CHAPTER 3

REVIEW OF LITERATURE ON NATURAL RESOURCE ACCOUNTING

3.1 Introduction

The purpose of this chapter is two-fold. First, literature is reviewed on capital theory and sustainable development and the state of the art of natural resource accounting and how it has been applied in the management of renewable and non-renewable resources. Second, literature is reviewed on how information related to biodiversity (e.g. ecological monitoring) may be used within the context of natural resource accounting for the conservation and management of biodiversity.

3.2 The concept of sustainable development and capital theory

Development is a process by which the well-being or welfare of a society is improved over some period of time (Pearce and Perrings, 1995). The motivation of environmental accounting has been the adoption by governments of the notion of sustainable development coupled with the understanding that economic activities play a central role in determining whether development is sustainable or not (Lange, 2003b). The World Commission on Environment and Development (1987) defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' In terms of resource use, sustainable development does not imply that renewable resources are prevented from being depleted, or even kept at the current or some other level (van Kooten and Bulte, 2000). Rather, it implies that environmental assets should not be depleted, and if they are used, they should not be depleted beyond some limits (Serageldin, 1996). As defined by the World Commission on Environment and Development (1987), sustainable development is an ethical principle because it entails aspects of equity or fair division of access to global resources (Blignaut, 2004; Moffat et al., 2001). Equity therefore appeals to the concepts of freedom and justice (Holmberg and Sandbrook, 1992). Society or individuals should have equal rights of resource access to satisfy their human wants (Blignaut, 2004).

According to this definition, a country can attain a maximum level of development (non-declining human welfare or per capita consumption) without running down its capital assets. While the definition of sustainable development emphasizes non-declining welfare there are challenges to measuring welfare directly. The concept of capital basis for sustainable development has been suggested to overcome this problem as capital stock indicates the ability of an economy to produce output to generate well-being (Alisjahbana et al., 2004). Thus, non-declining welfare per capita is guaranteed by non-declining stock of capital (United Nations, 2003).

The literature on economic growth and exhaustible resources forms the origin of capital theory approach, which is based on the idea of maintaining a constant capital stock as a necessary condition for sustainable development (Stern, 1995). In neoclassical theory, the economic notion of capital stock includes man-made or produced capital (Alisjahbana et al., 2004). However, what constitutes capital is not only man-made capital but also other forms of capital which are human capital, natural capital and social capital/organizational (Turner, 1992; Alisjahbana et al., 2004).). Manufactured or man-made capital comprises goods such as machines, buildings and other infrastructure; human capital refers to the individual capacities for work (Ekins et al., 2003; Perman et al., 2003). Social/organizational capital includes the networks or relationships among individuals or institutions/organizations (Pearce and Atkinson, 1998). Natural capital refers to environmental or ecological resources that provide resources of production and absorb waste material from production. Natural capital comprises basic life support functions and contributes to human welfare through amenity services (Ekins et al., 2003).

Economists worldwide do not ascribe to one single theory of capital growth (Victor, 1991). There are two main components of sustainability differing in their treatment of the substitutability relationship between manufactured and natural capital: weak and strong sustainability. (De Groot et al., 2003; Chiesura and De Groot, 2003; Prugh et al., 1995 Weak sustainability is based on the view of the main stream neoclassical school on capital, that the aggregate stock of capital assets should remain constant over time to ensure that there is no decline in per capita well-being over that time horizon (Pearce and Atkinson, 1998; Cairns, 2000). Since the emphasis of weak sustainability is on aggregate stock of capital stock (Kosz, 1998) it is not necessary to calculate components of total economic value or ecological capital or economic capital to determine if a country is on a sustainable development path. The rule requires that some suitably defined value of services of these stocks should be maintained over time (Hediger, 1999). The implication of aggregating capital is that the degradation of certain types of capital such as natural capital is not given due regard in the quest for attaining overall constant or non-declining capital stock. According to this view, the elasticity of substitution between natural capital and man-made capital is one, and if any of the total assets is reduced, its reduction will be offset by an increase in the value of other assets in order that the unit's income may be sustained (Stern, 1995; El Serafy, 1997; Turner, 1992). This compensation or intergenerational equity is achieved by investing rents from depleted capital into other forms of capital (Lange and Wright, 2004; Collados and Duane, 1999). Thus, the change in the aggregate value of assets at any point in time must be at least zero in the aggregate (Pearce and Atkinson, 1998). This rule has come be known as the Hartwick and Solow rule or the constant capital rule (Pearce and Atkinson, 1998; Lange et al., 2003; Hediger, 1999).

The rule assumes substitution between different reproducible capital and natural capital to ensure that economic growth can be sustained while generating a continuous decline in resource stocks (van Kooten and Bulte, 2000; Prugh et al., 1995; Lange, 2003b; Serageldin, 1996). Substitutability also assumes that it is possible to lump natural capital and manufactured capital and measure then using one common yardstick, which is money (De Groot and Chiesura, 2003). Because of the possibilities of substitution, the proponents of this view do not see any difference between different forms of capital or between the different kinds of welfare which the different forms of capital generate (Ekins et al., 2003). However, there are limits to substitution between natural and man-made capital based on non-utilitarian reasons (Stern, 1995). For instance, if people are asked about their willingness to pay for protection (existence value) they are those who would refuse to do because of moral reasons. Such people are said to be having lexicographic preferences (Kosz, 1998). As a result of this refusal, the valuation founded on neoclassical theory becomes flawed. Thus, the existence of lexicographic preferences does not fit in the assumed model of substitution between natural and man-made capital (Stern, 1995; Kosz, 1998).

The weak sustainability rule also emphasizes technological change and population change. According to this rule, positive technological change can lead to increased output and consumption thereby leading to increased present discounted value of current and future utility from consumption (Arrow et al., 2004; Pearce and Atkinson, 1998). Consequently, declining capital stock is not perceived as a major concern because technological growth will compensate for the decline. In the context of population growth, weak sustainability assumes that the growth in population can improve the well-being of the society by stimulating technological change (Pearce and Atkinson, 1998). However, population growth is also more likely to deplete natural capital as pressure is put on it.

The second view is that of strong sustainability which asserts that is not enough to protect the overall level of capital because some capital is not substitutable (Turner, 1992; Victor, 1991). In other words, minimum amounts of different forms of capital should be maintained independently or separately which therefore assumes that reproducible capital and natural capital are complements rather than substitutes (Prato, 1998, El Serafy, 1997; Serageldin, 1996; van Kooten and Bulte, 2000). The strong sustainability rule is perceived by some environmental economists as a modified view of the weak sustainability rule because in addition to maintaining the *overall value* of capital, the stocks of individual natural capital should not decline (Pearce and Atkinson, 1998; Turner, 1992).

According to this view, the possibility of substitution as assumed by weak sustainability is seriously limited by environmental characteristics such as irreversibility in the context of environmental degradation or loss, scientific uncertainty and the existence of critical components of natural capital (Pearce and Turner, 1990; Ekins et al., 2003; Perman et al., 2003). Proponents of strong sustainability argue that substitutability declines as resources stocks are depleted, and that there are no substitutes for many natural resources such as wilderness, implying that the elasticity of substitution between natural capital and reproducible capital becomes zero (van Kooten and Bulte, 2000).

