvoicing of exports to avoid export restrictions, taxes, and royalties. The recorded harvest rises to a peak of more than 25 million m^3 in 1979 and 1980, then declines due to export restrictions and domestic processing requirements. Alternative World Bank estimates, not incorporated here, place the annual harvest in the 1980s at about 25 million m^3 per year. The log output is composed of *meranti, kerning, ramin, teak,* and a few other species, extracted predominantly from Kalimantan and Sumatra during the period reviewed. These harvest figures are entered directly into the physical accounts.

d. *Deforestation and Degradation*

Deforestation denotes transfers of forest lands to other uses, including shifting and permanent cultivation, reservoirs, and other infrastructure. The area deforested annually in Indonesia is the highest in the region, due mainly to agricultural conversion. The national transmigration program settled 50,000 families from the Inner Islands on Sumatra and Kalimantan between 1974 and 1978, each on 5 hectares of land, and moved about 300,000 households between 1979 and 1984. Between 1980 and 1986, the government cleared about 800,000 hectares of land for transmigrants, of which perhaps 600,000 was logged or secondary forest. In addition, about 330,000 hectares of land still forested were allocated to transmigrants and will probably have been cleared by the end of the decade. (World Bank, 1987) Land clearance by spontaneous migrants is thought to be of the same order of magnitude as clearance by sponsored transmigrants. Other planned deforestation, largely in designated "conversion forests" for estate crops and other development projects, is estimated at about 100,000 hectares per year in the 1980s. (World Bank, 1987)

An estimated 10 to 12 million people on the Outer Islands subsist by shifting cultivation, largely on Kalimantan, Sumatra, Sulewesi, and Malaku. Most of the area affected has been reduced to poor secondary forest and scrub or converted to grassland. An estimated 20 percent of the total land area in Kalimantan has been affected by shifting cultivation, and 14 percent in Irian Jaya. Expansion of shifting cultivation is most rapid in logged productive forest and slowest in unproductive closed forest, due to differences in accessibility.

Taking into account all causes, an FAO study estimated that 9.27 million hectares were deforested between 1950 and 1977, at annual rates of 550,000 ha/year during the 1970s and rates of 600,000 in 1981 and 1982.[9] Estimates for the mid-1980s compiled by a recent World Bank assessment suggest a higher figure of over 700,000 hectares annually, but the more conservative FAO figure is used in the timber resource accounts. If a stocking rate of 200 m^3/ha (the average stocking rate for secondary forests) is used, annual volume losses of 110 and 120 million m^3 are implied for the 1970s and 1980s respectively.

Degradation refers to forest deterioration due to such natural disasters as fires, earthquakes, and pests, and due to destructive exploitation of forest resources in logging operations, grazing, and fuelwood collection. Intensive logging in Indonesia has been estimated to damage up to 40 percent of the residual trees. Logging damage has been estimated through a residual balance equation that equates the difference between stocking rates on virgin and logged forest to harvest removals and logging damage. The resulting estimate of 79 m^3 per hectare is consistent with the figure of 40 percent of volume remaining after harvest. This calculation yields a ratio of 1.98 m^3 damaged for every cubic meter harvested, and this ratio is assumed in the accounts to hold in each year.

Fires are also an important factor. The El Niño perturbation in 1982–1983 provoked severe drought, and led to disastrous forest fires in Kalimantan and neighboring Sabah in 1983–84, especially in logged-over areas littered with dead trees and branches. The damaged area in Kalimantan has been estimated at 800,000 ha of primary lowland rainforest, 550,000 ha of peat forest, and 1,200,000 ha of selectively logged primary forest. In addition, 750,000 ha of swidden area was affected, bringing the total to 3,700,000 ha. (Prance 1986) Sampled mortality rates in the burned area averaged 60 percent for small trees and 25 percent for those greater than 30 cm./dbh. Making the most conservative assumption that only 25 percent of timber resources in the areas burned were lost, the fire still cost over U.S. $3.5 billion in timber assets.

Based on results of a consultant study, fires in the preceding five years consumed an average of 60,000 hectares, mostly in secondary forests. Taking this rate to represent normal fire losses in other years adds 14 million m^3 in annual timber losses to the accounts.

e. *Summary of Physical Accounts*

These categories constitute the principal sources of increase and decrease in Indonesia's forest resources. Together with the 1980 benchmark estimates of growing stock, they permit construction of the physical accounts presented in Table II.3 for the years 1970 to 1984. They imply a cumulative net decrease in growing stock of 1,866 million m^3, about 7.2 percent of the total standing timber resource in 1970. Losses due to deforestation and degradation appear to have been several times greater than those due directly to timber harvests, but it must be remembered that logging roads increased access for settlers and accelerated forest conversion. Throughout the period, direct harvest volume appears to be less than total annual growth, but when associated logging damages are also considered timber operations have resulted in losses that exceeded growth. Since the growth of commercial species is estimated to be less than 1 m^3 per hectare, selective cutting has unambiguously reduced the forest in value.

2. *The Value Accounts*

a. *The Measure of Economic Rent*

The relevant measure of economic value to be applied to these changes in the physical resource base is the value of the standing timber prior to any value added by processing. Timber's economic rent corresponds to its

Table II.3. Forestry Accounts 1970–1984

PHYSICAL UNITS (million cubic meters)	1970	1971	1972	1973	1974
Opening Stock	25,773.1	25,672.5	25,562.7	25,445.8	25,303.1
Additions					
Growth	51.9	51.9	51.9	51.9	51.9
Reforestation	1.3	3.4	5.5	7.6	9.7
Reductions					
Harvesting	10.0	13.8	16.9	26.3	23.3
Deforestation	110.0	110.0	110.0	110.0	110.0
Logging Damage	19.8	27.3	33.4	51.9	46.0
Fire Damage	14.0	14.0	14.0	14.0	14.0
Net Change	−100.6	−109.8	−116.9	−142.7	−131.7
Closing Stock	25,672.5	25,562.7	25,445.8	25,303.1	25,171.4
UNIT VALUES (US$/m³)					
FOB Export Price	10.90	15.10	17.10	29.30	41.60
Costs	4.90	6.80	7.90	13.18	18.72
Primary Rent	6.00	8.30	9.20	16.12	22.88
Secondary Rent	3.00	4.15	4.60	8.06	11.44
MONETARY ACOUNTS (US$ millions)					
Opening Stock	—	108,335.7	149,346.6	164,910.4	287,546.3
Additions					
Growth	155.7	215.4	238.7	418.3	593.7
Reforestation	0	0	0	0	0
Reductions					
Harvesting	60.0	114.5	155.5	424.0	533.1
Deforestation	330.0	456.5	506.0	886.6	1,258.4
Logging Damage	59.4	113.3	153.6	418.3	526.2
Fire Damage	42.0	58.1	64.4	112.8	160.2
Net Change	−335.7	−527.0	−640.8	−1,423.4	−1,884.2
Revaluation[a]	—	41,537.9	16,204.5	124,059.3	120,609.6
Closing Stock	108,335.7	149,346.6	164,910.4	287,546.3	406,271.7

a. The Revaluation category accounts for changes in the value of the overall stock which are due only to differences in the rental rates.

