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ACCOUNTING FOR FOREST RESOURCES IN ZIMBABWE

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EXECUTIVE SUMMARY

The major motivation for this study comes from a growing awareness among economists that standard measures of national income reported in the System of National Accounts (SNA) suffer several shortcomings as measures of economic welfare. An important problem is that the standard measures do not reflect the short and long term economic impacts of environmental degradation and natural resource depletion. Depending on the nature of the interaction between the economy and the environment, adjustments may be needed to either expand the definition of national well-being and/or to seek a summary measure of future well-being. This paper applies some of the theoretical adjustments suggested in the natural resource accounting literature to the forestry sector in Zimbabwe. Forestry is an appropriate variable to focus on. The country's forest resources cover approximately 66 percent of the total land area. Like many other countries in sub-Saharan Africa, forest stocks generate a wide range of timber and non-timber products and services directly and indirectly benefiting the population. According to the official national accounts figures for Zimbabwe, forests contribute significantly to the economy, accounting for on average 3% of gross domestic product (GDP) and employing 8% of the total people in the manufacturing sector. These figures are likely to understate the true contribution of forests to national income, wealth and welfare largely because several of the high-value tangible and intangible benefits/losses and value of standing stocks of forest resources are not accounted for. As well as building physical stock accounts for both natural and commercial forests, the study establishes monetary values for a number of major products and services of the forests.

The major forest plantation species grown in Zimbabwe are *Pinus patula, P. elliottii* and *P. taeda, Eucalyptus grandis, E. cloeziana* and *Acacia mearnsii.* While the SNA would capture the annual depreciation of harvesting and processing equipment used to manufacture commercial wood products and commercial logging of fuelwood, it does not capture the depreciation of the natural capital (the forest stocks) upon which subsequent commercial uses are based in the asset accounts balance sheet. The first task was then to construct physical accounts for commercial forestry. The relationship

between standing volume per hectare (net of defect) and age for the different species was estimated using growth functions used for South Africa and Swaziland in similar work. The changes due to economic activity refer to production activities such as harvest, harvest damage, and afforestation that affect the stock (decrease/increase) of forests. Additions were made of growth calculated using the timber growth models applied to all age groups of all tree species standing in the base year. Replanting of harvested land and new afforestation were entered as the zero-one year age group for the respective year in the growth calculations. Commercial timber stocks show a steady decline over the whole period. It is clear that reductions to timber stocks due to harvest, cyclone, resettlement, and fire exceeded additions from growth and afforestation/replanting, leading to net depletion of stocks.

As well as creating physical timber accounts for commercial forestry, the study also used the environmental accounting approach to obtain values of forest stocks for commercial forestry, using both the change in asset value and the net depletion method. The data required for the estimation include costs of harvesting, the discount rate and harvest volume data. The estimates from the net depletion method differ from the change in asset values. The net depletion method tends to overstate both the appreciation of young forests and the depreciation of mature forests by a factor of 1.2 on average. Because the net depletion method tends to overstate both the appreciation and depreciation of forests, the biases are not offsetting and can be serious. The overall bias appears to be largely driven by two separate factors: assumptions about forest rotation age and choice of the discount rate.

National accounts only measure market-based transactions and exclude consumptive uses such as domestic fuelwood cut by villagers, which occur outside the market place. No accurate economic value has been established for these goods and services but case studies are used to provide some point estimates. A modified contingent valuation study (CVM) for 1994 estimated the mean direct and indirect values of a range of timber and non-timber products in natural woodlands of Zimbabwe at Z$700 per hectare per year. Based on this figure (and mindful of many caveats about extrapolating the very specific results), the total stock value of indigenous woodlands can be crudely estimated at Z$14.7 billion, which translates to 33% of overall GDP for that year. This figure is an order of magnitude estimate only. It was based on a specific study in one small area of the country. More accurate estimates of woodland values require extensive CVM research across a wider range of geographic areas and forest types.

Also in this study, an effort to build in values for ecological services such as carbon sequestration and water abstraction for natural forests was made. Although carbon sequestration may not have immediate productive effect for households in the rural areas of Zimbabwe. In the long run it impacts negatively on productivity. Such losses will have general equilibrium effects mainly through links with agriculture, resulting in relative price shifts which necessitate inter-sect oral factor substitutions, changes in household income and consumption patterns, as well as affecting industries with strong links to agriculture. Based on a previous study of Zimbabwe, the net carbon stock stored in the form of biomass is assigned an economic value of Z$60 per hectare per year, which translates to 1.5% of overall GDP and 9.4% of agricultural GDP in 1997. This is the contribution to other sectors' GDP from forestry that is not explicitly acknowledged in the SNA. At the global level, however, if the estimated mean annual increment of 47 million tonnes in natural vegetation due to the growth of the remaining stock is correct, then Zimbabwe would be a net emitter of carbon (25,462 Gg CO_2 equivalents) rather than a net sink. Clearly, given the relatively extensive woodland cover across the country, Zimbabwe has the potential to be a carbon sink, but current pressures for more agricultural land and for wood for various purposes, including fuelwood, make this unlikely.

The price of water in the natural woodlands and forests (de-coupled from the vegetation-hydrology complexities) through its effect on production, using the specific methods, data and assumptions outlined in the study, is Z$96.60 per hectare per annum. Scaling this up to the national level gives an aggregate figure of Z$2.03 billion, which amounts to about 2.5% of GDP or 15% of agricultural GDP. In one sense these values provide an estimate of how the contribution to national well-being of other non forestry sectors and agriculture in particular, is currently overestimated in the SNA as a result of not paying for inputs from the forestry sector.

We believe that the type of work contained in this study gives a clearer insight into two main policy issues in the forestry sphere: the issue of "benefit capture" and that of the "informational value" of forestry statistics. Starting with the former, the study illustrates that people do value forest products even though they may not be appropriately captured in the SNA. The values implied by these adjustments are quite significant. However, a major problem in most forest settings is one of benefit capture. For example, carbon values are essentially public goods values. They cannot be realised unless some form of market mechanism is created to compensate local people for the storage of carbon in their woodlands. However, even if such benefits generated for the public were paid for, there could also be the issue that these values may be somewhat smaller than the value associated with converting the woodland to agricultural production. The capture of benefits by local people is more direct in the case of conversion to agriculture and the benefits are higher. Thus, pressures for increased conversion of suitable woodland to agricultural land is expected to continue, even if carbon benefits can be paid to local people. This boils down to the issue of how to internalize environmental and social values in public policy and market behaviour, so that environmental protection is both cost-effective and equitable. This points to the need for valuing more accurately forest resources than is currently the case, as well as a greater need for more forestry-sector research on issues of resource benefit and cost sharing.

Concerning the latter issue, policy makers, particularly those in central planning and finance agencies, are not fully aware of the monetary value of forest stocks in the country. This information gap pertains to both direct-use values from products such as fuelwood, fruits, fodder, and building materials, and indirect values from ecological functions including reducing soil erosion and maintaining water quality. Without adequate information about the value of forests, policy makers are in a weak position to establish guidelines and institutions for addressing forestry management issues. The results in this study emphasise that using conventional SNA measures of welfare can be misleading. The consequences could be severe by sending the wrong signals to policy makers. Development could be biased towards short-term goals, which could lead the country down an unsustainable path. For planning purposes, especially in central government agencies such as Planning Commissions and Ministries of Finance, using results from environmental accounting provides a better measure of natural resource capital exploitation and the impact of drawing down this stock on the national economy.

1. Introduction

The growing awareness among economists that standard measures of national income such as Gross Domestic Product (GDP) and Gross National Product (GNP) suffer several shortcomings as measures of economic welfare has created the need for a revised framework of national accounting[1]. One of the major shortcomings that have been identified is in the interaction of the natural environment and the economy. Standard measures of national income in the system of national accounts (SNA) do not reflect the short and long term economic impacts of environmental degradation and natural resource depletion. Rising GNP can exaggerate long-term growth prospects in resource rich countries (Vincent 1997) or can exaggerate short-term improvements in welfare if it is accompanied by degradation of environmental quality[2]. Depending on the nature of the interaction between the economy and the environment, adjustments may be needed to GDP or Net Domestic Product (NDP)[3] or both. Thus, one aspect of this adjustment is to expand the definition of national well-being by expanding the measurement of consumption to include non-market environmental values, while another is to seek a summary measure of future well-being. With respect to the latter, economists have subsequently identified NDP and net investment (gross investment minus depreciation) as indicators of sustainability in countries with exhaustible natural resources (Weitzman 1976; Hartwick 1977; Dasgupta and Heal 1979).

An influential article by Repetto *et al.* (1989) sparked considerable interest in environmental adjustments to national accounts in order that they become better indicators of well-being. Since then, many studies have been conducted in many other countries (Sheng 1995; Newson and Gie 1996), while the World Bank and the United Nations have been sponsoring further conceptual and applied work in the area (Ahmad *et al.* 1989; Lutz 1993). There are many different adjustments to the national accounts proposed in the studies, many largely ad hoc (Vincent 1999a). At the same time, there is a growing body of

[1] GDP is economic activity generated within a nation's border while GNP is economic activity generated by a country's nationals.

