

Economic sciences, with the emphasis on economic efficiency as a normative goal, have led to the development of indicators that support and measure this goal. For example, national income is usually defined without taking depreciation of natural and environmental resources and reinvestment in sustainable capital into account. Furthermore, companies do not readily account for their impacts on the natural environment, unless forced to do so through user charges or taxation. Sustainability assessment in such a context is a merely a reinterpretation within the boundaries of existing economic approaches and would not lead towards the sustainability of natural and environmental resources. At best, certain economic operations can be performed more efficiently, leading to savings in resource use and less pollution and waste. However, such approaches are not broad-based and sufficiently lateral to include possible alternative agricultural and economic systems.

An alternative conceptual framework is proposed here that builds on arguments made earlier in this paper. The fact that reality is larger than that encompassed by mainstream economic and agricultural sciences warrants the investigation of alternative approaches. This does not necessarily imply that such sciences are not useful in certain contexts, but that they are evaluated for their application to sustainability in a broader, interactive process that take cognisance of different value-judgements.

Neo-classical economic science and industrial agricultural science both lack inherent value judgements necessary in moving towards sustainability. Environmental indicators repeatedly point out that short-term orientated economic activity, including agriculture will not be able to reach a goal of sustainability. Although one can argue about the details of what constitutes sustainability, the focus is rather on movements of agricultural and economic systems towards or away from sustainability.

A conceptual solution needs to be sought in a broader reinterpretation of what value systems need to be engrained in economics and agriculture. An alternative to industrial agriculture is ecological agriculture. An alternative to mainstream economic science of maximising profits and minimising costs is one of stewardship, an economy of care and sufficiency. Both ecology and economics is rooted in the Greek word oikos. Such a household economy is aimed at achieving a certain quality of life without impeding on the ability of their support systems to produce this quality in a sustainable fashion. The following observations are important in shaping a broader base for indicator development needed for the assessment of agricultural sustainability:

There is no apparent conflict between ecological agriculture (oecology) and oikonomia  
There is no apparent conflict between industrial agriculture and a short-term economic focus  
Oecological farming will only thrive if oikonomia exists  
Oikonomia can be better supported if oecological farming management is widely practiced

Therefore, the lack of progress in the assessment of sustainability can probably be explained by inherent tensions and thus, a lack of a common goal, i.e. there is no direction; therefore, there can be no progress. Furthermore, it should never be forgotten that it is not science and technology alone that ultimately determines what will be done on the land. Land users have a significant impact on land management.

## **7 AGRICULTURAL CASE STUDY**

Since most of the earth's surface has been altered for the purpose of agriculture (Srivastava, 1996), it can be deduced that the conflict is often between environmental conservation and industrial agriculture. Therefore, agriculture was considered an appropriate economic activity to illustrate the influence of conflicting value systems on the perceived lack of progress with sustainability assessment.

The early 1960's, according to Harwood (1990) & Barker (1996), was a time of agricultural scientific euphoria. However, the accompanying environmental, financial and social costs of decreasing energy efficiency in agriculture were either ignored or undervalued. Furthermore, no or little cognisance was taken of the anomalous benign climate. During this period, there was little debate, in the biological sciences, on

agricultural development direction. Industrial agricultural technologies were so dominating that they stifled serious debate of alternatives.

However, since the late 1970's, the numbers of publications that raise concerns over the sustainability of industrial agriculture, have continued to increase (Besson & Vogtman, 1978; Boeringa, 1980; Stonehouse, 1981; Hill & Ott, 1982; Lockeretz, 1983; Bezdicek & Power, 1984; Edens *et al*, 1985; Mollison, 1988; Conway & Barbier, 1988; Edwards *et al*, 1990; MacRae *et al*, 1990; Maser, 1994; Pretty, 1995; Matson *et al*, 1997).

During this same period, i.e. the past three decades, a similar trend is discernable concerning publications on the topic of conflict between the conventional economic system and the environment, including anthropological environments (Glaeser, 1988; Nijkamp & Soeteman, 1988; Daly & Cobb, 1989; Ayres, 1998).

