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Rashid M. Hassan
Eric D. Mungatana *Editors*

Implementing Environmental Accounts

Case Studies from Eastern and Southern Africa

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ECO-EFFICIENCY IN INDUSTRY AND SCIENCE

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Springer

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Preface

Over the past three decades, attention to the importance of monitoring status of the world's renewable and exhaustible natural assets has rapidly moved from theoretical and scientific knowledge to development and implementation of operational tools to account for change in their capacity to sustain life on earth and human well-being. Global efforts to operationalize the concept of "sustainable development" introduced by the Brundtland Commission Report, *Our Common Future,* have culminated in the publication of the UN's manual: System of Economic and Environmental Accounts (SEEA) in 1993. The search for more appropriate sustainability indicators continued, and the SEEA was followed by several other supplements. As a result, many regional and national initiatives have attempted to use natural resource and environmental accounting to correct for shortcomings of the widely adopted systems of national accounts.

The experiences of a number of countries in sub-Saharan Africa with implementing the SEEA and its specialized supplements have been documented in two earlier volumes produced by the Centre for Environmental Economics and Policy in Africa (CEEPA) of the University of Pretoria. The first two books, *Environmental Accounting in Action: Case Studies from Southern Africa (2004)* and *The Economics of Water Management in Southern Africa: An Environmental Accounting Approach (2006)*, documented results of research and country level implementation efforts in Botswana, Namibia and South Africa. This volume is the third in CEEPA's environmental accounting book series extending the Southern Africa efforts to other countries mainly in the Eastern Africa region. The current book also covered new resource sectors and extended the work to account for ecosystem assets and their services.

This book opens with a chapter on the application of inclusive wealth accounting to evaluate how Namibia has managed its natural capital in pursuit of economic growth over the past few decades and whether it has increased or decreased its total wealth. The environmental accounting work in Namibia was also extended to account for the value of the countries' wildlife resources as documented in "Wildlife Accounts: A Multi-sectoral Analysis in Namibia".

Attempts in accounting for the value of and contributions of subsoil assets in Tanzania, forest resources in Uganda and Ethiopia and the fishery of Mozambique to economic welfare are then reported in "Accounting for Mineral Resources in Tanzania: Data Challenges and Implications for Resource Management Policy", "Fisheries Resource Accounts for the Maputo Coastal Districts of Mozambique", "Forest Resource Accounts for Ethiopia", and "Contribution of Uganda's Forestry Sub-Sector to the National Economy: Natural Resource Accounting Approach". A general framework for ecosystems accounting with examples of valuing non-provisioning ecosystems services and changes in the underlying capital stocks and their importance for human well-being are presented in "Accounting for the Value of Ecosystem Assets and Their Services". "Valuing Regulating and Supporting Ecosystem Services of the Subtropical Estuaries of KwaZulu-Natal in South Africa" then applies ecosystem accounting to value the regulating and supporting services of estuarine ecosystems in South Africa.

Many individuals and agencies in the study countries and regions contributed to these efforts as acknowledged in respective chapters. We are especially grateful for the financial support provided by the Swedish International Development Agency (SIDA) and the International Development Research Centre (IDRC) of Canada. Valuable review comments from a large number of colleagues from various parts of the world contributed significantly to the scientific quality and presentation of the material documented in the chapters. Copyediting and word-processing assistance was competently provided by Dalène du Plessis and Yvonne Samuels.

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Abbreviations

CBNRM	Community-based natural resource management
CDM	Clean Development Mechanism
CEEPA	Centre for Environmental Economics and Policy in Africa
CITES	Convention on International Trade in Endangered Species
eaNDP	Environmentally adjusted net domestic product
EDRI	Ethiopian Development Research Institute
GHGs	Green house gases
GNP	Gross National Product
GoT	Government of Tanzania
IDRC	International Development Research Centre of Canada
INE	National Institute of Statistics in Mozambique
IUCN	International Union for Conservation of Nature
KZN	KwaZulu Natal
MAI	Mean annual increment
NAPHA	Namibian Professional Hunters Association
NEMA	National Environmental Management Authority
NNI	Net national income
NP	Net price
NPK	Nitrogen, Phosphorous and Potassium
NPV	Net present value
NRA	Natural resource accounting
NTR	Non tax revenue
NWFPs	Non wood forest products
SEEA	System of Economic and Environmental Accounts
SEEAF	System of environmental and economic accounting for fisheries
SIDA	Swedish International Development Agency
SNA	System of national accounts
SURE	Seemingly unrelated regression estimation
TAC	Total allowable catch
TCM	Travel cost method
TEV	Total economic value

UNCTAD	United Nations Conference on Trade and Development
UNSD	United Nations Statistics Division
UWA	Uganda Wildlife Authority
VAD	Value added
VBGF	von Bertalanffy growth function
WBISPP	Wood biodiversity strategic planning project
WCS	Wildlife Conservation Society

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Natural Capital, Total Wealth and Sustainable Development in Namibia

Glenn-Marie Lange

Abstract A country's income and economic well-being depend on its wealth, where wealth is defined in the broadest sense to include produced, natural, human and social capital. Recognising this, international agencies have begun to shift their emphasis from economic development as Gross National Product (GNP) growth to economic development as a process of 'portfolio management' that seeks to optimise the management of each asset and the distribution of wealth among different kinds of assets. In resource-rich economies such as Namibia, building national wealth requires that natural capital be transformed into other forms of capital. However, there has been growing concern that economic growth, especially in resource-rich developing countries, has been achieved by liquidation of natural capital without adequate provision for replacement of these assets for future generations. Several studies have attempted to measure total national wealth or changes in wealth but have been seriously hampered by a lack of data, especially for natural and human capital. Using newly available accounts for natural capital in Namibia, total national wealth accounts are constructed and used to assess its development paths, comparing it to its neighbour, Botswana, for which total wealth are also available, albeit not for as long a time series. In Namibia's pre-independence period (before 1990), there was significant liquidation of capital, natural and produced. With new policies and a new investment environment since independence, Namibia has slowly started to rebuild its national wealth although per capita wealth has not recovered to the level of 1980.

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1 Introduction

Theoretical work has demonstrated that sustainable development requires non-declining per capita wealth, where wealth is defined in the broadest sense to include produced, natural and human (including social) capital (e.g. Arrow et al. 2004; Dasgupta and Maler 2000; Dasgupta 2001; Heal and Kristrom 2005; Kunte et al. 1998 Pad 2004). This implies a shift in focus from economic development as GNP growth to economic development as a process of 'portfolio management' that seeks to optimise the management of each asset and the distribution of wealth among different kinds of assets (Alfsen and Greaker 2006; Hamilton 2002; Dasgupta 2002; Mäler et al. 2007; Norwegian Ministry of Finance 2005; World Bank 2002, 2005). The particular challenge for resource-rich economies is to transform natural capital into other forms of productive wealth, a process that requires policies to promote efficient resource extraction that maximises resource rent and reinvestment of that rent.

Many resource-rich developing countries have not been successful in this transformation of natural capital. Indeed, as a group, their economic performance has lagged behind that of other developing countries, a phenomenon known as the 'resource curse' (Auty 1993; Auty and Mikesell 1998; Brunnschweiler and Bulte 1996, 2002, 2008; Sachs and Warner 1995. Clearly, the ability to monitor total per capita wealth and analyse changes in this indicator is central to economic development. The challenge of this wealth-based approach to sustainable development is the lack of data, particularly for natural and human capital. There have been several attempts to measure total national wealth or changes in national wealth for a large number of countries, notably, Dasgupta (2001, 2002), Hamilton and Clemmens (1999) and the World Bank (2005). However, these estimations are applied over a large number of countries with often crude data and assumptions that may not accurately reflect economic values for natural capital in a given country. Most provide estimates only for a single year, giving no indication of the trend over time.

A few resource-rich developed countries have begun to implement natural capital accounts as part of their official statistics, mainly in their balance sheets,[1] following the System of Environmental and Economic Accounting (SEEA) developed by the UN and other international agencies (United Nations et al. 2003). These include Australia, Canada and Norway; several other countries have implemented natural capital accounts for selected natural capital, mainly oil and natural gas, such as the UK and the Netherlands. In the developing countries, total wealth accounts were constructed for Botswana and Namibia (Lange 2003a, b, c, 2004; Lange and Wright 2004) for the

[1] Norway also includes related indicators for (1) GDP by income including resource rent from (a) renewable and (b) nonrenewable resources and (2) depletion adjusted NDP and in the national income accounts.

years 1980–2000 based on their most important, commercial natural resources: minerals and (in Namibia only) commercial fisheries.

This chapter presents the updated and expanded accounts for Namibia, with an emphasis on performance since independence in 1990. Namibia's economy is highly dependent on its natural resources, minerals, fisheries and agricultural land, which together account for roughly 30% of GDP, 85% of exports and about 10% of government revenues (Central Bureau of Statistics 2008). Prior to independence, Namibia's economy was based largely on rapid depletion of its natural capital, and this can be seen in the decline of all forms of capital and per capita GDP from 1980 to 1990 (Lange 2004). Natural resources were exploited without any regard for building the national economy; fishing was carried out in an open-access environment, and minerals were exploited with little reinvestment of rents in the domestic economy. But since independence, natural resource management has changed, and there have been signs of turning around. In recent years, Namibia has benefited from the global commodities boom, especially the growth of nuclear power; Namibia is a major source of the world's supply of uranium. This chapter now looks at a longer time series to assess the post-independence trend towards sustainability of economic growth in Namibia.[2]

The organisation of this chapter is as follows: The next section discusses the general methodology and data used for the estimation of total wealth. Section 3 presents the accounts for natural capital. Section 4 presents the wealth accounts and analyses Namibia's economic sustainability over the post-independence period and the success of the government in turning around the previous trend of unsustainable development based on depletion of natural capital. These are compared to the performance of the Botswana economy over the same time period. Concluding remarks are provided in the final section.

2 Methodology and Data Sources

2.1 Wealth and Sustainability

A commonly accepted definition of sustainable economic development is a time path where per capita well-being does not decline at any point (Pezzey 1992). Solow (1974, 1986) and Hartwick (1977) derived the conditions necessary for economic sustainability in an economy dependent on a nonrenewable resource, which came to be known as the Solow-Hartwick rule. The rule requires non-declining total wealth, which is achieved by reinvesting some portion of the rents from the nonrenewable

[2] However, the value of human capital is still not included because there is no agreement about how to measure it. The potential bias in the measure of national wealth that results from the omission of human capital and the impact of HIV/AIDS, which is an especially important factor in development in many Southern African countries, is discussed in the concluding section.

resource in other forms of capital (assuming, among other things, that resources are priced efficiently). The relationship between sustainable well-being and non-declining wealth was further developed by, among others, Mäler (1991), Pearce and Atkinson (1993), Dasgupta (2001), Dasgupta and Maler (2000) and Hamilton and Clemmens (1999).

The theoretical literature has defined wealth as consisting of produced capital, natural capital and human (including social) capital. Drawing on Hamilton and Clemmens, a highly simplified version of this formalisation defines a closed economy producing a composite good that can be consumed or invested in either produced capital or human capital, $F(S_P, Q, S_H) = C + \Delta S_P + m$, where S_i are stocks of produced (S_P), natural (S_N) and human capital (S_H); Q is use of a nonrenewable resource; C is consumption; S_P is investment in produced capital; and m is investment in human capital. The change in the stock of human capital is a function of investment, $S_H = q(m)$, and the depletion of natural capital is equal to extraction, $S_N = -Q$. Well-being, V, at time t is then defined as the discounted sum of all future utility, $V_t = \sum_{\tau=t}^{\infty} \frac{U(C_t)}{(1+r)^{\tau-t}}$. For this economy, a change in well-being is proportional to the change in the value of assets:

$$\Delta V_t = U_{t,c} \cdot \sum p_{t,i} \Delta S_{t,i}, \quad (1)$$

where U_c is the marginal utility of consumption, p_i are the shadow or accounting prices of produced (p_P), natural (p_N) and human capital (p_H).[3] It is relatively straightforward to expand this model for renewable resources, pollution and environmental degradation, as well as for other specifications of the utility functions, including, for example, utility derived from environmental quality (Dasgupta 2001; Dasgupta and Maler 2000). Dasgupta (2001) also considered various ways in which demographic change could be incorporated into the index of sustainable development; much depends on the extent to which well-being, V, is a function of population size, P. The simplest rule derived by Dasgupta is that '…social well-being increases if and only if wealth per head accumulates' (Dasgupta 2001, p. 258).[4] In the format of Eq. 1, this rule for sustainability can be expressed as

$$k_{t-1} \geq k_t, \quad (2)$$

[3] The accounting price is the social worth of a good, which is not always reflected by its market price; indeed, some goods, notably environmental goods, do not have market prices at all. Thus, implementation of this index of sustainability requires estimation of accounting prices for at least some forms of capital, a subject taken up in the next section.

[4] The most simple form is used because there is insufficient information at this time to estimate how well-being changes with population size. Population growth can, for example, have negative impacts due to increased congestion. Of greater concern in Southern Africa is the potential impact of population decline or the skewed age distribution due to HIV/AIDS. The impact of HIV/AIDS on human capital and productivity is directly accounted for by the stocks of human capital; the additional impact on well-being is not known at this time.

where k is the value of per capita (K/P) total wealth, the sum of the products of the per capita stocks of assets (S/P) and their shadow prices $k_t = \sum k_{t,i} = \sum p_{t,i} s_{t,i}$. To implement this indicator of sustainability for open economies, such as Botswana and Namibia, the concept of wealth must take into account claims on foreign stocks of capital, which are represented by net holdings of foreign financial assets.[5] Total per capita wealth, k, is thus defined to include $k_{t,f}$, net foreign financial assets as well as produced, natural and human capital:

$$k_t = \sum \left(k_{t,P} + k_{t,N} + k_{t,H} + k_{t,F} \right) \tag{3}$$

In using Eqs. 2 and 3 to monitor sustainability over time, it is essential that all assets be included. Human capital is not readily measurable at this time; however, measures for the other three components of wealth can be estimated. The following modification of Eq. 3 is implemented for Botswana and Namibia:

$$k_t = \sum \left(k_{t,P} + k_{t,N} + k_{t,F} \right) \tag{4}$$

Methods and data sources for each component of national wealth are described in the next two sections.

2.2 *Measuring National Wealth*

Implementation of Eq. 4 requires information about produced capital, natural capital, net foreign financial assets and population. For produced capital and net foreign financial assets, data are readily available and observed market prices can be taken as reasonable approximations of their accounting prices. For natural capital, market prices of the assets *in situ* are usually not available. Accounting prices can be reasonably derived for the major natural resources using methods developed for the SEEA, which are described in this section. Prices cannot be estimated for all natural capital at this time, an issue taken up in Sect. 2.3; the report addresses the most economically important forms of natural capital: minerals and fisheries.

2.2.1 Produced Capital

The stock of produced capital includes all manufactured structures and equipment. The standard method for measuring produced capital, which has been recommended by the System of National Accounts 1993 (UN et al. 1993) and implemented by

[5] Claims on domestic and foreign assets are not explicitly differentiated in theoretical models, but empirical work on wealth has recognised that net foreign financial assets are an important component of wealth for open economies. Further theoretical work might make this distinction explicit in order to examine the impact of international trade and finance on the wealth and sustainability of open economies.

most statistical offices around the world, is the perpetual inventory method (PIM). PIM at any given time is simply cumulative gross investment in fixed capital minus depreciation of existing stock. Depreciation is based on an assessment of the lifetime of fixed capital in each industry, and capital stock is revalued each year so that it represents replacement value rather than historical value. Namibia's Central Bureau of Statistics provides estimates of manufactured capital stock based on the PIM in its annual national accounts.

2.2.2 Foreign Financial Capital

Foreign financial assets represent claims by domestic agents—government agencies, enterprises and private individuals—on assets held in foreign countries. For small countries with relatively limited opportunities for profitable domestic investment, these assets can represent an important alternative investment of resource rents. In most countries, the foreign assets of government agencies and enterprises are reported regularly to the central bank. Information about these assets was obtained for Namibia from (Bank of Namibia 2001, 2007; IMF 2007). For Namibia, it was only possible to construct accounts from 1989 onwards; no information was available for the period before independence. Until 1990, Namibia was administered by South Africa, and its finances were largely intertwined with those of South Africa. For several years after independence, there were disputes with South Africa about Namibia's financial obligations, which were eventually settled by negotiation (World Bank 1995). The lack of data prior to 1989 is not a serious omission because, as we will see, the volume of Namibia's net foreign financial assets is quite small relative to other forms of wealth.

Information about holdings of foreign assets by individuals is not regularly reported in most countries and is often obtained only through special surveys. There is no published information for Namibia. Because of its colonial past and a relatively well-off minority population with ties to other countries, it is not unlikely that some of Namibia's private citizens have substantial holdings of foreign assets, but there is no way to estimate these holdings.

2.2.3 Natural Capital: Physical Accounts

The major natural resources for Namibia include minerals, marine fisheries, water and land that provide ecosystem services supporting both a strong agricultural sector as well as an important nature-based tourism industry. Annual accounts are only available for minerals and fisheries at this time. Experimental, one-time accounts were constructed for wildlife and forests, but no further information is available at this time. This section describes the approach for mineral and fisheries accounts. More detailed information can be found in Lange et al. (1998, 2004); Lange (2003a, b, c, 2002).

Namibia mines a wide range of minerals, but a few minerals account for virtually all of the economic value: diamonds, gold and uranium. The increase in global commodity prices in the last few years resulted in reopening of some old mines and establishment of some new mines, particularly for copper and zinc. But with deteriorating economic conditions at the end of 2008, many of these mines are struggling and some have already closed.

The mineral accounts include the most important minerals: diamonds, uranium and gold, which provide more than 95% of mining GDP. There is not sufficient information about other minerals at this time to include them in the accounts. Diamonds are by far the most important mineral, accounting for roughly 85% of mining GDP. Information about extraction of minerals is published in the annual reports of the Ministry of Mines and Energy and the Namibian Chamber of Mines. Information about reserves is more difficult to obtain because many companies treat this as confidential information. Information about reserves was obtained from a combination of public and private sources. The main source was a survey of the companies that mine Namibia's three major minerals. This was supplemented by information from annual reports published by the mining companies and, in the case of uranium, from an international trade organisation, the World Nuclear Association.

For diamond reserves, the information obtained from companies remains confidential and cannot be reported here, except for a couple of years, 1999–2000, in which De Beers reported reserves in its Annual Reports. De Beers has since stopped publication of reserves. Data about uranium reserves were obtained for 2005 from the World Nuclear Association website (www.world-nuclear.com); stocks for earlier years were estimated by adding back annual extraction. This method assumes no new discoveries or redefinition of assets over the previous 25 years. This does not give a realistic picture of the severe economic fluctuations faced by uranium mining companies because companies have revised estimates of proven and probable reserves in response to changes in market prospects over time. However, it does give a reasonable time trend for the asset. Data for gold mining was obtained from the mining company, Navachab. Information is also publicly available from the annual report of its parent company, AngloGold. Where the estimated reserves differed, we use the publicly reported data.

Namibia's fisheries accounts include the three commercially most important fisheries: hake (*Merluccius capensis* and *Merluccius paradoxus*), horse mackerel (*Trachurus capensis*) and pilchard (*Sardinops ocellatus*), which account for more than 80% of the value of fish production. There are several other smaller but important fisheries, which in recent years have come under similar controls (Total Allowable Catch (TAC) established for the fishery and quota fees levied to recover resource rent): crab, lobster, orange roughy and monk fish. Fisheries only became part of Namibia's national wealth at independence from South Africa in 1990. Prior to that time, Namibia was unable to exert control over its 200-mile exclusive economic zone, which contained the most lucrative fisheries, because no country would recognise South Africa's jurisdiction over the area. Namibia's fisheries were exploited, largely by foreign operators, under virtually an open-access regime, a practice that severely depleted the fish stocks and was halted after 1990. There is little reliable information about fisheries stocks prior to 1990, but since 1990, Namibia's Ministry of Fisheries and Marine Resources has provided information about fish stocks and annual catch.

2.2.4 Natural Capital: Monetary Accounts

Asset valuation is ideally based on market prices, but there are no markets for minerals and fisheries resources in Namibia. In an optimising economy, the price of an asset would be equal to the present value of the stream of net income an asset is expected to earn over its lifetime. Where market prices for assets are missing, the SEEA recommends estimating the present value of the future stream of income (resource rent) directly, a method that involves two steps: (1) calculating resource rent in a given year and (2) calculating the likely future stream of rent over the lifetime of the resource.

The resource rent, p_j, represents the accounting price of natural resource, j, and is calculated as the residual between product price (unit revenue), v_j, and the unit marginal production costs, mc_j:

$$p_{t,j} = v_{t,j} - mc_{t,j}, \tag{5}$$

where production costs include intermediate consumption, labour costs and the costs of fixed capital (depreciation and the opportunity cost of capital). Having calculated the value of rent in a given year, the asset value is the sum of rent generated each year over the remaining lifespan of the resource, T:

$$K_{t,j} = \sum_{\tau=t}^{T} \frac{p_{t,j} Q_{t,j}}{(1+r)^t} \tag{6}$$

$$T = \frac{S_{t,j}}{Q_{t,j}}, \tag{7}$$

where variables are defined as above and in Sect. 2.1.

For renewable biological resources like fisheries or forests, the net present value approach to asset valuation may take a slightly different form. If the resource is being 'mined', that is, harvested at an unsustainable rate, then the lifespan of the resource is finite and the asset value is determined using Eqs. 6 and 7. However, resources managed sustainably have an infinite lifespan, and assuming constant unit rent, Eq. 6 collapses into the following form, where the asset value of resource j is simply the total resource rent, pQ, divided by the discount rate:

$$K_{t,j} = \frac{p_{t,j} Q_{t,j}}{r}. \tag{8}$$

Implementation of these relatively simple models of asset valuation poses a number of challenges. Regarding the calculation of resource rent, data about marginal costs are not generally available, so average cost is commonly used, which may introduce an upward bias into the measure of rent and asset value. In Namibia, national statistical offices provided unpublished economic data from the annual mining company surveys that are used to compile the national accounts. These surveys provide reasonably accurate information for the calculation of accounting prices for minerals. For fisheries, the statistical office provides data about each of the major fisheries based in part on observed data (for fish catch, fish prices, fuel costs) and partly on a model of fishing costs for each fishery. This model is being revised on the basis of a recently introduced annual survey of fishing companies, which should improve estimates in future. Approximately, 50 companies exploit the three major fisheries. The data are less accurate for fisheries than for minerals but probably provide a reasonable picture of fisheries value over the long term.

From these data, a modified version of Eq. 5 was used, based on total rather than unit revenue and costs: total rent, *R*, was calculated for each resource, *j*, as gross revenue GR, minus total production costs: intermediate consumption IC, compensation of employees CE, consumption of fixed capital CFC, and 'normal profit' NP, the opportunity cost of produced capital invested in resource exploitation:

$$R_{t,j} = \mathrm{GR}_{t,j} - \mathrm{IC}_{t,j} - \mathrm{CE}_{t,j} - \mathrm{CFC}_{t,j} - \mathrm{NP}_{t,j}. \tag{9}$$

Normal profit is the rate of return (*i*) to produced capital used for production of resource *j*:

$$\mathrm{NP}_{t,j} = iK^{j}_{t,P}. \tag{10}$$

From Eq. 8, the unit rent is calculated as total rent divided by the quantity of resource extracted or harvested $p_{t,j} = \dfrac{R_{t,j}}{Q_{t,j}}$.

All figures except normal profit are obtained from observed data. For minerals, normal profit for mining was calculated with a 10% rate of return on fixed capital in line with guidelines of government planning agencies. For fisheries, a 20% return was recommended by the Ministry of Fisheries and Marine Resources to reflect the higher degree of risk in that industry.[6]

These prices can then be implemented in Eq. 6 to obtain asset value. Asset valuation should be based on expected future extraction paths, production costs and market prices. However, in many instances, this information is lacking, so the SEEA recommends an assumption that both the future volume of extraction and the per unit rent remain constant over time. This assumption is not unreasonable for fully established mines that expect to operate for the estimated lifespan; under these circumstances, mining companies themselves often assume a constant level of extraction for long-term planning. However, in the current climate of high global demand for commodities and rising prices, it is likely that companies are changing their extraction paths. In some instances, annual reports of mining companies or from the Ministry of Mines and Energy provide information about a company's plans in a given year, and where available, these are incorporated in asset valuation.

[6] In more detailed reports, a sensitivity analysis for the return to capital was performed.

Compilation of fisheries asset accounts presents greater challenges than other resources because of a combination of characteristics unique to fisheries: fish stocks cannot be directly observed, some fish species are highly mobile and may migrate out of territorial waters, fisheries are affected by complex predator–prey interactions and stocks are often subject to large, unpredictable, inter-annual variations. The present value of each fish stock depends on future fish prices, fishing technology and costs of production, and fish stock levels and exploitation.

As with minerals, in the absence of alternative information, common practice has been to assume that the current year's prices, technology and production costs remain constant in the future. There is a high degree of uncertainty about future stock levels because the dynamics of many fish populations and of large marine ecosystems like Namibia's Benguela ecosystem are poorly understood. While Namibia's Ministry of Fisheries and Marine Resources has set a goal of restoring fish stock to the high levels seen decades ago, only hake has seen some improvement over the past decade; other fisheries have remained more or less the same, subject to considerable inter-annual fluctuations.[7] For the purpose of asset valuation, a conservative approach was taken that assumes fish stocks have stabilised at current levels and will generate the same rent in the future. This is not an entirely satisfactory assumption, but it is used for lack of any other information at this time.

2.3 Missing Assets: Ecosystem Accounts

Non-urban land provides a wide range of ecosystem services as described in the Millennium Ecosystem Assessment. The major use values from Namibia's terrestrial ecosystems which can be readily measured include agriculture, tourism and biodiversity conservation. In developed countries, where most land is privately owned, land value is measured based on market transactions. However, in Namibia, no market prices exist for the very large portions of the land where sales or long-term leasing is not allowed: 41% held under traditional tenure and 15% state-owned land, mostly for national parks and protected areas. Only 44% of land is privately held, and it is not taxed, so there is no assessed value that can be used for constructing monetary land asset accounts.[8] There is an active market in private farmland, but prices in recent years have been driven in part by speculation and uncertainty regarding future land reform policy, making them less useful for assessing the social value of land. Purely agricultural use has been replaced in many areas by mixed agro-tourism operations, but there is no national estimate of the value of land under this new use at this time.

Namibia has large areas of non-agricultural land set aside for biodiversity conservation that provide subsistence benefits to local communities, international tourism and provide significant global non-use values. Studies in many countries indicate

[7] See Lange (2003b) for more detailed discussion of how fish stocks are estimated, confidence intervals for stock estimates and sensitivity analysis of assumptions used in calculating asset value.

[8] A commercial land tax has been introduced and may provide information for land valuation in future accounts.

that tourism generates the largest single value from these ecosystems. In 2004, Barnes et al. (2004) estimated asset value of wildlife for tourism and subsistence uses in all regions and all systems of land tenure (private, government, traditional), which provides a rough proxy for the tourism and subsistence value of terrestrial ecosystems.[9] A later report on the value of Namibia's protected areas provided similar values, supporting these estimates (Turpie et al. 2004). Although there are no comprehensive figures on tourism values in Namibia over time, the number of tourists has risen substantially since independence in 1990, growing at 10% or more annually. It is likely that the value of these natural areas has grown a great deal, at least keeping pace with population growth. The impact of missing natural capital on the measure of wealth and sustainability will be discussed further in the conclusions.

3 Natural Capital in Namibia

This section reviews the level and composition of wealth in Namibia over the past 20 years to determine whether the economy, largely dependent on natural capital, has been managed in a manner that promotes sustainability, that is, whether per capita wealth is non-decreasing and whether depletion of natural capital is compensated for by an increase in other forms of wealth. Discussion begins with a review of the physical and monetary accounts for natural capital.

3.1 Physical Accounts for Natural Capital, 1980–2005

The volume of annual extraction and reserves of minerals is shown in Table 1 for the three major minerals. Gold mining began only in 1993. Reserves of minerals can be shown only for 2 years due to confidentiality issues mentioned earlier. The table shows considerable fluctuation of annual extraction.

There are no confidentiality constraints on information about fisheries, so the entire account can be shown for each of the three major fisheries, including opening and closing stocks, annual catch and other volume changes. As mentioned earlier, reliable information about catch and stocks has only been available since Namibian independence in 1990.

3.2 Resource Rent and Taxes

The amount of resource rent generated and the amount recovered through taxes are shown in Table 3. The mining sector has generated substantial amounts of resource rent,

[9] The wildlife accounts are being updated but were not available at the time this report was written.

Table 1 Reserves and extraction of major minerals in Namibia, 1980–2005

	Extraction			Reserves		
	Diamonds (million carats)	Uranium (thousand tons of U308 metal)	Gold (tons)	Diamonds (million carats)	Uranium (thousand tons of U308 metal)	Gold (tons)
1980	1.3	5.5		Confidential data	131	NA
1981	1.0	5.3			126	NA
1982	0.8	5.1			121	NA
1983	0.8	5.2			116	NA
1984	0.7	4.9			111	NA
1985	0.6	4.4			106	NA
1986	1.0	4.6			102	NA
1987	0.8	4.8			97	NA
1988	0.9	4.9			92	NA
1989	0.8	4.2			88	NA
1990	0.6	4.3			84	NA
1991	0.8	3.3			80	NA
1992	0.9	2.3			78	NA
1993	0.6	2.3	2.0		76	17
1994	0.7	2.6	2.3		73	16
1995	0.6	2.9	2.0		70	16
1996	0.7	3.5	2.1		67	15
1997	0.8	4.1	2.5		63	12
1998	1.5	3.3	1.9		59	10
1999	1.6	3.2	2.0	7.0	56	11
2000	1.5	3.2	2.4	16.2	53	10
2001	1.4	2.6	2.9	Confidential data	50	8
2002	2.6	2.8	2.7		48	20
2003	2.9	2.4	2.3		45	17
2004	3.7	3.6	2.1		42	15
2005	3.6	3.7	2.5		38	17

Source: Extraction: Lange (2003a); Ministry of Mines and Energy (annual); Namibia Chamber of Mines (annual); USGS (2008)
Reserves: Various sources and methods described in the text and for diamonds, DeBeers (1999, 2000), for uranium, World Nuclear Association (2008), for gold, AngloGold (2006, 2005, 2004)
missing entries indicate mineral was not mined in that year

mostly from diamonds. In all years, diamond rent is positive and a large component of total mining rent. In some years, diamond rent even surpasses total rent. This occurs in years when rents for other minerals (not reported here) are negative, that is, mining companies do not earn enough to cover their full capital costs including a normal profit.

Pilchard generated the most rent at the beginning of Namibian independence but was eventually surpassed by hake. This is not surprising since Namibia already had an established pilchard fishery prior to independence and only achieved control over the other fisheries over the past decade. Pilchard has shown the greatest volatility of rent over the decade. Rent became nearly zero in 1996 when virtually no pilchard was caught that year. It has not recovered well since that time.

Table 2 Fisheries accounts: stock and catch for hake, horse mackerel and pilchards, 1990–2005 (fishable biomass in thousands of tons)

	Opening stock	Catch	Other volume changes	Closing stock
(A) Hake				
1990	136	55	199	281
1991	281	56	249	474
1992	474	87	135	522
1993	522	108	–39	375
1994	375	112	73	335
1995	335	130	161	366
1996	366	129	75	312
1997	312	110	461	663
1998	663	141	−100	422
1999	422	161	51	312
2000	312	160	86	238
2001	238	173	54	119
2002	119	155	219	184
2003	184	189	243	237
2004	237	174	217	280
2005	280	158	60	182
(B) Horse mackerel				
1990	1,450	409	309	1,350
1991	1,350	434	1,184	2,100
1992	2,100	426	126	1,800
1993	1,800	479	179	1,500
1994	1,500	360	260	1,400
1995	1,400	314	114	1,200
1996	1,200	319	119	1,000
1997	1,000	306	1,106	1,800
1998	1,800	258	266	1,808
1999	1,808	288	–46	1,474
2000	1,474	320	96	1,250
2001	861	315	257	803
2002	803	359	615	1,059
2003	1,059	367	683	1,375
2004	1,375	315	579	1,639
2005	1,639	325	NA	NA
(C) Pilchard (sardines)				
1990	500	89	249	660
1991	660	68	49	641
1992	641	82	−128	431
1993	431	116	−100	215
1994	215	115	25	125
1995	125	95	–25	5
1996	5	2	147	150
1997	150	32	182	300
1998	300	65	40	275

(continued)

Table 2 (continued)

	Opening stock	Catch	Other volume changes	Closing stock
1999	275	42	−8	225
2000	225	27	−107	92
2001	92	11	−81	0
2002	0	4	558	554
2003	554	22	−137	395
2004	395	29	−318	49
2005	49	27	NA	NA

Source: Lange (2003b) and unpublished data from the Ministry of Fisheries and Marine Resources

Table 3 Resource rent and taxes on rent from minerals and fisheries in Namibia, 1980–2005 (millions of Namibia $)

	Minerals		Taxes on mineral rent	Fisheries					Taxes on fisheries rent
	All mining	Diamonds		Pilchard	Hake	Horse mackerel	Other	Total	
1980	355	281	66						
1981	179	93	30						
1982	189	57	30						
1983	157	86	33						
1984	190	66	38						
1985	482	159	57						
1986	538	199	94						
1987	395	201	83						
1988	579	414	92						
1989	769	466	121						
1990	380	241	83	117	27	9	NA	153	–
1991	364	370	99	65	30	30	NA	125	–
1992	355	343	135	135	36	20	NA	192	–
1993	151	150	180	112	106	40	12	270	98
1994	462	400	174	115	162	46	21	345	118
1995	279	237	144	76	163	41	38	318	100
1996	759	595	178	0	96	51	20	167	57
1997	761	590	371	14	146	45	34	241	89
1998	801	655	265	67	299	71	62	499	91
1999	889	935	305	32	294	75	43	444	91
2000	1,343	1,093	379	29	390	84	40	542	91
2001	2,284	1,941	521	19	406	161	66	652	109
2002	3,073	2,460	812	58	564	183	94	898	129
2003	1,326	1,428	498	71	656	130	71	927	147
2004	1,642	1,693	462	56	473	73	53	654	119
2005	1,441	1,305	481	13	320	106	42	482	70

Source: Author’s calculation of rent; quota levies obtained from CBS (2007)

Notes: Rent is calculated for minerals assuming a 10% rate of return on fixed capital and for fisheries a 20% rate of return

Taxes on fisheries reported here include quota levies that are designed to recover resource rent, but not other forms of taxes. It is not possible to determine the amount of taxes collected from each fishery

The rent per ton for hake has been steadily rising, reflecting both improvements in the industry and also the devaluation of the Namibian dollar over time, which has a major impact on earnings because most Namibian hake is sold to the lucrative European market. Horse mackerel, though harvested in higher volumes than either of the others, generates the least rent.

Like many countries, Namibia levies a number of taxes and fees on its mineral and fisheries industries. Some of these are ordinary corporate profit taxes, but others are designed specifically to capture the resource rents. Table 3 includes only those taxes that target resource rent.

3.2.1 Rent Recovery in the Mining Sector

In the mining sector, government has recovered an average of 30% of the rent generated by all mining activities, but rent recovery has varied enormously from year to year (Fig. 1). Rent recovery improved significantly after independence, from an average of 17% before 1990 to 39% after 1990. In the past, taxes designed to recover rent were only levied on diamond mining; taxes paid by other mining operations fall within the range of normal corporate taxes on income. However, in the past few years, the government has introduced a tax on other minerals, 2–3% depending on the type of mineral.

Whether this degree of rent recovery is sufficient is difficult to determine. When rent is so volatile, it is not feasible to attempt full rent recovery, and government must be careful not to set taxes so high as to discourage investment. By comparison, the government of Botswana has recovered a greater share of resource rent, averaging 76% over the period 1980–1997 (Lange 2004; Lange and Wright 2004). However, diamond rent has been much more stable in Botswana over the past two decades, which makes it much easier to establish appropriate tax regimes.

3.2.2 Rent Recovery in the Fishing Sector

Substantial amounts of resource rent are generated by the Namibian fishing industry. The government established a system of quota levies in order to help achieve its objectives of sustainable and equitable management of the industry. While full recovery of rent is not practicable because of the significant year-to-year fluctuations in rent, recovery of a significant portion of the expected long-term rent is important for several reasons:

- Recovery of rent contributes to the *sustainable management* of fisheries by removing the economic incentives for overfishing and depletion of the resource.
- Set at the appropriate level, levies create incentives for the most *economically efficient* (most profitable) level of fishing, based on both biological and economic criteria.

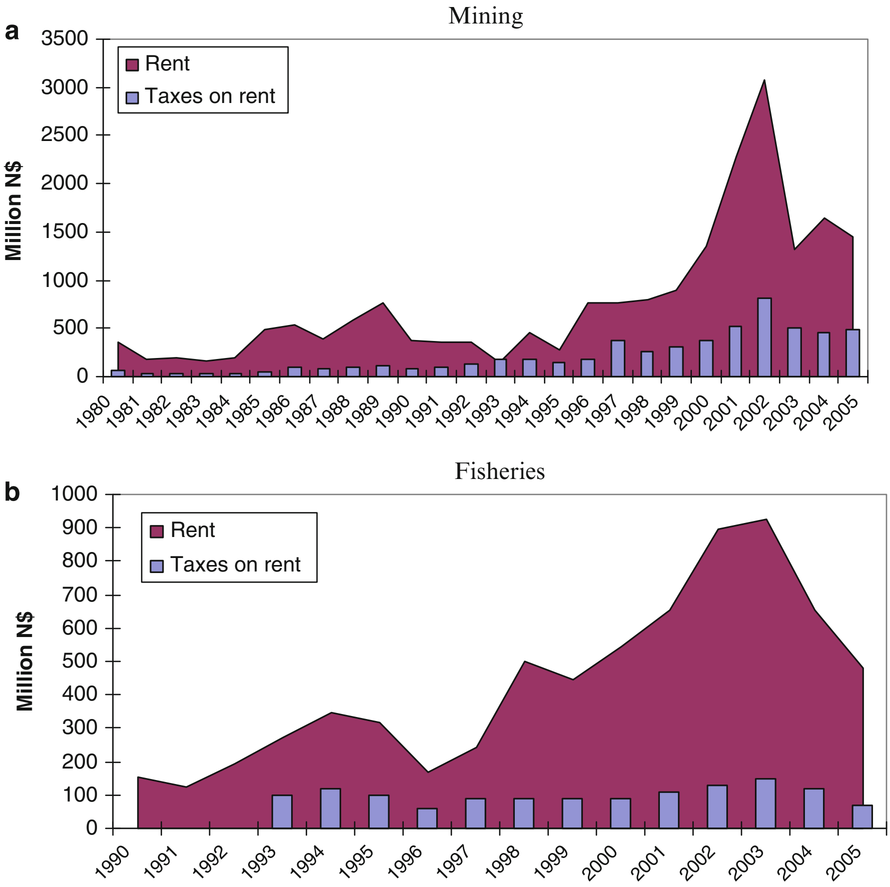

Fig. 1 Rent recovery from mining and fisheries in Namibia, 1980–2005. (**a**) Mining and (**b**) fisheries (Source: Table 3)

- Recovery of rent promotes *equity* by recovering excess profits obtained from a national asset which can be used for development that benefits all Namibians, not just the few involved in the fishing industry (see Lange (2003a, b, c) for further discussion of these issues).

In the first few years after independence, no quota fees were levied as the ministry established the new policy regime for fisheries management. Quota levies recovered a significant amount of rent when first introduced, but the share of rent recovered has since fallen to less than 20%. The probably unintended declining recovery of rent has two sources: first, an increasing share of Namibian-owned companies, which are eligible for up to 50% subsidies on their quota levies; secondly, the failure to index quota levies to inflation, a common problem faced by governments who find it politically difficult to adjust taxes for inflation. While quota levies have been increased in recent years, the increase has not kept up with inflation.

Table 4 Value of natural capital in Namibia, 1980–2005 (million N$ in current and constant 1995 prices)

	Current price			Constant 1995 prices		
	Minerals	Fish	Total natural capital	Minerals	Fish	Total natural capital
Pre-independence						
1980	2,352	–	2,352	11,330	–	11,330
1981	1,778	–	1,778	8,481	–	8,481
1982	1,624	–	1,624	6,737	–	6,737
1983	1,534	–	1,534	5,793	–	5,793
1984	1,451	–	1,451	4,908	–	4,908
1985	1,923	–	1,923	5,181	–	5,181
1986	2,695	–	2,695	6,583	–	6,583
1987	3,036	–	3,036	6,806	–	6,806
1988	3,567	–	3,567	6,565	–	6,565
1989	3,883	–	3,883	6,188	–	6,188
Post-independence						
1990	3,475	1,526	5,001	5,289	2,323	7,612
1991	3,212	1,250	4,463	4,670	1,818	6,487
1992	2,878	1,916	4,795	3,820	2,543	6,362
1993	2,136	2,699	4,835	2,611	3,300	5,911
1994	1,888	3,449	5,337	1,996	3,645	5,641
1995	1,709	3,181	4,889	1,709	3,181	4,889
1996	2,397	1,672	4,069	2,094	1,460	3,554
1997	3,060	2,407	5,467	2,496	1,963	4,459
1998	4,034	4,995	9,029	3,031	3,753	6,784
1999	4,575	4,440	9,015	3,226	3,131	6,357
2000	7,952	5,423	13,375	5,039	3,437	8,476
2001	9,113	6,516	15,629	5,088	3,638	8,726
2002	13,249	8,982	22,231	6,641	4,502	11,143
2003	13,298	9,269	22,567	6,706	4,674	11,380
2004	13,515	6,544	20,058	6,740	3,264	10,004
2005	10,131	4,816	14,946	4,866	2,313	7,179

Source: Based on (Lange 2003a, b) and recent updates by the author using data and methods described in the text

– indicates a zero value

3.3 Monetary Accounts for Natural Capital

In current prices, natural capital increased between 1980 and 2005 (from N$2,352 to N$14,946 million), but when the asset values are adjusted for inflation, the depletion of natural capital becomes clear (Table 4). In constant 1995 prices, the value of Namibia's natural capital fell by 36% from N$11,330 million in 1980 to N$7,179 million in 2005. The loss of asset value is almost entirely due to depletion of minerals. The value of fisheries, which only became part of Namibia's national wealth in 1990, has remained roughly constant, albeit fluctuating considerably over the 15-year period.

By dividing the time series into two parts, pre- and post-independence, a better assessment can be made of the performance of the economy under new Namibian management. In constant prices, Namibia's natural capital increased at independence (from N$6,188 million in 1989 to N$7,612 million in 1990), as fisheries became part of the national wealth. But the decline in total natural capital soon continued due to the continued decline in mineral assets and volatility of fish asset value.

Physical depletion of all minerals compounded by declining real rents for diamonds and uranium caused mineral assets to lose more than half their value in the first 5 years after independence. The decline in real rent is not surprising. The global market for uranium was not good at that time. Diamonds, the most valuable mineral, have been mined since the beginning of the twentieth century. Initially, the reserves consisted of relatively high quality gem and near gemstones, which could be mined relatively cheaply. But by independence at the end of the 1980s, Namibia had largely exhausted its most profitable diamond reserves and moved to more costly offshore diamond mining. It took some years before the new investments in offshore mining began to pay off; diamond assets only started to increase in value from 1998.

Although fish provide a bright spot in the Namibian economy, the asset value has fluctuated rather wildly over the past decade due to unpredictable environmental events that affect fish stocks. Despite government's goal to restore fisheries to high levels of stocks last seen in the 1960s, there has been little or no stock growth in the years since independence. At such a depleted level, Namibia's fisheries are less easy to manage and even more vulnerable to shocks and overexploitation. Although data are not available for the last few years yet, it is likely that asset values, particularly for minerals, have increased in response to the global commodity boom.

4 Total National Wealth in Namibia

The previous section has shown that the value of Namibia's natural capital has decreased over the past two decades, largely the result of the depletion of mineral assets and failure to restore fisheries to levels seen several decades ago. But depletion of natural capital is not necessarily bad for the economy, if the rents from natural capital are used to build wealth in the form of other assets. An assessment of total wealth—produced capital, natural capital and foreign financial assets—will show whether depletion of natural capital has contributed to building national wealth (Table 5).

During the pre-independence period, Namibia's total, real wealth declined by more than 10%, and per capita wealth fell by one-third. Total natural capital (minerals) fell by 45%, but the depletion of minerals was not offset by investment in produced capital: private capital actually fell slightly over the decade, while public infrastructure increased but only slightly, and net foreign financial assets were negative at the end of the decade. This is not surprising since the decade prior to independence was marked by civil conflict and extreme political uncertainty, factors that encourage rapid extraction of resources, discourage investment and drain resources

Table 5 National wealth of Namibia, 1980–2005 (millions of N$ in constant 1995 prices; per capita figures in N$)

	Produced capital					
	Private	Public	Natural capital	Net foreign financial assets	Total	Per capita wealth
Pre-independence						
1980	19,132	15,305	11,330	NA	45,766	45,616
1981	19,285	16,039	8,481	NA	43,805	42,398
1982	19,391	16,651	6,737	NA	42,778	40,159
1983	19,061	17,009	5,793	NA	41,863	38,118
1984	18,749	17,257	4,908	NA	40,914	36,134
1985	18,403	17,563	5,181	NA	41,146	35,246
1986	18,308	17,753	6,583	NA	42,643	35,430
1987	17,974	17,929	6,806	NA	42,709	34,418
1988	17,807	18,074	6,565	NA	42,446	33,177
1989	17,955	18,128	6,188	−1,426	40,845	30,966
Post-independence						
1990	18,176	18,282	7,612	−1,124	42,946	31,578
1991	18,101	18,353	6,487	−692	42,249	29,966
1992	18,457	18,557	6,362	−725	42,652	29,478
1993	18,842	18,447	5,911	463	43,663	29,405
1994	19,508	18,538	5,641	389	44,076	28,924
1995	20,344	18,691	4,889	8	43,932	28,092
1996	21,604	18,793	3,554	−226	43,725	27,244
1997	22,389	18,941	4,459	715	46,504	28,235
1998	23,815	19,020	6,784	709	50,328	29,775
1999	25,161	19,149	6,357	1,595	52,263	30,129
2000	25,864	19,350	8,476	1,653	55,343	31,089
2001	27,747	19,346	8,726	1,457	57,276	31,352
2002	29,723	19,349	11,143	1,308	61,523	32,816
2003	32,615	19,258	11,380	1,316	64,569	33,560
2004	34,596	19,157	10,004	1,350	65,107	32,957
2005	36,233	19,141	7,179	1,377	63,930	31,519

Source: Produced capital: CBS (2001, 2008). Natural capital: Table 4; Foreign financial assets: IMF (2007) and Bank of Namibia (2001; 2007)

from productive activities. There was no policy of reinvestment of rents from non-renewable resources, and economic incentives favoured very rapid extraction that were being depleted.

Trends in the years after 1990 are particularly important because independence provided an opportunity for new resource management and development policies. Real wealth in 1990 was N$31,578 per person, and wealth continued to decline until 1996, when it reached N$27,244 per person, its lowest point in 20 years. This situation is probably not surprising, as there were many uncertainties at the time of independence that would discourage private investment. Around 1997, this picture began to improve, and by 2001, total per capita wealth had recovered to the level achieved at independence. Since then, wealth has fluctuated, largely due to fluctuations in

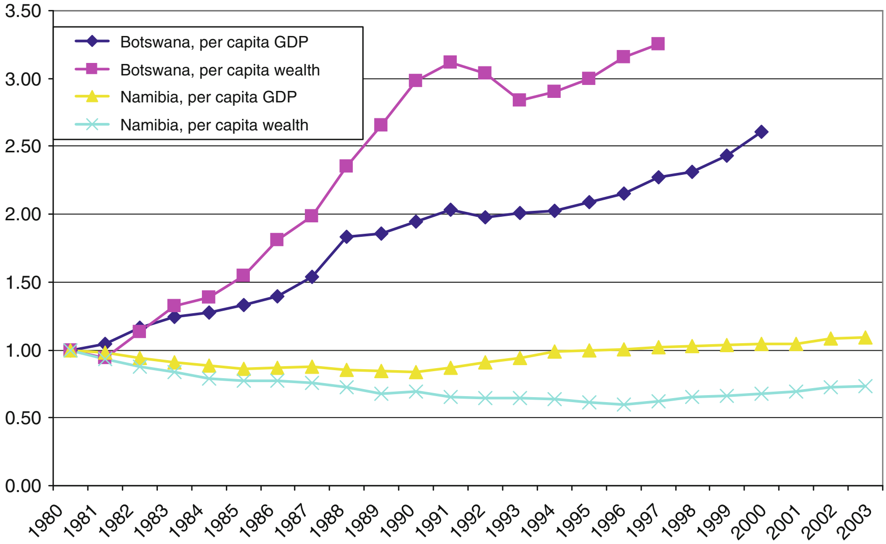

Fig. 2 Index of real per capita wealth and per capita GDP in Namibia and Botswana, 1980–2003 (1980 = 1.00) (Source: Namibia: index of wealth calculated from Table 3; GDP from CBS (2007). Botswana: based on (Lange 2004))

natural capital. Although the amount of capital available for each Namibian to work with is still less in 2005 than it was in 1980, it is particularly encouraging to note that private sector capital is the fastest growing component in the post-independence period, growing an average rate of 6% per year.

4.1 National Wealth and Well-Being in Namibia and Botswana

Economic well-being depends on wealth. Therefore, one would expect trends in indicators of well-being to reflect trends in per capita wealth. National income, despite its widely acknowledged weaknesses, is the most commonly used indicator of well-being. Figure 2 compares Namibia with Botswana, a neighbouring country with many similarities in terms of size, population and role of natural capital in the economy. Botswana is often cited as a model for other countries for its good management of its natural capital and macroeconomy. Figure 2 provides an index of growth of real per capita wealth and real per capita GDP for Namibia and Botswana from 1980 to 2000. (See Lange and Wright (2004), and Lange (2004) for a detailed discussion of Botswana's national wealth.)

In 1980, Namibia's national wealth was 75% greater than Botswana's (Lange 2004), but much of it was used purely for consumption during the pre-independence period. By contrast, over the last two decades, Botswana used its natural capital to build national wealth, which brought about growth in income. Real, per capita wealth more than doubled by 1997, while income increased 160% by 2000. The growth of national wealth is consistent with Botswana's development policy, which explicitly aimed to reinvest all mineral revenues for national development, investments that included public infrastructure, human capital and foreign financial assets. After a few years into the post-independence period, Namibia has begun to see its wealth grow and per capita income surpass 1980 levels again.

5 Concluding Remarks

Sustainable development requires non-declining levels of per capita wealth. In resource-rich economies, this requires that natural capital be transformed into other forms of capital to build wealth. However, there has been growing concern that economic growth, especially in resource-rich developing countries, has been achieved by liquidation of natural capital without adequate provision for replacement of these assets for future generations. Although natural capital may be a large component of wealth, it has not yet been systematically included in the national economic accounts of most countries. Consequently, conventional measures of well-being, such as GDP or NDP, are misleading indicators of sustainability—they indicate economic growth, but whether that growth is sustainable.

Wealth as an indicator of sustainable development requires that all forms of capital are included and that they are properly measured. The implications of some of these omissions were discussed in Sect. 2. The preliminary asset value for ecosystems—based solely on wildlife values for tourism and subsistence use—was estimated for 2003 at N$1,267 million in current prices; in 1995 constant prices, N$639 million, or N$332 per capita, about 1% of total wealth. Preliminary work based on the asset value of the Okavango Delta in Botswana indicates that ecosystem assets contribute significantly to Botswana's total wealth (Turpie et al. 2006).

While the measure of total wealth presented here is an important step towards a comprehensive measure of wealth, human capital continues to present a major challenge, especially in countries like Namibia, which are struggling with the HIV/AIDS pandemic. Recent work by Mäler et al. (2007) indicates a method to include all forms of capital.

References

Alfsen KN, Greaker M (2006) From natural resources and environmental accounting to construction of indicators for sustainable development. Ecol Econ 61(4)

AngloGold. (2004, 2005, 2006) Annual report. www.anglogold.com/Reports/Financial/Annual+Reports/Archives.htm. Accessed 18 June 2009

Arrow K, Dasgupta P, Maler KG (2003) Evaluating projects and assessing sustainable development in imperfect economies. Environ Res Econ 26:647–685

Arrow K, Dasgupta P, Goulder I, Daily G, Ehrlich P, Heal G, Levin S, Maler KG, Schneider S, Starrett D, Walker B (2004) Are we consuming too much? J Econ Perspect 18(3):147–172

Auty RM (1993) Sustaining development in mineral economies: the resource curse thesis. Routledge, London

Auty RM, Mikesell R (1998) Sustainable development in mineral economies. Clarendon, Oxford

Bank of Namibia (2001) Annual report 2000. Bank of Namibia, Windhoek

Bank of Namibia (2007) Annual report 2006. Bank of Namibia, Windhoek

Barnes J, Lange G, Nhuleipo O, Muteyauli P, Katoma T, Amupolo H, Lindeque P, Erb P (2004) Preliminary valuation of the wildlife stocks in Namibia: wildlife asset accounts. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek

Brunnschweiler C, Bulte E (1996) National accounts 1995. National Planning Commission, Windhoek

Brunnschweiler C, Bulte E (2002) Population census of Namibia. National Planning Commission, Windhoek

Brunnschweiler C, Bulte E (2008) The resource curse revisited and revised: a tale of paradoxes and red herrings. J Environ Econ Manage 55:248–264

Central Bureau of Statistics (2001) National accounts 1990–2000. National Planning Commission, Windhoek.

Central Bureau of Statistics (2007).

Central Bureau of Statistics (2008) National accounts 1996–2007. National Planning Commission, Windhoek

Commission of the European Communities, International Monetary Fund, Organisation for Economic Cooperation and Development, United Nations, and World Bank (1993) System of national accounts. United Nations, New York

Dasgupta P (2001) Human well-being and the natural environment. Oxford University, Oxford

Dasgupta P (2002) Economic development, environmental degradation and the persistence of deprivation in poor countries. Beijer discussion paper series no 168. Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences, Stockholm

Dasgupta P, Maler KG (2000) Net national product, wealth, and social well-being. Environ Develop Econ 5:69–94

Dasgupta P and Maler KG (2001) Wealth as a criterion for sustainable development. Discussion paper series no 140, Beijer Institute, Stockholm

DeBeers Corporation (1999) Annual report. Available from website www.debeersgroup.com. Accessed 10 Nov 2003

DeBeers Corporation (2000) Annual review. Available from website www.debeersgroup.com

Hamilton K (2002) Sustainable per capita welfare with growing population: theory and measurement. Paper presented at the second world congress of environmental and resource economists, Monterey, 23–27 June 2002

Hamilton K, Clemmens M (1999) Genuine savings rates in developing countries. World Bank Econ Rev 13(2):336–356

Hartwick J (1977) Intergenerational equity and the investing of rents from exhaustible resources. Am Econ Rev 67(5):972–974

Heal G, Kristrom B (2005) National income and the environment. In: Male KG, Vincent JR (eds) Handbook of environmental and resource economics, vol 3. North Holland Publishers, Amsterdam, Chap 22

International Monetary Fund (2007) International financial statistics yearbook. IMF, Washington, DC

Kunte A, K Hamilton, J Dixon and M Clemmens (1998) Estimating national wealth: methodology and results. Environment department papers, Environmental economics series no 57, The World Bank, Washington, DC

Lange G (2002) Environmental accounts: uses and policy applications. World Bank environment department paper no 87, World Bank, Washington, DC

Lange G (2003a) The contribution of minerals to sustainable economic development: mineral resource accounts in Namibia. Research discussion paper no 54, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek

Lange G (2003b). The value of Namibia's commercial fisheries. Research discussion paper no 55, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek

Lange G (2003c) Wealth, natural capital, and sustainable development in Namibia. Research discussion paper no 56, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek

Lange G (November 2004) Wealth, natural capital, and sustainable development: the contrasting examples of Botswana and Namibia. Environ Res Econ 29(3):257–283

Lange G, Wright M (August 2004) Sustainable development in mineral economies: the example of Botswana. Environ Develop Econ 9(4):485–505

Lange G, Barnes JI, Motinga J (1998) Cattle numbers, herd productivity, and land degradation in Namibia. Develop South Africa 15(4):555–572

Lange G, Hassan R, Hamilton K (2004) Environmental accounting in action: case studies from Southern Africa. Edward Elgar Publishers, Cheltenham

Mäler KG (1991) National accounts and environmental resources. Environ Res Econ 1(1):1–15

Mäler KG, Aniyar S, Jansson A (2007) Accounting for ecosystem services – a way to understand the requirements for sustainable development. PNAS 105(28):9501–9506

Ministry of Finance (Norway) (2005) Indicators for policies to enhance sustainable development. Ministry of Finance, Oslo

Ministry of Mines and Energy (2000 to 2005) Annual report. MME, Windhoek. www.mme.gov.na

Pearce D, Atkinson G (1993) Capital theory and the measurement of sustainable development: an indicator of weak sustainability. Ecol Econ 8:103–108

Pezzey J (1992) Sustainable development concepts: an economic analysis. World Bank environment paper no 2, World Bank, Washington, DC

Sachs J, Warner A (1995) Natural resource abundance and economic growth. Discussion paper no 517a, Harvard Institute for International Development, Harvard University, Cambridge

Solow R (1974) Intergenerational equity and exhaustible resources. Rev Econ Stud 41:29–45

Solow R (1986) On the intergenerational allocation of natural resources. Scand J Econ 88:141–149

Turpie J, Lange G, Martin R, Davies R, Barnes J (2004) Strengthening Namibia's system of national protected area: economic analysis and feasibility study for financing (with). Report to UNDP/GEF and Ministry of Environment and Tourism, Windhoek

Turpie J, Barnes J, Arntzen J, Lange G, Nherera B, Buzwani B (2006) Economic value of the Okavango delta, Botswana. Report to IUCN-Botswana the Department of Environmental Affairs, Gaborone, Botswana

United Nations, Commission of the European Communities, International Monetary Fund, Organisation for Economic Cooperation and Development, World Bank (2003) Handbook for integrated environmental and economic accounting. United Nations, New York. Draft available from the website of the UN Statistical Division, www.un.org

United States Geological Survey (2008) Minerals information: commodity statistics and information. www.usgs.gov/minrals/pubs/commodity. Accessed 12 Mar 2010

World Bank (1995) Namibia public expenditure review. The World Bank, Washington, DC

World Nuclear Association (2002) World development report. The World Bank, Washington, DC

World Nuclear Association (2005) Where is the wealth of nations? The World Bank, Washington, DC

World Nuclear Association (June, 2008) World uranium mining. Information and issue briefs. www/world-nuclear.org/info

Wildlife Accounts: A Multi-sectoral Analysis in Namibia

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Abstract The completion of a national wildlife inventory in 2004 enabled the development of a set of wildlife accounts for Namibia, comprising both physical and monetary asset accounts, as well as production or flow accounts. Some 2.04 million larger wild animals made up the physical wildlife asset base which produced gross output of some N$1.5 billion and directly contributed N$ 700 million to the gross national product (GNP). Non-consumptive wildlife-viewing tourism generated 62% of the total wildlife sector GNP contribution. Hunting tourism and live game production generated 19 and 10%, respectively. The wildlife use sector represented 2.1% of national GNP in 2004. Its contribution will likely triple in the next 30 years as the sector reaches potential. Namibia's standing wildlife assets in 2004 were estimated to have a value of N$10.5 billion, a value comparable with those estimated for fish and minerals. Findings suggest that development in the sector should emphasise both non-consumptive and consumptive tourism. Property rights should be secured, through the concessions policy and the community-based natural resource management (CBNRM) programme. Investments in building appropriate stocks of wildlife in both communal and private land should be facilitated.