It is argued that destruction of capital is very rarely irreversible and therefore not always possible to substitute manufactured capital for natural capital (Victor, 1991). This is because natural capital provides some life support functions which cannot be provided by man-made capital (De Groot et al., 2003: Pearce and Turner, 1990). For example, the scale effects of phenomenon such as climate change cannot be compensated for by manufactured capital even in the presence of high level of human knowledge or technology (Ekins et al., 2003). The resources for which substitution between natural capital and manufactured capital is not possible are called critical capital and they are responsible for important environmental functions (Ekins et al., 2003; Prug, 1995; England, 1999; Collados and Duane, 1999). Capital can also become critical because it is threatened or vulnerable (De Groot et al., 2003). However, quantifying the degree of threat to natural systems is not an easy task because a large number of different pressures-state impacts factors should be taken into account (De Groot et al., 2003).The proponents of this school also argue that standard economic valuation techniques can not be used to place a monetary value on this critical capital. Consequently, when there is depletion of critical non-substitutable capital, development becomes unsustainable.

It is also argued under this school of thought that there is scientific uncertainty about how natural processes such as climate regulation operate and how environmental capital, productivity and sustainability relate among themselves (Pearce and Turner, 1990). If it is assumed that natural capital can be given up for man-made capital, without fully understanding how ecological processes operate, it will only be realized that the consequences of such an assumption cannot be reversed once resource degradation has occurred. For example, effects such as species extinction occur once and cannot be reversed (Ekins et al, 2003). Based on limited substitution between manufactured and natural capital, strong sustainability calls for the *precautionary principle* which cautions against the use of renewable resources in excess of their regenerative capacity, imprudent and inefficient use of non-renewable resources that leads to essential functions being unavailable to future generations and using sink functions beyond their assimilative capacity (United Nations, 2003).

3.2.1 Some indicators of sustainability

Literature indicates that there are three indicators of weak sustainability, namely genuine savings, changes in net national product (NNP) and change in welfare per capita (Alisjahbana et al., 2004). Genuine savings is a measure of the true rate of saving in an economy after accounting for depreciation and depletion of capital assets (World Bank, 1997). Hamilton et al., (1997) defined genuine savings as “the sum of net investment in produced assets and human capital and the changes in various stocks of natural resources and pollutants, (valued at the shadow price), marginal changes in pollutants" Thus, the measure of genuine savings is a measure of net increase or decrease in the nation's wealth.

Persistently negative genuine savings indicates that development is not on a sustainable path and the well-being of the nation will decline in the future (World Bank, 1997). On the other hand, if genuine savings is positive, it is an indication that the society is refraining from current consumption, which this leads to an addition to the capital base (Alisjahbana et al., 2004). Pearce and Atkinson (1993) showed that a country will not be on a sustainable path (fails sustainability test) if it is not saving enough to offset depreciation of its capital assets by using the following formula:

$$Z > 0 \text{ iff } S > (\delta_M + \delta_N) \qquad (1)$$

where Z is a sustainability index, S is saving, δ_M is value of depreciation of man-made capital and δ_N is value of depreciation of natural capital.

However, genuine savings does not give an indication as to whether or not the total well-being is declining, and a new measure called change in wealth per capita has been proposed (Alisjahbana et al., 2004):

$$\dot{k} = \frac{d}{dt} = \left(\frac{K}{N}\right) = \frac{K}{N}\left(\frac{\dot{K}}{N} - \frac{\dot{N}}{N}\right) = \frac{K}{N}\left(\frac{\dot{K}}{K} - n\right) \qquad (2)$$

where $\dot{k}$ is growth of capital per capita, K is broadly-defined capital, N is population, n is the rate of population growth, and $\dot{K}$ is genuine savings i.e. net addition to total wealth. From this expression it can be seen that if growth of genuine savings ($\dot{K}$/K) is less than growth of population (n), then the change in welfare per capita ($\dot{k}$) will be negative, implying that the economy is not on a sustainable path (Alisjahbana et al., 2004).

Another measure of sustainability is net national product. Traditionally, net national product (NNP) is the difference between gross national product and depreciation of produced capital. Clearly, NNP does not include natural resource depletion and environmental degradation in the national accounts (Asheim, 2003). This is primarily because it is easier to net out economic depreciation from GNP for those assets which can be priced but not so for resources whose flows cannot be valued using market price (Hartwick, 1990). As a result of this situation, the unadjusted NNP is a misleading sustainability indicator because social welfare may decrease in the long term. According to Hartwick (1990) appropriate scarcity or shadow prices should be used to value flows for natural capital which does not have market prices in order to derive green NNP which takes into account depreciation of natural capital. According to Dasgupta and Mäller (2002), green NNP is not only an important quantitative measure of making welfare comparisons but also a measure of social well-being. Green NNP represents the maximum amount of produced output that can be consumed at a point in time while leaving this measure of wealth constant (World Bank, 1997).

On strong sustainability, the London School thought indicates that the maintenance of different forms of capital means that (i) the physical quantity of natural resources must not change, (ii) the unit value of the natural capital must not change and (iii) the value of the resource flows from natural capital must not change (Pearce and Turner, 1990). Kosz (1998) emphasizes the framework of total economic value as the basis for capturing all the economic values for a natural resource. In the absence of market prices for environmental resources, attaching monetary value to these resources using the willingness to pay (WTP) principle ensures that a common unit of value can be used in maintenance of constant stock of capital (Pearce and Turner, 1990).

While techniques such as WTP can be applied to value natural capital, Özkaynak et al. (2004) question such methodologies on three grounds: firstly, they argue that a single common unit of measurement (money) cannot be used to value complex and interrelated attributes of the ecosystem because of the moral aspects of the environment. Secondly, the measure of the WTP depends on the distribution of income/wealth and preference. Thus, the values are misleading as indicators of sustainability as they have no relationship to the biophysical condition of the ecosystem. Thirdly, the preferences of respondents in WTP surveys are not exogenously determined as assumed by the neoclassical model but are determined by the hypothetical situation as presented to them by the interviewer. Notwithstanding the criticism of putting a monetary value on natural capital, Pearce and Turner (1990) indicate that it remains a useful yardstick.

Proponents of strong sustainability also argue that operationalising strong sustainability cannot be analyzed solely in terms of economic tools since ecological sustainability is a prerequisite for strong sustainability (Perman et al., 2003; Turner, 1992). They argue that physical indicators for sustainability are better measures than economic indicators because they indicate threshold levels of critical capital. An example of such a measure is the change in the level of species which could reflect resilience of an ecosystem (see Perman et al., 2003). However, these indicators have been criticized because they are taken in abstraction and do not become useful for decision making processes (Özkaynak et al., 2004).

3.3 National Income Accounting and its deficiencies

The conventional measures of national income such as Gross Domestic Production (GDP), Gross National Product (GNP) and Net National Product (NNP) and other national income accounts were designed to monitor temporal changes in aggregate economic activities (Prato, 1998; Peskin, 1991). GDP for instance, is a measure of total economic activity, and mostly valuable for indicating the short- to medium-term changes in the level of economic activity in a country (El Serafy and Lutz, 1989). The measures were never intended to be measures of wealth and societal welfare because they do not account for the value of natural resources and changes in environmental and resource conditions upon which all production ultimately depends (Hassan et al., 1998; Peskin, 1991; Turner and Tschirhart, 1999). This is an unfortunate weakness because the natural environment provides the context within which all human action takes place and sustains life-support systems. Not only is the natural environment a life supporting system, it is also the source of raw materials and energy and the ultimate recipient assimilator of wastes of production and consumption (El Serafy, 1997).