According to Pretty (1995), the food and fibre production successes attributed to industrial agriculture lies in simplicity. In other words, industrial agriculture aims to ignore ecosystem complexities and succeeds in doing so with the aid of primarily the chemists intervention. However, inherent in this biotic simplification is increased vulnerability of both the biotic and abiotic components of ecosystems. Conventional manipulations of the environment, inevitably lead to simplification of the biotic components of an ecosystem, e.g. a crop of maize replaces the species rich natural vegetation (Booyesen, 1993). Primarily at the household level it also leads to economic vulnerability.

Reversal of this biotic simplification demonstrably increases the resilience of the household economy. Such an action should reduce the conflict with environmental science but, as discussed, will then come in conflict with a short-term focus in the economy. The following simplified example (a single field trial on an experimental station and not an integral part of an ecologically managed farm) illustrates this principle and encompasses the addition of only two species (i.e. increasing agrobiodiversity) to the system: one plant and one bacterium.

A field trial was conducted in moist subtropical Gauteng on the Roodeplaat Research Station. The objective was to compare animal production from annual ryegrass, Persian clover and a mixture of these forage crops (Paulsmeier *et al*, 1990). For the purpose of this paper, the annual ryegrass represents best practice conventional farming, i.e. an improved temperate grass, grown in monoculture, according to best industrial agricultural practice. The monocultured Persian clover represents the addition of one more species (a nitrogen fixing bacterium), i.e. the replacement of imported nitrogenous fertiliser with *in situ* nitrogen fixation by the legume-rhizobium symbioses. The ryegrass-clover mixture approaches what may be referred to as polyculture, i.e. three species in one field namely ryegrass, clover and one specific strain of a nitrogen fixing bacterium.

Four 0.1 ha paddocks of each pasture, i.e. *Lolium multiflorum* var *westerwoldicum* cv Enegra, *Trifolium resupinatum* cv Shaftal Maral and a mixture of these forage crops were established. Nitrogenous fertiliser was applied at the rate of 400, 0 and 60 kg N ha<sup>-1</sup>, respectively to the grass, clover and mixture (polyculture). The pastures were stocked with five SA Merino lambs and two adult wethers per paddock. The results are summarised in Table 1.

**Table 1 Pasture yield and animal production from ryegrass, clover and a ryegrass/clover mixture (Paulsmeier *et al*, 1990)**

Pasture	Ryegrass	Clover	Mixture
Dry Matter Yield t ha <sup>-1</sup>	11.24 <sup>b</sup>	8.02 <sup>a</sup>	10.22 <sup>b</sup>
Cost R t DM <sup>-1</sup>	113	71	69
<b>Animal production</b>			
Average daily gain kg day <sup>-1</sup>	0.163 <sup>a</sup>	0.216 <sup>b</sup>	0.215 <sup>b</sup>
Gross income R ha <sup>-1</sup>	5 056	6 484	6 319

It appears that ryegrass does not compare favourably with either the clover or the grass-clover mixture. Furthermore, only 5% of the lambs grazing ryegrass were graded as Super Lamb compared to 50% and 30% of the lambs on clover and the grass-clover mixture, respectively (Paulsmeier *et al*, 1990).

In a sustainability assessment context, the important consequences can be summarised as follows:

The production of forage by means of nitrogen fertilised annual ryegrass complies with short-term economically optimal industrial farming practice, but is in conflict with an assessment tool that measures biotic diversity (polyculture or agrobiodiversity) on the farm.

Forage production, by means of a nitrogen fixing annual clover, has negative implications for short-term economic optimality (non-reliance on nitrogenous fertiliser) but should reflect a biodiversity improvement if assessed for environmental sustainability.

The ryegrass-clover-rhizobium pasture is in conflict with certain input chains operating for short-term economic gain because of the significantly reduced reliance on nitrogenous fertiliser. However, in terms of agrobiodiversity this pasture should receive improved sustainability assessment ratings.

All three pastures are in conflict with the school of thought in environmental, sciences that does not acknowledge agrobiodiversity as a form of biodiversity.