Keywords Wildlife • Resource accounts • Namibia

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1 Introduction

This chapter describes the preliminary development of natural resource accounts for wildlife resources in Namibia. It forms part of the natural resource accounting (NRA) programme, established in the Ministry of Environment and Tourism. The NRA programme extends the conventional macroeconomic national accounts through the development of satellite asset accounts for natural resources such as fish, water, forests, minerals, livestock, energy and tourism. While the *use* of these natural resources is accounted for in the conventional national accounts, the resources are not been accounted for as capital *assets*. National accounts have historically only incorporated man-made or owned assets in their capital accounts. NRA aims to bring natural assets into national accounting and planning, in the interests of efficiency and sustainability.

In natural resource accounting, the natural assets are valued in two ways. First, the annual contribution of the resource to the national income is measured in a production, or *flow*, account. Second, the value of all existing stocks of the resource is estimated in an *asset* account. Here, the value of the stock, as a national capital asset, is measured in terms of its potential to generate resource rent (also known as economic rent or excess profit) in the future.

Wildlife as a resource is a complex entity, embracing all wild animal life, both vertebrates (mammals, birds, reptiles, amphibians, fish) and invertebrates. Wildlife, thus defined, has featured in resource accounts for fish (most wild aquatic organisms of economic value) and forests (non-timber forest products include some forest-dwelling invertebrates), and it forms part of the asset base for the tourism sector. To avoid double counting of assets, already recorded in other categories of accounts, *wildlife resources* are defined here as all wild animals other than fish and forest-dwelling invertebrates. For the purposes of the asset accounts, wildlife stocks are measured as estimated numbers of the large wildlife mammal species and ostrich.

Namibia embraces some 824,000 km^2 on the southwestern coast of Africa and has a human population of 1.8 million. The natural biomes range from extremely arid desert in the west, through arid semi-desert Karoo shrubland in the south, through semi-arid savanna in the north-centre, to semi arid and sub-humid woodland in the northeast. Wildlife in most of the country is dominated by southern African arid zone species, but in the northeast, wildlife typical of the central African plateau occurs.

The dry climate in Namibia means that very little of the land is converted for arable agriculture. Instead, natural vegetation is used as extensive grazing by livestock and wildlife. Land tenure can be divided into three broad types. In the centre and south most land is privately owned, and land use is large scale and commercially orientated. In the northwest, north and northeast, land tends to be communal, and land use is small scale and subsistence. In the dry west and parts of the north, north-east and south, state-owned land is maintained as protected parks and game reserves (Mendelsohn et al. 2002).

Natural resources have several types of economic value, and in resource economics, these values are commonly classified in the framework of 'total economic value'. *Total economic value* embraces direct use values, indirect use values and non-use values.

Direct use values derive from the direct use of the resource, that is, in production of tangible goods, are usually with market value. Indirect use values derive from the resource's value in ensuring ecological function, such as watershed conservation. Non-use values derive from the value of preservation of the resource either for future use (*option value*), for its mere existence (*existence value*) or to bequeath to future generations (*bequest value*). The preliminary wildlife accounts deal exclusively with direct use values.

2 Methods

2.1 Approach

The asset and flow accounts were developed in accordance with the standardised methodology for natural resource accounting – the Integrated Environmental and Economic Accounting/IEEA Manual – developed by the United Nations (2000) and later refined (UN et al. 2003). The IEEA Manual was developed to complement the conventional, internationally adopted System of National Accounts (SNA) used to measure economic performance in most countries around the world (CEC et al. 1993). Conventional national accounting incorporates capital accounts but tends to restrict these to assets that are owned or man-made. IEEA, on the other hand, aims to include accounts for natural resources that are not man-made, such as natural forests, fish and wildlife, in the national economic data records and the planning process.

The physical wildlife *asset* account was based on the estimated numbers of larger wildlife species, mainly mammals but including ostrich, in the country. These data are based on aerial and ground surveys conducted throughout the country and compiled in the Directorate of Scientific Services of the Ministry of Environment and Tourism. We assembled the available data on estimated numbers of larger mammal species in the protected areas, the districts on private land and the conservancies on communal land. No data were available for communal land outside conservancies, but it is known that wildlife on this land is extremely scarce. The physical accounts were then valued in order to produce monetary asset accounts, so that in future, changes in the capital value of wildlife stocks can be measured.

The current annual use of the wildlife asset base is detailed in *flow* accounts; the latter present the volumes and monetary values (economic characteristics) of this use. Flow accounts measure use in terms of output, contribution to gross national product (GNP) and employment, in conformity with the SNA.

The valuation of renewable natural resource assets such as forests, fish and wildlife can be done in several ways (UN 2000; UN et al. 2003). The most appropriate of these is the *net present value method*, which estimates the present value of all future returns in resource rent from the use of the resources. For the wildlife asset accounts, we applied the net present value method, using streams of rents from expected growth in use over the next 30 years. As was the case with forests, reasonably good predictions of future growth in wildlife use can and have been made, based on past records and future development plans (e.g. Erb 2003; Turpie et al. 2004; WTTC 2006; NTB 2008). With resources such as fish and minerals, future stock and use values are much less predictable, and to value these, it has been necessary to assume no growth in use (constant rent) into the long-term future (Lange 2004; Lange and Hassan 2003).

An important consideration in valuing natural asset stocks is that resources that are not exploitable, either for legal or economic reasons, have a zero value. Thus, only that portion of the natural stocks that can realistically be brought into viable production in the future was valued.

Wildlife use, current and future, conforms to national policy. Uses and the combinations of different types of use that can be practised differ depending on locality and land tenure. The approach adopted has been to divide the country into wildlife utilisation zones, reflecting differences in the possible uses and combinations of uses. The accounts are structured according to these zones.

2.2 Valuation of Flow and Asset Accounts

Monetary values in this chapter are given as Namibia Dollars (N$) at 2004 prices. In 2004, N$1.00 was equal to R1.00 (South African Rand) and approximately US$0.16 (United States Dollars).

The value of the current and potential output of wildlife resources is the product of the volumes produced and the market prices, as described above. A proportion of this output represents the direct contribution of the resource in terms of value added to the gross national product (GNP), as measured in the flow account. Another proportion of this output represents the resource rent that the resource use generates (the amount of economic rent or excess profit that the resource generates).

The approach to valuing wildlife use generally involved determining gross figures for output of particular uses derived from available data and literature and allocating these per utilisation zone. Thus, output data on wildlife-based tourism was calculated by taking the output for leisure tourism in the national tourism satellite accounts (WTTC 2006; NTB 2008) and multiplying that by the proportion of tourism value that is attributable to *wildlife* (as opposed to scenery, sense of space or other attributes). This proportion is very difficult to determine. We used data from a 2006 survey of protected area tourists in Namibia (SIAPAC 2007), where respondents were asked questions concerning which attribute(s) attracted them to make their trip in Namibia. Table 1 shows the results of this analysis. The average of three approaches was used to estimate that 51% of the tourists' expenditures were attributable to wildlife.

The gross output data for trophy hunting tourism were obtained from Humavindu and Barnes (2003), Novelli et al. (2006) and Erb (2003). Unpublished data on hunting concessions, from the Ministry of Environment and Tourism, were used to allocate hunting values geographically. Biltong hunting output values, a small portion of hunting tourism values, were obtained and synthesised from Erb (2003).

Table 1 Calculation of the value of wildlife as a component of total protected area tourism value in Namibia in 2006

Attribute	Results of different tourist preference ratings[a]						
	Frequency of mention		Frequency of first rating		Frequency of first ranking		Average
Wildlife	552,019	24%	152,438	29%	126,413	68%	51%
Landscape	298,409	13%	93,397	17%	28,292	15%	16%
Wide open spaces	268,848	12%	75,267	14%	12,370	7%	10%
Culture/people	248,709	11%	44,878	8%	8,416	5%	7%
Tranquillity	224,041	10%	49,738	9%	2,655	1%	5%
Sport	212,836	9%	25,523	5%	1,675	1%	3%
Freedom	183,216	8%	40,948	8%	3,754	2%	4%
Hospitality	158,974	7%	36,646	7%	852	0%	3%
History/archaeology	150,599	7%	15,294	3%	545	0%	2%
Total	2,297,651	100%	534,129	100%	184,972	100%	100%

[a]Relative values measured from different questions posed to protected area tourists by SIAPAC (2007)

Gross output values for live game capture for sale, small-scale meat production and commercial cropping for meat production were based on the results of analysis by Erb (2003) of licence records in the Ministry of Environment and Tourism and from past survey results of the Directorate of Scientific Services. Data on gross outputs for ostrich and crocodile production were obtained through synthesis of the unpublished stock census records of Directorate of Veterinary Services in Ministry of Agriculture Water and Forestry and empirical enterprise data from Botswana (FGU-Kronberg 1988a, b; Barnes 1998). Crafts outputs were partly derived from Terry et al. (1994) and Terry (1999).

The Environmental Economics Unit uses a system of empirically based enterprise models, originally developed by Barnes (1998), and subject to ongoing development, to measure the financial and economic values associated with natural resource use. These are detailed budget and cost-benefit analyses that measure returns to investors as well as the national economy. Such models have been developed for wildlife use activities such as non-consumptive wildlife viewing through lodges and campsites on private and public land, trophy hunting on private and public land, intensive ostrich breeding and rearing, intensive crocodile breeding and rearing, taxidermy and craft production.

For the monetary flow account, such enterprise models were used to calculate the direct contributions of wildlife uses in terms of *value added* to the GNP. *Value added* is defined as the return to the internal factors of production in the activity, namely, capital, labour and entrepreneurship. The value added is calculated in the models as a residual by subtracting intermediate expenditures from the gross output or total revenue. Value added/output ratios were then applied in the flow account to determine the *direct economic contribution* of wildlife use activities. Where specific representative models were not available, for example, for commercial, small-scale meat production and live game production, then ratios from other related enterprises were used. Ratios for some wildlife uses such as small-scale hunting for meat production, crafts production, ostrich production and crocodile production were also gleaned from models developed in Botswana (FGU-Kronberg 1988a, b; Barnes 1998; Terry 1999). Table 2 shows the ratios applied.

The direct economic contribution creates further demand in the broader economy through indirect multiplier and linkage effects. This represents the *total economic contribution* or impact of wildlife use in the economy. For example, the use of transport services in commercial game cropping would indirectly involve further value added being generated in the transport sector, or the purchase of food for a tourism lodge would indirectly involve further value added being generated in the food sector. The flow account included a measure of this total impact. To measure the total economic contribution, an income or value-added multiplier was used, derived from the national social accounting matrix (SAM) model of the Namibian economy (Lange et al. 2004). An overall income multiplier of 1.86 for the wildlife sector, following that derived by Turpie et al. (2004), was used. This means that for every N$1.00 contributed directly to the GNP through wildlife use, a further N$0.86 is contributed indirectly as a result.

Table 2 Ratios used to calculate the value added directly to gross national product and the generated resource rent in the wildlife accounts of Namibia in 2004

	Percentage of gross output	
Wildlife use	Gross national product (%)	Resource rent (%)
Wildlife viewing	47	28
Hunting tourism	47	27
Live game	47	27
Commercial meat	47	27
Small-scale meat	47	27
Ostrich farming	50	11
Crocodile farming	51	25
Guano harvesting	45	27
Meat processing	48	21
Taxidermy	48	33
Crafts production	67	16

For the monetary asset account, the financial and economic models were used to calculate the *resource rents* generated in wildlife use activities. These economic rents are calculated as a residual – by subtracting costs of production, including the compensation of employees, the consumption of fixed capital and normal profit from the gross output. Normal profit was assumed to be a 15% return on initial fixed capital. The rent calculations were used in valuing the assets, using the net present value method, described above. The portion of natural wildlife assets that was not likely to be used economically in the next 30 years was given a zero value in the monetary asset account.

One exception to the use of the net present value method was in the case of semi-domesticated ostrich, which are recorded in the Ministry of Agriculture, Water and Forestry's annual livestock census and are effectively owned. They were valued by multiplying number by price – the conventional way that livestock assets are valued.

After determination of the asset values of wildlife in the five utilisation zones, an attempt was made to allocate these values according to the species in the asset account. To do this, a relative, blend price per head for each species was calculated by averaging the per head live game auction value, a basic meat value and a hunting trophy value. The auction prices were obtained from published local and South African auction prices adjusted to 2004 values. The basic meat price was obtained using species body mass and a 2004 Meat Board low-grade livestock meat price. Hunting trophy prices for 2004 were obtained from hunting outfitter brochures and the Namibian Professional Hunters Association (NAPHA).

The blend price for each species was multiplied by the numbers of animals of each species in each use zone, to get relative values, which were then used to proportionally allocate the asset values by species and by zone.

3 Wildlife Utilisation in Namibia

3.1 Current Use of Wildlife Resources

The direct use values derived from the use of Namibia's wildlife resources come from diverse activities embracing several sectors of the economy. Wildlife viewing is one of the major products of leisure tourism activities on protected, private and communal land. It involves the broad spectrum of wildlife in its ecological setting but is driven by keystone large mammals. Consumptive use of wildlife takes place through trophy hunting tourism on private land, mainly involving plains game, and on communal and protected land, mainly involving high-value key species. Fee hunting, or biltong hunting tourism, of plains game takes place on private land. Wildlife, involving mainly large mammals, is captured live and dispersed via sale, mainly from private land and protected areas. Commercial cropping of more common plains game species, mainly springbok, is practised under permit on certain private properties for venison production. On most private land and some communal land, more common plains game species are hunted, at small-scale for own consumption and sale (known as the 'shoot-and-sell' system). Commercial cropping of Cape fur seals takes place under permit at selected coastal rookeries (Barnes and Alberts 2007). Intensive production systems involving breeding and rearing have been developed for ostrich and to a lesser extent crocodile. On the coast, guano, deposited by piscivorous sea birds, is harvested from islands and artificial platforms (Barnes and Alberts 2007).

Some processing of wildlife products takes place including taxidermy for hunted trophies, biltong manufacture, meat processing for export and crafts manufacture using wildlife products such as ostrich eggs and skins. These are considered as part of the marketing process, contributing to the economic rent generated by wildlife use, so they are included in the wildlife accounts. Further forward linkages, such as leather goods manufacture and retail of game meat products, are conserved separate from the use activities and excluded. Also excluded from the wildlife resource accounts are marine and freshwater fisheries, treated separately in the fish resource accounts (Lange 2004), and the use of invertebrates such as mopane worms and termites, treated as part of non-timber forest products in the forest resource accounts (Barnes et al. 2005).

3.2 Wildlife Utilisation Zones

In protected areas, policy dictates that use is dominated by non-consumptive tourism. Consumptive use through trophy hunting is limited to parts of a few protected areas. Live game capture and sale tend to be limited to protected areas south of the redline veterinary cordon fence, except in the case of certain species which are not vectors of foot-and-mouth disease. In communal land conservancies, policy allows the full range of wildlife uses, but in practice, the potential, lack of appropriate infrastructure, distances from markets and disease constraints (behind the veterinary redline) dictate that use is dominated by non-consumptive tourism, some trophy hunting and some small-scale hunting. In private land, which is south of the veterinary redline, better furnished with infrastructure, skills and capital; generally closer to markets; and the beneficiary of considerable private investment in wildlife stocks, all the wildlife uses described above are possible.

The wildlife stocks were divided according to their distribution in five wildlife utilisation zones, based on the current and likely future combinations of uses possible. The zones are the following:

Zone 1: Protected areas north of the veterinary redline, where wildlife use is limited to non-consumptive tourism, very limited trophy hunting tourism and limited live game.
Zone 2: Protected areas south of the veterinary redline, where, except for seal culling on the coast, wildlife use is limited to non-consumptive tourism and live game.
Zone 3: Communal land north of the veterinary redline, where wildlife use involves non-consumptive tourism, trophy hunting tourism and small-scale meat hunting.
Zone 4: Communal land south of the veterinary redline, where wildlife use involves non-consumptive tourism, trophy hunting tourism, live game and small-scale meat hunting.
Zone 5: Private land, wildlife use involves non-consumptive tourism, trophy hunting tourism, live game, commercial cropping and small-scale meat hunting.

The parts of the country in each zone are described in Table 3. Values for current and future wildlife use and asset value were estimated for each zone separately. The wildlife use zones do not coincide with regional boundaries.

Consolidated data on stock numbers for the whole country are only available for 2004, and the wildlife resource accounts are those of 2004. Asset accounts should normally include consideration of depletion, degradation, conversion and accumulation of stocks during the accounting year, so that changes in volume and value of stocks can then be accounted for over time. Closing stock or any additional numbers are not available at this time. Generally, while wildlife stocks are tending to increase in the country, their use is also increasing (Barnes and Jones 2009). Compared to sectors such as fisheries and forestry, the wildlife sector has relatively well-developed property rights through rights of management and use furnished on private land (Barnes and Jones 2009), communal conservancies (NACSO 2008) and in concessions (MET 2007). As a result, little current wildlife use is considered to be unsustainable, and potential is greater than current use levels. Changes in wildlife stocks appear to be the result of wet and dry climatic cycles, droughts and investment resulting from the above-mentioned property rights.

Table 3 Descriptive components of Namibian wildlife use zones

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5[a]
Bwabwata national park	Ai-Ais hot springs	Anabeb conservancy	!Khob !Naub conservancy	Bethanie district
Etendeka concession	Cape cross seal reserve	Ehirovapuka conservancy	≠Gaingu conservancy	Gobabis district
Etosha national park	Daan Viljoen game park	Joseph Mbambangandu conservancy	//Huab conservancy	Grootfontein district
Hobatere concession	Gross Barmen hot springs	kwandu conservancy	Doro !Nawas conservancy	Karasburg district
Khaudum game park	Hardap recreation resort	Marienfluss conservancy	Gamaseb conservancy	Karibib district
Mamili national park	Hobotere concession	Mashi conservancy	≠Khoadi-//Hoas conservancy	Keetmanshoop district
Mangetti game reserve	Namib-Naukluft park	Mayuni conservancy	Oskop conservancy	Lüderitz district
Mudumu national park	National west coast recreation area	N#a-Jaqna conservancy	otjimboyo conservancy	Maltahöhe district
Palmwag concession	Naute recreation resort	Nyae Nyae conservancy	Sorri-Sorris conservancy	Mariental district
Skeleton Coast Park	Von bach recreation resort	Okangundumba conservancy	Torra conservancy	Okahandja district
	Sperrgebiet National Park	Omatendeka Conservancy	Tsiseb Conservancy	Omaruru District
	Waterberg plateau park	Orupembe conservancy	Uibasen conservancy	Otjiwarongo district
		Ozondundu conservancy		Outjo district
		Puros conservancy		Rehoboth district
		Salambala conservancy		Tsumeb district
		Sanitatas conservancy		Windhoek district
		Sesfontein conservancy		
		Uukwaluudhi conservancy		

[a]Embraces only private land within the districts listed

3.3 Potential Use of Wildlife Resources

Valuation of the wildlife assets requires estimation of the expected flows of resource rent from the resource in the future. Predictions of the future growth in all forms of wildlife use need to be made. Clearly, this growth cannot take place beyond the ultimate potential of the resource to sustain utilisation into the future.

Depending on the wildlife product itself, only part of the total stock can be used at any one time. This is for several reasons. First, some uses, such as game meat production in protected areas, are prohibited through policy. Second, for most uses, only some animals are suitable for harvest, for example, those animals in the population of trophy quality or those adult animals in the population of suitable size for slaughter. Third, annual harvest of the products in question must be limited to the annual sustainable yield or less for those products. Fourth, some stocks cannot be viably exploited from an economic point of view, as they are too remote from human settlement and appropriate infrastructure, or have restricted markets for their products.

Current combinations of use are likely to change in future depending on relative returns to investment. The assumption is that combinations will emerge that maximise returns for land holders while spreading risk within the constraints of resources and markets. We used the relative return to investment as a guide but also drew from a study in Botswana, where the most rewarding combinations of wildlife uses were determined using linear programming (Barnes 1998, 2001).

Sustainable (maximum permissible) general off-take rates for each species were calculated as half of the inherent rate of increase for each species, the inherent rate being a function of the average weight of animals of the species population. The trophy off-takes are estimated at around 5% of the general off-take rates for each species. This follows the approach of Caughley (1983), Craig and Lawson (1990) and FGU-Kronberg (1987).

Maximum limits to use of wildlife populations in wildlife utilisation zones were assumed to be as follows:

Zone 1: Tourism, making use of 89.84% of the wildlife population; trophy hunting, making use of a maximum of 1.05% of the population; and quarantined live game production, making use of 4.55% of the population

Zone 2: Tourism, making use of 89.84% of the wildlife population; trophy hunting, making use of a maximum of 1.05% of the population; and live game production, making use of 9.11% of the population

Zone 3: Tourism, making use of 89.84% of the wildlife population; trophy hunting, making use of 1.05% of the population; quarantined live game production, making use of 4.55% of the population; and small-scale meat production, making use of 4.55% of the population

Zone 4: Tourism, making use of 89.84% of the wildlife population; trophy hunting, making use of 1.05% of the population; live game production, making use of 4.55% of the population; and small-scale meat production, making use of 4.55% of the population

Zone 5: Tourism, making use of 89.84% of the wildlife population; trophy hunting, making use of 1.05% of the population; quarantined live game production, making use of 4.55% of the population; and small-scale and commercial meat production and biltong hunting tourism, together making use of up to 4.55% of the population. Additional intensive ostrich production, unlimited except by feed constraints

Predicted expansion of wildlife use over the next 30 years was within these maximum limits. Non-consumptive wildlife-viewing tourism was assumed to continue growing at 6.9% per annum following WTTC (2006) and NTB (2008). An analysis of concession policy implementation in the context of protected area plans was made, which suggested that after 20 years, the wildlife tourism sector will stop growing as spatial and tourism carrying capacity limits are reached inside and outside of parks. The trophy hunting tourism sector was assumed to grow at a slower rate, 5% per annum, also until year 20 when it would stop growing. Growth rates in the live game, small-scale meat and commercial meat production uses were assumed to be 2.8%, through to year 30, based on analysis of past growth (Unpublished permit records from the MET; Erb 2003). Intensive ostrich production, crocodile production, seal cropping and guano production were assumed to have no further growth, as all these are considered to feed or market constraints.

4 Wildlife Accounts, 2004

4.1 Physical Wildlife Asset Account

The wildlife communities in the drier parts of the country, the desert, shrublands and savannas, are dominated by desert-adapted species such as springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), kudu (*Tragelaphus strepsiceros*), warthog (*Phacochoerus aethiopicus*), red hartebeest (*Alcelaphus buselaphus*), ostrich (*Struthio camelus*), steenbok (*Raphicerus campestris*) and duiker (*Sylvicapra grimmia*), with less widespread mountain zebra (*Equus zebra hartmannae*), eland (*Taurotragus oryx*), plains zebra (*Equus burchelli*), blue wildebeest (*Connochaetes taurinus*), giraffe (*Giraffa camelopardalis*), elephant (*Loxodonta africana*), black-faced impala (*Aepyceros melampus petersi*), black rhino (*Diceros bicornis*), klipspringer (*Oreotragus oreotragus*) and dik-dik (*Madoqua kirkii*) also occurring. Introduced to some savanna localities are species not characteristic of arid areas, such as common impala (*Aepyceros melampus*), waterbuck (*Kobus ellipsiprymnus*), sable (*Hippotragus niger*), roan (*Hippotragus equinus*), lechwe (*Kobus leche*), tsessebe (*Damaliscus lunatus*) and white rhino (*Ceratotherium simum*). Some introduced species alien to Namibia, such as blesbok (*Damaliscus dorcas*), black wildebeest (*Connochaetes gnou*) and others, also occur. Semi-domesticated ostrich flocks are also maintained on private land.

In the better watered parts of the country, the woodlands and associated riparian environments of the northeast, wildlife species representative of the central African plateau occur, including buffalo (*Syncerus caffer*), elephant, hippo

Table 4 Physical wildlife asset account, 2004: estimated wildlife stock numbers in Namibia[a]

	Wildlife utilisation zone					
Species	1	2	3	4	5	Total
Buffalo	1,025	250	90	0	0	1,365
Cheetah	706	149	405	270	2,970	4,500
Eland	1,704	524	245	0	34,743	37,216
Elephant	9,043	24	735	155	0	9,957
Gemsbok	11,450	3,115	18,670	5,084	350,092	388,411
Giraffe	3,683	229	666	68	5,769	10,415
Hartebeest, red	1,468	115	700	0	122,805	125,088
Hippopotamus	1,262	0	300	0	0	1,562
Impala, black-faced	1,500	0	0	0	1,870	3,370
Impala, common	77	0	385	0	14,980	15,442
Kudu	2,063	1,484	1,545	1,000	345,801	351,893
Lechwe	0	0	250	0	284	534
Leopard	1,970	430	960	640	4,000	8,000
Lion	574	23	109	22	0	728
Ostrich	3,947	530	2,840	2,020	36,336	45,673
Rhino, black	816	43	45	75	134	1,113
Rhino, white	54	62	0	0	75	191
Roan	440	120	95	0	435	1,090
Sable	256	60	15	0	902	1,233
Springbok	33,811	1,771	37,150	37,270	621,561	731,563
Tsessebe	0	15	0	0	162	177
Warthog	148	61	40	0	173,866	174,115
Waterbuck	0	0	0	0	4,475	4,475
Wildebeest, blue	4,975	224	470	0	16,623	22,292
Zebra, plains	18,098	0	20	0	7,303	25,421
Zebra, mountain	8,564	4,347	2,130	2,175	55,520	72,736
Total	107,634	13,576	67,865	48,779	1,800,706	2,038,560

[a] Excludes an additional 22,000 semi-domesticated ostrich, used in intensive production in zone 5, and some 800,000 Cape fur seals used for skins and other products mostly in zone 2.

(*Hippopotamus amphibius*), kudu, common impala, sable, roan, lechwe, tsessebe, reedbuck (*Redunca arundinum*), duiker, bushbuck (*Tragelaphus scriptus*) and sitatunga (*Tragelaphus spekei*).

Larger predators occurring widely in the country are leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), brown hyaena (*Hyaena brunnea*) and spotted hyaena (*Crocuta crocuta*), while more localised populations of lion (*Panthera leo*) and wild dog (*Lycaon pictus*) also occur. In perennial rivers of the northeast and northwest, crocodile (*Crocodylus niloticus*) are present. On the coast, a large population of the piscivorous marine mammal, the Cape fur seal (*Arctocephalus pusillus*), occurs.

Table 4 shows the physical wildlife assets for 2004. Not all the species listed above are recorded in the table, due to their being too inconspicuous, too localised or too uncommon and thus overlooked in surveys. It is noteworthy that the list of species, including as it does only the more economically important larger mammals and ostrich, is representative of a broader wildlife resource.

It is clear that by far, the majority of the wildlife numbers (88%) is present on private land, zone 5. This is the result of the private incentives, capital and skills long prevalent in the zone which permitted significant investment in the wildlife resource.

4.2 Wildlife Flow Account

Table 5 shows the estimated value of Namibia's use of wildlife resources in 2004. This is given as the gross output (the aggregate turnover of all wildlife use activities), the direct contribution of wildlife use to GN, and the total of the direct and indirect contributions that the use of wildlife made to GNP. The indirect contribution incorporated the backward linkage (multiplier) effects in the broader economy. Total output in the wildlife use sector was N$1.5 billion. This sector contributed N$700 million of direct value added to the GNP, and the total direct and indirect impact on the GNP amounted to N$1.3 billion.

The most significant component of wildlife use was non-consumptive wildlife-viewing tourism, which generated some 62% of the total direct sector GNP contribution. Hunting tourism contributed 19% of the total direct sector GNP contribution. Of this hunting tourism contribution, trophy hunting made up 97% and biltong hunting made up only 3%. Live game production contributed 10% of the total sector GNP. Other use activities which were somewhat important were meat production (mostly small scale, under the 'shoot-and-sell' system on private land), intensive ostrich production and taxidermy (which adds value in particular to the hunting tourism activities). None of these other uses contributed more than 3% of the total direst sector contribution.

The total direct value-added contribution of the wildlife use sector of N$700 million represented approximately 2.1% of GNP. This proportion can be compared with the estimated direct contributions made by other sectors (CBS/Central Bureau of Statistics 2004): 4.6% for agriculture, 5% for fishing (which includes some on-board fish processing), 6.8% for mining and 3.4% for tourism (WTTC 2006). Much of the contribution of the wildlife use sector is part of the tourism sector contribution, and some of it is part of the agriculture contribution.

4.3 Monetary Wildlife Asset Account

The net present value method of valuing natural assets requires estimates of current and future resource rents generated by use of the resource. Table 6 shows the estimated rents generated by wildlife use and by zone. The rent generated in the sector amounts to an estimated N$403 million.

Table 5 Wildlife flow account, 2004: estimated gross output and direct and total contributions to gross national product made by wildlife utilisation in Namibia

	Wildlife utilisation zone					
Wildlife use	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Gross output in wildlife use sector (N$'000, 2004)						
Gross output	268,473	76,929	80,093	29,877	1,019,517	1,474,889
Direct contribution to gross national product (GNP)[a] by utilisation zone (N$'000, 2004)						
Wildlife viewing	107,497	12,366	7,361	4,089	302,976	434,289
Hunting tourism	1,754	0	26,312	7,017	99,368	134,451
Live game	17,511	17,511	0	0	35,023	70,045
Commercial meat[b]	0	2,836	0	0	1,529	4,365
Small-scale meat	0	0	484	0	15,641	16,125
Ostrich farming	0	0	0	31	11,186	11,217
Crocodile farming	0	0	0	0	1,955	1,955
Guano harvesting	0	3,400	0	0	0	3,400
Meat processing	0	0	48	3	3,031	3,083
Taxidermy	133	0	2,024	532	9,445	12,133
Crafts production	0	0	2,148	3,436	3,007	8,591
Total	126,895	36,113	38,377	15,108	483,159	699,653
Total (both direct and indirect) contribution to GNP[c] (N$'000, 2004)						
Total impact	236,025	67,170	71,382	28,101	898,676	1,301,354

[a]Direct contribution of the wildlife use industry to the economy, in terms of value added to GNP

[b]Includes seal culling on coast (zone 2) and game culling on private land (zone 5)

[c]Total direct contribution to, and indirect impact on, the economy, in terms of value added to GNP, measured using a social accounting matrix of the Namibian economy (Lange et al. 2004)

Table 6 Estimated resource rent[a] generated in wildlife use activities in Namibia in 2004 (N$'000)

	Wildlife utilisation zone					
Wildlife use	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Wildlife viewing	63,580	7,314	4,354	2,419	179,198	256,865
Hunting tourism	1,008	0	15,116	4,031	57,084	77,238
Live game	10,060	10,060	0	0	20,119	40,239
Commercial meat	0	1,629	0	0	878	2,507
Small-scale meat	0	0	278	0	8,985	9,263
Ostrich farming	0	0	0	6	2,358	2,365
Crocodile farming	0	0	0	0	970	970
Guano harvesting	0	2,025	0	0	0	2,025
Meat processing	0	0	28	1	1,319	1,348
Taxidermy	90	0	1,374	361	6,410	8,234
Crafts production	0	0	513	821	718	2,052
Total resource rent	74,738	21,028	21,662	7,638	278,041	403,106

[a] Resource rent or economic rent or excess profit = gross output less costs of production, including a reasonable return on capital

The ratios, determined from wildlife use enterprise models and used to calculate rent as a proportion of gross output (shown in Table 2), are between 11% and 33%. These are significantly lower than the ratios, determined by Barnes et al. (2005), from models of forest use enterprises, which were between 40% and 84%. This is surprising at first glance, as forest use tends to take place on public land under open access, where rents should get dissipated, and wildlife use is characterised by better property rights, where rents should be maintained. However, forest use is commonly small scale with no resource investments, and use levels remain generally very low, compared with potential. In such circumstances, rents might remain high until the resource starts to be fully utilised. Wildlife users, on the other hand, are generally required to invest significantly in the resource and may face product markets that are more mature and competitive. Here, rents should tend to be smaller.

Natural resource accounts provide the opportunity to measure the extent to which resource rents are captured for redistribution and investment in the economy. As shown above, rents in the wildlife sector are not particularly high, but enterprise models to hand indicate that rent capture is fairly efficient. Well-developed property rights on communal and private land, the concessions policy in protected areas and appropriate tender process appear to be ensuring that landholders (government communities and farmers) capture available resource rent.

Table 7 shows the resource rent generated in 2004 as well as that that can be expected to be generated after 30 years, in 2034. The predicted growth in wildlife use and the changes in combinations of uses, according to the criteria and assumptions made above, will result in approximately three times more use by 2034. At this stage, much of the physical potential for expansion, mainly for tourism, will be used, and further increases in value will tend to be as a result of intensification.

Table 7 shows the value of Namibia's wildlife assets in 2004, estimated in terms of the resource rent that could be generated from them during the next 30 years,

Table 7 Monetary wildlife asset account, Namibia, 2004: estimated rent generated, asset value[a] and the effect on asset value of different discount rates

Value	Wildlife utilisation zone					Total
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	
Current and anticipated resource rent generated in the wildlife sector (N$'000, 2004)						
Rent in year 2004	74,738	21,028	21,662	7,638	278,041	403,106
Rent in year 2034	251,135	52,110	59,641	22,614	872,908	1,258,409
Wildlife asset value @ 6% discount (N$'000, 2004)						
Asset value @ 6%	2,034,485	448,913	525,427	194,136	7,249,271	10,452,232
Sensitivity to discount rate						
Asset value @ 2%	3,762,557	803,778	952,839	354,695	13,319,180	19,193,050
Asset value @ 4%	2,724,232	591,140	696,622	258,367	9,674,644	13,945,004
Asset value @ 6%	2,034,485	448,913	525,427	194,136	7,249,271	10,452,232
Asset value @ 8%	1,564,705	351,246	408,090	150,211	5,594,091	8,068,343
Asset value @ 10%	1,236,748	282,418	325,622	119,415	4,436,107	6,400,310

[a] Net present value of future rents generated in expected growth over the next 30 years

Table 8 Monetary wildlife asset account, 2004: estimated asset values for wildlife in Namibia by species

Species	Wildlife utilisation zone Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Asset value by species @ 6% discount (N$'000, 2004)						
Buffalo	61,604	29,839	3,192	0	0	94,634
Cheetah	15,658	6,548	5,298	1,921	21,320	50,744
Eland	28,780	17,576	2,442	0	190,008	238,806
Elephant	462,409	2,437	22,178	2,543	0	489,568
Gemsbok	143,634	77,601	138,203	20,466	1,422,036	1,801,940
Giraffe	70,542	8,710	7,527	418	35,779	122,977
Hartebeest, red	18,460	2,872	5,194	0	500,026	526,552
Hippo	33,803	0	4,742	0	0	38,544
Impala, black-faced	26,995	0	0	0	10,897	37,892
Impala, common	919	0	2,712	0	57,893	61,523
Kudu	26,775	38,249	11,833	4,165	1,453,220	1,534,242
Lechwe	0	0	2,821	0	1,759	4,580
Leopard	48,004	20,808	13,804	5,005	31,561	119,182
Lion	18,685	1,482	2,098	228	0	22,493
Ostrich	45,582	12,155	19,354	7,486	135,877	220,454
Rhino, black	144,913	15,165	4,716	4,274	7,705	176,774
Rhino, white	3,992	9,103	0	0	1,795	14,891
Roan	34,265	18,558	4,366	0	10,969	68,158
Sable	13,805	6,426	477	0	15,750	36,458
Springbok	386,924	40,248	250,870	136,870	2,303,185	3,118,097
Tsessebe	0	605	0	0	1,065	1,670
Warthog	1,682	1,376	268	0	639,645	642,971
Waterbuck	0	0	0	0	25,694	25,694
Wildebeest, blue	68,151	6,094	3,799	0	73,734	151,777
Zebra, plains	246,904	0	161	0	32,261	279,326
Zebra, mountain	132,000	133,060	19,373	10,758	277,093	572,285
Total value @ 6%	2,034,485	448,913	525,427	194,136	7,249,271	10,452,232

using the net present value method. The wildlife assets in Namibia in 2004 were estimated to be worth N$10.5 billion. The basic model used for net present values necessarily contains a prediction on the future discount rate, about which there is some uncertainty. To test the sensitivity of values to the future discount rate, several options for the rate were tested. If discount rates between 2 and 10% are used, the total wildlife asset value varies between N$19 and N$6 billion. We consider a future real discount rate of 6% as the most likely, and so the total value of the wildlife asset base is taken as N$10.5 billion.

Table 8 shows the asset values, calculated at 6% discount, for the wildlife resource in 2004, allocated by species and by use zone. As described above, the allocation is based on the relative value of each species as measured by a live animal, meat and trophy blend price. It is interesting to note that zone 5, which contained 88% of the total wildlife stock numbers in Table 4, only contained 69% of the total wildlife asset

Table 9 Comparative estimates of asset value for some Namibian natural resources and the manufactured capital stock in 2004

Resource	Asset value (N$ million)
Wildlife	10,500
Fish[a]	12,000
Minerals[b]	14,300
Forests[c]	18,700
Manufactured capital[d]	82,000
Total national wealth[e]	137,500

[a] Derived from Lange (2004)
[b] Derived from Lange and Hassan (2003)
[c] Derived from Barnes et al. (2005)
[d] Fixed capital stock; derived from the national accounts (CBS 2004); includes tangible, produced assets
[e] Partial estimate only; excludes, for example, some asset values for land, water and tourism

value. The asset value per head in zone 5 on private land was N$4.03, while in the other four zones on protected and communal land, the asset value per head was N$13.47.

This can be explained by the fact that the wildlife stocks in zone 5 are largely made up of plains game with only moderate value. Key high-value key species such as elephant, buffalo, lion and rhino are few on private land and more concentrated in the protected areas and communal conservancies. Novelli et al. (2006) illustrated this point when comparing hunting values for Namibia (mostly in zone 5) and Botswana. Private land in Namibia, being drier, tended to lack key species in any case, but it was also developed primarily for livestock, making introduction or reintroduction of key species very difficult.

Table 9 shows a comparison between our 2004 wildlife asset values and the estimates made for some other Namibian natural resources. Asset accounts for Namibia's marine fish stocks (Lange 2004) show an estimated value of N$12 billion in 2001 (converted to 2004 prices). The value of mineral assets in Namibia has also been estimated (Lange and Hassan 2003), namely, N$14 billion in 2001 (also converted to 2004 prices). The value of Namibia's forest assets, as estimated for 2004 by Barnes et al. (2005), was N$19 billion. Our estimate of the value of wildlife assets, at N$10.5 billion, is lower than any of these but comparable and significant. The fact that resource rent as proportion of output appears to be relatively low for wildlife uses may account for the lower asset values involved.

5 Conclusion

The completion of a national wildlife inventory in 2004 enabled the development of a set of wildlife accounts for Namibia. For the purposes of the accounts, wildlife was defined as all wild animals except fish and forest-dwelling invertebrates.

The physical accounts included the larger mammals and ostrich. Five wildlife use zones were identified, corresponding to conditions of differing land tenure and veterinary status. Each wildlife use zone was characterised by having different combinations of use and possible use.

The wildlife accounts conform to the internationally recognised IEEA methodology and include flow accounts detailing the contribution made by the use of the resource to the national economy and asset accounts detailing the capital asset value of the resource stocks.

Some 2.04 million larger wild animals made up the physical wildlife asset account, and 88% of these were on private land. This likely reflects the fact that property rights for use and management of wildlife were bestowed on private landholders some 40 years ago. Skills, appropriate infrastructure and proximity to markets resulted in significant investment in wildlife resource on private land. Another contributing reason is that a very large part of the protected area system is desert with little potential for wildlife.

The wildlife assets are responsible for gross output of some N$1.5 billion. All wildlife uses contribute N$ 700 million directly to the gross national product (GNP). The most significant component of wildlife use was non-consumptive wildlife-viewing tourism which generated some 62% of the total wildlife sector GNP contribution. Hunting tourism contributed some 19%, and live game production contributed some 10%. Other wildlife use activities contributing between 2 and 3% of the total sector GNP were meat production, intensive ostrich farming and taxidermy.

The total direct value-added contribution of the wildlife use sector of N$700 million represented approximately 2.1% of GNP. This proportion can be compared with 4.6% for agriculture, 5% for fishing (which includes some on-board fish processing), 6.8% for mining and 3.4% for the whole tourism sector. Much of the GNP contribution of wildlife is part of this tourism sector contribution, and some of it is part of the agriculture contribution. The *total* impact of wildlife use on the broader economy is greater than the direct contribution. Inclusion of the indirect impacts resulting from the income multiplier (a further N$600 million) makes the total impact some N$1.3 billion.

Resource rents generated in the wildlife sector are fairly low, possibly due to the fact that wildlife users commonly have to pay for much of the investment in the resource. Capture of wildlife resource rents by landholders appears to be relatively efficient, due to tenure conditions and appropriate tender process.

Barnes and Jones (2009) showed that, on private land between 1970 and 2000, the main game species numbers increased by some 100%, while livestock numbers decreased by some 45%. Mendelsohn et al. (2006) confirmed that wildlife use is increasing relative to livestock production. Our predicted growth in wildlife use values over the next 30 years will likely triple the economic contribution of the sector and bring it close to its full spatial potential. Further increases in direct use value from wildlife will likely occur through intensification.

Namibia's standing wildlife assets (the natural capital stock) were estimated to have a value of N$10.5 billion in 2004. Wildlife stocks represent a significant national asset, comparable with those for fish, minerals and forests. Wildlife, fish, mineral and forest stocks – as well as several other natural resources – are not included in the national account for manufactured capital stock, which was valued at some N$86 billion in 2004, and incorporated only owned or produced assets.

Asset values were calculated for all the species in the physical asset account. Private land, which contained 88% of the total wildlife stock numbers, only contained 69% of the total wildlife asset value. The asset value per head of wildlife on protected and communal land was three times higher than that on private land. Although there has been a lot of investment in wildlife on private land, this has mostly involved plains game and not high-value key species.

Some policy implications have arisen from the findings in this study:

The development of the wildlife sector should continue to place emphasis on tourism activities, both consumptive and non-consumptive.

Appropriate property rights, notably through the concessions policy and the community-based natural resource management (CBNRM) programme, should continue to be an important element of policy.

Investments in building up stocks of wildlife in the communal lands, particularly as driven through the CBNRM programme, should continue to be encouraged and facilitated.

As wildlife use through tourism becomes more established on private land, introductions of high-value key wildlife species should be permitted and facilitated.

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References

Barnes JI (1998) Wildlife economics: a study of direct use values in Botswana's wildlife sector. PhD thesis, University College, University of London

Barnes JI (2001) Economic returns and allocation of resources in the wildlife sector of Botswana. South Afr J Wildl Res 31:141–153

Barnes JI, Alberts M (2007) Sustainable tourism options for the coastal zone of Namibia and refinement of available data on coastal natural resource use practices. Namibian Coast Conservation and Management (NACOMA) Project, Ministry of Environment and Tourism, Windhoek

Barnes J, Jones B (2009) Game ranching in Namibia. In: Suich H, Child B, Spenceley A (eds) Evolution and innovation in wildlife conservation: from parks and game ranches to transfrontier conservation areas. Earthscan, London

Barnes JI, Nhuleipo O, Muteyauli, PI, MacGregor J (2005) Preliminary economic asset and flow accounts for forest resources in Namibia. DEA Research Discussion Paper, no 70, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek

Caughley G (1983) Dynamics of large mammals and their relevance to culling, Owen-Smith RN Management of large mammals in African conservation areas. Haum Educational Publishers, Pretoria

CBS/Central Bureau of Statistics (2004) Republic of Namibia national accounts: 1995–2003. National Planning Commission, Windhoek

CEC, IMF, OECD, UN, WB (1993) System on national accounts 1993 (SNA93). CEC, Brussels; IMF, NewYork; Eurostat, Luxembourg; OECD, Paris; UN, NewYork; WB, Washington, DC

Craig C, Lawson D (1990) Quota setting methods for cropping and trophy hunting of wildlife species in Botswana. Department of Wildlife and National Parks, Gaborone, Unpublished Paper

Erb KP (2003) Consumptive wildlife utilization as a land use form in Namibia. MBA thesis, Graduate School of Business, University of Stellenbosch, Cape Town

FGU-Kronberg (1987) Review of the aerial monitoring programme of the department of wildlife and national parks. Ministry of Commerce and Industry, Gaborone

FGU-Kronberg (1988a) Review of wildlife utilisation in Botswana and proposals for the development of projects and programmes in this field. Ministry of Commerce and Industry, Gaborone

FGU-Kronberg (1988b) Wildlife industry support in Botswana in the context of selected production economics studies. Ministry of Commerce and Industry, Gaborone

Humavindu MN, Barnes JI (2003) Trophy hunting in the Namibian economy: an assessment. South Afr J Wildl Res 33(2):65–70

Lange G-M (2004) Economic value of fish stocks and the national wealth of Namibia. In: Sumaila UR, Steinshamn SI, Skogen MD, Boyer D (eds) Ecological, economic and social aspects of Namibian fisheries. Eburon Academic Publishers, Delft

Lange G, Schade K, Ashipala J, Haimbodi N (2004) A social accounting matrix for Namibia 2002: A tool for analyzing economic growth, income distribution and poverty. Namibia Economic Policy Research Unit working paper 97 (NEPRU), Windhoek

Lange G-M, Hassan R (2003) Mineral accounts: managing an exhaustible resource. In: Lange G-M, Hassan R, Hamilton K (eds) Environmental accounting in action: case studies from southern Africa. Edward Elgar Publishing, Cheltenham

Mendelsohn J, Jarvis A, Roberts C, Robertson T (2002) Atlas of Namibia: a portrait of the land and its people. David Philip Publishers, Cape Town

Mendelsohn J, el Obeid S, de Klerk N, Vigne P (2006) Farming systems in Namibia. Namibia National Farmers Union (NNFU), Windhoek

MET/Ministry of Environment and Tourism (2007) Policy on tourism and wildlife concessions on state land. Ministry of Environment and Tourism, Windhoek

Novelli M, Barnes JI, Humavindu M (2006) The other side of the tourism coin: consumptive tourism in Namibia. J Ecotour 5:62–79

NTB/Namibia Tourism Board (2008) Namibia tourism satellite account, 2nd edn. Namibia Tourism Board, Windhoek

SIAPAC/Social Impact Assessment and Policy Analysis Corporation (2007) Study on characteristics of demand of tourists and use patterns of protected areas in Namibia. Ministry of Environment and Tourism, Windhoek

Terry ME (1999) The economic and social significance of the handicraft industry in Botswana. PhD thesis, School of Oriental and African Studies, University of London

Terry ME, Lee, FJ, le Roux K (1994) A survey of natural resource-based craft production and marketing in Namibia. World Wildlife Fund (US) Living in a Finite Environment Programme (WWF LIFE Programme) and Rossing Foundation, Windhoek

Turpie J, Lange G-M, Martin R, Davies R, Barnes J (2004) Economic value and financing of Namibia's protected areas. Ministry of Environment and Tourism, Windhoek

UN, EC, IMF, OECD, WB (2003) Integrated environmental and economic accounting, final draft. Studies in methods series F, no 61. Statistics Division, Department of Economic and Social Affairs, UN, New York/; EC, Brussels/; IMF, Washington, DC/; OECD, Paris/; WB, Washington, DC

UN (2000) Integrated environmental and economic accounting: an operational manual. Studies in methods series F, no 78. Statistics Division, United Nations Department of Economic and Social Affairs, United Nations, New York

WTTC/World Travel and Tourism Council (2006) Namibia: the impact of travel and tourism on jobs and the economy. Namibia Tourism Board and Ministry of Environment and Tourism, Windhoek

NACSO/Namibia Association of CBNRM Support Organisations (2008) Namibia's communal conservancies: a review of progress and challenges in 2007. Namibian Association of CBNRM Support Organisations (NACSO), Windhoek

Accounting for Mineral Resources in Tanzania: Data Challenges and Implications for Resource Management Policy

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Abstract There is a new line of thinking in development and growth theory demonstrating that sustainable development requires non-declining per capita wealth (Hamilton K, Clemmens M. World Bank Econ Rev 13(2):336–356, 1999; Lange G-M. Environ Res Econ 29:257–283, 2004; Lange G-M. Introducing environmental sustainability into the Uganda system of national accounts. Draft Final Report, ENR Sector Working Group, 2005; World Bank. The International Bank for Reconstruction and Development. The World Bank, Washington, DC, 2006). In this conceptualization, wealth is defined in a very broad sense to include produced, natural and human (including social) capital. The challenge posed by this approach to growth and development is for economies to manage their asset portfolios so as to realize the objectives of sustainability (non-declining per capita wealth). This requires economies to have the ability to monitor total per capita wealth and analyse changes in this indicator (e.g. see Lange G-M. Environ Res Econ 29:257–283, 2004). It is well known that the current System of National Accounts (SNA) does not adequately represent natural (and human) capital stocks, and the consequences of this omission (neglect) have been well documented (e.g. see Hamilton K, Clemmens M. World Bank Econ Rev 13(2):336–356, 1999; Lange G-M. Environ Res Econ 29:257–283, 2004; Lange G-M. Introducing environmental sustainability into the Uganda system of national accounts. Draft Final Report, ENR Sector Working Group, 2005; World Bank. The International Bank for Reconstruction and Development. The World Bank, Washington, DC, 2006). However, there presently

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exists a standardized framework (and methodologies) for constructing environmental accounts, called the System of Integrated Environmental and Economic Accounts, or SEEA (United Nations, Commission of the European Communities, International Monetary Fund, Organisation for Economic Cooperation and Development, and World Bank (2003) Handbook for integrated environmental and economic accounting. United Nations, New York), which extends the asset boundary of the SNA to include all natural resources, recording asset values, depletion and improvements in the stock of natural capital (Lange G-M. Environ Res Econ 29:257–283, 2004). The results from implementing the SEEA could potentially be used to better represent natural assets in the SNA.

Keywords UN SEEA for minerals • Depletable resources • Minerals resource rent • Economic sustainability • Tanzania

1 Introduction

In this chapter, we attempt to measure the value of important subsoil assets of Tanzania as a step towards developing more comprehensive measures of total national wealth. Tanzania is endowed with a rich array of minerals including precious metals (e.g. gold, silver, platinum),[1] non-metallic coloured stones (e.g. tanzanite), base metals (e.g. lead, copper, tin, zinc), fibrous minerals (e.g. asbestos), amorphous materials and mineral fuels (petroleum, natural gas, coal) and a range of industrial rocks and minerals.[2] Although mining and quarrying in Tanzania are not domestically very large (Fig. 1), they play a particularly important role in export earnings. Figure 2 shows that between 1998 and 2005, Tanzania witnessed a dramatic change in the composition of export GDP. While in 1998 traditional export commodities[3] accounted for 61% of the value of exports (with non-traditional commodities[4] accounting for 39%), by 2005, the former accounted for only 21% while the latter accounted for 79%.

Much more important however is the observation that the composition of non-traditional export commodities also changed during the same period. While minerals accounted for only 11% of these in 1998 (with other exports accounting for a mega 73%), by 2005, minerals accounted for 54% while the value of other exports had dropped down to 34% (Fig. 3). This clearly manifests the growing importance of minerals in the export revenues of Tanzania.

[1] Tanzania is the third largest producer of gold in Africa after South Africa and Ghana.

[2] http://www.tanzania.go.tz/ (Accessed 5 April 2011).

[3] Traditional export commodities: coffee, cotton, sisal, tea, tobacco, cashew nuts and cloves.

[4] Non-traditional export commodities: petroleum products, minerals, manufactured goods and others.

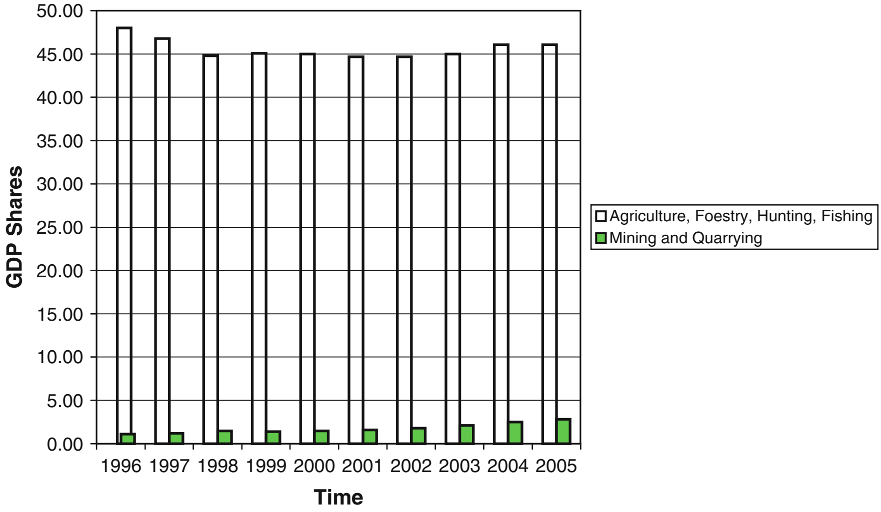

Fig. 1 GDP shares of the two primary sectors, Tanzania, 1996–2005

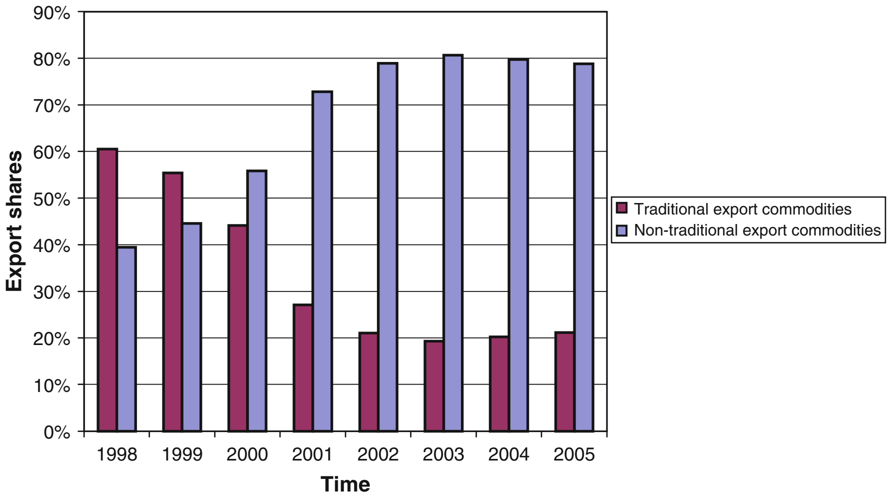

Fig. 2 Shares of traditional and non-traditional commodities in export GDP, Tanzania, 1998–2005

In addition, the sector raises revenues for government through royalties and taxes and provides employment, and mining companies invest in the provision of roads, water infrastructure and health facilities among other developments in the rural areas they operate in (on these, see the report on the Tanzania mineral accounts (CEEPA 2007)).