[2] Strictly speaking, this is only true for impacts on non-market goods that are directly consumed.

studies that offers a green accounting framework that relies on economic theory (Hartwick 1992; Maler 1991; Vincent 1999a,b). This is a welcome development because empirical natural resource accounting studies based on economic theory are likely to generate internally consistent national accounts that are theoretically sound. This paper examines the empirical aspects of the theoretical adjustments described in these studies to forestry resources in Zimbabwe.

Forestry is an appropriate variable to focus on in Zimbabwe. The country is a land-locked Southern African country with a total land area of just under 391,000 km^2. The country's forest resources covering approximately 66 percent of the country's total land area fall into three broad categories namely; rainforest, indigenous woodlands and plantations (Table 1).

Table 1. Definitions of land-cover categories and the area covered by each land-cover type as determined from visual interpretation and mapping of land cover from Landsat 5 satellite imagery for 1992.

Land cover category	**Definition and notes**	**Area (km^2)**	**%**
Natural moist forest	Tree height >15m, canopy cover >80%	11,554	<0.1
Plantations	Areas planted with exotic tree species	155,853	0.4
Woodland	Tree height 5-15m, canopy cover 20-80%	20,797,405	53.2
Bushland	Tree height 1-5m, canopy cover 20-80%	4,974,130	12.7
Wooded grassland	Tree height 1-15m, canopy cover 2-20%	1,204,762	3.1
Grassland	Tree canopy cover <2%	689,208	1.7
Cultivated land	Includes disturbed and fallow lands	10,738,077	27.5
Rock outcrops	Large areas of bare rock with little or no plant cover	78,481	0.2
Waterbodies	Surface area of large dams	300,900	0.8
Settlements	Areas of human habitation, mainly urban areas	139,205	0.3

Source: Forestry Commission of Zimbabwe (1996).

[3] NDP is GDP minus depreciation of human made physical capital.

Woodland forms much of the natural vegetation, with bushland becoming more prominent in the drier regions in the south and west. Almost two-thirds of the country is covered with woodland (53%) or bushland (13%). Woodland cover is most extensive in the State Forest reserves, National Parks and Safari Areas, which together account for about 15% of the country. Grassland and wooded grassland occur in areas with restricted drainage and low daily minimum temperatures during the dry winter months (May-July). Natural forest is confined largely to sites in or adjacent to the mountains in the east: montane forest patches occur above 1,800 m a.s.l.; sub-montane forests cover the steep east-facing slopes below 2,000 m; and patches of lowland tropic forest occur in the valleys of the main rivers bisecting the Eastern Highlands (Chenje *et al.* 1998). The rainforests occupy 11,554 hectares (<0.1 percent of surface land area).

Like many other countries in sub-Saharan Africa, Zimbabwe's forest stocks generate a wide range of timber and non-timber products and services. The products include: fuelwood, fuelwood for charcoal making, sawn timber, pulpwood, building materials, wood for small artisinal crafts, fodder, fruits, honey, mushrooms, insects, bark for rope, medicines, leaf litter, and gum. The services include watershed conservation; carbon fixation; microclimatic stabilisation; and the provision of windbreaks, shade, soil stability and wildlife habitat. According to the official national accounts figures for Zimbabwe, forests contribute significantly to the economy, accounting for 3% of GDP and employing 8% of the total people in the manufacturing sector. These figures are likely to misstate the true contribution of forests to national income, wealth and welfare in the country largely because several of the high value tangible and intangible benefits/losses of forest resources described above are not accounted for in these conventional SNA measures.

This study is by no means the first of its kind in Zimbabwe. In the past several years, a limited number of studies have been done to illustrate how national income accounts can be modified to incorporate forestry-related activities. Adger (1993) completed a preliminary study on sustainable national income looking at deforestation for 1987. According to the study, the net reduction of forest stocks in 1987 amounts to 2.66 million tonnes. The study uses the net price method (also known as the net depletion method) to arrive at a depreciation figure of Z$93.77 million, which is 9% of agricultural GDP[4]. Crowards (1994) also carried out detailed work on forestry, soils, and gold reserves. With forests and woodlands, the objective of the study was to derive estimates of total rents attributable to depletion and adjust GDP values accordingly. Using the net price method to compute depreciation, the study finds that total rents due to forest and woodland depletion rise rapidly from 0.5% to 2.5% of agricultural GDP between 1980 and 1989. The study makes adjustments at the national (not regional) level. Building on these earlier works, Campbell *et al.* (1997) attempted to estimate values of economic depreciation of timber stocks using the more refined approach suggested in Vincent and Hartwick (1997). The main difference in approach is in the valuation of physical stocks by multiplying the net depletion of the resource by an estimate of rent. The previous studies had used average net price as a measure of unit rent while the latter study used marginal net price. The study finds that fuelwood adjustments represent about a 1% adjustment to GDP. Adding the value of fuelwood consumption to the national income measures of well being in Zimbabwe helps develop a better understanding of current well-being. A clear conclusion highlighted in the study is that the data are not available to satisfy the requirements of the marginal net price method proposed. Recommendations are made on a different and more useable form of data collection in the future.

Outside Zimbabwe, there has been considerable attention focused on accounting issues related to forests (Sheng 1995; Vincent 2000). In fact, in late 1996, the U.N. Food and Agriculture Organisation launched a project to

[4] The study goes on to look at soil erosion and mineral extraction. The difference in gross yield between soil conserving and non-conserving farms is used to approximate the value of erosion. From this estimate, the lost production in maize and cotton due to erosion of soil was estimated to be Z$203.23 million in 1987 prices, which accounted for 30% of agricultural GDP. Finally, for mineral resources, depreciation amounted to 20% of NDP in mining in 1990 and 27% in the first

prepare a handbook on forest accounting. A review conducted for that project identified more than 30 forest accounting studies that had been conducted in more than 20 countries since 1989 (Vincent and Hartwick 1997). Working on commercial forestry in South Africa, Hassan (2000) makes adjustments to the SNA measures at the national level for hydrological externalities, change in value of carbon storage in plantations and timber values. The cost of the water externality is equivalent to a quarter to a third of forestry value added[5]. Hassan also compares estimates based on the conventional net depletion method to ones from an expression that takes years to maturity into account and finds that the net depletion method yields estimates that are only about half as large as the more accurate ones. A similar study by Hassan *et al.* (2002) for Swaziland established that timber and carbon assets' values of cultivated timber omitted from the SNA would improve measures of gross domestic savings by 2.3%. Natural forests and woodlands were found to contribute benefits equivalent to 2.2% of total GDP. Working on old growth timber in the Brazilian Amazon, Seroa da Motta and Ferraz (2000) compare estimates of change in value from the net-price method (using average cost) to estimates from a generalized El Serafy (1989) method and find that the net price method tends to exaggerate the depreciation of nonrenewable resource assets. The authors treat forests as a non-renewable resource based on the reasoning that exploitation of timber derives from conversion of forestland to agricultural production and cattle ranching. As a result, land is usually fully converted and the possibility of second growth forest is almost nil. The authors find substantially low depreciation estimates as a consequence of the high timber stocks and scarcity perception by economic agents due to the lack of property rights in the region. Haripriya (2000) examines a broader range of forest values in addition to timber and fuelwood for Maharashtra state in India. She finds that the actual (market plus non-market) value-added associated with these products is approximately 150 percent larger than the sector estimate in the official gross state domestic product, while the reduction in value of stocks was found to be equivalent to a quarter to a third of value added in

quarter of 1991. The increase is attributable to a currency devaluation that encouraged extraction.

[5] The form that this externality takes is that timber plantations have reduced runoff and as a result reduced the amount of irrigation water available to downstream farmers.

forestry.

The rest of the paper is divided into five sections as follows. Section 2 discusses the needed adjustments to the SNA. Section 3 presents some empirical estimates of the magnitude of adjustments for natural forests while section 4 discusses similar adjustments for commercial forestry. Section 5 summarizes the main observations and discusses their policy relevance.

2. Adjustments to the Zimbabwean system of national accounts

In the forestry sector, the annual depreciation of harvesting and processing equipment used to manufacture commercial wood products is deducted when deriving net value added. The same would hold for commercial logging of fuelwood. However, the SNA does not capture the depreciation of the natural capital (the forest stocks) upon which subsequent commercial uses are based. This is a major omission that natural resource accounting attempts to correct in the SNA current account measures. National accounts only measure market-based transactions and exclude consumptive uses such as domestic fuelwood cut by villagers, which occurs outside the market place. This is another major omission that needs to be corrected. A better approach to valuing forests is to measure the net forest product by accounting for the depreciation of the natural capital stock and the non-market costs and benefits. Then, the national accounts can be adjusted to show the macro-economic values of forest stocks and the costs of deforestation from fuelwood consumption. Finally, forests as a source of environmental services that benefit (e.g. watershed protection which benefits downstream agriculture) are not explicitly accounted for in the SNA, and will entail sectoral readjustments that may change the balance of sectoral contribution to domestic output. In many instances these values are not appropriately attributed to the natural resource sectors supplying such intermediate services and as a result, sectoral contribution of using sectors is overestimated. Failure to adjust the SNA measures for such intermediate use values often means incorrect policy decisions may be made regarding forestry, resource management and land use.