The conventional measures of income treat gradual wear of physical capital (machines and equipment) as depletion rather than income, but respond poorly to depletion of natural resources (Peskin, 1991; Prato, 1998). For instance, El Serafy (1997) argues that ‘the production of a mineral for a particular year registers an increase in gross national product equivalent to its monetary value and inflates the GDP just as it inflates the gross profits of an enterprise’. However, the resultant depletion of the country’s natural wealth due to such production is not recorded in the system of national accounts (Santos and Zaratan, 1997; Hartwick, 1990; El Serafy, 1997; Ryan et al., 2001). Winter-Nelson (1995) also argues that while export expansion has been associated with growth in GDP in most countries, it has often been based on extraction of natural capital without commensurate investment to maintain total capital stock or generate increased production. According to Ryan et al. (2001), depletion in an economic sense results because the value of the resource has been lowered through its use in a productive activity, and the use has reduced the asset's ability to produce in the future. Thus, in the absence of discoveries of fixed resources such as minerals, their extraction and consequent decline will lead to their reduced capacity to generate sustainable income and employment for future generations (Blignaut and Hassan, 2001; Prato, 1998; Ryan et al., 2001; Minnitt et al., 2002; El Serafy, 1989; Winter-Nelson, 1995). It therefore follows that if depletion of a country's mineral assets are not accounted for in the system of national accounts, the national wealth and social welfare in the economy of that country is over- estimated (Blignaut and Hassan, 2001; Hassan et al., 1998; Lange, 2003b). Thus, countries such as Botswana, with mineral dependent economies should strive for economic diversification. The more diversified the economy is, the more resilient it will be in times of economic disturbances (Lange, 2003b).

El Serafy (1989) argues that the basic problem of not taking depletion of natural resources into account is because the true or sustainable income is not accurately calculated by economies based on natural resources. As El Serafy (1997) puts it 'if economists accept the measurement of conventional accounts as valid, and set out to analyze the economic problems of a country that is selling its natural assets on an appreciable scale while counting this as value added, their analysis is likely to be wrong, and the policy measures they prescribe are likely to be unsuitable or even harmful.'
Hicks (1946) quoted by El Serafy (1989) noted that:

> the purpose of income calculation in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves. Following out this idea, we ought to define a man's income as the maximum value which he can consume during a week, and still expect to be well off at the end of the week as he was at the beginning. Thus, when a person saves he plans to be better off in the future; when he lives beyond his income, he plans to be worse off.

> Remembering that the practical propose of income is to serve as a guide to prudent conduct, I think it is fairly clear that this is what the central meaning must be.

Thus, proper measurement of income will guide the person or nation on how much to spend on consumption, hence investment for any particular period in order to maintain a constant or increasing level of income (Santos and Zaratan, 1997). According to Minnitt et al. (2002), any resource based economy in which gross investment is less than resource depletion means that the asset base is being run down rather than being built up. Furthermore, natural resource endowment is being used to fund current consumption. The component of the revenue which is known as the user cost must be deducted from the GDP to arrive at a socially sustainable gross domestic product (Santos and Zarantan, 1997; Winter-Nelson, 1995; Bartelmus, 1999, El Serafy, 1989). To compensate future generations with future stocks as a result of consumption of the natural asset, the deducted component must be re-invested in other forms of capital assets that can provide the same stream of benefits in the future (Blignaut and Hassan, 2001; Kellenberg, 1996). Thus, when the finite flow of user cost is re-invested, it is transformed into infinite income flow which will ensure that the society is not worse-off in the future as result of depletion of its resource base (Santos and Zaratan, 1997). In other words, income will not be a declining asset, which is an essential condition for the maintenance and well-being of the society (Blignaut and Hassan, 2001; El Serafy, 1997).

Conventional measures of national income also poorly reflect efforts to defend against environmental expenditures made to reduce adverse welfare effects of resource depletion and environmental degradation (Peskin, 1991). Prato (1998) proposes that expenditures made by governments as well as medical and relocation expenses incurred by households to reduce the adverse effects of environmental pollution should be subtracted from, and not added to aggregate measures of economic welfare because these expenditures do not increase economic welfare.

Many resource costs are also excluded from national income accounts because they are not priced (Prato, 1998). These costs include user fees for grazing on public rangelands and water subsidies (Prato, 1998; Lange, 1998). For instance, Prato (1998) argues that if the grazing fee for public rangelands is set below the true resource costs of grazing, resource users would have the incentive to shift from private to public grazing lands leading to overgrazing. As a result, the retail price of meat product would be lower, and consumption of the meat product would be higher than would be if grazing fee reflected the full cost of grazing. Since the costs of reduced capacity of the grazing land on public grazing land are not reflected in retail meat price and consumption, national income accounts are overstated.

National Income Accounts also neglect subsistence economic activities because they focus on production of market goods and services (Hassan et al., 1998; Peskin, 1989). As a result of this, benefits derived from the use of tangible and intangible non-market goods and services are missing. These benefits include the value of firewood collected directly by many households, the carbon sink function of standing forests and watershed protection and other indirect services offered by various ecosystems (Hassan et al., 1998). Peskin (1989) cautions that it should be clear that if non-market activity is widespread in an economy, and if such activity is ignored in national data system, then these systems will not be able to support accurate analysis of economic behaviour. Lack of data on non-market activities, especially those that lead to negative externalities such as pollution, may produce a distorted view of the likely benefits of actual and proposed development projects (Peskin, 1989). Such a view is likely to result in sub-optimal allocation and unsustainable extraction and use of natural resources (Hassan et al., 1998; Winter-Nelson, 1995; El Serafy, 1997).

3.4 What is Natural Resource Accounting?

Natural resource accounts, also known as green accounts, are an accounting framework designed to provide information that tracks important changes in economic use of environmental resources (Statistics New Zealand, 2002). The natural resource accounting framework consists of physical and monetary accounts (Blignaut and Hassan, 2004). The physical accounts consist of stock accounts and flow accounts. The stock accounts show opening and closing stock level of a resource and changes that occurred during the period that is usually a year (Statistics New Zealand, 2002). Thus, stock accounts can reveal the extent to which a resource has been depleted. The monetary valuation of the natural asset or changes in use of that asset should be fully integrated into economic accounting (Bartelmus, 1999).

The flow accounts show how the natural resources have been supplied and used within the economy (Blignaut and Hassan, 2004). Depending on the type of material and energy and the nature of the origins of physical flows, the flows can be categorized according to natural resources (for example, timber from saw mills), products (for example, wood products from saw mills to furniture) or residuals (for example, timber treatment chemicals (Statistics New Zealand, 2002). Flow accounts can also be measured in monetary terms, though there is a need to aggregate the accounts into a condensed form called 'economy wide material flow accounts' (Statistics New Zealand, 2002).
As discussed in the following sections, many of the ecosystem goods and services provided by natural systems such as the Okavango Delta are not included in the calculation of GDP because the market system fails to capture such services (Blignaut, 2004). The use of natural resource accounting in determining the value of goods and services is crucial for policy decisions affecting the use of such resources.

Since the standard measures of economic performance such as GDP do not fully account for unsustainable use of natural resources, natural resources accounts complement these measures to provide a more complete picture of a country's economic and environmental performance (Statistics New Zealand, 2002). Natural resource accounts achieve this goal by adjusting conventional measures for the missing environmental values, and establishing the link between economic activities and use of natural resources and impacts on the environment (Hassan et al., 1998). Natural resource accounts provide information that can improve resource management and help determine whether natural resources are being utilized efficiently on a national basis (Statistics New Zealand, 2002).