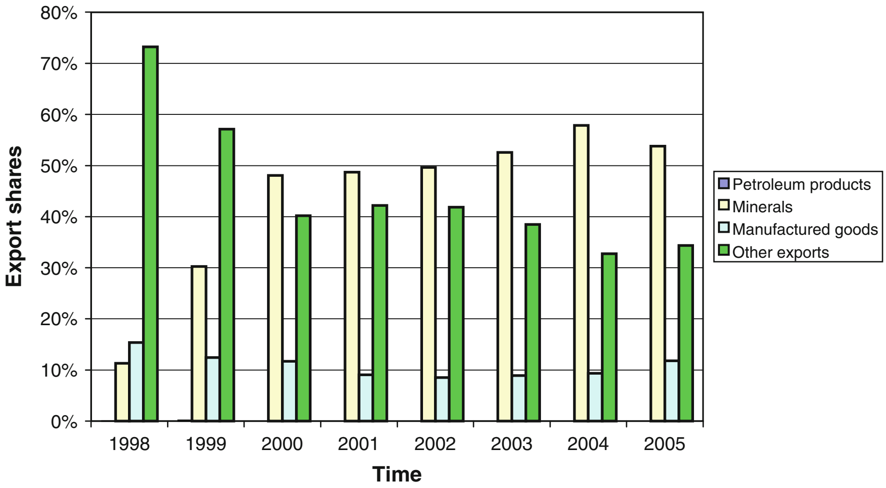

Fig. 3 Changes in the composition of non-traditional commodities to export GDP, Tanzania, 1998–2005

All this evidence suggests that the mining and minerals sector of Tanzania is not only presently important, but this importance is growing over time. In the interest of present and future welfare, it would be prudent to implement management policies ensuring the sector is developed within a framework supporting the objectives of social and environmental sustainability. Consequently, the main objective of this chapter is to estimate the value of Tanzania's mineral reserves using the SEEA methodology. As stated earlier, this is a step in measuring total wealth, which forms the basis for assessing whether development is sustainable or not. To the best of our knowledge, such a study has not been done in Tanzania before. Other studies on the valuation of subsoil assets in sub-Saharan Africa using the SEEA methodology include Blignaut and Hassan (2002), Lange (2004) and, more recently, Statistics South Africa (2011). The balance of this chapter is structured as follows: Sect. 2 provides a review of the UN SEEA framework for minerals. The data and methods used to compile the accounts reported in this chapter are presented in Sect. 3, results and discussions in Sect. 4 and finally the policy applications in Sect. 5.

2 The SEEA Framework for Minerals

Generic environment and natural resource accounts have four basic components (e.g. see Lange et al. 2003):

1. Natural resource asset accounts, which are stocks of natural resources constructed to revise the balance sheets of the System of National Accounts (SNA) and improve resource management. These measure stock levels at the beginning and end of the accounting period and evaluate the changes in stock levels over the period.

2. Pollutant and material (energy and resource) flow accounts, which provide information at the industry level about the use of energy and materials as inputs to production and final demand, and the generation of pollutants and solid waste. These accounts are linked to the supply and use tables of the SNA, which are used to construct input–output tables and social accounting matrices.
3. Environmental protection and resource management expenditure accounts, which identify expenditures in the conventional SNA incurred by industry, government and households to protect the environment or manage resources.
4. Environmentally adjusted macroeconomic aggregates, which include indicators of sustainability such as environmentally adjusted net domestic product (eaNDP).

Data permitting, it would be ideal to construct all these accounts. However in this study, we only concentrate on the first component due to data limitations. Lange (2001) provides a comprehensive example of the steps involved in constructing physical asset accounts for diamonds in Botswana (1980–1999). Monetary accounts ideally should convert the information provided by physical accounts into commensurate monetary values. To compile the monetary equivalent of the physical accounts, one has to monetarily value each of the row entries. In the SNA, the preferred method for asset valuation is based on the prices realized in market transactions at the time to which the balance sheet relates (e.g. Eurostat 2000). When market prices do not exist, valuation is done by calculating the net present value of future resource rents (e.g. Eurostat 2000; Lange 2004). Three steps are involved in calculating the net present value of future resource rents:

1. Estimate the level of the resource rent in the current period.
2. Project the resource rent into the future.
3. Discount the set of future resource rents to a value in the present period.

Current resource rent is calculated using the following formula (Lange 2004):

$$R_t = \mathrm{TR}_t - \mathrm{IC}_t - \mathrm{CE}_t - \mathrm{CFC}_t - \mathrm{NP}_t \tag{1}$$

$$\mathrm{NP}_t = i_t K_t \tag{2}$$

R	= the resource rent
TR	= total revenue from the mining sector
IC	= intermediate consumption
CE	= compensation of employees
CFC	= consumption of fixed capital
NP	= ‘normal profit’, a return to fixed capital
K	= fixed capital stock invested in an industry
i	= the rate of investment considered the opportunity cost of capital

Projecting the resource rent into the future depends on a number of parameters including the number of years the mine will remain in operation; how the number of years will be affected if the extraction rate alters; the effect of new discoveries on the expected life length of the mine and what would happen to the projections if the unit resource rent varies (Eurostat 2000). The formula for calculating the net present value of mineral assets V at period τ is:

$$V_\tau = \sum_{t=\tau}^{T} \frac{p_t Q_t}{(1+r)^t} \tag{3}$$

$$p_t = \frac{R_t}{Q_t} \tag{4}$$

$$T_t = \frac{S_t}{Q_t} \tag{5}$$

V = value of the asset
P = unit rent price of the resource
Q = quantity of resource extracted
r = the discount rate
R = total resource rent
T = the remaining lifespan of the resource
S = the stock of mineral reserves at the close of the accounting period

3 Data and Methods

3.1 Minerals Included in the Accounts

Several factors were considered in selecting the mineral assets to be included in the accounts: social importance, economic importance and data availability. We stated in the introduction that although Tanzania is endowed with a rich array of minerals, gold, diamonds, tanzanite, coal and natural gas are of greater social and economic significance given current extraction technology and economic conditions. In the following section, we will also show that current data collection efforts only allow for the construction of physical accounts for these minerals.

Information obtained from a variety of sources indicates the following companies are actively involved in mining for gold[5]: Resolute Mining Limited, Geita Gold Mining Limited, Kahama Mining Corporation Limited, Placer Dome Gold Incorporated, Meremeta Limited, Barrick Gold Corp and MDN, Northern Mining and Exploration and Gallery Gold Limited. *Resolute Mining Limited* of Australia owns the Golden Pride Mine through its Tanzanian subsidiary, Resolute (Tanzania) Limited (started

[5] For example: http://www.tanzaniagold.com/ (Accessed 22 January 2009).

production in 1998). *Geita Gold Mining Limited* operates the Geita Mine (started production in 2000, USGS 2001), which was initially owned 50% by Ashanti of Ghana and 50% by AngloGold of South Africa (USGS 2003). In 2004, the two companies merged to form the AngloGold Ashanti Ltd. (USGS 2004). *Kahama Mining Corporation Limited* (a subsidiary of Barrick Gold Corporation) owns the Bulyanhulu Mine, which started commercial production in 2001 (Global InfoMine 2005). *Placer Dome Gold Incorporated* owns the North Mara Mine (started production in 2002). *Meremeta Limited* owns the Buhemba Mine, which started production in 2003 (USGS 2003). *Barrick Gold Corp* and *MDN of Canada* own the Tulawaka Mine and 14 prospecting licences, 3 of which are held by Tan Range while the remaining 11 are held under *Northern Mining and Exploration* (USGS 2003). *Gallery Gold Limited* owns the Kitongo Mine and is also doing some exploration in the Buckreef deposits where no production has so far been reported. In addition to large-scale mining, there are many small-scale mines scattered across the country: around Lake Victoria in the north-west (Kagera, Mwanza, Musoma, Shinyanga and Tabora regions), in the southern highlands (Ruvuma, Mbeya and Rukwa regions), in the central part (Singida and Dodoma regions), in the northern part, in the Tanga region and in the southern part (Mtwara region).

There are two large-scale diamond companies operating in Tanzania, both situated in Mwadui: *Williamson Diamonds Limited* and *Hillal Minerals Limited*. The former was for a long time owned 75% by De Beers and 25% by Government of Tanzania (GoT). However in 2008, De Beers sold its shares to Petra Diamonds Limited.[6] The latter, which was established in 1993 after GoT liberalized the mining sector, is wholly owned by the GoT (Mwadui News 2005).

The world's only known source of tanzanite is situated in Simanjiro District of Tanzania.[7] Geological tests reveal this supply will be exhausted in the next 15–20 years given current technology and exploitation. In 1990, GoT demarcated the area where tanzanite is mined into blocks A, B, C and D to regulate its exploitation by both large-scale and artisanal miners.[8] Blocks A and C were allocated to two large-scale producers, *Kilimanjaro Mines* and *Graphtan Limited*, respectively.[9] Blocks B and D were allocated to small-scale miners. *Graphtan* ceased its activities in 1996, subsequent to which *Afgem* acquired the licence for block C. In 2000, *Afgem* completed a feasibility study for the commercial mining of tanzanite and mine development commenced in 2001. *Afgem* sold its tanzanite business and assets to *TanzaniteOne (SA) (Proprietary) Limited* in 2004. In the same year, *TanzaniteOne (SA) (Proprietary) Limited* changed its status from private to the public company, *TanzaniteOne (SA) Limited*.

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[6] http://kurayangu.com/ipp/guardian/2008/09/10/122288.htmlb (Accessed 22 January 2009).

[7] http://www.tanzaniteone.com/ (Accessed 22 January 2009).

[8] For example, see http://www.tanzaniteone.com/ (Accessed 22 January 2009).

[9] Graphtan Limited is a graphite mining company; graphite is a by-product of tanzanite.

Coal, which is presently mined from Kiwira, is one of the major energy resources of Tanzania. Kiwira started production in 1998 and currently supplies 6 MW of power to the national grid. Plans are under way to expand its power generation capacity to 30 MW under a joint venture with China Hunan International Economic and Technical Cooperation Corporation. Plans are also under way to develop the coal reserves at Mchuchuma for power generation foreseen to begin in 2018. The Mchuchuma plant will have an output of 400 MW.

The most important natural gas discoveries in Tanzania are located in Songo Songo (Lindi region) and Mnazi Bay (Mtwara region), with reserves estimated at 30 and 15 billion cubic metres, respectively (DEA 2005). The Songo Songo gas to electricity project was commissioned in 2004 supplying natural gas for power generation in Dar es Salaam (MEM 2004) and thus adding 192 MW of electricity to the national grid. Mnazi Bay is yet to be developed.

3.2 Data for Physical Accounts

In countries where subsoil assets form an important component of national wealth (and with a history of constructing NRA), there is a standardized code that is used for reserve and resource classification and reporting (e.g. see Statistics South Africa 2012). Unfortunately at the time of this study, the Tanzania Ministry of Minerals and Energy did not avail published guidelines that major mining companies were required to follow in reporting their reserves and resources. As a result, there were no figures for reserves and resources for all the minerals in Tanzania, and consequently, the figures we report on here are based on data provided by the United States Geological Survey (USGS).

USGS provides data for gold reserves and resources for the period 1994–2004, in some instances by mining company and others by mine.[10] We attempted in this report to compile the data by mining company before aggregating it to the industry. However, this process encountered several difficulties. First, prior to 2001, USGS only reported its data by mining company (before 2001, data was reported by the company and the properties from which it had a licence for mineral exploration). In 1997, for example, Samax Resources Ltd. (UK) reported a figure for reserves and resources for Geita, and in the same report, Ashanti (Ghana) reported a figure for reserves and resource for Geita. It was thus not clear whether the two should be added to obtain a single figure for reserves and resources for Geita. Where this problem was encountered, we used the larger of the figures presented to minimize the potential for double-counting. As a consequence, the compilation of figures for

[10] This is not a criticism but a reflection of the fact that USGS collects data for its own purposes and not for constructing natural resource accounts. The NRA compiler has to use the available data and package it in a form consistent with the NRA reporting framework.

reserves and resources before 2001 may be subject to interpretation errors on our part. Second, the reporting of the actual locations where exploration was taking place is not easily tractable through the years. In particular, USGS reports on locations without giving other details that could help an analyst identify the same location in subsequent years. A location could be mentioned in a given year and then it does not feature in any of the subsequent reports. This makes following the evolution of reserves and resources by the location where exploration takes place difficult. In some cases, the properties where exploration was taking place were owned as joint ventures by different mining companies, further complicating the compilation of reserves and resources by the company with the rights to exploit. If the total volume of a reserve or resource for a particular year is accredited to two potential right holders, it becomes problematic compiling reserves and resources by mining company. There also were many changes in the ownership of exploration and mining licences beginning 1994 making the task of constructing a timeline for reserves and resources by mining company difficult. Finally, the USGS data before 1999 is generally provided without much detail.

Data for coal reserves, resources and production was obtained from several sources including Ministry of Energy and Minerals,[11] DEA (2005), United Republic of Tanzania Economic Survey (2005) and USGS. Data for natural gas reserves was obtained from the Ministry of Energy and Minerals and USGS. Data for natural gas production was obtained from USGS (only for 1 year). At the time of this study, there was no published data for diamond reserves and resources, either from official sources or from companies involved in exploration and mining. The study was specifically informed that in the case of gemstones like diamond and tanzanite, it is difficult to give such a figure since these occur as pockets in the earth crust by chance, making it difficult to estimate availability by conventional methods (Uwoya, personal communication).[12] The only available estimate for diamond reserves in Tanzania at present is 3.8 million carats (USGS 1994), and these were reported only once. For the same reasons, there was also no available data for tanzanite resources and reserves. According to the annual report of TanzaniteOne (2005), 'although reserve and resource figures have been prepared, reviewed and verified by independent mining experts, these values, given the unique operating environment, remain best estimates only. The Group continues to make efforts to further refine its interpretation and understanding of the ore body'. This report indicated resources of 60–80 million carats with a potential value of +US$ 2 billion.

We know from Sect. 2 that the minimum requirement for implementing the SEEA framework for minerals is reserve and/or resources data. It follows that in this study, we were only able to compile physical resource accounts for gold, coal and natural gas.

[11] http://www.tanzania.go.tz/energy.htm (Accessed 27 January 2009).

[12] Inasmuch as this might be true, this does not explain why a firm would invest in diamond mining without knowledge of the size of reserves.

3.3 Data for Monetary Accounts

To estimate monetary accounts, one has to implement the SEEA methodology for resource rent calculation (Eq. 1) and then use it for asset valuation (Eq. 3). In a first best world, one would expect to obtain all information required to calculate resource rent from national accounts. Unfortunately the Tanzania National Bureau of Statistics (NBS), in presenting the national accounts, reports the gross operating surplus (GoS) of mining and quarrying together, which makes it impossible to isolate mining GoS. In addition, even if it was possible to isolate mining GoS, what we required for asset valuation were individual estimates of resource rent for gold, coal and natural gas. An alternative to using national accounting data was to use data from the Tanzania industrial survey. However, strict confidentiality requirements ruled out this possibility. Consequently, we resorted to the World Bank (2006) estimates of resource rents to enable asset valuation.[13] The World Bank methodology for estimating resource rents is reported in the *Manual for Calculating Adjusted Net Savings* (Bolt et al. 2002) and we could only find resource rent estimates for coal and gold. Consequently, asset valuation in this study was only limited to these two minerals.

In Bolt et al. (2002), resource rent was calculated as the international market price of extracted material minus average cost of production. In applying this methodology to coal, international export prices of steam and coking coal, adjusted to reflect the same net calorific value, were used to estimate an average world price for hard coal. The international export prices were obtained from the International Energy Agency statistics (2001). Considering that international export prices were used in the calculation, export price is bound to be higher than the unit price of coal sold locally in Tanzania. There however was no data for average cost of production available for Tanzania. According to this methodology, for those countries for which no production cost data was available, a surrogate production cost from another country was used. The surrogate in the case of coal was the world average, computed from the average production costs data for the following countries: Australia, USA, Canada, Colombia, South Africa, Indonesia, Poland, Czech Republic, China, Russia, Mexico and India. It is also clear that the average production costs used in the World Bank resource rent estimates for coal are bound to be higher than the average production costs that will prevail in Tanzania, where at the minimum, labour is expected to be much cheaper. Without more information, it is not possible to know whether the unit rent estimates for coal used by the World Bank overestimate or underestimate the unit rent that prevails in Tanzania. All unit rent estimates were recorded in current US$/ton.

In applying this methodology to gold, Bolt et al. (2002) recognize that production costs for metals and minerals are proprietary information and very difficult to obtain, which probably goes to explain why we could not get this information locally in

[13] http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTEEI/0,,contentMDK:20487828~menuPK:1187788~pagePK:148956~piPK:216618~theSitePK:408050,00.html (Accessed 6 April 2011).

Table 1 Unit rent estimates for gold and coal

	Gold (unit rent)		Coal (unit rent)	
Year	($/ounce)	($/ton metric)	($/ton)	($/million ton)
1990	80.94	2,855,073.84		
1991	49.18	1,734,779.54		
1992	23.54	830,259.55		
1993	32.23	1,136,942.16	3.08	3,080,000
1994	49.47	1,745,031.49	2.56	2,560,000
1995	42.76	1,508,183.09	3.44	3,440,000
1996	39.82	1,404,418.21	3.40	3,400,000
1997	33.17	1,169,940.05	2.70	2,700,000
1998	31.33	1,105,204.74	2.03	2,030,000
1999	30.64	1,080,690.27	1.40	1,400,000
2000	29.61	1,044,454.02	1.17	1,170,000
2001	28.48	1,004,439.19	1.90	1,900,000
2002	32.72	1,154,148.50	1.85	1,850,000
2003	38.76	1,367,301.51	2.01	2,010,000
2004	8.89	313,579.58	2.05	2,050,000

Tanzania. Bolt et al. (2002) obtained price data from the United Nations Conference on Trade and Development (UNCTAD) monthly commodity price bulletin. There however was no data on average cost of production available for Tanzania. According to this methodology, for those countries for which no production cost data was available, a surrogate production cost from another country was used. All unit rent estimates were recorded in current US$/ounce. For gold in Tanzania, the average production cost for market economies was used as the surrogate. Following the reasoning outlined above, the gold resource rent estimate the World Bank used on Tanzania is likely to overestimate the true estimate. The unit rent estimates used to compile the asset accounts for gold and coal are reported in Table 1.

4 Results and Discussion

4.1 Physical Accounts

The physical accounts for gold are presented in Table 2.

Two important observations derive from the data presented in Table 2. First, one would naturally expect that, given extraction, the size of reserves and resources would monotonically decline. However, this is not what one observes from the table. In fact, there are a number of instances where reserves and resources in fact increase despite production in the previous years. This can basically be explained by the fact that given time, improvement in economic circumstances and technological developments, our ability to define what can be considered as reserves and resources improves. Second, it is clear from Table 2 that in the earlier years of extraction,

Table 2 Physical accounts for gold in Tanzania, 1990–2004 in metric tons

	Opening stocks			Changes		Closing stocks	
Year	Reserves	Resources	Production	Reserves	Resources	Reserves	Resources
1990	751.801	NA	3.500	NA	NA	748.301	NA
1991	748.301	NA	3.851	NA	NA	744.450	NA
1992	744.450	NA	3.201	NA	NA	741.249	NA
1993	741.249	NA	3.264	NA	NA	737.985	NA
1994	737.985	NA	2.861	NA	NA	735.124	NA
1995	735.124	NA	0.320	NA	NA	734.804	NA
1996	734.804	NA	0.318	NA	NA	734.486	NA
1997	734.486	NA	0.232	NA	NA	734.254	NA
1998	734.254	NA	0.427	NA	NA	733.827	NA
1999	733.827	NA	4.767	NA	NA	729.060	NA
2000	729.060	NA	15.060	NA	NA	714.000	NA
2001	714.000	1,050	29.785	97	97	781.000	1,147
2002	781.000	1,147	35.632	26	79	771.000	1,200
2003	771.000	1,200	40.768	45	10	775.00	1,202
2004	775.000	1,202	43.666	NA	NA	NA	NA

NA means the figure is not available

Table 3 Physical accounts for coal in Tanzania, 1993–2004 in million tons

Year	Opening stocks (proven economic reserves)	Production	Changes	Closing stocks (proven economic reserves)
1993	140.00	0.04	NA	139.96
1994	139.96	0.05	NA	139.91
1995	139.91	0.04	NA	139.87
1996	139.87	0.05	NA	139.82
1997	139.82	0.03	NA	139.79
1998	139.97	0.05	NA	139.75
1999	139.75	0.08	NA	139.67
2000	139.67	0.08	NA	139.59
2001	139.59	0.08	NA	139.51
2002	139.51	0.08	NA	139.43
2003	139.43	0.05	NA	139.38
2004	139.38	0.07	NA	139.32

All figures are expressed in tons millions

production had a very little impact on the magnitude of reserves. For example, in 1990, production was only 0.466% of the available reserves, which substantially improved to 5.634% by 2004. This could clearly be a manifestation of technological developments and improved economic circumstances that enable greater extraction of reserves. What comes out clearly from this discussion is that Tanzania still has great potential to expand the contribution of the mining and minerals sector to economic development by exploiting its gold reserves. The same story appears to repeat itself when we consider the physical accounts for coal in Table 3.

Table 3 tells us that Tanzania has huge coal reserves which have hardly been exploited. Production was a paltry 0.029% of proven economic reserves in 1993, and by 2004, it was only 0.05%. All this is evidence that Tanzania has a huge unexploited coal production potential.

A pattern similar to that discussed above for gold and coal emerges when one considers natural gas. The United States Geological Survey (1993) estimates the stocks of natural gas in Tanzania at 968 billion cubic feet. The USGS (2004) reports that production of natural gas only commenced in 2004 when 119 million cubic metres (equivalent to 4.2024 ft^3) were extracted. Between 1993 when stocks were first recorded and 2004, there was no production. Again, we see that Tanzania has a huge unexploited potential for natural gas production.

4.2 Monetary Accounts

Several simplifying assumptions were used in implementing Eq. (3) for asset valuation. First, we assumed that extraction will continue at current levels up to the date of mineral depletion. Second, we assumed that the resource rent will remain constant at today's levels through depletion. We investigated two extreme values of the discount rate in deciding the social discount rate to use. According to the Bank of Tanzania,[14] the discount rate in December 1999 was 20.2% while that of December 2003 was 12.3%. The Tanzania Economic Survey (2005) reports the average rate of inflation in 2004 was 4.2%. Consequently, using a social rate of discount of between 5 and 8% for asset valuation might be appropriate. In this study, we present asset value estimates using two rates of discount, 5 and 10%, to test the sensitivity of asset value estimates to the choice of discount rate. The discount rate was held constant through the accounting period as a simplifying assumption. We present asset values using the current rent (the rent that obtains every year) and using a 5-year moving average to reflect the fact that mineral prices can fluctuate a great deal from 1 year such that the real value of mineral assets is not always best represented by the price (the per unit rent) in any single year (e.g. see Lange 2001). The detailed monetary accounts for gold and coal are presented in Tables 4–7, respectively. In what follows, we just highlight the main results.

The results summarized in Figs. 4, 5, 6, and 7 show that the asset value of gold in Tanzania is very high while that of coal is extremely low. This should not come as a surprise because Tanzania has huge reserves of coal, these resources are going to be used far into the future, which makes their current values very low. The results also show that the present value of the stocks of gold increase with time while that of coal remains more or less constant. A possible explanation that accounts for this is as follows: as gold is mined, the amount remaining underground shrinks, which means that assets become more valuable with time because of

[14] http://www.bot-tz.org/

Table 4 Monetary accounts for gold, current prices

	Opening Stocks		Extraction		Revaluation		Closing Stocks	
Year	5%	10%	5%	10%	5%	10%	5%	10%
1990	209,842,033	109,920,343	9,992,758	9,992,758	0	0	199,849,274	99,927,584
1991	199,849,274	99,927,584	6,680,636	6,680,636	–72,927,897	–39,801,861	133,602,013	66,806,359
1992	133,602,013	66,806,359	2,657,661	2,657,661	–83,107,116	–42,887,412	53,152,558	26,576,608
1993	53,152,558	26,576,608	3,710,979	3,710,979	17,354,846	6,822,205	74,218,383	37,109,792
1994	74,218,383	37,109,792	4,992,535	4,992,535	20,639,425	7,823,024	99,850,343	49,925,351
1995	99,850,343	49,925,351	482,619	482,619	–90,680,590	–45,581,784	9,652,372	4,826,186
1996	9,652,372	4,826,186	446,605	446,605	–1,166,877	–806,741	8,932,100	4,466,050
1997	8,932,100	4,466,050	271,426	271,426	–3,775,004	–2,023,215	5,428,522	2,714,261
1998	5,428,522	2,714,261	471,922	471,922	3,538,004	1,533,041	9,438,448	4,719,224
1999	9,438,448	4,719,224	5,151,651	5,151,651	88,383,713	41,645,606	102,973,812	51,516,481
2000	102,973,812	51,516,481	15,729,478	15,729,478	164,758,203	88,333,785	283,461,493	155,579,743
2001	283,461,493	155,579,743	29,917,221	29,917,221	118,493,675	89,096,871	431,872,389	274,593,835
2002	431,872,389	274,593,835	41,124,619	41,124,619	63,314,287	43,233,599	536,311,296	358,952,053
2003	536,311,296	358,952,053	55,742,148	55,742,148	81,823,669	51,671,308	673,877,113	466,365,509
2004	673,877,113	466,365,509	13,692,766	13,692,766	–523,427,163	–366,062,836	164,142,716	113,995,439

Table 5 Monetary accounts for gold, five year moving average

Year	Opening Stocks		Extraction		Revaluation		Closing Stocks	
	5%	10%	5%	10%	5%	10%	5%	10%
1990	209,842,033	109,920,343	9,992,758	9,992,758	0	0	199,849,274	99,927,584
1991	199,849,274	99,927,584	8,837,763	8,837,763	31,945,948	–20,387,721	176,741,089	88,377,626
1992	176,741,089	88,377,626	5,783,260	5,783,260	–66,860,574	–36,328,281	115,663,776	57,832,605
1993	115,663,776	57,832,605	5,350,557	5,350,557	–14,004,926	–9,677,592	107,009,407	53,505,570
1994	107,009,407	53,505,570	4,750,454	4,750,454	–16,751,124	–10,751,484	95,008,737	47,504,539
1995	95,008,737	47,504,539	445,133	445,133	–86,551,219	–43,498,347	8,902,651	4,451,325
1996	8,902,651	4,451,325	421,339	421,339	–897,201	–659,270	8,426,789	4,213,395
1997	8,426,789	4,213,395	323,153	323,153	–2,286,873	–1,305,013	6,463,070	3,231,535
1998	6,463,070	3,231,535	592,059	592,059	4,786,055	2,096,998	11,841,184	5,920,592
1999	11,841,184	5,920,592	5,976,327	5,976,327	101,640,359	47,866,325	119,457,870	59,763,244
2000	119,457,870	59,763,244	17,483,778	17,483,778	178,134,164	95,684,452	315,075,812	172,931,475
2001	315,075,812	172,931,475	32,195,966	32,195,966	117,495,613	90,381,750	464,767,391	295,509,191
2002	464,767,391	295,509,191	38,403,719	38,403,719	–2,343,420	1,290,038	500,827,690	335,202,948
2003	500,827,690	335,202,948	46,076,267	46,076,267	10,120,534	4,216,901	557,024,490	385,496,116
2004	557,024,490	385,496,116	42,652,275	42,652,275	–88,380,492	–73,058,355	511,296,273	355,090,036

Table 6 Monetary accounts for coal, current prices

Year	Opening Stocks		Extraction		Revaluation		Closing Stocks	
	5%	10%	5%	10%	5%	10%	5%	10%
1993	2,857,200	1,355,200	123,200	123,200	0	0	2,464,000	1,232,000
1994	2,464,000	1,232,000	128,000	128,000	−32,000	−80,000	2,560,000	1,280,000
1995	2,560,000	1,280,000	137,600	137,600	54,400	−41,600	2,752,000	1,376,000
1996	2,752,000	1,376,000	170,000	170,000	478,000	154,000	3,400,000	1,700,000
1997	3,400,000	1,700,000	81,000	81,000	−1,861,000	−971,000	1,620,000	810,000
1998	1,620,000	810,000	101,500	101,500	308,500	103,500	2,030,000	1,015,000
1999	2,030,000	1,015,000	112,000	112,000	98,000	−7,000	2,240,000	1,120,000
2000	2,240,000	1,120,000	93,600	93,600	−461,600	−277,600	1,872,000	936,000
2001	1,872,000	936,000	152,000	152,000	1,016,000	432,000	3,040,000	1,520,000
2002	3,040,000	1,520,000	148,000	148,000	−228,000	−188,000	2,960,000	1,480,000
2003	2,960,000	1,480,000	100,500	100,500	−1,050,500	−575,500	2,010,000	1,005,000
2004	2,010,000	1,005,000	143,500	143,500	716,500	286,500	2,870,000	1,435,000

Table 7 Monetary accounts for coal, five year moving average

	Opening Stocks		Extraction		Revaluation		Closing Stocks	
Year	5%	10%	5%	10%	5%	10%	5%	10%
1993	2,587,200	1,355,200	123,200	123,200	0	0	2,464,000	1,232,000
1994	2,464,000	1,232,000	141,000	141,000	215,000	37,000	2,820,000	1,410,000
1995	2,820,000	1,410,000	121,067	121,067	–519,733	–320,400	2,421,333	1,210,667
1996	2,421,333	1,210,667	156,000	156,000	542,667	193,333	3,120,000	1,560,000
1997	3,120,000	1,560,000	91,080	91,080	–1,389,480	–740,280	1,821,600	910,800
1998	1,821,600	910,800	141,300	141,300	863,100	360,900	2,826,000	1,413,000
1999	2,826,000	1,413,000	207,520	207,520	1,116,880	454,680	4,150,400	2,075,200
2000	4,150,400	2,075,200	171,200	171,200	–897,600	–534,400	3,424,000	1,712,000
2001	3,424,000	1,712,000	147,200	147,200	–627,200	–387,200	2,944,000	1,472,000
2002	2,944,000	1,472,000	133,600	133,600	–405,600	–269,600	2,672,000	1,336,000
2003	2,672,000	1,336,000	83,300	83,300	–1,089,300	–586,300	1,666,000	833,000
2004	1,666,000	833,000	125,720	125,720	722,680	298,480	2,514,400	1,257,200

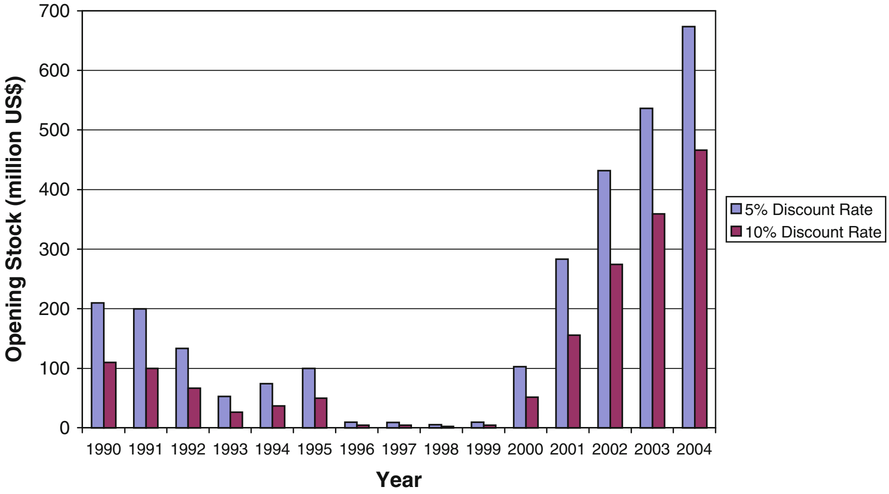

Fig. 4 Monetary accounts for gold in Tanzania, 1990–2004, millions US$ current

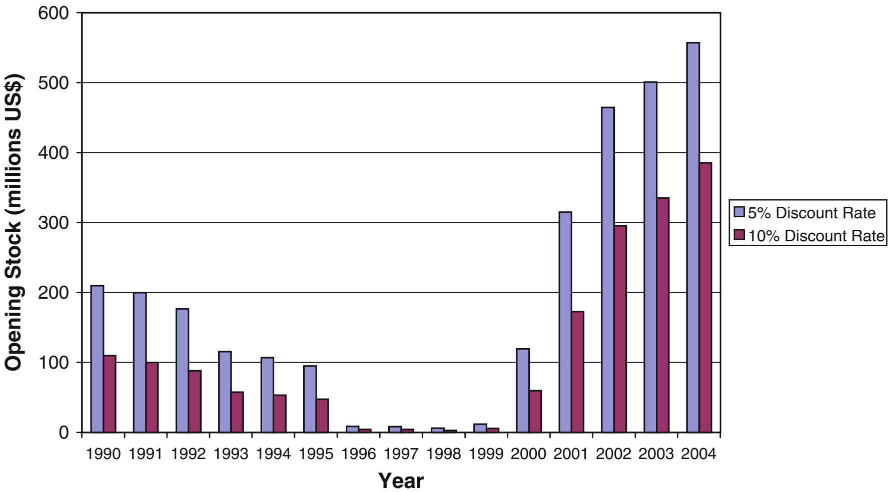

Fig. 5 Monetary accounts for gold in Tanzania, 1990–2004, millions US$ 5-year moving average

scarcity. The size of the coal reserves on the other hand is massive relative to the extraction rate, which means that current extraction rates virtually have no impact on the reserves. Finally, there does not seem to be much difference in the behaviour of the series, when measured at current prices and when measured using the 5-year moving average. This might be a reflection of the very rough estimates of the resource rent values used in these calculations.

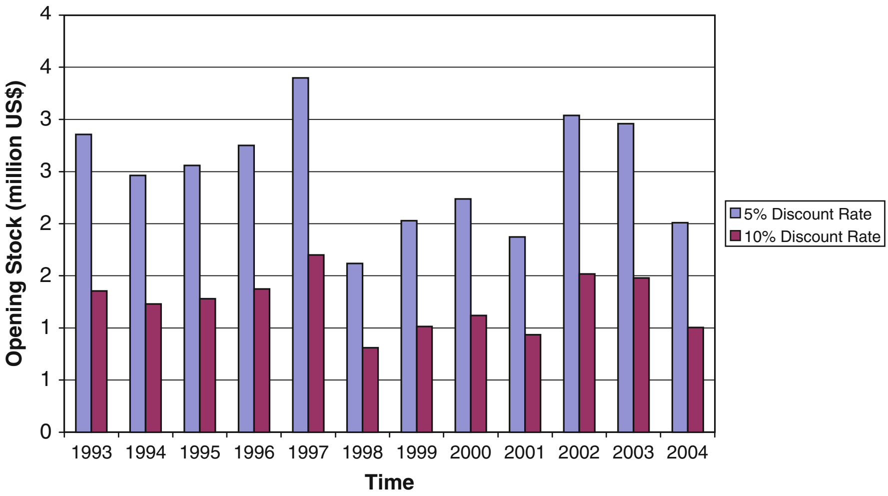

Fig. 6 Monetary accounts for coal in Tanzania, 1993–2004, millions US$ current

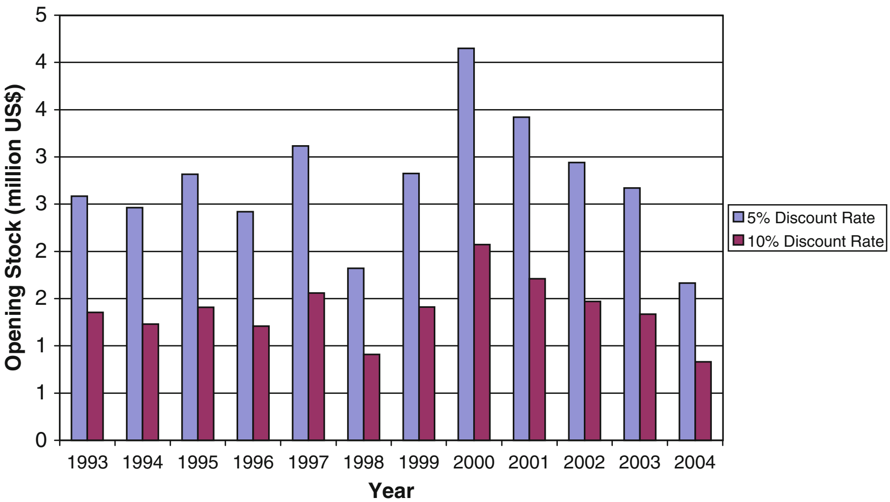

Fig. 7 Monetary accounts for coal in Tanzania, 1993–2004, millions US$, 5-year moving average

5 Policy Implications

As stated at the beginning of this chapter, the basic reason that we construct environmental accounts is to enable countries to estimate the value of their natural assets (minerals, forests, fisheries, etc.), information can then be used in deriving more comprehensive measures of genuine savings (e.g. see Bolt et al. 2002). With such a measure, it is possible to make an assessment of whether a country is following a sustainable path. Inasmuch as this study cannot provide such a measure as a stand-alone, it should be considered as a first step towards developing such a measure for Tanzania. It is hoped that as Tanzania develops resource accounts for other assets, it would be possible in future to estimate the total wealth, as has been the case in Namibia, for example (see Lange 2001).

Second, this study has clearly demonstrated that the contribution of the mining and minerals sectors in Tanzania has a huge unexploited potential. In view of the difficult economic circumstances being experienced in the country at the moment, this is a window of opportunity that policymakers should definitely exploit.

A final important policy application of a study of this type is to assess whether the minerals sector in Tanzania is currently being managed so as to satisfy the objectives of sustainability. It is well known from the wealth accounting literature that to sustain welfare from the exploitation of an exhaustible resource, a proportion of the resource rent must be invested in other substitute forms of capital. El Serafy (1989) derives the following formula to decompose the total resource rent (R_t) into its capital component ($R_t - X_t$) as the proportion that needs to be reinvested, and its income component X_t as the proportion that can be consumed:

$$X_t = R_t \left[1 - \frac{1}{(1+r)^{N+1}} \right] \tag{6}$$

where r is the rate of return and N is the number of years extraction can take place at the current rate. Table 4 shows the results of applying the El Serafy formula to the rent for minerals in Tanzania.

The results from coal suggest that Tanzania does not have to invest any of the revenue from mining coal into other substitute forms of capital. Although this might be a consequent of the very small exploitation to resources ratio (it is actually very close to zero), it might also be a consequence of the fact that the study used crude estimates of resources and rent. This underpins the fact that if Tanzania is ever to know whether it is on a sustainable path or not, it is important to invest in institutions that can collect the data required to implement resource accounts. What this study has shown is the potential benefits to be reaped from establishing such institutions. The data for gold on the other hand suggest that the capital component for rent is positive, especially in the later years. The important policy question then becomes: does the government of Tanzania have the kind of institutions in place to not only guarantee that the right proportion of the rent is not only collected but that it is also invested in expanding other forms of wealth? Again, this is a question that can only be answered with the right kind of country level data (e.g. data on the amount of taxes/royalties collected from the sector and how these funds are invested).

References

Blignaut J, Hassan R (2002) Assessment of the performance and sustainability of mining sub-soil assets for economic development in Southern Africa. Ecol Econ 40(1):89–101

Bolt K, Matete M, Clemens M (2002) Manual for calculating adjusted net savings. Environment Department, World Bank, Washington, DC

CEEPA (2007) Accounting for subsoil assets in Tanzania. Report submitted to CEEPA as part of the Natural Resources Accounting Project in Eastern and Southern Africa (NRAESA) Project

DEA/ Energy and Development in Africa (2005) unpublished proceedings of the Tanzania first national workshop held on 12th September 2005 at the Palm Beach Hotel, Dar Es Salaam, Tanzania

El Serafy S (1989) The proper calculation of income from depletable natural resources. In: Ahmad Y, Serafy SE, Lutz E (eds) Environmental accounting for sustainable development. World Bank, Washington, DC, pp 10–18

EUROSTAT (2000) Accounts for Subsoil assets—results of pilot studies in European countries. Luxembourg: office for official publications of the European communities

Hamilton K, Clemmens M (1999) Genuine savings rates in developing countries. World Bank Econ Rev 13(2):336–356

International Energy Agency (2001) http://www.iea.org/statist/key2001/keyworld-2001.pdf

Lange G (2001) Mineral accounts for Namibia, unpublished paper for the Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia

Lange G-M (2004) Wealth, natural capital, and sustainable development: contrasting examples from Botswana and Namibia. Environ Res Econ 29:257–283

Lange G-M (2005) Introducing environmental sustainability into the Ugandan system of national accounts. Draft Final Report, Environment and Natural Resources Sector Working Group (ENR SWG)

Lange G, Hassan R, Hamilton K (2003) Environmental accounting in action: case studies from southern Africa. Edward Elgar Publishers, Cheltenham

Ministry of Energy and Minerals (2005) Investment opportunities in energy and minerals, United Republic of Tanzania

Mwadui News (2005) http://www.mwadui.co.uk. Accessed 22 Jan 2009

Statistics South Africa (2011) Mineral accounts for South Africa, 1980–2008. Discussion Document (D0405.2) Statistics South Africa Pretoria, http://www.statssa.gov.za/publications/D04052/D040522008.pdf. Accessed 01 Sep 2012

Statistics South Africa (2012) Energy accounts for South Africa, 2002–2009. Discussion Document (D0405.1.1) Statistics South Africa Pretoria, https://www.statssa.gov.za/publications/D04051.1/D04051.12009.pdf. Accessed 01 Sep 2012

Tanzania Economic Survey (2005) http://www.tanzania.go.tz/economicsurveyf.html. Accessed 27 Jan 2009

TanzaniteOne Annual Report, (2005) Johannesburg, South Africa, TanzaniteOne Limited

United Nations, Commission of the European Communities, International Monetary Fund, Organisation for Economic Cooperation and Development, and World Bank (2003) Handbook for integrated environmental and economic accounting. United Nations, New York

United Republic of Tanzania Economic Survey (2005) http://www.tanzania.go.tz/economicsurveyf.html. Accessed 27 Jan 2009

USGS (1993) http://minerals.usgs.gov/minerals/pubs/country/africa.html

USGS (1994) http://minerals.usgs.gov/minerals/pubs/country/africa.html

USGS (2001) http://minerals.usgs.gov/minerals/pubs/country/africa.html

USGS (2003) http://minerals.usgs.gov/minerals/pubs/country/africa.html

USGS (2004) http://minerals.usgs.gov/minerals/pubs/country/africa.html

Global InfoMine (2005) http://www.infomine.com

World Bank (2006) Where is the wealth of nations? measuring capital for the 21st Century. The International Bank for Reconstruction and Development, The World Bank, Washington, DC

Fisheries Resource Accounts for the Maputo Coastal Districts of Mozambique

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Abstract The main purpose of compiling national income accounts is to provide a comprehensive overview of the nation's economy and to facilitate decision-making by policymakers. The most important indicator in national economic accounts is the gross domestic product (GDP). However, GDP ignores the interactions between economic activity and the environment (including natural resources), although these interactions have become increasingly evident. In Mozambique, as a result of population growth, persistent rural poverty and a fast pace of growth and development in the private sector, the degradation of a number of environmental and natural resources has reached such proportions that the economic growth capabilities are already being compromised. However, the economic effects of these trends are not reflected in the traditional GDP based upon which most economic policy decisions are made.

Keywords UN SEEA for fisheries • Management of renewable resources • Fisheries resource rent • Economic sustainability • Mozambique

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1 Introduction

A response to the shortcomings of conventional economic accounts has been the development of environmental accounting. Integrated Environmental and Economic Accounting (SEEA 2003) builds on the existing system of national accounts. It brings together economic and environmental information in a common framework to measure the contribution of the environment/natural resources to the economy and the impact of the economy on the environment/natural resources. It provides policymakers with indicators and descriptive statistics to monitor these interactions as well as a database for strategic planning and policy analysis to identify more sustainable paths of development (UNSTATS 2005). It generates and systematically assembles data needed to support a set of environmental and resources policies that will be consistent with overall economic sustainability. In Mozambique, policy documents such as the Biodiversity Strategy and Annual Planning for Mozambique recommend including the depletion of natural capital in the analysis of economic growth indicators.

With funding from the Swedish International Development Agency (SIDA), the Centre for Environmental Economics and Policy in Africa (CEEPA) at the University of Pretoria supported implementation of natural resource accounting (NRA) in four countries in Eastern and Southern Africa (Tanzania, Uganda, Ethiopia and Mozambique). In Mozambique, the NRAESA project was implemented on a pilot basis in the fisheries and water sectors. This chapter presents the findings of the pilot project on fisheries resource accounts.

The objective of this study was to initiate a process leading to the institutionalisation of natural resource accounting (NRA) in the fisheries sector. The emphasis was on demonstrating the UN system of environmental and economic accounting for fisheries (SEEAF) methodology and its practical applicability to developing satellite accounts for the sector. Environmental-economic accounts in fisheries can provide measures of the economic value of stocks and changes in volume of the stocks as result of fishing activities and/or other environmental impacts. The expected results will demonstrate how the satellite fisheries NRA can be used to correct the traditional indicators of economic performance provided by the system of national accounts (SNA). This study establishes the classification to be used in constructing marine fisheries accounts for Mozambique and estimating the physical and monetary accounts for the fisheries.

2 The Fishery Sector of Mozambique

Fisheries are important in Mozambique contributing more than 2% of the national gross domestic product (GDP) (INE 2005). However, the sector's potential is not very high, and there is not much room for growth as Mozambique's coastal tropical waters are warm and relatively less productive compared to the waters of other countries off the East African coast. It is estimated that the potential for sustainable catch of all species combined in Mozambique is about 300,000 tons a year, and about half of that is being caught at the moment (DNEP 1994).

The fisheries of Mozambique are classified into artisanal or industrial (also called commercial) depending on the types of fishing boats employed. In general, artisanal fishers do not have formal settings for their business but rather operate under informal schemes. By regulation, they can operate boats up to a maximum of 10 m in length, and when powered, the engines are limited to a maximum of 100 HP (74 KW). Commercial fishers, which include industrial and semi-industrial operators, are obliged by law to register their enterprises. The main difference between industrial and semi-industrial commercial enterprises is the size and engine power of their boats. A semi-industrial boat is typically under 20 m length and fitted with engine not exceeding 350 HP (259 KW) of propulsion power. Industrial boats permitted to fish in the coastal area (within 12 nautical miles) are over 20 m in length but generally not greater than 40 m. By regulation, industrial fishing boats can be fitted with engines not exceeding 1,500 HP (1,110 KW) of propulsion power. Tuna fishing boats, operating in the Exclusive Economic Zone (EEZ), are not subject to the building and construction specifications of the Maritime Fisheries Regulation (2003).

According to the national fisheries policy, artisanal fishing is reserved for national citizens and operated by local communities found concentrated in the so-called fishing centres. The main species for the artisanal fishery, ranked by the quantity of catch, are finfish (e.g. *magumba*), prawn, shark, octopus/squid and crab. The catch of prawn by artisanal fishers is mostly composed of non-penaeid shrimps. Artisanal fisheries represent an important source of cash income and food for coastal communities and employ a significant number of people. Between 70,000 and 100,000 fishermen are estimated to be directly involved in this fishery. According to an IDPPE census (2002), approximately 8,000 additional people are involved in other artisanal fishery-related activities. Commercial fishing in Mozambique is open to foreign direct investment. The observed situation is to have joint ventures between Mozambican and foreign commercial fishing companies, with the foreign partners holding the majority of shares. About 60% of the commercial shrimp fishing business is controlled by three joint venture companies with Spanish majority private capital. Other smaller joint venture companies include firms originating from other European countries, Japan and South Africa. The main species for the industrial and semi-industrial fishery, ranked by the quantity of catch, are kapenta, prawn, tuna, by-catch (small pelagic fish species) and deep-sea fish. With the exception of kapenta, all others are sea fisheries. Kapenta is a freshwater fish from the man-made Cahora Bassa Dam found in the central province of Tete. Whereas artisanal fishing is of key importance for domestic supply of relatively cheap protein with over 60% of fish landings, commercial fishing is an important source of export revenues.

Table 1 shows that over 67% of the fishing catches in Mozambique (2003–2005) are artisanal and less than 35% are industrial or semi-industrial (tuna excluded from the totals as it is fished by foreign fleets). Note from Table 1 that catch data for artisanal fisheries is underestimated due to the fact that over the reported period,

Table 1 Industrial (including semi-industrial) and artisanal fishing catches of Mozambique (tons)

Description (in tons)	2003			2004			2005		
	Industrial	Artisanal	Total	Industrial	Artisanal	Total	Industrial	Artisanal	Total
Sea crustaceans	9,320	6,191	15,511	9,417	3,985	13,402	10,602	1,932	12,534
Shallow-water prawns	7,690	5,835	13,525	8,106	3,783	11,889	8,520	1,759	10,279
Deep-water prawns	1,425	–	1,425	993	–	993	1,774	–	1,774
Crayfish	124	–	124	132	–	132	149	–	149
Lobster	–	–	–	2	–	2	1	12	13
Crab	81	356	437	184	202	386	158	161	319
Sea fish	1,075	58,188	59,263	484	52,176	52,660	660	50,917	51,577
Pelagic fish	–	57,759	57,759	–	51,908	51,908	–	50,024	50,024
Deep-sea fish	1,075	–	1,075	484	–	484	660	–	660
Tuna fish[a]	*7,450*	–	*7,450*	*14,783*	–	*14,783*	*5,396*	–	*5,396*
Sharks	–	429	429	–	268	268	–	893	893
Freshwater fish	10,978	–	10,978	18,760	–	18,760	12,991	–	12,991
Kapenta	10,978	–	10,978	18,760	–	18,760	12,991	–	12,991
Pende		–	–	–	–	–	–	–	–
Tiger		–	–	–	–	–	–	–	–
Molluscs	131	389	520	195	255	450	165	239	404
Octopus/squid	131	389	520	195	255	450	165	239	404
By-catch	1,608	–	1,608	1,354	–	1,354	1,830	–	1,830
Others	–	2,306	2,306	–	3,962	3,962	–	4,660	4,660
Total	23,112 (26%)	67,074 (74%)	90,186	30,210 (33%)	60,378 (67%)	90,588	26,248 (31%)	57,748 (69%)	83,996

Source: DNEP (Ministry of Fisheries) (2003)

[a]Tuna is fished by foreign fleets, so it should not be included in the national fish production

only five coastal provinces were covered by the fisheries statistics system: Maputo, Inhambane, Sofala, Zambézia and Nampula. No artisanal catch data was available for the remaining two coastal provinces of Gaza and Cabo Delgado and for the entire inland fisheries.

In the central and northern provinces of Mozambique where richer fishing grounds can be found, fisheries play an even bigger role in the economy than in Maputo province. Fishing from the central provinces is especially important in supplying Maputo city markets. To satisfy internal demand especially in the main urban areas, Mozambique also imports fish, for example, mackerel from Namibia and Angola, estimated at 15,000–20,000 metric tons per year (*author's estimates*). As the demand for fish is huge in Maputo city, additional fish and prawns are imported from Inhambane and Gaza provinces.

Table 2 shows the commercial value of fish exports for the period 2000–2005. Note from the table that shallow-water and aquaculture shrimp accounts for 85% of the total value of exports. Gamba and kapenta are the second and third most important export species, with 7 and 4% of export value, respectively. Table 2 does not include exports of fish from artisanal production. No substantial catch from artisanal fish suppliers reaches official export markets. Exports from artisanal fishers are to a great extent channelled to regional markets informally. Although some of the artisanal fish production is sold to local fish processors, most of these processors do not meet the international standards for quality assurance, meaning that a negligible portion of the output from these contribute to export volume.

The aquaculture industry in Mozambique is recent with the first commercial production recorded in 2002. The potential for aquaculture development is estimated at over 30,000 ha of readily available land for marine shrimp culture and over 258,000 ha for the culture of freshwater species (DNEP 1994). So far, slightly over 2,500 ha of marine shrimp culture have commercially been developed with the highest harvest of 1,106 tons of prawns recorded in 2005. Sea algae culture was another successful commercial undertaking in aquaculture development, but at the moment, there is a decline in production (Table 3).

Freshwater fish culture is developing at the household level in almost all provinces, with Manica and Tete provinces taking the lead. The production is essentially for self-consumption, but there is one entrepreneurial operation in Manica province, producing freshwater fish at commercial scale and with prospects to enter the export market.

In 1995, the government adopted a fisheries policy whose main objective is sustainable development of fishing activities, enhancement of the economic value of small-scale fisheries production and development of commercial aquaculture with special attention to boosting fisheries exports. The fisheries policy emphasises the increase of fish availability for domestic supply through adoption of small-scale production technologies with potential for reducing postharvest losses, augmenting fish landings and ensuring that more fish reaches consumer markets.

The main management tool in the fisheries sector is licensing. Up to 1990, the management and regulation of fishing licences was governed by the Marine Fishery Regulations 1971, the Shrimp Fishery Regulations 1971 (Ministry of Fisheries 1971a, b)

Table 2 Mozambique fish exports (2000–2005)

Description	Annual exports (in thousand US$)							
	2000	2001	2002	2003	2004	2005	Total	(%)
Lobsters	1,122.00	220.0	1,100.0	230.0	334.4	69.8	3,076.2	1
Crabs	234.0	306.0	330.0	1,301.0	575.4	360.1	3,106.5	1
Gamba (deep-sea prawns)	8,077.0	10,471.0	7,500.0	5,061.0	4,519.6	3,163.2	38,791.8	7
Finfish	1,563.0	2,163.0	1,250.0	1,113.0	1,516.5	460.1	8,065.6	2
Shallow-water shrimp	87,561.0	83,979.0	72,800.0	71,665.0	72,671.0	44,070.8	432,746.9	83
Aquaculture shrimp	–	–	–	3,915.0	1,285.8	3,223.9	8,424.7	2
Subtotal shrimp	87,561.0	83,979.0	72,800.0	75,580.0	73,956.8	47,294.8	441,171.6	85
Cray fish	940.0	1,160.0	700.0	1,275.0	1,165.0	432.0	5,672.0	1
Octopus/squid	150.0	205.0	250.0	212.0	506.3	122.7	1,446.0	0
Kapenta	4,576.0	2,066.0	2,441.0	3,309.0	6,179.3	1,856.2	20,427.4	4
Marine algal-aquaculture	–	–	–	–	110.4	43.0	153.4	0
Other	3.0	10.0	10.0	4.0	0.0	0.2	27.2	0
Total	104,226.0	100,580.0	86,381.0	88,085.0	88,863.7	53,802.0	521,937.7	100

Table 3 Commercial aquaculture production in Mozambique 2002–2006 (in tons)

	2002	2003	2004	2005	2006
Shrimp (tons)	600	329	450	1,106	613
Algae (tons)	155	523	129	20	15

and the Inland Waters Fishery Regulations (Ministry of Fisheries 1960). With the promulgation of the Fisheries Law in 1990 which established the Ministry of Fisheries, existing licensing powers were revoked, and the issuing of fishing licences and licences for aquaculture was made the exclusive responsibility of the new ministry. As from 1997, new Marine Fishery Regulations took effect which laid down licensing procedures and also defined the types of fishing techniques that may be used (DNEP 1997). In 2003, a new Maritime Fisheries Regulation replaced the one of 1997. Inland fishing still lacks specific regulations so that its management still relies on the 1990 law (Ministry of Fisheries 1990) and the Marine Fisheries Regulation of 2003 (Ministry of Fisheries 2003). Aquaculture Regulation was adopted in 2001, which establishes extensive and semi-intensive production systems for marine shrimp culture, whereas artisanal production is limited to extensive systems only (Ministry of Fisheries 2001).

With the exception of subsistence activities, all fishing and aquaculture activities are subject to licensing. The issuing of a fishing licence is subject to payment of an annual fee, the amount of which is fixed by a joint dispatch from the Minister of Fisheries and the Minister of Finance. The fees are applied according to the type of fishing (industrial, semi-industrial and artisanal), and within each type of fishing, they vary according to the commercial value of the resource being caught. Every year, the total allowable catch (TAC) and quotas for each of the industrial species are established. For fisheries regarded as non-excedentary[1] (such as the shallow-water shrimp, gamba and large demersals, i.e. line fish), the quotas granted refer to the maximum allowable catch per vessel or series of vessels per company. Semi-industrial fishing (specifically with boats without freezing on-board capacity) is not subject to quota limits, even when fishing the same non-excedentary species mentioned above. The economic agents operating in the fisheries sector, mainly the industrial and semi-industrial fishing companies or groups of artisanal fishermen, participate in decision-making on matters concerning fisheries management especially on matters concerning the establishment of TAC's, fishing quotas and the number of vessels to be licenced per fishery, among other issues. This consultation takes place through the fishery administration commission (CAP), which is a consultative body that brings together representatives of the fisheries administration and of the fishing industry through the industry's associations or fishermen's associations. The Minister of Fisheries takes his final decision on TAC's and quotas after listening to the opinion of the fishery administration commission. Whereas for artisanal and semi-industrial fishing the tax is paid upon issuing of a fishing licence for each boat, industrial fishing is taxed on the basis of quotas allocated for the fishing season.

[1] Non-excedentary is a terminology utilized in fisheries literature to mean low stock relatively to catching capacity, therefore requiring rather restrictive management measures.

All fishing, except for subsistence, requires licensing. Quotas and number of vessels per individual company are the main control measures, and fees are subject to quota. For industrial shrimp trawlers, gamba trawlers and industrial line fishers, there are fees per individual quota. For the rest, there are annual fees per fishing licence. In commercial shrimp fishery, there are fishing rights granted to traditional operators, as the fishery was declared closed for new comers as from 2000. On this basis, a maximum of 78 freezer trawlers are licenced every year.