The study does not address the impact of all possible adjustments to economic welfare. Instead, it focuses on net timber stock accumulation, nontimber products collected and consumed by households but not necessarily bought and sold in markets and certain services provided by the forestry sector that are not appropriately accounted for in the SNA. As shown in Vincent (1999b) the net stock accumulations entail adjustments to NDP to make it a better long-term measure of welfare while inclusion of nonmarket goods and services (including ecological services) entails adjustments to GDP in order that it becomes a better short-term measure of economic welfare. An adjustment to the level of GDP for non-market activities directly consumed requires estimation of non market values. There are a variety of methods for valuing amenities (e.g. contingent valuation, travel cost or hedonic pricing methods). As pointed out in Vincent (1999b), studies of amenity values typically focus on a particular site or species, which makes for a shaky foundation for constructing aggregate national estimates. Incorporating the nonmarket consumption of tangible nontimber products like fuelwood is much more feasible. If at least some of the nontimber product is purchased in a market, then one can use that market price to value similar non-market products (Hulkrantz 1992; Katila 1995; Vincent 1999b). If no market price is available, then one can use the idea that total consumption value is proportional to the opportunity cost of labour used in collecting those products; the shadow price of household labour times the amount of labour used (Campbell *et al.* 1997). Total consumption value exactly equals the opportunity cost of labour only if the marginal product of the forest equals zero, i.e., if the forest earns no rent (Peskin 1989; Katila 1995)[6].

The next set of adjustments is to NDP. NDP is conventionally computed as GDP minus the depreciation of human made capital. With forestry resources, NDP should also reflect changes in value of natural stocks (carbon and timber stocks). The treatment of SNA adjustments of carbon stocks differs in the

[6] The forest earns no rent when households have free access to the forest. When access is instead restricted, the consumption value of nontimber products is larger than the opportunity cost

literature. Some authors treat it as a stock variable so that net accumulation in carbon stocks is calculated and adjustments made to national savings and asset accounts. Alternative treatments of carbon sink functions consider this to be a flow service by forestry to receiving sectors, so that climate sensitive industries derive indirect benefits from carbon sequestered in forests, mitigating the climate change impacts of higher concentration of atmospheric carbon and its negative environmental consequences. In this case, the value of the flow benefits estimated need to be reallocated from source sectors to forestry.

The adjustment for timber stocks should ideally include both the processes that tend to increase the value of stocks as well as the processes that decrease this value (Vincent 1999a). The asset value of a natural resource is the discounted sum of net returns generated by the resource over time, while the net accumulation of the resource is the change in asset value from one period to the next, which can be positive or negative. Assuming a constant price of the extracted resource, the value of a natural resource at time t (V_t) is,

$$V_t = \sum \left\{ (1+r)^{t-s} \left[pq(s) - C(q(s)) \right] \right\} \qquad (1)$$

where p is the price of a unit of the extracted resource, q(s) is the quantity extracted in period s, C(q(s)) is total extraction cost and r is the discount rate. The magnitude in the rectangular bracket is current resource rent. The resource rent in period t, which is not discounted, can be separated from discounted sum so that asset value is,

$$V_t = p_t q_t - C(q_t) + \frac{V_{t+1}}{(1+r)} \qquad (2)$$

The change in the value of the natural asset (or net accumulation) is,

$$\Delta V_t = V_{t+1} - V_t \qquad (3)$$

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of labour, and in this case the opportunity cost of labour provides a lower-bound estimate of the consumption value of nontimber products (Vincent 1999b).

Inserting (2) into (3) results in,

$$\Delta V_t = \frac{rV_{t+1}}{(1+r)} - [p_t q_t - C(q_t)] \quad (4)$$

This is the fundamental equation of asset equilibrium (Hartwick and Hagemann 1993) and holds regardless of assumptions about the optimality of resource use or future paths of prices, costs or quantity extracted. It indicates that net accumulation consists of two forces: (i) the realization of current resource rent, which decreases asset value and (ii) the shifting of the discounted stream of future rents toward the present, which increases asset value (Vincent 1999a).

In continuous time, (4) simplifies to the negative of the product of marginal rent and quantity extracted as follows (see Hartwick 1977,1990; Hartwick and Hageman 1993),

$$\Delta V_t = -[p - C^{/}(q_t)]q_t \quad (5)$$

where $C^{/}(q_t)$ is marginal cost of extraction so that the expression in parentheses is the marginal rent associated with resource extraction. This is the net price method and derives resource rent (stumpage value) as the residual of the selling price of harvested timber after deducting all production, harvesting, transport and capital costs. Most applied work in resource accounting has used this expression, completely ignoring the capital gains term (Vincent 2000). This expression is the correct version of the net price method for a nonrenewable natural resource (the incorrect method is to multiply the negative of quantity extracted by average rent [price minus average cost]) and yields current resource rent (ignoring the effect of capital gains)[7]. Its advantage is that it allows one to calculate net accumulation using only current data on prices, marginal extraction costs and quantity extracted and does not need

[7] Use of average rent instead of marginal rent tends to overstate the reduction in asset values due to natural resource depletion (Vincent 1999a).

projections of future rent needed to calculate V_{t+1} in (4). This result requires the extraction cost schedule and the discount rate to be constant over time and the extraction programme to be optimal (Hotelling's r percent rule holds) (Vincent 2000).

These formulas do not apply automatically to renewable resources like forests because they fail to take into account renewability and that optimality conditions for renewable resources differ from those for nonrenewables (i.e., Hotelling's rule). The net price method can be modified in straightforward fashion to handle renewable resource stocks (Maler 1991). The result is the well-known net depletion method,

$$\Delta V_t = -[p - C^{/}(q_t)][q_t - g_t] \qquad (6)$$

where g is growth of the resource. Most forest accounting studies conducted up to 1997 applied the net depletion method (Vincent 1999a). According to Vincent and Hartwick (1997), this expression is valid for renewables if the resource in question can be harvested immediately. This is unlikely to be the case for forestry resources, which grow over a length of time before they mature so that at any point in time, the standing stock of a biological resource may consist of a mixture of different age groups. To allow for the age effect (remaining time in years to maturity) in the case of forest resource and correct for the fact that standing timber stocks vary in age and hence do not command the same value, Vincent (1999a) uses the change in asset value based on the present value criteria as follows:

$$\Delta V_T = -[p - C^{/}]V^h(Y)[1 - (1+r)^{t-T}]/r \qquad \text{Mature forest} \qquad (7)$$

$$\Delta V_T = [p - C^{/}]V^h(1+r)^{t-T}. \qquad \text{Immature forest} \qquad (8)$$

where T is the optimal rotation age (years), t is age of forest, V^h is volume of timber growth at optimal rotation age (in m^3/ha/yr), $C^{/}$ is marginal cost of harvesting timber (per m^3) and p is the price of harvested timber. This is considered to be the correct version of the net price method applied to renewable resources as it provides for variations due to natural regeneration and time to maturity of a resource (Hassan *et al.* 2002). It allows for additions to timber stocks through growth in immature forests and reductions due to harvesting of mature timber and natural factors (e.g. fire and disease). Again, this assumes that the forest is harvested sustainably at regular intervals, that intervals correspond to the optimal rotation age, price, marginal cost and the discount rate, and are all constant over time.

If the same assumptions made for the net price method hold with the exception that the harvest interval is not necessarily optimal, then the change in the asset value per hectare according to the El Serafy method for forests is (Vincent 1999a):

$$\Delta V_T = -[(pV - cV)]\left[\frac{[1-(1+r)^{1-T}]}{[1-(1+r)^{-T}]}\right] \qquad \text{Mature forest} \qquad (9)$$

$$\Delta V_T = [pV - cV]\left[\frac{[r(1+r)^{t-T}]}{[1-(1+r)^{-T}]}\right] \qquad \text{Immature forest} \qquad (10)$$

where p is the price of harvested timber (per m^3), c is average cost of harvesting (per m^3), V is volume of timber harvested (m^3/ha), r is the discount rate, t is the age of forest (years) and T is rotation age (not necessarily optimal) in years. This paper uses (9) and (10) to derive change in value of forests.

The determination of the appropriate social discount rate is full of controversy, and its value should lie between the social rate of time preference and the opportunity cost of capital. Given the debates surrounding discount rates and the sensitivity of model outcomes to the rate chosen we use different rates to test the sensitivity of the outcome. We will use a real discount rate in the range of 2-10%. Although this is arbitrary, it is clear from the literature that time preference is essentially a subjective issue, which at the national level (social rate of discount) really implies political choices that affect the inter-generational distribution of resources. At the best of times it would be pretty futile to try to derive a value for the social rate of discount from data (requires, in strict theoretical terms, assumptions like being on an optimal growth path). In Zimbabwe today, with such huge distortions, such an approach would be seriously misleading.