## 8 DISCUSSION AND CONCLUSIONS

Neither philosophy nor science yielded a comprehensive understanding of and thus ability to control reality. The latest developments in science point to the importance of acknowledging the complexity of reality, thereby implying a more limited role for absolutism in science and a humble approach in attempting to understand and control complex systems. Although science plays an important role in providing an objective view of economic efficiency in industrial approaches to agriculture, sustainability assessment would need to take a more lateral view in questioning value systems in the first place, rather than perfecting certain parameters within the generally accepted translation of values into science and, in turn, to C&I for sustainability assessment.

This paper presents the case that lateral evaluations of value systems underlying certain so-called objective scientific approaches need to be included in the sustainability assessment procedures. In the case of agriculture, this would mean that changes from industrial farming to oecology and from economy to oikonomia should be debated as a baseline for sustainability assessment of these activities. If this does not happen, there will always be a conflict between those value systems underlying agricultural economic activity and those underlying environmental sciences. This would only perpetuate the current sluggish progress in sustainability assessment, and more importantly, will lead to unsustainable ecological and

As illustrated in our case study, such an approach could have significant positive impacts on both the economy and the ecology of agricultural activities. However, how land will be managed for food and fibre production in an environmentally and economically sustainable way, will largely determine the nature of a future agricultural economy.

## APPENDIX 1            TERMINOLOGY

**Agriculture.** According to Harris (1972) and Booyesen (1993), agriculture is the manipulation of the environment by humans to produce yields of use to them

**Industrial agriculture syn. conventional agriculture syn. commercial agriculture.** Industrial agriculture is the result of the chemist's intervention or, in other words, the "Green Revolution" approach to food and fibre production.

**Oecology.** Ernst Heinrich Haeckel, philosopher-biologist, is credited with the invention (1869) of the word ecology, which he and others after him spelled oecology, since the first part of the word came from the Greek root oikos, meaning home. Haeckel considered ecology to deal with the general economy of the household of nature (Graham, 1944).

**Oikonomia.** Household economy, i.e. "the management of the household so as to increase its value to all members of the household over the long run" (Daly & Cobb, 1989).

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## Natural Resource Accounts for Gold in South Africa: 1910 – 2000

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### 1 INTRODUCTION

The Bureau of Census and Statistics compiled the first official estimates of domestic and national income in South Africa in 1946, little more than 55 years ago, but the profound economic and political impact make the national income accounts one of the significant inventions of the Twentieth Century (SARB, 1999). The national income accounts reflect the great aggregates of Keynesian analysis – consumption, savings, investment and monetary flows – that forms the basis for framing economic analysis and policy and from which the performance of the economic system can be analysed. The principle criticism of Lutz and El Serafy (1988) and Repetto *et al.* (1989) is that GDP is a short term, highly aggregated system of accounting that measures economic activity in monetary terms, but ignores the productive role and depletion of natural resources. Hence the fact that the GDP is a weak measure for a change in welfare. The system nevertheless provides a number of important economic indicators such as GDP growth and GDP growth per capita. This ability to measure and quantify economic growth has meant firstly that governments can understand the factors affecting economic growth and stability and secondly that they have accepted responsibility for the management of their economies.

Natural resource scarcity has occupied the minds of economists since Adam Smith first confronted the issue in 1776. Concern about the long-run availability of mineral commodities was recently discussed at a workshop on the held in Washington by Tilton (Tilton, 2001).

Classical economics identifies land, labour and capital as the principle assets on which returns are based, but with time the importance of natural resources as a principle input fell away and the neo-classical economists concentrated on labour and invested capital. After World War II the surplus of labour further affected thinking about the problems of economic development were seen almost entirely as a problem of savings and investment in physical capital (Repetto *et al.*, 1989).

According to Repetto *et al.* (1989), such practices have meant that there is a dangerous asymmetry about the way in which we measure and as a consequence value natural resources. Man-made assets are written off against the value of production over a period of time as they age and decline in value with use (depreciate). The implication is that the level of consumption and the associated rate at which the stock of capital is drawn down exceeds sustainable levels of income. However there is acknowledgement that part of the gross product has to be set aside to maintain the existing man-made capital intact (SARB, 1999). Unfortunately there is no parallel appreciation for the way in which the irreplaceable consumption of natural resources should be accounted for (BEA, 1994). The decrease in potential future production is a loss that entails no debit charge against current income to account for the loss in the value of the resource. Repetto *et al.* (1989) have stated,