3 The Maputo Province Case Study

This case study is limited to the coastal districts of Maputo province: Manhiça, Marracuene, Maputo City and Matutuine district. These administrative units constitute the working definition of the coastal zone in Mozambique. This area was chosen to embrace a clearly defined zone in an area that is well accessible. Maputo province, with an area of 26,358 km^2, had a population of 2,152,000 in 2003 (INE 2004). The majority of people live in the coastal districts. In general, the Mozambican population tends to concentrate around 50 km from the sea maximising the use of water, marine and terrestrial resources. The Mozambican coastal resources include fish stocks, coral reefs, land, beach, mangrove forests, flora, fauna, water and air. The main species for artisanal fishing in the province, ranked by captured amounts, are finfish (small pelagic species such as horse mackerel), prawn, crab and octopus/squid (Table4).

Most of the available statistical information on fisheries currently exists either at the national or provincial levels, but it is not disaggregated to the district level. It was therefore necessary to assume in this study that no significant inland fishing activity takes place in Maputo province. This allowed the research team to collect primary fisheries data only from coastal areas. There was also the likelihood that existing secondary statistical information was incomplete or incorrect. This meant that all information collected from primary sources was closely scrutinised before being used in this study.

A total of 5,458 persons were involved in fisheries activities in 2002 in the province; they were working as sailors, fishermen without vessels, in fish processing activities and in boat repairing among others (IDPPE 2002). The fisheries sector consists not only of fishermen and sailors but also of fish vendors who buy fish from fishermen and then sell it at the markets. This means that the number of people involved in fisheries is much higher than those operating in the boats. The IDPPE study also showed that there were 532 fishing boats counted in 2002 with an estimated 2,218 fishers. According to the IDPPE study, there were 34 fishing centres in the province in 2002. A fishing centre is the landing site for artisanal fishers, where the catch is unloaded and sold to local vendors and where the fishing boats and gear are regularly checked. It is maintained by the fishermen themselves, and it functions as a kind of informal association of the fishermen. They select a leader who has the contact with the Ministry and manages the centre.

Table 4 Captured amounts of the main artisanal fishing species in Maputo province (tons)

Year	Prawn	Finfish	Crab	Octopus/squid	Other	Total
2004 (tons)	445	3,705	4	0	261	4,415
2005 (tons)	451	2,755	9	3	188	3,406

Source: IIP – Fisheries Research Institute (2005)

Table 5 Fish catch by kind of fishing gear in Maputo province in 2004 (in tons)

Gear type	Gillnet	Line fishing	Beach seines	Total
Fish caught (tons)	3,276 (92.2%)	92 (2.59%)	185 (5.21%)	3,553 (100%)

Source: IIP – Fisheries Research Institute (2005)

Table 6 Classification of fisheries accounts for the study area

Species	Gamba rosa	Magumba	Marreco
Fishing operator	Industrial fishing	Artisanal fishing	Artisanal fishing, semi-industrial fishing
Fishing vessel	Industrial vessels	Artisanal boats (motorised and nonmotorised)	Artisanal boats (motorised and nonmotorised)
Fishing gear	Bottom trawl	Gillnet	Line

In these centres, there are people with carpenter or mechanical skills to build, maintain and repair boats and engines.

Industrial fishing in the province is only for the gamba fishery (deep-sea prawns) which is almost 100% based in Maputo. Additionally, a few semi-industrial ships are operating in the waters off Maputo Bay, mainly for prawns and some line-fishing vessels. The vessels used in the province for artisanal fishing are flatboats, round boats and boats made of fibreglass. Approximately 13% of the vessels are motorised, mostly with outboard motors. The other vessels work with helms or sails.

According to the IDPPE (2002) census, the province had a total of 560 fishing gears in 2002 distributed as follows: gillnets (206 units), beach seines (200 units) and hand lines (115 units) (Table 5).

The fisheries in Maputo province are classified according to species, fishing operator and fishing vessels or gear (Table 6):

Species: magumba, marreco, bamba rosa, shrimp and squid
Fishing operator: artisanal, semi-industrial and industrial
Fishing vessels/gear: artisanal boats (motorised and nonmotorised), industrial vessels, line and gillnet

4 Methodology and Data

Economic information on fisheries (e.g. production, manufacturing and consumption of fish products) is compiled in the SNA mostly in monetary terms. Physical information on fish stocks, catches and physical flows of fish and fish products is often compiled by fisheries ministries according to concepts, definitions and classifications which respond to specific regulatory or administrative purposes and often are not consistent with economic statistics. The National Institute for Statistics (INE) in Mozambique has a branch responsible for compilation of economic statistics, including that of fisheries, whereas the Ministry of Fisheries compiles physical statistics. There is an ongoing process of harmonisation, and one of the first outputs is a manual of concepts and definitions, to be approved by a Decree, providing classification for a number of economic sectors, including fisheries. The main challenge for this study is attempting to integrate the physical fisheries data with the economic data in an accounting framework in order to obtain a consistent data set, which can be used for the derivation of a coherent set of indicators and for performing more in-depth analysis of the impact of fishery policies on the economy and environment and economic policies on the fisheries sector. The SEEAF handbook provides guidelines for this purpose, and in this report, we attempt to implement the SEEAF methodology in Mozambique.

Based on the classification suggested, the study identified data needs according to the SEEAF methodology, including biomass data, catch statistics and economic data. Data sources included the statistics branch of the Ministry of Fisheries, the Fisheries Research Institute, the Small-Scale Fisheries Development Institute, the Maputo Provincial Department of the Ministry of Fisheries, selected private fishing companies and some fisheries input suppliers. Secondary data in the form of available publications was also considered, especially the IDPPE census of 2002, INE publications and written reports from relevant institutions. The research team held two workshops with relevant stakeholders and a number of separate technical meetings with relevant institutions and individual information sources. The work of the fisheries NRA team was guided by the process flow chart shown in Fig. 1.

4.1 The SEEA Framework for Fisheries Resources Accounting

Fish resource accounts are based on the SEEA (UN 2003b) and the specialised Integrated Environmental and Economic Accounting for Fisheries, SEEAF (UN & FAO 2003a). Fisheries accounts are constructed in physical and monetary terms.

4.1.1 Physical Accounts

As with all asset accounts, fish accounts are constructed for opening stocks, changes that occur during the accounting period and the closing stock. Changes that occur

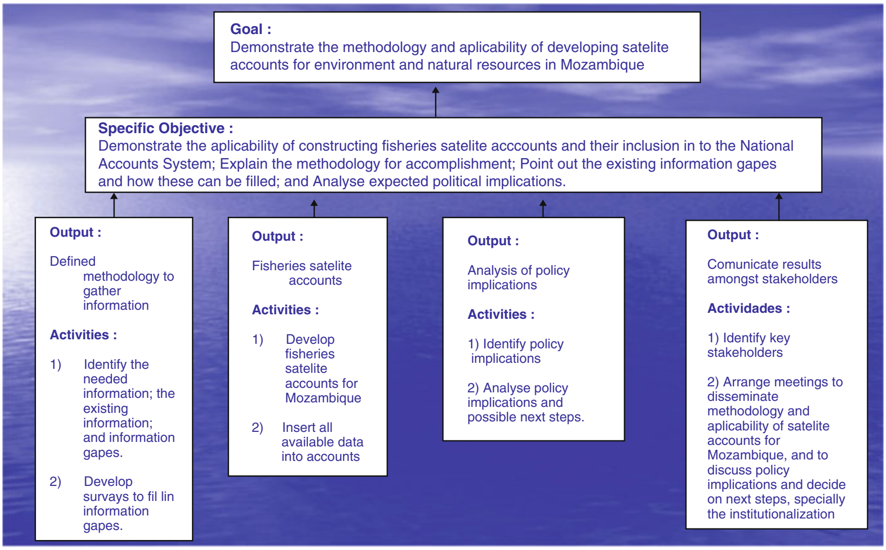

Fig. 1 Process flow chart

during the year consist of catch, recruitment, mortality and other volume changes. Other volume changes can include factors such as the migration of fish stocks out of the country's territorial waters due to environmental events. In practice, there is not enough information to quantify all the different sources of change so that changes are collapsed into two categories: "Catch" and "Other Volume Changes" (Lange 2003a, b). For long-lived species, it would also be useful to construct accounts by age class, as is done for forestry (Hassan 2000).

In this study, physical accounts were constructed for two species, *Haliporoides triarthrus* (gamba pink or gamba rosa), which represents about 70% of the commercial catch in deep-water shrimp, and *Hilsa kelee* (magumba), a small pelagic species caught by artisanal fishers. The fisheries research institute estimates the stock size for each species using the Schaefer production model (IIP 2005). The model requires a time series corresponding to an observed commercial abundance index and catch representative of the whole stock. Because it is a non-linear model, it requires the pre-estimation of two stock parameters: r (intrinsic rate of growth) and K (carrying capacity) (Conrad 2010). Catch is essential to calculating stock abundance of the following year. Analysis of commercial landings for catch and effort and on-board biological sampling programmes provided additional information for the analysis. There are a number of limitations to the empirical application of this method. First, the stock estimates are only based on data provided by commercial fishing boats. However, only a well-designed biomass survey can provide a more reliable estimate of the overall fish biomass. There is also a need for ecological studies in which the present state of health of the ecosystem is determined and the availability of stock flows ascertained. This issue is particularly important in that it provides information on the state of exploitation or health of the fishery.

4.1.2 Monetary Accounts

The value of fish, like any other asset, is the net present value of the stream of income (rent) it is expected to generate in the future. Constructing monetary accounts has two components: (1) defining how rent is to be calculated and (2) making projections about the future rent a fishery is likely to generate. Both components raise unique challenges for fisheries.

Rent is defined as the value of production minus the marginal exploitation costs. When markets are lacking, rent is often measured with the residual approach (see Lange 2003a). However, for fisheries managed under an individually tradable quota (ITQ) system such as Iceland and New Zealand, a market for quotas may develop that, under the right circumstances, reflects the rent. The resource rent formula is

$$\mathrm{RR} = \mathrm{TR} - (\mathrm{IC} + \mathrm{CE})$$

where RR is resource rent, TR is total rent, IC is intermediate consumption and CE is compensation of employees. In actual implementation of rent calculations, average cost is used rather than marginal cost because data about marginal cost are generally not available.

As mentioned above, the value of each fish stock is the net present value of the rent it will generate in the future. The present value calculations require projections of future prices, technology, costs of production, fish stock levels and resource exploitation paths. Future stock levels depend partly on fisheries policies and partly on environmental conditions and their impacts on fish stocks, which are difficult to forecast. In the absence of alternative information, common practice has been to assume that the current year's prices, technology and production costs remain constant in the future. The calculation then relies on the remaining variables: levels of stock and exploitation.

Prediction of future stock levels is much more difficult with marine capture fisheries than with other renewable resources, like forests, because there is a high degree of uncertainty resulting from poorly understood dynamics of many fish populations and of large marine ecosystems. In some relatively well-understood fisheries, a bio-economic model can be used to assess the likely future stocks, costs of fishing and rent under different management regimes. If government is clear about its management objectives, the model can be used to assess the value of the fish stock with reasonable accuracy. Such a model was used, for example, to assess the value of Iceland's fisheries (Danielsson 2000).

In principle, given a harvest regime and a stock size, a stock of fish has the biological potential to either increase, remain constant or decline in the long run. Each of these possibilities has different implications for future rent and the value of the asset. If fish stocks remain constant, then rent and asset value will remain constant. If there is a recovery from depletion and fish stocks increase, then rent will increase over time, and the present value of the asset is much higher than under the constant stocks assumption. If, on the other hand, fish stocks decline, then the asset value will be much lower. Assuming a fishery is currently efficiently managed, one could further assume that the stocks have stabilised at current levels and will generate the same rent in the future. Under this assumption, the net present value formula takes the following form:

$$V_t^i = \frac{\text{Rent}_t^i}{r}$$

where

V^i the value of the resource stock at the close of period
Rent^i total rent
r the discount rate

For each fishery, *i* and *t* is time.

4.2 *The Primary Data*

4.2.1 Species Included in the Survey

Prior to consulting the relevant sources of information, the project team internally discussed the terms of reference and decided to consider some changes in the classification to be adopted for the fisheries NRA work. Since there are many species exploited by fishers, the team decided to include only a few in the accounts selected on the basis of data availability and economic value as discussed below:

For the artisanal fishing, the following classes were considered:

Shrimps: two main species were to be considered, *Fenneropenaeus indicus and Metapenaeus monoceros. The two represent over 60% of the mean catch*
Large demersals: cachucho, marreco, robalo and magumba

For the semi-industrial fishing, the following were the considerations:

Large demersal species: the concern was that this fishery not only operates in Maputo Bay and the surrounding coastal areas but also further up in the north. The problem then was to allocate the catch between that obtained within and that obtained outside the waters of Maputo province. After checking the vessels' logbooks at the provincial department, it was not possible to make this allocation. Consequently, large demersal species were excluded from the fisheries NRA.
Shrimp: after discussions with the fisheries research institute in Maputo, the team concluded that information on biomass was unavailable and thus shrimps were excluded from the fisheries NRA.

In short, this case study does not include any semi-industrial fishers in the NRA. However, fish species such as large demersals covered in the accounts for artisanal line fisheries are the same ones fished by the semi-industrial fishers.

For industrial fishing, only the gamba fishery (gamba rosa) was considered. This type of fishing occurs not only in Maputo Bay and the surrounding coastal areas, but also further in the north. The issue again was to determine how many of the fishers leave the case study area and how much of their catch is obtained outside of Maputo province. Checking the logbooks was the answer, and these were usable compared to the ones for the semi-industrial fleet. Another concern was that the statistics had to be checked carefully as fishers often care more for the by-catch than for gamba itself, as the former is more valuable. The main by-catch species, ranked in order of importance, include crayfish, deep-sea crabs, lobsters, a variety of deep-water finfish species and cephalopods. Crayfish and lobsters are of much higher commercial value than gamba, and there is a ready export market for them. In the gamba fishery, fishers are allowed to land crabs, all types of finfish and cephalopods as by-catch, but these are of low commercial value and can be sold in the local market. Company owners will normally distribute a huge amount of this type of fish to their employees, as a social benefit. No clear policy is currently in place for the management of the crayfish fishery. The absence of scientific information on the resource base can be considered as the main reason for the precautionary approach to management currently being observed, consisting of not licensing any exploitation. Exploitation of the lobster fishery was banned in 1997/1998 due to stock depletion, and about 9 years down the road, this management measure is yet to be revised.

Recreational and sport fisheries activities are mainly done in Ponta d'Ouro and Maputo Bay. Information on the main species for this fishery (i.e. the large pelagic species) is obtained from the provincial directorate. It has been realised that a programme for monitoring this activity had just been launched, and there was insufficient data readily available to construct the accounts for this activity at present. Consequently, these fisheries were not included in the Mozambique fisheries NRA. Inland fishery was also excluded from the NRA due to lack of data in spite of its importance, especially tilapia-dominating local markets.

It can thus be seen that adequate information could only be obtained for gamba and magumba making the team concentrate on these two species in constructing the accounts. For gamba, stock and catch data was obtained from 1995 to 2005, and for magumba, stock and catch data was obtained from 1992 to 2006. In constructing the physical accounts, the team could not estimate the magnitude of illegal catch as there was insufficient data available within the project time frame. There are no statistics at all on production costs, particularly in the artisanal fishery, and hence, the study made the assumption of constant base cost for this time period. The constant base cost being the one derived from the case study survey for the year 2006.

In summary, the fish stocks of interest in this study (magumba and gamba) are not confined to the study area giving rise to the question of whether the study area was well defined.

It was not possible to know from the operator's logbooks (industrial and semi-industrial) how many of them operate outside the study area and how much of their catch is obtained from outside. It was therefore decided to consider two case study areas for the different species of interest: (1) Maputo Bay for the magumba accounts and (2) a wider area, off Maputo Bay and extending to the south of parallel 21°S for the gamba accounts.

It was also concluded that it would not be possible to use any logbook information for the semi-industrial shrimp and line fishing (e.g. marreco).

Lack of reliable data was the main reason for this study to concentrate on a few species. The information database that fisheries sector institutions are collecting are limited to catch statistics and fishing effort and generally does not include other socio-economic attributes. By law, industrial companies are required to submit copies of their annual accounts, but this practice is not being regularly observed by most companies. The National Census of Artisanal Fisheries, conducted by IDPPE in 2002, did not attempt to collect any economic data. Therefore, for the purpose of developing the monetary accounts, we decided to design and implement primary data surveys with commercial and artisanal fishers. The residual approach was used in measuring the resource rent. The survey covered commercial and artisanal operators (including fish vendors).

4.2.2 The Survey of Commercial Fishing Operators

All 11 commercial firms that were active in the gamba fishery in 2006 were surveyed via mail questionnaires. Only 3 of the 11 companies approached responded to the questionnaires. These three companies however were representative of the fishery given that they produce over 50% of the total catch of gamba (in 2005 they produced 58% of the total gamba catch). Of the three companies that responded, one dedicates over 80% of its effort to gamba fishing and the other 20% to shallow-water shrimp fishing. The other two companies are mainly shrimp fishers dedicating over 50–70% of their effort to shallow-water shrimp fishing.

The accounting structure of all the companies is aggregated without providing a clear separation between gamba and magumba operations. This means that for the calculation of resource rent, we had to use the allocation of effort between gamba and magumba to determine how much of the total costs should be imputed to gamba operations and how much should be imputed to magumba operations. The 11 companies operated a total of 27 boats in 2006, of which only 4 were owned by one of the companies, and 23 were charter boats. There is some level of reluctance to invest (owning of gamba boats) due to the high market uncertainty involved in this business (commercial risk). So, only four boats operating in the gamba fishery are Mozambican, and rest are chartered from abroad. Thus, the issue of capital invested in the fishery was neglected, and all capital cost-related variables of the resource rent formula were assumed to be equal to zero. Furthermore, companies are not required by law to provide this information, so the study had to rely on the goodwill and cooperation of companies.

4.2.3 The Survey of Artisanal Fishers and Vendors

Unlike the survey of commercial firms, the survey of artisanal fishers and fish vendors was rather complex, both for questionnaire development and survey implementation, which consisted of deploying groups of enumerators to the fishing centres to collect information. The questionnaire was developed by the project team and would have benefited from a wider participation in a focus group. However, there was not sufficient time to allow for such participation.

Five university students and one fisheries officer were recruited and trained as enumerators to carry out the surveys of artisanal fishers and vendors. The training consisted of two sessions of about 2 h each and was probably too short, since none of the enumerators had any previous experience with surveys. The surveys were carried out over five working days, and each survey team member was expected to interview five persons (both fishers and fish vendors) per day. In total, they were expected to cover a sample of 150, but they managed to provide only 103 responses distributed as follows:

39 responses for magumba
48 responses for line fish
16 responses for fish vendors

The data resulting from the survey of artisanal fishers was generally poor, with lots of unanswered questions and or inconsistent answers. The short training of enumerators, inexperience and lack of ability to deal with “rather defensive” fishermen can be pointed out as the main reasons for this poor outcome. The survey team also subsequently learnt that questions such as frequency of fishing trips, amounts of catch, etc. should be asked on weekly basis because fishermen can hardly remember their total catch or the number of days they went out fishing, for longer periods like 1 month or a season or a year.

After the survey of artisanal fishers, the project team analyzed individual questionnaires, took note of the types of problems in the answers and then held a briefing with the survey teams to get clarifications on the questionnaires. From this briefing, the research team observed that after less than 2 weeks, the students could not quite remember how they arrived at a number of answers. As a consequence, not much improvement (data cleaning) could be made to the database. From this experience, the research team learnt that much greater supervision of the survey was required, and briefing sessions with the enumerators should be carried out on daily basis at the end of each daily survey campaign in order to revise the questionnaire and provide additional clarification to the enumerators. Consequently, the information collected from fish vendors was not utilised for the accounts. The team realised that, apart from having a limited number of answers from vendors, it would become more complex (and probably irrelevant) to attempt to reflect in the accounts the vendor’s sale price of fish because that would also imply aggregating vendor’s costs in the calculation of the rent.

5 Results and Discussion

NRA have been constructed for three species: gamba rosa, magumba and line fish. However, due to the lack of biomass and growth information for line fish, it is only the accounts for gamba rosa and magumba that can be considered complete.

5.1 The Gamba Rosa NRA

5.1.1 Physical Accounts

Gamba is the third most important export species for Mozambique after shallow-water shrimp and kapenta. It is a migratory species and companies fish for the species in the whole area south of parallel 21°S. There are 11 fishing companies registered in gamba fishery operations, and with the exception of one, all are based in Maputo fishing port. Management of the gamba fishery is based on fishing licences, TAC and the quota system. The gamba fishery is multi-species, operated by bottom trawl nets, and the by-catch includes crayfish, lobster, squid, demersal finfish and crab, among others. Most of the by-catch often earns higher sales value than the gamba itself, which makes the fishery quite complex to manage as fishers tend to target the by-catch rather than gamba. Quotas for the authorised by-catch are set as a percentage of the target species, and fishers are prohibited from landing non-authorised by-catch species, such as deep-sea lobsters. From 1994 to 2004, the TAC for the whole gamba fishery was set at 5,000 tons; after that, it was reduced to 3,000 tons. However, the total catch per year has never reached 2,000 tons probably because the majority of licenced vessels only fish gamba in periods when the catch rates of shallow-water shrimp are low or during the closed season of the shrimp fishery (December–March).

There is more than one gamba species although the main one is *Haliporoides triarthrus* (commonly known by gamba rosa), representing over 80% of the targeted catch. The fisheries research institute (IIP) is running a specific monitoring and stock assessment programme for gamba rosa using the Schaefer model for stock predictions. For data sources, IIP is using logbook statistics, on-board sampling and surveys. Table 7 (physical stock accounts for gamba rosa) was constructed based on the IIP stock assessment data. Note that data on "observed catch" corresponds to total gamba species (including red gamba that represents 20% of the total gamba catch). By reducing 20% of the "observed catch", one is able to construct the physical stock accounts for gamba rosa.

The information used for compilation of Table 7 was based on:

Species: Haliporoides triarthrus (gamba rosa)
Type of fishing and gear: industrial fishing, bottom trawling
Extent of fishing zone: whole distribution zone including Maputo and Sofala provinces
Source of data: IIP logbooks statistics, on-board sampling and surveys
Model of stock prediction: the Schaefer model (general production model)
Data quality: 88% fit
Margin of error: 12%
Observed catch: the total catch, including pink (gamba rosa, 20%) and red gamba (80%)
A multispecies fishery whose by-catch includes crayfish, lobster, squid, large demersal finfish, crab and other gamba species.
Gamba rosa is a migratory species.

Table 7 Physical accounts for gamba rosa species (in tons)

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Opening stock		3,112	2,061	2,108	1,819	1,974	2,153	2,247	2,324	2,335	2,465	2,561
Changes in stock	Total	−1,051		−289	155	179	93	96	−8	130	96	196
	Observed catch	1,690	1,128	1,457	1,035	1,006	1,066	1,040	1,115	979	964	820
	Estimated illegal catch											
	Net natural growth	639	1,175	1,168	1,190	1,185	1,159	1,136	1,107	1,109	1,060	1,051
Closing stock		2,061	2,108	1,819	1,974	2,153	2,247	2,342	2,335	2,465	2,561	2,756

Catch variation is quite consistent with variation in effort, that is, catch goes down as effort goes down. Effort is based on the total number of fishing days of the operating boats. Due to its low commercial appeal, the fishery has not been attracting much investment, and most (almost all) gamba fishers are not specialising in this fishery but rather, they are doing combined fishery, with shallow-water shrimp fishery. Other reported types of management problems include underreporting and filling of logbooks on land rather than while fishing.

5.1.2 Monetary Accounts

Only 3 of 11 active gamba fishers in 2006 did respond to the primary survey, and contrary to the legislated requirements, the Ministry of Fisheries did not keep any copies of the companies' books of accounts. Therefore, only data from the three commercial companies was analyzed, and the accounts reflect one single year of operation rather than an average taken from a series of years as was originally intended. All the three companies studied are involved in gamba and shrimp operations and they keep aggregate rather than separate accounts per type of operation (fishery). However, one of them is more gamba oriented and keeps a specific fishing fleet for gamba and a separate boat for shrimp trawling, but still, the accounting of this company is aggregate.

For the gamba-oriented company, the team assumed that 80% of total costs are gamba related (four out of five boats) and 20% are from the shrimp operations. The second company is using the same boats for both fisheries, and the shifts from one fishery to another are done along the year, based on the season's catch rates and quota criteria, that is during shrimp high season (March, April and May), and while shrimp quotas are not exhausted, the whole fleet will be used for shrimp trawling. Thereafter, when shrimp season is low or shrimp quotas are reached, the fleet shifts to gamba fishery. We analyzed the behaviour of this fleet over the period of years 2000–2004 and concluded that they are doing about 50% of the time in each fishery. Therefore, we assumed that 50% of total costs can be imputed to gamba and neglected the fact that trawling for gamba costs relatively more as bottom trawling of over 300–650 m depth requires higher power engines and the consequent higher fuel consumption. The trawl system is also relatively more costly as an intermediate input, as compared to the gears for shallow-water trawling. The third company is mostly shrimp fishery oriented, and when in season, it will use the entire fleet on the shrimp fishery. When the shrimp season is over, a smaller part and not the whole fleet will shift to gamba operations and remain there until quotas are reached or the year closure. On the basis of time and fleet allocation per fishery, we have assumed that 20% of the total costs can be imputed to gamba.

Resource rent calculations for the three companies is presented in Table 8 where it is calculated as total revenue less labour costs, intermediate inputs and financial costs.

The structure and management setting of the three analyzed companies are completely different, which renders their accounts to be poorly comparable. Therefore, the monetary accounts can be built on the basis of net revenues of company 1, which

Table 8 Gamba resource rent calculation (US$1 = MZN18.900)

Structure	Comp 1	Comp 2	Comp 3	Total
Revenues				
Annual production (tons)	500	235	293	1,028
Production value (10^3 MTn)	62,020,000	28,209,094	23,255,600	113,484,694
Costs				
Labour costs (10^3 MTn)	3,813,201	5,641,839	1,130,409	10,585,449
Intermediate inputs (10^3 MTn)	217,481	26,117,493	469,521	26,804,495
Financial costs (10^3 MTn)	30,353,813	26,254,243	25,001,359	81,609,415
Capital costs (10^3 MTn)	0	n.a.	n.a.	
Net revenues				
Net revenue (10^3 MTn)	27,635,504	−29,804,481	−3,345,689	−5,514,665
Capital opportunity cost (10^3 MTn)				
Profit	27,635,504	−29,804,481	−3,345,689	−5,514,665
Average rent (on each unit "ton of fish") (10^3 MTn)	55,271	−126,828	−11,419	−5,364

is specialising in gamba fishery, rather than an average taken from the three companies. Otherwise, the mean net revenue derived for the three companies is negative (−5,364 MTn). If capital costs were included in the calculations, the net revenue would be even more negative. However, it should be noted that the production value of by-catch has not been included in the calculations and that it would have a contrary effect and work as buffer to the negative rent of gamba.

As our exercise was based on a sample rather than the whole fishery, we have derived an average rent (per each unit "ton of fish") which is (−5,364.00 MTn) under current exploitation using the average of all three companies and 55,271 MTn if we will apply the "ideal" value using the unit rent from company 1. If we were to apply the scenario of average rent of the three companies, which is negative, the asset value would be negative. When asset value is negative because of negative resource rents, the value of asset is reported as zero. Thus, we have chosen to build the accounts on the basis of the "ideal" scenario, using the unit rent of company 1.

5.1.3 Asset Valuation

SEEAF defines the value of each stock as the net present value of the rent it will generate in the future. The present value calculations require projections of future prices, technology, costs of production, fish stock levels and resource exploitation paths. Future stock levels depend partly on fisheries policies and partly on environmental conditions and their impact on fish stocks, which are difficult to forecast. In the absence of alternative information, common practice has been to assume that the current year's prices, technology and production costs remain constant in the future. The calculations of Table 9 below have relied on the remaining variables: levels of stock and exploitation, as given in the physical accounts of Table 8, and assumed all other variables are constant.

For the resource rent of 55,271 MTn per each ton of fish caught, company 1 paid in 2005 an average of 2,436 MTn per ton as licence fee corresponding to 4% of the rent. This percentage of rent recovery can be much lower if we consider the production value of the by-catch which has not been accounted for. One may want to discuss whether this is a fair pay for the recovery of rent by the State, but this requires further investigation. On the other hand, as derived from the total labour costs and the number of local employees in the company, the average salary paid (month/man) in 2005 was 4,965.11 MTn which is 3.5 times as much as the minimum wage.

5.2 Magumba Fishery NRA

5.2.1 Physical Accounts

Magumba (*Hilsa kelee*) can be considered the most important artisanal fishery species in Maputo Bay given that it is fished by 37% (206 gillnets) of the 560 units of fishing effort (IDPPE National Census 2002). It is the most abundant fish in the local markets, and the landings are much higher compared to the catch of other fish species. Because of its very low market price, it is the most accessible source of protein for the low-income consumers.

The stock of magumba is composed of a unique species that is highly concentrated around Maputo Bay making its monitoring and stock assessment relatively easy. A similar stock is located in the waters of Sofala Bay, off the coast of Beira. The main management measures consist of access by fishing licence and mesh size regulation. However, this fishery can be considered to be an open access for two main reasons: (1) there are no limits to the number of licences issued to fish (anyone can get a licence to fish magumba); (2) due to the poor capacity for monitoring and enforcement, most of the fishers are operating without fishing licences. For instance, in the primary survey we have carried for the study, only few respondents answered the question related to payment of licence fees. The Fisheries Research Institute (IIP) is running a specific monitoring programme of the magumba fishery, which includes compilations of landing statistics, and a data series is available for the period from 1992 to 2005. According to IIP, the process of data collection and processing varied throughout the time, and it can be divided overall in two main periods: the period from 1992 to 1997 and the period post 1999 when a new system of data sampling came into practice for the artisanal fisheries. The physical stock accounts for magumba are reported in Table 10.

Table 9 Monetary accounts for gamba rosa (in 10^6 MTn)

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Opening stock		1,720	1,139	1,165	1,005	1,091	1,190	1,242	1,294	1,291	1,362	1,416	1,523
Changes in stock	Total	−581	26	−160	86	99	51	53	−4	72	53	108	
	Observed catch	934	623	805	572	556	589	575	616	541	533	453	805
	Estimated illegal catch												
	Net natural growth	353	649	646	658	655	641	628	612	613	586	561	
Closing stock		1,139	1,165	1,005	1,091	1,190	1,241	1,295	1,290	1,362	1,416	1,523	

Table 10 Physical stock accounts for magumba (in tons)

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Opening stock		168	1,627	2,232	2,809	3,574	4,723	6,440	15,457	10,137	9,820	8,757	7,816
Changes in stock	Total	−61	605	577	765	1,149	1,717	9,017	−5,320	−317	−1,063	−941	661
	Observed catch	1,401	691	1,132	1,304	1,346	1,304	3,528	6,809	4,024	4,811	4,755	3,115
	Estimated illegal catch												
	Net natural growth	1,339	1,296	1,709	2,069	2,494	3,021	12,545	1,489	3,707	3,748	3,814	3,776
Closing stock		1,627	2,232	2,809	3,574	4,723	6,440	15,457	10,137	9,820	8,757	7,816	8,477

The information used for compilation of Table 10 was based on the following:

Species: Hilsa kelee (magumba)
Type of fishing and gear: artisanal, gillnet
Extent of fishing zone: Maputo Bay, 70% of catch from Costa do Sol
Source of data: IIP data base
Model of stock prediction: Schaefer Model (general production model)
Data quality: 99% fit
Margin of error: 1%
Observed catch: sampling estimations
Type of management: no TAC's or quotas established, control through licensing of boats, mesh size of nets determined with 2¼ in., but no regular enforcement

The CPUE was derived based on the assumption that there has been no significant changes in the fishing effort over the study period so that the 206 fishing units (gillnets) captured in the IDPPE census (2002) remained constant. Since there has only been one national census of artisanal fisheries ever conducted so far, there is no basis for assessing trends in these fisheries.

A very drastic rise in CPUE has been observed between 1999 and 2000, and thereafter, it remained very high (compared to earlier years). The dramatic change in the estimated biomass and catch, and consequently the CPUE, can be attributed to the earlier mentioned change in data collection systems. While acknowledging this fact, the Fisheries Research Institute has attributed this trend primarily to unexpected environment modification in Maputo Bay as a consequence of a massive flood which affected the inshore primary production of the southern Mozambican coastal zones, and as an instant response, the stocks increased significantly. Our primary survey of artisanal fisheries collected catch data, which upon analysis produced an estimate of 7,250 kg for CPUE. As the figures on fish catch from IIP for the period 2001–2005 are unlikely too high, we decided on one scenario from IIP figures which are consistent with our primary survey, and the physical accounts were developed on this basis. Until 1999, we had just a normal variation in catch data, and it is within a range that is consistent with the estimate derived from our case study survey (7,250 kg). For our analysis, we have excluded data from the period 2000 to 2005, that is, we have utilised available data only for the period between 1992 and 1999.

5.2.2 Monetary Accounts

Data for the construction of monetary accounts was collected through primary surveys as described in earlier sections of this document. The outcome of the surveys was so poor that we had to select best cases that could be utilised for the accounts. Of 39 responses received for magumba, only four could be used in the analysis. The results from these cases were cross checked with IIP catch statistics and with information collected from suppliers before being used in the analysis. The analysis derived average net revenue received for the four selected cases of 36,824.12 MTn. This net revenue is inclusive of revenue received by boat owner (or fishing gear owner), labour costs and opportunity cost of capital so that the actual

Table 11 Magumba fishery resource rent calculations

Structure	Case 1	Case 2	Case 3	Case 4	Average
Revenues					
Estimated annual production (kg/fishing unit)	7,250.0	7,250.0	7,250.0	7,250.0	7,250.0
Production value (MTn)–at prices from the survey	54,375.00	72,500.00	65,250.00	67,664.25	64,947.31
Costs					
Labour costs (MTn)	7,100.00	24,350.00	6,000.00	17,750.00	13,800.00
Intermediate inputs (MTn)	12,000.00	10,800.00	8,400.00	4,080.00	8,820.00
Estimate financial costs (MTn)	4,000.00	4,000.00	4,000.00	4,000.00	4,000.00
Capital costs (MTn)	435.0	2,000.00	577.78	3,000.00	1,503.19
Net revenues (MTn)					
Net revenues (MTn)	30,840.00	31,350.00	46,272.22	38,834.25	36,824.12
Estimate owner's labour cost (minimum wage) (MTn)	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00
Capital opportunity cost (10%) (MTn)	543.75	1,500.00	520.00	1,500.00	1,015.94
Profit (MTn)	12,296.25	11,850.00	27,752.22	19,334.25	17,808.18
Average rent (on each unit "kg of fish") (MTn)	1.70	1.63	3.83	2.67	2.46

Table 12 Monetary stock accounts for magumba (in 10^6 MTn)

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Opening stock		49	41	42	40	55	69	88	116	158	380	249	241	215	192
Changes in stock	Total	−8	1	−2	15	14	19	28	42	222	−131	−8	−26	−23	16
	Observed catch	46	32	34	17	28	32	33	32	87	167	99	118	117	77
	Estimated illegal catch														
	Net natural growth	38	33	33	32	42	51	61	74	308	37	91	92	94	93
Closing stock		41	42	40	55	69	88	116	158	380	249	241	215	192	208

net profit on capital is 17,808.18 MTn, which is about the current national minimum wage. The calculation of production value was based on the first sale price (fisherman's price). In calculating the financial costs, we included estimates of asset depreciation based on individually declared lifespan of the boats, and then an average of the four cases was taken. We assumed 10% rate of capital opportunity cost. Results of resource rent calculation for the magumba fishery are given in Table 11.

5.2.3 Asset Values

The asset value of magumba fishery was calculated by applying the average unit rent of the four cases, 2,46.00 MTn/kg of fish (Table 11). The calculations of Table 12 used the physical data of Table 10.

Table 12 shows that the magumba fishery is a reasonable source of income for the boat owners as it provides an average of 17,808.12 MTn of profit. For this level of profit, each boat owner has paid 394 MTn of licence fee, according to survey data, representing 2% of rent recovery. This can be considered a very good level of rent recovery by the State taking into consideration the social objective pursued in this fishery, which is to secure a sustainable source of income for the poor fishermen. Nonetheless, it should be noted that the officially applying licence fee for magumba is 245 MTn for boats with outboard engine, which represents only 1% of rent recovery from this fishery. This is not consistent with the declared amount in the survey. However, the fishermen working for the boat owners are very poorly paid, and this can be a big challenge to the sustainability of the fishery. The average number of paid labour is two fishermen per boat. The labour costs are estimated at 13,800 MTn per year which correspond to a monthly pay of 575 MTn per fisherman – less than half the national minimum wage. Given that this fishery is of open access, these working conditions can be an incentive for the individual fishermen to attempt to have their own fishing boat and gear so as to better their individual income level. The immediate implication of this would be an increase in fishing effort. The Government pursues a development promotional policy based on soft credit schemes for the fishermen. This is a great opportunity for more and more fishermen to become self-employed boat owners. While this is good for poverty alleviation, it requires strong capacity for monitoring the resource exploitation so as to keep it within sustainable levels.

5.3 Line Fish NRA

5.3.1 Physical Accounts

Line fishing is the third most important type of artisanal fishing gear in Maputo Bay, accounting for a total of 115 units of artisanal fishing effort according to the IDPPE census of 2002. Total catch recorded in 2004 for the artisanal fishers was 92 tons. The fishery is operated mainly by semi-industrial boats, with a mean annual catch

Table 13 Physical stock accounts for Marreco (in tons)

		1998	1999	2000	2001	2002	2003	2004	2005
Opening stock									
Changes in stock	Total								
	Observed catch	18	n.a.	60	66	18	28	66	n.a.
	Estimated illegal catch								
	Net natural growth (e.g. birth, recruitment, death)								
Closing stock									

varying between 350 and 400 tons. The main concentration of semi-industrial fishing effort is at the south of Save River, along the coast of Maputo, Gaza and Inhambane provinces. Unlike magumba which has very localised stocks in Maputo and Sofala Bays, the stock of line fish is distributed through a much wider area across the southern provinces, and other stocks are recognised to occur in the central and northern provinces.

Line fishing is a multispecies fishery, and the respective catch statistics are reported with no discrimination by individual species. However, the existing stock assessment programme, run by the Fisheries Research Institute, is only for Marreco *Chrysoblephus puniceus*, considered to be the most important species in the catch composition. For this reason, we were unable to build complete physical accounts for this fishery. The physical accounts for Marreco are given in Table 13.

The information used for compilation of Table 13 was based on:

Species: Chrysoblephus puniceus (Marreco)
Source of data: IIP

5.3.2 Monetary Accounts

The primary survey collected 48 responses from fish operators, but due to data quality, only four of these were selected for further analysis. The annual catch data estimated from these four units ranged from 1.9 to 7.8 tons per unit, giving a total of between 218.5 and 897.0 tons of artisanal fish production for the 115 fishing units. These figures are not consistent with and are far beyond the estimated catch reported by the Fisheries Research Institute, which estimated the annual catch in 2004 at 92 tons. In Table 14, we compute the net benefits to the individual fishing unit based on the survey data and complementary information from suppliers. We generally conclude that with the exception of case 1 which recorded negative net revenue (−7,113.00 MTn), the line fishery is generally profitable.

The column of averages in Table 14 shows that line fish fishery is much more profitable than the magumba fishery, which is consistent with the observed reality. According to the primary survey data, line fishermen paid an average of 303.5 MTn

Table 14 Line fishery resource rent calculation

Structure	Case 1	Case 2	Case 3	Case 4	Average
Revenues					
Estimated annual production (kg/fishing unit)	1,935	4,380	7,200	7,840	5,339
Production value (MTn) – at prices from the survey	98,100	226,800	360,000	470,400	288,825
Costs					
Labour costs (MTn)	41,400	68,040	108,000	84,000	75,360
Intermediate inputs and financial costs (MTn)	63,398	12,300	18,000	104,400	49,524
Capital costs (MTn)	415	30,000	6,000	3,200	9,904
Net revenues (MTn)					
Net revenues (MTn)	−7,113	116,460	228,000	278,800	154,037
Estimate owner's labour cost (minimum wage) (MTn)	18,000	18,000	18,000	18,000	18,000
Capital opportunity cost (10%) (MTn)	510	4,500	3,000	1,600	2,402
Profit (MTn)	−11,397	93,960	207,000	259,200	133,635
Average rent (on each unit "kg of fish") (MTn)	−5.89	21.45	28.75	33.06	25.03

for licence fee. Relative to the average net revenues of 154,037 MTn (Table 14), this represents a meagre 0.20% of rent recovery. Based on these findings, one could consider revisiting the present taxation policy. Considering that each fishing unit employs on average four paid labourers, it is estimated that salaries in this fishery are just as much as the minimum wage in Mozambique. However, the rent generated in the line fishery suggests that there is potential for paying better salaries and this study hypothesises that this is not happening because of excess labour supply in the fishery.

6 Conclusions and Policy Implications

It is our conclusion that constructing fisheries NRA in Mozambique is feasible for all commercially fished species but rather complex for most artisanal fisheries. For the industrial shrimp fishery, gamba and kapenta, the routine for calculating physical and monetary accounts can be established in a quite straightforward way. It will require revisiting existing legislation on statistics reporting and ensuring effective enforcement for non-compliance, which can be combined with education campaigns for the industry.

For the semi-industrial shrimp and line fish fisheries, there is need to enhance capacities, enabling the Fisheries Research Institute to perform the existing stock assessment programmes. The Fisheries Provincial Directorates should be enabled to utilise the logbook information collected from the fishing boats and produce relevant reports that will be the source of information for development of fisheries accounts.

Changes should be considered in collecting and processing catch statistics in order to identify separately at least the most relevant fish species.

Artisanal fishing is rather complex, and one may consider different options for the classification of the accounts, depending on specific characteristics of the fishery concerned. The magumba fishery, which consists of a unique fish species and is fished with a rather selective gillnet, appears to be an exception in the complexity of developing artisanal fisheries accounts. Magumba accounts can be developed in a quite straightforward way provided that required improvements in primary data collection methodologies are in place.

Other main artisanal fisheries are operated by none or less selective types of fishing gears, such as beach seines (nonselective at all) and hand lines (selectively used for finfish species), among others. The species captured with these fishing gears are generally of the same stocks as those fished by the semi-industrial and industrial boats, and this will require a special attention in the classification of the accounts and on the methods of information gathering and aggregation.

We have concluded that the system of fisheries statistics needs to be revisited, and appropriate adjustments are required, specifically for the artisanal fisheries, in order to improve quality of the data. The 5-year national census on artisanal fisheries should also capture economic data rather than being limited to catch and effort statistics, and in the interim periods between national censuses, regular surveys should be conducted in order to build up a robust reference database. A critical aspect to be taken care of in conducting the census and surveys is the design of questionnaires and training and supervision of survey teams. Institutional development and relevant investments should be considered in capacity building, including human resources and adequate equipment.

In the revision of the fisheries statistics system, the role of fisheries institutions and coordination matters should be considered very carefully as it appears that roles and competences of each partaking institution are not very well established, and some institutions are "forced" to perform others' roles. For instance, the Fisheries Research Institute has been charged with responsibilities to provide catch statistics for artisanal fisheries, and for performing this task, there is less time available for scientific tasks such as fish biology sampling and analysis.

Environmental accounts generate information that is useful and crucial for both enlightenment and effective management measures. For instance, issues like setting appropriate levels of taxes and levies for the industry, specific sector labour polices, among others, can be supported by this type of NRA studies.

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References

Conrad JM (2010) Resource Economics, 2nd edn. Cambridge University Press

Danielsson A (2000) Integrated Environmental and Economic Accounting for Commercial Exploitation of Wild Fish Stocks. National Economic Institute and Economics Department, University of Iceland, Unpublished Paper

DNEP (Ministry of Fisheries) (1960) Inland waters fisheries regulations 1960. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (1971a) Marine fisheries regulations 1971. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (1971b) Shrimp fisheries regulations 1971. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (1990) Fisheries Law 1990. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (1994) Fisheries and fishery master plan 1994. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (1997) Maritime fisheries regulations 1997. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (2001) Aquaculture regulations 2001. Government of Mozambique, Maputo

DNEP (Ministry of Fisheries) (2003) Maritime fisheries regulations 2003. Government of Mozambique, Maputo

Hassan RM (2000) Improved measure of the contribution of cultivated forests to national income and wealth in South Africa. Environ Develop Econ 5:157–176

Hassan R, Mungatana E (2005) Environmental economics and policy analysis in Eastern, Central and Southern Africa: assessment of existing capacity, training programs and needs for future investments. Assessment of existing capacity. The Centre for Environmental Economics and Policy on Africa, University of Pretoria, Pretoria

IIP (Fisheries Research Institute) (2005) Government of Mozambique, Department of Aquaculture, Maputo

IDPPE (2002) Censo Nacional da Pesca Artesanal em Águas Marítimas. IDPPE, Maputo, p 76

INE (National Institute of Statistics) (2004) Anuário Estatístico 2003. INE, Maputo

INE (National Institute of Statistics) (2005) Anuário Estatístico 2004. INE, Maputo

Lange GM (2003a) The value of Namibia's commercial fisheries DEA research discussion paper number 54, February 2003, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia

Lange GM (2003b) Fisheries accounts: management of a recovering fishery. In: Environmental accounting in action, case studies from southern Africa. Edward Elgar Publishing, Cheltenham

UN FAO (2003) Handbook of national accounting: integrated environmental and economic accounting for fisheries, SEEAF, final draft. Food and Agriculture Organization of the United Nations (UN FAO), Rome

UN (2003b) Handbook of National Accounting, Integrated Environmental and Economic Accounting. Southeast Energy Efficiency Alliance (SEEA), Atlanta

Forest Resource Accounts for Ethiopia

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Abstract Ethiopia is a natural resource dependent country that needs an assessment of its natural resources for the sustainable use of the country's resources as well as to facilitate the formulation of effective and integrated environmental and economic policies. Gross domestic product (GDP) growth has for long been the key indicator for macroeconomic policy-making. However, national income accounts suffer from the major limitation that they focus mainly on goods and services that are bought and sold in markets and ignore nonmarketed services such as those provided by natural assets. As a result, there is inconsistent treatment of man-made capital and natural capital. Capital goods like machinery, tools and equipment are valued as productive capital and are written off against the value of production as they depreciate. However, no account is made for the depletion or degradation of natural resources: they are viewed as a 'free gift of nature'. In addition, no account is made for growth in natural capital (e.g. through tree planting and natural regeneration). On the other hand, in the present system of national account (SNA), changes in man-made capital (i.e. investment) are recorded and form part of the GDP/GNP. The failure to capture

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properly the accumulation and depletion of natural resources in the SNA leads to generation of incorrect measures of economic performance and wellbeing such as the rate of savings and capital formation.

Keywords Forest resource accounts • Ethiopia • Forest ecosystem services

1 Background to Ethiopia's Forest Resource Accounting Project

The Net National Income (NNI), which is GDP less depreciation of capital, is the measure of the nation's sustainable income. However, as currently measured, it does not take into account depreciation, depletion or permanent degradation of the nation's natural assets, especially forest resources. As a result, it is not possible to know whether the forest capital is being depleted or used in a sustainable manner using the present SNA. In addition, it is not possible to know whether the economy is genuinely growing or not. For sustainable use of the resource, we need to explicitly measure and track the changes in stocks as well as flows of the resources.

In reaction to this criticism of SNA, the United Nations Statistics Division (UNSD) developed an SNA 'satellite' System of Integrated Environmental and Economic Accounts (SEEA) rather than modifying the core SNA itself (UN SEEA 2003). SEEA provides a measure of forest values that is more comprehensive than SNA in two respects. First, SEEA forest accounts include both cultivated and natural forests in the asset accounts. Second, SEEA forest accounts try to include all forest goods and service, both marketed and nonmarket, in the flow accounts (Lange 2004).

The main objective of this study was to construct forest resource accounts for Ethiopia and to define further areas of research activities for the construction of complete set of forest accounts. The specific objectives of this report are to:

Construct physical asset and flow accounts for forestry for the years 1995 and 2005

Construct monetary asset and flow accounts for forestry for the years 1995 and 2005

2 The Forestry Sector of Ethiopia

Ethiopia's forest resources covering about 50.6% of the country's total land area (1.12 million km^2) fall into six broad categories, namely, forestlands, woodlands, shrublands, bushlands, plantations (man-made forest) and bamboos (Table 1). The definition of each category is presented in Appendix 1.

Table 1 Ethiopia's forestland cover (ha)

Forest category	Total area (ha)	Share as % of country's total area
Forest land	3,403,441	3.0
Wood land	26,219,177	23.4
Shrub land	22,897,872	20.4
Bush land	2,182,853	1.9
Plantation(man-made forest)	955,705	0.9
Bamboo (lowland and highland)	1,101,201	1.0
Total	56,760,249	50.6

Source: WBISPP (Woody Biomass Inventory and Strategic Planning Project) (2004)

Biomass energy at the national level provides more than 99% of the total domestic energy consumption. Of the total biomass energy, about 78, 9 and 12% is derived from woody biomass, crop residue and animal dung, respectively (WBISPP 1994). Households consume about 92% of all biomass energy, with the remaining being consumed by small-scale industry and food enterprises.

The forestry sector offers employment opportunities both for urban and rural communities. The Central Statistics Authority—CSA (2005a) 0.29% (0.2% and 0.09% of the work force absorbed in forest-related industry and agricultural sectors, respectively) of the nation's total employed persons (31.44 million). However, this figure does not include the employment opportunities for households in the collection and sales of biomass fuel and exudates. For instance, more than 15,000 urban-based women carry ~35% of the wood fuel requirements of Addis Ababa city. For 82% of these women, this is the only source of income (WBISPP 2004). The forestry sector employment contribution will mount to 2.45% if these other employment opportunities are considered.

The forestry sector contributed on average 5.7% of the total GDP in Ethiopia over the years 1995–2005 (MoFED 1995–2007). However, as stated above, this figure is likely to underestimate the true contribution of forests to national income, wealth and welfare in the country largely because the SNA does not account for some of the direct (bamboo, fodder grass, honey, coffee, medicinal plants) and indirect (carbon storage, biodiversity, watershed protection) use values of forest resources.

Ecologically, the forest gives invaluable environmental benefits to the country by providing watersheds protection services (protect soil erosion, flooding and downstream agriculture), carbon sink service and by providing habitats for a multitude of animal and plant life (i.e. storehouses of biodiversity). Ethiopia is a centre of diversity for both fauna and flora due to its diverse agro-ecological zones (the country has about 32 agro-ecological zones). Ethiopia is believed to be home for about 7,000 species of plants of which 12% are endemic and hence one of the six plant biodiversity-rich countries in Africa (UNEP 1995). Of the total number of wild faunal resources (1,403), about 30, 28, 3, 17 and 3 are endemic mammals, birds, reptiles, amphibians and fish, respectively (IBC 2005).

3 Implementing Forest Resource Accounting in Ethiopia

Natural assets may be described in physical quantities using physical units of measurements (e.g. hectares, tonnes and cubic metres) and in monetary units. Forest physical accounts consist of a set of tables recording physical measures of stocks and flows of forest resources at the beginning and end of the accounting period. They include records of changes in quantity and, to some extent, changes in the quality of resources—indicators of depletion and degradation. The physical accounts serve as basis for the valuation of environmental goods and services. In this section, we discuss the framework of the physical (and monetary) forest accounts along with their data requirements and sources. All asset accounts have three parts: opening stocks, changes during the accounting period and closing stocks. Changes during the period are divided into those that are due to economic activities and those that are due to natural or other causes (Lange 2004).

3.1 Framework for Physical Forest Accounts by Area

The following framework was used in compiling the physical asset accounts for Ethiopia by area:

Opening area
Changes due to economic activity
Area afforested (+)
Other area changes
Area naturally regenerated (+)
Other accumulations
Area converted to non-forest use (−)
Net change in area (=2+3+4)
Closing area (=1+5)

3.2 Framework for Physical Forest Accounts by Volume

The following framework was used in compiling the physical asset accounts for Ethiopia by volume:

Opening volume (M^3)
Natural growth (M^3) [+]
Changes due to economic activity (M^3)
Afforestation [+]
Depletion (fuelwood, charcoal production, construction wood) [−]
Other volume changes (M^3)
Regeneration [+]
Forest fires [−]

Insect damage [−]
Harvesting damage [−]
Changes in classification (M^3)
Conversion to non-forest use [+]
Closing volume = 2 + 3 + 4 + 5 (M^3)

3.3 Framework for Monetary Asset Accounts

Monetary accounts attach a monetary value to the physical accounts presented earlier using various valuation techniques. Various methods for valuing environmental goods and services are employed for this purpose. It is important to realise that techniques used to value forest flow benefits differ from those used to derive their asset values (Hassan 2002).

3.3.1 Structure of the Monetary Accounts

The structure of the monetary accounts is shown below. The entries correspond to the volume accounts but contain an additional entry for revaluation, which records the change in asset value due to changes in prices between the beginning and end of the period under ideal circumstances. All entries are in national currency units, Ethiopian birr (ETB).

Opening volume (ETB)
Natural growth (ETB)
Changes due to economic activity (ETB)
Afforestation
Depletion (fuelwood, charcoal production, construction wood)
Other volume changes (ETB)
Regeneration
Forest fires
Insect damage
Harvesting damage
Changes in classification (ETB)
Conversion to non-forest use
Net change (ETB)
Closing volume (ETB)

3.3.2 Value of Standing Timber

The asset value of forests is based on the stream of benefits a forest generates over its lifetime. In principle, the asset accounts should include the value of all goods and services provided by forests, but so far, the accounts have been limited to land and standing timber because of the problems of valuation of nonmarket forest goods and services.

The value of any asset is the discounted present value of the economic benefits it will generate in future years. For forests, the theoretical value of timber based on this concept was first established by Faustmann (1849). Timber asset value is the discounted future stumpage price for mature timber after deducting costs of bringing the timber to maturity. The stumpage price is the price paid to the owner of the forest for standing timber, or in the absence of such markets, the stumpage value can be estimated by deducting the costs of logging and transportation from the price received for raw wood. Costs include thinning (net of any income), other forest management costs and rent on forestland.

The general expression for the value of the asset, V, in the base year, 0, is simply the sum of the net economic benefits it yields in each year, t, over the lifetime, T, of the asset, discounted to the present value by the discount rate, r:

$$V_0 = \sum_{t=0}^{T} \frac{p_t Q_t}{(1+r)^t}$$

Here, p is the unit rent (stumpage price) calculated as revenue minus the marginal cost of harvest, and Q is the total harvest in a given period. The Faustmann method is rather complex as it bases forest asset value on the age structure of forests and the time of harvest. SEEA identifies three alternative methods for valuation of standing timber:

Stumpage value method: this method (also called the stumpage value approach) is the simplest of the three approaches. Asset value of standing timber, V, is given as the product of total forest area in hectares, A, the stumpage price per cubic metre of timber, p, and the quantity of timber per hectare (m^3), Q:

$$V = ApQ$$

Consumption value method: this method expands the stumpage value method to account for the difference in value of trees of n different age or diameter classes, k:

$$V = \sum_{k=1}^{n} A_k p_k Q_k$$

Net present value method: the total value of standing timber, V, is the sum of v_τ, the value per hectare of forestland of age class τ, weighted by A_τ, the total area in age class τ, where T is the actual cutting age, A_τ is the stumpage price and q_T is the timber yield at actual cutting age. The value is discounted at a rate, r, by the *time remaining until harvesting*, $T - \tau$:

$$V_t = \sum A_{t,\tau} v_{t,\tau} \quad \text{for } \tau = 1, \ldots, T - 1$$

$$v_{t,\tau} = \frac{p_t q_T}{(1+r)^{T-\tau}},$$

or

$$V_t = \sum_{\tau=1}^{T-1} \frac{A_t p_t q_T}{(1+r)^{T-\tau}}$$

This method may be implemented using the average stumpage value for all removals or by distinguishing stumpage values for different species.

Measuring stumpage value: in some instances, the resource rent from timber, or stumpage value, is known from the value paid for standing timber. For individual companies, stumpage value equals raw wood prices minus the logging, transportation and stacking costs. Total national resource rent from logging may also be calculated from the national accounts if this is recorded separately. Here, stumpage value is calculated as a residual after estimating all other components of mixed income.

3.4 Choice of Goods and Services for Inclusion in the Forestry NRA

The choice of forest goods and services for inclusion in the accounts was based on the availability of data and their importance in the economy of Ethiopia. The following forest goods and services, which are classified by type of use following Hassan (2002), were included in the accounts.

A. Products for direct, intermediate use by processing industries:

Tangible, timber products for wood processing industries (commercial logs and craft wood)
Tangible, non-timber (grazing) resources for livestock production

Under this category, only fodder provision was included. Fodder provision was considered important because Ethiopia has one of the largest inventories of livestock in Africa, with livestock ownership currently supporting and sustaining the livelihoods of an estimated 80% of the rural poor. Forest resources are one of the most important sources of livestock fodder, especially the leaves of trees and shrubs. About 5% of forestland, plantation and bamboo and 24% of woodland, bushland and shrubland are subject to livestock grazing (WBISPP 2004). This makes the total forest area subject to grazing about 13.96 and 13.51 million ha in 1995 and 2005, respectively. Based on the current accounting conventions of the SNA, the value of fodder grass from forest resources, which is embedded in the output of the livestock sector, is not attributed to forestry.