3. Indigenous forest physical and monetary accounts

3.1 Indigenous forest physical account

The area of indigenous forest is comprised of natural forests, woodlands, bushlands and wooded grasslands cover types as reflected in Table 2. The 1996 inventory data provided by the Forestry Commission indicates a total of just less than 27 million hectares of non-plantation forest in Zimbabwe. However, no corresponding information on timber volumes by species and age class is yet available. Thus, while a significant proportion of the country contains indigenous forest, especially in the woodland category (20-80% crown closure and 5-15 metres in height), there is no way to determine at this point, a corresponding level of forest stock volumes. The inventory data also do not classify these forests by dominant species that might help identify the various timber and non-timber products and services that flow from them.

Table 2. Forest resource classification by crown closure and height (1992)

Cover class	**Canopy closure (%)**	**Height (metres)**	**Area (000ha.)**	**% of forest land area**
Natural forests	80-100	15+	11.6	0.03
Exotic plantations	80-100	<1-15+	155.9	0.40
Woodlands	20-80	5-15	20 797.4	53.20
Bushlands	20-80	1-5	974.1	12.72
Wooded grassland	<20	1-15+	1 204.8	3.08
Total			27 143.8	69.43

Source: Forestry Commission, 1996

The following paragraphs, which follow from Campbell *et al.* (1997) do, however, provide more descriptive detail of what can be considered to be all forests outside of exotic plantations.

a) Miombo woodlands

The Miombo woodlands, locally known as the "musasa or munondo" are the most extensive woodland types occurring in most parts of the central watershed of the country. Miombo woodlands have diverse uses ranging from watershed protection, provision of soil fertility (leaf-litter), grazing and browsing, firewood, edible fruits, mushrooms, caterpillars, and timber. Thickets of miombo woodland hold little merchantable volume over bark except for small areas in demarcated forests. Furthermore, most of the forests have been converted into intensive agricultural areas.

b) Teak woodlands

The teak woodland, exclusive to Kalahari sands, is predominantly found in the demarcated forests of western Zimbabwe and parts of Hwange National Park. The woodland has a long history of management for commercial timber exploitation, wildlife utilisation, cattle grazing and water catchment. Degradation of the *Baikiaea* woodlands results in the formation of different vegetation types.

c) Mopane woodlands

Mopane woodlands are widespread in Zimbabwe and are often associated with low altitudes and, hot areas with sodic or alluvial soils. The woodlands can be divided into: the dry early deciduous (in north and west Zimbabwe); the dry deciduous (in Save Valley and Upper Limpopo); and the dry early deciduous shrubs (on basalt soils in southern Zimbabwe). Where *mopane* is dominant, it assumes economic importance especially as a source of browse for both domestic and wild animals. It is also a source of timber for craftwork, very good firewood, small household items, fence posts, hut poles, mine-props, railway sleepers, and sometimes parquet floors.

d) Acacia woodlands

In Zimbabwe, the Acacia woodlands occupy large tracts of land especially in dryer areas. Such woodlands are therefore important in pastoral systems as the trees provide browse (leaves, flowers and pods) and grasses for grazing.

e) Terminalia/Combretum woodlands

The *Terminalia/Combretum* woodlands are often found as tree-shrub combinations. In its natural state, *Terminalia* tends to be associated with other species (mainly *Burkea africana* on granite or gneossic soils) but tends to be dominant when it colonises burnt sites. It provides firewood, poles for construction and tool making. *Combretum* is an important component of this woodland type and provides similar products to *Terminalia*. However, this woodland type has been severely cut and most of the existing vegetation is secondary.

Table 3 gives the corresponding physical stock account for indigenous forestry in Zimbabwe. The information is obtained from a variety of sources scattered across research institutions in the country and refined in this study in order to make them coherent and consistent with other studies where possible. Protected areas are included in the figures.

Table 3. Stock accounts for indigenous forests in Zimbabwe

	1992	1993	1994	1995	1996	1997	1998	1999
Opening Stocks	1168	1165.34	1162.68	1160.02	1157.36	1154.7	1152.04	1149.38
Additions	44.34	44.34	44.34	44.34	44.34	44.34	44.34	44.34
Reductions	47	47	47	47	47	47	47	47
Net Changes	-2.66	-2.66	-2.66	-2.66	-2.66	-2.66	-2.66	-2.66
Closing Stocks	1165.34	1162.68	1160.02	1157.36	1154.7	1152.04	1149.38	1146.72

Source: Authors' calculations discussed in text.

The opening stocks represent the growing stock of resources present at the beginning of the accounting period, which is taken to be 1992 in this case. The starting point in computing opening stocks for indigenous forests was to divide the country into three broad categories of natural forest in 1992 as recommended by the Forestry Commission in that year[8] as follows:

Wooded grassland 1.2 million ha
Bushland 4.9 million ha

[8] Even this generalization is not all that appropriate because it lumps together forest communities which are quite different in their natural attributes; the classification criterion used here is only the relative tree canopy cover.

Woodland	20.7 million ha

Millington and Townsend (1989) suggest the following stocking densities for the three woody biomass classes that compare well with the Forestry Commission (1996) woody cover classes:

Wooded grassland	11.42 tonnes per ha
Bushland	23.36 tonnes per ha
Woodland	49.89 tonnes per ha

These stocking levels are conservative enough when compared to Chidumayo (1995)'s levels of 53 tonnes per hectare in western dry miombo and 72 tonnes per hectare in eastern dry miombo of Zambia. However, the figures are within the general ranges of 21.16 tonnes of wood biomass per hectare to 39.73 tonnes per hectare for the miombo plots in Sengwa and Marondera respectively (Frost 1996). The average growing stock across all provinces was 30.2 tonnes per hectare (ranging from 6.1 in Bulawayo to 37.3 in Matabeleland North). Using these figures, the following totals for the woody biomass growing stock are obtained:

Wooded grassland	13.7 million tonnes
Bushland	116.1 million tonnes
Woodland	1038.1 million tonnes

Thus, the total overall biomass of trees in natural forest, woodland, bushland and wooded grassland in 1992 is 1.168 million tonnes. Frost (2001) also suggests a similar figure. Changes due to economic activity refer to the human production activities such as harvesting and afforestation that affect (increase/decrease) the stock of forests. The area of indigenous woodland in Zimbabwe has shown a continuous decline in the past two decades (Kunjeku et al. 1998; Forestry Commission 1996). This is driven by deforestation, fuelwood consumption and other conversions. About 70 percent of the country's total population live in communal areas and depend directly on forests for firewood, construction timber, food and fodder. The open access, common property situation in these forests lends itself to over-exploitation. The gradual erosion of cultural and ethical values tied to forests has also contributed to woodland degradation. Fires, insects, disease and browsing by wildlife are also significant factors. By far however, the opening up of forestland for agricultural expansion tied to resettlement is the major reason for the loss of forest biodiversity.

It would appear that between 1985 and 1992 the woodlands of Zimbabwe were being depleted at an average rate of 2.01 percent per annum[9]. Overall, biomass depletion has been taking place at an annual average of 47 million tonnes per annum between 1985 and 1992 (Kunjeku *et al.* 1998). Other volume changes are due to net additions to stock (due to natural growth and regeneration). According to Crowards (1994), the net reduction in forestry cover between 1985 and 1992 is approximately 2.66 million tones per annum. This implies a current mean annual increment of different species of 44.34 million tonnes due to growth of the remaining stock.

The closing stocks are computed as opening stocks less reductions plus additions. In practice, closing stocks are the actual stocks available at the end of the period and any differences in the computed closing stock and actual growing stocks are accounted as statistical discrepancy. In our case, the closing stocks are the derived stocks as there is no assessment on growing stock after the Millington and Townsend study. In the absence of better estimates, we assume that the reductions and additions in forest resources profile for 1985-1992 reported in Kunjeku *et al.* (1998) extended to the period 1993-1999. Thus, mean annual loss of growing stock due to deforestation, land clearance for agriculture, settlement and fuelwood consumption for the period 1992-1999 is estimated to have been 47 million tones per annum while addition remained at 44.34 million tones per annum. As to assuming that stock increments and losses, estimated in the early 1990s, might remain unchanged

[9] Those figures originally came from the forestry commission. They have some small plot measurements of mean annual increments but it is a big (and tenuous) step to extrapolate from these essentially point data to the whole country.

in subsequent years, this would be a difficult assumption to make (though in the absence of any other data, we are left with no alternative)[10].

3.2 Indigenous forest monetary accounts

Establishing monetary accounts is hampered not just by poor quality physical stocks data, but also by poor price and costs data. The situation has not improved in any significant way since the earlier work of Campbell *et al.* (1997) calling for massive changes in forestry data collection and dissemination. There is a general lack of information on the value of goods and services provided by natural woodlands at local and national levels. This study does not do any primary surveys: results from other studies are used. The important point of this work is to underscore the fact that the value of ecological resources reflects the range of benefits flowing from those resources.