Natural resource accounting can also be used to assess the physical and monetary extent of environmental depletions of natural resources that can threaten living standards, the food chain, ecological stability, and economic productivity. Natural resource accounting can also be used to assess the extent of environmental protection expenditures; and measure health and welfare costs associated with degradation of the environment (Statistics New Zealand, 2002). Hassan et al. (1998) also point that natural resource accounting can, and has, been linked to economic planning and policy analysis models for evaluating alternative development strategies in terms of their environmental impacts.

3.5 Application of natural resource accounting in resource management

Although natural resource accounting as a field of study is relatively young, most studies undertaken in natural resource accounting have had an element of sustainable management of natural resources. El Serafy and Lutz (1989) emphasize the need to collect data on renewable and non-renewable resources for long-run planning of resource exploitation in order to achieve sustainable economic activity.

3.5.1 Mineral Resources

In the management of non-renewable resources such as minerals, the objective and application of natural resource accounting has been to find out how the system of national accounts may be corrected for resource extraction so that industries dependent on these resources can be managed to contribute to sustainable economic growth.

In the Philippines, Santos and Zaratan (1997) used El Serafy (1989) user cost method to estimate mineral depletion during the 1980-1990 period in the copper and gold industry. The El Serafy (1989) formula for partitioning the revenue from mineral extraction between income and user costs is as follows:

$$X/R = [1-1/ (1+r)^{n+1}] \qquad (3)$$

where *X* is true income, *R* is total revenue (net of extraction costs), *r* is the rate of discount and *n*, the number of periods during which the resource is to be liquidated. *R-X* would be the user cost or depletion factor. According to van Kooten and Bulte (2000), the user cost of removing ore from the mine today is actually the benefit that one obtains from the same ore at some future date, appropriately discounted.

The application of the user cost method in Santon and Zaratan (1997) was important in the following three respects: firstly, it gave an idea of how much the GDP must be reduced for any given time to arrive at a socially sustainable value. Secondly, such an estimate can also be used to test how well the decision makers in the industry have used the mining revenue. Finally, since the difference between the industry's revenue and user cost is sustainable income, estimate of the latter can give an idea of how much disposable income the industry can provide without adversely affecting the economic welfare of future generations. The authors found the user cost in the copper and gold mining industries to be relatively smaller than true income, and attributed the low depletion rate and user cost to the maintenance of high levels of reserves relative to production. They concluded that the small proportion of the user cost in revenue very likely led the mining industry to invest at least as much as the value of depleted minerals.

Kellenberg (1996) examined natural capital depletion in Ecuador from 1971-1990, a period that corresponded with an oil boom. The depreciation method and the user cost method were utilised to measure the economic value of natural capital depletion in the production of petroleum. The value of natural capital depletion derived using the depreciation method equaled 4.3 percent of GDP while that derived using the user cost method was 8.9 percent of GDP. Kellenberg (1996) attributed the unsustainable development path to the failure by Ecuador government to reinvest oil revenues in other capital assets, but used oil reserves to sustain consumption which was equal to 6 percent of GDP and a reduction of taxes equal to 2 percent of GDP.

In South Africa, where mining has been an important economic activity during the country's early stages of economic growth, Blignaut and Hassan (2001) analyzed the change in the state of and value of the mineral resources (mainly gold and coal), and how they have been managed to support sustainable development. Resource accounting indicators and measures of sustainable management of the mineral resources sector were derived, and the components of the resource rent that needed to be reinvested and true income were calculated using the El Serafy (1989) formula. Mineral rent is defined as the difference between total revenue generated from extraction of natural resources and all costs incurred during the extraction process including the costs of produced capital (Minnitti et al, 2002). According to Lange and Wright (2004) capturing maximum rent generated from natural resources and investing it in other alternative assets that will generate as much income once the natural resource have been exhausted, is key to sustainable economic development. Thus it creates a permanent source of income. This is essentially the operationalisation of the Hartwick-Solow rule. Blignaut and Hassan (2001) found that the royalties captured were a very small percentage of total resource rent and were approximately a third of what should be captured according to El Serafy (1989). The lower rent captured was attributed to the nature of property rights related to the resource and the system of royalties and levies in place for its exploitation.

Contrary to the situation in South Africa, Lange and Motinga (1997) found that in Namibia and Botswana, where the central governments own the mineral resources, governments have been successful in recovering resource rents from mining to the extent that this reflects the longer-term rent generating capacity of the mining industry. In Botswana for instance, recovery of mineral rents in Botswana has been achieved through the levying taxes and royalties on minerals (Lange and Hassan, 2003; Lange and Wright, 2004). Lange (2003a) reported that Botswana receives about 50 percent of its revenues from taxes in the mining sector. The Government of Botswana has also constructed the Sustainable Budget Index (SBI) to monitor whether minerals are used in a manner that will promote development (Lange and Wright, 2004). SBI measures the extent to which annual consumption by the public sector is financed out of mineral revenues which are considered to be non-recurrent revenues. i.e. $SBI = \frac{Spending_{non-investment}}{\mathrm{Re}venue_{recurrent}}$ Essentially, an SBI value of 1.0 or less indicates that consumption is sustainable because it is financed entirely out of revenues other than from minerals, and that mineral revenue is used for public investment, while an SBI value of greater than 1.0 means that consumption relies on mineral revenues which is unsustainable in the long run (Lange and Wright, 2004).

In many African states, especially those whose economies are dependent on extractive industries, there is a substantial discrepancy between growth in production and growth in Gross Domestic Production (Winter-Nelson, 1995). Revenues from activities that reduce the stock of capital are treated as income without considering the impact of lost stock on future consumption opportunities. Given this state of affairs, Winter-Nelson (1995) adjusted the national income accounts of 18 African countries for mineral and petroleum depletion using the El Serafy method. For the countries with large extractive sectors (Botswana, Gabon and Nigeria), the El Serafy adjustment lowered the income levels by 5-10 percent relative to the conventional GDP estimates. For other countries, Winter-Nelson (1995) did not find the accounting correction to have any significant impact on income. Thus, the adjusted measures indicated that rates of income growth were very different from those suggested in conventional analysis.

There is, thus, a tendency among mineral dependent economies to ignore the contribution of exhaustible resources to national income and account for it in some way that is reflected in national income. Minnitt et al. (2002) undertook a study in which they examined the performance of the South African gold mining industry since its inception in terms of the capture of resource rents and capital component. Resource rent arising from the gold mining during 1910-1917 and 1970-2000, as calculated using the El Serafy (1989) method indicated that the exploitation of South Africa's gold deposits has not been undertaken in a fashion that was consistent with sustainable development. The surplus rents have flowed to investors at the expense of income and employment opportunities of future generations. Although the capture of a large proportion of rents (47 percent) may be justified by the risky nature of the mining industry and the fact that resource rents serve as the main stimulant of investment, Santos and Zaratan (1997) argue that decision makers in the mining industry, whether in the private or public sector, must ensure that the capital portion of the revenues from minerals or any extractive resource are regularly invested in the most rewarding and socially beneficial projects.