B. Products for final consumption:

Three categories of products fall under this group according to Hassan (2002):

Tangible, nonmarket (extracted but not traded in the market), timber products, for example, fuelwood and construction poles.
Tangible, nonmarket, non-timber products (the whole or parts of plants and animals for food, medicinal and other purposes)
Intangible, forest amenities (use of the resource for social, religious and recreational purposes)

Construction wood, fuelwood and charcoal can be considered as the most important outputs of the forestry sector in Ethiopia making their inclusion in the accounts mandatory.

Forest and semi-forest coffee production from forests is considered important because Ethiopian forests are depositories and gene pools for several domesticated and/or important wild plants and wild relatives of domesticated plants. For example, coffee (*Coffee arabica*) is found in the wild in the moist evergreen montane forests of the south and south-west of the country (IBC 2005). Coffee contributes to about 67% of export earnings, and about 25% of the population depends directly or indirectly on coffee for its livelihood (Oxfam 2001; Cousin 1997). About 50% of the total produce is consumed locally.

Coffee is currently produced on more than 400,000 ha of land, mainly in the eastern, southern and western parts of the country (MoA 2003). There are four types of coffee production systems: forest (wild) coffee, semi-forest coffee, garden coffee and plantation coffee. Forest coffee is self-sown and grown under the full coverage of natural forest trees. The coffee yield under this production system varies between 200 and 250 kg/ha (Teketaye 1999). Forest coffee accounts for about 10% of Ethiopia's total coffee production (Paulos and Teketay 2000; Workaffess and Kassu 2000). Under the semi-forest production system, farmers acquire forestland for coffee farms. However, there is not much farming activity practised inside the semi-forest coffee areas. They slash weeds once a year to facilitate the coffee bean harvest. In some instance, naturally regenerated or raised seedlings are planted under naturally growing trees. The productivity of semi-forest coffee ranges between 400 and 500 kg/ha (Teketaye 1999). It accounts for about 35% of Ethiopia's total coffee production (Workaffess and Kassu 2000). About 70% of the semi-forest coffee production is attributed to forest.

Honey and beeswax are considered important because the ecological and climate conditions of Ethiopia are suitable for sustaining a large number of bee colonies (Deffar 1998). Honey production in Ethiopia is mainly based on traditional methods where hives made from naturally occurring materials are suspended in trees to attract swarms of local bees. Ethiopia stood tenth in honey production and fourth in beeswax production on a world level (Deffar 1998). The productivity of honey bees and beeswax from traditional beehives is low, 5–8 kg honey per hive (EFAP 1994; Reichhuber and Requate 2007) and 1 kg beeswax per hive (EFAP 1994). Honey is almost exclusively used for local consumption, to a very large extent (55–60%) for the brewing of mead (also called tej), whilst a considerable proportion of wax is exported.

Medicinal plants are considered important because Ethiopia is characterised by a wide range of ecological, edaphic and climatic conditions that accounts for the wide diversity of its biological resources both in terms of floral and faunal wealth. The flora of Ethiopia is estimated at about 7,000 species of which 12% are endemic (UNEP 1995). Studies indicate great difficulty, and hence uncertainty in estimating the real willingness to pay for biodiversity benefits in economic analysis (Sander 2000). In this study, we focus on the pharmaceutical value of Ethiopian forests since traditional medicinal practices are the basis of health care for both human beings and animals. About 85% of the Ethiopian population relies on traditional medicine for the fight against various diseases of human beings and animals (Zewdu and Demissie 2001).

Bamboo forest resource is recognised as an ideal species for afforestation, soil conservation and social forestry programmes in many parts of the world due to its fast growth, easy propagation, soil binding property and short maturity period. Because of its strength, flexibility and versatility, the culms have been used mainly in housing and for other construction purposes for centuries, particularly in rural areas. Other uses of bamboo are many and varied. It is used in the making of furniture, handicrafts, basket ware, matting, rayon and paper and is used as food, medicine, fodder, fuelwood and fences. The Ethiopian natural bamboo forest is more than 1 million ha, which is about 7% of the world total and 67% of the African bamboo forest area (Embaye 2003). Ethiopia has two types of indigenous bamboo species, namely, lowland and highland bamboo. The highland bamboo (*Yushania alpina*) growing naturally in the highlands of southern, south-western, central and north-western Ethiopia covers more than 127,000 ha (Kelbessa et al. 2000). On the other hand, the lowland bamboo (*Oxytenanthera abyssinia*) growing in the western parts of the country along major river valleys and in the lowlands bordering Sudan covers more than 959,000 ha (Kelbessa et al. 2000). The mean growth stock is 26 and 83 m^3/ha for lowland and highland bamboo forests, respectively (WBISPP 2004). The average annual increment is 1.30 and 3.9 m^3/ha in the lowland and highland bamboo forest, respectively (Kelbessa et al. 2000).

Exudates (gums and incenses) are one of the most important non-wood forest products that serve as sources of foreign exchange earnings and employment in Ethiopia. The average annual production and sale of exudates is 5,290 tons/year over the years 1995–2007 (MoA 2007a, b). Of the total exudates production, incenses cover about 90%. About 50% of the exudates production is used for local consumption (EFAP 1994).

Thatch grass production is considered important because thatch grass is one of the most important construction materials in the rural areas of the country, making its inclusion in the accounts mandatory.

C. Services for indirect, intermediate use by other industries:

These include a wide range of environmental (ecological) services indirectly benefiting other industries. Examples are:

Services benefiting other industries but causing no damage to forest health (watershed protection benefiting agriculture and the hydropower sectors, biological

diversity, soil conservation and carbon sequestration benefiting source and non-point sources)
Services benefiting source sectors which may be damaging to forest health such as pollution deposition (acid rain) benefiting manufacturing industries

Two forest services were considered for inclusion in our accounts under this category: carbon sequestration services and watershed protection benefits. The carbon sequestration services were considered given their increasing importance in climate change science. Watershed protection benefits were considered given that the impacts of change in forest cover on watershed functions can encompass soil erosion, altered downstream water flows, flooding and sedimentation and consequent damage to agriculture, fisheries, dam storage and power generation.

3.5 Needed Adjustments to the National Accounts

Drawing on the recent work of Vincent and Hartwick (1997), a forest resource accounting framework for correcting conventional measures of income and net savings for missing values of forest resources is presented below with the objective of subsequently using it to correct the forest resources accounts for Ethiopia.

GDP is the measure of total annual Value Added (VAD) by all productive activities in the economy. The value of products that enter the market (category A) is usually captured in the conventional system of national accounts and hence requires no further adjustments. On the other hand, the value of most of the products for final consumption that are directly harvested by users without entering trade (category B) is typically missing from conventional measures of income. These values need to be added to GDP as omitted contributions of forest resources to VAD that escape trade. Environmental services listed as category C are also not accounted for in the current SNA. However, the required adjustments for the value of these services differ from that applied to category B.

GDP does not need to be adjusted for benefits provided by woody resources to production activities by other sectors. Indirect environmental benefits and ecological services provided by the resource are already accounted for through the manifestation of such impacts on the affected sector and activities. For instance, the benefits of watershed protection services of forests are already realised as higher output within the agriculture sector (as potential damage leading to reduced output is avoided). The value of these services, however, needs to be estimated and reallocated to VAD of the respective sectors without altering existing GDP. An estimate of the value of the contribution of forestry through watershed protection must be established and reallocated to forestry, that is, subtracted from agriculture VAD and added to forestry VAD (Vincent and Hartwick 1997). The same applies to carbon sequestration. Whilst the benefits from carbon sequestration by forest plantations are realised within climate sensitive industries (as a result of reduced climate change impact), source sectors are not charged with the social costs of their carbon dioxide emission externality. Accordingly, the value of these benefits needs to be established and reallocated (reduced) from VAD of source sectors and added to forestry VAD. The same also applies to the treatment of the negative water abstraction externality of cultivated exotic plantations.

4 Data and Methods: Physical Accounts

The primary sources of information used to construct the physical (area and volume) accounts were the Woody Biomass Inventory Strategic Planning Project (WBISPP) data for 1994 and 2004 (hereafter referred to as WBISPP (1994, 2004)). WBISPP (1994, 2004) is a comprehensive data base that was used to inform the National Strategic Plan for the Biomass Energy Sector in Ethiopia. It gives the following details (among others) by regions of Ethiopia: (1) area, (2) population, (3) area under natural forest, (4) area under woodlands, (5) area under bushlands, (6) area under shrublands, (7) area under bamboo and (8) area under plantation forests. WBISPP (1994, 2004) further divides each region into zones so that the data identified above can also be disaggregated by zones within a region (a zone is a lower administrative unit than the region). This study considered the area relevant for forestry NRA (i.e. area under forest cover) to be the sum of areas under natural forest, woodland, bushland, shrubland, bamboo and forest plantations.

4.1 Data and Methods for Constructing Area Accounts

To construct the area accounts, we needed opening and changes due to economic activities and natural effects to derive end of period closing values as indicated earlier. Opening area was obtained as the sum of the land area under forest, woodland, bushland, shrubland, bamboo and forest plantations. Changes due to economic activity were calculated as the area afforested, which is only relevant to plantation forests (by definition, there is no afforestation in the other forest categories). There was no afforestation in all plantation forests in all regions in 1995. There however was afforestation in 2005. Data for the extent of areas afforested in 2005 was obtained from the regional Bureaus of Agricultural offices (BoAa 2007; BoAb 2005; BoAc 2005; BoAd 2005). In calculating the area afforested in 2005, we assumed that only 50% of the planted area survived due to the open grazing system and poor forest management systems. Other changes were defined as the area naturally regenerated. WBISPP (1994, 2004) calculated area expansion parameters for each region by vegetation type as follows: forestry (0.1%), woodland (0.2%), bushland (0.2%), shrubland (0.2%) and bamboo (0.3%).[1] By assumption, the area under plantation (managed) forest is fixed. The product of the natural expansion parameter and area under each

[1] In India, because of frequent fires and grazing, it is assumed that 16% of the total forest area has regeneration potential of important species (SFR, 1995 cited in Haripriya 2000a, b).

Table 2 Mean growth stock and annual increment (m^3/ha)

Forest type	Growth stock m^3/ha	Mean annual increment (m^3/ha/year)
Forest land	130.5	5.65
Woodland	21	0.79
Bush land	15	0.2
Shrub land	14.9	0.5
Plantations	178.8	12.5
Lowland bamboo	26	1.3
Highland bamboo	83	3.9

Source: WBISPP (2004)

forest category was used to compute area regenerated. Other accumulations consist of only one category—area converted to non-forest use, that is, to agriculture and settlement (there is no conversion from plantation forest to non-forest use). Forest conversion data was obtained from WBISPP (1994, 2004) for Gambella, Southern, Oromiya and Benishangul-Gumuz regions. For the rest of the regions, the estimated FAO (2006) deforestation rate of 0.8% per annum was used. The computations proceeded as follows. WBISPP (and FAO) provides a coefficient of the percentage of land converted from forestry to non-forestry use for each zone by forest type. For example, in Zone 24 (*Mirab Wellega* in *Oromiya Region*), the amount of land transferred from forest to other uses per annum is 1.16%, from woodland to other uses 20%, from bushland to other uses 0.80%, from shrubland to other uses 16% and from bamboo to other uses 0.80%. The product of these coefficients and the total area of land under each forest category were then used to compute the amount of land converted from forestry to non-forestry use. Finally, the closing area was calculated as opening area, add area afforested, add area naturally regenerated and subtract area converted to non-forestry uses.

4.2 Data and Methods for Constructing Volume Accounts

Similar to the physical area accounts, one needs to derive end of period closing volumes based on opening volumes and volume changes during the accounting period. Opening volumes were calculated from WBISPP (1994, 2004) parameters, according to which the growing stock (m^3/ha) for the different forest types is as given in Table 2. To compute the opening volume, we multiplied the opening area (from area accounts) by the growing stock.

Natural growth was computed as the product of the area under each forest category (area accounts) by the mean annual increment. Changes due to economic activity consisted of afforestation and depletion. We know from the area accounts that there was no afforestation in 1995, but there was afforestation in 2005. The volume increment due to afforestation in 2005 was computed as the product of the area afforested (area accounts) and growing stock. The volume of forest resources depleted consists of three classes: volume collected for firewood as a final consumption good, volume collected as an intermediate input in charcoal production and volume collected for the supply of construction wood.

The volume harvested as firewood (including twigs) was calculated as follows. WBISPP (1994, 2004) has an estimate of annual per capita consumption (kg/person/annum) for firewood and twigs. The Ministry of Finance and Economic Development (MoFED) which is responsible for the construction of national accounts does not use these estimates; instead, it uses the average per capita expenditure approach to compute total consumption of forest products.[2] As stated in the introduction, this approach underestimates the value of the flows from the forestry stock as considerable volumes of production goes unrecorded. We added kg/person/annum firewood to kg/person/annum twigs to obtain *total* kg/person/annum firewood. To obtain the volume equivalent (m^3/person/annum), we divided kg/person/annum by a factor of 600 following a methodology reported in MoA (1990a, b).[3] Finally, the total volume of firewood consumed per annum was obtained as the product of m^3/person/annum and population.

WBISPP (1994, 2004) gives an estimate for annual per capita consumption (kg/person/annum) for charcoal. We converted kg/person/annum *charcoal* to equivalent kg/person/annum *wood* following a methodology detailed in MoA (1990a, b)[4] and then used the preceding procedure to obtain the volume (wood) equivalent. The product of per capita (wood) consumption and population gives the volume of wood harvested for charcoal production. The computation of the volume harvested for construction wood production proceeded as follows. WBISPP (1994, 2004) has an estimate of annual per capita consumption (kg/person/annum) for construction wood. This was converted from the mass to the volume equivalent using a methodology reported in MoA (1990a, b).[5] The product of per capita consumption (wood) and population gives the volume of wood harvested for construction wood.

Other volume changes consist of the volume regenerated, the volume lost to forest fires, the volume lost to insect damage and the volume lost to harvest damage. To calculate the volume regenerated, recall from the area accounts that we calculated the area regenerated by forest type (except plantation forests). The product of area regenerated and the respective Mean Annual Increment (MAI) gives the volume regenerated. To calculate the volume lost to fire damage, we assumed that forest fires affect only the volume regenerated and the volume afforested, since it is the young saplings most likely to be affected by forest fires. There is no estimate of area lost to forest fire damage in Ethiopia. However, FAO (2006) reports that about 0.2%

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[2] In 2005/2006, the average per capita expenditure estimates of split and round firewood are Ethiopian Birr (ETB) 45.58 and 61.84, respectively, whilst the average per capita expenditure of charcoal estimate is ETB 2.88. These values were multiplied by the total number of households of the nation to arrive at the total firewood and charcoal consumption of the country.

[3] 1 m^3 of firewood is equivalent to 600 kg of solid wood.

[4] We divided kg/person/annum by a factor of 0.18.

[5] We divided kg/person/annum by a factor of 0.3.

of the total forest area is subject to forest fires. Thus, the volume of forest stock affected by forest fires in this study was derived by multiplying the naturally regenerated and the afforested volume by 0.2% for each forest type. Data on volume lost to insects, pests and diseases is not available in Ethiopia except for bamboo forests. Consequently in this study, we borrowed estimates from India showing that the average volume rendered unusable annually due to insect attacks, diseases and pest infestation is about 0.031% of the total growing stock for broad-leaved species and 0.005% for coniferous species (Haripriya 2000a, b). In Ethiopia, broad-leaved species are dominant (*Podocarpus falcatus* and *Juniperus excelsa* are the only indigenous coniferous tree species). Consequently for all forest types (except bamboo), stand mortality of 0.031% was assumed. For bamboo forest, we assumed stand mortality of 20% based on the empirical study by Embaye (2003).

To calculate the volume lost to harvest damage, we assumed that the volume lost whilst harvesting fuelwood and wood for charcoal production is 5% of the volume harvested; when harvesting timber for construction wood, it is 12.5% of the volume harvested. The rest of the calculations follows from the methodology used above.[6] The change in classification only considers conversion of forestland into non-forest uses. The product of the area of land converted to non-forest uses (area accounts) and growth stock gives the volume of land converted to non-forest uses. Finally, the closing volume was calculated as opening volume; add mean annual increment; add volume afforested; subtract depletion (fuelwood, charcoal, construction wood); add regeneration; subtract volume reductions due to forest fires, insect damage and harvest damage; and finally subtract the volume converted to non-forest uses.

4.3 Data and Methods for Estimating Annual Flows of Forest Goods and Services

This basically represents wood harvested for construction, fuelwood and charcoal production (mass and volume). Fodder production from forests: the average fodder Dry Matter (DM) on forestland and other forest types (woodland, bushland and shrubland) is 0.7 and 1.2 DM tons/ha/year, respectively (FAO 1987). For bamboo forest, we considered the leaf biomass DM since we do not have data on dry matter grass production.[7] The leaf biomass dry matter varies between 0.02 and 4.4 tons/ha/year depending on the age structure of bamboo trees (Embaye et al. 2004). Given that not all fodder produced is available for consumption by cattle, we used an average value of 0.94 tons DM/ha/year. We adjusted the fodder DM values downward by

[6] Haripriya (2000a, b) used a flat rate of 10% to calculate harvest damages in their India NRA study.

[7] There is no fodder DM data on plantation forest.

Table 3 Annual amount of fodder produced from the forests of Ethiopia (1995/2005)

Forest type	1995	2005
	Area subject to grazing (ha)[a]	
Forest	203,056	172,249
Woodland and shrubland	13,704,056	13,281,331
Bamboo	55,337	55,337
	Productivity of fodder (t/ha)	
Forest	0.35	0.35
Woodland and shrubland	0.6	0.6
Bamboo	0.94	0.94
	Total yield of fodder (t)	
Forest	71,070	60,287
Woodland and shrubland	8,222,434	7,968,799
Bamboo	52,017	52,017

[a]About 5% of forestland, plantation and bamboo and 24% of woodland, bushland and shrubland are subject to livestock grazing (WBISPP 2004).

Table 4 Quantity of forest and semi-forest coffee produced (1995/2005)

	Forest coffee		Semi-forest coffee	
	1995	2005	1995	2005
Area allocated to coffee production (ha)	36,000	59,557	96,000	178,671
Average yield (kg/ha)	225	225	450	450
Assumed share supplied from forest sector (%)	100%	100%	70%	70%
Total production of coffee attributed to the forestry sector (kg)	8,100,000	13,400,325	30,240,000	56,281,365

50% to take into account the effect of trampling, inaccessibility, fire, cattle selectivity, overstocking and wildlife (Le Houerou and Hoste 1977). Data on the area subject to grazing was obtained from WBISPP (2004). The results of this estimation procedure are presented in Table 3 below. From these assumptions, we see that the total fodder produced from forests in the country is 8.35 million tons in 1995 and 8.08 million tons in 2005.

We present in Table 4 the methodology used to estimate the quantity of forest and semi-forest coffee produced from Ethiopia in 1995 and in 2005.

In 1995 (2005), a total of 200,000,000 kg (320,794,000 kg) of coffee was produced in Ethiopia. Of the total, about 4% was produced from forest coffee and 16.6% from semi-forest coffee (Table 4). Data on average yield of coffee for Ethiopia was obtained as the quotient of total coffee production and area allocated to coffee production. Data for the average yield for forest and semi-forest coffee production were obtained from Teketaye (1999). Total production was calculated as the product of average yield and the land area allocated to each enterprise. Finally, we assume that 100% of forest coffee is obtained from forests and 70% of semi-forest coffee is obtained from forests to obtain the total yield. The total production in 1995 (2005) was 38,340,000 kg (69,681,690 kg).

Table 5 Production of honey and beeswax (1994/2004)

	Honey		Beeswax	
	1995	2005	1995	2005
Estimated beehives in Ethiopia (number)	3,545,580	3,957,737	3,545,580	3,957,737
Average production per hive (kg/hive)	6.5	6.5	1	1
Total production in Ethiopia (kg)	23,046,270	25,725,290.5	3,545,580	3,957,737
Assumed share of total production derived from forest resources (%)	70%	70%	70%	70%
Quantity of production attributed to forests (kg)	16,132,389	18,007,703	2,481,906	2,770,416

Table 6 Number of people having access to bamboo resource 1995

	Population in 1995	Region area (ha)	Bamboo area (ha)	Bamboo area (% region area)	People having access to bamboo
Amhara	13,834,297	15,917,366	152,752	0.96	132,761
Oromiya	18,226,318	35,300,681	302,800	0.86	156,341
SNNPR	10,377,028	11,234,319	39,639	0.35	36,614
Benishangul-Gumuz	460,459	4,928,946	328,211	6.66	30,661
Tigray	3,136,267	5,007,864	283,333	5.66	177,443
Total	46,034,369	72,389,176	1,106,735		533,820

Source: Kelbessa et al. (2000); CSA (2005b); Population for 1995 is based on 1994 census

The methodology used to calculate the annual amount of honey and beeswax produced from the forests of Ethiopia is summarised in Table 5. Data on the estimated number of beehives in Ethiopia was taken from CSA (1995, 2005a). Data on average production per beehive was obtained from Reichhuber and Requate (2007).

In this study, we did not calculate the total quantity of medicinal plants harvested from the forests of Ethiopia every year due to lack of data. Our method of valuation was based on a case study on the economic contribution of medicinal plants to traditional health practitioners in Yayu and Sheko districts of south-west Ethiopia (Reichhuber and Requate 2007) as reported in the valuation section of this report.

To calculate the annual amount of bamboo forest resource produced from the forests of Ethiopia, we first estimated the number of people having access to these resources in 1995 (Table 6) and in 2005 (Table 7). Assuming that on average a person consumed five culms of bamboo resource per annum, the total consumption of bamboo forest resources in 1995 was 2,669,100 culms and 1,434,410 culms in 2005.

The average annual production and sale of exudates is 5,290 tons/year over the years 1995–2007 (MoA 2007a). Of the total exudates produced, incenses cover

Table 7 Number of people having access to bamboo resource 2005

	Population	Region area (ha)	Bamboo area (ha)	Bamboo area (% region area)	People having access to bamboo
Amhara	19,120,005	15,917,366	152,752	0.96	183,486
Oromiya	26,553,000	35,300,681	302,800	0.86	227,765
SNNPR	14,901,990	11,234,319	39,639	0.35	52,580
Benishangul-Gumuz	625,000	4,928,946	328,211	6.66	41,618
Tigray	4,334,996	5,007,864	283,333	5.66	245,264
Total	65,534,991	72,389,176	1,106,735		750,713

Source: Kelbessa et al. (2000); CSA (2005b)

about 90%. About 50% of the exudates production is used for local consumption (EFAP 1994).

In this study, we did not calculate the total quantity of thatch grass harvested from the forests of Ethiopia annually. However, in the valuation section of this report, we report the value of thatch grass published by the Ministry of Finance and Economic Development.

In this study, we estimate the amount of carbon stored in each forest type (carbon volume computed only for above-ground woody biomass) following a methodology developed by Brown (1997). Let *C* be the carbon stored in above-ground biomass [tons/ha], BV the biomass of inventory volume [tons/ha], BEF the biomass expansion factor (i.e. ratio of above-ground oven-dry biomass of trees to oven-dry biomass of inventory volume), VOB the inventory volume over bark of free bole [m^3/ha] and WD the volume-weighted average wood density [tons/m^3]. Assuming the carbon content of greenwood is approximately 0.5 times the respective biomass estimate (WBISPP 2004), the carbon content by forest type is given by

$$C_i = \mathrm{BV}_i \cdot \mathrm{BEF}_i \cdot 0.5$$

where

$$\mathrm{BV}_i = \mathrm{VOB}_i \cdot \mathrm{WD}$$

$$\mathrm{BEF}_i = \exp\{3.213 - 0.506 \cdot \ell n(\mathrm{BV})\} \text{ for BV} < 190 \text{tons/ha and}$$
$$= 1.74 \text{ for BV} \geq 190 \text{tons/ha}$$

Noting that above-ground biomass equals the product of biomass of inventory volume (BV) and biomass expansion factor (BEF), the above result follows. The inventory volume over back of free bole (VOB) was obtained from the volume accounts. The volume-weighted average wood density (WD) was assumed to be

Table 8 Parameters used to compute the carbon volume in woody biomass

	Biomass expansion factor (ton/ha)	Inventory volume over bark of free bole (m^3/ha)
Forestland	2.74	131.5
Woodland	6.9	21
Shrubland	8.20	14.9
Bushland	8.18	15
Highland bamboo	3.44	83
Lowland bamboo	6.19	26
Plantations	2.33	178.8

0.6 ton/m^3 for all forest types (WBISPP 2004). The BEF and VOB parameters used in the computations are given in Table 8.

5 Data and Methods: Economic Accounts

Monetary accounts ideally should convert the information provided by the physical accounts into commensurate monetary values. To compile the monetary accounts, the row entries used for the volume accounts were converted into commensurate monetary values using the methodologies discussed below.

5.1 Valuation of Forest Goods

The net price (stumpage price) method was used to value the wood used as construction wood, fuelwood and charcoal. The net price equals the price of a product less the cost of harvesting, transport and a margin for normal return to capital, which represents an allowance for normal profit and risk associated with the production activity. The stumpage prices used in this study were obtained from computations done by the Ministry of Agriculture (1990a, b) and Bartelheimer (1997). In doing the valuation, unit stumpage prices are multiplied by the respective volumes of construction wood, firewood and charcoal (Table 9).

A *weighted* stumpage price was used to value the volume of wood lost due to harvest damage, deforestation, insect damage and fire damage. It was also used to value increment (natural growth and natural regeneration), afforestation, forest conversion, opening stocks and closing stocks. In each case, value was calculated as the product of the respective volume (from the physical volume accounts) and the weighted stumpage price. For each forest type (forest, woodland, bushland, shrubland, bamboo and plantation), we calculated the share of the total volume of wood harvested for firewood, charcoal and construction wood in the volume accounts. For

Table 9 Stumpage prices used for valuation in ETB and USD

	Stumpage price/m³ wood	
	Ethiopian birr (ETB)	USD
Lumber	292	46
Poles	78	12
Firewood	51	8
Charcoal	54	9

example, from the volume accounts, we calculate that 91.4% of the wood was for fuelwood, 3.4% for charcoal making and 5.6% for construction wood. We then used these percentages as weights in calculating the weighted price using the formula:

$$\begin{aligned}\text{Weighted stumpage price} = & \left(\%\ \text{firewood} \cdot \text{stumpage price firewood}\right) \\ & + \left(\%\ \text{charcoal} \cdot \text{stumpage price charcoal}\right) \\ & + \left(\begin{array}{l}\%\ \text{construction wood} \cdot \text{stumpage price} \\ \text{construction wood}\end{array}\right).\end{aligned}$$

A market for fodder is not well established in Ethiopia. In this study, the value of forests in supplying fodder was estimated using the *opportunity cost of agricultural land* needed to grow the amount of fodder supplied from forests (e.g. see Haripriya (2000a, b)). This is equivalent to the loss in agriculture income as a result of cultivating the fodder supplied from forests on agricultural land. The total yield of fodder (tons/ha/annum) by forest type was obtained from Table 3. The estimated dry matter (DM) grass[8] yield on agricultural land under rain-fed conditions ranges from 7 to 20 DM tons/ha/year (MoA 2007a). In this study, we assume a yield of 13.5 DM tons/ha/year. The quantity of agriculture land required to supply the quantity of fodder obtained from forests was calculated as the quotient of the total yield of fodder obtained from the forest and the average productivity of fodder on agricultural land (Table 10). The MoA has data on the total hectares of agricultural crop area harvested (both annual and perennial crops) and agricultural GDP (both annual and perennial crops). Based on these, we calculated the unit value of agricultural land as the quotient of agriculture GDP and total harvested crop area. The total opportunity cost of agricultural land was then obtained as the product of the unit value of agricultural land and the quantity of agricultural land required supplying the fodder obtained from the forest (see Table 10). The value of fodder produced from forest resources in 1995 was ETB 1,195,571,724 and in 2005, ETB 1,732,947,000.[9]

Forest and semi-forest coffee was valued using the net price method (Table 11). Total yield of coffee attributed to the forestry sector is obtained from Table 4. The

[8] The dominant grass types selected by Ministry of Agriculture and rural development for forage production and development include Rhodes, Elephants, Oats, Phalaris and Sudan grasses.

[9] 1$USD = ETB 6.32 and 8.66, respectively, during 1995 and 2005.

Table 10 Valuation of the benefits of fodder (1995 and 2005)

	Forests		Woodland and shrubland		Bamboo	
	1995	2005	1995	2005	1995	2005
Total yield of fodder in forests (t)	71,070	60,287	8,222,434	7,968,799	52,017	52,017
Average productivity of fodder on agricultural land (t/ha)	13.50	13.50	13.50	13.50	13.50	13.50
Quantity of agricultural land required to supply the fodder obtained from the forest (ha)	5,264	4,466	609,069	590,281	3,853	3,853
Agricultural area planted (ha)	8,937,150	11,137,953	8,937,150	11,137,953	8,937,150	11,137,953
Agriculture GDP 1995/1996 (birr)	17,286,203,000	32,246,432,000	17,286,203,000	32,246,432,000	17,286,203,000	32,246,432,000
Unit value of agricultural land (birr)	1,934	2,895	1,934	2,895	1,934	2,895
Total opportunity cost of agricultural land (birr)	10,180,576	12,929,070	1,177,939,446	1,708,863,495	7,451,702	11,154,435

Table 11 Valuation of forest and semi-forest coffee (1995, 2005)

	Forest coffee		Semi-forest coffee	
	1995	2005	1995	2005
Total production of coffee attributed to the forestry sector (kg)	8,100,000	13,400,325	30,240,000	56,281,365
Average local market price of coffee (birr)	3.92	4.99	3.92	4.99
Harvesting and marketing costs/kg	1.00	1.00	1.60	1.60
Net price per kg (birr)	2.92	3.99	2.32	3.39
Contribution of coffee to forestry GDP (ETB)	23,652,200	53,467,297	70,156,800	190,793,827

national average local market price is based on CSA producers' price of agricultural products (CSA 1995, 2005b). The harvesting and marketing costs for semi-forest and forest coffee production amount to ETB 1.6 and 1 per kg, respectively, (Reichhuber and Requate 2007). The net price was calculated the difference between market price and harvesting and marketing costs. It follows that the contribution of coffee to total forestry GDP in 1995/1996 was ETB 93,808,800. The contribution of coffee to total forestry GDP in 2005/2006 was ETB 244, 261, 124 (Table 11).

The net price method was used to estimate the value of honey and beeswax produced from forests (Table 12). To assess the value of honey production, national average local market prices were obtained from CSA (1995, 2005b). The data on beehives was taken from CSA (1995, 2005a). Following Reichhuber and Requate (2007), production cost of 40 % of the product value was assumed. During the accounting period of 1995–2005, the value of honey contribution to forestry sector is ETB 85.5 million (108.0 million) and that of beeswax is ETB 16.9 million (42.2 million).

Different economic valuation approaches can be used to determine the medicinal value of forests (Bann 1998). One approach is the option value, which relates to the extent to which biodiversity conservation is required to protect future value of medicinal plants. Another approach is the value of forests in producing commercial and traditional medicines. In this study, we used the latter approach combined with the percentage-based valuation.

Reichhuber and Requate (2007) carried out a study on the economic contribution of medicinal plants to traditional health practitioners in Yayu and Sheko districts of south-west Ethiopia where the major tropical forest resources are found.[10] We draw on their results to value the benefits of forest resources to provide medicinal plants. They estimate US$3 and US$1.80 per ha for Sheko and Yayu districts, respectively, after accounting for collection costs. These estimates are in line with other studies. For instance, Pearce and Moran (1994) suggest a value of US$0.01–US$21 per ha for medicinal plants in general. Simpson et al. (1994) estimate a value of US$1.10

[10] The two districts have 23.3 thousand hectares of forest.

Table 12 The value of honey/beeswax produced from forest areas (1995, 2005)

	Honey		Beeswax	
	1995	2005	1995	2005
Quantity of honey/beeswax production attributed to forests (kg)	16,132,389	18,007,703	2,481,906	2,770,416
Market price of honey/beeswax (birr/kg)	8.9	10.0	6.81	15.2
% of market price attributed to production and marketing costs.	40%	40%	40%	40%
Net price of honey/beeswax (birr/kg)	5.3	6.0	4.1	9.1
Contribution of honey/beeswax to the GDP of forestry (birr)	85,501,662	108,046,220	16,901,780	42,221,138

Table 13 Valuation of bamboo resource consumed

	1995	2005
People having access to bamboo resource (number)	533,820	750,713
Average consumption per person (culms/person/annum)	5	5
Average farm gate price (birr/culm)	0.5	1.5
Harvest, transport and market cost (% of farm gate price)	20%	20%
Stumpage price (birr/culm)	0.4	1.2
Contribution of bamboo resource to forest sector GDP (birr)	1,067,640	4,504,272

per ha per annum for pharmaceutical genetic material in the Ivory Coast forest areas. In this study, we consider the lower end value of Reichhuber and Requate (2007) estimate (US$1.80 per ha per annum) for the pharmaceutical value of Ethiopian forests to avoid overestimation since the two districts might not be representative of the entire nation. Each forest category may have different contribution in terms of supplying medicinal plants. We, therefore, assume that forestland, plantation and other forest types (woodland, bushland and shrubland), respectively, will supply 100, 5 and 60% of medicinal plants. The pharmaceutical value of a specific forest is derived by multiplying the respective forest area by per hectare value and its percentage contribution of medicinal plants. Accordingly, the total pharmaceutical value of Ethiopian's forest resource is ETB 435.20 million in 1995 and ETB 569.74 million in 2005.

The market price of bamboo for 1995 is taken from LUSO (1997) and for 2005 is from our own survey in Benishangul-Gumuz region. The collection cost is assumed to be 20% of market price (Reichhuber and Requate 2007). The total value of bamboo resource attributed to the forest sector is about ETB 1.07 million (1995) and ETB 4.50 million in 2004 (Table 13).

Exudates are valued using net price method (Table 14). The volume and export price data were obtained from MoA (2007a) and Ethiopian Customs Authority (2007), respectively. The harvesting and marketing costs are estimated to be 53% of

Table 14 Valuation of exudates

Items	1995	2005
Total annual exudates production(kg)	5,237,000	7,970,500
Export price (ETB/kg)	8.60	11.20
Production and marketing costs (ETB/kg)	53%	53%
Forest gate price (ETB/kg)	4.04	5.26
Total value of exudates contribution to forest sector (ETB)	21,157,480	41,924,830

the market value (MoA 2007a). The detail data for computation of the value of exudates are presented in Table 14.

The total value of exudates was ETB 21.16 million (1995) and ETB 41.92 million (2005). The value of thatch grass was obtained directly from the Ministry of Finance and Economic Development publications (MoFED 2007). The value of thatch grass recorded in the national accounts is ETB 127.04 million (1995) and ETB 147.82 million (2005).

5.2 Valuation of Forest Services

For valuation of carbon sink service of forests, one can either estimate the marginal social damage or use the market price for tradable CO_2 (1 ton C = 3.6667 ton CO_2) emission permits. Marginal social damage costs refer to the economic value of the damage caused by the emission of an additional metric tonne of carbon to the atmosphere. IPCC suggests that the marginal damage of a tonne of carbon would hardly exceed US$50/ton C (Smith et al. 2002). Fankhauser (1994) based on review of a number of marginal social damage studies gives a range of carbon values between US$6 and US$45/ton C with an average value of US$20/ton C. In southern part of Ethiopia, the World Bank using its BioCarbon Fund purchased carbon at US$4.40/ton CO_2 from community managed natural regeneration forest project. The carbon monetary account is therefore derived by multiplying the physical carbon account by US$16.13/ton C. Accordingly, the closing value of the forest carbon sink service during the years 1995 and 2005 is ETB 270.37 (US$43) billion and ETB 384.48 (US$40) billion, respectively (see detailed carbon accounts in the Appendix 3 – Table 3B). In the national accounts, the tree can be valued for either timber or carbon but not both because carbon is sequestered within the timber.

The effects of forests in watershed protection can be valued using replacement cost approach or the change in productivity method (e.g. in terms of loss in crop yields due to soil erosion, sedimentation or flooding) (Gregersen et al. 1995). In this report, the change in productivity approach is used to value soil erosion prevention benefits of forest resources. According to a recent estimate by World Food Programme Ethiopia (WFPE), the value of crop productivity loss of 1 ton of soil loss on cultivated land varies from ETB 0.35 to ETB 0.73, with an average value of

ETB 0.395 (WFPE 2005). In this accounting, the average value of ETB 0.395 per ton of soil loss is used.

Average annual soil loss from forestland, other forest types (wood, bushland and shrubland) and bare land is estimated at 5, 1 and 70 tons/ha/year, respectively (Hurni 1988). The soil conservation efficiency of forestland and other forest types (woodland, bushland and shrubland) is assumed to be 99 and 93%, respectively, compared to bare land. Data on soil conservation efficiency for bamboo and plantation forests are not available. For bamboo, however, we assume soil conservation efficiency of 99% compared to bare land. This is because bamboo forests are characterised by a complex network of rhizome-root systems, which makes the bamboo forest better than other forest types in effectively holding soil particles together, thereby preventing soil erosion and promoting water percolation (Embaye 2003).

The values of the watershed protection benefits of forestland, bamboo and other forest types (woodland, shrubland and bushland) are ETB 27.25, 22.12 and 25.68 per ha, respectively. The value of watershed benefits of each forest resource is derived by multiplying the respective area account by per hectare watershed value and its soil conservation efficiency value. Based on this, the total watershed value of Ethiopian forest resources is estimated to be worth ETB 230.32 million in 1995 and ETB 161.29 million in 2005.

6 Results and Discussion

6.1 Physical Forest Accounts: Area, Volume and Carbon Storage Accounts

Detailed physical forest area and volume as well as carbon volumes accounts at the national level are presented in Appendix 2. The summary net change in area results reported in Table 15 shows that with the exception of the bamboo and plantation forest areas, the other categories of forest vegetation experienced declines between 1995 and 2005. Since Table 15 is self-explanatory, our discussion will be limited to the net change row entries. In 1995 and 2005, net change was calculated as the difference between the area that was added to a particular vegetation category and the area that was removed from that vegetation category. With the exception of plantation forestry in 2005, the net gain was consistently negative. Our results suggest that between 1995 and 2005, there was a reduction of about 27% in the difference between additions and subtractions to the forest vegetation category (i.e. there was a decline). Since over the same period the rate of regeneration also declined, the data suggests that the improvement in net gains can probably be attributed to the decline in the area subjected to deforestation. This suggests that in the intervening period, the amount of pressure subjected to forests for extractive uses appears to have reduced. The same appears to hold for the woodland and shrubland vegetation categories, although the greatest gain in terms of containing the pressure for extractive use appears to be in the forest vegetation category. For the bushland vegetation category, the pressure for extractive uses increased by about 75% in the 10-year period.

The pressure for extractive uses from the bamboo vegetation category was constant, whilst the plantation forest estate in fact expanded during the 10-year period. From the point of view of forest resource management and sustaining the inter-temporal welfare of forest dependent communities, the bushland vegetation type presents the greatest challenge.

The forest carbon sink accounts follow the same pattern as they are based on changes in forest volumes (see Table 2C in Appendix 2).

6.2 Monetary Forest Accounts and Potential Corrections to SNA

Detailed monetary forest accounts are derived based on the physical accounts and the various assumptions discussed in Sect. 5 above for each product and service considered. Table 16 summarises the values of forest goods and services produced in years 1995 and 2005. Total forest values that are either missing from or incorrectly allocated in the SNA are aggregated in Table 17 for the two study periods (1995 and 2005).

Entry 1 of Table 17 suggests that if Ethiopia was to do a total wealth accounting exercise, then the value of its forest resources to enter into total wealth asset accounts would be ETB 88 billion in 1995 and ETB 83 billion in 2005.

The values for fuelwood, charcoal and construction wood computed in Table 17 assume that all the woods harvested from Ethiopian forests are traded through the market. For example, agricultural GDP in 1993/1994 was estimated by FAO at about ETB 5 billion. If agriculture also includes the contribution of the forestry sector, then there is clear evidence that the true contribution of forestry to GDP in the Ethiopia SNA is highly underrepresented given forest values reported in Table 17 (about ETB 6 billion in 1995 for forests alone).

As stated earlier, entries 5–12 of Table 17 are entries that already exist in the current SNA. However, instead of being attributed to the forestry sector which provides these services, they are wrongly attributed to other sectors of the economy. The recommended correction to GDP is to remove these values from the sectors where they presently appear and add them to forestry. So, for example, the agricultural GDP for 1995 should be reduced by a value of ETB 86 million (honey value), and this value attributed to the 1995 forestry GDP. Note that we have not included adjustments for other values of forest goods and service such as watershed protection and carbon sequestration in Table 17. With all such adjustments, it should be possible to have better estimates of the true contribution of forest resources to the welfare of Ethiopians.

Table 15 Percentage increase (+) or decrease (–) in forest area between 1995 and 2005

	Forestry	Woodland	Bushland	Shrubland	Bamboo	Plantation	Total
1 Opening area	(–) by 18%	(–) by 4%	(–) by 8%	(–) by 2%	No change	(+) by 15%	(–) by 4%
2 Afforestation	No change	No change	No change	No change	No change	(+) by 100%	(+) by 100%
3 Regeneration	(–) by 18%	(–) 4%	(–) by 8%	(–) by 2%	No change	No change	(–) by 4%
4 Deforestation	(–) by 26%	(–) by 8%	(+) by 71%	(–) by 6%	No change	No change	(–) by 5%
5 Net change	(–) by 27%	(–) by 8%	(+) by 75%	(–) by 6%	No change	(+) by 100%	(+) by 8%
6 Closing area	(–) by 18%	(–) 3%	(–) by 11%	(–) by 2%	No change	(+) by 24%	(–) by 3%

Table 16 Production of forest goods and services, 1995 and 2005 (national level)

	Forest good/forest service	1995	2005
1	Fodder (ETB)	1,195,571,724	1,732,947,000
2	Forest coffee (ETB)	23,652,200	70,156,800
3	Semi-forest coffee (ETB)	53,467,297	190,793,827
4	Honey (ETB)	85,501,662	108,046,220
5	Beeswax (ETB)	16,901,780	42,221,138
6	Medicinal plants (ETB)	435.20 million	569.74 million
7	Bamboo resources (ETB)	1,067,640	4,504,272
8	Exudates (ETB)	21,157,480	41,924,830
9	Thatch grass (ETB)	127.04 million	147.85 million

Table 17 Estimated potential corrections to Ethiopia's GDP, 1995 and 2005

	Value of forest good or service	Source	1995	2005
1	Closing stock (ETB)	Table 3A (Appendix 3)	88 billion	83 billion
	Subtotal:		88 billion	83 billion
2	Fuelwood (ETB)	Table 3A (Appendix 3)	3 billion	4 billion
3	Charcoal (ETB)	Table 3A (Appendix 3)	721 million	688 million
4	Construction wood (ETB)	Table 3A (Appendix 3)	348 million	481 million
	Subtotal:		4 billion	5 billion
5	Fodder (ETB)	Table 16	1 billion	2 billion
6	Forest coffee (ETB)	Table 16	24 million	70 million
7	Semi-forest coffee (ETB)	Table 16	53 million	191 million
8	Honey (ETB)	Table 16	86 million	108 million
9	Beeswax (ETB)	Table 16	17 million	42 million
10	Medicinal plants (ETB)	Table 16	435 million	570 million
11	Bamboo resources (ETB)	Table 16	1 million	5 million
12	Exudates (ETB)	Table 16	21 million	42 million
13	Thatch grass (ETB)	Table 16	127 million	148 million
	Subtotal:		2 billion	3 billion

7 Conclusions and Implications for Policy

This study made an attempt to construct forest accounts in Ethiopia and identify research (data) gaps in order to formulate complete forest accounts. The forest accounts (physical and monetary accounts) include both direct (timber, poles, charcoal, firewood, fodder, medical plants, honey and beeswax, forest (wild) and semi-forest coffee, exudates, thatch and bamboo) and indirect use values (carbon storage and watershed protection services).

The total value of forest products harvested (firewood, charcoal and construction wood harvested) and non-wood forest products (coffee, fodder, medicinal plants, exudates, honey, bamboo, beeswax, thatch grass) is estimated at about ETB 6.2 billion in 1995 and ETB 8 billion in 2005. The watershed benefits of the forest sector in 1995 are estimated at ETB 230 million and ETB 161 million in 2005. The total value (closing) of carbon is estimated at ETB 270 billion in 1995 and ETB 348 billion in 2005. The economic contribution of forestry sector to total GDP is estimated at 11.60% in 1995 and 9.0% in 2005. When watershed service value is included, forest economic contribution to GDP increases to 27.5% in 1995 and 18.8% in 2005. Percentage contribution would be even higher if we include the value of wild edible plants, spices resources and the contribution of protected areas to the national economy. The economic contribution of forestry sector according to the SNA was estimated at only 6.4% in 1995 and 4.7% in 2005. This indicates that the true economic contribution of forest resources to the national economy of Ethiopia is highly underestimated.

Physical accounts results also suggest that natural forest assets are being depleted and consequently their direct and indirect benefits due to conversion to other land uses. Trade-offs between gains from increased supply and values of these alternative land uses and the foregone values of reduced supply of forest ecosystem services need to be carefully evaluated to be able to judge whether the wellbeing of Ethiopians has improved or declined by this substitution. This certainly requires correcting measures of change in wellbeing through more inclusive wealth accounting system that adjusts net national product and saving indices for depletion of forest assets.

Our first recommendation relates to the compilation of forestry-related information systems in Ethiopia. It is clear that information currently available on forestry in Ethiopia is insufficient for the construction of comprehensive physical and monetary stock and flow accounts for forestry. In this report, we had to make many assumptions in compiling these accounts. An information system that tracks the acreage of land under forestry by year and the physical quantities of forest goods extracted by year (and the associated accounting prices) is thus needed. We thus recommend that the forest sector invests in setting up a forestry information system that will eventually provide data in a form that is useful for forest resources accounting.

We also recommend that an information system should be established and managed for collecting data on the value of natural forests and woodlands so that in the long run, a time series of these values can be produced. This can be done by incorporating questions related to the use of natural forests and woodlands in one of the regular surveys carried by the Central Statistics Authority. We trust that incorporating these additional questions in these surveys can be done at no significant additional costs to CSA.

As we stated earlier on, one of the main uses for forest resources accounting is to correct the SNA to properly account for the contribution of the forestry sector to national income. It is recommended that once Ethiopia implements SNA 93, corrections for forest values be made to the necessary accounts, for example, adjusted net savings for 1994 and 2004 can be adjusted with the value of net accumulation in timber of natural forests and woodlands. A first step has been taken in this work to value forest resources. Incorporating these values enables production of adjusted national income accounts on a regular basis. This also serves as a foundation to expanding the accounts to incorporating other environmental resources.

Appendices

Appendix 1: Definitions of Forest Strata in Ethiopia

WBISPP has used the definition of Friis (1992) who defined 'forest' as 'a relatively continuous cover of trees, which are evergreen or semi-deciduous, only being leafless for a short period, and then not simultaneously for all species. The canopy should preferably have more than one story'.

The WBISPP defines woodlands as 'a continuous stand of trees with a crown density of between 20 and 80%. Mature trees are usually single storeyed, although there may be layered understoreys of immature trees, and of bushes, shrubs and grasses/forbs. Maximum height of the canopy is generally not more than 20 m, although emergent may exceed this'. Open woodlands have between 150 and 400 stems per ha, whilst dense woodland has more than 400 stems per ha.

Shrublands are defined as 'a continuous stand of shrubs with a crown density of between 20 and 100%. There may be scattered individual trees with a crown cover of less than 20% or scattered clumps (i.e. less than 0.5 ha) of trees (as modifiers)'. Dense shrublands have more than 1,000 stems per ha, whilst open shrubland has between 999 and 400 shrub stems per ha. Scattered trees within the shrub layer are classified according to three categories of stem density: densely scattered between 80 and 149 stems per ha, moderately scatted trees between 40 and 79 stems per ha and sparsely scattered less than 39 stems per ha.

Bushland is a general term for low tree-high grass vegetation occurring in semi-arid or seasonally arid regions (ICRAF Agro forestry Database).

Appendix 2: Detailed Physical Forest Resource Accounts for Ethiopia for 1995 and 2005 (National Level)

Table 2A Forest area accounts in ha

	Forest		Woodland		Bushland		Shrubland	
Hectares	1995	2005	1995	2005	1995	2005	1995	2005
1. Opening area	4,061,118	3,444,976	29,339,420	28,346,405	2,449,854	2,263,577	25,310,961	24,728,897
2.1. Afforestation	0	0	0	0	0	0	0	0
3.1. Regeneration	4,061	3,445	58,679	56,693	4,900	4,527	50,622	49,458
3.2. Deforestation	56,628	44,980	2,357,005	2,183,921	25,006	85,251	1,987,170	1,880,483
4. Net change	−52,567	−41,535	−2,298,326	−2,127,228	−20,106	−80,724	−1,936,548	−1,831,025
5. Closing area	4,008,551	3,403,441	27,041,094	26,219,177	2,429,748	2,182,853	23,374,413	22,897,872

	Bamboo		Plantation		Total	
Hectares	1995	2005	1995	2005	1995	2005
1. Opening area	1,106,735	1,106,735	723,752	852,293	62,991,840	60,742,883
2.1. Afforestation	0	0	0	103,412	0	103,412
3.1. Regeneration	3,320	3,320	0	0	121,582	117,443
3.2. Deforestation	8,854	8,854	0	0	4,434,662	4,203,489
4. Net change	−5,534	−5,534	0	103,412	−4,313,080	−3,982,634
5. Closing area	1,101,201	1,101,201	723,752	955,705	58,678,760	56,760,249

Table 2B Physical forest volume accounts in m^3

	Forest		Woodland		Bushland		Shrubland	
Volume units (m^3)	1995	2005	1995	2005	1995	2005	1995	2005
1. Opening volume	529,975,899	449,569,368	616,127,824	595,274,505	36,747,806	33,953,655	377,133,319	368,460,565
2. Increment	22,945,317	19,464,114	23,178,142	22,393,660	489,971	452,715	12,655,481	12,364,449
3.1 Afforestation	0	0	0	0	0	0	0	0
3.2 Fuelwood	8,262,183	10,215,672	15,927,966	20,050,984	5,423,585	6,681,493	25,910,898	33,462,133
3.3 Charcoal	269,450	280,858	4,766,840	3,829,676	41,134	50,214	7,816,169	7,888,193
3.4 Construction wood	508,754	628,530	779,747	1,018,012	292,694	363,250	1,292,501	1,784,804
4.1 Regeneration	22,945	19,464	46,356	44,787	980	905	730,734	713,389
4.2 Forest fires	46	43	93	99	2	2	51	55
4.3 Harvest damage	490,176	587,680	1,132,209	1,295,834	309,823	372,910	1,832,111	2,226,518
4.4 Insect/disease damage	164,343	139,409	191,102	184,535	11,392	10,526	116,911	114,223
5 Conversion to non-forest use	7,389,922	5,869,866	49,497,097	45,862,346	375,085	1,278,766	29,608,837	28,019,200
6. Net change	5,883,388	1,761,520	−49,070,555	−49,803,039	−5,962,765	−8,303,539	−53,896,686	−61,105,948
7. Closing volume	535,859,287	451,330,888	567,057,361	545,471,466	30,785,043	25,650,116	323,236,633	3,073,541,617

Volume units (m^3)	Bamboo		Plantation		Total	
	1995	2005	1995	2005	1995	2005
1. Opening volume	48,431,788	48,431,788	129,406,858	152,389,988	1,737,823,493	1,648,079,870
2. Increment	2,106,812	2,106,812	9,046,900	10,653,663	70,422,621	67,435,412
3.1. Afforestation	0	0	0	1,292,650	0	1,292,650
3.2. Fuelwood	1,324,071	2,064,451	4,926,983	9,320,930	61,775,686	81,795,663
3.3. Charcoal	347,062	367,949	119,555	216,955	13,360,209	12,633,846
3.4. Construction wood	56,783	100,420	231,917	473,749	3,162,396	4,368,765
4.1. Regeneration	6,320	6,320	0	1,292,650	807,336	2,077,516
4.2. Forest fires	13	14	0	0	204	3,064
4.3. Harvest damage	90,655	131,662	281,317	524,269	4,136,290	5,138,874
4.4. Insect/disease damage	15,014	15,014	40,116	47,241	538,725	510,905
5. Conversion to non-forest use	387,454	387,454	0	0	87,258,395	81,417,632
6. Net change	−107,920	−953,832	3,447,012	1,363,169	−99,707,371	−115,751,831
7. Closing volume	48,323,868	47,477,956	132,853,870	153,753,157	1,638,116,122	1,532,328,039

Table 2C Physical carbon accounts in ton C

	Forest		Woodland		Bushland		Shrubland	
	1995	2005	1995	2005	1995	2005	1995	2005
1. Opening stock	435,032,891	369,030,860	1,274,655,285	1,231,513,599	90,135,138	83,281,636	928,170,035	906,825,355
2. Increment	18,834,757	15,977,198	47,951,318	46,328,369	1,201,802	1,110,422	31,146,645	30,430,381
3.1. Afforestation	0	0	0	0	0	0	0	0
3.2. Fuelwood	6,782,046	8,385,576	32,952,035	41,481,802	13,302,986	16,388,387	63,769,808	82,354,297
3.3. Charcoal	221,179	230,544	9,861,716	7,922,897	100,892	123,166	19,236,522	19,413,783
3.4. Construction wood	417,612	515,932	1,613,154	2,106,080	717,921	890,981	3,181,000	4,392,615
4.1. Regeneration	18,835	15,977	95,903	92,657	2,404	2,221	1,798,424	1,755,734
4.2. Forest fires	38	35	192	204	5	134	125	12
4.3. Harvest damage	402,363	482,399	2,342,332	2,680,843	759,934	914,676	4,509,044	5,479,727
4.4. Insect/disease damage	134,902	114,435	395,355	381,974	27,947	25,822	291,700	284,989
5. Conversion to non-forest use	6,066,047	4,818,304	102,400,402	94,880,769	920,009	3,136,558	72,870,876	68,958,591
6. Net change	4,829,442	1,445,986	−101,517,772	−103,033,338	−14,625,484	−20,366,947	−130,913,881	−148,697,887
7. Closing stock	439,862,334	370,476,846	1,173,137,512	1,128,480,261	75,509,654	62,914,688	797,256,154	758,127,469

	Bamboo		Plantation		Total	
	1995	2005	1995	2005	1995	2005
1. Opening stock	82,707,785	80,163,454	90,578,312	106,665,351	2,901,279,446	2,777,480,255
2. Increment	3,912,137	3,912,137	6,332,376	7,457,030	109,379,036	105,215,537
3.1. Afforestation	0	0	0	904,790	0	904,790
3.2. Fuelwood	2,458,667	3,833,478	3,448,641	6,524,184	122,714,183	158,967,724
3.3. Charcoal	644,459	683,243	83,683	151,858	30,148,451	28,525,490
3.4. Construction wood	105,440	186,470	162,330	331,600	6,197,458	8,423,678
4.1. Regeneration	11,736	11,736	0	904,790	1,927,301	1,878,326
4.2. Forest fires	0	0	0	1,996	359	359
4.3. Harvest damage	168,336	244,483	196,90	366,962	8,378,917	10,169,090
4.4. Insect/disease damage	4,533,456	4,533,456	28,079	35,062	5,411,439	5,375,737
5. Conversion to non-forest use	719,464	719,464	0	0	182,976,798	172,513,686
6. Net change	–4,705,949	–6,276,721	2,412,735	952,154	–244,520,909	–275,976,753
7. Closing stock	78,001,836	73,886,733	92,991,047	107,617,505	2,656,758,537	2,501,503,502

Table 2C (carbon storage) was constructed from Table 2B (forest volumes)

Appendix 3: Detailed Monetary Forest Accounts for Ethiopia for 1995 and 2005 (National Level)

Table 3A Monetary forest accounts in ETB

	Forest		Woodland		Bushland		Shrubland	
ETB	1995	2005	1995	2005	1995	2005	1995	2005
1. Opening stock	28,838,800,565	24,463,180,646	33,154,988,202	32,072,084,338	1,985,334,986	1,835,095,056	20,308,947,661	19,894,658,996
2. Increment	1,248,576,423	1,059,133,875	1,247,259,080	1,206,521,268	26,471,133	24,467,934	681,508,311	667,606,007
3.1. Afforestation	0		0		0		0	
3.2. Fuelwood	421,371,311	520,999,279	812,326,242	1,022,600,162	276,602,813	340,756,123	1,321,455,812	1,706,568,799
3.3. Charcoal	14,550,292	15,166,343	257,409,358	206,802,516	2,221,209	2,711,573	422,073,103	425,962,424
3.4. Construction wood	56,013,761	69,201,163	85,850,159	112,083,143	32,225,616	39,993,835	142,304,405	196,506,911
4.1. Regeneration	1,248,576	1,059,134	2,494,518	2,413,043	52,942	48,936	1,363,017	1,335,212
4.2. Forest fires	2,497	2,336	5,045	5,376	107	109	2,755	2,968
4.3. Harvest damage	49,193,536	60,536,679	115,558,576	134,148,582	31,104,964	38,346,153	188,583,332	232,903,813
4.4. Insect/disease damage	8,940,028	7,583,586	10,278,046	9,942,346	615,454	568,879	6,295,774	6,167,344
5. Conversion to non-forest use	402,124,838	319,406,994	2,663,531,196	2,470,962,577	20,264,315	69,113,471	1,594,460,876	1,512,868,650
6. Re-evaluation	297,628,736	67,296,629	−2,695,205,024	−2,747,610,391	−336,510,403	−466,973,273	−2,992,304,729	−3,412,039,690
7. Closing stock	29,136,429,301	24,530,477,275	30,459,783,178	29,324,473,947	1,648,824,583	1,368,121,783	17,316,642,932	16,482,619,306