3.2.1 Economic values and wood supply in natural forestry

Adjustments to the level of GDP start with total economic value of natural forest (including amenities, option value etc.). The natural woodlands generate a wide range of products and services. No accurate economic value has been established for these goods and services, although case studies have produced some point estimates. The problem is that whereas the private benefits from woodland loss are obvious and are often reflected in market prices, the social costs are not. The valuation of woodlands is generally concerned with estimating either the social cost of the depletion of species or the social benefits of their conservation. In many situations, markets for ecological goods and services are either non-existent or poorly developed. Estimation of the value of forests is complicated by uncertainty about system boundaries. An additional source of difficulty lies in the fact that the same

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[10] Growth is a function of the growing conditions at the time and the development stage of the woodlands, while losses vary with offtake (both commercial and subsistence), climate conditions (affecting plant death rates), and age of woodlands, among others (e.g. fire, frost). Woodland clearance for agriculture and other developments will also influence losses, but these developments tend to be episodic rather than continuous. So, extrapolation is not easy, unless supported by a model of the interactions among factors influencing growth and decline.

resources have widely divergent values to different stakeholders. This is partly because of differences in preferences and technology, income and endowments. But it is also because of differences in ethical and cultural values.

One of the rare and better studies that estimate the *overall* value of woodlands is by Campbell *et al.* (1991). The study uses a modified contingent valuation study (CVM) to estimate the mean direct and indirect values of a range of timber and non-timber products in natural woodlands of Zimbabwe and finds a value of Z$200 per hectare per year. In follow up work, Campbell *et al.* (1994) use a CVM to value a much broader set of goods and services than Campbell *et al.* (1991) and then ask respondents to trade off various tree and woodland uses against this value, thereby establishing a consistent hierarchy of natural woodland values. An average value of about US$100 (Z$700) per household per year was found. Based on this figure (and mindful of many caveats about extrapolating the very specific Campbell *et al.* (1994) results)[11], the total stock value of indigenous woodlands can be crudely estimated at Z$14.7 billion. This translated to about 32.6% of GDP and 141.9% of agricultural GDP These figures are in order of magnitude estimates only. They are based on a study of one small area of the country. More accurate estimates of woodland values require extensive CVM research across a wider range of geographic areas and forest types. However, it does give an indication of how conventional GDP can undervalue current well-being by omitting some important flow benefits.

3.2.2 Adjustments for non-market fuelwood consumption

Although fuelwood is included in the willingness to pay measure reported above, it is still instructive to explicitly account for it, given the very good survey data available on fuelwood consumption in the country. Conceptually, incorporating the nonmarket consumption of tangible nontimber products like fuelwood is straightforward. It boils down to estimating total consumption value by multiplying total fuelwood consumption by the market price. Table 4 reports the volume of fuelwood consumption. Fuelwood consumption figures are obtained from Campbell *et al.* (2000). For residents of communal areas, fuelwood demand is for cooking and heating and for the less frequent but highly consumptive fuel requirements of brick-baking, brewing and special occasions like weddings and funerals (Bradley and Dewees 1993). Altogether the typical rural Zimbabwean household fuel budget is in the region of 4.2 tonnes per household per year in 1999, down from around 5 tonnes per household per year in 1994. The corresponding figures for residents of urban areas follow from Campbell *et al* (2000). The main fuel requirements of residents of high-density suburbs are for cooking and lighting; specific use of fuels for space heating is not usual (Attwell *et al*. 1989). Urbanites consumed a median 1.5 tonnes per household per year of wood in 1994 and 0.7 tonnes per household per year in 1999 per household. To compute annual demand requires population estimates.

Table 4 Fuelwood consumption and GDP adjustments

Activity/Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Weighted price per ton	122.50	144.55	170.57	201.27	237.50	280.25
Quantity consumed	8.76	8.89	9.13	9.38	9.63	9.89
Gross fuelwood product	1073.10	1285.05	1557.29	1887.93	2287.13	2771.68
As % of GDP	2.38	2.60	2.27	2.31	2.10	2.45
As % of GDP in Agriculture	14.62	19.85	11.35	14.06	11.18	14.66

Source: Authors' calculations

The price data in Table 4 is obtained from Campbell *et al.* (2000). The price of rural fuel-wood is estimated on average to be Z$120 per tonne in 1994 while that of urban fuel-wood is Z$230 per tonne. Since then, prices of wood have not kept pace with the overall rate of inflation in Zimbabwe, so that in 1999 wood costs less relative to rural household incomes than it did in 1994, at least in deforested areas close to urban centres. The vast majority of households in most towns used electricity in their homes in 1999. Fuel-wood market surveys in Harare show that the maximum price was Z$1.62 per kilogram in Chitungwiza, Unit J. and the minimum was Z$0.89 per kilogram in Mabvuku.

[11] These caveats are that the study was for a particular site and species, which makes the study a shaky foundation for constructing aggregate national estimates.

The average price in Harare was Z$1.26 per kilogram. The following were the average prices in other towns: Gweru Z$1.20 per kilogram, Bulawayo Z$1.32 per kilogram, Gwanda Z$0.84 per kilogram, Masvingo Z$0.76 per kilogram and Mutare Z$0.95 per kilogram. In real terms the price of firewood has dropped from Z$0.38 per kilogram to Z$0.26 per kilogram. A weighted price, based on volumes used (from Campbell and Mangono 1994) is presented for all years.

The results of the value of fuelwood in Table 4 show that the values increased between 1994 and 1999. In order to analyse the relative importance of the values with respect to the national accounts figures, we compare the estimated values to overall GDP and to agricultural value added. These values, when compared to agricultural value added revealed higher values, reaching up to about 20% in 1995. However, when compared to overall GDP, the relative magnitudes of the value estimates are very low, varying from 2.1% to 2.6% of the total GDP. The share values exhibit some volatility, with increases interrupted by decreases in 1996 and 1998. The upward variation is largely driven by increased consumption and the reduction is largely due to a general slowdown in price increases.

3.2.3 Indirect material uses and values

Indirect use values are tied to ecological benefits of woodland biodiversity and supporting ecosystems. As mentioned earlier, these include nutrient cycling, watershed protection, waste assimilation, microclimatic stabilisation and carbon storage. Such ecological functions are important in maintaining the dynamics and health of the ecosystem, and hence its capacity to sustain the various organisms dependent on it. If the role of species in mediating such functions is understood, it is possible to derive the indirect use value of such species. Although these values are critical from an ecological perspective, they are very difficult to measure in practice. In this section, an attempt at estimating the economic value of carbon sequestration and water in the natural woodlands is made.

3.2.3.1 Value of carbon sequestration

Carbon sequestration may not have immediate productive effect for households in the rural areas of Zimbabwe but the loss of such a service may be linked to productivity losses in the long run. There is a general agreement that global warming will lead to significant reductions in agricultural productivity in developing countries (Nordhaus 1991; Cline 1992) and that subsistence agricultural systems stand to suffer the most because of their inability to take advantage of the risk pooling opportunities offered by markets (Reily *et al.* 1993) and constraints on adaptation. Productivity losses will have general equilibrium effects through links with agriculture, resulting in relative price shifts which necessitate inter-sectoral factor substitutions, changes in household income and consumption patterns as well as affect industries with strong agriculture links. If future international agreements on climate change eventually require all jurisdictions to implement measures aimed at reducing atmospheric concentrations of greenhouse gases, then carbon sequestration will assume a direct productive role in the economy.

The environmental economics literature provides a number of techniques to value carbon sequestration. One such approach is the use of a damage function, which provides physical information about how damage (e.g. global warming) is affected by carbon dioxide emission levels and relates damages to monetary values. The value of an activity that reduces atmospheric concentrations of carbon dioxide (e.g. the value of natural woodlands for carbon sequestration) may be measured as the amount of carbon sequestered times the cost of damages caused by an additional tonne of carbon dioxide released into the atmosphere. These measures of damages ($/tonne of carbon emission) can be used to assess the benefits of sequestering carbon in that units of carbon sequestration reduce the damage effects.

Kundhlanden *et al.* (2000) in a study of Zimbabwe model carbon flow by keeping track of the biomass (an organic storage for carbon) in living and dead trees, grasses and shrubs. Since 45% of biomass is comprised of carbon, gross carbon stored in vegetation will be the stock of biomass in the woodland multiplied by 0.45 plus carbon storage in removal. Given assumptions about biomass decay and release of carbon as carbon dioxide in each end use category, net carbon stock per period was calculated as:

$$C_{st} = 0.45\left(B_t + \sum_{t=0}^{t-1} 0.9^{t+1} P_{t-t} + \sum_{t=0}^{t-1} 0.9^{t+1} L_{t-t} - G_t - W_t \right) \qquad (11)$$

where C_{st} is the net carbon storage in year t, B_t is biomass stocks at the end of period t, P_t represents poles harvested, L_t represents commercial timber harvested, G_t represents grass removals and W_t is the amount of firewood used in period t. Carbon stocks are tracked in each period relative to the base case, keeping account of the changes in living biomass as well as the accumulation (and depreciation) of woodland products. Kundhlanden *et al.* (2000)'s estimate was based only on above ground biomass, although below ground biomass can be a critical component of net carbon storage.