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

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<sup>8</sup> Views expressed are those of the authors and do not necessarily reflect those of institutions they may be involved

Typically resource or mineral based economies would almost completely ignore their principal assets, the exhaustible mineral deposits, by using such a national accounting system. In fact the South African Reserve bank in a recent overview of South Africa's national accounting system (SARB, 1999), have admitted that in South Africa:

*No allowances are made at present for the depletion of natural resources, such as reserves of gold, gas and other minerals.*

The tendency to ignore the contribution of exhaustible resources to national income and to account for it in some way that is reflected in the national accounts means there is a failure to properly value South Africa's patrimony inventory. Such a failure must manifest itself at some future time in ways that clearly make current production unsustainable and will, according to the Bureau for Economic Analysis (1994), inevitably lead to over- or under-exploitation, and incomplete analysis and policy decisions in regard to productivity and budgeting.

The basic problem is that the definition of income is flawed. Both Edwards and Bell (1961) and Hicks (1946), have defined income in similar ways referring to it as *the maximum amount that the recipient can consume in a given period without reducing the amount of possible consumption in a future period*. This is identical in substance to the definition of sustainable development. The depreciation account reflects the fact that unless the capital stock is maintained and replaced, future consumption possibilities will inevitably decline (Repetto *et al.*, 1989). Any resource based economy in which net investment is less than resource depletion means that the asset base is being run down rather than being built up and that the natural resource endowment is being used to fund current consumption. For obvious reasons exhaustible resource capital stocks can neither be maintained nor replaced (unless through exploration), but they can be transformed into other types of capital that yield higher returns. The capital stock embodied in natural resources provides a significant source of income for resource-based economies. Rather than simply considering natural resources as consumer goods they should be thought of as productive assets and the main priority is to account for the depletion of these assets in a way that emphasises the cost associated with their depletion, which is their depreciation. Mikesell (1989) is of a similar opinion and considers that natural resources should be treated as capital assets and their depletion as capital consumption. Furthermore he believes that by treating natural resources in this way it is possible to reconcile the discounting of future benefits with intergenerational equity and sustainable development. According to Repetto and his co-workers failure to incorporate the concept of depreciation in the accounting procedure associated with the use of natural resources is a major omission and inconsistency.

## 2 GOLD MINING IN SOUTH AFRICA

### Introduction

For over a century the gold resources of South Africa have been exploited and depleted. This activity has created employment, industrial and infrastructural development and economic prosperity for the nation and the investors, which benefits should be measured against the cost of depreciation. It has allowed South Africa to progress from being an essentially minerals based economy to one in which the contribution to GDP from manufacturing now exceeds that of mining. The linkage between mining and economic development is less clear and less strong in the majority of developing countries than it is in South Africa. As the intensity and level of gold mining activity begins to decline and as the issues of sustainable development increasingly demand attention the question as to whether or not the gold resources have been sustainably developed is raised, a question that has already been addressed in part by Blignaut and Hassan (2001). They carry a complaint from mineral economists (Repetto *et al.*, 1989; Mikesell, 1989; Devarajan and Weiner, 1995) that while the contribution to mining is captured in the System of National Accounts (SNA) the cost of depletion of the natural resources is not captured in the balance sheet of the assets of any country in the world. Thus the state of national wealth and social welfare are seriously misrepresented. Failure to capture portion of the mineral rents flowing from the liquidation of such assets means that the opportunity cost to future generations of depleting the resources is very high (Blignaut and Hassan, 2001). As a follow-up to the work undertaken by Blignaut and Hassan (2001), the need has arisen to examine the

performance of the South African gold mining industry since its inception in terms of the capture of resource rents and the capital component thereof in particular. This is the subject of this study.