3.5.2 Forest resources

The application of natural resource accounting in the management of forestry resources has also revealed substantial weaknesses in the system of national accounts of many countries. In China, where the main natural forests and timber stocks have been greatly reduced by deforestation ensuing from agricultural conversion and the high demand for timber consumption, Liu (1998) estimated the economic damage of forest resources in national accounts from 1976 to 1992. Both El Serafy (1989) method and the net price method were applied to reach forest-adjusted income accounts. Economic depreciation, which was calculated as a reduction of timber volume multiplied by the stumpage value, was found to be 2.02 to 8.31 billion Yuan from 1976 to 1992. Although the two methods gave different results of depreciation, they both showed that depreciation accounted for a high percentage of gross output. Both approaches also reflected the real scarcity of forest resources.

In their study of the contribution of natural woodland and forests for national income and economic welfare, Schakleton et al. (2002) established the value of natural woodlands and forests in South Africa, and used the estimated values to correct measures of national income and wealth and to derive better indices of economic performance and welfare change. The study revealed that woodlands and forest contributed up to R3.6 billion value added in direct use values in 1998 prices. This value, which is typically missing from the current income accounting, was found to be equivalent to three-fold the total contribution of forestry to the country’s GDP reported in 1996. The study also found the total value of standing asset stocks and carbon externality to be more than R7 billion in 1998 prices, a value which was found to be more than five-fold the reported contribution of forestry to GDP in 1996. The study concluded that as a result of omissions of the values of woodlands and forests, the measures of the country’s genuine savings or wealth formation (NNP) in 1996 was underestimated by about 2%.

Hassan (2003) found that the national income accounts estimate of the value added in agriculture, forestry and fishery combined was an underestimate of the contribution of cultivated forests to national income wealth in South Africa. In this study, changes in the value of standing stock of trees (for example, economic appreciation or depreciation due to natural growth and harvesting) were not captured in conventional measures of income and capital formation. The study further revealed that the value of other non-timber products and environmental amenities and expenditures were missing. In a related study, Hassan (1999) corrected the measures of national income for the missing water abstraction and carbon sink externalities in the South African industrial plantations. The loss value to agriculture of water abstraction amounted to 1.43 percent and 23.53 percent of value added in agriculture and forestry, respectively, while the net economic benefit from carbon storage functions was found to be about half of the economic costs of water reduction by plantation.

In Maharashtra, India, Haripriya (2003) undertook a study in the forestry sector to adjust the value added to include non-timber forest production of timber, fuel wood and non-timber forest products that are usually left out in the calculation of the GDP. In this study, the net state domestic product was adjusted for the depletion and degradation of forest assets to yield the environmentally adjusted net state domestic product. Results showed that the value added of forest was 3.5 percent of the net state domestic product and the value for depletion was 19.8 percent of the estimated value added. The environmentally adjusted net state domestic product was found to be 99.3 percent of the estimated net state domestic product.

In Ghana, where more than 60% of the forest has been destroyed in search of agricultural land, firewood, and logging, Baytas and Rezvani (1993) attempted to set up physical and monetary accounts for the timber resources between 1970 and 1987. When adjusting the GDP to net basis to reflect depreciation, the authors found that the GDP was reduced by 2.2%. This was in spite of the fact that the constructed accounts did not represent the total value of the country's forest resources which yield many important non-timber products such ad resins, oils, foodstuff and other forest services.

3.5.3 Water and fish resources

In Namibia, where water supplies are not being used sustainably Lange (1998) applied natural resource accounting to examine water policy as an example of the kind of analytical perspective that natural resource can provide to policy makers. Despite the scarcity of water in Namibia, Lange (1998) reported a number of factors that explain the unsustainable management of water resources. Firstly, groundwater resources are increasingly being depleted, there is increased harvesting pressure of ephemeral surface water and water is wasted through losses in the distribution network due to poor maintenance. Secondly, no user of government-provided water pays the full financial cost (operational and capital costs), a situation that represents an inefficient use of society's scarce water resources. Lange (1998) argued that the full social costs of using water must reflect the opportunity cost that measures the lost revenues from alternative uses, and that omission of capital costs can distort decision making regarding alternative water supply strategies. She concluded that a reallocation of resources from such activities that can generate income sufficient to pay the full cost of water or any other input needed for production, would bring about an economic improvement.

In the fishing industry, application of natural resource accounting in Namibia indicated that the major commercial fishes (hake, pilchard and mackerel) generated significant resource rent (Lange and Motinga, 1997; Lange, 2003b). However, rent recovery in the fishing industry was sub-optimal mainly because the government has been cautious in introducing high taxes to capture rents because the industry is still relatively new and government regards it as source of potential employment.

3.6 The status of natural resource accounting in Botswana

The first attempts to construct natural resource accounts at national level in Botswana were carried out by Perrings et al. (1989). The objectives of the study were to determine how national accounts might be extended to accommodate non-market resource based activities and to develop estimates of value of such activities; to recommend an appropriate system of natural resource accounts for Botswana and to develop a methodological data guide for the construction of the accounts; and to indicate how the extended national accounts and the natural resource accounts might be incorporated in the planning process in the country's development plans and in the national conservation strategy. According to Lange (2000), there was no follow-up to this work until in 1997 when a small pilot project involving the Central Statistics Office (CSO) and the National Conservation Strategy Agency (NCSA) led to the development of the current natural resource accounts that enabled the government to participate in regional initiatives to establish natural resource accounts in Southern Africa. Construction of natural resource accounts in Botswana is still at an early stage. Natural resource accounts have been constructed for minerals and water. In the mineral accounts, only proven reserves as opposed to both proven and probable reserves have been included (Lange, 2000). Natural resource accounts for water consist of stock and use accounts, with stock accounts including information about quantities of water stored in dams, annual runoff to rivers, and estimated ground water (Republic of Botswana, 2001).

Though the values of asserts and services in this thesis are those of the Okavango Delta region only, some of the corresponding values are missing in the national accounts of Botswana. For instance attempts to construct accounts for wildlife and livestock have been hampered by lack of data (Lange and Wright, 2004). In addition, natural resource accounts for products harvested and used for subsistence by communities from the wild (e.g. forest and fishery resources, traditional medicinal plants, wild fruits, fuel wood, basket making resources) and indirect goods and services (e.g. livestock grazing, honey production carbon sequestration) are also missing from the national accounts primarily because these products do not normally enter the trade and market sphere. Further, in the national accounts, tourism is not a clearly defined sector because its activities and output are assumed to form part of the Trade, Hotels, and Restaurant sectors (Republic of Botswana, 1999). This is in spite of the fact that tourism has become the second most important economic activity after mining.

3.7 Biodiversity conservation and resource accounting

This section outlines the nature of biodiversity, the problems threatening it, and its place in the construction of natural resource accounts.

3.7.1 Definitions, value and loss of biodiversity

According to UNEP (1992), biological diversity or biodiversity is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems". Biological diversity is usually considered at three different levels: genetic, species and ecosystem diversity. Genetic diversity refers to the variety of genetic information contained in all of the individual plants, animals and microorganisms, while species diversity refers to the variety among living things. Ecosystem diversity relates to the variety of ecosystems, biotic communities and ecological processes, as well as the tremendous diversity present within ecosystems in terms of habitat differences.