The net carbon stock stored in the form of biomass is assigned an economic value by multiplying the change in stock by the value of a tonne of carbon. An estimate of Z$250 for the value of carbon is used[12]. In calculating the present value of carbon, a discount rate of 5% per annum was used. The present value of carbon benefits illustrates that guaranteeing to leave these lands in natural woodland for a period of 50 years would realize a benefit of approximately Z$3000 per hectare. If we reduce this figure to average annual values this translates to Z$60 per hectare per annum. Extrapolating this figure to the national level and again being mindful of the many caveats, natural forests contributed 1.5% of 1997 GDP that is not reflected in the forestry sector or 9.4% of 1997 agricultural GDP. This is the contribution to other sectors' GDP from forestry that is not explicitly acknowledged in the SNA.

At the global scale, in terms of carbon dioxide emissions, Zimbabwe contributes minimally to global emissions, in both absolute and *per capita* terms (Table 5). According to Frost (2001), commercial energy use in the country accounts for only about 0.1% of global energy consumption, and just over 3% of energy consumption in Africa. In 1990, the country produced just over 0.1% of total global anthropogenic CO_2 emissions but by 1997 this had

[12] At the time of the study, 1 US$ was equivalent to Z$10.

fallen to 0.08% (Frost 1996,1997). Emissions *per capita* are about half the global average, but twice the average for the rest of Africa. Most people, especially in rural areas, depend almost entirely on biomass fuels to meet their daily household energy needs. According to Frost (2001), if the estimated mean annual increment of 47 million tonnes in natural vegetation due to the growth of the remaining stock is correct, then CO_2 emissions would be about 49,820 Gg more than that claimed in official circles (see Table 6), which would make Zimbabwe a net emitter of carbon (25,462 Gg CO_2 equivalents) rather than a net sink. Clearly, given the relatively extensive woodland cover across the country, Zimbabwe has the potential to be a carbon sink, but current pressures for more agricultural land and for wood for various purposes, including fuelwood, make this unlikely.

Table 5. Indicators of commercial energy use and carbon dioxide emissions in Zimbabwe.

Indicator	Units	Year	Zimbabwe	Africa	World
Commercial energy usage	10^3 t.o.e [a].	1990	8,934	273,093	8,608,414
		1997	9,926	323,921	9,431,190
Per capita commercial energy use	Kg oil equivalent	1990	917	705	1,705
		1997	866	695	1,692
GDP per unit energy use	PPP$ per kg t.o.e.	1990	2.6	2.5[b]	4.3[c]
		1997	3.1	2.6[b]	5.1[c]
Total CO_2 emissions	10^6 metric tonnes	1990	16.6	465.3	16,183.10
		1997	18.4	471.7	22,690.10
Per capita CO_2 emissions	Metric tonnes	1990	1.7	0.9	3.3
		1997	1.6	0.8	3.4

Notes: (a) tons of oil equivalent; (b) average of 12 African states; (c) average of 20 NFCC Annex I countries.
Source: Frost (2001)

Table 6. Summary of anthropogenic greenhouse gas emissions by major sector for Zimbabwe in 1994. All emission estimates are in Gg (10^9g).

	Greenhouse gas (global warming potential)					
Greenhouse gas source sector	CO_2 (1.0)	CH_4 (24.5)	N_2O (320.0)	NO_x (40.0)	CO (3.0)	CO_2 equivalents
Energy (fuel combustion and fugitive emissions)	14,772.13	77.19	1.18	10.08	544.46	19,076.68
Industrial processes	2,316.35	19.08	6.05	0.21	1.38	4,732.20
Agriculture	0.00	236.84	2.39	66.91	1,381.81	13,388.96
Land-use change and forestry	-62,269.00	1.26	0.01	0.20	18.44	-62,171.75
Waste	0.00	25.15	0.00	0.00	0.00	616.06
Total	-45,180.52	359.52	9.63	77.40	1,946.08	-24,357.85

Source: Ministry of Mines, Environment and Tourism (1998)

3.2.3.2 Marginal value of water

The value of water in the natural woodlands and forests stems from the fact that vegetation cover may stabilize the local climate and maintain rainfall patterns (Botkin and Talbot 1992; Myers 1995) and may reduce water loss by acting as a windbreak and by providing soil cover. Furthermore, trees and shrubs in the water catchment zones may also help regulate the stream flow (maintaining stream flow during the dry season), help improve water quality, prevent soil erosion and flooding and affect the recharging of ground water reservoirs (Bruijnzeel 1990; Huntoon 1992). However, trees may also result in removal of water from the system through evapotranspiration – thus the specific vegetation may either enhance or detract from water availability.

Kundhlanden *et al.* (2000) estimate the value of water availability, de-coupled from the vegetation-hydrology complexities through its effect on production. In this setup, water obtains its value from (i) influencing the supply of products (wild foods, timber and firewood) and services (e.g. carbon sequestration), (ii) influencing crop production. Water is treated as a component of the production process, and changes in this aspect are assessed by examining the response of the producer through a model of crops and woodland products. The marginal value of water is examined by introducing 'small' variations in the mean rainfall variable and determining the impact of rainfall on the value of crops, wild foods, grass production and in carbon sequestration. Thus, this approach captures the marginal value of water via mean annual rainfall through production functions for market goods (crops) and through the implicit production process for non-market goods (carbon sequestration)[13]. In the crop production model, the total value of agricultural output (mainly maize) is obtained by multiplying the output by the market price for a tonne of maize in 1997, and changes in productivity are calculated as the difference between the values of output at the different levels of water availability. A discount rate of 5% per annum is used over a period of 50 years to obtain the capitalized value of agricultural production.

Adding the values for carbon sequestration, firewood and wild foods and assuming a mean annual rainfall of 700 millimeters, the capitalized marginal value of water over 50 years is found to be Z$4,830 per hectare. This translates to Z$96.60 per hectare per annum as the marginal value of water in the natural woodlands. Scaling this up to the national level gives an aggregate figure of Z$2.03 billion, which amounts to about 2.5 of GDP and 15% of agricultural GDP. To avoid double counting, these values are not added to GDP. In one sense they provide an estimate of how the contribution to national well-being of other non forestry sectors and agriculture in particular, is currently overestimated in the SNA as a result of not paying for inputs from the forestry sector.

[13] This is only a subset of productive activities that are affected by water availability and it does not include the impact on human health and productivity of livestock for instance. These are significant omissions but the data to assess these impacts were not available. Therefore, values here must be regarded as highly conservative.

4 Commercial plantation forest physical and monetary accounts

4.1 Commercial forest overview

Zimbabwe has a well-established plantation forest resource base covering some 155,853 hectares. About 90 percent of the plantations are located in the eastern districts. This area is characterised by high altitudes (700 to 2,200 metres above sea level) and high rainfall (average of 1,000 mm/annum). The major forest plantation species grown in Zimbabwe are *Pinus patula, P. elliottii* and *P. taeda, Eucalyptus grandis, E. cloeziana* and *Acacia mearnsii*. Pines are used mainly for structural timber production, pulp and paper. The eucalypts are used for poles, pulp and paper while wattle (*A. mearnsii*) are used for the production of tannin. Of the total plantation area 68% is planted to softwoods, 20% to eucalypts, 11% is under wattle and the remaining 1% under other species which include *Populus deltoides* which is used in the production of matchsticks. With respect to the plantation ownership pattern, about 42 percent belong to the State, 54 percent to private companies and the remainder to small private growers who include co-operatives.

The major players in the commercial forestry sector include the Forestry Commission, Border Timbers and Wattle Company. The Forestry Commission is the Government enterprise with operations which include plantations, sawmilling, manufacturing, and marketing. Border Timbers is the largest private forestry company in Zimbabwe. It is a subsidiary of the Anglo-American Corporation. The Wattle Company is a subsidiary of the Lonrho Group, which has diversified interests in Zimbabwe and is active in agriculture and mining. The institutions collecting statistics on forestry are the Forestry Commission (collects information on commercial and non-commercial plantations, and on roundwood processing, including plantation areas by species, end use, age, ownership, province and information on employment), the Timber Producers' Federation (TPF) (a voluntary association of Zimbabwe plantation timber growers and sawmillers established in 1995). The TPF collects information on area of plantations, distribution of commercial forests, productivity by species, round wood utilisation, sawn timber production, sales and employment) and the Central Statistics Office (collects on an annual basis, information on agricultural crops and employment figures in the sector and forestry volume and value of timber). International organisations such as the FAO, WWF and IUCN also collect information on forestry.

The level of employment in the commercial plantation forests is shown in Table 7. Trends in employment on the commercial plantations indicate that employment was increasing until 1997. Conditions deteriorated sharply in 1998/99, when employment levels declined overall by 20.2% and by 5.2% the following year. Average wages, in real terms, also dropped. The decrease in employment can be explained by the retrenchments by Border Timbers and the Forestry Commission during the past three years. Employment levels are expected to decrease in the future due to the restructuring of the Forestry Commission which may result in staff retrenchments and the increased mechanisation of forest operations. Although the number of employees grew by about 4.4% between 1998/99 and 2000/2001, this only represents an average annual growth rate of 2.2%, well below the rate of increase of the population.