### **Depletion of mineral resources**

Depletion of exhaustible resources means that future generations are deprived of employment opportunities and income as a consequence of current production. However the limitations of mineral resource estimation mean that it is incorrect to simply use current consumption rates and existing estimates of resources to arrive at a time when mineral stocks will be ultimately depleted (Tilton, 2001). It is possible that in our inordinate concern about the aspects of mineral production and depletion that it is possible to lose sight of the fact that not only will our descendants inherit our pollution and resource depletion, but they will also enjoy the fruits of our labour in the form of human and physical capital, including investments in other natural resources (World Bank, 1992). Thus the economic benefits we enjoy today as a consequence of mineral development will not be lost to future generations. Cash flows from such mineral sales allow us to make important and necessary environmental, social and economic investments in the form of infrastructure, schools, libraries, research facilities, safety and health requirements, improvements to the environment that remain to benefit future generations.

### **The concept of sustainable development**

In 1987 the Brundtland Commission coined the term *sustainable development* a new paradigm that is defined as, *development that meets the needs of the present without compromising the ability of future generations to meet their needs* (NRCan, 1997:4). Critical assumptions in support of this paradigm are the role of technological advances and the high level of substitution between the various forms of capital (financial, social, human, manufactured, intellectual, and natural capital). It also assumes that the total stock of assets remains intact and that they are completely interchangeable. This assumption was adopted and verified by Robert Solow the 1987 Nobel Prize winner for economics, who was among the earliest researchers to assess the impact of depletion on inter-generational equity (Solow, 1974). He demonstrated that the max-min criterion<sup>9</sup> was a reasonable criterion for intertemporal planning decisions. By introducing exhaustible resources into his analysis he also found that the elasticity of substitution between natural resources and labour-and-capital goods was less than unity.

He concluded that earlier generations are entitled to draw down the pool of natural resources provided they add to the stock of reproducible capital (Solow, 1974:41). Investigations into intergenerational equity undertaken by Mikesell (1989) also suggest that mineral resources should be regarded as a form of social capital asset, the value of which should be preserved for future generations even though the minerals may be extracted and consumed by the present generation (Mikesell, 1989:294).

In line with the arguments of both Solow and Mikesell, Blignaut and Hassan (2001) have stated that it is necessary to compensate future generations with fixed stocks as a result of consumption of the natural assets by reinvesting part of their value (resource rents) in other forms of capital assets that can provide the same stream of benefits in the future. This does not mean that the asset base of natural resources is not reduced, but rather that the ability to generate a stream of income into the future remains intact. Mikesell (1989) is of the opinion that annually saving and reinvesting an amount equivalent to the net revenue from the sale of mineral products can achieve sustainability. This again assumes the substitutability of reproducible capital for minerals assets.

For this particular analysis the *user cost allowance* approach taken by Blignaut and Hassan (2001) in the application of the methods suggested by El Serafy (1989) and Hartwick (1990) is adopted and applied to gold mining in South Africa from 1910. This method approximates the net present value for the depletion of natural resources and provides a way of decomposing total resource rent into two components, namely a *capital* component ( $R_t - X_t$ ) as the proportion that is required for reinvestment and an *income* component

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<sup>9</sup> The max-min principle states that in order for social welfare to be equally distributed through time, consumption per head should be constant through time (the same for all generations), assuming there is no technical obstacle to the

( $X_t$ ) as the portion available for current consumption. The results of the analysis are shown in Appendix 1 (Table 1).

### The Determination of Mineral Rents

Economic rent is defined as the return to any factor of production (e.g. a mineral deposit) over its normal supply cost (the minimum amount required to retain it in its present use). Mineral rent is defined slightly differently as the difference between total revenue generated from the extraction of natural resources and all costs incurred during the extraction process including the cost of produced capital, but excluding taxes, royalties and other costs that are not directly due to the extraction process (UN, 2000:226).

Mineral rents may arise as a result of exceptional quality, scarcity, location or any other cost advantage of the mineral deposit, but the concept of mineral rent is central to the valuation of natural resources. Hotelling rent is defined as the net return realized from the sale of a natural under particular conditions of long-term market equilibrium. It is defined as the revenue received minus all costs of resource exploitation, exploration and development including a normal return to fixed capital employed, and it is often used as a measure of natural resource depletion. (UN, 2000:223). This last definition although popular is only partially correct and a fuller explanation is given as a corollary to the discussion by the Bureau for Economic Analysis (BEA, 1994:4) on whether mineral capital should be treated as fixed capital or inventories. They provided a definition of rent to owners of fixed assets as *the reduction of value of the asset due to its use in the current period (depreciation) and a return equal to what the current value of the asset could earn if it were invested elsewhere*. Later they reiterate the statement under a section dealing with valuation issues that:

In theory, the rent to owners of both the invested capital and the oil in the ground should equal the reduction in the value of each asset due to its use in the current period (depreciation and depletion, respectively) plus a return equal to what the current value of the well... ..could earn if invested elsewhere (BEA, 1994:5).