Table II.3. (cont.) Indonesian Forestry Accounts

PHYSICAL ACCOUNTS (million cubic meters)	**1975**	**1976**	**1977**	**1978**	**1979**
Opening Stock	25,171.5	25,062.6	27,940.6	24,818.4	24,692.3
Additions					
Growth	51.9	51.9	51.9	51.9	51.9
Reforestation	11.8	13.8	15.9	18.0	20.1
Reductions					
Harvesting	16.3	21.4	22.2	24.2	25.3
Deforestation	110.0	110.0	110.0	110.0	110.0
Logging Damage	32.2	42.3	43.8	47.8	50.0
Fire Damage	14.0	14.0	14.0	14.0	14.0
Net Change	−108.8	−122.0	−122.2	−126.1	−127.3
Closing Stock	25,062.6	24,940.6	24,818.4	24,692.2	24,565.0
UNIT VALUES (US$/m³)					
FOB Export Price	26.40	44.70	47.50	46.70	85.21
Costs	11.88	20.12	21.38	21.05	29.84
Primary Rent	14.52	24.58	26.12	25.65	55.37
Secondary Rent	7.26	12.29	13.06	12.82	27.68
MONETARY ACCOUNTS (US$ millions)					
Opening Stock	406,271.7	256,848.6	432,898.5	457,956.5	447,586.3
Additions					
Growth	376.8	637.9	677.8	665.6	1,436.9
Reforestation	0	0	0	0	0
Reductions					
Harvesting	236.7	526.0	579.9	620.7	1,400.9
Deforestation	798.6	1,351.9	1,436.6	1,410.8	3,045.3
Logging Damage	233.8	519.9	572.0	613.0	1,384.3
Fire Damage	101.6	172.1	182.8	179.6	387.6
Net Change	−993.9	−1,932.0	−2,093.5	−2,158.5	−4,781.3
Revaluation[a]	148,429.2	177,981.9	27,151.5	−8,211.7	518,669.0
Closing Stock	256,848.6	432,898.5	457,956.5	447,586.3	961,474.0

Table II.3. (cont.) Indonesian Forestry Accounts

PHYSICAL ACCOUNTS (million cubic meters)	**1980**	**1981**	**1982**	**1983**	**1984**
Opening Stock	24,565.0	24,440.0	24,334.5	24,238.8	24,001.3
Additions					
Growth	51.9	51.9	51.9	51.9	51.9
Reforestation	22.1	24.2	26.3	29.6	35.3
Reductions					
Harvesting	25.2	16.0	13.4	15.2	16.0
Deforestation	110.0	120.0	120.0	120.0	120.0
Logging Damage	49.8	31.6	26.5	30.0	31.6
Fire Damage	14.0	14.0	14.0	153.8[b]	14.0
Net Change	−125.0	−105.5	−95.7	−237.5	−94.4
Closing Stock	24,440.0	24,334.5	24,238.8	24,001.3	23,906.9
UNIT VALUES (US$/m^3)					
FOB Export Price	106.93	95.84	100.59	78.75	93.15
Costs	34.24	37.93	41.00	43.31	51.23
Primary Rent	72.69	57.91	59.59	35.44	41.92
Secondary Rent	36.34	28.95	29.79	17.72	20.96
MONETARY ACCOUNTS (US$ millions)					
Opening Stock	961,474.0	1,256,046.9	996,266.8	1,020,959.6	601,049.0
Additions					
Growth	1,886.3	1,502.8	1,546.4	919.7	1,087.8
Reforestation	0	0	0	0	0
Reductions					
Harvesting	1,831.8	926.6	798.5	538.7	670.7
Deforestation	3,998.0	3,474.6	3,575.4	2,126.4	2,515.2
Logging Damage	1,810.0	915.0	789.6	531.6	662.3
Fire Damage	508.8	405.4	417.1	3,870.9	293.4
Net Change	−6,262.3	−4,218.8	−4,034.2	−6,148.3	−3,053.8
Revaluation[a]	300,835.2	−255,561.3	28,727.0	−413,762.7	109,775.0
Closing Stock	1,256,046.9	996,266.8	1,020,959.6	601,049.0	707,770.2

b. The value for fire damage in 1983 is made up entirely of estimates for the Kalimantan fire, assuming mortality rates of 25%.

"stumpage value," the market value of standing trees. With full knowledge of the resource and competitive bidding, this is the maximum amount potential concessionaires would pay for harvesting rights. Since the Indonesian government has not administered its forest resource so as to recover a large fraction of these rents from concessionaires, stumpage value must be estimated by the net price method described earlier—by subtracting costs of extraction and transportation to the port from the export value of the timber.

The export value has been measured directly by the free on board (f.o.b.) export unit value, which is simply the ratio between gross export receipts and the volume of log exports. This figure is a conservative estimate of timber value because log exports were considerably underinvoiced throughout the period to avoid export taxes. This value is applied to timber extracted for domestic processing as well since it is the relevant measure of economic opportunity cost.

Published information on extraction and transportation costs were sparse. Average production cost estimates were available for 1973 and for 1980.[10] Deducting these total cost estimates from the respective weighted average f.o.b. price per m^3 of exported logs (the 'export unit value') yielded estimates of average stumpage values or rents per m^3 for those two years for logs actually harvested. In 1973, this method produced a rent figure of $16.15/$m^3$, based on an f.o.b. unit export value of $30.34 less a production cost estimate of $14.19 (for E. Kalimantan). These calculations are given in Table II.3. For both benchmark years, unit rents equal 53–55 percent of f.o.b. export unit values. Rents for the period 1970–78 and 1983–84 have been estimated by assuming that the same relation held for other years in those periods. Thus, unit rents are assumed to be 55 percent of f.o.b. value in each year. The 1979–82 f.o.b. values, production costs, and rents have been taken directly from a detailed study of rents and rent capture covering those years.[11]

Domestic processing of roundlogs into sawnwood and plywood for export dissipated *potential rent* from the roundlog harvest during 1979–83 because restrictions on log exports protected inefficiencies in Indonesia's wood-processing industries. The potential rent obtainable from roundwood at the time of harvesting, equivalent to that on log exports, is therefore a more valid economic measure of depletion costs for the timber resource than the rents actually earned.

The rental value of harvested timber and mature virgin forest stands from which future commercial extraction can be anticipated cannot be applied without modification to the remaining elements of the timber accounts—reforestation/afforestation, deforestation, and degradation—which refer only to secondary forests. The value of each cubic meter of timber initially harvested from an area of virgin forest may be anticipated to exceed that of the remaining timber and of subsequent harvests from the logged-over forest. This implies that lower rent values should be assigned to changes in timber resource levels that arise from growth, deforestation, or degradation in secondary forests.

However, subsequent harvests will typically not exhaust the stumpage value in secondary forests, in part because trees worth less than the royalties and taxes that would be due on them will never be harvested. For example, if such charges total $20 per cubic meter, rational concessionaires will never deliberately harvest trees with a lower stumpage value, even though those trees are not economically worthless.

For commercial species, one indicator of stumpage values in secondary forests can be derived from the rotation period between successive harvests, which is set to allow stands to regenerate. In the Indonesian selective cutting system, the prescribed period between harvests is thirty-five years. Immediately after logging, the present value method implies that the resource rent on the residual stand is the discounted present value of the income from the next harvest thirty-five years in the future. Since secondary forests contain stands last harvested varying numbers of years ago (from one to thirty-five), an average of such present values yields an estimate of the resource rents for commercial species in secondary forests. This estimate must then be adjusted for the distribution of trees between commercial and non-commercial species. Applying this reasoning to the Indonesian case in the absence of extensive data, results in an estimate of an average resource rent in secondary forests equal to approximately one-half that of the timber harvest. This estimate has been applied to the physical accounts for stocks, regeneration, deforestation, and degradation of secondary forests.