Table 7. Employment in commercial forestry sector, 1996-2001.

Year	Number of employees
1996	14,268
1997	18,435
1998	14,718
1999	13,955
2000	14,445
2001	14,572

Source: Timber Producers' Federation (2001)

4.2 Physical stock account for commercial plantations

4.2.1 Area and species composition

As Table 8 shows, there has been a steady increase in areas planted with commercial forests between 1994/95 and 2000/01. The area under commercial plantations increased by 8.3% from 1994/5 to 2000/2001 and declined by 0.9% between 1999/2000 and 2000/2001. The increase has mainly been attributed to afforestation of existing land by the Forestry Commission and purchases of new land made by Border Timbers in 1997/8, while the recent decline is largely a result of losses due to resettlement.

Table 8. Land utilisation (hectares)

Year	Commercial Plantations
1995	110000
1996	110700
1997	111602
1998	118104
1999	118621
2000	120182
2001	119130

Source: Timber Producers' Federation (1995-2001)

As Table 9 shows, the area under pines has increased from 77900 hectares in 1994/5 to 80 989 hectares in 1998/9 before falling to 78007 hectares in 2000/2001. It is predicted that the area under pines will decrease, as some of the areas will be withdrawn from production in compliance with sound environmental conservation. The area under eucalypts increased from 16 800 in 1994/95 to 29314 hectares in 2000/2001. The area under wattle has decreased from 14300 hectares in 1994/5 to 11529 hectares in 2000/2001 due to conversion of wattle to pine in the Nyanga area. Area under wattle is expected to decrease due to reduced demand of tannin on the world market.

Table 9. Commercial plantation area by species (hectares)

Year	Pine	Eucalypt	Wattle	Others	Total
1995	77900	16800	14300	1000	110000
1996	79000	17400	14000	300	110700
1997	77593	19840	13814	355	111602
1998	80087	23812	13627	578	118104
1999	80989	23910	13434	288	118621
2000	79082	29036	11789	275	120182
2001	78007	29314	11529	280	119130

Source: Timber Producers' Federation (1995-2001)

4.2.2 Area of forest and rotation age

The starting point in implementing the valuation methods for commercial forestry is to classify forests by type and, within each type, by age class. This data is obtained from TPF and 1999 is taken to be the base year. The data suggests that the age class structure of pine species is not balanced with most being young (10 years or less). The unbalanced age structure is attributed to increase in processing capacity in recent years following the commissioning of two big mills in Nyanga and Chimanimani areas and the reduced afforestation during the war prior to 1980. A number of trees are in the over mature class (30 years or more) and this is due to remoteness of some growing stocks and the poor quality of the over mature stock caused by poor planting material and no silvicultural management during the war period. For eucalypts, the age structure is skewed towards the younger trees due to the short rotation nature of transmission poles, which is 12 years. The trees above 15 years are moribund and those above 20 years of age can only be used for sawtimber. Wattle is also a short rotation crop, hence there are very few over-mature plantations.

Unfortunately, data is not collected on the age of harvested timber. Harvesting ages vary according to product and locality. The typical working circles in Zimbabwe are given as follows by the TPF:

- Pine sawlogs, 25 years with productive thinnings at 13 years and 18 years.
- Pine pulpwood 14 years (Plus thinnings arising from sawlog working circle).
- Eucalyptus Vumba Midlands Transmission Poles 10-12 years 16 - 18 years
- Eucalyptus Vumba Midlands Light Poles 4 - 6 years 9 -10 years
- Wattle Extract 10 years

These have been used (mid-points) to distinguish between mature and immature forests in each species as follows: Pines (19 years); Eucalyptus (11 years); Wattle (10 years) and Poplar (10 years). The relationship between standing volume per hectare (net of defect) and age for the different species is estimated using growth functions used for South Africa (Hassan *et al.* 2002; Hassan 2000) and take the following form:

$$q_h(y) = a\left(1 - e^{bA}\right)^l \qquad (12)$$

where $q_h(y)$ is volume of timber, A is age of tree, a, ß and ? are parameters of the tree growth model. The following parameterization for South Africa is also adopted for Zimbabwe:

Table 10. Growth model parameters

Species	?	?	?
Pinus patulla	453.171	-0.157	4.166
Pinus elliotti	503.74	-0.103	2.877
Eucalyptus	510	-0.2	4.17
Wattle	24.3	-0.25	4.166

Source: Hassan *et al.* (2002)

Using these parameters and the growth models above, standing timber volumes by age for 1999 were estimated. Combining these with the available data on actual areas under each age class for each species in the base year, opening stocks of standing timber in the base year were derived to obtain the following:

Table 11. Opening stocks for commercial forestry by species

Species	Opening timber volumes (000m^3)
Pine	19878.5
Eucalyptus	3983.7
Wattle	114.9
Poplar	8.1
Total Volume	23985.2

Source: Authors' calculations based on Timber Producers Federation (1999-2001) and method discussed in the text.

4.2.3 Changes due to different activities

The changes due to economic activity refer to production activities such as harvest, harvest damage, and afforestation that affect (decrease/increase) the stock of forests. Estimates of growth were calculated using the above timber growth models applied to all age groups of all tree species standing in the base year. Replanting of harvested land and new afforestation were entered as the zero-one age group for the respective year in the growth calculations. The volume of timber decrease due to harvesting is shown in Table 12. Harvest from commercial plantations in 2001 was 1,132,640 m^3, down from 1,241,383 m^3 in 1999.

Table 12. Roundwood harvested (m^3)

Year	Pine	Eucalypt	Wattle	Total
1999	923,236.00	258,958.00	59,189.00	1,241,383.00
2000	971,650.00	254,009.00	34,826.00	1,260,485.00
2001	845,886.00	240,623.00	46,131.00	1,132,640.00

Source: Timber Producers Federation (2001)

Table 12 shows that in 1999 of the 1,241,383 m^3 harvested from commercial plantations, 74% were pines and 26% were eucalypts. Most of the harvest, an average of 71%, was delivered to sawmills. Other volume changes are due to forest fires. The frequency of fires and area lost are influenced by weather patterns particularly rainfall. The data was only available in some areas and not allocated by species and forest age (Table 13). Therefore, fire damage effects were converted into volume equivalents and reduced using the average standing volume for the respective year.

Table 13. Area lost due to fire (hectares)

Year	Pine	Eucalypt	Wattle	Total
1999	113	33	20	166
2000	97	36	15	148
2001	0	0	0	0

Source: Timber Producers Federation (2001)

There were also changes due to calamities such as a cyclone. This is not an annual event but had devastating impacts in 1999/2000 (due to the el Niño effect). The damage associated with this calamity is reported in Table 14, which shows that in total, 4% of plantation area was devastated by the cyclone. The worst affected was wattle plantation, with an area of 13.7% destroyed. As in the case of fire damage, because the data was only available in areas and not allocated by forest age, damage effects were converted into volume equivalents and reduced using the average standing volume for the respective year for each species.

Table 14. Cyclone damage by area in 2000 (hectares)

	Pine	Eucalyptus	Wattle	Total
Cyclone damage	2689	431	1746	4866

Source: Timber Producers Federation (2000)

Finally, there have been other important changes caused by transfer of forestland to non-forest uses. In recent years the main one has been brought about by the Government's resettlement of peasant farmers in 2001. The total area transferred per species is given in Table 15. Again, similar to the case of fire and cyclone damage, land resettlement effects on forestry data was only available in areas and not allocated by forest age. Damage effects from this source were consequently converted into volume equivalents and reduced using the average standing volume for the respective year for each species.

Table 15. Resettlement losses by area in 2001 (hectares)

	Pine	Eucalyptus	Wattle	Total
Resettlement Losses (ha)	90	1228	0	1318

Source: Timber Producers Federation (2001)

4.2.4 Closing stocks

The implied closing stocks for the commercial forestry sector are shown in Table 16.

Table 16. Physical stock account for commercial forestry (million m^3)[14]

Year	Species	Opening Stocks	Afforest-ation	Growth	Harvest-ing	Fire	Cy-clone	Resettle-ment	Closing Stocks
1999	Pine	19.877	0.001	0.009	0.923	0.027	0.000	0.000	18.937
	Eucalyptus	3.983	0.001	0.011	0.259	0.006	0.000	0.000	3.730
	Wattle	0.115	0.000	0.001	0.059	0.000	0.000	0.000	0.056
	Poplar	0.008	0.000	0.001	0.004	0.000	0.000	0.000	0.004
	Total	**23.983**	0.002	0.021	1.245	0.033	0.000	0.000	**22.728**
2000	Pine	18.937	0.001	0.009	0.972	0.025	0.684	0.000	17.267
	Eucalyptus	3.730	0.001	0.011	0.254	0.007	0.085	0.000	3.396
	Wattle	0.056	0.000	0.001	0.035	0.000	0.012	0.000	0.010
	Poplar	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.004

[14] Note that we have not taken into account the fact that we must account for the asset value of land in not only its former forestry use but also in its new non-forestry use to which it has been converted to.