This is in fact the definition of the per unit resource rent for any mineral deposit, namely the change in value of the ore deposit as a consequence of the extraction of one unit of ore. This definition of mineral rent can be expressed in a mathematically rigorous form arising from the first derivative of the net present value criterion for valuation of a mineral deposit as derived by Lane (1988). The present value criterion has been accepted as the most universally accepted method for valuing properties and evaluating new properties. Lane (1988) used it as a basis for determining optimal operating policies that would add to the overall economic value of a mining operation. For gold deposits the value is described as a Rand per kilogram value and is given by:

This definition says that the unit change in the value of the resource as a consequence of the depletion of one unit of reserve ( $dV/dS$ ) is equal to the revenue from sale of the product ( $p(q_t)$ ) minus working costs ( $c(q_t)$ ) minus opportunity cost of depletion ( $rV$ ) minus depreciation ( $dV/dT$ ).

$$dV/dS = p(q_t) - c(q_t) - rV_t - dV/dT$$

This highly rigorous mathematically derived definition provides a solution for the determination of mineral rents. For this particular analysis mineral rent has been calculated as the difference between the value of the output minus the production costs, where production costs include cost of intermediate inputs, wages, depreciation and the opportunity cost of capital. In this particular case the opportunity cost of capital is calculated from the consumption of the fixed capital stock for the mining industry only and not for the economy as a whole.

### 3 THE DATA

#### Sources of data

Data for the compensation of employees, fixed investment and intermediate consumption (also referred to as stores consumed) was collected for this study from the Chamber of Mines Statistical Tables from 1910 to 2000 (CoM, 1910-2000). The fixed capital stock and depreciation data were calculated from data presented by Frankel (1967) and Willers (1955) as well as the South African Reserve Bank. The capital stock, investment and depreciation data was recalculated to reflect these aggregates at replacement values from 1910 to 2000. This recalculation was done to be consistent with the Systems of National Accounts definition for these calculations. Using capital stock and depreciation at replacement values implied that the results differ from earlier studies when book values are used (Blignaut and Hassan, 2001). The data used in this particular exercise are shown in Table 2, Appendix 1.

#### Discount Rate

In a discussion on the choice of discount rates to be used (in this case for depreciating capital investment), Mikesell (1989) is of the opinion that discounting the future value of exhaustible resources encourages current consumption at the expense of future generations and is incompatible with the concept of sustainable development. By treating natural resources as capital assets in social accounting, we can achieve intergenerational equity without using zero or artificially low social rates of discount (Mikesell, 1989:294). In this particular exercise a fixed 3 per cent discount rate is used for the calculation of the opportunity cost. There are three different view points in regard to the rate of discount that should be applied specifically with regard to the calculation of the opportunity cost of capital for the gold mining industry.

The first query arises out of the choice of real values rather than nominal values for use in the calculation of the opportunity cost. The principle argument against using nominal values is that the values used are for *replacement stock* and so account has been taken of the effects of inflation. The values therefore for capital stock at replacement value are not market values. It has been suggested that the use of nominal values implies that a nominal interest rate should be used.

The second query arises in regard to the use of the same discount rate over relatively long periods of time. The use of a three per cent discount rate may be acceptable for a 30-year time horizon, but its use over a hundred year period could be considered somewhat inflexible. The use of a variable discount rate over such a long period has been argued to be more realistic.

The last reason for using a lower rather than a higher discount rate is that the so-called opportunity cost is not really an opportunity cost at all. Once the commitment to mine has been made the capital for shaft sinking, development and other underground excavation has to be spent. There is no possible alternative investment opportunity that presents itself, so the cost is simply part of fixed cost rather than an opportunity cost. For this reason a somewhat lower, rather than a higher discount rate should be used and thus the 3 per cent rate is probably justified.