The value of changes in plantation timber levels (reforestation/afforestation and harvesting) has been estimated as zero because plantation investments in Indonesia have not been shown to yield more than a normal rate of return on investment. In fact, a normal rate of return may be a generous estimate of their profitability to date. Further, the proportion of the total harvest originating from plantations is small and has been provisionally estimated as zero. In summary, physical stocks have been valued as follows:

Virgin forests	Primary rent (PR)
Logged forests	Secondary rent (PR × 0.50)
Protection forests	Secondary rent (PR × 0.50)
Plantations	Zero

B. Indonesian Petroleum Resource Accounts, 1970–1984

Indonesia's geological situation at the intersection of several continental plates may account for the vast reserves of oil and natural gas in the region. In 1849, there were reports of oil seepages in West Java, but it wasn't until 1871 that exploratory wells were drilled and 1885 that commercial production began. Between 1880 and 1930, seven of the fourteen major basins were discovered, and by 1965 three more large fields were found, including the Minas field in Central Sumatra—the region's largest.

After 1966, technological developments and political stabilization encouraged exploitation of offshore oil resources. Rising production and world oil prices in the early 1970s led to boom conditions, which were dampened by the revelation in 1974 of serious financial mismanagement by the state oil company, PERTAMINA. After several years of reduced exploration while foreign oil company contracts were renegotiated and Indonesia's oil-related businesses were reorganized, development resumed in 1978 and accelerated during the second oil boom. After 1982, falling oil prices led to a downward trend in investment.

Most experts believe that all major fields have been discovered and further exploration will yield no great surprises. Future production prospects are apparently mediocre, given that proven reserves of 9.7 billion barrels in 1984 were enough for only another 18 years at the 1984 production rate of about 500 million barrels per year. Production is already declining in most major oilfields, and estimates of undiscovered reserves range from 10 to 40 billion barrels.[12] Significant natural gas production began only in the 1970s, however, after the Minas field was found, and production since then has grown sharply. Indonesia's vast gas resources are found in more remote regions of the archipelago and remain largely unmapped. Current proven reserves exceed 12.7 billion barrels of oil equivalent (BOE) and possible reserves are estimated at 45 billion barrels. The huge Arun gas field alone has estimated reserves of 2.7 billion BOE, and the recently discovered Natuna field may have twice that much.[13] (Resource accounts for natural gas are not included in this report, due to paucity of data on output, reserves, and production costs, but will be constructed for future analysis.)

Oil has accounted for more than 50 percent of export earnings and government revenues since 1967, and it has financed rapid growth in investment and consumption expenditures. In the 1980s, falling oil prices and growing domestic consumption sharply reduced export receipts. The Indonesian government has responded by devaluing the currency to promote other exports and by reducing domestic petroleum subsidies to restrain domestic consumption and improve government finances.

PERTAMINA remains responsible for oil and gas development, but with powers more limited than they were before 1975. Over 90 percent of exploration and production is contracted to foreign oil companies. Early contracts exchanged exploration and production concessions for royalty payments. In the early 1960s, new "contract of work" agreements were introduced, under which the government holds title to the oil and collects a share of profits rather than royalties. Most current production is under production-sharing contracts that require the contractor to pay a bonus when the agreement is signed, spend a specific amount on exploration within a stipulated period, supply 25 percent of output to PERTAMINA at cost plus $0.20 (formerly $0.30) per barrel, and pay an additional amount such that the net worth of the oil is split according to negotiated ratios between PERTAMINA and the oil company. PERTAMINA's share ranges from 65 to 88 percent.

1. The Physical Accounts

Petroleum resources are divided into identified and undiscovered reserves. Identified reserves are subdivided into *proven reserves,* those that can be recovered under current economic and technical conditions, and *probable reserves,* those estimated to exist on the basis of engineering and geological data that are obtained with current operating practices. Undiscovered reserves are surmised to exist on the basis of broad geologic theory and experience. By definition, since only proven reserves have a positive rental value (their net price exceeds their estimated recovery cost), only proven reserves enter the resource accounts.

Additions to reserves in the physical accounts consist of discoveries (reserves found in new reservoirs by exploratory drilling) and upward adjustments of reserve estimates in existing reservoirs because of new information or changed technological and economic conditions. *Subtractions* from reserves are attributable to extractions, downward adjustments to proven reserves, and other depletion losses, such as oil spills. *(See Table II.4.)*

Within this framework, data on flow items are more reliable than stock estimates because Indonesia's exploration and extraction is closely monitored by other members of OPEC and by the international oil community. Data on Indonesia's proven reserves is sketchy and of limited reliability, in part because such information is treated as sensitive by the government. Reported revisions to reserves seem also to be influenced by companies' strategic interests. In most years, they closely parallel reported production to keep total reserves stable. While significant discoveries were reported during the period, upward and downward revisions of reserve figures were negligible. This differs significantly from typical experience in other oil-producing regions, where, as discussed earlier, upward revisions add substantially to initially reported reserve figures. Moreover, in years of sharp oil price hikes, which ought to have made more oil economically recoverable, reported reserves did not increase. However, in 1974, in the wake of changes in U.S. tax law and Indonesian contracts favorable to exploration activities, reported reserves increased sharply.

For these reasons, the net changes in resources that correspond to resource depletion within the national income accounting framework are more useful than the valuation and revaluation of total resource stocks. Even data for the flow items are not without problems. Production data are probably understated, since Indonesia, as a member of the OPEC cartel, has been obliged to limit production below the amount it would wish to sell. Undeclared production is primarily in the form of condensate

Table II.4. Petroleum Accounts 1970–1984

PHYSICAL ACCOUNTS (million barrels)	**1970**	**1971**	**1972**	**1973**	**1974**
Opening Stock	9,000	9,957	11,774	12,054	12,389
Additions					
Discoveries	1,269	2,143	676	824	1,762
Upward Revisions	0	0	0	0	0
Depletions	312	326	396	489	502
Net Change	957	1,817	280	335	1,260
Closing Stock	9,957	11,774	12,054	12,389	13,649
UNIT VALUES (US$/barrel)					
FOB Export Price	1.70	2.21	2.96	3.73	10.80
Production Costs	0.50	0.79	0.78	0.80	1.74
Rent/barrel	1.20	1.42	2.18	2.93	9.06
MONETARY ACCOUNTS (million US$)					
Opening Stock	—	11,948.4	16,719.1	26,277.7	36,299.8
Additions					
Discoveries	1,522.8	3,043.1	1,473.7	2,414.3	15,963.7
Upward Revisions	0	0	0	0	0
Depletions	374.4	462.9	863.3	1,432.8	4,548.1
Net Change	1,148.4	2,580.2	610.4	981.5	11,415.6
Revaluation	—	2,190.5	8,948.2	9,040.6	75,944.6
Closing Stock	11,948.4	16,719.1	26,277.7	36,299.8	123,659.9

oil, which is extracted at the rate of about 100,000 barrels a day.

The physical accounts show the net resource flow, or change in the petroleum reserve, in millions of barrels per year. Depletions, essentially extraction, peaked in 1977 and 1978. Net resource flows were positive during the early 1970s, as reported discoveries exceeded depletion, but have been negative through the latter part of the period.