Biological diversity provides many important benefits for mankind (Balmford, 2002; Myers, 1996). In spite of the significance of biodiversity in maintaining the integrity of life-supporting ecosystems and support for human life, the past century has seen a strikingly high rate of species loss as a result of anthropogenic and natural factors. Market and policy failures have been reported as some of the underlying causes of loss of biodiversity (see Kahn, 1997; Perrings et al., 1995). The failure of the market stems from the fact that significant external effects in resource systems and public good features of biodiversity are not accurately valued and included in current decision making, while policy failure stems from the fact that government's decision to promote inefficient conversion of natural capital into other assets (van Kooten and Bulte, 2000; Barbier and Bugas, 2003). The proximate causes of loss of biodiversity are many and include habitat change by humans caused directly through land use change, urbanization, infrastructure development and industrialization (Perrings et al., 1995). Many species are found in specific habitats, and when these habitats are destroyed by conversion into other land uses the species may become extinct (Kahn, 1997). Conversion alters the structure, composition and function of natural ecosystems by modifying their basic physical properties (hydrology, topography, soil structure) and their predominant vegetation (World Resource Institute, 2000). In freshwater ecosystems Braga et al. (1998) reported that between 20 to 35 percent of fresh water fishes are vulnerable, endangered or extinct, mostly because of habitat alteration. Pagiola et al. (1997) identified agriculture as one of the most important causes of loss of habitat and species diversity. Barbier and Bugas (2003) found that data on stratified random sampling of the 10 percent of the world's tropical forests indicated that direct conversion by large-scale agriculture was the main source of deforestation, accounting for around 32 percent of total forest cover change, followed by conversion to small scale agriculture, which accounted for 26%.

The second major cause of biodiversity loss is the introduction of invasive and alien species, that may subsequently out-compete native species and lead to their extinction (Miani and Fajardo, 2001; World Resources Institute, 2000). Exotic species may be introduced into other environments by accident or through deliberate release. Brag et al. (1998) pointed out that freshwater ecosystems or other aquatic ecosystems are particularly vulnerable to these introductions because of the impact of activities beyond their boundaries such as forest clearance or industrial effluence. In North American freshwaters the freshwater zebra mussel, which was introduced from Russia in the 1980s through ship ballast water, has invaded Canada and the Great Lakes and has expanded into the inland waters at an alarming rate (World Resources Institute, 2000). The introduction of the Leidy comb jellyfish proliferated in the Baltic Sea after its introduction from the Western Atlantic in 1982 and led to the devastation of the natural zooplankton stocks (World Resource Institute, 2000). In East Africa's Lake Victoria, which is characterised by high species endemism of over 200 species, the introduction of the Nile perch into this lake in 1960 to improve local fishing for sport fishing and food was responsible for the extinction of 60% of the fish fauna (Braga et al., 1998).

The introduction of pollutants contributes to loss of biodiversity because pollutants alter ecosystem primary productivity, nutrient availability and hydrological cycle and other essential processes, leading to changes in the conditions and composition of the organisms (Perrings et al., 1995). Multiple pollutants can create a toxic synergy that weakens the organism and gradually reduce ecosystem productivity and resilience (World Resources Institute, 2000). In Lake Victoria, Lake Malawi and Lake Tanganyika, excessive suspended sediments from soil erosion caused by deforestation and over grazing and pollution from domestic and industrial wastes are causing eutrophication which has resulted in a serious reduction of fish populations in these lakes (Braga et al., 1998). D'Eposito and Feiler (2000) cited in the World Resources Institute (2000) reported that in the year 2000, an amount of 99 000 cm^3 of cyanide-laden wastes escaped the Romanian gold mine when the earthen tailings dam collapsed, and found its way into the Danabe floodplains and tributaries, wiping out virtually all aquatic life along the 400 kilometre stretch of the Danube.

Another important factor that leads to loss of biodiversity is open access harvesting which is associated with over-harvesting (Kahn, 1997). Around Lake Victoria, which is source of water and food for millions of people and their livestock, the lake's biodiversity and fisheries productivity have been depleted by over-harvesting and other factors (Braga et al., 1998). One reason why over-harvesting occurs is because no one owns the resources and that biological resources are harvested at a rate faster that they can regenerate naturally.

3.7.2 The structure, composition, and function of an ecosystem

3.7.2.1 Structure of ecosystems

It has become customary to define the structure and the operation of an ecological community largely with regard to feeding relationships, dividing the member species in terms of the trophic role (Shugart, 1998). Feeding relationships are by far the most common route of interaction between different organisms of the community. Such relationships may be *commensal* (one organism deriving benefits from the other while the other neither gains nor loses) *mutualistic* (both organisms gaining from the association), *parasitic* (one organism feeding upon the other to the benefit of itself but at the expense of its host) or *holozoic* (animals feeding directly one upon the other or on plants) (Kimmins, 2004). Thus, a forest, lake or pasture ecosystem is bound to be characterized by definite trophic structures determined by the interaction of the food chains and the metabolism relationship among its organisms. Communities having a high number of different species usually have complex trophic structures (Shugart, 1998).

Each step in the food chain represents a trophic level, with the first trophic level belonging to producers, the second to herbivores, the third to carnivores and the fourth to decomposers (Kimmins, 2004; Molles, 2002). Trophic structures may be measured and described as standing crop per unit area or in terms of energy fixed per unit area or per unit time at successive trophic levels (Odum, 1971; Molles, 2002). Each trophic level contains at any one time a certain amount of living material composed of a number of kinds of organisms and since some energy is lost between successive trophic levels, the total mass supported at each level is limited by the rate at which energy is being stored below (Shugart, 1998). Thus**,** the biomass of the producers must be greater than that of herbivores that they support, and the biomass of herbivores must be greater than that of carnivores, and so on. The pyramid of biomass would thus indicate that the total numbers of organisms in each trophic class decrease as we ascend the trophic scale because each organism relies on more than one organism in the previous level to support it (Molles, 2002). While this is true for most of ecosystems, exceptions occur in aquatic ecosystems where phytoplankton has small smaller biomass than zooplankton (Dajoz, 1977).

Not all organisms in communities are equally important in determining the nature and function of the whole community. For instance, out of hundreds of thousands of kinds of organisms that might be present in a community, a relatively few species or species groups generally exert a major controlling influence by virtue of their numbers, size, distribution over a large area, largest contribution to energy flow or mineral cycling or by some other means that can influence the rest of the community (Odum, 1971). These are driver species. The removal of dominant species would result in important changes, not only in the biotic community, but also in the physical environment, whereas removal of non-driver species would produce much less change (Odum, 1971; Kimmins, 2004). This however, does not necessarily mean that the non-dominant communities do not have important roles in the community.

The structure of a community is not only affected by the actual relationship among species, but also by the relative number of organisms in those different species (Molles, 2002; Magguran, 1988). The diversity of species within a community reflects in part the diversity in the physical environment in which the organism is found. Species diversity can be defined on the basis of the number of species in a community (species richness) or on the basis of the relative abundance of species (species evenness) (Molles, 2002). In general, species diversity increases with environmental complexity of heterogeneity (Molles, 2002). Accordingly, the greater the variation in the physical environment, the more numerous are species because there are more microhabitats available. A more diverse plant community is expected to support a more diverse animal community because food for a variety of herbivores will be abundant (Chapman and Reiss, 2003).

According to Magguran (1988), relative abundance is a better measure of species diversity than species richness because a community spread over a large area does not necessarily imply that it is species richer than one which is geographically restricted. The relative abundance of individuals in a particular species may have a marked influence on the nature and function of the community, the distribution of individual species between species within the community, and ultimately on its stability (Chapman and Reiss, 2003).