ETB	Bamboo 1995	Bamboo 2005	Plantation 1995	Plantation 2005	Total 1995	Total 2005
1. Opening stock	2,593,266,586	2,604,612,297	6,944,567,176	8,207,970,425	93,825,905,177	89,077,601,758
2. Increment	112,808,640	113,302,185	485,498,265	573,823,436	3,802,121,851	3,644,854,704
3.1 Afforestation	0		0	69,624,213	0	69,624,213
3.2 Fuelwood	67,527,627	105,287,013	251,276,157	475,367,426	3,150,559,963	4,171,578,803
3.3 Charcoal	18,741,334	19,869,221	6,455,996	11,715,583	721,451,292	682,227,660
3.4 Construction wood	6,251,815	11,056,233	25,534,080	52,159,727	348,179,836	481,001,012
4.1 Regeneration	338,426	339,907	0	69,624,213	5,497,479	5,196,231
4.2 Forest fires	688	759	0	155,154	11,091	166,702
4.3 Harvest damage	9,252,078	13,621,247	28,326,623	53,924,274	422,019,109	533,480,747
4.4 Insect/disease damage	803,913	807,430	2,152,816	2,544,471	29,086,031	27,614,057
5 Conversion to non-forest use	20,746,133	20,836,898	0	0	4,701,127,357	4,393,188,590
6. Re-evaluation	−10,176,522	−57,836,709	171,752,593	47,581,014	−5,564,815,349	−6,639,206,636
7. Closing stock	2,583,090,064	2,546,775,588	7,116,319,769	8,325,175,652	88,261,089,828	82,508,019,335

Table 3B Carbon monetary accounts in US$

	Forest		Woodland		Bushland		Shrubland	
	1995	2005	1995	2005	1995	2005	1995	2005
1. Opening stock	7,017,080,537	5,952,467,779	20,560,189,739	19,864,314,347	1,453,879,782	1,343,332,785	14,971,382,667	14,627,092,978
2. Increment	303,804,636	257,712,207	773,454,757	747,276,587	19,385,064	17,911,104	502,395,391	490,842,046
3.1. Afforestation	0	0	0	0	0	0	0	0
3.2. Fuelwood	109,394,410	135,259,347	531,516,320	669,101,460	214,577,163	264,344,680	1,028,607,004	1,328,374,815
3.3. Charcoal	3,567,618	3,718,668	159,069,482	127,796,322	1,627,394	1,986,665	310,285,103	313,144,320
3.4. Construction wood	6,736,088	8,321,975	26,020,167	33,971,074	11,580,065	14,371,524	51,309,530	70,852,881
4.1. Regeneration	303,805	257,712	1,546,910	1,494,553	38,770	35,822	29,008,576	28,319,997
4.2. Forest fires	3,828	4,911	19,491	28,483	489	683	12,660	18,709
4.3. Harvest damage	6,490,112	7,781,098	37,781,811	43,241,997	12,257,736	14,753,720	72,730,887	88,387,999
4.4. Insect/disease damage	2,175,965	1,845,833	6,377,071	6,161,234	450,788	416,512	4,705,116	4,596,867
5. Conversion to non-forest use	97,845,344	77,719,241	1,651,718,481	1,530,426,799	14,839,751	50,592,688	1,175,407,230	1,112,302,072
6. Re-evaluation	77,898,904	23,323,755	−1,637,481,666	−1,661,927,745	−235,909,064	−328,518,862	−2,111,640,902	−2,398,496,910
7. Closing stock	7,094,979,441	5,975,791,534	18,922,708,073	18,202,386,602	1,217,970,718	1,014,813,923	12,859,741,764	12,228,596,068

	Bamboo		Plantation		Total	
	1995	2005	1995	2005	1995	2005
1. Opening stock	1,334,076,566	1,293,036,509	1,461,028,167	1,720,512,109	46,797,637,458	44,800,756,507
2. Increment	63,102,773	63,102,773	102,141,231	120,281,887	1,764,283,853	1,697,126,604
3.1. Afforestation	0	0	0	14,594,266	0	14,594,266
3.2. Fuelwood	39,658,297	61,834,005	55,626,586	105,235,081	1,979,379,779	2,564,149,389
3.3. Charcoal	10,395,120	11,020,717	1,349,804	2,449,466	486,294,521	460,116,158
3.4. Construction wood	1,700,754	3,007,756	2,618,389	5,348,713	99,964,993	135,873,923
4.1. Regeneration	189,308	189,308	0	14,594,266	31,087,369	44,891,659
4.2. Forest fires	1,118	1,589	0	278,133	37,586	330,919
4.3. Harvest damage	2,715,265	3,943,512	3,176,118	5,919,099	135,151,930	164,027,423
4.4. Insect/disease damage	73,124,647	73,124,647	452,919	565,551	87,286,506	86,710,645
5. Conversion to non-forest use	11,604,949	11,604,494	0	0	2,951,415,756	2,782,645,748
6. Re-evaluation	−75,906,950	−101,243,504	38,917,415	15,358,243	−3,944,122,264	−4,451,505,024
7. Closing stock	1,258,169,615	1,191,793,005	1,499,945,582	1,735,870,351	42,853,515,194	40,349,251,483

References

Bann C (1998) The economic valuation of tropical forest land use options: a manual for researchers. Economy and environment program for Southeast Asia, Tanglin, Singapore
Bartelheimer P (1997) Price policy and organization of timber marketing in the state forests of the Oromia regional state. German House of Cooperation, GTZ Office, Addis Ababa
BoAa (Bureau of Agriculture) (2007) Summary report of forestry and agro-forestry activities. Department of Forestry and Agro-forestry Development and Protection. Amhara National Regional State Bureau of Agriculture, Bahir Dar, Ethiopia
BoAb (Bureau of Agriculture) (2005) Annual report. Oromiya National Regional State Bureau of Agriculture, Addis Ababa, Ethiopia
BoAc (Bureau of Agriculture) (2005) Annual report. Southern Nations, nationalities and Peoples Regional State Bureau of Agriculture, Hawassa, Ethiopia
BoAd (Bureau of Agriculture) (2005) Annual report. Tigray national regional state Bureau of Agriculture, Tigray, Ethiopia
Brown S (1997). Estimating biomass and biomass change of tropical forests. FAO forestry paper no 174. Food and Agriculture Organization of the United Nations (FAO), Rome
Cousin TL (1997) Ethiopia coffee and trade. Case number: 397, Case mnemonic: coffeeth http://www1.american.edu/TED/ethcoff.htm. Accessed 3 Nov 2012
CSA (Central Statistics Authority) (1995) Agricultural sample survey 1994/95 (1987 E.C.). Report on livestock poultry and beehives population (private peasant holdings), vol II, Statistical Bulletin 132, 243p. CSA, Addis Ababa, Ethiopia
CSA (Central Statistics Authority) (2005a) Agricultural sample survey. Report on livestock poultry and beehives population (private peasant holdings), Addis Ababa, Ethiopia
CSA(Central Statistics Authority) (2005b) Analytical report of each region. Government of the Federal Democratic Republic of Ethiopia. Addis Ababa, Ethiopia
Deffar G (1998) Non-wood forest products in Ethiopia. EC-FAO Partnership Programme (1998–2000), Project GCP/INT/&/)/EC, Data Collection and Analysis for Sustainable Forest Management in ACP Countries - Linking National and International Efforts, Non-wood Forest Products in Ethiopia, Addis Ababa
EFAP (Ethiopian Forestry Action Plan) (1994) Final report. vol II–the Challenge for Development. EFAP Secretariat, Addis Ababa
Embaye K (2003) Ecological aspects and resource management of bamboo forests in Ethiopia. Doctoral Thesis, Department of short rotation forestry, Swedish University of Agricultural Sciences, Uppsala
Embaye K, Weih M, Ledin S, Christersson L (2004) Biomass and nutrient distribution in a highland bamboo forest in southwest Ethiopia: implications for management. For Ecol Manage 204(2/3):159–169
Ethiopian Customs Authority (2007) Report downloaded from http://www.2merkato.com/2008043034/customs-regulation-in-ethiopia. Accessed 6 Nov 2012
Fankhauser S (1994) Evaluating the social costs of greenhouse gas emissions. Energy J 15(2): 157–184
FAO (1987) Master land use plan, Ethiopia. Range/livestock consultancy. Report prepared for the government of the people's democratic republic of Ethiopia, Technical Report AG/ETH/82/010. FAO, Rome
FAO (2003) The state of the world's forests. Food and Agriculture Organization of the United Nations, Rome
FAO (2006) Global forest resources assessment 2005. Progress towards sustainable forest management. FAO forestry paper 147. FAO, Rome
Friis I (1992) Forest and forest trees of northeast tropical Africa: their natural habitats and distribution patterns in Ethiopia Djibouti and Somalia. Kew Bull Add Ser 15:1–396
Gregersen HM, Arnold JEM, Lundgren AL, Contreras-Hermosilla A (1995) Valuing forests: context, issues and guidelines. FAO Forestry paper 127. FAO, Rome

Hamilton K, Clemmens M (1999) Genuine savings rates in developing countries. World Bank Econ Rev 13(2):336–356

Haripriya GS (2000a) Integrating environmental and economic accounting: an application to the forest resources in India. Environ Res Econ 19:73–95

Haripriya GS (2000b) Integrating forest resources into the system of national accounts in Maharashtra, India. Environ Dev Econ 5:143–156

Hassan MR (2002) Accounting for the stock and flow of woody land resources: methods and results from South Africa. Centre for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria, Pretoria

Hurni H (1988) Degradation and conservation of the resources in the Ethiopian highlands. Mt Res Dev 8(2/3):123–130

IBC (Institute of Biodiversity Conservation) (2005) National biodiversity strategy and action plan. Government of the Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia

Kelbessa E, Bekele T, Gebreehiwot A, Hadera G (2000) A socio-economic case study of the bamboo sector in Ethiopia: an analysis of the production-to-consumption system. INBAR working paper 25, pp 1–20. International Network for Bamboo and Rattan, Addis Ababa, Ethiopia

Lange G (2004) Manual for environmental and economic accounts for forestry: a tool for cross-sectoral policy analysis. FAO Forestry Department Working paper, Itlay

Le Houerou HN, Hoste CH (1977) Rangeland production and annual rainfall relations in the Mediterranean basin and in the Africa Shahelo-Sudanian zone. J Range Manage 30(3): 181–189

LUSO Consult GmBH (1997) Study on sustainable bamboo management, GTZ

MoA (Ministry of Agriculture) (1990a) Forest products pricing and marketing study, vol 1. Technical report, Ministry of Agriculture, Addis Ababa, Ethiopia

MoA (Ministry of Agriculture) (1990b) Forest products pricing and marketing study, vol 2. Technical report, Ministry of Agriculture, Addis Ababa, Ethiopia

MoA (Ministry of Agriculture) (2003) Coffee development and marketing comprehensive plan. Ministry of Agriculture, Addis Ababa, Ethiopia

MoA (Ministry of Agriculture) (2007a) Natural gum development and marketing plan report. Department of forestry, land use and soil and water conservation, MoA. Addis Ababa, Ethiopia (Amharic Version)

MoA (Ministry of Agriculture) (2007b) Livestock forage resource development strategy. Department of Livestock and Fishery resource development. MoA, Addis Ababa, Ethiopia

MoFED (Ministry of Finance and Economic Development) (2007) Report downloaded from http://www.mofed.gov.et/English/Pages/Home.aspx. Accessed 6 Nov 2012

Oxfam (2001) Bitter coffee: how the poor are paying for the slump in coffee prices. Oxfam International, London

Paulos D, Teketay D (2000) Some ecological parameters occurring in the major coffee growing areas of southwestern and southern Ethiopia. In: Proceedings of the workshop on control of coffee berry disease (CBD), Addis Ababa, Ethiopia, 13–15 Aug 1999

Pearce DW, Moran D (1994) The economic value of biodiversity. In association with the biodiversity programme of IUCN. Earthscan Publication Ltd., London

Reichhuber A, Requate T (2007) Alternative use systems for the remaining cloud forest in Ethiopia and the role of Arabica coffee-A cost-benefit analysis. Economics Working paper no 2007–07, Department of Economics, Christian-Albrechts-Universitat zu Kiel, Kiel

Sander K (2000) Financial and economic analysis of forest management systems at FOMISS-samling pilot area (FSPA). Consultancy report no 52, Malaysian-German technical cooperation project, Forest Department of Sarawak and Forest Management Information System Sarawak (FOMISS), Kuching, Malaysia

Shanmughavel P, Francis K (1996) Biomass and nutrient cycling in bamboo (*Bambusa bambos*) plantations of tropical areas. Biol Fertil Soils 23(4):431–434

Simpson D, Sedjo R, Reid J (1994) Valuing biodiversity: an application to genetic prospecting. Resources for the Future, Discussion Paper 94–20, Washington, DC

Smith BJ, Schellnhuber JH, Mirza QM, Lin E, Fankhauser S, Leemans R, Ogallo L, Richels GR, Safriel U, Tol JSR, Weynant PJ, Yohe WG (2002) Synthesis. IPPC third assessment report. Cambridge University Press, Cambridge

Teketaye D (1999) History, botany and ecological requirements of coffee. Walia 20:28–50

UNEP (1995) Global biodiversity assessment. United Nations Environment Programme, Cambridge University Press, Cambridge

United Nations, Commission of the European Communities, International Monetary Fund, Organisation for Economic Cooperation and Development, World Bank (2003) Handbook of national accounting: integrated environmental and economic accounting 2003 (SEEA 2003). United Nations, New York

Vincent JR, Hartwick JM (1997) Accounting for the benefits of forest resources: concepts and experience. Report commissioned by the Forestry Department, Food and Agricultural Organization (FAO), Rome

WBISPP (Woody Biomass Inventory and Strategic Planning Project) (1994) A national strategic plan for the biomass energy sector. Federal Democratic Republic of Ethiopia, Ministry of Agriculture, Addis Ababa

WBISPP (Woody Biomass Inventory and Strategic Planning Project) (2004) A national strategic plan for the biomass energy sector. Federal Democratic Republic of Ethiopia, Ministry of Agriculture, Addis Ababa

WFPE (World Food Program Ethiopia 2005) report downloaded from http://www.wfp.org/countries/Ethiopia?gclid=CJLjr7WWurMCFSnJtAod0jwA3g. Accessed 6 Nov 2012

Workaffess W, Kassu K (2000) Coffee production systems in Ethiopia. In: Proceedings of the workshop on control of coffee berry disease (CBD), Addis Ababa, Ethiopia, 13–15 August, 1999

World Bank (2006) Where is the wealth of nations? Measuring capital for the 21st Century. The International Bank for Reconstruction and Development, The World Bank, Washington, DC

Zewdu M, Demissie A (2001) Conservation and sustainable use of medicinal plants in Ethiopia. In: Proceedings of the national workshop on biodiversity conservation and sustainable use of medicinal plants in Ethiopia, Institute of Biodiversity Conservation and Research, Addis Ababa, Ethiopia

Contribution of Uganda's Forestry Sub-sector to the National Economy: Natural Resource Accounting Approach

Moses Masiga, Eugene Muramira, and Ronald Kaggwa

Abstract Forests and forest products have a high monetary and nonmonetary value in Uganda. Over 90% of total energy resources used in the country is derived from fuelwood. Forests offer provisioning ecosystem services which include wood products, non-timber forest products such as honey, medicinal plants and raw materials for small industry, amongst others. Forests also provide regulatory ecosystem services such as soil protection, maintenance of the hydrological cycle and sequestration of greenhouse gases.

Keywords Uganda forests • Green accounting • Forest ecosystem services

1 Introduction

The National Statistical Abstract (UBOS 2010) estimates the contribution of forest sub-sector to national income (GDP) was Ugandan shillings (Ushs) 1,038 billion in 2010. This amount is disputed as being too small and under-representing the actual contribution of the sub-sector. For example, Slade and Weitz (1991) pro-

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duced evidence that the environment and natural resources, including forests, contributed about 4–11% of the country's national income. Similarly, Yaron et al. (2003) indicated contributions of between 6% and 7%. In 2005, an attempt was made to develop national forest resource accounts to provide improved information on the true annual contribution of forests to the economy. This process stalled because the necessary data was not available. Subsequent studies estimated the Total Economic Value (TEV) of limited parts of the country's forest estate (Moyini 2006). A comprehensive annual estimate of the economic value of forests was however not made. The urgency of a national estimate of the contribution of the forestry sub-sector to the national economy was highlighted in the National Development Plan (NDP) for Uganda (GoU 2009). The present study aims to determine the annual contribution of the country's forestry resources to the national economy.[1]

Under this overall objective of establishing the contribution of the country's forestry resources to the national economy, the following specific objectives have been pursued:

1. To determine the physical stock and flow of forestry resources and their ecosystem services in Uganda
2. To determine the monetary value of the physical stocks and flows of forestry resources in Uganda
3. To estimate the aggregate contribution of forestry resources to the national economy

What we present in this chapter is based on desk study, review of existing data and literature and intense consultations with key actors in the country's forestry sector. The results reflect estimates based on the national biomass surveys, reports and secondary data held by public and private actors in the country's forestry sub-sector. The study serves as a starting point to more comprehensive natural resource accounting and provides an indicative estimate of the true contribution of the sub-sector for national, subnational and sectoral planning purposes in the country.

This report is divided into six sections. The next section describes the methodology followed and tools for collecting data and analysis. Physical and monetary stock and flow forestry resource accounts in the country are described in Sects. 3 and 4, respectively. Section 5 derives aggregate contributions of the forestry subsector at the national economy, and Sect. 6 concludes with implications for policy and research.

[1] The study to determine the economic value of forest resources in Uganda and their contribution to the national economy was carried out between October 2010 and May 2011 under the supervision of the National Environment Management Authority (NEMA) with support from the World Bank and national stakeholders including the National Forestry Authority (NFA), Uganda Wildlife Authority (UWA), the National Planning Authority (NPA) and Uganda Bureau of Statistics (UBOS) and Wildlife Conservation Society (WCS), while ENR Africa Associates provided technical expertise.

2 Methodology

The economic value of forestry resources in Uganda was established following the forest natural resource accounting methodology described in Lange (2004). This United Nations System of Integrated Economic and Environmental Accounts for Forestry – SEEAF (Lange 2004) requires specific types of data as summarised in Table 1 below.

Major data issues, however, constrained full implementation of the SEEAF in Uganda. Forestry resource data for Uganda was last collected in 1990 and then in 2005. Such extremely long interval makes it difficult to undertake conventional forest resource accounts for that period, and hence a compromise was made. Under the inventorying plan of the National Forestry Authority (NFA), comprehensive data are collected every 5 years if sufficient resources are available. Although resources were not fully available, extrapolations and simulations were carried to produce plausible estimates of the state of Uganda's forests between 2005 and 2010. This provided the basis for our forest accounts.

The needed data were collected from various secondary and primary sources, with the former being the dominant activity. The process benefited enormously from the National Biomass Survey 2005 (NFA 2009). Additionally, discussions with NFA staff yielded additional data on forest physical stocks. Further data was obtained through estimates generated together with the staff of the NFA, NEMA, Uganda Wildlife Authority (UWA), WCS and Uganda Bureau of Statistics (UBOS). All the stakeholders provided secondary data available to them. Data for Non-Wood Forest Products (NWFPs) was compiled based on discussions with key actors in the product value chain in the country.

This study employed the Net Price (NP) methodology for constructing the forest monetary accounts corresponding to the developed physical accounts. The NP method derives the stumpage value (resource rent) as the residual of the selling price of harvested timber (P) after deducting all production (silvicultural costs for cultivated plantations), harvesting, transport and capital costs (C) (Hassan 2000). This method calculates net accumulation in asset values (D) as the following simple product of the NP ($P_t - C_t$) and net change in standing stocks ($S_{t+1} - S_t = G_t - H_t$, i.e. additions minus extractions):

$$D_t = \left(G_t - H_t\right) \cdot \left(P_t - C_t\right)$$

where

- P_t and C_t refer to per unit resource price and extraction costs, respectively
- S_t is the stock of the asset at t
- G_t denotes growth from natural regeneration and other additions
- H_t refers to extraction (harvesting, damage etc.)

Table 1 Components of forest resource accounts

1. Forest-related asset accounts
Wooded land: land area and economic value by main species, natural and cultivated forest land, available for wood supply or not available, etc.
Standing timber: volume and monetary value of, by main species, natural and cultivated forest land, available for wood supply or not available, etc.
Depletion and depreciation of standing timber
Flow accounts: forest goods and services (volume and economic value)
2. Forestry and logging products (market and nonmarket production)
Non-timber products (output of game, edible plants, medicinal plants, etc.)
Forest services
Direct intermediate inputs to other sectors, e.g. livestock grazing
Recreation and tourism
Carbon sequestration
Protective services: biodiversity and habitat preservation; protective services such as preventive soil erosion
Supply and use tables for wood products, forestry and related industries
Degradation of forests due to forestry and non-forestry activities, e.g. soil erosion from logging, water and air pollution from wood processing industries
3. Expenditure on forest management and protection
Government expenditures and private sector expenditures
4. Macroeconomic aggregates
Value of forest depletion and degradation
Measures of national wealth, national savings and net domestic product adjusted for forest depletion or accumulation
Memorandum item employment; households dependent on NWFP; rights of forest exploitation, stumpage fees, taxes or subsidies; and manufactured assets, e.g. roads, equipment for forestry, logging and other

Source: Lange (2004)

The following additional assumptions were used to develop the forest resource accounts for Uganda:

- Forested land was calculated using the Net Present Value (NPV) method at a 10% social discount rate (World Bank 2007). The land value/ha/year was based on lease rates (Ushs 199,000) charged for commercial forest operators by the NFA and land rent on farms for private forest land at Ushs 240,000/ha/year. A 49-year discounting period was used as is common in forestry leases and land leases in Uganda. Leases were considered because public land transactions also include leasehold tenure transactions.
- Value of non-wood forest products (NWFPs) were determined based on the net price method using current market prices. The term wood was preferred over forest in the description of these products because of the need to correctly distinguish timber from other wood products.
- Biodiversity values were extrapolated based on estimates of the annual contributions of biodiversity in Uganda (Moyini 2006). Similarly, estimates of value of

butterflies and bees as pollinators were adapted from a recent PhD thesis research (Munyuli 2010).

- Carbon stocks and changes since 2005 were adapted from NFA figures (FAO 2010).
- Recreational services were estimated using the Travel Cost Method (TCM). Estimates were extrapolated from estimated costs of wildlife and forestry tourism in the Murchison Falls Conservation Area (NEMA 2010). The cost of forestry recreational services was calculated as product of proportion of nature-based tourists that target forestry resources and full expenditure for experience including transportation and expenses at tourism sites.
- All other wood products, ecosystem services were valued using the net price method.

3 Physical Forest Resource Accounts

3.1 Stock of Forested Land and Standing Biomass Volumes

The physical stock accounts consist of area and volume accounts. Area accounts projected change in physical stocks of forested land based on the findings of the national biomass survey which estimated an annual deforestation rate of 1.86% (NFA 2009). Accordingly, the area accounts suggest that aggregate forested land in Uganda declined from 3.6 to 3.3 million ha between 2005 and 2010 (Table 2).

Total above-ground volume of wood biomass was projected to have dropped from 280 million m^3 in 2005 to 277 million m^3 by 2010. This represents an annual decline rate of 0.6% (Table 2). However, biomass under Tropical High Forests (THFs) is believed to have increased despite the fall in overall biomass volumes. The overall decline was attributed to the high deforestation in the woodland areas.

3.2 Wood Available and Wood Not Available for Supply

National estimates have been made of timber yield from central forest reserves (MWE 2002; Odokonyero 2005; Namaalwa et al. 2009). The most recent estimates have only covered a fraction of the forest estate eligible for harvest (Table 3). Currently, only five central forest reserves of Budongo and Bugoma in the mid-west, Kalinzu and Itwara in south-western and Mabira in central Uganda have been designed for commercial wood harvesting. The estimated net volume available for harvest is 1.6 million m^3 from 5.3 million m^3 as net volume of production (NFA 2010).

About two-thirds of the country's forest estate is found on private land, and production is controlled by private citizens on that land. Therefore, estimates of

Table 2 Stock and changes in stock of forested land area and volume of standing wood biomass in Uganda (2005–2010)

Forested land area (ha)						
Summary	Total forested land	Broad-leaved plantation	Conifer plantation	THF well stocked	THF low stocked	Woodland
Opening stock (2005)	3,594,462	14,841	16,536	542,787	201,644	2,816,423
Annual rate of increase in forested area (%)	−0.02	0.13	0.13	−0.01	−0.02	−0.02
Est. change forested land area 2005–2010	−285,420	12,382	13,796	−29,248	−17,145	−262,974
Est. closing stock 2010	3,309,042	27,223	30,332	513,539	184,499	2,553,449
Standing wood biomass volume ('000 m^3)						
Summary	Total biomass	Broad-leaved plantations	Conifer plantations	THF well stocked	THF low stocked	Woodlands
Opening stock 2005	280,414	1,438	2,576	162,098	30,883	85,996
Average annual reduction in biomass	−1,583	−12	8	1,280	164	−2,001
Estimated reduction in biomass (2005–2010)	−7,913	−61	2,148	6,402	822	−10,004
% Annual change	−0.56%	−0.85%	–	0.79%	0.53%	−2.33%
Est. closing stock 2010	277,227	1,377	4,725	168,499	31,704	75,992

Adapted from NFA (2009) and FAO (2010)

Table 3 Harvestable wood volume in Uganda based on 30-year cycle and removal of 20 m³/ha

Forest	Stocked area (ha)	Net vol/ha (m³)	Net volume (m³)	Available harvest volume (m³)	Annual allowable cut (m³)	Area for annual removal (ha)/ISSMI area	Net volume retained (forest integrity)
Budongo	29,445	62.5	1,839,826	588,900	19,630	982	1,250,926
Bugoma	24,550	76.8	1,699,447	491,000	16,367	818	1,208,447
Mabira	13,640	75.0	1,028,045	272,800	9,093	455	755,245
Kalinzu	7,035	70.0	490,262	140,700	4,690	235	349,562
Itwara	4,496	60.0	266,056	89,920	2,997	150	176,136
Total	**79,166**	**68.9**	**5,323,636**	**1,583,320**	**52,777**	**2,639**	**3,740,316**

Source: NFA (2010)

production have often been based on actual wood flows rather than changes in standing timber. Odokonyero (2005) estimated sustainable yield of about 19.68 million m^3 of timber from tropical high forests (280,000 m^3), woodlands (19,300,000 m^3) and plantations (100,000 m^3). However, production from woodlands has generally declined with their degradation, and current production mainly comes from tropical high forests and plantations. A clear picture is described in the section for wood product flows below.

3.3 Flows of Wood Products

Estimates of wood product flows were based on production figures provided by the National Forestry Authority (NFA) and the Uganda Bureau of Statistics (UBOS 2010) and reports of international timber trade (SPGS 2010; FAOSTAT 2010). The figures from the National Statistical Abstract (UBOS 2010) indicated that timber production in the country grew at a rate of 4.25% annually, between 2003 and 2007.

Total wood production was projected to increase from 31.6 to 39.1 million m^3 between 2005 and 2010 (Table 4). Only one-third (31–34%) of the wood production was for commercial purposes, and the rest was generally for meeting domestic energy needs. About 95% of the flows of wood products were fuelwood and charcoal, while sawn timber production contributed only 5% of the total (UBOS 2010).

Whereas, officially, export of roundwood timber is prohibited in order to avoid depleting the indigenous stock, trade data from Uganda Revenue Authority (URA) showed export and import of roundwood do take place (SPGS 2010). About 17,000 m^3 of roundwood were exported annually between 2008 and 2010 (FAO 2010). The roundwood imports mainly consisted of softwood, while the majority of exports were exotic hardwood species such as eucalyptus (SPGS 2010). Industrial roundwood imports comprise softwoods from the Democratic Republic of Congo (DRC).

Table 4 Timber flows based on natural production in Uganda (‘000 m^3)

Description flows	2005	2010
Monetary		
Sawn timber (‘000 m^3)	902	1,029
Poles (‘000 m^3)	253	288
Wood fuel (‘000 m^3)		
Households	802	914
Commercial	676	771
Industrial	1,562	1,632
Charcoal (‘000 m^3)	6,080	6,978
Total wood production monetary	10,274	11,612
Nonmonetary		
Poles (‘000 m^3)	555	601
Wood fuel (‘000 m^3)		
Household	18,219	19,576
Commercial	2,219	2,328
Industrial	346	361
Total wood production nonmonetary (‘000 m^3)	21,339	22,866
Total wood production		
Sawn timber (‘000 m^3)	902	1,029
Poles (‘000 m^3)	808	889
Wood fuel (‘000 m^3)		
Household	19,021	20,491
Commercial	2,895	3,099
Industrial	1,908	1,993
Charcoal (‘000 m^3)	6,080	6,978
Total wood production (‘000 m^3)	31,614	39,061
Sawn timber and poles (%)	5.4	4.9
Total wood fuel production (%)	94.6	95.1

Source: Adapted from UBOS (2010)

The Forest Monitor (2007) indicated that imports into Uganda of 40,000 m^3 of roundwood from the DRC with 20,000 m^3 moving on to Kenya and the rest consumed within the country.

Exports of poles to neighbouring countries increased to 1,400 tons while imports declined to 350 tons in 2009 from about 800 tons in 2007 (Table 5). Other products traded included veneer, plywood, particle boards, fibreboards and carpentry and joinery (SPGS 2010). Veneer is used in plywood and furniture manufacturing. About 117 tons were imported, while 31 tons of veneer was exported. Similarly, 2,414 tons of plywood imported and 1,715 tons were exported mostly to the neighbouring countries of Sudan, DRC, Kenya and South Africa. Particle board and fibreboard imports were about 1,900 and 747 tons, respectively, while exports of carpentry and joinery were estimated at 200 tons (FAOSTAT 2010).

Table 5 Other wood product flows, 2010

Product	Volume of other wood products ('000 m^3) Exports	Imports
Roundwood	1,691	401
Poles	1,400	350
Veneer	117	31
Plywood	1,715	2,414
Particle boards	2,055	1,924
Fibreboards	43	747
Carpentry and joinery	200	0
Totals	**7,221**	**5,867**

Source: FAOSTAT (2010); SPGS (2010)

3.4 Non-wood Forest Products

Non-wood forest products (NWFPs) consist of food products and food additives, medicinal products, clothing and product used for house construction, amongst other uses. For the purpose of this report, 15 main NWFPs were explored. Those were butterflies, pet animals, honey, aloe vera, drums and fiddles, tonic root (*Mondia whitei*), bark powder from *Prunus africanas*, bark tree (*Warburgia ugandensis*), bamboo shoots, shea butter, tamarinds (*Tamarindus indica*), African tulip (*Spathodea campanulata*), gum arabic, mushrooms (*Termitomyces aurantiacus*), and rattan cane.

3.4.1 Pet Animals

The economic contribution of pet animals was explored in terms of international pet trade, as pet trade within the country is not recorded. Pet animal exports from Uganda consisted of about 69 species of birds, 12 species of chameleons, 6 species of tortoises and turtles, 11 species of lizards and 19 species of snakes between 2003 and 2008 period (NEMA and ACODE 2008). The actual total exports over the 6-year period were 13,176 birds; 11,169 chameleons; 3,977 tortoises and turtles; 1,167 lizards, geckos and skinks; and 2,811 snakes captured outside national parks and wildlife reserves (UWA 2004).

In 2009, it was estimated that wildlife contributes US$3 million per year to the national revenues (Parliament of Uganda 2009; MTTI 2010). These revenues derive from exports of crocodile skins, snakes, chameleons and butterflies, all of which are raised on private land but obtain breeding stock from protected areas.

3.4.2 Honey and Bee Products

Apiculture involves keeping of bees to get honey and wax (Parliament of Uganda 2009 – Committee on Tourism, Trade and Industry). Uganda is endowed with a rich variety of bees, e.g. *Apis mellifera scutellata*, *A. mellifera adansonii* and *A. mellifera* *monticola* and several species of stingless bees (Ogaba 2002). Honey production in Uganda ranges between 4,000 and 9,000 metric tonnes. Uganda's honey production potential is estimated at 100,000–200,000 metric tonnes of honey per year (Maku 2004). In 2009, it was reported that apiculture contributed about $17m (about sh15.5b) to the national economy.

Whereas the market for honey is considered to be available in Uganda, information about it is not as readily available. Arua Park is the main honey-trading place in Kampala City. Traders travelling with honey from different parts of the country converge at Arua Park (Maku 2004). Some of the buyers come from neighbouring countries mostly from Rwanda and Kenya. Some beekeepers and traders travel to sell their honey in Nairobi as they complain of delays and cheap prices of buyers in Kampala.

3.4.3 Aloe Vera

There are about 130,000 aloe vera farmers in 26 districts in Uganda. The majority of the country's aloe vera production comes from central and western Uganda (Sessanga 2007). At an average yield of 20 tonnes/ha total annual production of 7,200 tonnes is obtainable from the 380 ha under production. Aloe vera and its by-products are used for the manufacture of toothpaste, medicinal liquids, cosmetics (soaps and skin creams) and as animal feed. Aloe vera is one of the leading raw materials for Uganda's cosmetics industry (UEPB/Biotrade 2005).

3.4.4 Drums and Fiddles

Drum making is based on extraction and processing of stems of soft species and current utilisation concentrated on softwood species and means less competition with timber harvesters (Omeja et al. 2004). Drums and fiddles in Uganda are produced mainly from the central Uganda District of Mpigi with additional production reported in Masaka District further to the west of central Uganda and some production in eastern Uganda. According to the drum makers groups in Mpambire Town, Mpigi District, drums and fiddles generally mean a collection of nine main items: traditional drums (eng'oma), tube or cylindrical drums (e'ngalabi), xylophones (amadinda), one-string fiddles (e'ndingidi), bowl lyre (e'ntongoli), nine-string harps (adungu), shakers (e'biseso), beads (e'nsaasi) and small tube drums (e'jjembe).

The wood carving industry in Uganda produces mainly musical instruments. Between September 1999 and October 2000, drums sales from Mpambire Town in Mpigi District amounted to US$11,000. This revenue was important in complimenting income from agriculture (Samula 2001). From discussions held with drum makers at Mpambire Town, Mpigi District and drum sellers in Kampala, the following estimates were made about drum production in Uganda (Table 6).

Table 6 Estimates of production of drum and fiddles and prices in Uganda

Item	Sub-items	Est. production number (every 4 months)	Price range for each item (Ushs)
Drums	1–11 in.	1,000	3,000–30,000
	10–11 in.	4,000	30,000–35,000
	12–16 in.	2,000	35,000–60,000
	16–17 in.	1,000	60,000
	18–20 in.	1,000	60,000–100,000
Tube drums	Small	500	10,000
	Ordinary	2,800	60,000
	Decorated	800	100,000
Xylophones	15 in.	200	100,000
	12 in.	200	75,000
	9 in.	200	50,000
One-string fiddles		1,000	10,000
Bowl lyre		400	10,000–15,000
Sets of 9-string bowl harp	Seven harps in a set	500	400,000
Shakers		200	5,000–10,000
Beads (in a gourd)		120	10,000–15,000
Very small tube drums	6–12 in.	2,000	10,000–100,000

Source: Authors own estimates

3.4.5 Tonic Root (*Mondia whitei*)

Tonic root is the economic part of *Mondia whitei*, and they are largely perceived as sexual stimulant, appetiser, flavours for food and drinks and stimulant for milk production in lactating mothers. Chewing the roots is also believed to help clear hangovers from beers as well as controlling stomach ache. The roots are also reportedly used for treating gonorrhoea and also for contracting the uterus in women after delivery. Based on the work of Agea et al. (2008), this study estimated that over 1 tonne of *M. whitei* roots are consumed every month in Kampala City. Men and adolescent boys are the main consumers although there is a lot of 'hidden' consumption by women and adolescent girls.

Retailers mainly buy the roots directly from collectors and sell to consumers. The prices charged per piece and kilogram increase from collectors, middlemen and to the retailers. The average retail price was US$0.12 per piece of the root and US$1.50 per kg, while collectors charge US$0.06 and 0.60 per piece and kilogram, respectively. A survey undertaken in Kampala showed that *Mondia whitei* consumed in Uganda generally is sourced from Luwero, Mityana and Mubende districts in central Uganda. Wholesale traders estimated that the Kampala market could consume about 5–6 bags per month, approximately 360 kg/month at a price of Ushs

30,000/kg. The highest season of production and consumption is the peak first rain season months of March to June. At the national scale, the market was estimated to be on average 1.2 metric tonnes per month (although this may fluctuate in the dry season when the production is lower).

3.4.6 *Prunus africana:* Bark Powder for Medicinal Purposes

Prunus africana is classified by the World Alliance for Nature (IUCN) as vulnerable species, which led to its listing in the Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES). This decision had a significant impact on the revenues produced from this non-wood forest product in the range countries (Cunningham and Mbenkun 1993). Commercial production is in the districts of Kasese, Bundibugyo, Kabarole, Mukono, Jinja and Mbale. The bark is traded internationally with major importers in Europe, Asia and USA. The bark powder is used to treat prostate cancer, as well as beer fermentation troughs 'beer boats', traditional medicine, fuelwood, building poles and timber (Betti 2008).

Uganda exported only 50 kg in 2003 for entire period (1995–2003). In 1992, prior to CITES App. II listing, Uganda exported *Prunus africana* bark to France via Kenya, but this was stopped due to destructive effects on Kalinzu-Maramagambo Forest Reserve. Uganda has recently applied for a CITES permit. This needs to be considered with caution. The Kalinzu-Maramagambo Forest Reserve has high conservation value but is under threat by illegal activity (hunting, charcoal burning, small-scale gold panning) (Howard et al. 1996), and Bwindi Impenetrable National Park has recovering *Prunus africana* stocks and vulnerable mountain gorilla populations; this recent request from Uganda needs to be carefully considered (Betti 2008). The biotrade programme reported on the country has a potential for producing 50 kg, *Prunus africana*, per annum and more if policies have been established to ensure the sustainable management of forests having *Prunus africana* stands in them (UEPB/Biotrade 2006).

3.4.7 Bark Cloth

Bark cloth is a unique fabric produced in parts of central and eastern Africa. In Uganda, specifically central Buganda, bark cloth production started way back in the thirteenth century and played significant cultural, financial and social roles. Locally known as Mutuba, (*Ficus natalensis*), it is a tropical fig tree species that is indigenous, widely grown and part of the traditional agroforestry system (Katebalirwe 2010). Bark cloth is also exported. It is sold in Germany (Bark Cloth Oliver Heintz Germany), Europe, and to designers in the UK and Netherlands (Mugula et al. 2010). Bark cloth is made in two types: the very good quality 'kimote' and the average quality type. The 'kimote' type is used regularly for clothing and fashion designs both for men's and women's wear for official functions in Uganda especially in central Uganda. Because of its softness and tenderness, 'kimote' is regular used in designs for wrapping and to add style and texture in other industries. The ordinary average quality bark clothing is used for traditional functions and well as clothing for wrapping corpses before burial.

Bark cloth is produced through central Uganda although production is centred in Masaka and Rakai districts. The cultural leaders within central Uganda are encouraging the growth of the art of bark cloth making. The wholesale market for bark cloth in Uganda is difficult to estimate because traders are in many places and monitoring production is poor. Generally, traders believe that the total production of the good quality 'kimote' is about 5,000 pieces of cloth coming to Kampala every 3 months. The price for kimote ranges between Ushs 50,000 and 80,000; however, prices reduce as the quality fades to about Ushs 25,000. For the average quality, bark cloth production is estimated at about 20,000 pieces every 3 months, and the price ranges between Ushs 15,000 and Ushs 25,000.

3.4.8 Bamboo

Bamboo is a product of great importance to most village populations in Uganda. Rural people collect bamboo for use as a building material and its shoots for consumption and selling (Inbar 2009). Houses in some rural areas are constructed using bamboo for roofs, wall partitions, panelling, mats, ladders, blinds and furniture. Bamboo is also used in the production of certain fishing tools and paper and is sometimes used to make musical instruments such as flute and guitar. In Uganda, most of the country's bamboo resources are located in a few major sites, namely, the north-western district of Arua, the western and south-western districts of Hoima and Kabale, respectively, in addition to significant portion of the resource in the eastern district of Mbale. Most of the bamboo resources are located in protected areas under government control. *Arundinaria alpina* is one of the species that generally offers high utilisation potential and is abundant in most of the sites (Buyinza 2009).

Bamboo harvesting and processing in Uganda is concentrated in the Mt. Elgon forest in Mbale district in the eastern part of Uganda, Rwenzori in the west and Echuya, Bwindi and Mgahinga in Kabale district in the south-western corner of the country. There are also other small pockets of bamboo vegetation scattered in various parts of Uganda. The importance of bamboo has long been recognised by several cultures in the country. In particular, bamboo shoots are a major source of income to communities adjacent to bamboo forests such as the Gishu in Mbale where they are regarded as a traditional delicacy (Buyinza 2009). So far, a total of 52 species have been documented. The mountainous northern part of Mt. Elgon is one of the richest areas for bamboo. Surveys show it holds at least 50 species, 30 of which differ from those in central and southern Uganda.

3.4.9 Shea Butter

Shea nut trees widely and wildly grow in northern and north-eastern Uganda. The tree is also found along the borders of Congo (north of Lake Albert) and Sudan, with a small and isolated population in Nakasongola. Shea nut products, the solid fat (butter) and liquid oil (olein), are ideal raw materials in cooking oil, margarine, cosmetics, soap, detergents and candles. The production of shea nut products remained traditional, until 1994 when USAID started financing a community-based programme for processing shea nut oil in northern Uganda as well as a conservation programme for the shea nut trees. Shea butter and its products are also exported and sold in Europe and Japan where it is used in cosmetic industries (soaps, creams, moisturisers, hair conditioners and shampoo) and chocolate production. In the Ugandan shea production area, a Vaseline type product is used for babies and for other quasi-religious ceremonies.

The variety of shea nut, which grows in Uganda, is *Vitellaria nilotica* preferred for the cosmetic industry due to its higher olein fraction (Ferris et al. 2001). The variety is primarily grown in northern Uganda. The commercial development of shea products in Uganda remains at an embryonic stage, with little documentation on the market dynamics of the crop in Uganda and its surrounding countries.

Potential shea nut production in Uganda is estimated to be between 70,000 and 385,000 metric tonnes; this would yield between 15 and 80 million litres of oil using traditional methods at a value of US$30 million. However, current estimates show that the total quantity of shea nuts traded through the northern Ugandan markets per year is approximately 6,000 tonnes equivalent to US$0.66 million (Ferris et al. 2001; NEMA 2008).

3.4.10 Tamarinds (*Tamarindus indica*)

Tamarind (*Tamarindus indica*) is a valuable tree species in Uganda for fruit, timber, leaves and shade. In Uganda, it is mainly found in the eastern part of the country. Household surveys carried out in eastern Uganda from July 2004 to February 2005 estimated mean production of *T. indica* at 127 kg/ha/year and 84 kg/ha/year from open woodland and cropland areas, respectively, a statistically significant difference (Buyinza 2010). The net present value from *T. indica* products was US$893/ha in woodland and US$684/ha in cropland. In terms of foreign export earnings, *T. indica* juice from woodland and cropland was estimated to generate US$0.03/ha and US$0.02/ha, respectively. Returns from alternative land-use activities of agricultural cropping were highest for maize and lowest for finger millet in both open woodland and cropland sites. Sensitivity analysis revealed that an increase in the real discount rate from 9.86% (base case) to 15% decreases the financial NPVs of both the open woodland and cropland areas by 24%.

3.4.11 African Tulip (*Spathodea campanulata*)

Like *Mondia whitei*, *Spathodea campanulata* is an aphrodisiac for women. It is called kifabakazi in the Luganda language, and it is believed that when it is consumed or added in the food for women, it enhances their sexual desire. According to traders in Kampala, Spathodea was sourced (produced) from Masaka, Wakiso and the Busoga region of eastern Uganda. Based on the units used in the market, about ten bags every month in Owino market in Kampala and trader estimate that elsewhere in Kampala about ten extra (60 kg) bags could be sold per month. Throughout the country, and largely based on information from central Uganda, overall market supply would be about 40 bags every month. The price is quite low at Ushs 20,000 per bag.

3.4.12 Gum Arabic

Gum arabic is a product used in confectioneries, soft and alcohol drinks, pharmaceuticals, printing, ceramics and textile industries and as an ingredient in local medicine. In Uganda, it is mainly produced in Karamoja. The main tree species that are used to produce gum arabic are *Balanites aegyptiaca*, *Acacia senegal*, *A. seyal*, *A. sieberiana*, *A. gerrardii* and *Lanea humilis*, but the dominant species producing gum arabic are *A. senegal*, *A. seyal* and *A sieberiana*. The local uses of gum arabic are food, gumming spears and pots, gluing arrows, gluing broken stools, calabashes and joining leather (Egadu et al. 2007).

Karamoja has the potential to produce 20,000 tonnes of gum arabic. However, recent investor interest estimates that current production is only likely to reach 7,700 tonnes in the short term under the Uganda Gum Arabic Cooperative Society (TUGACS). TUGACS brings together 2,018 farmers in Moroto District with capacity to produce 4,700 tonnes under *Acacia senegal* and 3,000 tonnes of Acacia seyal trees (New Vision – February 2010)

3.4.13 Mushrooms (*Termitomyces aurantiacus*)

Another important NWFP are wild edible and farmed mushrooms, which are generally consumed in the local diet. Whereas estimates of commercial mushroom production can be made, the greater contribution of mushrooms is to the subsistence diet at household level. Subsistence consumption of mushrooms in Uganda is generally unknown. Nevertheless, we were able to make estimates of mushroom use based on discussions held in the markets in Kampala and the related supply chain simulations based on discussions with traders.

Wild (and farmed) mushrooms sold in Kampala are generally sourced from Mityana, Mubende, Luwero and parts of Mukono, Buikwe and Kayunga districts in central Uganda. However, production is known to exist throughout the country especially in moist forest areas. Supply of mushrooms in Kampala markets is estimated at 4 metric tonnes/month. It is sold in containers known as debe. Estimates of sales are equivalent to about 15–20 bags/month for the 20 main markets in Kampala. A 15–20 kg Debe of mushrooms is sold at Ushs 60,000.

3.4.14 Rattan Cane

Rattan is a climbing palm native to tropical forest regions such as sub-Saharan Africa. It is estimated that over 650 species exist worldwide but 20 are most common in Africa all under four genera (Laccosperma, Eremospatha, Oncocalamus and Calamus) (Inbar 2006). In the past, many forests in Uganda supported large stocks of wild rattan, but the rattan has been rapidly declining due to commercial exploitation (Environmental Alert 2008). As such, out of the four traditional producing districts, Masindi, Mukono, Mpigi and Hoima, only Bugoma (Hoima) and Budongo (Masindi) remain as producers (Forestry Research Institute 2000; Environmental Alert 2008).

Overall production of rattan is estimated at about 4.8 tonnes in 2010 down from about 11 tonnes between 2000 and 2005 (Forestry Research Institute 2000; Inbar 2010). Although actual estimates for the producing districts, Mpigi, Mukono and Hoima, were about 4,068 bundles produced in 2005 (Table 7), only Hoima maintained production in 2010 (Environment Alert 2008; Inbar 2010).

3.5 Biodiversity Stocks

Forest accounting for biodiversity conservation services takes into account both stocks and flows of biodiversity from Uganda's forestry resources. Accounting for forest biodiversity in Uganda concentrates on the three main components of biodiversity stock in Uganda. They are (1) diversity of species, (2) genetic diversity and (3) ecosystem diversity. This report will concentrate on the first component of diversity of species due to current data limitations.

A series of studies were conducted under the auspices of the forest department aimed at providing a comprehensive account of the state of knowledge of the flora and fauna in Uganda's central forest reserves (MWLE/Forest Department 1996). The studies covered 65 of Uganda's major reserved forest, which together accounted for 1.2 million ha of land managed by government as permanent forest estate. The studies indicated that Uganda is one of the most biologically diverse countries in Africa, with much of its biodiversity represented in a system of 10 national parks, 10 wildlife reserves and 710 forest reserves covering 33,000 km^2 (14%) of the country's area (Howard et al. 2000). In the late 1980s, a policy was instituted to dedicate half the area of forest reserves to sustainable timber production and the other half to environmental protection (with 20% nature reserves). The results represented in the report included 14 forests that together with existing national parks accounted for 96% of species

Table 7 Rattan cane supplied annually by district

	Volume produced (bundles)		Value of production (Ushs)		Value of supply (US$)	
District	2005	2010	2005	2010	2005	2010
Mpigi	1,500	–	1,800,000		987.7	–
Mukono	1,800	–	14,400,000		7,901.3	–
Hoima	768	768	3,072,000	11,059,200	1,685.6	4,790.4
Totals	**4,068**	**768**	**19,272,000**	**11,059,000**	**10,574.6**	**4,790.4**

Source: Forest Research Institute (2000); Environmental Alert (2008); Inbar (2010)

represented in protected areas. The 14 forests were classified as 'prune' and 'core' sites and were selected for the establishment of large native reserves (averaging 100 km^2). The addition of 25 smaller 'secondary' forest nature reserves (averaging 32 km^2) would protect more than 99% of the indicator species (Howard et al. 2000). For Uganda total, there were 1,259 species of trees and shrubs, 1,011 species of birds, 75 species of rodents (small mammals), 1,245 species of butterflies, 115 species of hawk moth (large moths) and 96 species of silk moths (Forest Department 1996).

3.6 Carbon Sequestration Services

Carbon storage was calculated using a factor multiplied by the biomass (0.5) to determine the carbon stock and another factor (44/12) to determine the carbon dioxide equivalent (CO_2e^-) (FAO 2010). Total carbon stock declined by 2%, from 564.5 to 556 MtC, while the tons of carbon equivalent declined from 2,070 to 2,040 (Table 8). The management cycle for Uganda's forests is based on a 30-year cycle. If the carbon stock is assumed to have been accumulated over the 30-year cycle, therefore in the most recent year of the cycle, carbon accumulated would be 18.5 MtC (equivalent to 68 $MtCO_2e$).

The decline in carbon storage mirrors similar declines in forested area and biomass over the project period. Therefore, the decline in carbon stocks of about 2% is comparable with the 3% for biomass from a 9% decline in forested land (FAO 2010; NFA 2009).

3.7 Recreational and Aesthetic Services

Recreational services (and products) from the country's forest resources and wildlife reserves (and national parks) include forest walks, chimpanzee tracking, community walks, bird watching, butterfly watching and long-distance walking (4–5 days). Recreational and aesthetic services from Uganda's forest resources are generally bundled, and disparate data is collected on revenues received for different activities (UWA 2010; UEPB/Biotrade 2006; NFA 2010).

Table 8 Estimates of stock of carbon storage in Uganda's forest estate, 2005 and 2010

	Carbon sequestered (million MtC)				Overall total		CO_2e (MtC * 44/12)	
Type of biomass	2005	2010	2005	2010	2005	2010	2005	2010
Above-ground biomass	97.6	85.6	13.5	15.9	111.1	101.5	407.4	372.2
Below-ground biomass	26.4	23.1	3.7	4.3	30.1	27.4	110.4	100.5
Carbon in litter	7.2	6.3	6	7.1	13.2	13.4	48.4	49.1
Subtotal					0	0	0	0
Soil carbon	222.9	194.2	187.2	219.9	410.1	414.1	1,503.7	1,518.4
Total	**354.1**	**309.2**	**210.4**	**247.2**	**564.5**	**556.4**	**2,069.8**	**2,040.1**

Source: Adapted from NFA (2009); FAO (2010)

Table 9 Number of visitors to national parks and wildlife reserves by category

Categories	Numbers of visitors
Non-resident foreign tourists	61,000
Resident students	42,000
Foreign residents	14,000
Local adults	31,000
Transit	3,000
VIPs	1,000
Totals	**152,000**

Source: MTTI (2010)

The Ministry of Tourism Trade and Industry (MTTI) Statistical Abstract (MTTI 2010) stated that while Uganda received about 817,000 tourist visitors, only 16% were interested in leisure and recreational activities. In 2009, only 152,000 people visited the country's national parks and forest reserves up from 138,000 the previous year (Table 9). The contribution of forestry sector to tourism is estimated based on tourist numbers, assuming that about one-third of overall tourist visitors are interested in forestry-based tourism (MTTI 2010).

3.8 Soil Protection Services

Soil and water protection services provided by forests include soil stabilisation through soil erosion reduction, maintenance of soil organic matter and increasing water infiltration and storage. Trees take atmospheric inputs in the air as part of greenhouse gases (GHGs) mitigation (van Noordwijk et al. 2002). Forests also contribute to water supply protection through filtering water pollutants and regulating water yield and flow, enhancing precipitation and moderating floods, reducing surface erosion and sedimentation and trapping aerial pollutants. For the forest accounts of Uganda, there will be one major consideration contribution towards soil erosion control, therefore soil nutrient protection.

The soil protection services to soil nutrient were determined as the loss in stock of soil nutrients reduced or prevented as a result of maintaining forest cover loss compared to stock soil nutrients retained elsewhere where the forest cover was removed, replaced or converted. To determine the annual soil nutrient loss from THF and surrounding lands due to soil erosion, findings were taken from soil nutrient losses due to erosion in Mabira Forest Reserve. Mabira was used because several studies were conducted in the forest under FOREAIM initiative (Kizza et al. 2005). On the other hand, estimates of soil nutrient losses associated with soil erosion were based on studies conducted in the eastern and central Uganda (Wortmann and Kaizzi 1998; Nkonya et al. 2005; Zake et al. 2002; de Jager et al. 2003; Bekunda and Manzi 2003; McArthur and Sachs 2011). Kizza et al. (2005) estimated soil and nutrient losses from Mabira forest restored blocks.

Table 10 Soil nutrient losses from land-use change, forests to agriculture

Cause of soil nutrient losses	Soil nutrients in central forest reserve (FR) (NPK) (tons/ha)	Soils in neighbouring areas (NPK) (tons/ha/year)	Difference NPK (kg/ha)	Land area 2010 ('000 ha)	Total losses of NPK (2010) (tons)
Soil erosion losses					
THF and plantations	0.13	0.03	0.105	755.59	78,733
Reduction in stock woodlands	0.60	0.44	0.157	2,553.45	400,407
Total					**479,130**

Source: Adapted from Nabalegwa et al. (2006) de Jager et al. (2003); Wortmann and Kaizzi (1998); Kizza et al. (2005)

For forests converted to agriculture, Wortmann and Kaizzi (1998) estimated average NPK losses of more than 130 kg/ha/year in maize, potato and soya bean in central and eastern Uganda although losses sometimes exceeded 200 kg/ha/year. These losses of NPK were much higher than the 30 kg/ha/year estimated in Wakiso (Zake et al. 2002) or the 54 kg/ha/year estimated NPK loss in central Uganda (Magunda et al. 2003). However, de Jager et al. (2003) also found soil nutrient losses on farmlands of 200 kg/ha/year of NPK in Kabarole, western Uganda, a district equally rich in THFs. Therefore, a modest estimate of 130 kg/ha/year NPK loss was adopted for THF (Table 10).

For the purpose of this study, the aggregate soil nutrient losses due to erosion in the areas surrounding forests during the short and long rains were taken for stable forest areas older than 10 years. Therefore, aggregate nutrient losses were calculated as 7.94 kg/ha/ N, 0.43 kg/ha P and 17.44 kg/ha K, which is equal to 25.81 kg/ha NPK loss from the areas surrounding forests (Kizza et al. 2005).

For woodlands, estimates were drawn from a study on changes in soil chemical and physical properties due to land-use conversion in Nakasongola District. Nabalegwa et al. (2006) compared fallowed woodland areas where regeneration occurred over a 10 (and 5)-year period with areas left open for grazing. Results showed losses of 157 kg/ha/year (Table 10).

4 Monetary Forest Accounts

4.1 Monetary Value of Forest Land

Estimation of the monetary value of the forested land was based on the valuation system applied for leasing land for commercial timber plantations or other industrial use by the National Forestry Authority (NFA) and Uganda Wildlife Authority (UWA). The current rate is Ushs 199,000/ha/year, which was the uniform rate

Table 11 Uganda's opening and closing stock of forested land value (2005 and 2010)

	Total forested area ('000 ha)		Annual land lease and rent value (million US$)[a]		Present value (million US$)	
Description of land use	2005	2010	2005	2010	2005	2010
Central forest reserves (CFRs)	627.9	593.3	67.5	51.4	7,203.5	5,489.0
National parks, wildlife reserves, animal sanctuary	641.1	629.01	70.	54.5	7,471.2	5,819.8
Dual joint management (DJM)	30.7	28.9	3.4	2.5	358.3	267.3
Local forest reserves	1.211	1.1	0.1	0.1	14.1	10.3
Private forested land	2,293.6	2,035.3	302.0	212.8	32,232.9	22,708.5
Total value	3,594,462	3,287.89	443.0	321.4	47,280.0	34,294.7

[a]USD = UGX 1,822.48; 2,308.60 (BoU 2005, 2010)
Source: Adapted from NFA (2009) and BOU (2005, 2010)

applied for all public land in this study, while the rental rate for land commonly used in the country averages at about Ushs 240,000/ha/year (SPGS 2008). In estimating the forested land, we are interested in determining the present value of the land based on the lease agreements. The most common lease period used for public land is 49 years. The 49-year lease period was also simulated for the rent of land. The NPV of forested land assets was accordingly derived using a social discount rate of 10% commonly applied by the World Bank (World Bank 2007)

The present value of total forested land declined from US$47 (in 2005) to US$34 billion (2010) (Table 11). The forested land value declined because forested land also decreased by about 300,000 ha of forested land between 2005 and 2010.[2] However, for the purpose of annual accounting, our interest was in the annual value of US$321.4 million in 2010.