2. *The Value Accounts*

Petroleum resources are valued by the net price method, defined as the market price less all factor costs of extracting the resource and bringing to the point of sale. The alternative

Table II.4. (cont.) Indonesian Petroleum Accounts

PHYSICAL ACCOUNTS (million barrels)	1975	1976	1977	1978	1979
Opening Stock	13,649	13,342	13,261	12,742	12,246
Additions					
Discoveries	170	469	94	101	76
Upward Revisions	0	0	2	0	1
Depletions	477	550	615	597	581
Net Change	−307	−81	−519	−496	−504
Closing Stock	13,342	13,261	12,742	12,246	11,742
UNIT VALUES (US$/barrel)					
FOB Export Price	12.60	12.70	13.63	13.63	13.98
Production Costs	2.36	2.14	1.49	1.52	1.96
Rent/barrel	10.24	10.56	12.14	12.11	12.02
MONETARY ACCOUNTS (million US$)					
Opening Stock	123,659.9	136,622.1	140,036.2	154,687.9	148,299.1
Additions					
Discoveries	1,740.8	4,952.6	1,141.2	1,223.1	913.5
Upward Revisions	0	0	24.3	0	12.0
Depletions	4,884.5	5,808.0	7,466.1	7,229.7	6,983.6
Net Change	−3,143.7	−855.4	−6,300.6	−6,006.6	−6,058.1
Revaluation	16,105.8	4,269.5	20,952.3	−382.2	−1,102.1
Closing Stock	136,622.1	140,036.2	154,687.9	148,299.1	141,138.8

method—estimating the present value of future net income from the field—requires estimates of recoverable reserves, production costs, future output prices, and interest rates that are not available. As with timber, the market price is measured as the f.o.b. export price, which is also the opportunity cost of sales on the domestic market. The unit cost panel in the resource accounts gives the f.o.b. export price for 1970-84 in U.S.$ per barrel.

The factor costs of developing, extracting, and transporting a barrel of oil are estimated for the same time period by dividing the total annual expenditures for exploration and development of the contracting companies by their total annual production.[14] More detailed data on costs per barrel are calculated by the companies and submitted to PERTAMINA in accordance with contract provisions, but are sensitive and not publicly available. The cost

Table II.4. (cont.) Indonesian Petroleum Accounts

PHYSICAL ACCOUNTS (million barrels)	**1980**	**1981**	**1982**	**1983**	**1984**
Opening Stock	11,742	11,306	10,943	10,631	10,181
Additions					
Discoveries	141	223	172	71	67
Upward Revisions	0	0	0	0	0
Depletions	577	586	484	521	517
Net Change	–436	–363	–312	–450	–450
Closing Stock	11,306	10,943	10,631	10,181	9,731
UNIT VALUES (US$/barrel)					
FOB Export Price	28.11	35.83	35.74	34.75	31.94
Production Costs	3.80	5.50	8.59	9.15	7.64
Rent/barrel	24.31	30.33	27.15	25.60	24.30
MONETARY ACCOUNTS (million US$)					
Opening Stock	141,138.8	274,848.9	331,901.2	288,631.6	260,633.6
Additions					
Discoveries	3,427.7	6,763.6	4,669.8	1,817.6	1,628.1
Upward Revisions	0	0	0	0	0
Depletions	14,026.9	17,773.4	13,140.6	13,337.6	12,563.1
Net Change	–10,599.2	–11,009.8	–8,470.8	–11,520.0	–10,935.0
Revaluation	144,309.2	68,062.1	–34,798.7	–16,478.1	–13,235.3
Closing Stock	274,848.9	331,901.2	288,631.6	260,633.6	236,463.3

estimates used in this exercise are reasonable approximations, according to industry experts. PERTAMINA, which accounts for less than 10 percent of production, was excluded for lack of data, so the implicit assumption is that PERTAMINA's cost structure equals the average for the industry. Exploration costs are treated as current production costs in this exercise while taxes and royalties are not treated as production costs.

The difference between unit revenues and costs gives the resource rent per barrel of oil. It rises sharply over the period in response to increases in petroleum prices. Since 1985, average rents per barrel have declined even more sharply than world oil prices have. This rent is divided between the contractors and the government in accordance with the terms of the various production contracts in force. The reduction in government rental receipts from petroleum has forced a sharp curtailment in development expenditures.

The final monetary accounts presents the values of stocks and flows in current dollar figures. They are analogous to the value accounts given for forest resources: they value the net additions to and subtractions from the resource base in terms of the relevant economic rent. In the petroleum sector, the sharp swing from positive to negative value flows stems from the fact that extractions began to exceed apparent additions to reserves at the time when the unit value of the resource was rising sharply. From 1980 to 1984, the annual net resource depletion on petroleum account exceeded U.S. $10 billion, an amount that is significant relative to annual GDP growth and annual gross fixed capital formation. Treating this net depletion of a limited natural resource asset as current income rather than asset depreciation must seriously distort perception and analysis of Indonesia's economic performance.

C. Indonesia's Soil Account: Java

Soil erosion has both physical and economic effects. Removing part of the topsoil and depositing it elsewhere lowers the agricultural potential and economic value of the eroded land. The loss of potential future farm income is equivalent to the depreciation of an economic asset. Besides the on-site costs of soil erosion are off-site or downstream costs, such as siltation of reservoirs and irrigation systems, harbors, and other waterways.

1. Estimates of Soil Erosion in Physical Terms

Comprehensive data on soil erosion in Indonesia are not available, so estimates were based on erosion models. (The relevant determinants of soil erosion are the topography, climate, soil characteristics, and land uses of the specific areas affected.) Among the data available with which to estimate erosion rates are maps at the scale 1:1,000,000 of three variables that play a major role in determining erosion rates—soil types and slope, rainfall erosivity and land use.

The soil map used for this study (FAO, 1959) combines soil types with topography to create 25 soil classes:

—five classes of soils on level to undulating land, with dominant slopes under 8 percent (units 01–05);
—eleven classes of soils on rolling to hilly land, with dominant slopes from 8–30 percent (units 06–16); and
—nine classes of soils on hilly to mountainous land, with dominant slopes over 30 percent (units 17–25).

(Areas of soil types by province are included in Annex Table A.1.)

The kinetic energy released as raindrops strike the ground contributes to soil erosion. Bols (1978) has prepared a map of Java based on correlations of a measure of the kinetic energy of storms with annual rainfall data, which is available for most of Java over an extended period. Eleven rainfall erosivity classes are mapped at a scale of 1:1,000,000. (Area estimates for each erosivity class are shown in Annex Table A.2.) In 1985 the Ministry of Forestry produced a land use map of Java, which distinguishes five types of land use (or vegetation cover) that influence erosion rates:

—Areas of *sawah* (irrigated ricefields), including fishponds. These areas are characterized by low erosion rates; in fact, in large areas sedimentation prevails over erosion;

—Areas of *tegal* (dryland farming), mostly on sloping uplands where erosion rates are very high;

—Areas of natural and planted forest, including perennial plantation crops where erosion is slight;

—Degraded forest areas, including areas of shifting cultivation and degraded *pekarangan* (home gardens) where erosion is moderate to high; and

—Wetlands, where erosion is low. *(See Table II.5.)*

Aggregate land use data of questionable reliability are also available for Java from the Central Bureau of Statistics. *(See Table II.6.)* The mapped areas of *sawah* exceed the Central Bureau of Statistics figures for every province, totalling about one third more land for the whole of Java. The Forestry Ministry map is based in part on aerial photos that can measure *sawah* area accurately. Provincial discrepancies for *tegal,* on which erosion is more severe, range from 80 to 177 percent of CBS estimates, but for Java as a whole average only 11 percent.