	Total	**22.728**	0.002	0.021	1.260	0.032	0.780	0.000	**20.678**
2001	Pine	17.267	0.261	0.014	0.846	0.000	0.000	0.039	16.657
	Eucalyptus	3.396	0.363	0.015	0.241	0.000	0.000	0.599	2.935
	Wattle	0.010	0.014	0.000	0.046	0.000	0.000	0.000	-0.021
	Poplar	0.004	0.000	0.008	0.072	0.000	0.000	0.000	-0.059
	Total	**20.678**	0.639	0.037	1.204	0.000	0.000	0.638	**19.512**

Source: Authors' own computations based on data from Timber Producers Federation (1999-2001)

Commercial timber stocks show a steady decline over the whole period. It is clear that reductions to timber volume due to harvest, cyclone, resettlement, and fire exceeded additions in volume due to growth and afforestation/replanting, leading to net negative accumulation of stocks.

4.3 *The monetary asset accounts for commercial plantation timber*

As argued before, this study uses both the change in asset value and net depletion method to estimate the value of commercial timber assets. The data required for the estimation sets are prices, costs, the discount rate and harvest volume data.

While it is possible to use data from the Central Statistics Office to obtain an implicit price for timber by dividing the sales value of timber by the quantity extracted and sales value, this method was not used in this paper because it gave prices at large variance to those reported by timber producers. As a result, we opted to use price data from a survey of all major timber producers in the country. The typical sales prices reported in the surveys are reported in Table 17.

Table 17. Typical Sales Prices ($/m³)

	1999	2000	2001
Pine Graded Structural Timber	$7,000.00	$9,800.00	$23,000.00
Eucalypt Industrial Timber	$7,500.00	$8,000.00	$19,000.00
Wattle	$5,000.00	$6,000.00	$20,000.00
Poplar	$6,500.00	$7,933.33	$20,666.67

Source: Based on interviews with members of the Timbers Producers Federation

The estimates of costs of extraction and processing of wood are not available in published sources. Instead, it is assumed in this study that the cost function is linear for all tree species as follows:

$$C(q_h(Y)) = cq_h(Y) \qquad (13)$$

To get a value for c, we opted to do a quick survey of all firms in the industry. Consistent figures could only be obtained for 1999. The cost of extraction of eucalyptus was approximately Z$2,500/$m^3$. The cost of extraction of pine was approximately Z$2,600/$m^3$ (delivered sawmill) while processing costs of pine sawn timber were Z$3,500/$m^3$, to give an overall cost of Z$3,050/$m^3$. The corresponding costs for wattle and poplar are Z$2,775/$m^3$. We use the average inflation figures for 2000 and 2001 to move these costs from 1999 to the remaining years.

Table 18 reports the total change in value and net depletion method estimates for our central discount rate of 5% per annum. As the results indicate, the estimates from the net depletion method differ from the change in asset value estimates. The net depletion method tends to overstate both the appreciation of young forests and the depreciation of mature forests. It overstates the appreciation of young forests and the depreciation of mature forests by a factor of 1.2 on average.

Because the net depletion method tends to overstate both the appreciation and depreciation of forests, the biases are not offsetting and can be serious. The overall bias appears to be largely driven by two separate factors: the rotation age and the discount rate. Generally, the higher the discount rate, the larger is the overestimation. In contrast, if the discount rate is low (2%), then the net depletion method will tend to produce downward biased estimates. Perhaps the correct rate would probably be at the low end of the range for something like forestry where long-term investments and development benefits are anticipated.

Alternatively, because the forest is dominated by short rotation forest and the dominant species in terms of volume (pine) is mostly young (10 years or less), the net depletion method tends to overstate the change in asset value. When we experiment with longer rotation cycles (pines), the net price method tends to produce downward biased estimates of net accumulation.

Table 18. Net accumulation estimates

Characteristics of forest			Net Accumulation	
Age (years)	Volume (m3)[a]	Total Growth (m3)[a]	Change in Asset Value (Z$)[b]	Net Depletion Method (Z$)[c]
1	2 089	0	588	12 512
2	27 596	3	7 531	162 681
3	119 513	9	41 926	734 784
4	208 338	22	74 505	1 272 723
5	421 536	38	141 122	2 514 163
6	634 267	58	219 398	3 762 049
7	508 952	79	193 617	3 040 747
8	827 100	100	261 552	4 737 213
9	904 710	121	317 587	5 230 657
10	1 047 075	140	69 246 845	87 114 771
11	1 041 735	157	72 726 004	85 797 255
12	872 564	172	56 828 634	66 174 074
13	873 712	185	34 295 619	41 824 870
14	906 984	196	40 562 462	48 737 329
15	1 193 147	205	28 041 131	37 038 006
16	856 609	214	15 127 904	21 196 364
17	1 152 527	220	13 430 538	21 127 009
18	760 940	226	9 391 294	14 558 140
19	372 787	231	124 207 813	161 854 361
20	350 096	235	113 991 860	149 739 814
21	424 954	238	135 525 920	178 092 506
22	668 726	241	208 102 269	275 427 507
23	856 500	243	263 835 416	349 145 287
24	754 374	245	229 298 382	304 627 822
25	648 377	246	200 449 697	262 429 872
26	420 149	247	132 936 889	171 111 167
27	641 360	248	196 834 796	257 430 506
28	361 211	249	109 972 209	144 472 741
29	291 347	250	87 451 826	115 816 542
30	351 043	250	108 478 506	140 845 536

31	5 482 696	251	1 866 017 134	2 269 124 178
TOTAL	**23 983 014**	**172**	**-4 115 495 322**	**-5 225 153 188**

Notes: (a) See equation 12.
(b) Change in Asset Value: see equations 9 and 10
(c) Net Depletion Method: see equation 6.

5. Summary and policy observations

This study presents the outcome of a survey of the forest sector in Zimbabwe. It describes the forest sector, activities and outcomes, and uses resource accounting techniques to determine how much of its forestry resources Zimbabwe is losing and gaining. It also attaches monetary values to these changes.

The country has a well-established plantation forest resource base. This study constructed physical accounts for the sector. Commercial timber stocks show a steady decline over the whole period. It is clear that reductions to timber volume due to harvest, cyclone, resettlement and fire exceeded additions in volume due to growth and afforestation/replanting, leading to net negative accumulation of stocks. As well as creating physical timber accounts for commercial forestry, the study also used the environmental accounting approach to obtain values of forest stocks for commercial forestry, using both the change in asset value and the net depletion method. The net depletion method tends to overstate both the appreciation of young forests and the depreciation of mature forests. The overall bias appears to be largely driven by two separate factors: the rotation age and the discount rate.

Of direct concern to this study is the fact that national accounts only measure market-based transactions and exclude consumptive uses such as domestic fuelwood cut by villagers, which occurs outside the market place. A modified contingent valuation study estimated the mean direct and indirect values of a range of timber and non-timber products in miombo woodlands at Z$700 per hectare per year. Based on this figure (and mindful of many caveats about extrapolating the very specific results), the total stock value of indigenous woodlands can be crudely estimated at Z$14.7 billion, which translates to

32.6% of overall GDP for 1994. This figure is an order of magnitude estimate only. Also in the study, an effort to build in values for ecological services such as carbon sequestration and water abstraction for natural forests was made. Net carbon stock stored in the form of biomass is assigned an economic value of Z$60 per hectare per year, which translates to 1.5% of overall GDP and 9.4% of agricultural GDP in 1997. At the global level, however, Zimbabwe is likely to be a net emitter of carbon rather than a net sink. Clearly, given the relatively extensive woodland cover across the country, Zimbabwe has the potential to be a carbon sink, but current pressures for more agricultural land and for wood for various purposes, including fuelwood, make this unlikely. The value of water availability (de-coupled from the vegetation-hydrology complexities) through its effect on production is Z$96.60 per hectare per year, or 2.5% of GDP or 15% of agricultural GDP.

The results in this study emphasise that using certain SNA aggregates as measures of welfare can be misleading. While the livelihoods of most people in Zimbabwe are highly dependent on natural woodlands and forest resources, it is typical that all the mentioned values are excluded from conventional national accounts. Underestimation of the value of natural forests and woodlands is one of the major reasons leading to over conversion of these resources. Failure to attach a true value to the resource means the opportunity cost of conversion is grossly misstated. Likewise, the failure to capture forest asset values in the SNA leads to generation of incorrect measures of economic performance and well being such as the rate of savings and capital formation. The consequences could be severe by sending the wrong signals to policy makers. Without good information on the value of forests, policy makers are in a weak position to establish guidelines and institutions for addressing forestry management issues. As a result of these problems, incorrect policy decisions may be made regarding forestry development, resource management and land use. Development could be biased towards short-term goals, which could lead the country down an unsustainable path. A clear understanding of the relationship between forest stand characteristics and value must guide forest management and harvesting decisions.

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