4.2 Value of Standing Timber

The value of timber in Uganda's forest estate was estimated by multiplying the value of timber (plantations and tropical high forests) Ushs 41,798/m^3 by the volume of standing timber and the value of the poles (Ushs 18,800), the common product from woodlands by the volume of standing timber in woodlands. The value of standing timber was estimated as US$4,362 million (Ushs 10,051 billion) a slight increase from US$4,275 million (Ushs 9,850 billion) estimated for 2005 (Table 12).

[2] USD = Ushs 1,822.48 and 2,308.60, respectively, for 2005 and 2010 (BoU 2005, 2010). Total value of forest area actually declined by a small fraction of the observed reduction of about 28% of the total value of forested land. This was due to the fall in exchange rate by 20% between 2005 and 2010 whereas forested area declined by 8%.

Table 12 Monetary value of standing timber in Uganda's forests (2005 and 2010)

Summary		Total biomass	Broad leaved plantations	Conifer plantations	THF well stocked	THF low stocked	Woodlands
Value in 2005	(Million Ushs)	9,850,721.8	60,105.5	107,671.6	6,775,372.2	1,290,847.6	1,616,724.8
	Million US$	4,275.2	26.1	46.7	2,940.5	560.2	701.7
Value in 2010	(Million Ushs)	10,051,786.0	57,555.8	197,495.6	7,042,921.2	1,325,163.8	1,428,649.6
	Million US$	4,362.47	24.98	85.71	3,056.62	575.12	620.03

Source: Authors own calculations

4.3 Value of Wood Flows

The monetary value of forest products recorded in the national accounts (UBOS 2010) increased from Ushs 235,202 to 258,965 million between 2005 and 2010. Our calculations, however, indicate an actual decline from US$129.06 to 112.17 million (Table 13). The nonmonetary wood products had a higher value than the monetary products. Because the producers use these products at a subsistence level, the likelihood of low estimates of value are high.

For internationally traded forest products, the trade balance for 2010 was about Ushs 1 billion or US$437,000. However, this underestimates the true level of activity, which is substantially higher. Total exports were Ushs 9.4 billion (US$4.1 million), while total imports were about Ushs 8.4 billion (US$3.6 million) (Table 14). There are some illegal imports especially from the Democratic Republic of Congo and exports which cannot be effectively tracked (Forest Monitor 2007).

4.4 Value of Carbon Sequestration Services

Forest resource activities mitigating atmospheric carbon emissions in developing countries include reforesting degraded lands, implementing sustainable agricultural practices on existing lands and slowing tropical deforestation. Niles et al. (2002) proposed that in calculating the carbon sequestration services, the estimation will rely on a central price of $10/metric tonne of carbon and a discount of 3%. The State of the Voluntary Carbon Markets Report 2010 (Hamilton et al. 2010) established that prices for verified emission reductions ranged between $7.6 and 12.1/mt$CO_2$e. However, often only one-third of the value is captured for forest projects in developing countries (Hamilton et al. 2010). For the Environmental Conservation Trust in Uganda (ECOTRUST), lower carbon prices are associated with low scores on permanence (Rainforest Alliance 2009). Similarly, CDM carbon credits from forestry are priced lower because they are not permanent. Therefore, the estimated US$4/mt$CO_2$e is only a fraction earned by permanent carbon emission reductions (CERs), estimated at US$12–24 in 2010 (Forbes India Magazine 2010). The voluntary carbon standards available in Uganda include Plan Vivo and the Climate, Community and Biodiversity Standard (CCBS), which are applied in agricultural landscapes and involve planting trees and especially aimed at enhancing or maintaining local biodiversity and high co-benefits. Therefore, a conservative price of US$4/mtC was used to value carbon in this study. The annual value of carbon stored in the country's forest estate including estimates of both above and below biomass declined from US$276 to 118 million from 2005 to 2010 (Table 15).

Table 13 Monetary value of wood product flows in Uganda (2005 and 2010)

Description	Value of forest product flows (million Ushs) 2005	2010	Value of forest product flows (million US$) 2005	2010
Monetary				
Sawn timber	37,648	43,012	20.66	18.63
Poles	4,758	5,414	2.61	2.35
Wood fuel				
Household	5,794	6,412	3.18	2.78
Commercial	4,884	5,343	2.68	2.31
Industrial	11,290	12,319	6.19	5.34
Charcoal	36,545	41,825	20.05	18.12
Total monetary flows	**100,919**	**114,325**	**55.37**	**49.52**
Nonmonetary				
Poles	10,419	11,288	5.72	4.89
Wood fuel				
Household	105,323	113,602	57.79	49.21
Commercial	16,044	17,095	8.80	7.40
Industrial	2,499	2,656	1.37	1.15
Total nonmonetary	**134,282**	**144,640**	**73.68**	**62.65**
Total wood production	**235,202**	**258,965**	**129.06**	**112.17**

Source: UBOS (2010)

Table 14 Value of flows of other forest products in 2010

Wood products	Flows of other forest products 2010 ('000 Ushs)	Flows of other forest products 2010 ('000 US$)
Exports		
Sawn timber	2,587,941	1,121
Poles	31,663	14
Veneer	309,352	134
Plywood	2,731,074	1,183
Particle boards	3,003,489	1,301
Fibreboards	73,875	32
Carpentry and joinery	692,580	300
Total exports	9,429,974	4,085
Other imports		
Sawn timber	517,126	224
Poles	6,648.768	2.88
Veneer	143,133	62
Plywood	4,432,512	1,920
Particle boards	2,338,612	1,013
Fibreboards	983,464	426
Carpentry and joinery	0	0
Total imports	8,421,496	3,648
Trade balance	1,008,478	437

Source: FAOSTAT (2010)

Table 15 Monetary value of carbon sequestered in Uganda's forests (2005 and 2010)

	Carbon sequestered (million tCo_2e)		Value of tCo_2e (millions US$)	
Type of biomass	2005	2010	2005	2010
Above-ground biomass	13.6	12.4	54.3	49.6
Below-ground biomass	3.7	3.3	14.7	13.4
Carbon in litter	1.6	1.6	6.5	6.5
Soil carbon	50.1	50.6	200.5	202.4
Total	69.0	68	276.0	272.0

Source: Adapted from FAO (2010)

4.5 Value of Forest Biodiversity Services

Biodiversity richness of a forest generally represents an option value because it is perhaps one of the least translated into tangible benefits (Bush et al. 2004). In addition to undisclosed plant-based pharmaceuticals, there is considerable genetic potential especially for farmed or domesticated species (Howard 1995). Various estimates have been used to show the value of biodiversity in sub-Saharan Africa. Ruitenbeek (1989) estimated a biodiversity value of £0.1/ha/year for the Korup Park, although Howard (1995) suggested that Uganda's forests might be less biodiverse than Cameroon's Korup Park. Similarly, Pearce and Moran (1994) suggested that the average value of tropical forests ranges between US$0.1 and 21/ha/year. Nonetheless, a commonly used average value for biodiversity in Uganda's forests is US$1.5/ha/year (Bush et al. 2004; Moyini 2006).

Annual contribution of biodiversity in Uganda's forests was determined by multiplying the estimated annual value per hectare by the area of natural forest in Uganda. The value increased from Ushs 9.2 billion in 2005 to 10 billion in 2010. However, this should be distinguished from the present value of the cumulative contribution of biodiversity, which is often much higher. As Bush et al. (2004) noted, biodiversity value is enormously underestimated because much of the tangible values of pharmaceuticals, agricultural technology and other traditional uses have not been closely examined.

There have been separate attempts to establish the contribution of butterflies and bees to the national economy (Munyuli 2010). Munyuli's estimates were based on a global finding that pollinators contribute ecological services estimated to be over €150 billion per year (US$200 billion). The presence of forest patches in fringe zones of agricultural matrices was found to diversify bee and butterfly communities delivering pollination services to nearby agricultural fields. Munyuli's study was undertaken in the coffee-banana farming system of central Uganda Munyuli (2010). It was established that bees contributed to over 60% of coffee (Coffea robusta) fruit set. Bee biodiversity, foraging activities and services delivery to coffee (fruit set) were found to be driven by several local, landscape and regional level factors. Coffee potential yield and bee contribution to fruit set were positively related to bee abundance, species richness, foraging rate, percentage young fallow in the vicinity of

Table 16 Value of biodiversity in Uganda's forest (2005 and 2010)

Description	Area ('000 ha) 2005	Area ('000 ha) 2010	Rate (US$/ha/year)	Value of biodiversity ('000 US$) 2005	Value of biodiversity ('000 US$) 2010	Value of biodiversity (million Ushs) 2005	Value of biodiversity (million Ushs) 2010
Natural forests	3,398	2,937	1.5	5.097	4.405	9,290.0	10,170.5
Pollinator services of bees and butterflies					149.4		344,904.84
Total					154.8		357,371.3

Source: Adapted from FAO (2010) and Moyini (2006)

coffee fields and proportion of seminatural habitats within 1 km^2 of coffee fields. About 0.3–0.5 million tonnes of coffee were produced in central Uganda during year 2007 for a mean economic value of US$214 million from which US$149.4 million (62%) were attributable to pollination services delivered by bees (Table 16). This pollinating service value was equivalent to 24% of annual earnings from export of agricultural products and 2.99% of GDP.

The pollinator services of bees and butterflies towards coffee and banana, US$149.4 million, were added to the value of biodiversity, although pollinator services have not been previously considered in the valuation of forest ecosystem services (Munyuli 2010; Moyini 2006; Yaron et al. 2003). Therefore, the total value of biodiversity was estimated as US$154.8 million (Table 16).

4.6 Value of Non-wood Forest Products

The total flow of non-wood forest products (NWFPs) was estimated at Ushs 65 billion (US$22 million) in 2010 (Table 17). The highest contribution was from honey, where the reported value is dominated by exports. The value of honey in the domestic market especially the noncommercial use is envisaged to be higher than reported. Shea butter also contributes about US$0.66 million annually to the national economy, making it the second highest earning NWFP after honey. The value of NWFPs generally relies on production from natural forest estate. There has been limited effort to consider optimal production of NWFPs in the country.

4.7 Recreational Services

The monetary value of recreational services was calculated based on tourist visitors to the country and data generated from a recent survey undertaken in the Murchison Falls Conservation Area (NEMA 2011; MTTI 2010). In Sect. 3.7 of this report, it

Table 17 Monetary value of non-wood forest products flows for 2010

Non-wood forest products	Monetary value (million Ushs)	Monetary value (US$)
Pet animals and butterflies	6,470.7	3,000,000
Honey	39,246.2	17,000,000
Aloe vera	2,104.0	911,377
Drums and fiddles	807.5	349,779
Tonic root (white's ginger)	129.6	56,138
Prunus africana	6.9	3,000
Bark cloth	8.7	3,769
Bamboo	922.7	40,000
Shea butter	15,225.3	660,000
Tamarinds	36.4	1,577
African tulip	9.6	4,158
Gum arabic	29.7	12,859
Mushrooms	216.0	93,563
Rattan cane	11.1	4,790
Total	**65,224.4**	**22,141,010**

Source: Adapted from NEMA and Acode (2008), UWA (2006), UEPB/Biotrade (2005), (2009)

was indicated that the number of tourists visiting national parks, wildlife reserves and forest reserves was 152,000 people. Of these 61,000 depended on foreign travel, while 91,000 generally relied on local travel. NEMA (2011) established four ranges of travel costs covering transportation, air travel and/or road, park fees and accommodation for foreign non-resident tourists and tourists travelling with local transportation (Table 18). Overall foreign non-residents paid between US$1,000 and 5,000, while local travel tourists paid between US$300 and 801.

When the survey findings were applied to the number of national tourists visiting national parks and forest reserves, the value of forestry tourism could be estimated. Overall, 91,000 tourists used local transportation, while 61,000 travelled as foreign non-residents. The findings of NEMA (2011) have been used to estimate the average travel cost for tourists to destinations in Uganda and when multiplied with the number of tourists gives an estimate of the overall nature-based tourism to the country (Table 19).

However, Moyini (2006) indicated that the whole package of tourism in Uganda so often referred to as nature-based tourism is generally shared between the forestry and wildlife sectors. Moyini proposed that only three of the conventional nine components of the package can be attributed to forestry alone (Table 20).

Similarly, NEMA (2011) found that 80% of the tourists indicated that they visited all the attractions. Therefore, the estimate of the forestry-based tourism can be estimated by multiplying the total monetary value of national park and forest reserve tourism with a coefficient that introduces the two adjustments above (US$297,111,050 * 0.8 * 3/9). The result gives the monetary value of tourism to the country's forest resources of US$79,150,384.

Table 18 Travel cost ranges for foreign non-residents and local travel tourists

Travel cost ranges for foreign non-resident ranges	Proportion of tourists (%)
Less than up to US$1,000	2
Between US$1,001 and 3,000	24
Between US$3,001 and 5,000	33
Above US$5,001	40
Tourists using local travel	
Less than up to US$300	20
Between US$301 and 500	29
Between US$501 and 800	35
Above US$801	15

Source: NEMA (2011)

Table 19 Estimated monetary value of forestry tourism to Uganda

Categories of tourist	No. of tourists	Average travel cost	Value (US$)
Foreign non-resident tourism	61,000	(1,000 * 0.02) + (3,000 * 0.24) + (4,000 * 0.33) + (5,001 * 0.4)	247,684,400
Local tourist travel	91,000	(300 * 0.2) + (400 * 0.29) + (650 * 0.35) + (801 * 0.15)	49,426,650
Total			**297,111,050**

Source: Authors own estimates

Table 20 Revenues received by Uganda wildlife authority from recreational services

Recreational categories for UWA	Revenues (Ushs)
Chimpanzee viewing	1,363,580,913
Mountain gorilla tracking	9,650,939,069
Hiking and biking	41,798,061
Nature walks	158,844,874
Lodging and accommodation	9,710,797
Birding, butterfly viewing and primate walks	168,000,000

Source: UWA (2010)

Forestry tourism revenue captured by UWA and the NFA was reported as Ushs168 million (Table 19) and 18.6 million, respectively (UWA 2010; NFA 2010). This was only 10.2% of the entire revenue calculated. It would seem that most of the revenue remained within the value chain and is shared by travel agencies, airlines and hotels.

4.8 Soil Protection Services

From Sect. 3.8, it was indicated that losses of NPK from farmlands surrounding tropical high forest and plantation areas were about 104.2 kg/ha/year, while losses from farmlands surrounding woodlands were about (156.81 kg/ha over a 10-year

Table 21 Estimated value of forest soil nutrient protection from avoided soil erosion

Forest categories	Area 2010	NPK losses (kg/ha)	Est. NPK losses (tons)	Price ('000 Ushs/ton)	Monetary value (million Ushs)	Monetary value (million US$)
THF	698.04	0.1042	72,736	1,400	101,830	44
Woodlands	2,553.45	0.15681	400,407	1,400	560,569	243
Plantations	57.55	0.1042	5,997	1,400	8,395	4
Total					**670,794**	**291**

period) 156.81 kg/ha/year (Nabalegwa et al. 2006; de Jager et al. 2003; Wortmann and Kaizzi 1998; Kizza et al. 2005). These losses were carried forward to 2010. The price of NPK was reported as Ushs 70,000 per 50 kg bag in 2010 (MAAIF, personal communication). According to these, the monetary value of forest nutrient protection service through avoided soil erosion in the area under forest cover was estimated at US$291 million (Ushs 671 billion) (Table 21). The largest proportion of the losses was from soil erosion in woodlands especially from keeping large numbers of livestock, which trample the soil exacerbating soil erosion (Nabalegwa et al. 2006).

5 Economic Aggregates for Uganda Forest Sub-Sector

This section derives selected aggregates summarising information on the supply and use of forest resources within the economy; indices related to forest management services, employment and research; and measures of the contribution of forest sub-sector to the national economy.

5.1 Supply and Use Table

This study made an attempt to use available data to compile supply and use tables for Uganda's forest resources. These, however, are not comprehensively developed for data limitations. Much of the work needed for a comprehensive quantitative value chain analysis for the sector has not been undertaken yet. This section uses information from the NFA and the Sawlog Production Grant Scheme (SPGS) on the contributions of different actors in the sector to develop indicative supply and use tables for 2010. SPGS has commissioned a study to establish a comprehensive database of the forestry economy within the country.

The physical and monetary wood and wood products supply and use through the entire value chain are presented in the Appendix A. It is estimated that 1 million m^3 of sawlogs, 889,000 m^3 of poles and 25 million m^3 of fuelwood were supplied and used in Uganda in 2010. As indicated in Table 13, there were some exports, but these formed a very small fraction of 1–5% of the entire volume and monetary value of wood supplied and used in the country.

5.2 *Other Forest Management Services*

5.2.1 Accounting for Employment Management Services

A submission made by the National Forestry Authority (FAO 2010) indicated that Uganda's forestry sub-sector directly employed 201,000 people (Table 22). However, there was little clarity about the value of employment and whether or not the people worked in the public or private sector. Instead an alternative review based on the institutional arrangements, particularly in public sector, was used to determine the contribution of forestry management services to the sub-sector in Uganda.

The NFA and FSSD

The Ministry of Water and Environment (MWE) sector performance report (MWE 2010) indicated that public expenditure towards supporting the activities of the Forestry Support Services Department (FSSD) and the NFA was Ushs 40.8 and 9.5 billion in 2009/2010, respectively (Table 23). The financing for FSSD also included funds for implementing the Farmer Income Enhancement and Forestry Conservation (FIEFOC) project. The FIEFOC project supports afforestation, agroforestry and watershed management within farming communities and areas as a means of income enhancement for participating farmers.

In addition to the public finance support, the NFA received financial support from development partners and generates its own revenue from licences, timber auctions and fines and charges (NFA 2009). Preliminary estimates for 2010 indicate that nontax revenue (NTR) contributed 67% of the total revenue resources available to the NFA, while development partners and government funding was 24% and 7%, respectively (Table 24) (MWE 2010).

District Forest Service

The District Forest Service in local governments governs 64% of the forest estate delivering decentralised forest services for managing local forest reserves and private and customary forests, in essence supervising forestry activities outside protected areas. Although both NFA and DFS were meant to complement one another, it is only the NFA, which is significantly funded. UWA, on the other hand, has resources to effectively execute its mandate in national parks and wildlife reserves. However, FSSD and DFS receive very little funding and so have not taken up their position adequately. The total financing for forestry activities in Uganda remains under Ushs 0.8 billion for the DFS (MFED-BTTB 2010). These resources were shared amongst over 100 districts.

Table 22 Employment in the forestry sub-sector of Uganda (2010)

Categories of employment	No. of employees
Firewood and charcoal production	89,000
Household production	71,000
Commercial and industrial wood production	36,000
Plantation establishment and management	1,400
Institutions	2,600
Pole production	1,000
Total	**201,000**

Source: FAO (2010)

Table 23 Central government financing for forestry management at national level

Agencies financed by central government	Amount of financing (Ushs)		
	Budget	Actual release	Expenditure
Budgetary allocations for the Forestry Support Services Department (FSSD) including FIEFOC funds for District Forest Service	40.827	26.714	20.101
NFA	9.512	5.18	1.94

Source: MWE (2010)

5.2.2 Education and Research

There are two institutions of higher education that teach forestry management in Uganda; Makerere University Faculty of Forestry and Nature Conservation (FFNC, now under the College of Agricultural and Environmental Sciences) and Nyabyeya Forestry College in Masindi District.

The Makerere University Fact Book (Munyuli 2010) stated that there were 212 students at different stages of their education in the FFNC at Makerere University and 43 staff. On the other hand, the student population at Nyabyeya was 385 in 2010 (Okoija 2010). Estimated public expenditure for the Nyabyeya Forestry College, the only technical forestry college in the country, was about Ushs 960,562,794.

At Makerere University's Faculty of Forestry and Nature Conservation, the expenditure was estimated based on the estimated cost per student. The cost is spread to include education, practical living expenses, lecture salaries and other wages and expenses. The cost per student is Ushs 6,000,000 usually also quoted as US$3000 per student (Students' Guide of Uganda 2010). For the 212 students, the cost was Ushs 1,272,000,000 (or US$636,000). On the other hand, public expenditure

Table 24 NFA annual revenue by source (2004/2005–2009/2010) billion UGX

Period	2005	2006	2007	2008	2009	Budget. 2009–2010	Prel. 2010
Total revenue (TR)	12.26	13.91	14.30	14.08	17.28	27.51	16.54
Nontax revenue (NTR)	5.42	6.44	8.26	11.34	15.04	18.00	11.34
Forest products	4.06	4.44	4.94	6.84	7.82	7.35	9.16
Revenue from plantations	3.91	4.6	5.50	7.23	9.50	9.95	6.21
Revenue from plantations % of TR	32	33	38	51	55	36	38
Revenue from plantations % of NTR	72	72	67	64	63	55	55
Government subvention	0.164	0.194	0.024	0.042	0.176	1.200	1.175
Development partners	6.679	7.289	6.013	2.700	2.069	8.276	4.028
%NTR	44	46	58	81	87	65	67
% Development partners	55	52	42	19	12	30	24
% GoU subvention	1.3	1.4	0.2	0.3	1.0	4.4	7.1
Personnel costs as % of NTR	94	87	63	53	40	45	37

Source: MWE (2010)

on forestry research at the National Forestry Resources Research Institute (NaFORRI) was Ushs.8 billion.

The total expenditure on forestry management and regulation, education and research was estimated as US$23.85 million (or Ushs 55 billion) per year in 2010 (Table 25). This cost does not include private sector investments as well as investments from development partners under programmes such as the Sawlog Production Grant Scheme (SPGS) although the projected production is captured under plantations in the component on timber available and not available for production.

5.3 Contribution of Forestry to the National Economy of Uganda

Based on the above described forest accounts, conservative estimates were established on the total contribution of the forestry sub-sector to the national economy which amounted to approximately US$1,277 million in 2010 (Ushs 2,960 billion) (Table 26). When compared with the GDP of 2009 at current prices of Ushs 34,166

Table 25 Estimated expenditure on forestry management, education and research

Category	Expenditure Ushs	Expenditure in US$
Management and regulation		
FSSD	20,101,000,000	8,707,009
NFA	16,540,000,000	7,164,515
DFS	800,000,000	346,530
Local government FIEFCO	7,200,000,000	3,118,773
Education		
Makerere University Faculty of Forestry and Nature Conservation	1,272,000,000	636,000
Nyabyeya Forestry College	960,562,794	416,080
Research		
National Forestry Resources Research Institute	8,000,000,000	3,465,304
Totals	**54,873,562,794**	**23,854,211**

Table 26 Summary of monetary value of forest products, services and management

Description of forest products, services, management and regulatory components	Value (million Ushs)	Monetary value (million US$)	% of total
1. Forested land	741,984.04	321.4	25.17%
2. Timber flows recorded in statistical abstract	258,955.66	112.17	8.78%
3. Other timber trade exports	9,430.63	4.09	0.32%
4. Less other timber trade imports	−8,421.77	−3.65	−0.29%
5. Non-wood forest products	65,224.40	22.14	1.73%
6. Carbon sequestration service	627,939.20	272	21.30%
7. Biodiversity conservation service	357,371.30	154.8	12.12%
8. Recreational services	182,726.58	79.15	6.20%
9. Soil protection services	670,794.00	291	22.79%
10. Hydrological services	–	–	–
11. Forestry management, regulation, education and research	54,873.56	23.85	1.87%
Estimated total contribution of sub-sector	**2,960,877.60**	**1,276.95**	**100.00%**

billion, the forestry sector was equivalent to 8.7% of that amount (BOU 2010). One must remember that some of the values reported in Table 26 are already included in the SNA GDP estimates, e.g. timber trade values and forest management services. The value of other important components of the estimated contributions while do form part of the current SNA, their values are attributed to the wrong sectors. Those include regulating services which provide intermediate input services to the production of many economic goods traded and valued in the SNA such as carbon sequestration (21%), pollination and soil protection services (23%), whose values are captured as part of agricultural production and other sectors' values. The most important element in the estimated forest values is the annual value of forested land (25%). Adjustments of the SNA to correct for this value should be through adjusting change in wealth and savings' accounts (e.g. net national product) for depreciation of forest assets as part of total wealth of the nation. Some of the estimated values are ordinarily missing from the current measures of GDP such as some non-wood forest products (2%) and informal timber trade (0.6%).

6 Conclusions and Recommendations

The Uganda forest accounts were developed to establish the annual contribution of the country's forestry sub-sector to the national economy. The national forest accounts show that forest resources contribute significant values to the national economy some of which are missing from the current SNA and others are captured by other sectors of the economy.

The study revealed that there is dearth of data on forest products and service value chains, and this limits a complete description of the forestry sector. Some studies have been undertaken with limited scope. Indeed, only a countrywide survey can effectively measure the extent of the forestry economy in the country. The national biomass surveys done by the NFA were extremely useful in undertaking this study. In some areas, projection data was used when primary or processed data could be provided; however, the constraints in assembling all the resources needed limited the usefulness of NFA data.

Whereas the NFA and MWE have made considerable effort at the national level, many institutions have not published information about their recurrent expenditures, forestry management, research and educational activities.

Therefore, if the natural resource accounting methodology is to be effectively used for forest resources management and policy design, more effort in developing the capacity of institutions generating information on the supply and use of forest resources is needed. This report provides a first step towards strengthening the discussion on the greening of national accounts in Uganda. This would require that not only forests but all other major natural resources must also be accounted for such as soils, wetlands and water, amongst others.

The study makes some immediate and long-term actions to improve the utility of green accounting for improved policy design and resource management decisions. One immediate action of this study is to design a strategy for disseminating these findings and share them with a number of resource sector ministries and the Ministry of Finance, Planning and Economic Development (MFPED) and Uganda Bureau of Statistics, amongst others. While timber, non-wood forest products and wood fuel are already major items but have poorly developed supply and value chains, the supply and value chains for carbon sequestration, non-wood forest products, recreational services and other ecosystem services are quite inadequately developed.

Key conservation messages from this study relate to enhancing soil protection services of forests, better use of carbon markets and trade, enhancing hydrological services, biodiversity conservation especially in relation to recreational services and protection of important habitats. New tools are emerging such as the REDD plus, payments for ecosystem services and environmental financing mechanisms, all of which can enhance conservation while also contributing to economic development.

The findings of this study can be refined further through research to integrate other values such as hydrological services and conducting field studies to improve current results. More importantly, that natural resource accounting should be extended to all other major natural resources. Rather than creating a parallel process, it is important to realise that the backbone for generating data already exists at the MWE, NFA, UWA, NEMA, UBOS and District Forest Services. However, there are weaknesses in existing institutional capacity to implement these both in terms of human capacity and the infrastructure and regular financing resources to effectively strengthen existing institutions.

Appendix A Uganda's Supply and Use Tables (2010)

Table A1 Physical wood and wood products supply table

	Forestry and logging	Wood products	Pulp and paper	Printing	Recycling	Total	Imports	Total
Standing timber ('000 m^3)	27,501						0	27,501
Sawlogs ('000 m^3)	1,029						0.40	1,029
Poles ('000 m^3)	889						0.35	889
Fuelwood ('000 m^3)							0	
Household	20,491						0	20,491
Commercial	3,099						0	3,099
Industrial	1,993						0	1,993
Pulpwood ('000 m^3)								
Wood and wood products ('000 m^3)								
Veneer		–					0.031	–
Plywood		–					2.414	–
Particle boards		–					1.924	–
Fibreboards		–					0.747	–
Carpentry and joinery		–					0	
Pulp ('000 t)		–					0	
Paper ('000 t)		–					0	
Wood waste as a product ('000 t)		–					0	

Table A2 Physical wood and wood products use table

Products	Forestry and logging	Wood products	Pulp and paper	Printing	Recycling	Total	Exports	Total
Standing timber ('000 m^3)	27,501						0	27,501
Sawlogs ('000 m^3)	1,029						1.70	1,030.7
Poles	889						1.40	890.4
Fuelwood ('000 m^3)								
Household	20,491						0	20,491
Commercial	3,099						0	3,099
Industrial	1,993						0	1,993
Pulpwood ('000 m^3)								
Wood and wood products ('000 m^3)								
Veneer ('000 m^3)							0.12	–
Plywood ('000 m^3)							1.72	–
Particle boards ('000 m^3)							2.06	–
Fibreboards ('000 m^3)							0.04	–
Carpentry and joinery ('000 m^3)							0.20	–
Pulp ('000 t)								
Paper('000 t)								
Wood waste as a product ('000 t)								

Table A3 Monetary wood and wood products supply table

	Forestry and logging	Wood products	Pulp and paper	Printing	Recycling	Other	Total	Imports	Total
Standing timber	94.06								498.88
Sawlogs	18.63							0.22	
Poles	7.24							0.003	
Fuelwood									
Household	52								
Commercial	10								
Industrial	6								
Pulpwood									
Wood and wood products									
Veneer								0.062	
Plywood								1.92	
Particle boards								1.013	
Fibreboards								0.426	
Carpentry and joinery								0	
Pulp									
Paper									
Wood waste									

Table A4 Monetary wood and wood products use table

	Forestry and logging	Wood products	Pulp and paper	Printing	Recycling	Other	Total	Final consumption	Capital formation	Exports	Total
Standing timber	94.06										94.06
Sawlogs	18.63									1.12	19.75
Poles	7.24									0.014	7.23
Fuelwood											
Household	52										
Commercial	10										
Industrial	6										
Pulpwood											
Wood and wood products											
Veneer										0.134	
Plywood										1.183	
Particle boards										1.301	
Fibreboards										0.32	
Carpentry and joinery										0.30	
Pulp											
Paper											
Wood waste											

References

Agea J, Katongole B, Waiswa D, Nabanoga G (2008) Market survey of *Mondia whitei* (*mulondo*) root in Kampala city, Uganda. Afr J Tradit Complement Altern Med 5(4):399–408

Bekunda M, Manzi G (2003) Use of the partial nutrient budget as an indicator of nutrient depletion in the highlands of southwestern Uganda. Nutr Cycl Agroecosyst 67:187–195

Betti JL (2008) Non-detriment findings report on Prunus africana (Rosaceae) in Cameroon. Report preparae for the international expert workshop on non-detriment findings, Mexico 17–22 Nov 2008

BOU (2005) Bank of Uganda annual report 2004/5. http://www.bou.or.ug. Accessed 4 Nov 2012

BOU (2010) Bank of Uganda annual report 2009/2010. http://www.bou.or.ug. Accessed 4 Nov 2012

Bush G, Nampindo S, Aguti C, Plumptre A (2004) The value of Uganda's Forests: a livelihood and ecosystem approach, Wildlife Conservation Society, EU Forest Resources Management & Conservation Programme and National Forestry Authority, Kampala, Uganda

Buyinza MB (2009) Biogeography and livelihood effects of edible bamboo shoots in Mt. Elgon National Park, Eastern Uganda. Environ Res J 3(2):35–41

Cunningham AB, Mbenkum FT (1993) Sustainability of harvesting Prunus africana bark in Cameroon: a medicinal plant in international trade. People and plants working paper. Unesco, Paris Environmental Alert (2008) Inventory of critical issues in the forestry sector in Uganda, Environmental Alert, Kampala, Uganda. Available http://www.envtalert.org. Accessed 4 Nov 2012

De Jager A, Onduru D, Walaga C (2003) Facilitated learning in soil fertility management: assessing potentials of low-external-input technologies in east African farming systems. Agric Syst 79(2):205–223

Egadu SP, Mucunguzi P, Obua J (2007) Uses of tree species producing gum arabic in Karamoja, Uganda. Afr J Ecol 45:17–21. doi:10.1111/j.1365-2028.2007.00732

FAO (2010) Global Forest Resources Assessment 2010: country report Uganda, FAO Forest Resource Assessment, FRA 2010/218, Rome, Available at http://www.fao.org. Accessed 4 Nov 2012

FAOSTAT (2010) Global production and trade of forest products in 2010: summary statistics by country – Uganda, FAO. http://www.fao.org/forestry/country/57025/en/uga/. Accessed 4 Nov 2012

Ferris RSB, Collinson C, Wanda K, Jagwe J, Wright P (2001) Evaluating the marketing opportunities for shea nut and shea nut processed products in Uganda. IITA Foodnet, Kampala, Uganda

Forbes India Magazine (2010) The carbon project in Uganda. Forbes India Magazine. http://business.in.com/. Accessed 26 Jun 2010

Forest Department (1996) Biodiversity reports for national forest reserves in Uganda. Forest Department, Ministry of Water Lands and Environment (MWLE), Kampala, Uganda

Forest Monitor (2007) The timber trade and poverty alleviation in upper great lakes region. Available at http://www.forestmonitor.org. Accessed 4 Nov 2012

Forestry Research Institute (2000) Rattan and bamboo in Uganda: a study of the production to consumption systems, Forestry Research Institute. Kampala, Uganda. www.inbar.int/

Hamilton K, Sjardin M, Pettes-Stanley M, Marcello T (2010) State of the voluntary carbon markets 2010: building bridges. Ecosystem Marketplace and Bloomberg New Energy Finance, New York. http://www.ecosystemmarketplace.com

Hassan R (2000) Improved measure of the contribution of cultivated forests to national income and wealth in SA. Environ Develop Econ 5:157–176

GoU (2009) National Development Plan (NDP) 2010/11 – 2014/15, Kampala, Uganda. http://npa.org/doc. Accessed 4 Nov 2012

Howard P (1995) The economics of protected areas in Uganda: costs, benefits and policy issues, MSc dissertation, University of Edinburgh

Howard PC, Davenport T, Mathews R (1996) Biodiversity reports Nos 1–33. Forest Department, Kampala

Howard PC, Daven Port TRB, Kigenyi FW, Viskanic P, Baltzer MC, Dickson CJ, Lwanga J, Mathews PA, Mupada E (2000) Protected areas planning in the tropics Uganda's national system of forest nature reserves. Conserv Biol 14(3):858–875

INBAR (2006) International network for bamboo and rattan web site. Available at www.inbar.int. Accessed 4 Nov 2012

INBAR (2009) International network for bamboo and rattan web site. Available at www.inbar.int. Accessed 4 Nov 2012

INBAR (2010) International network for bamboo and rattan web site. Available at www.inbar.int. Accessed 4 Nov 2012

Katebalirwe S (10–11 May 2010) Bark cloth from Uganda as a potential GI product. GI: ACP-EU Cape Town Ministerial Conference, Cape Town

Kizza CL, Majaliwa JGM, Nakileza B, Kansiime F (2005) Soil and nutrient loss from Mabira forest restored blocks, FOREAIM third reporting period. Scientific report, Makerere University Institute of Environment and Natural Resources, Kampala, Uganda

Lange G (2004) Manual for environmental and economic accounts for forestry: a tool for cross-sectoral policy analysis. Working paper, FAO Forestry Department, Italy

Magunda MK, Majaliwa JGM, Tenywa MM, Musitwa F (2003) Runoff, soil and nutrient losses from major agricultural land-use practices in the Lake Victoria basin, Uganda. Afr J Trop Hydrobiol Fish 11(1):87–103

Maku J (2004) Honey market in Uganda, APIACTA 38 (2004) 302–306. The Uganda National Nile Region Apiculture Development Organisation, Kampala, Uganda

McArthur JW, Sachs JD (2011) A general equilibrium model for analyzing African rural subsistence economies and an African green revolution. Submitted to Oxford CSAE 2011 Conference on Economic Development in Africa, St. Catherine's College, Oxford. http://www.columbia.edu

MFED-BTTB (2010) Background to the budget, Uganda Ministry of Finance, Kampala, Uganda. Available at http://www.finance.go.ug. Accessed 4 Nov 2012

Moyini Y (2006) Bujagali hydro-electric power project economic assessment of resource values affected by the 220 KV powerline wayleave traversing Mabira, Kifu and Namyoya central forest reserves. Appendix D REPORT forest economic assessment report, Burnside

MTTI (2010) MTTI statistical abstract 2010. Parliamentary Avenue, Kampala, Uganda. http://www.mtti.o.ug

Mugula B, de Vries B, Bingi S (2010) Mechanisms for sustainable use of biodiversity in and beyond natural ecosystems: a study on conservation and commercial production of *Prunus Africana* in Uganda. Int J Biodivers Conserv 2(7):180–185. http//:www.academicjournals.org/ijbc

Mukadasi B, Muyanja S, Lusiba B (2010) Economic valuation of a Tamarind (Tamarindus indica L.) production system: green money from drylands of eastern Uganda. Small Scale For 9(3):317–329

Munyuli T (2010) Pollinator biodiversity and economic value of pollinator services in Uganda PhD. Makerere University Institute of Environment and Natural resources, Makerere University, Kampala, Uganda

MWE (2002) National Biomass Survey 2002, Forest Department, Ministry of Water and Environment, Kampala, Uganda. Accessed 4 Nov 2012

MWE (2010) Water and Environment Sector Performance Report (SPR) 2010, Ministry of Water and Environment (MWE), Kampala, Uganda. Accessed 4 Nov 2012

Namaalwa J, Hofstad O, Sankhayan PL (2009) Achieving sustainable charcoal supply from woodlands to urban consumers in Kampala, Uganda. Int For Rev 11(1):64–78

Natural Ingredients Sector Strategy for Food, Cosmetics and Pharmaceuticals (2005–2007) Ministry of Trade Tourism and Industry/United Nations Development Programme supported Uganda Biotrade Programme, Kampala. http://www.biotrade.org. Accessed 4 Nov 2012

NEMA (2008) National state of the environment report for Uganda. NEMA House, Kampala, Uganda
NEMA (2010) Uganda state of environment report, Kampala, Uganda. Available at http://www.nemaug.org. Accessed 4 Nov 2012
NEMA (2011) Valuation of protected areas in Uganda: the case of Murchison Falls Conservation Area and Budongo Central Forest Reserve. Valuation of Protected Areas in Uganda: a case study of murchison falls conservation complex. In: Kipkoech A, Moyaka H, Okeyo-Owour JB (eds) Towards implementation of payment for ecosystem service BoD Publishing, VDM Verlag Dr. Müller E.K., Germany, pp 213–227. ISBN 978-3-639-35888-9
NEMA, ACODE (2008) Building a foundation for sustainable wildlife trade in Uganda: a review of the national wildlife trade policies in support of the convention on international trade in endangered species of fauna and flora (cites) national. NEMA House, Kampala, Uganda
New Vision (2010) Gum arabica gets new investor. http://www.newvision.org, February 2010. Accessed 4 Nov 2012
NFA (2009) National biomass survey 2005. National Forestry Authority, Springs Road, Kampala, Uganda
NFA (2010) Data estimates and projects from NFA databases. National Forestry Authority, Springs Road, Kampala, Uganda
Niles JO, Brown S, Pretty J, Ball AS, Fay J (2002) Potential carbon mitigation and income in developing countries from changes in use management of agricultural and forest lands. Phil Trans R Soc Lond A 360(1797):1621–1639
Nkonya E, Kaizzi C, Pender J (2005) Determinants of nutrient balances in a maize farming system in eastern Uganda. Agr Syst 85:155–182
Odokonyero GGO (2005) Pitsawn timber production in the natural forests of Uganda: a forest harvesting case study. Food and Agricultural Organization, Rome
Ogaba M (2002) Household poverty reduction through bee-keeping amongst Uganda rural women. Standing Commission of Beekeeping for Rural Development, Monmouth
Okoija (2010) Brief on Nabyeya forest college for Makerere University Vice Chancellor, Masindi, Uganda
Omeja P, Obua J, Cunningham AB (2004) Carved wood drums and trade in Mpigi District Uganda. In: Sunderland T, Ndoye O (eds) Forest products, livelihoods and conservation: case studies of non-timber forest product systems, vol 2. Centre for International Forestry Research (CIFOR), Bogor Barat, http://www.cifor.cgiar.org
Parliament of Uganda (2009) Report of the sessional committee on tourism, trade and industry on the ministerial policy statement and budget estimates for the ministry of tourism, trade and industry for the financial year 2009/2010. Eighth Parliament of Uganda, Kampala, Uganda
Pearce and Moran (1994) The economic value of biodiversity, IUCN, Gland, Switzerland in association with Earthscan Publication Ltd
Rainforest Alliance (2009) Guidance on coffee carbon project development using the simplified agroforestry methodology, Climate Initiative, Rainforest Alliance. http://eco-index.org. Accessed 4 Nov 2012
Ruitenbeek HJ (1989) Social cost analysis of the Korup project, Cameroon. A report prepared for the world wide fund for nature and the republic of Cameroon, London
Samula A (2001) The dynamics of wood volume and values of trade in musical instruments in central Uganda. MSc thesis, Makerere University, Kampala
Sawlog Grant Scheme (2010) SPGS timber market study, Kampala, Uganda. http://www.sawlog.ug. Accessed 4 Nov 2012
Sessanga A (2007) Uganda set to increase Aloe Vera processing exports. African Agriculture, Dakar
Slade G, Weitz K (1991) Uganda environmental issues and options. Unpublished Masters Thesis, Duke University,
SPGS (2008) Forest investment opportunities in Uganda: opportunities and challenges, Sawlog Production Grant Scheme (SPGS), Issue No. 16. Available http://www.sawlog.ug. Accessed 4 Nov 2012

Students Guide of Uganda 2010 Fountain Publishers 2010 Students' Guide of Uganda, Kampala, Uganda, http:// www.fountainpublishers.co.ug. Accessed 4 Nov 2012

UBOS (2010) National statistical abstract 2010.Uganda Bureau of Statistics, Kampala. http://www.ubos.org

UEPB (2004) National biotrade pre-assessment study and proposed country programme structure. Ministry of Tourism, Trade and Industry/United Nations Conference on Trade & Development (UNCTAD), Export Development Programme. www.ugandaexportsonline.com/biotrade. Accessed 4 Nov 2012

UEPB/Biotrade (2005) Natural Ingredients Sector Strategy for Food, Cosmetics and Pharmaceuticals 2005–2007, Ministry of Trade Tourism and Industry/United Nations Development Programme supported Uganda Biotrade Programme, Kampala, http://www.biotrade.org. Accessed 04 Nov 2012

UEPB/Biotrade (2006) Opportunities and strategies for wildlife trade sector strategy in Uganda, Uganda Biotrade Programme, Ministry of Trade Tourism and Industry/United Nations Development Programme supported Uganda Biotrade Programme, Kampala, http://www.biotrade.org. Accessed 4 Nov 2012

UWA (2004) Number of birds, reptiles and amphibians allocated in Uganda's quota for wildlife, Uganda Wildlife Authority, Kampala

UWA (2010) Main sources of revenue from national parks and wildlife reserves in Uganda, Uganda Wildlife Authority information brief 2010, Kampala, Uganda

van Noordwijk M, Minang PA, Dewi S, Hall J, Rantalla S (2009) Reducing Emissions from All Land Uses (REALU), The case for a whole landscape approach. ASB policy brief 13, Nairobi, ASB partnership for tropical forest margins. Available at http://www.asb.cgiar.org. Accessed 4 Nov 2012

World Bank (2007) Methodologies to evaluate early childhood development programs, Poverty reduction and economic management, Thematic Group on Poverty Analysis, Monitoring & Impact Evaluation. http://siteresources.worldbank.org. Accessed 4 Nov 2012

Wortmann CS, Kaizzi CK (1998) Nutrient balances and expected effects of alternative practices in farming systems of Uganda. Agric Ecosyst Environ 71:115–129

Yaron G, Moyini Y, Wasike D, Kabi M, Barungi M (2003) The role of environment in increasing growth and reducing poverty in Uganda, GY Associates, Kampala, Uganda

Zake YK, Bwamiki DP, Nkwiine C (2000) Soil management requirements for Banana production on the heavy soils around Lake Victoria in Uganda. In: Karamura E, Vuylsteke D (eds) First international conference on banana and plantain for Africa, Kampala. International Society for Horticultural Science, Leuven

Accounting for the Value of Ecosystem Assets and Their Services

Karl-Göran Mäler, Sara Aniyar, and Åsa Jansson

Abstract Almost all decisions made by agents (individuals, households, companies, associations, governments, etc.) are preceded by some comparisons of the expected gains from making the decision versus the costs of making the same decision. These comparisons may be completely informal, involving only some rough thoughts on the consequences of the decision or may use an elaborate decision theoretical model (Raiffa H. Decision analysis. Introductory lectures on choices under uncertainty. Random House, New York, 1968). Most decisions made by a household do not need any elaborate theoretical analysis. They are mainly made on the basis of experience. But when a household is going to make a major investment, buying a house, for example, they will try to make a rational choice, given the information they have accessible. Based on this information, they will make a valuation of the consequences, in order to see which side will dominate – buying the house now or wait for another opportunity. In this example, the household will probably consult experts that can translate the consequences of buying the house for the household into something concrete, such as the net income of the household. In this case the household is doing a valuation. Similarly, when a society is going to make a decision on say the construction of a new highway, the society should know how this new highway

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affects the citizens (e.g. higher taxes, shorter transport time, more air pollution and deforestation where the highway is going to be built) before making a decision. In the end, all these factors and many, many more have to be compared in some way or another so that a decision can be made.

Keywords Ecosystem services • Accounting prices • Ecosystem values

1 Introduction

Valuation is a technique for doing just that. In theory, it tries to identify the consequences of the construction of the highway for each affected household and then aggregate this over all households. The former part that is identifying the consequences for households can in principle be done without imposing any moral or ethical values. We are simply interested in whether a household is better or worse off. However, the second part, aggregation, needs values on how we should think of the interpersonal consequences of the construction. Some households may be better off while others will be worse off. The first part is valuation, and economists have developed a rich toolbox for assessing household-specific values.

Thus, valuation was developed as a tool for decision making. However, it is also used to find out whether the welfare in a society has increased over a specified time period. It is very common in newspapers to find references to the gross national product as an index of whether welfare has increase or not. We will introduce a different and more relevant index, namely, wealth per capita. In constructing such an index, it is necessary to value ecosystem services and more important, the capital stocks embodied in an ecosystem. In doing that, essentially the same valuation techniques as used in decision making will be used. In this chapter, we will focus on this latter aspect, although they are very much related to each other (as will be underlined later). This chapter applies the analysis of Dasgupta and Mäler (2000) to valuation of ecosystems services and the ecosystem capital stocks. We are interested in finding the accounting prices of the capital stocks that are defining an ecosystem. These accounting prices are derived from the provisioning services they are supporting, using what is known on the dynamics of the ecosystems. This chapter draws heavily on a number of already published works at the Beijer Institute of Ecological Economics (Arrow et al. 2003; Mäler et al. 2008, 2010).

We have excluded here an analysis on human capital, perhaps the most important asset; we are working on it, and that work is still not published. A working paper on that issue can be requested to the authors.

2 Ecosystems and Ecosystem Services

It will be useful to have a simple background in ecosystem ecology. We have therefore included a quotation from *Encyclopaedia Britannica*. The biosphere is a relatively thin life-supporting stratum of the Earth's surface, extending from a few kilometres into the atmosphere to the deep-sea vents of the ocean. The biosphere is a global ecosystem composed of living organism (biota) and the abiotic (non-living) factors from which they derive energy and nutrients.

Before the coming of life, the Earth was a bleak place, a rocky globe with shallow seas and a thin band of gases – largely carbon dioxide, carbon monoxide, molecular nitrogen, hydrogen sulphide and water vapour. It was a hostile and barren planet. This strictly inorganic state of the Earth is called the geosphere; it consists of the lithosphere (the rock and soil), the hydrosphere (the water) and the atmosphere (the air). Energy from the Sun relentlessly bombarded the surface of the primitive Earth, and in time – millions of years – chemical and physical actions produced the first evidence of life: formless, jellylike blobs that could collect energy from the environment and produce more of their own kind. This generation of life in the thin outer layer of the geosphere established what is called the biosphere, the "zone of life", an energy-diverting skin that uses the matter of the Earth to make living substance.

The biosphere is a system characterised by the continuous cycling of matter and an accompanying flow of solar energy in which certain large molecules and cells are self-reproducing. Water is a major predisposing factor, for all life depends on it. The elements carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur, when combined as proteins, lipids, carbohydrates and nucleic acids, provide the building blocks, the fuel and the direction for the creation of life. Energy flow is required to maintain the structure of organisms by the formation and splitting of phosphate bonds. Organisms are cellular in nature and always contain some sort of enclosing membrane structure, and all have nucleic acids that store and transmit genetic information.

All life on Earth depends ultimately upon green plants, as well as upon water. Plants utilise sunlight in a process called photosynthesis to produce the food upon which the animals feed and to provide, as a by-product, oxygen, which most animals require for respiration. At first, the oceans and the lands were teeming with large numbers of a few kinds of simple single-celled organisms, but slowly, plants and animals of increasing complexity evolved. Interrelationships developed so that certain plants grew in association with certain other plants, and animals associated with the plants and with one another to form communities of organisms, including those of forests, grasslands, deserts, dunes, bogs, rivers and lakes. Living communities and their non-living environment are inseparable and constantly interact with each other. For convenience, any segment of the landscape that included the biotic and abiotic components is called an ecosystem. A lake is an ecosystem when it is considered in totality as not just water but also nutrients, climate and all of the life contained within it. A given forest, meadow or river is likewise an ecosystem. One ecosystem grades into another along zones termed ecotones, where a mixture of plant and animal species from the two ecosystems occurs. A forest considered as an ecosystem is not simply a stand of trees but is a complex of soil, air and water; of climate and minerals; of bacteria, viruses, fungi, grasses, herbs and trees; and of insects, reptiles, amphibians, birds and mammals.

Stated another way, the abiotic or non-living portion of each ecosystem in the biosphere includes the flow of energy, nutrients, water and gases and the concentration of organic and inorganic substances in the environment. The biotic or living portion includes three general categories of organisms based on their methods of acquiring energy: the primary producer, largely green plants; the consumers, which include all the animals; and the decomposers, which include the microorganisms that break down the remains of plants and animals into simpler components for recycling in the biosphere. Aquatic ecosystems are those involving marine environments and freshwater environments on the land. Terrestrial ecosystems are those based on major vegetational types, such as forest, grassland, desert and tundra. Particular kinds of animals are associated with each such plant province (Biosphere 2009).

A similar definition of ecosystems is given by the Millennium Ecosystem Assessment[1] (MEA 2003) as a dynamic complex of plant, animal and microorganism communities and the non-living environment interacting as a functional unit. Humans are an integral part of ecosystems.

Ecosystems vary enormously in size, a temporary pond in a tree hollow and an ocean basin can both be ecosystems. Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits. The definitions of ecosystem given above do not give a precise guide on how to delimit an ecosystem. In principle, organisms in one area can (and will) interact with organisms elsewhere on the planet, given enough time, and we would end up with one global ecosystem. That is obviously very impractical, so we should adopt a more practical rule for bordering one ecosystem from a different one, and the only way of doing that is to use common sense. When does it seem acceptable to exclude some connections and when is it necessary to include others?

These questions may seem academic for an ecologist, but an economist needs to delimit a system very precisely in order to develop the tools for valuing the services and managing the system in a rational way. The same problem is familiar to regional economists who more or less arbitrarily define the spatial extent of the regions to be studied. In the end, only experience, theoretical insights and common sense can resolve this problem.

We will in the next section treat ecosystems as capital assets. How do we measure the "size" of these assets? We will discuss this question shortly (in Sect. 5).

3 Ecosystem Services and Human Well-Being

The MEA classifies ecosystem services into more or less obvious groupings, namely, provisioning, regulating, cultural and supporting services (MEA 2003). Humans derive many benefits from these services, and hence, their quantity and quality affect

[1] The Millennium Ecosystem Assessment was initiated by the United Nations as a complement to the Intergovernmental Panel on Climate Change and with the objective to assess the state of ecosystems.

human well-being in many ways. They directly or indirectly influence the multiple constituents of human well-being, including basic material for a good life, freedom of choice and action, health, good social relations and security (MEA 2003). The constituents of well-being, as experienced and perceived by people, are situation dependant, reflecting local geography, culture and ecological circumstances.

Provisioning services are those services that are directly used by man and openly changing human welfare. Examples are many: fish from the seas, timber from the forest, agricultural output from cultivated land, etc.

Cultural services are services that are not material but still affect man directly. The view of large mammals – whales, elephants, lions, moose, wolfs – is something many persons are willing to pay substantial amounts to see, which is a clear indication that the existence of these animals are welfare enhancing. Similarly, gigantic sequoias, rare orchids, a cloud forest in Costa Rica or a boreal forest in Northern Scandinavia may by their existence provide well-being to many citizens. Thus, these kinds of assets often generate *intrinsic* values. An intrinsic value is roughly defined as the value of change in a resource, even if this change in the resource does not change the behaviour of individuals. We will come back later to a discussion of intrinsic values.

Regulating services do not directly provide welfare to humans. Their importance derives from the fact that they are essentially important intermediary goods and services. Thus, their value derives from the values of the provisional services they are input to.

Similarly, supporting services are another kind of intermediary services that derive their value from the value of the provisioning services they support. Therefore, we will below call the regulating and supporting services simply intermediary services. From a valuation point of view, there is therefore not much difference between regulating and supporting services, and we will treat them as one in what follows. As provisioning services are generating direct inputs to human production agencies (households, private and public organisations, etc.) we will rename them for final demand (or final consumption) in order to keep the text in line with established economic definitions. Thus, we have two different kinds of ecosystem services, final consumption services and intermediary services.

However, it is important to remember that an intermediary service, besides providing a necessary input to production of provisioning services, may also provide a provisioning service directly. An example is given by a forest that regulates the local hydrology (the regulating service) but also provides fuel wood or recreational opportunities. That is, an intermediary service may also be generating final consumption, and we will give many examples of this later. It may be desirable also to repeat that the values of intermediary services is derived from their role in providing final consumption, and we will see many examples of this later.

It is most often assumed without reason that ecosystem services are positive for man. This is not necessarily true. Marine ecosystems support jellyfish which can be very painful for persons that are in contact with them, and they can even be fatal. Mosquitoes carrying malaria parasites are very unwelcome guest in human bodies! Thus, there are negative ecosystem services, and **they should be included in the final valuation**.

For our discussion on valuation techniques later, it may be worthwhile already now to recall that both final consumption and intermediary services may either be characterised as public goods or as private goods. This distinction has nothing to do with whether the producer is a private or public agency. It has to do with whether the output from a service shares the characteristic of a private or public good. A service is a private good when an increase of the use of the service by one household will diminish the potential use by other households.

A public good is just the opposite – a service is a public good if an increase of the use of this service by one household will not diminish the potential use by other households. We will see several examples on the analytical use of this distinction soon. However, two examples may illustrate the distinction.

A forest provides many provisional services, but for now, let us consider the supply of fuel wood. If one household increase its collection of fuel wood, there will be less available for other households to collect (if fuel wood is scarce). Thus, there is a competition between households for fuel wood. This is true irrespective of the institutional arrangements – more fuel wood to one household will necessarily reduce the available fuel wood that can be used by other households. Thus, the fuel wood is a private good.

The forest also controls the hydrology of the surrounding area. A clear cutting of parts of the forest will change the pattern of water flows, and that change will be the same for all inhabitants of the forest area. The change in hydrology is a public (dis) service. The only way for a household to avoid experiencing this change in hydrology is by moving away from the catchment area. But for all those who remain in this area will face the same change in the water flows. The reasons why these concepts are important are two: Valuation depends on whether an ecosystem service is a private or a public good; management of the ecosystems will very much be influenced by the distinction between private and public goods

We will later see that these two reasons are intimately connected.

Ecosystems can be looked upon as a set of capital assets that together with abiotic inputs – water, sunshine, runoff of fertilisers – produces ecosystem services that will, positively or negatively, affect human well-being. This chapter focuses on the study of these assets and in particular on their importance for human well-being. Thus, our immediate interest is not to value ecosystems services but to value the underlying capital stocks.

For doing so, we need to understand the dynamics of ecosystems. We need to know what happens in ecosystems when a particular stock is perturbed. Most of this chapter will be devoted to a discussion of just that: exemplify how to understand ecosystems dynamics.

Focusing on the valuation of capital assets that are making up ecosystems and on ecosystems' dynamics is important because these issues are connected with the analysis of sustainable development. Derived ecosystem values (accounting prices) will also be the tool for judging and comparing alternative policies and management choices.

4 Sustainable Development and Accounting Prices

Before going into a discussion of valuation techniques, it is necessary to discuss the purpose of valuation. Here, we will argue that valuation is primarily a tool for first assessing whether the economic development is sustainable or not and second for generating information for decision makers in a way that supports sustainable development. As mentioned before, this discussion will take place within the framework developed by Dasgupta and Mäler (2000) and Arrow et al. (2003)

4.1 Wealth as an Indicator of Sustainable Development[2]

Let $C_s=(C_{1,s}, C_{2,s},\ldots, C_{m,s})$ be a list (or vector) of consumer goods and services in period s. The list must contain what we traditionally regard as consumer goods but also environmental amenities, public goods etc. These are included because all of them contribute to human well-being in one way or another.

We add the critical assumption that we have a forecast of the future consumption vectors. Such a forecast obviously must depend on three factors: the present stocks of capital $K_{i,t}$ (where the current period is t and i denotes the ith capital stock), a forecast of future knowledge (including technological) knowledge, a forecast of the future institutions of the economy and a knowledge of the dynamics of stocks involved. Given such a forecast, the forecasted consumption will depend on these four factors. We will focus on the role of the present stocks of capital (but we will touch upon the remaining two a few times later).