Given these discrepancies, the estimates of per hectare erosion rates were based on the forestry map, which could be matched spatially with the other elements of the soil erosion model. However, because the Central Bureau of Statistics estimates for land uses other than *sawah* appear to be somewhat more reliable in the aggregate, this data is used in the final economic calculations.

The three maps described above were converted to digital form and analyzed using the Geobased System by the World Bank's Environmental Operations and Strategy Division.[15] Essentially, the procedure overlays the three maps to estimate land areas by 1,375 possible combinations of slope and soil type, erosivity, and land use. The analysis also divided Java along provincial boundaries to generate 5,500 possible combinations.[16]

The estimates of actual erosion rates corresponding to each of the possible combinations were based on actual measurements under given conditions of plant cover or cropping when possible, supplemented by judgments based on erosion elsewhere under comparable conditions. Several recent projects on Java have yielded valuable data on actual erosion of uplands. These include the successive UNDP/FAO Projects in the upper Solo watershed, the USAID Project in the Citanduy watershed, the Dutch-sponsored projects in the upper Brantas (Kali Konto), and the Upland Agricultural Projects of Jogyakarta and the Jratunseluna watersheds financed by USAID and the World Bank. Other erosion data have been collected by the Soils Department of the Agricultural University in Bogor, by the Soil Research Centre in Bogor, and by the Watershed Management Centre in Solo.

Table II.5. Land Use on Java ('000 ha)

Land Use	**West Java**	**Central Java**	**Jogyakarta**	**East Java**	**Java**
Sawah	1,350	1,380	121	1,752	4,603
Forest	542	731	4	1,222	2,499
Degraded Forest	299	34	—	53	386
Wetlands	—	29	—	103	132
Tegal	2,546	1,127	210	1,401	5,283
TOTAL	4,737	3,301	335	4,531	12,903

Source: Calculated from Ministry of Forestry (1985)

Table II.6. Comparison of Land Use Estimates ('000 ha)

	CBS	Ministry of Forestry	Model as Percent
Sawah Area Estimates			
West Java[a]	1,215	1,350	110
Central Java	1,023	1,380	135
Jogyakarta	64	121	191
East Java	1,199	1,752	146
JAVA	3,501	4,603	131
Tegal Area Estimates[b]			
West Java	1,440	2,546	177
Central Java	1,366	1,127	82
Jogyakarta	196	210	107
East Java	1,744	1,401	80
JAVA	4,747	5,283	111

a. Including D.K.I. Jakarta.
b. House compound and surroundings and bareland/border/shifting cultivation.

Estimates of annual soil loss by soil type and land use for Java's four provinces are presented in Annex Tables A.3–A.6. Table II.7 shows *tegal* suffers by far the greatest per hectare and total soil loss. On a per hectare basis, soil loss is highest on *tegal* land on West Java, followed by *tegal* on Central Java. The soils of East Java are least subject to erosion.

If it is assumed that geologic erosion, the rate of soil loss that occurs without human intervention, is similar to that which occurs under forest cover, incremental erosion due to human intervention can be estimated by the difference between per-hectare loss on forestland and on *tegal*. On average, each hectare that is deforested and brought into agricultural production causes the loss of an additional 133 metric tons annually. In the calculations that follow, no attempt is made to segregate the costs of man-made erosion.

2. *Estimates of the Economic Costs of Erosion*

Erosion reduces the availability and concentration of plant nutrients and alters soil structure in ways that affect water availability and root growth. Subsoil weathering may partially replace these soil elements over the long term.[17] Erosion's impacts on productivity depend on soil type and crop. Some soils contain most of their organic matter in the top few centimeters. In other soils, nutrients are dispersed over the whole soil profile. In addition, such demanding crops as tobacco suffer more drastically from nutrient loss than non-demanding crops—cassava, for example. This study distinguishes two groups of rainfed food crops:

—sensitive crops (maize, soybeans, groundnuts, green beans, and dryland rice)
—insensitive crops (cassava).

Table II.7. Predicted Soil Loss By Region and Land Use (metric tons per hectare and hundred thousand metric tons)

	West Java		Central Java		Jogyakarta	
	per ha	total	per ha	total	per ha	total
Tegal	168.1	4,279	145.8	1,643	108.1	227
Forest Land	10.3	56	5.3	39	5	0.2
Degraded Forest	100.3	300	38.2	13	0	0
Sawah	0.8	11	0.4	6	0.4	0.5
TOTAL	98.1	4,647	52.0	1,701	68.0	227

	East Java		JAVA	
	per ha	total	per ha	total
Tegal	87.2	1,221	139.5	7,370
Forest Land	4.4	54	6.0	150
Degraded Forest	50.9	27	88.3	341
Sawah	0.3	6	0.5	23
TOTAL	29.5	1,308	61.7	7,883

Few studies of erosion effects on yields are available for Indonesia. From scanty experimental data, yield-erosion relationships have been estimated for the study's 25 soil types and two crop groups, as shown in Tables II.8 and II.9. Soil losses of less than 15 tons/ha/yr are estimated to result in no yield loss.[18] Applying these estimates of productivity loss to the areas of the different soil types under *tegal* yields estimates of the extent and severity of physical yield loss. *(See Tables II.10 and II.11.)* This procedure predicts average yield losses of 6.8 percent per year for sensitive crops and losses of 4.3 percent per year for insensitive crops. Among provinces, Jogyakarta is the most severely affected, followed in descending order by West, East, and Central Java.

These predicted yield declines can only cautiously be compared with actual yield trends for dryland crops, which have consistently risen, despite erosion, because of continued intensification of farming practices. From 1972 through 1983, upland rice, maize, and cassava yields on Java increased on average by 4.3, 4.7, and 2.8 percent per year, respectively. (Roche 1987) However, fertilizer use on maize increased from 38 kg/ha to nearly 106 kg/ha and on cassava from 8 kg/ha to more than 16 kg/ha. (Central Bureau of Statistics) Labor costs have also been rising on upland crops. (Roche 1987) The release and rapid adoption of high-yielding maize varieties may also have masked declines in the productivity of the resource base.[19]

Table II.8. Productivity Loss Estimates as a Result of Soil Erosion for Major Soils of Java

I. For Maize, Soybeans, Groundnuts

Soil Loss (tons/ha/year)	**Soil Types** 1, 17	2, 3, 4, 6, 9, 16	5, 8, 10, 11, 12, 15, 18, 20, 21, 25	7, 13, 14, 19, 22, 23, 24
0–15	0.00	0.00	0.00	0.00
15–60	0.02	0.03	0.05	0.07
60–250	0.03	0.05	0.08	0.10
250–600	0.04	0.07	0.10	0.12
Over 600	0.05	0.09	0.12	0.15

As the results of erosion, farm output and income have fallen in some regions without major changes in farm practices; some farmers have been induced to change cropping patterns and input use; and, in extreme cases, land has been withdrawn from cultivation. McIntosh and Effendi (1983) cite the example of the upper Citanduy Watershed, where farmers grow corn, upland rice, and cassava on better soils. As erosion becomes more severe, rice is replaced by peanuts, and on nearly depleted soils only cassava is grown.

Whatever the response, farm revenues decline as crop output falls, but costs may not. Erosion may lead some farmers to work harder and purchase more fertilizer to make up for productivity losses, while costs for harvest labor, crop transport, and other inputs might decrease. Available farm budget data suggest that costs that would fall along with output account for a small share of farm production costs, so erosion lowers net farm income and eventually leads to the adoption of less profitable crops.