3.7.2.2 Composition of an ecosystem

Living organisms and their non-living environment are inseparably interrelated and interact upon each other. Odum (1971) defines an ecological system or an ecosystem as ‘any unit that includes all of the organisms in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles within the system.’ An ecosystem is composed of populations (groups of interbreeding organisms of the same kind occupying a particular space), that assemble into communities (naturally occurring assemblage of plants and animals that live in the same environment) (Chapman and Reiss, 2003). A population can be considered in different ways: it is a demographic unit; it is characterised by density (number of organisms occupying a definite unit of space); it possesses a certain age structure and a death rate; it experiences the movement of new individuals into itself (immigration) and loses others through emigration (Chapman and Reiss, 2003).

Biotic communities have definite functional unity within feeding structures and patterns of energy flow as well as compositional unity in that there is a certain probability that certain species will occur together (Odum, 1971). According to Chapman and Reiss (2003), a key quality of communities is that the organisms making up communities somehow interact as a society does. As Clapham (1983) puts it ' communities have a structure at all times and in all situations that is reflected in the roles played by the constituent populations, their ranges and types of areas they inhabit, the diversity of species in the community and the spectrum of interactions among them and the precise flow patterns of energy and nutrients through the community'. Thus, the interactions that occur among individuals in their habitats define their exact role in the community.

All ecosystems, whether terrestrial or aquatic, have four basic components: producers (autotrophs or green plants), the primary consumers (herbivores), secondary consumers (carnivores) and the decomposers (mainly microorganisms) (Kimmins, 2004). Producers are the only group within the community that can actually synthesize organic compounds and thus produce food for the community, while primary consumers such as ungulates, feed on producers for their energy needs (Osborne, 2000). In terrestrial ecosystems, the synthesis of organic compounds is carried out by higher plants, while in the sea, it is executed by microscopic plankton algae (Dajoz, 1977). In general, secondary consumers (carnivores), such as lions, are larger organisms that kill and eat smaller prey. Decomposers are mainly microorganisms such as bacteria or saprophytic fungi which may attack plant and animal material, slowly breaking them down and releasing energy.

3.7.2.3 Energy flow and material cycles in ecosystems

Energy flow through the ecosystem starts with the process of photosynthesis in which solar energy is used to produce simple organic carbon compounds from water and carbon dioxide (Townsend et al., 2003). According to Smith and Smith (2001), energy stored in the chemical bonds of organic carbon-based compounds forms the basis of energy flow in the ecosystem. The fixation of energy by plants is called primary productivity while all the energy that is assimilated in photosynthesis is called gross primary production (Molles, 2002; Smith and Smith, 2001).

Plants require energy for metabolic processes which they acquire through the oxidation of organic compounds during the process of respiration (Smith and Smith, 2001). The energy remaining after respiration is stored as organic matter and is called net primary production (Molles, 2002). Thus, net primary production equals gross primary production minus respiration. Net primary production is allocated to plant growth, the buildup of components such as stems and leaves and storage (Smith and Smith, 2001). Storage involves accumulation (increase of compounds that do not directly support plant growth), reserve formation (the synthesis of storage compounds from resources that otherwise would be allocated directly to promote growth) and recycling (retaining compounds that otherwise would be lost to litter) (Smith and Smith, 2001).

According to Molles (2002), the importance of nutrients, their relative scarcity and their influence on primary productivity makes nutrient cycling one of the most significant ecosystem processes. Biogeochemical cycles are the means through which nutrients move through the ecosystem, and the cycles involve chemical exchange of elements in the atmosphere rocks, water and living organisms (Smith and Smith, 2002). Some of the important elements such as carbon, phosphorus and nitrogen are made available to plants through the carbon cycle, phosphorus cycle and nitrogen cycle, respectively. While carbon and nitrogen enter the ecosystem through the atmosphere, phosphorus does not because it occurs in mineral deposits (Molles, 2002). The rate at which nutrients such as nitrogen and phosphorus are made available to primary producers (plants) in terrestrial ecosystem depends on the rate at which nutrients supplies are converted from organic to inorganic forms during the mineralization process which takes place through decomposition (Molles, 2002).

3.7.2.4 Ecosystem goods and services

Ecosystem functions are the capacity of natural processes and components to provide goods and services. The provision of environmental goods and services of ecosystems is a result of complex interaction between biotic and abiotic components of the ecosystem through the universal forces of matter and energy (de Groot et al., 2002; Norberg, 1999).

3.7.2.4.1 Direct consumptive use values

Food and raw material: Natural ecosystems are a source for local people of edible plants and animals, ranging from non-timber forest products such as raisins, to game and bush meat (de Groot et al., 2002). They are also a source of energy (for example, fuel wood) and building materials.

Genetic resources: A varying but often substantial proportion of the benefits of biodiversity accrue to agriculture through the provision of genes for the development of improved varieties in terms of productivity and disease resistance (Pagiola et al., 1997;

Field, 2000). Many important crops could not maintain commercial status without the genetic support of their wild relatives (de Groot et al., 2002).

Medicinal resources: Nature provides chemicals that can be used as drugs and pharmaceuticals, or which may be used as models to synthesize drugs (de Groot et al., 2002). According to WHO (2004) 80% of the population in Africa depends on traditional medicine for primary health care while in China, herbal medicines account for 30-35% of total medicinal consumption.

3.7.2.4.2 Direct non-consumptive use value

Recreation and ecotourism: Natural ecosystems have an important value as a place where people can come for rest, relaxation, refreshment and recreation. Recreational use may be consumptive, such as through hunting (Field, 2000). Through aesthetic qualities and almost limitless variety of landscapes, the natural environment provides many opportunities for recreational activities, such as walking, hiking, camping, fishing swimming and nature study (de Groot et al., 2002). In 1994, whale watching in 65 countries and dependent territories attracted 5.4 million views and generated tourism revenues of $504 million (Myers, 1996).

3.7.2.4.3 Indirect-consumptive use value

Environmental services comprise the main indirect values of biodiversity as opposed to direct use values in the form of material goods such timber, fish, plant based pharmaceuticals and germ-plasm for agricultural crops. They include generating and maintaining soils, converting solar energy into plant tissue, sustaining hydrological cycles, storing and recycling essential nutrients, supplying clean air and water, absorbing and detoxifying pollutants, decomposing wastes, pollinating crops and other plants, controlling pests, running biogeochemical cycles of such vital elements such as nitrogen, phosphorus and sulphur, controlling the gaseous mixture of the atmosphere and regulating climate and weather at both macro and micro levels (Myers, 1996).

Water supply: Lakes, stream, rivers and aquifer perform the function of filtering, retaining and storing water through the surrounding vegetation and soil biota (de Groot et al., 2002). The thick and diverse vegetation in some natural ecosystems allow a slower and more regulated runoff, allowing water supply to make a sturdy and more substantive contribution to the ecosystem, instead of quickly running off (Myers, 1996).

Crop pollination: Wild bees and honey bees pollinate $30 billion worth of 90 US crops annually, plus many more natural plant species (Myers, 1996). Without pollination many plant species would go extinct and cultivation of most modern crops would be impossible (de Groot et al., 2002). Thus, pollination is a service for which there is no substitute technology.

Carbon sequestration: Carbon sequestration service values are potentially of great interest for domestic and international policies because they involve local and global externalities (Kundhlende et al., 2000). Vegetation can serve as a source of sink for carbon dioxide. According to Myers (1996) evidence abound that species rich ecosystems can consume carbon dioxide (carbon sequestration) at a faster rate than less diverse ecosystem, which indicates that biodiversity loss or decline may promote the build up of carbon dioxide in the atmosphere.