Let $K_s=(K_{1,s}, K_{2,s},\ldots, K_{m,s})$ be a list (or a vector) of capital stocks in the beginning of periods. Given a dynamic system that determine the future capital stocks, we can write

$$K_{t+1} - K_t = \theta\left(C_t, K_t, t\right) \tag{1}$$

We assume, as is standard in economics, that there is a utility function $U(C_1, C_2,\ldots, C_m)$ that describes the production of well-being in any given period. Note that the list of consumption "goods" is not equivalent to what we ordinarily measure as consumption. The list $(C_1, C_2,\ldots, C_m)$ of consumption goods includes all goods and

[2] Most often, this analysis is presented in models with continuous time. This is in general more convenient – simpler, faster and less cumbersome, but as applications will be based on data organised on discreet intervals, we have chosen to use a time defined in discrete periods. Furthermore, with continuous time, some serious interpretation problems would arise if we introduce randomness into the analysis.

services that affect the feeling of well-being: food, recreation, health, natural amenities and even the improvement of other peoples well-being and also those goods and services that reduce the feeling of well-being (bads) such as pollution, labour and time. Given the assumption in the previous paragraph, the future consumption C_τ will be a function of the present stocks:

$$C_\tau = \alpha\left(\tau, t, K_{1,t}, K_{2,t}, \ldots, K_{m,t}\right) \tag{2}$$

The α function will be called a resource allocation mechanism, and the characteristics of this function are determined by our forecasts of the future knowledge and the future institutions.

We will define social welfare as the present value of the stream of future utilities.

$$W_t = \sum_{s=t}^{\infty} \frac{U\left(C_s\right)}{\left(1+\delta\right)^{s-t}} \tag{3}$$

We will return to the interpretation of the discount rate and the utility function later. Mathematically, the accounting price on assets i at time t is defined as

$$\tilde{p}_{i,t} = \sum_{s=t}^{\infty} \frac{\partial U\left(C_s\right)/\partial\left(K_{i,t}\right)}{\left(1+\delta\right)^{s-t}} \tag{4}$$

It is worth remembering that forecasted future consumption is a function of the current capital stocks. The intuition behind this definition should be clear: the accounting price of capital stock i at time t, with utility as the numeraire, is the present value of the future marginal return (measured in utility units) of small perturbation of the stock at time t. Very often in the rest of this chapter, we will replace the list with a single variable C, but it would be quite easy intellectually to carry with us the whole list, although it might be typographically boring. We will make the rather strong assumption that there is only one individual in society in order to avoid difficulties associated with interpersonal comparisons.

$$W_{t+1} - W_t = \sum_{i=1}^{n} \tilde{p}_{,t}\left(K_{i,t+1} - K_{i,t}\right) + v_t \tag{5}$$

Neglecting the last term, Eq. 5 says that the change in social welfare between two time periods is equal to the sum over all capital stocks of the value of changes in these stocks, when the value is calculated with the accounting prices $\tilde{p}_{it}$. Thus, the economy is on a sustainable path if the changes in welfare from one period to the next are always nonnegative. It is easy from this definition of accounting prices for stocks to derive the corresponding prices for flows (flows of consumption and of capital goods).

4.2 Choice of Numeraire

The analysis above is with utility as the numeraire. The accounting price of one stock is a price in utility: that is, how much utility we would be willing to abstain from in the current period in order to have the stock in the end of the period increased by one unit. In empirical studies, it would not be very convenient to use utility as the numeraire. Instead, we would like using consumption in the current period as the numeraire: that is, using the costs of a basket of consumption goods in the current period as the numeraire. In order to simplify, we assume that the basket contains only one good: good #1. With this as the numeraire, the accounting prices are defined as

$$p_i(s) = \frac{\tilde{p}_i(s)}{\partial U / \partial c_1} \tag{6}$$

However, in order to use these prices with consumption as the numeraire, we need to use the discount rate with consumption as the numeraire r instead of the utility discount rate δ, and this is discussed in the next section.

4.3 Discounting

The way of looking at δ is as a moral parameter indicating how we want to compare well-being of future generations with well-being of the present generations. The utility discount rate is related to the consumption rate of discount rate. This latter concept (r) is basically measuring the marginal rate of future consumption for present consumption. The relation follows from the Ramsay equation:

$$r = \delta + \mathbf{n}g \tag{7}$$

That says the consumption rate r equals the utility rate δ plus the elasticity of marginal utility $\mathbf{n} = -C\left(u'' / u'\right)$ of consumption times the predicted future growth rate g of consumption. **n** can be interpreted as our regard for equity between different generations, regardless of when these generations live[3]; g as how much better a future generation is predicted to find life compared to the present generation; and δ as our preferences for individuals living in the future relative current individuals. The Ramsey equation can be interpreted as a rule that provides us with an “exchange rate” between measuring well-being in utility terms and in consumption terms. We will soon discuss the way of converting streams of utility (or well-being) into streams of consumption and vice versa. One can now show that these accounting

[3] Can also be interpreted as the relative risk aversion.

prices for stocks and flows are the correct prices for marginal cost-benefit analysis of “small” projects (see Arrow et al. 2003). Thus, these prices are the correct prices with which we should evaluate suggested policy reforms.

Let us now go back to Eq. 5. In this equation, the first term gives the “endogenous” change in social welfare, that is, the change which is due to changes in resources inside the system. The last term v_t reflects changes in social welfare due to causes outside the studied system. For example, changes in a country’s terms of trade (for a small country) independent of changes inside the country. The term will also reflect autonomous changes in technology (i.e. technical changes that are independent of capital accumulation in the country). Although both terms of trade and technical changes can be quite important for social well-being, we will neglect these effects in this chapter, that is, we will neglect the “drift term”. (For a motivation to this, see Xepapadeas (2005) and Dasgupta and Mäler (2000).) However, the main reason for not including this term in this text is that we want to focus on how to include ecosystem services in this framework.

5 Ecosystems as Capital Assets and Estimation of Accounting Prices

We regard ecosystems as collection of organisms that are interacting with each other and such that these interactions can be described as a dynamic system, and the biomass of the various organisms can be interpreted as capital assets. Thus, the assumption implies that we can interpret an ecosystem as dynamical system with the interactions described by the dynamical equations. However, the number of different organisms in an ecosystem may be extremely large, and in order to make empirical analysis of an ecosystem, we need to aggregate them to a small number of measurable variables. We assume, from now, that the system we are studying have been simplified in this way. We will illustrate with specific models.

5.1 Odum’s Control Model

Odum (Odum and Odum 2000) tried to develop a complete model of an ecosystem by writing down differential equations for all important assets in the system in which exogenous factors (human intervention, solar radiation, precipitation, etc.) appear as inputs to the equations. By solving this system, we would consequently be able to predict the future evolution of these assets, and by doing that, we could evaluate the value of the changes in the stocks and thereby judge whether the economy is on a sustainable path or not. However, it is notoriously difficult to solve such a system unless the equations are linear with constant coefficients.[4] This approach

[4] There are numerical solution procedures that would give us a chance of evaluating the system.

was used by a group at Resources for the Future (RFF) in the early 1970s to model the Delaware Estuary (Russel et al. 1976). In this application, the dynamics were rather simple. The main variable was the flow of the river that carried sediments (nutrients) and pollutants downstream, and linearisation of the equations were considered acceptable. Besides this, we are not acquainted with any other studies based on this approach. Our next model type can be considered as a generalisation of the Odum's approach but will also be limiting its applicability to only one or two assets.

5.2 *The Schaeffer Model of a Fishery*

Although the Schaeffer model is not an ecosystem model as it only includes one species, we include this surplus model[5] in our discussion on valuation as it will set the tone for more general models.

Let x_t be the stock of fish in the beginning of period t. The dynamics of this stock is given by

$$x_{t+1} - x_t = gx_{i,t}\left(1 - \frac{x_t}{\overline{x}}\right) - h_t \tag{8}$$

where h_t is the harvest in period t, g is the intrinsic growth rate and $\overline{x}$ is the carrying capacity of the system.[6] If the current stock is very small compared to the carrying capacity, the biomass will approximately grow at the constant rate g. However, that is not sustained forever as food for the species is limited, and thus, the growth rate must go down. If the harvest is zero, the limiting stock will be the carrying capacity. With positive harvest, the limiting stock will be smaller. The harvest is, of course, a provisional service, and there are no regulating services in the system according to the model.

We can now try to derive the accounting price for the fish stock at beginning of the period which may in general be different from the price of the catch. However, we must first make a forecast of the future of the fishery. Such a forecast will be influenced by the institutions controlling the use of the fishery. Let us start by assuming

[5] Surplus model definition can be found in books on fishery economics; see, for example, (Clark 2010). Roughly speaking, the biomass of the fishery grows at a rate depending on the available food and the consumption of the fishes. If the growth is greater than the natural consumption, there will be a surplus that man can exploit.

[6] This seems to be very simple model mathematically, but it is surprisingly complex and can for high growth values generate chaotic behaviour. See May (1976) for an interesting analysis. See Aniyar (2002) for the case when access is defined in terms of a dynamic process and for a complete analysis, including the case of fixed costs.

the system to be optimally managed. The optimum is defined as the harvest strategy that maximises the present value of future harvests:

$$\sum_{s=t}^{\infty} \frac{ph_t - C(e_t)}{(1+r)^{s-t}} \tag{9}$$

where e_t is the fishing effort in period t (say measured by number of boats in the fishery), $C(e_t)$ is the cost of the effort and p is the price net of fishing costs, for the harvest.

A necessary condition for an optimal management is the existence of an accounting price, q_s, on the fish stock.

$$q_s = p - \frac{C'(e_s)}{x_s} \tag{10}$$

In a steady state, the accounting price is thus equal to output price minus the marginal cost effort per unit of fish stock. Note that the service of the fish stock is a provisional service (final service in our terminology) and that service is a private good with a market price, and if our assumption of the dynamics is correct, the estimation of the accounting price is very simple.

Let us now assume that the fishery is an open-access fishery, that is, anyone can enter and leave the fishery without cost.[7] That implies that as soon as expected profit is positive, fishermen will enter the fishery, and when it is negative, they will leave. In equilibrium, net revenues must be zero.[8] The rent from the fishery has been completely dissipated. But that implies that the accounting price must be zero. Or at the margin, an increase in the fish stock is worth nothing. This example shows that valuation of ecosystem services must be seen in an institutional context. Accounting for ecosystem services is, thus, very closely connected with the institutions that determine the management of the ecosystems.

6 Mangrove Forests and Fisheries

The carrying capacity of the fish stock in the previous example is in general determined by the physical and biological environment in which the fish reproduce. One example of that is the importance of mangrove forests for fisheries. Thus, let us assume that the carrying capacity $\bar{x}$ is a function of the size of the mangrove forest. Once again, we have to face the problem of how we should define size. Possibly, the best way is to simply define it as the area covered by the forest. For our purpose, the

[7] See Aniyar (2002).

[8] See Aniyar (2002) for details.

exact definition is of importance. Of course, the mangrove forest offers many more services (wood for charcoal production, wood for construction, recreational area, protection of coastal land, etc.) but we will neglect them here and concentrate on the regulating services. Thus, we postulate

$$\bar{x}_s = \bar{x}\left(M_s\right) \tag{11}$$

where M_s is the size of the forest.

While keeping the Schaeffer model, we could also have assumed that the intrinsic growth rate is affected by the size of the mangrove forest. However, the case we are going to study is enough to show the general principles. The dynamics of the fish stock can as in the previous section be written

$$x_{s+1} - x_s = rx_s\left(1 - \frac{x_s}{x\left(M_s\right)}\right) - h_s \tag{12}$$

We also need to know the dynamics of the mangrove forest. The simplest (but perhaps erroneous) assumption is that the logistic model describes the forest growth sufficiently well.

$$M_{s+1} - M_s = r_M M_s\left(1 - \frac{M_s}{\bar{M}}\right) - h_{M,s} \tag{13}$$

where M_s is the harvest of forest products in period s.

We now have two different equations, and it is not possible to derive closed form solutions to them. However, the accounting price for both mangrove and fish stocks (given the price of fish catch) can be obtained by using, for example, Stella simulation software. Note that the accounting price for the regulating service of the mangrove forest is derived from the price of the fish catch.

7 Plaice Fishery and Environmental Disservice[9]

The surplus model, discussed in the previous section, is based on the idea that food is the limiting factor for growth. However, the assumptions behind the surplus model are not always correct.

Plaice (a fish belonging to the flounders) is an important fish in the North Atlantic. Its reproduction requires bare bottoms (hard or sandy bottoms). Thus, the really scarce factor determining the biomass of plaice is the suitable breeding areas.

[9] This section is based on a chapter in Dr. Sandra Silva Paulsen PhD thesis (Paulsen 2007).

The size of the breeding area determines the annual production of juveniles. After almost a year, the juveniles are recruited into the adult population. Every individual in a generation is assumed to consume the same amount of food, but the food consumption will increase with the age of the individual (of course up to a certain limit). The food consumption (and therefore the growth of the fishes in that cohort) is given by the von Bertalanffy growth function (VBGF) equation where total biomass of one cohort in 1 year is determined by multiplying the weight of the average individual (given by VBGF) with the number of individuals in the surviving generation and then summed overall cohorts.

The biology of plaice is such that the Schaeffer model is not a good choice for describing the dynamics of this species population because it is based on the idea that food is what is scarce and limits the population growth. For plaice, this is not the case; what limits population growth is breeding space. Reproduction areas are threatened by eutrophication (e.g. due to runoff of nitrogen from agricultural land or discharge of sewage). When the bottom has been covered by algae, it can no longer be used for reproduction. Thus, the growth of algae can be seen as a regulatory disservice, and suitable reproduction areas are an asset which has an accounting price. This accounting price can be estimated as follows.

The Beverton–Holt model is most appropriate for describing the dynamics of plaice population. It is a classic discrete-time population model which gives the expected number (or density) of individuals in one generation as a function of the number of individuals in the previous generation. The model focuses on the growth of individuals over time.

This growth is described by the so-called von Bertalanffy growth function (VBGF) equation,[10] where total biomass of one cohort in 1 year is determined by multiplying the weight of the average individual (given by VBGF) with the number of individuals in the surviving generation, then summed over all cohorts. The model is complicated, and it is impossible to derive mathematical solutions except in some extremely simple cases. Instead, one can use GAMS (General Algebraic Modelling System) to simulate the fishery and thereby estimate the accounting price on suitable reproduction areas.

Such an estimate of the accounting price is obviously needed for accounting for the changes in hard bottoms. However, it is also important for social cost-benefit analysis. If we are contemplating a project aiming at a reduction of the flow of nutrients to the breeding areas in order to reduce eutrophication. The benefits of such a project is then equal to the value of the increased area of hard bottoms, where the value is defined by the accounting price! This is a general result. The accounting prices we have been discussing are exactly the prices that are the correct prices to use in social cost-benefit analysis.[11]

[10] The von Bertalanffy growth function (VBGF) equation was introduced by von Bertalanffy to predict the length of a shark as a function of its age (Bertalanffy 1938).

[11] See Arrow et al. 2003 for a general analysis of this issue.

8 Pollination Services from Wild Bumblebees

This is based on a study that we carried out on the sustainable development of the Stockholm County parts of which is to be found in Mäler et al. (2008, 2010).

Many types of rapeseed (Canola), a major cash crop in North America, are pollinator dependant. For certain Canola lines, the seed weight per plant can increase over 80% with bumblebee's pollination (Steffan-Dewenter et al. 2002). The growing demand for urban development has significant impacts on terrestrial ecosystems (McYntyre et al. 2000) and on habitat fragmentation (Sala et al. 2000), which represents a major threat to wild pollinators (Allen-Wardel et al. 1998). In this context, it is relevant to assess the pollination ecosystem services. In our Stockholm Country Project, we attempted to estimate the accounting price for the pollination-regulating service by calculating how the pollination potential of Canola can vary due to land-use change, in an urban development.

It has shown that the availability of mass-flowering crops (as Canola) has strong positive effects on bumblebee densities, and the strongest correlation between the proportion of mass-flowering crops and bumblebee (*B. terrestris*, *B. lucorum*, *B. lapidaries*, *B. pascuarum*) densities was found for landscape sectors with 3,000 m radius (Westphal et al. 2003).

The bumblebees also require a 2% area of semi-natural habitat within the circles surrounding the canola fields, to obtain adequate nesting sites. By using a GIS (ArcView) and information on area and geographical location of Canola fields, we could then place circles (3,000 m radius) around the canola fields of the study area (Stockholm County, Sweden) and calculate the pollination potential in each circle. By changing land use according to a regional development plan (Stockholm Regional Planning Office 2001) of the study area, we can then estimate the change in the pollination potential of the Canola. The parameters upon which our estimates of pollination potential changes are based on the proportion of mass-flowering crops within the circle and the minimum requirement of semi-natural habitat.

As there is also a correlation between bumblebee density and harvest index (30), the change in pollination potential can be linked to crop output. The change in crop output can then, in turn, be translated into monetary units through a market price method. Using a similar approach, it has been shown (Rickettes et al. 2004) that forest-based pollinators increased coffee yield in plantations in Costa Rica by 20% and estimated that during 2000–2003 pollination services from two forest fragments translated into about USD 60,000.

Furthermore, the scales of operation of ecosystem services are essential consideration when valuing ecosystem services (Hein et al. 2006). The scale of operation of solidarity wild bees as well as some long-tongued bumblebees (Walter-Hellwig and Frankl 2000) is in the realm of hundreds of metres, as opposed to several thousand metres, as is the case for the included generalist bumblebees; in our example, there are potentially several scales of operation to consider.

The distribution of resources at the landscape is an important issue to consider in the context of mobile organisms contributing to ecosystem services (Kremen 2007). Landscape connectivity is needed for different pollinators and potentially also for relevant pest control species, the freedom of choice to switch between different crops, in the face of, for example, climate change, is enhanced. This freedom allows adaptation to future environmental and other changes and should also be considered an option value, at least partly ascribed to the pollination service.

The dynamics of the interactions between the wild pollinators needs therefore at least two capital stocks, the size of the canola plantation and the size of the natural and semi-natural habitat. The bee population seems to adjust very quickly to changes in the canola cultivation; thus, there is a very fast positive feedback from increases in the canola area to the increase in stock of bees and the following increase in canola production. On the other hand, the increase in impacts on the size of the natural or semi-natural habitat seems to reach a saturation point with regard to impacts on the size of the bee populations. If the habitat is smaller than saturation size, a decrease of habitat will result in lower bee population and therefore lower harvest of canola.

We will try to summarise the above description by the following model structure. Let

x_t be the stock of bumblebees in the beginning of period t
y_t be the canola production
N_t be the size of natural habitat for the bumblebees
L_t be the land used for canola cultivation

Then we could represent the dynamics of the bumblebees by

$$x_{t+1} - x_t = rx_t \left(1 - \frac{x_t}{\overline{x}_t}\right) \tag{14}$$

Here, we have assumed that there is no predation of bumblebees. However, it is possible to change that assumption without difficulties. This is a logic growth model with carrying capacity given by

$$\overline{x}_t = \overline{x}\left(N_t, L_t\right) \tag{15}$$

The canola production y_t is described by

$$y_t = \psi\left(L_t\right) \tag{16}$$

Here, we have assumed that the Canola production is determined by the size of land allocated to its growth. Of course, labour, fertiliser, etc. and other inputs will affect the production, but we will disregard such factors in this presentation. The production of canola seeds (S_t) is given by

$$S_t = \varnothing\left(y_t, x_t\right) \tag{17}$$

Finally, the value of the seed production in year t is

$$v_t = q_t S_t - C(L_t) \tag{18}$$

where $C(L_t)$ is the cost of cultivating the land L_t.

Finally, the accounting prices for the stocks of natural land N, cultivation land L and bumblebees are defined as the partial derivatives with respect to these variables of objective function

$$\sum_{s=\tau}^{\infty} \frac{v_\tau}{(1+r)s-t} \tag{19}$$

If the dynamics of the bumblebees are fast enough, then Eq. 14 can be simplified to

$$x_t = \overline{x}(N_t, L_t) \tag{20}$$

This substantially simplifies the estimation of the accounting prices.

In flow accounting, the only quantity of interest is v_t, as it is done in the standard system of national accounts (SNA). This v_t can easily be found from agricultural statistics. However, here, we are interested in the value of changes in capital stocks, and therefore, we are interested in the value of the change in the stock of bumblebees during the time period considered. The change in the stock of bumblebees is, however, determined by changes in other stocks – stock of rapeseed (food for bumblebees) – as well of the stock of suitable habitat for the bees. For an analysis sustainability – which focuses on future rapeseed production – this is much more interesting than the current harvest of rapeseed. The contributions from the bumblebees do not need to be accounted for, as these are already, implicitly accounted for in v_t.

9 Forests and Water

In all previous examples, the value of a regulating service has been calculated from an assumed knowledge of the value of a provisional service. We will in this example study a case where we first have to estimate the marginal value of the provisional service before we can estimate the value of the regulating service.

It seems to be accepted that a forest will retain water in greater quantities and for longer periods than a corresponding area in which all trees have been removed. In particular, the transport of water in the soil will be much slower in forested area, which means a higher quality, both of ground water as well as surface water. This can be studied by using detailed hydrological models.

We will thus assume that we do have such a model that relates changes in forested area to changes in water flow, to changes in the variance of the water flow and to changes in the quality of the water flow.

Thus, associated with a change ΔF of forested area, there are corresponding changes in the average water flow, ΔW, in the variance in the flow, $\Delta\sigma$, and in the quality (measured e.g. by its turbidity), ΔQ. If we can value these changes, we will be able to estimate the accounting price, p, for the forested area.

Assume now that this water will be used for irrigation. Then turbidity does not matter, but the variance of the flow does matter. An increase in the variance of the flow will mean a waste of water which otherwise could have been used for increased productivity of the land, and vice versa.

10 Accounting Price for Resilience

Ecosystems are often characterised by positive feedbacks which imply that external disturbances will be reinforced and the system may switch to a completely different equilibrium. Such equilibrium may have totally different characteristics with a different supply of ecosystem services. A collection of studies dealing with this situation were put together in Dasgupta and Mäler (2004).

This is the case when there will exist thresholds, and when reaching such a threshold would cause a substantial change in the supply of ecosystem services. However, the present situation for the ecosystem may be that only large disturbances will cause the system to move to the threshold. The largest disturbance the system can manage without undergoing a major change is known as *resilience*. The larger the resilience is, the smaller is the probability that a disturbance will be large enough to move the system to the threshold. Thus, resilience has a value to society and should therefore be accounted for.

In Mäler and Li (2010), an analysis was done using a model with continuous time. In line with the general approach in that paper, we should present a derivation of the accounting price in a model with discrete time. However, we have not accomplished this as yet.

References

Allen-Wardel G et al (1998) The potential consequences of pollinator declines on the conservation of biodiversity and stability of crop yields. Conserv Biol 12:8–17

Aniyar S (2002) The impacts of changes in the size of a mangrove forest and in the property right system on the fishermens' rent. The ninth Ulvön conference on environmental economics. Ulvön, Sweden

Arrow K, Dasgupta P, Mäler K-G (2003) Evaluating projects and assessing sustainable development in imperfect economies. Environ Res Econ 26:149–187

Bertalanffy L (1938) A quantitative theory of organic growth (Inquires on growth laws II.). Hum Biol 10:181–213

Biosphere (2009) Encyclopedia Britannica 2009, Deluxeth edn. Encyclopedia Britannica, Chicago

Clark C (2010) Mathematical bioeconomics: the mathematics of conservation. Wiley, New York

Dasgupta P, Mäler K-G (2000) Net national product, wealth and social well-being. J Environ Dev Econ 5(1):69–93

Dasgupta P, Mäler K-G (eds) (2004) The economics of non-convex ecosystems. Kluwer Academic Publishers, Dordrecht

Hein L et al (2006) Spatial scales, stakeholders and the valuation of ecosystem services. Ecol Econ 57(2):209–228

Kremen C (2007) Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use changes. Ecol Lett 10:299–314

Mäler K-G, Li C-Z (2010) Measuring sustainability under uncertainty: a resilience pricing approach. Environ Dev Econ 15(06):707–719

Mäler K-G, Aniyar S, Jansson Å (15 July, 2008) Accounting for ecosystem services as a way to understand the requirements for sustainable development. PNAS 105(28):9501–9506

Mäler K-G, Aniyar S, Jansson Å (2010) Accounting for regulating services. In: Kumar PW (ed) Valuation of regulating services of ecosystems. Methodology and applications. Routledge, London/New York, pp 80–120

May R (1976) Simple mathematical models with very complicated dynamics. Nature 261:459–467

McYntyre NE, Knowles-Yanez K, Hope D (2000) Urban ecology as an interdisciplinary field: differences in the use of "urban" between the social and natural sciences. Urban Ecol 4:5–24

Mea ME (2003) Ecosystems and human well-being synthesis. Island Press, Washington, DC

Odum HT, Odum EC (2000) Modelling for all scales: an introduction to system simulations. Academic, San Diego

Paulsen SS (2007) Topics on the ecological economics of coastal zones: linking land uses, marine eutrophication and fisheries. Swedish University of Agricultural Economics, Uppsala

Raiffa H (1968) Decision analysis. Introductory lectures on choices under uncertainty. Random House, New York

Rickettes TH et al (2004) Tropical forest fragments enhance pollinator activity in nearby coffee crops. Conserv Biol 18(5):1262–1271

Russel C, Spofford O Jr, Kelly RA (1976) Environmental quality management: an application to the lower Delaware valley. Resources for the Future, Washington, DC

Sala OE et al (2000) Global biodiversity scenarios for the year 2100. Science 287:1770–1774

Steffan-Dewenter I, Müzenberg U, Bürger C, Thies C, Tscharntke T (2002) Scale-dependent effects of landscapes context on three pollinator guilds. Ecology 83:1421–1432

Stockholm Office of Regional Planning and Urban Transportation (2001) Regional development plan for Stockholm County http://www.stockholmsregionen2030.nu/english/index.html. Accessed 19 May 2006

Walter-Hellwig K, Frankl R (2000) Foraging habitats and foraging distances of bumblebees, bombus spp. (hym. apidae) in agricultural landscape. J Appl Entomol 124(7–8):299–306

Westphal C et al (2003) Mass-flowering crops enhance pollinator densities at a landscape scale. Ecol Lett 6:961–965

Xepapadeas A (2005) Economic growth and the environment. In: Vincent K-GM (ed) Handbook of environmental economics, vol 3. Elsevier, Amsterdam, pp 1219–1272

Valuing Regulating and Supporting Ecosystem Services of the Subtropical Estuaries of KwaZulu-Natal in South Africa

Jackie Crafford and Rashid Hassan

Abstract Supporting ecosystem services constitute essential intermediate inputs in the production of final ecosystem goods and services. Typical examples include primary production, nutrient cycling and photosynthesis. Another set of services known as "regulating services" control and normalise ecosystem functioning and thus insure the benefits supplied by ecosystems (MEA 2005; Perrings C. Int J Ecol Econ Stat 6:8–22 (2002); Barbier et al. 2009; Simonit and Perrings. Ecol Econ 70(2011):1189–1199 (2011)). In spite of their crucial role as the basis of all other provisions of nature, the literature on valuing such regulating and supporting services is sparse, leaving an important gap in our knowledge of sustainable management of ecosystems for human well-being. Efforts to improve our scientific understanding of the complex nature of the involved dynamics of socioecological interactions that characterise the role and value of these services are therefore necessary for prudent ecosystem management.

Keywords Estuaries ecosystem assets • Valuing ecosystem services • Ecological production functions

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1 Introduction

The present study is an attempt to contribute to such needed effort to develop and apply methodologies to support measuring of accounting prices for ecosystem assets (Mäler 1991; Barbier et al. 2009) to derive improved sustainability indicators for evaluation of economic performance. As an example, known production function formulations will be extended to value the contribution of regulating and supporting ecosystem services of the estuaries of KwaZulu-Natal (KZN) in South Africa. This will be achieved through establishing an explicit link between various estuarine habitat components and processes (physical structure, composition and functional ecosystem dynamics, e.g. type and area of habitat, species diversity, nutrient influx, water retention functions) and provision of the final service (i.e. fish biomass) directly usable by human society.

The next section presents the production function (PF) approach to environmental valuation of ecosystems and how it is extended in this study to control for the effects of ecological attributes of these systems. Section 3 presents the case study area where the developed ecological production functions are applied to value selected key regulating and supporting ecosystem services of the KZN estuaries. The empirical model for implementing the intended analysis is developed in Sect. 4. Section 5 presents and discusses results, and implications for policy and future research are drawn in Sect. 6.

2 The Production Function Valuation Approach

The theoretical foundations for the production functions approach (PFA) were pioneered by Mäler (1991) and have been applied to many case studies. PFA studies attempt to measure values of ecosystem services by quantifying their contribution as intermediate inputs (supporting and regulating ecosystem services) in the production or consumption of goods and services used by economic agents employing knowledge of ecosystem functioning and processes (Mäler 1991; Perrings 2006; Kinzig et al. 2007, Acharya and Barbier 2000, Barbier 2003; Barbier et al. 2009). In its simplest form, such a production function would model as dependent/response variable an ecosystem service (e.g. biomass) as a function of one or more ecosystem component (stocks) and/or process indicators as independent/influencing factors. Examples of attempts to develop and apply ecological production functions in the fishery literature include the work of Barbier (2007) and Rodwell et al. (2003) on integrating habitat quality as input into fisheries production models, marine reserves enhancing the 'insurance value' of protecting commercial fish species (Mardle et al. 2004; Sumaila 2002) and nutrient enrichment in the Black Sea affecting the balance between invasive and beneficial species (Knowler et al. 2001).

Although the production function (PF) approach is theoretically sound, our understanding of the linkages between management actions and ecosystem functioning, their linkages to the supply of ecosystem services and linkages to the value of these services to humans remain weak (Barbier et al. 2009). Several studies used PF models to value how a change in estuarine habitat components and functions affects commercially harvested fish (Lynne et al. 1981; Ellis and Fisher 1987; Freeman 1991; Sathirathai and Barbier 2001).

Commonly used PF formulations define the following fishery production function:

$$H = h\left(E_i, S\right) \tag{1}$$

where H is the marketed harvest of the fishery, E_i measure effects of standard inputs of a commercial fishery (e.g. effort, costs) and S denotes estuarine ecosystem stock (asset) characteristics (environmental asset quality). In the literature, S has predominantly been treated as habitat area as, for instance, in the work of Barbier (2000, 2003, 2007) who used adjacent coastal wetland or mangrove areas to control for habitat effects. Habitat area is, however, an inadequate indicator of the environmental quality and hence ecosystem services supplied by estuaries. Estuarine functioning is characterised by a complex set of ecosystem components and processes, which, together, regulate and support the production of provisioning and cultural services supplied by an estuarine system. The components are, for the most part, physical characteristics of the estuary. The processes relate mainly to the exchange of water, through terrestrial and marine inflows resulting from daily, seasonal and annual tidal, flood and storm events. Productive estuaries generally have high-nutrient content, high water body retention times and suitable substrate where nutrients can accumulate and thus feed the benthic and higher species within the system. We can accordingly redefine Eq. 1 to be

$$H = h\left(E_i, S\left(A_i\right)\right) \tag{2}$$

where Ai refers to indicators of the species, components and processes regulating estuarine ecosystem functionality. Under economic optimization behavioural assumptions, the value of any of the specified ecosystem components of Eq. 2 can then be derived from the profit maximisation or cost minimization decision problem of the optimising agent

$$\text{Profit} = P * H - C\left(E, H\right) = P * h\left(E_i, S\left(A_i\right)\right) - C\left(H, E\right) \tag{3}$$

where P is price of the final product (fish), C is the cost of fishing, which is a function of the levels of harvest H and fishing efforts E. Optimality conditions will require equality of marginal costs ($\delta C/\delta X$) and marginal benefits ($P^* \delta H/\delta X$) from fishing. One can then derive the marginal contribution (value) of any ecosystem service of interest indirectly from these optimality conditions, i.e. the marginal value of a biodiversity supporting service xi would be

$$\text{MVP}_i = P * \left[\delta h / \delta S\right] * \left[\delta S / \delta x_i\right] \tag{4}$$

where MVP_i is the marginal value product of factor *i*, which represents the accounting price of this ecosystem service or asset quality since these are natural assets' services typically not acquired at a market cost through trade.

3 The Estuarine Ecosystem of KwaZulu-Natal

The east coast of South Africa forms a bight (a gentle inward curve of the shoreline) between Cape St. Lucia and Durban, known as the KZN Bight. Seaward of the KZN Bight lies the Thukela Bank section of the coastal shelf (Fig. 1). The Agulhas Current, one of the major western boundary ocean currents of the world, plays a key role in the functioning of this system and dominates the oceanography of the Thukela Bank in several ways (CSIR 1998). Shelf waters carry higher plankton biomass than oceanic waters. The KZN coast lies within a recognised area of fish endemism which lies within the Indo-Pacific region of high fish species diversity. More than 73% of the approximately 200 fish species from over 150 families are primarily Indo-Pacific, 16% are endemic to the subtropical estuaries of the KZN coast, a number of which are classified as endangered or threatened by the IUCN Red List of Threatened Species (Van der Elst 1988; Weerts 2002). And the majority of these species are strongly associated with estuaries (Whitfield 1998 in Weerts 2002).

The numerous rivers entering the sea discharge large quantities of sediment into the sea, resulting in physical conditions unsuitable to coral reefs, but that settle to provide important habitat to benthic organisms. Terrestrial plant material is also washed down rivers, which, together with decaying seaweed, is macerated by wave action and provides a major input of nutrients to filter feeders such as mussels, oysters and ascidians (Van der Elst 1988).

The KZN fish fauna includes resident fish that spawn locally and have local nurseries (many of which are estuaries), pelagic summer migrants from tropical Indian Ocean waters that spawn in the tropics and have distant nurseries, demersal (benthic feeders) or estuary summer migrants from south-eastern Mozambique that spawn locally and have local nurseries (many depend on the littoral and estuary environments for the recruitment of their juveniles) and winter migrants from Cape waters once the temperatures drop below 21 °C that are mostly endemic to South African waters, spawn locally and use the Agulhas Current as a dispersal mechanism to transport eggs and larvae to the nutrient-rich Cape waters and nurseries (Van der Elst 1988; Weerts 2002).

A number of biotic and abiotic components are typical to the type of estuarine ecosystem of KZN. Key among those are (a) mangroves and near-shore terrestrial habitats, (b) tidal flats (intertidal and shallow sub-tidal flats of both sandy and muddy substrates), (c) upper estuary areas, (d) freshwater system of lakes and pans, (e) rivers providing freshwater and nutrient inflow, (f) deep water channels and (g) papyrus swamps, secondary vegetation and coastal dunes.

The main body of mangroves in the KZN estuarine metasystem comprises white mangrove (*Avicennia marina*) occurring on the fringes of selected estuaries, the largest of which (about 1,200 ha) is in the Mhlathuze estuary. Tidal flats, both intertidal

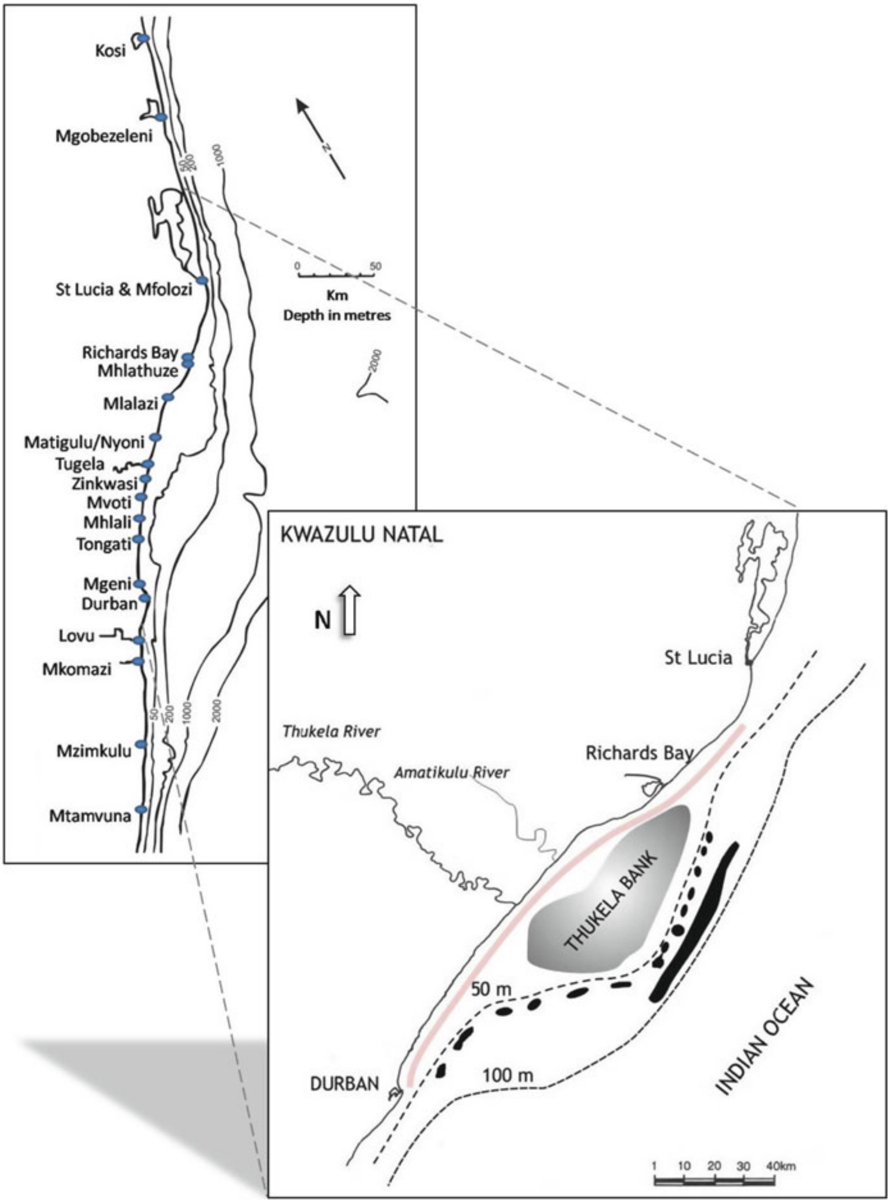

Fig. 1 KwaZulu-Natal coastline showing the location of large estuaries (>100 ha) with an inset of the Natal Bight (*shaded pink*), Thukela Bank (*shaded grey*), reef areas (*black*) and −50 m isobaths (Adapted from Forbes and Demetriades 2005)

and sub-tidal, comprise the most extensive habitat in the metasystem. These, together with the upper estuary areas, bear productive benthic faunas and are the important nursery habitats of juvenile estuary-dependent fish, crustacea and other marine animals, and also of waterbirds and fish that feed on them (Weerts et al. 2003; Cyrus and Wepener 1998a). Rivers and estuarine canals supply fresh water runoff and nutrients into the estuaries. They are often lined with white mangroves and together with the tidal flats support the most productive area in the KZN coast in terms of crustacean abundance and diversity (Weerts 2002; Weerts et al. 2003).

Today, there are small remnants of the once extensive papyrus swamps on the floodplains and upstream of various estuaries. Due to canalization and deliberate diversion from swamp areas, much of the functional value of papyrus swamps “such as flood attenuation, sediment trapping, water storage and water cleansing have been seriously impaired” (EAS 1993). These swamps are, in most cases, considered to no longer be performing the same ecological function as before (Dr. Allan Whitfield, personal communication). Deep water channels support relatively little benthos because tidal exchange maintains a low-nutrient seawater body in them and because of low light levels on the bottom benthic zone.

4 Specification of the Empirical Ecological Production Function for the Fisheries of KZN Estuaries

In Eq. 2 above, the environmental quality input variable *S* is defined to depend on structural, compositional and functional/process components of the estuarine ecosystem asset. Structure is the physical organisation or pattern of a system, from habitat complexity as measured within communities to the pattern of patches and other elements at a landscape scale. Composition has to do with the identity and variety of elements in a collection and includes species lists and measures of species and genetic diversity. Function involves ecological and evolutionary processes, including gene flow, disturbances and nutrient cycling.

Whitfield (2000) demonstrated that biological production of fish stock is driven primarily by nutrient influx into the system. As discussed earlier, the eastern coast of Southern Africa is located in a high-nutrient-depleted section of the Indian Ocean and is thus believed to rely heavily on nutrient influx from terrestrial runoff (Connell (2007). The nutrient load is supplied from approximately 8 million hectares of terrestrial catchment area along the KZN coast and enters the fish production system through the ecosystem of subtropical 72 estuaries comprising approximately 43,000 ha of estuarine area. Estuaries are important structural or physical components of the fish production system, for two reasons. Firstly, they serve as nutrient traps during the periods between flood events and thus regulate nutrient supply into the system. This ecosystem service is thus characterised not only by the volume of nutrient influx into a particular estuary but also by the water retention time inherent to every individual estuary. Water retention time is a factor of the physical attributes of the particular estuary, such as the dimension of the water body, the volume of daily tidal exchange and the physical complexity of the system which creates eddies and settlement areas within the estuary. Secondly, estuaries provide physical infrastructure that is fundamental to the life cycle dynamics of nearly half the fish [and prawn] species caught commercially and for recreational purposes along the KZN coast. This physical infrastructure relates to various components of habitat where nutrients are trapped and thus enters the food chain through various levels of benthic species. Such habitats, primarily shallow sub-tidal sand and mud flats, as well as mangrove swamps, thus serve a dual purpose in that they provide various levels of physical security to various fish and prawn species during the juvenile phase of their life cycles. Such species spawn on the Tugela Banks and/or the near-shore surf zones, from where the juveniles find their way into estuaries until maturity. Stable estuarine habitats provide both food and physical security from predators who are prevented from access either through physical encumbrances or salinity gradients.

Estuaries are also prone to degradation due to various forms of human activity, relating to various forms of water pollution, physical destruction and other disturbances. As a result, various estuarine ecology studies have developed indicators of human disturbance through rating the condition of estuaries. It is therefore important to control for the effect of anthropogenic disturbances and their resultant degradation of system quality conditions. In addition to such key structural and functional characteristics, compositional element of an estuarine ecosystem is crucial for biological production of fish. There is strong evidence in the literature that a higher system resilience, and thus productivity, is achieved through higher levels of species diversity. Species-area studies further suggest that species diversity is significantly related to the available area of suitable quality habitat.

4.1 The Data and Variables Included in the Empirical Analysis

Two data sources were available for this study to measure the relationship between fish biomass production and above ecosystem characteristics of the KZN estuaries. Both data sets contain cross-section data collected independently by two research teams from subsets of the east coast subtropical estuaries of South Africa. One dataset was compiled by Dr. George Begg and was published in hard copy as **The Estuaries of Natal Volumes 1 and 2** (Begg 1978, 1984). This data was based on extensive environmental monitoring carried on 72 estuaries during the late 1970s and early 1980s. A second data set was compiled by Dr. Trevor Harrison for the State of the Estuaries Report for the Department of Environmental Affairs in 2000 (DEA 2004). The Harrison data evaluated 47 estuaries along the KZN coast.

The combined Begg-Harrison (B&H) cross-section data recorded in excess of 120 measures of various estuary components and processes. Both B&H conducted extensive trawl samples and recorded the abundance (biomass) and number of fish species in the surveyed estuaries. Several other compositional and structural characteristics of the KZN estuaries were measured in the Begg-Harrison cross-section data. Key among those are (a) estuary depth and shoreline length used as proxies for the extent of tidal flat area, (b) the type of estuary reflecting degree of openness of the estuary and (c) rating of the general condition of the estuary. These variables all have important functions in the production of estuarine ecosystem services. The degree of openness measures the connectivity of an estuary to the marine ecosystem. Highly connected estuaries (i.e. which are open for 12 months of the year) will be more productive than estuaries that are only temporarily open and would be expected to have higher species richness. The shoreline length (in kilometres) and area of shallow sub-tidal flats (in hectares) are both measures of habitat area. In estuaries, nutrients collect on shallower habitats which are thus more productive. Shallower zones also provide physical protection against predator species. The condition of the estuary is rated through an index which measures its general health and levels of human disturbance (e.g. pollution, physical alterations). Although the B&H data do not contain measures of terrestrial runoff, they contain dissolved oxygen measurement in mg/L which is indirectly proportional to nutrient content, as higher dissolved oxygen in these estuaries is commonly associated with lower nutrient load conditions (Chambers et al. 2006). This attribute of conductivity is used as proxy indicator of estuaries' condition.

4.2 The Empirical Model

Available data as described above allowed specification of the following system of ecological PF equations:

$$\mathrm{BIOMF}_i = \alpha_0 + \alpha_1 * \mathrm{SPECS}_i + \alpha_2 * \mathrm{TYPE}_i + \mu_i \tag{5}$$

$$\mathrm{SPECS}_i = \beta_0 + \beta_1 * \mathrm{COND}_i + \beta_2 * \mathrm{SHRLN}_i + \beta_3 * \mathrm{TYPE}_i + \beta_4 * \mathrm{NUTRI}_i + \varepsilon_i \tag{6}$$

where BIOMF_i measures the total weight of fish caught in grammes per trawl sample in estuary *i* and SPECS_i is the number of fish species in the trawl sample from estuary *i*. COND_i is an index of the condition of estuary *i* measured through the Harrison-Whitfield multi-metric estuary index (Harrison and Whitfield 2004); SHRLN_i measures the length of estuary *i* shoreline in metres. TYPE_i is an index that refers to the classification of estuary *i* as defined by the Whitfield physical classification of estuaries (see Table 1 below); NUTRI_i is an index of the nutrient capacity of the estuarine system and was calculated by dividing the catchment area (in km^2) by the volume of the estuary waterbody (in m^3); α_j and β_j are model parameters and μ_i and ε_i are the residual error terms.

Equation 5 specifies the biological production of fish biomass to be a function of the number of species present in the system (diversity composition effect) and the type of estuary.

In Eq. 6, the number of species present in the system (species richness) is modelled to vary with differences in key ecosystem component and process variables: estuarine condition as measured by the Harrison-Whitfield multi-metric estuary index is a good indicator of the overall ecosystem health of an estuary. Shoreline

Table 1 Whitfield's (1992) physical classification of estuaries

Type	Index	Tidal prism	Mixing process	Average salinity[a]
Estuarine bay	5	Large (>10 × 10^6 m^3)	Tidal	20 to 35
Permanently open	4	Moderate (1–10 × 10^6 m^3)	Tidal/riverine	10 to >35
River mouth	3	Small (<1 × 10^6 m^3) negligible	Riverine	<10
Estuarine lake	2	(<0.1 × 10^6 m^3) absent	Wind	1 to >35
Temporarily closed	1		Wind	1 to >35

[a]Total amount of dissolved solids in water in parts per thousand by weight (seawater = ~35)

Table 2 SURE method estimates of parameters of the system of Eqs. 5 and 6 for the linear model

	Coefficient	Std. error	*t*-Statistic	Prob.
α_0	19,067.46	6,000.157	3.177827	0.0021
α_1	611.4853	134.8634	4.534108	0.0000
α_2	6,138.141	2,225.491	2.758106	0.0071
β_0	26.50365	2.759125	9.605816	0.0000
β_1	0.314998	0.075095	4.194630	0.0001
β_2	0.000414	4.26E−05	9.715507	0.0000
β_3	8.312492	1.345027	6.180166	0.0000
β_4	0.017566	0.007376	2.381606	0.0195

Determinant residual covariance 2.58E+09

Equation 5: $\text{BIOMF}_i = \alpha_0 + \alpha_1 * \text{SPECS}_i + \alpha_2 * \text{TYPE}_i$

Adjusted R-squared 0.428138

Equation 6: $\text{SPECS}_i = \beta_0 + \beta_1 * \text{COND}_i + \beta_2 * \text{SHRLN}_i + \beta_3 * \text{TYPE}_i + \beta_4 * \text{NUTRI}_i$

Adjusted R-squared 0.733166

length is a proxy for the extent of tidal flat area, which is an indicator of the area of shallow sub-tidal flats area and which is important fish feeding habitat. Estuarine type is important because larger estuaries that are permanently open to the sea generally provide more diverse habitat and improved connectivity between marine and estuarine habitats and thus allows for a greater number of fish species. The nutrient capacity is important because estuaries with larger catchment areas (within the same metasystem) would produce more detritus and thus be more nutrient rich per unit of water volume and thus have higher productivity.

5 Results and Discussion of the Empirical Analysis

The empirical model specified in Eqs. 5 and 6 is estimated as a system of equations using the seemingly unrelated regression estimation (SURE) procedure of Zellner (1962) under the assumption of cross-equations error correlations. Two functional form specifications have been tested: the linear and Cobb-Douglas (double log) forms. The linear function gave the best statistical fit. Results of the SURE of the linear system are presented in Table 2.

The influences of all factors in the linear SURE model are of high statistical significance and all show the expected sign, i.e. direction of effect. Equation 5 relates the number of species ($SPECS_i$) and the estuarine type ($TYPE_i$) to fish biomass ($BIOMF_i$), and these two variables explained 43% of the variation in fish biomass ($BIOMF_i$).

As expected, fish biomass in an estuary increases with increasing number of fish species at 99.9% confidence limit. This result is of high importance as it provides strong scientific evidence that biodiversity, as measured by species abundance, is positively correlated with biomass abundance and thus the productivity of the estuarine system. Similarly, levels of fish biomass in an estuary are higher in larger estuaries with a higher degree of openness, as measured by the Whitfield physical classification index of estuaries ($TYPE_i$ was significant at a 99.9% confidence limit).

Equation 6 explores ecosystem component factors that affect fish species abundance which explained more than 70% of the variation in fish species. The area of shallow, sub-tidal flats, as measured by shoreline length ($SHRLN_i$), estuarine type ($TYPE_i$) and the nutrient capacity ($NUTRI_i$) of the estuary, was all highly statistically significant variables (99.9, 99.9 and 95% confidence limits, respectively). This means that larger estuaries with larger shallow, sub-tidal flat habitats, higher degrees of openness and larger nutrient capacities will accommodate a richer diversity of fish species. The estuarine condition as measured by the Harrison-Whitfield multimetric estuary index and which use a multiple of indicators ($COND_i$) showed a strong positive correlation with species diversity and was significant at the 99.9% confidence limit.

Parameter estimates reported in Table 2 can now be used to compute the accounting prices (marginal values) of the various components of the estuaries ecosystem of KZN as defined in Eq. 4 and accordingly derive values of the estuaries ecosystem various asset constituents.

6 Conclusions, Implications and Limitations of the Study

This study applied the production function approach to estimate shadow values (accounting prices) of the KZN estuaries ecosystems. The study used two available cross-section data sets independently collected on various structural, compositional and functional/process components of the estuarine ecosystem asset and fish biomass. A two equations system of ecological production functions has been empirically specified to measure the effects of these ecosystem structure and composition attributes on fish biomass production in the estuary. Using the SURE method, the estimated system has given highly significant statistical performance and parameter effects consistent with scientific knowledge. The results provided compelling evidence of the importance of estuarine structure and composition on fish biodiversity and biomass. These results are of great importance to estuarine management, harbour development and planning, and various other coastal sustainable development strategies and policies.

The study, however, experienced some limitations mainly due to lack of appropriate data. It is expected that seasonal effects related to, for instance, fish population size and rainfall events would explain a large component of the variation in fish biomass. The modelling of such relationships would require time series data sets, which were not available for the purposes of this study. The study also did not have access to the right data to allow for controlling for the effects of economic efforts (e.g. economic inputs) on fish biomass harvesting. Accordingly, one would be overestimating the marginal effects and accounting prices based on the derived estimates of the effects of estuaries ecosystem assets structure and composition attributes to compute shadow values of their services.

References

Acharya G, Barbier EB (2000) Valuing groundwater recharge through agricultural production in the Hadejia-Jama'are wetlands in northern Nigeria. Agric Econ 22:247–259

Barbier EB (2003) Habitat-fishery linkages and mangrove loss in Thailand. Contemp Econ Policy 21(1):59–77

Barbier EB (2007) Valuing ecosystem services as productive inputs. Econ Policy 22:177–229

Barbier EB, Baumgärtner S, Chopra K, Costello C, Duraiappah A, Hassan RM, Kinzig AP, Lehman M, Pascual U, Polasky S, Perrings C (2009) The valuation of ecosystem services (Chapter 18). In: Biodiversity, Ecosystem Functioning, and Human Wellbeing: An Ecological and Economic Perspective. Editors: ShahidNaeem, Daniel E. Bunker, Andy Hector, Michel Loreau, and Charles Perrings. Print publication date: 2009. Print ISBN-13: 9780199547951. Published to Oxford Scholarship Online: September 2009

Begg GW (1978) The estuaries of natal. NTRP report, vol 41, Natal Town and Regional Planning Commission, Pietermaritzburg

Begg GW (1984) The estuaries of natal. Part 2. Supplement to NTRP report vol 41. NTRP Report, vol 55, Natal Town and Regional Planning Commission, Pietermaritzburg

Chambers PA, Culp JM, Glozier NE, Cash KJ, Wrona FJ, Noton L (2006) Northern rivers ecosystem initiative: nutrients and dissolved oxygen – issues and impacts. Environ Monit Assess 113:117–141

Connell A (March 2007). Marine fish eggs and larvae from the east coast of South Africa. Durban. http://www.fisheggsandlarvae.com/. Accessed 11 Nov 2008

CSIR (1998) Environmental impact assessment for the proposed exploration drilling in petroleum exploration lease block 17/18 on the continental shelf of KwaZulu-Natal. CSIR, Stellenbosch

Cyrus DP, Wepener V (1998a) The enhancement and conservation potential of the 'mangroves and mudflats' area in Richards Bay Habour, including recommendations for the development of a new sand spit within the area. Coastal Research Unit of Zululand (CRUZ) investigation report no 56, University of Zululand, Mtunzini

DEA (Department of Environmental Affairs) (2004) South African National Spatial Biodiversity Assessment. Technical Report. Volume 3: Estuary Component. http://bgis.sanbi.org/nsba/NSBA_Vol3_Estuary.pdf

EAS (1993) Initial assessment concerning the potential environmental impact of constructing berths 605 and 606 at the Port of Richards Bay. Report prepared for Protekon (KwaZulu-Natal). EAS.

1996. An environmental review of the master plan for the Port of Richards Bay. EAS Investigational report no 89, 62p, Environmental Advisory Services, Dayton
Ellis GM, Fisher AC (1987) Valuing the environment as input. J Environ Manage 25:149–156
Forbes AT and Demetriades NT (2005) A review of the commercial, shallow water penaeid prawn resource of South Africa: status, fisheries and aquaculture. Specialist Report, April 2005. Prepared for Ezemvelo KZN Wildlife. Marine and Estuarine Research, South Africa
Freeman AM III (1991) Valuing environmental resources under alternative management regimes. Ecol Econ 3:247–256
Harrison TD, Whitfield AK (2004) A multi-metric fish index to assess the environmental condition of estuaries. J Fish Biol 65(3):683–710
Kinzig A, Perrings C, Scholes RJ (2007) Ecosystem services and the economics of biodiversity conservation. Arizona State University, Phoenix. http://www.public.asu.edu
Knowler D, Barbier EB, Strand I (2001) An open-access model of fisheries and nutrient enrichment in the Black Sea. Mar Res Econ 16:195–217
Lynne GD, Conroy P, Prochaska FJ (1981) Economic value of marsh areas for marine production processes. J Environ Econ Manag 8:175–186
Mäler K-G (1991) The production function approach. In: Vincent JR, Crawford EW, Hoehn JP (eds) Valuing environmental benefits in developing countries. Special report 29. Michigan State University, East Lansing, pp 11–32
Mardle S, James C, Pipitone C, Kienzle M (2004) Bioeconomic interactions in an established fishing exclusion zone: The Gulf of Castellammare, NW Sicily. Natural Res Model 17(4):393–447
MEA/Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: current state and trends, Volume 1. Hassan R, Scholes R, Ash N (eds). World Resources Institute. Island Press, Washington
Perrings C (2006) Ecological economics after the millennium assessment. Int J Ecol Econ Stat 6:8–22
Rodwell LD, Barbier EB, Roberts CM, McClanahan TR (2003) The importance of habitat quality for marine reserve – fishery linkages. Can. J. Fish. Aquat. Sci. 60: 171–181 (2003)
Sathirathai S, Barbier EB (2001) Valuing mangrove conservation in Southern Thailand. Contemp Econ Policy 19:109–122
Sumaila UR (2002) Marine protected area performance in a model of a fishery. Nat Res Model 15(4):439–451
Van der Elst R (1988) Shelf ichthyofauna of natal. In: Schuman EH (ed) Coastal ocean studies off Natal, South Africa. Springer, New York, pp 209–225
Weerts SP (2002) Habitat utilisation by juvenile fishes in Mhlathuze estuary and Richards Bay Harbour. MSc thesis. Department of Zoology, University of Zululand, Zululand
Weerts SP, Cilliers G, Cyrus DP (2003) Estuarine macrocrustacea of Richards Bay Harbour, South Africa, with particular reference to the penaeid prawns. Afr Zool 38(2):285–296
Whitfield AK (1992) A characterisation of southern African estuarine systems. S Afr J Aquat Sci 12:89–103
Whitfield AK (1998) Biology and ecology of fishes in southern African estuaries. Ichthyological Monographs of the J.L.B. Smith Institute of Ichthyology, no 2, 223p, Grahamstown
Whitfield AK (2000) Available scientific information on individual estuarine systems. WRC. Report no. 577/3/00. Water Research Commission, South Africa
Zellner A (1962) An efficient method of estimating seemingly unrelated regression equations and tests for aggregation bias. J Am Stat Assoc 57:348–368