To account for adjustments in cropping systems, a variety of farm level data for Java's provinces were used to develop sets of representative farm budgets.[20] The budgets published by Roche were updated to 1985 prices, adjusted to reflect yield changes by

Table II.9. Productivity Loss Estimates as a Result of Soil Erosion for Major Soils of Java

II. For Cassava

Soil Loss (tons/ha/year)	**Soil Types** 1, 17	2, 3, 4, 6, 9, 16	5, 8, 10, 11, 12, 15, 18, 20, 21, 25	7, 13, 14, 19, 22, 23, 24
0–15	0.00	0.00	0.00	0.00
15–60	0.01	0.02	0.03	0.05
60–250	0.02	0.03	0.05	0.06
250–600	0.03	0.05	0.07	0.08
Over 600	0.04	0.07	0.10	0.12

Table II.10. Area and Severity of Estimated Erosion-Induced Productivity Losses on Tegal on Java

	Annual Productivity Loss as a Percent of Current Total Productivity[a]				
	0%	2%	3%	5%	7%
			Area ('000 ha)		
West Java	512	3	27	417	22
Central Java	190	1	120	216	3
Jogyakarta	19	0	26	0	0
East Java	194	45	91	128	67
JAVA	914	49	264	762	92

	Annual Productivity Loss as a Percent of Current Total Productivity				
	8%	10%	12%	Total Area	Average Productivity Loss (%)
			Area ('000 ha)		
West Java	429	802	351	2,563	7.0
Central Java	168	366	61	1,126	6.4
Jogyakarta	47	118	0	209	7.8
East Java	481	408	0	1,413	6.6
JAVA	1,125	1,693	412	5,312	6.8

a. Productivity loss based on maize.

Note: All values do not sum exactly due to rounding.

using the Central Bureau of Statistics and Malang data, and then used to estimate the effects of yield losses on net farm incomes. Insofar as can be determined, the farm budgets are consistent with land values and rental rates for *tegal.*

Table II.12 summarizes the cropping systems for each region and provides an estimate of their relative occurrence. These farming systems appeared to be marked by a large proportion of fixed costs. Costs categories in the Central Bureau of Statistics that seem most likely to vary with output are harvesting labor and transportation. These variable costs were assumed to decline in proportion to cassava yield declines, while yields of maize and other more sensitive intercropped cultivars declined further. Consequently, farm income declines linearly as erosion increases, at rates that vary by cropping system and by region.

The estimated loss in farm income from a 1-percent decline in yield depends on both the basic profitability of the cropping system and the importance of fixed production costs. On the assumption that the farming systems are distributed independently of rates of productivity decline, in Table II.12 the costs of a 1-percent decline in productivity for each cropping system and the predicted weighted average yield declines are applied to the *tegal* areas allocated to each cropping system. These costs are for only a single year. But, the appropriate economic measure of soil depletion is the present value of losses in farm income in current and future years.

Table II.11. Area and Severity of Estimated Erosion-Induced Productivity Losses on Tegal on Java

	Annual Productivity Loss as a Percent of Current Total Productivity[a] 0%	1%	2%	3%	5%
			Area ('000 ha)		
West Java	512	3	27	417	451
Central Java	190	1	120	216	171
Jogyakarta	19	0	26	0	47
East Java	194	45	91	128	548
JAVA	914	49	264	762	1,217

	Annual Productivity Loss as a Percent of Current Total Productivity 6%	7%	8%	Total Area	Average Productivity Loss (%)
			Area ('000 ha)		
West Java	659	144	351	2,563	4.4
Central Java	201	165	61	1,126	4.1
Jogyakarta	118	0	0	209	4.7
East Java	394	14	0	1,413	4.1
JAVA	1,371	322	412	5,312	4.3

a. Productivity loss based on cassava.

Note: All values do not sum exactly due to rounding.

If soil loss is recurrent and exceeds soil formation, productivity losses occur with each successive net loss of soil depth. The correct measure of the cost of the initial episode of erosion is the capitalized value of the infinite stream of productivity losses associated with that episode. Loss of productivity associated with future erosion should be charged against income when it occurs.

On Java, erosion is clearly a recurrent phenomenon, and productivity losses are permanent. As productivity falls, land eventually goes out of production, and its production value falls to zero. Current and future technical change that raises farm productivity has no effect on these losses unless technical change is faster on good soils or, on the contrary, is driven to compensate for erosion losses. If the former holds true, as is likely, the cost of erosion is larger than estimated above.

The one-year costs of erosion have been capitalized to obtain a total present value of future losses of Rp 539 billion (U.S. $484 million). To put this figure into perspective, Table II.13 shows the approximate value of output of six major rainfed crops at 1983/84 prices. The *one-year* costs of erosion are about 4 percent of the annual value of dryland farm output, and they are of the same order of magnitude as annual recorded *growth* in agricultural production in the uplands. Thus, despite apparently healthy growth, upland farming on Java has

Table II.12. Costs Due to Soil Erosion for Various Cropping Systems on Java

Cropping System	Crops	Estimated Proportion of Tegal (%)	Area[a] ('000 ha)	Estimated Current Net Income (Rp/ha)[b]	Weighted Production Loss (%)[c]	Annual Cost of a One Percent Productivity Decline (Rp/ha)	Single Year Cost (million Rp)	Capitalized Cost (million Rp)
West Java								
I	Cassava, Corn Upland Rice & Legumes	58	835	139,496	4.4	4,309	15,831	158,310
II	Cassava, Corn & Upland Rice	27	389	49,531	4.4	3,616	6,186	61,860
III	Pure Stand Cassava	15	216	1,279	4.4	1,563	1,485	14,850
Total Tegal		100	1,440	95,039	4.4	3,718	23,508	235,080
Central Java								
I	Intercropped Corn & Cassava	57	779	6,698	4.1	800	2,555	25,550
II	Intercropped Corn, Cassava & Legumes	43	587	10,183	4.1	937	2,255	22,550
Total Tegal		100	1,366	8,196	4.1	859	4,810	48,100

a. Based on Central Bureau of Statistics. *See* Table II.6.
b. Net income equal to returns to land and management.
c. Based conservatively on rates for land cultivated in Cassava. Annual productivity loss for sensitive crops ranges from 6.8 to 7.8 percent.

Source: Adapted from Roche 1984, Central Bureau of Statistics, and data provided by the Agroeconomic Survey, Bogor. *See* Magrath, Arens, 1987.

Table II.12 (cont.)

Cropping System	Crops	Estimated Proportion of Tegal (%)	Area[a] ('000 ha)	Estimated Current Net Income (Rp/ha)[b]	Weighted Production Loss (%)[c]	Annual Cost of a One Percent Productivity Decline (Rp/ha)	Single Year Cost (million Rp)	Capitalized Cost (million Rp)
Jogyakarta								
I	Intercropped Corn & Cassava	57	112	8,220	4.7	1,011	532	5,320
II	Intercropped Corn, Cassava & Legumes	43	84	11,279	4.7	1,047	416	4,160
Total Tegal		100	196	9,531	4.7	1,026	948	9,480
East Java								
I	Intercropped Corn & Cassava Level Tegal	30	523	298,327	4.1	4,926	10,567	105,670
II	Intercropped Corn & Cassava Terraced Hillsides	30	523	58,130	4.1	2,876	6,169	61,690
III	Pure Stand Cassava Level Tegal	20	349	145,005	4.1	3,746	5,357	53,570
IV	Pure Stand Cassava Terraced Hillsides	20	349	27,806	4.1	1,816	2,597	25,970
Total Tegal		100	1,744	141,499	4.1	3,453	24,690	246,900
TOTAL TEGAL			4,747	83,649	4.3	2,686	53,956	539,560

Table II.13. Comparison of the Value of Output of Six Major Rainfed Crops to the Cost of Erosion (million rupiah)

	West Java	Central Java	Jogyakarta	East Java	JAVA
Dry Rice	46,533	18,194	12,682	26,358	103,767
Maize	21,809	123,596	15,061	262,981	423,447
Cassava	81,041	109,148	22,410	134,962	347,561
Sweet Potatoes	22,191	12,131	542	15,331	50,195
Peanuts	44,916	56,475	18,340	74,615	194,346
Soybeans	17,807	45,398	37,664	124,171	225,040
Total	234,297	364,942	106,699	638,418	1,344,356
Cost of Single Year Erosion Loss	23,508	4,810	948	24,690	53,956
Capitalized Value of Erosion Losses	235,080	48,100	9,480	246,900	539,560
Single-year Erosion Cost as a Fraction of Value of Agricultural Output	0.10	0.01	0.01	0.04	0.04

been on a treadmill: each current increment in production is offset by an equal but unrecorded loss in soil productivity.