Climate regulation: Local weather and climate are determined by the complex interaction of regional and global circulation patterns with local topography, vegetation, albedo as well as the configuration of lakes, rivers and bays (de Groot et al., 2002). The Amazonian region, which contains two-thirds of all above-ground freshwater on earth, has at least half of its moisture retained within the forest ecosystem, which is constantly being transpired by plants before being precipitated back onto the forest (Myers, 1996).

Waste assimilation: Natural ecosystems are able to store and recycle certain amounts of organic and inorganic wastes through dilution, assimilation and chemical re-composition (de Groot et al., 2002). A number of tree species such as beech, elm oak and sycamore willow and wilder have been found to serve to clean up sulphur dioxide pollution (Myers, 1996). Forests filter dust particles from the air, and wetlands and other aquatic ecosystems can treat relatively large amounts of organic wastes from human activities acting as free water purification plants (de Groot et al., 2002).

Soil protection/stabilization: While soil erosion is a major problem in certain environments, leading to declines in production in croplands and pastures, plant root systems hold the soil. Plants foliage also intercepts storm impacts, thus preventing compaction and erosion of soil as well as prolonging water discharge (Norberg, 1999; de Groot et al., 2002).

Nutrient cycling: The existence of the living world depends on the flow of energy and the circulation of material through the ecosystem (Smith and Smith 2001). Many structural and functional aspects of natural ecosystems facilitate nutrient cycling at local and global levels. Soil organisms decompose organic matter thereby releasing nutrients to both local plant growth, but also to the atmosphere (de Groot et al., 2002).

3.7.2.4.4 Basic information requirement to account for biodiversity

Most of managed biodiversity is found in protected areas. Protected areas are designated natural areas aimed at keeping natural areas relatively intact and restricting commercial development (van Kooten and Bulte, 2000). The World Conservation Union has defined ten categories of protected areas with different objectives (Dixon and Sherman, 1990). These are *scientific reserve/strict nature reserve* (to protect nature and maintain natural processes in an undisturbed state in order to have ecologically representative examples of the natural environment for scientific, monitoring educational purposes); *national parks* (to protect large and scenic areas of national and international significance); *natural nature reserve/natural landmark* (to protect and preserve nationally significant natural features because of their special interests or unique characteristics); *managed nature reserve* (to ensure the natural conditions necessary to protect nationally significant species, groups of species, biotic communities or physical features of the environment requiring human intervention for their perpetuation); *protected landscape* (to maintain nationally significant landscapes characteristics); *resource reserves* (to protect the natural resources of the area for future use and curb development that can affect the area); *natural biotic area/anthropological reserve* (to allow societies living in harmony with the environment to continue their way of life undisturbed by modern technology); *multiple-use management area/managed resource area* (to provide for the sustained production of water, timber, wildlife, pasture, and outdoor recreation).

Although the initial intention for establishing parks was to protect scenic and recreational resources, and not to conserve biological diversity per se, protected areas, to a large extent constitute in situ protection of biodiversity and other environmental value (Dixon and Sherman, 1990; van Kooten and Bulte, 2000). The Keystone Centre Report (1991) as cited in Stohlgren et al. (1994) argues that the national parks system provides both fully protected habitats for the long term maintenance of biological diversity and a baseline against which to measure change. In the Kwazulu Natal Province of South Africa, game ranching has significantly enhanced the species status of large herbivore and predator species (elephant, white rhino, black rhino, lion, leopard, wild dog) and the survival prospects of wider ranging species, whose populations are not entirely secured in the formal protected areas (Goodman et al., 2002). Jones (1996) is of the view that protected biodiversity should be listed, described and monitored so that the basic requirement for conservation and management of these resources is met. Common and Norton (1995) view ecological monitoring as an essential component of any viable strategy to conserve biological diversity because it provides a basis to track the status of various components of biodiversity over time in the context of different management regimes. As Stohlgren et al. (1994) puts it 'these assessments are essential to form natural resource management policies, manage the natural diversity within existing national parks, and identify potential new or expanded reserves to encompass biotic diversity not now effectively protected within the park system.' According to the World Resources Institute (2000), the condition of forest diversity in forest reserves can be directly measured by changes in the number of species found in the forest, including the extinction of native species or introduction of non-native species. Accordingly, any change in the number or relative abundance of different species represents ecosystem degradation from the standpoint of biodiversity. In many situations, however, data on biodiversity accounts is not available and most of what is known about the condition of forest species is only inferred from various measures (for example, habitat fragmentation, logging and loss of habitat) of pressures on forest diversity (World Resources Institute, 2000).

In the Cosmeston Lakes Country Park in Wales, UK, Jones (1996) compiled physical resource accounts for wildlife habitats, flora and fauna using a natural inventory model which comprised six broad levels of hierarchical criticality moving from critical (irreplaceable) natural capital to non-critical natural capital. Since the park was a community asset, and not in the commercial domain, there was no open market valuation. A best estimate of the amenity value of the different managed natural habitats was made to accompany the ecological grading in which a habitat with a great ecological worth was assigned grade 1, and a habitat with little ecological worth was assigned grade 5. According to Jones (1996), the fauna accounts suggested that the increase in bee orchids was sustainable as it was aided by good conservation work.

Similarly, because wildlife habitats form a major focus of nature conservation policies, Scott (2001) reports that, in the UK, habitat accounts have been produced using results of a country survey for the period 1990 to 1998. The accounts, which take the form of a simple balance sheet, present the opening stock of habitats, the major transfers of land between habitats, and the closing stock and net change. In addition to habitat accounts, a number of habitat condition measures have been developed based on the plants observed in vegetation plots, which include direct measures of species diversity such as mean species richness and measures of ecological status such as nutrient level or acidity. The constructed habitat accounts showed that there were high rates of exchange of land between intensive agriculture habitats and semi-natural habitats, leading to a net loss of 60,000 hectares of semi-natural habitats, apparently due to agricultural intensification. The gains in agricultural intensification were however offset elsewhere by losses from agriculture to woodland and developed land habitats. With regard to habitat conditions, results showed a significant loss in species richness in grassland vegetation types over the period 1990 to 1998, and increased fertility in semi-natural grasslands which resulted from agricultural intensification.

3.8 Chapter conclusion

In this chapter, the concept of sustainable development has been discussed, particularly in the context of capital theory and the paradigms of weak and strong sustainability. According to El Serafy, (1997) weak sustainability calls for keeping capital intact, meaning that a reduction in the form of capital must be offset by acquisition of other forms of capital in order that the unit's income may be sustained. Proponents of strong sustainability argue that substitutability declines as resources stocks are depleted, and that there are no substitutes for many natural resources such as wilderness, implying that the elasticity of substitution between natural capital and reproducible capital becomes zero (van Kooten and Bulte, 2000). The concept of sustainable development also entails ethical and social limits to growth (Blignaut, 2004). The society or individuals must have equal rights of resource access to satisfy their human wants. The social limit to growth is that high incidences of poverty, unemployment and inequality still occur during high economic growth periods.

The chapter has also given an overview of what resource accounting is, the deficiency of conventional national income accounting, and how natural resource accounting can be used to augment these measures. Case studies where natural resource accounting has been used have been reviewed. Natural resource accounting has been applied in the management of non-renewable resources such as minerals, and renewable resources such as forests in many areas of the world. The chapter has also reviewed the literature on how natural resource accounting can be used in the conservation of biodiversity at structural, compositional and functional levels.