The capitalized losses in future productivity are approximately 40 percent of the annual value of upland farm production. If erosion losses are regarded as the cost of obtaining the current year's livelihood from vulnerable upland soils, then these estimates show the bargain to be harsh. Nearly 40 cents in future income is sacrificed to obtain each dollar for current consumption. Whether such a bargain can be sustained is open to question, but ignoring the heavy costs of current farming practices unquestionably overstates dryland agricultural income.

The methodology and data used in estimating erosion costs produced results for a single year, 1985. Benchmark data for other years were not available. To extrapolate the results crudely to other years in the period under review, a double indexation procedure was used. First, physical erosion rates were indexed to the area under *tegal*. Since such other factors as topography, soil type, and climate remained constant throughout the period or varied randomly, physical erosion rates varied systematically only with changes in land use, of which conversion to annual cropping is the most important. (In fact, the area in upland crops changed little.) Then, the costs of given rates of erosion were indexed to dryland crop prices on the assumptions that 1) cropping patterns and practices changed little, and 2) net farm income remained a constant proportion of farm revenues. While these assumptions cannot be readily verified with existing data, indexation does at least correct for the general inflationary rise in farm prices during the period. *(See Table II.14.)*

Erosion simply moves soil particles from one place to another. The deposition of sediment on *sawahs* renews their fertility. More commonly, however, the off-site effects of soil erosion are negative. Silt clogs irrigation channels and ports, and it lowers the capacity of water-storage reservoirs.

Only a crude attempt was made to estimate the magnitudes of such costs as the increased expenditures needed to dredge waterways and clean irrigation channels.[21] These additional annual costs due to upstream erosion appear to be in the range of U.S. $15–50 million, an order of magnitude less than on-site productivity losses. Moreover, such costs already enter the national income and product accounts as additional government expenditures. This illustrates another anomaly of the current

Table II.14. Estimates of Erosion Losses 1971–1985

Year	Total Tegal in Java[a]	Per ha. Cost of a 1% Loss in Productivity[b]	Average Productivity Loss on Cultivated Area (%)	Single-year Cost of Erosion (mill. Rp.)	Capitalized Cost of Erosion (mill. Rp.)
1971	4,377	312.42	4.3%	5,880	58,800
1972	3,988	354.90	4.3	6,086	60,860
1973	4,777	471.77	4.3	9,691	96,910
1974	4,484	692.40	4.3	13,350	133,500
1975	4,232	781.63	4.3	14,224	142,240
1976	3,642	894.66	4.3	14,011	140,110
1977	3,982	1,019.92	4.3	17,464	174,640
1978	4,522	1,100.44	4.3	21,398	213,980
1979	4,111	1,288.32	4.3	22,774	227,740
1980	4,123	1,485.14	4.3	26,330	263,330
1981	4,356	1,610.40	4.3	30,164	301,640
1982	3,319	1,843.01	4.3	26,303	263,030
1983	4,081	2,308.24	4.3	40,506	405,060
1984	4,416	2,540.85	4.3	48,248	482,480
1985	4,747	2,686.00	4.3	53,956[c]	539,560

a. In thousands of hectares. Based on estimates of dryland crops in Java from Central Bureau of Statistics, Jakarta 1972–1984.
b. Current rupiah per hectare. The 1985 value is based on detailed budget analysis. Values for 1971–1984 are derived using indices of crop prices faced by farmers and the assumption that the ratio between revenue and the cost of a 1% productivity loss remained constant.
c. Value does not sum exactly due to averaging.

income-accounting system since these erosion costs enter with a positive sign—as *additions* to national income. Although the expenditures are made to prevent even greater damages from siltation, they are entered as additions to income and the production of goods and services because the expenditures are incurred by households and the government and are therefore defined as final expenditures. Were such "defensive" expenditures subtracted from the value of final output, Indonesian national income would be roughly $30–$100 million lower in each year.

D. Concluding Remarks

Three general points will suffice here:

First, these estimates were prepared with a modest expenditure of time and money, drawing entirely on data source and information already available, mostly in published sources. Estimation required some interpolation between benchmark years and extrapolation from samples of limited coverage, but such techniques are already common in national income accounting.

Second, the results require a significant reassessment of Indonesia's economic performance during the period, and they bring to light aspects of the sustainability of Indonesia's economic growth strategy that would not be readily apparent from the conventional national income accounting framework.

Third, efforts to improve the accuracy and coverage of such resource accounts are entirely complementary to efforts to improve the information base for better resource management. For example, the Government of Indonesia, with external assistance, is embarking on a new inventory of timber resources that will increase the accuracy of forest resource accounts and also provide better guidance in allocating timber concessions, delineating protected forest areas, siting transmigration projects, and other resource management decisions. The same kinds of data needed for resource accounting are essential for effective resource management.

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Annex

ANNEX A.1. Soils on Java Based on Slope and Soil Characteristics ('000 ha)

Soil Type	West Java	Central Java	Jogyakarta	East Java	JAVA
1	8	49		2	57
2	712	562	41	971	2,323
3	61	20	5	14	77
4	36	259	3	210	540
5		27			29
6			22	54	77
7	171	349	18	211	753
8	45			13	24
9	11	164		149	400
10	646	400		190	1242
11	67				91
12	223	10		4	237
13	174				174
14	308	36	82	111	738
15		200	3	153	359
16				26	21
17	116	175	60	259	609
18		7		451	481
19				12	13
20	537	384		309	1,210
21	149	198		227	571
22	582				582
23	722	131			850
24	6	202	34	196	425
25	160	128	66	608	979
TOTAL	4,737	3,301	335	4,170	12,868

Source: Calculated from FAO (1959).

ANNEX A.2. Areas of Java Subject to Alternative Levels of Erosivity ('000 ha)

Erosivity Level	West Java	Central Java	Jogyakarta	East Java	JAVA
1				115	104
2	314	151	10	1,178	1,632
3	644	377	170	2,178	3,360
4	757	902	89	436	2,217
5	771	696	48	367	1,882
6	872	459	17	196	1,546
7	670	302		96	995
8	575	249		47	867
9	21	111		3	135
10		43			36
11		13			13
TOTAL	4,625	3,304	334	4,612	12,788

Source: Calculated from Bols (1978).

ANNEX A.3. Predicted Soil Losses From Tegal By Region and Soil Type ('000 metric tons)

Soil Type	West Java	Central Java	Jogyakarta	East Java	JAVA
1	0	20	10	0	20
2	632	398	38	531	1,599
3	49	40	18	19	126
4	114	194	9	153	469
5	0	0	0	0	0
6	0	0	352	891	1,242
7	9,482	11,776	178	5,278	26,715
8	88	0	0	0	88
9	445	424	0	953	1,821
10	11,222	6,672	0	412	18,306
11	1,251	0	0	0	1,251
12	4,156	91	0	8	4,255
13	948	0	0	0	975
14	40,122	3,484	7,259	19,911	70,775
15	0	9,724	0	4,985	14,710
16	0	0	0	294	294
17	2,123	7,594	856	3,894	14,467
18	0	309	0	11,006	11,315
19	0	0	0	592	592
20	47,146	52,024	0	20,790	119,960
21	21,227	30,495	0	4,694	56,416
22	93,831	0	0	0	93,831
23	159,716	6,317	0	0	166,033
24	6,372	21,618	5,052	14,967	48,008
25	28,939	13,095	8,906	32,754	83,695
TOTAL	427,863	164,274	22,668	122,132	736,963

ANNEX A.4. Predicted Soil Loss from Sawah by Region and Soil Type ('000 metric tons)

Soil Type	West Java	Central Java	Jogyakarta	East Java	JAVA
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	2	0	2
7	29	30	4	7	70
8	3	0	0	0	3
9	1	9	0	5	15
10	71	43	0	3	118
11	11	0	0	0	11
12	5	0	0	0	5
13	111	0	0	0	111
14	0	1	0	30	31
15	0	108	2	37	147
16	0	0	0	0	0
17	128	99	41	91	358
18	0	6	0	132	138
19	0	0	0	0	0
20	244	196	0	95	535
21	63	5	0	8	76
22	164	0	0	0	164
23	112	5	0	0	117
24	0	57	0	91	148
25	148	21	3	83	255
TOTAL	1,091	580	51	582	2,304

ANNEX A.5. Predicted Soil Losses from Forest Land on Java by Region and Soil Type ('000 metric tons)

Soil Type	West Java	Central Java	Jogyakarta	East Java	JAVA
1	0	0	0	0	0
2	2	3	0	0	5
3	0	0	0	0	0
4	0	1	0	0	1
5	0	0	0	0	0
6	0	0	0	2	2
7	0	81	0	18	99
8	0	0	0	2	2
9	0	6	0	2	8
10	86	78	0	7	171
11	0	0	0	0	0
12	0	2	0	0	2
13	0	0	0	0	0
14	0	0	1	176	177
15	0	40	0	194	234
16	0	0	0	0	0
17	0	47	0	178	225
18	0	7	0	174	181
19	0	0	0	17	17
20	0	431	0	779	1,210
21	0	857	0	1,404	2,261
22	2,705	0	0	0	2,705
23	2,851	257	0	0	3,108
24	0	1,860	0	2	1,862
25	0	261	27	2,419	2,708
TOTAL	5,644	3,931	28	5,376	14,979

ANNEX A.6. Predicted Soil Losses from Degraded Forest on Java by Region and Soil Type ('000 metric tons)

Soil Type	West Java	Central Java	Jogyakarta	East Java	JAVA
1	0	2	0	1	3
2	0	0	0	1	1
3	0	0	0	0	0
4	0	0	0	0	1
5	0	1	0	0	0
6	0	0	0	0	0
7	0	588	0	0	588
8	0	0	0	0	0
9	0	0	0	14	14
10	626	0	0	0	766
11	0	140	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	895	895
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	62	62
19	0	0	0	0	0
20	0	539	0	1,000	1,539
21	0	52	0	277	339
22	15,899	0	0	0	15,899
23	13,033	0	0	0	13,033
24	0	0	0	90	90
25	482	0	0	347	829
TOTAL	30,041	1,333	0	2,688	34,062

Notes

1. A. Soemitro, *Foreign Investment in the Forest Based Sector of Indonesia: Increasing Its Contribution to Indonesian Development* (Jakarta: Gadjah Mada University, 1975).

2. Malcolm Gillis, ''MNCs, Environment, and Resource Management in Indonesia's Tropical Forests,'' Charles Pearson, (ed.), *Multinational Corporations, Environment and the Third World: Business Matters,* Duke University Press, Durham, N.C. 1987.

3. FAO, *Tropical Forest Resources Assessment Project: Forest Resources of Tropical Asia,* prepared in conjunction with the United Nations Environment Programme, Rome, 1981.

4. Adrian Sommer, ''Assessment of World Tropical Resources,'' *Unasylva,* no. 28, 1976.

5. FAO, *op. cit.*

6. FAO, *Forest Resources in Asia and the Far East Region,* Rome, 1976.

7. FAO, 1981, *op. cit.*

8. *Ibid.*

9. *Ibid.*

10. I. Ruzicka, ''Rent Appropriation in Indonesian Logging: East Kalimantan 1972/3-1976/7,'' *Bulletin of Indonesian Economic Studies,* vol. XV, no. 2, July 1979, p. 54; V. Beunaflor, ''Forestry and Forest Product Development in Indonesia: Logging and Transportation,'' Working Paper no. 10, UNDP/FAO, Bogor, Indonesia, March, 1981.

11. Malcolm Gillis, ''Indonesia: Public Policies, Resource Management, and the Tropical Forest,'' in Robert Repetto and Malcolm Gillis, (eds.), *Public Policies and the Misuse of Forest Resources,* Cambridge University Press, 1988.

12. World Bank, Joint UNDP/World Bank Energy Assessment Program, *Indonesia: Issues and Options in the Energy Sector,* Washington, D.C., 1981.

13. U.S. Dept. of State, *Indonesia's Petroleum Sector, 1984,* Jakarta, U.S. Embassy, July 1984.

14. *Ibid.*

15. Rounding errors in the Geobased System program result in minor discrepancies in area estimates. Consequently, columns and rows may not add exactly. The errors introduced in this way are insignificant.

16. West Java, Central Java, D.I. Jogyakarta, and East Java, D.K.I. Jakarta was included in West Java.

17. For discussion of the impact of erosion on various dimensions of productivity see Pierce and others (1983).

18. It also takes, at least partially, into account the omission of plant cover and conservation practices in the erosion model.

19. For authoritative treatments of maize and cassava production systems in Indonesia, see, respectively, Mink, Dorosh and Perry (1987) and Roche (1984).

20. Crop budgets for many rainfed crops and years are compiled by the Central Bureau of Statistics (CBS) from large sample surveys. They omit family labor, which typically exceeds hired labor use on Java, but probably best depict the aggregate structure of production cost. Because they are available for current years, they were used to identify variable and fixed costs. Data from the Survey Agro Ekonomi (Agro-economic Survey) was also compared with the budgets prepared by Roche (1983, 1984). Roche's budgets, based on detail surveys of small samples of farmers throughout Java, include information on family and hired labor, purchased inputs and yields. Data from the Malang Institute for Food Crops (MARIF) (Brotonegoro, Laumans and Stavern 1986) were used to adjust Roche's budget to make it more representative of East Java as a whole. The MARIF data shows that Kediri Kabupaten has yields between 40 and 175 percent higher, depending on crop, than the average for East Java. In addition fertilizer use in Kediri is almost double that of the rest of East Java.

21. More detail is available in W.B. Magrath and P.L. Arens, "The Costs of Soil Erosion on Java: A Natural Resource Accounting Approach," unpublished paper, World Resources Institute, November 1987. (Forthcoming as World Bank Environment Department Working Paper).

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