#### The treatment of depreciation

Serious policy errors can occur if the imputed value associated with the depletion of natural resources or consumption of fixed capital stock is underestimated. As an ore body is mined a depreciation or depletion allowance should be calculated that amortises the value of the asset over its useful lifetime. Such an allowance will account for the decline in future productive potential of the ore body because it is non-renewable. If the future income-producing ability of the ore body (capital stock) is not to be impaired then new ore bodies must be discovered to offset the depreciation of existing ones.

Depreciation of the capital investments made in the gold mining industry since has been calculated as discussed above. These values were also used to calculate the so-called opportunity cost of capital. These data were used in the calculation of the mineral resource rent for the gold mining industry.

## 4 RESULTS OF THE ANALYSIS

### Resource rent

The total values of mineral resource rent calculated for the periods 1910 to 1971 and for 1970 to 2000 are shown graphically in Figures 1 and 2, respectively. Of particular interest is the fact that the mineral rents derived from the gold mining industry in the early part of the century are orders of magnitude greater than the rents in the second half of the century. The large increases in the mineral rents realised by the industry from 1973 onwards are due to the freeing of the gold price in the period post-1973, an effect that was accompanied by the depreciation of the Rand in the post-1980 (Figures 1 and 2).

The resource rent arising from the gold mining industry in the first (1910–1971) and second halves (1970–2000) of the last century was decomposed into its various components using the method described by El Serafy (1989) and are presented in Figures 3 and 4, respectively. These include the income and capital components of the rent, the latter being the portion that should be captured and retained in other investments in order to ensure long-term sustainable development. The income portion of rent is available for immediate current consumption, but the capital component has to be recovered and converted into a substitutable form of capital in order to ensure sustainability of the mineral development.

The capital component of the mineral rents that were generated from the gold mining industry during the first and second halves of the last century are shown graphically in Figures 5 and 6, respectively. It is these rents that should have been captured and invested in other forms in order to ensure that the flow of benefits to future generations is such that the resources are optimally utilised.

There are a number of years both at the beginning of the period of investigation and near the end of the period when resource rents were in fact zero. This means that expenditures in one form or another were in fact larger than the revenues generated by the gold production in those years.

### Capturing the capital component of resource rent

The understanding of natural resource accounting and the way in which natural resources should be developed in order to ensure inter-generational equity has only really emerged from the time that Harold Hotelling undertook his work in 1931 (Hotelling, 1931). Before that time, issues of intergenerational equity were not of primary concern to mineral project developers and less was understood about the size and nature of the rent component that required capturing.

In South Africa although the State is empowered to undertake mineral exploitation itself it prefers to allow private enterprise to run mining operations. Private companies have to apply for permission to prospect and mine and in return, private operations pay for their rights in the form of licence fees, rental, lump sums, royalties or lease considerations depending on the mineral rights ownership under which the land is held (Storrar, 1987). Although there is no official mechanism for capturing the capital component of the resource rent, there were however certain imposts that were designed to assist the governments of the day to capture an additional amount of the benefits from exploitation of the gold deposits in the country and to give the state a participation in the flow of revenues from mining. These took the form of a so-called sliding scale Lease Consideration for gold mines that was introduced in 1910, but was abandoned after 1992. This instrument was never designed to capture rent per se, but it is the closest available tool, performing the same operation with varying degrees of success. It is worth noting that where mineral rights were privately owned royalties (together with other types of payments) were designed to compensate the State for the utilization of their mineral assets. The lease consideration (royalty payment) in terms of type and rate for mines established before 1932 were usually negotiated between the lease holder and the Mining Leases Board (Storrar, 1987). After 1932 all gold mines are lease mines whose lease consideration was payable to the Receiver of Revenue on a sliding scale formula. No attempt was made to separate these payments from any other form of payment made to the State.

The statistical record from the Chamber of Mines provides details for the amount paid annually by Chamber members in term of the lease consideration. The success of this consideration as a means of capturing the

capital component of mineral rent can be seen in Figures 5 and 6, which compare the revenues captured by government through the lease consideration and the capital component of rents that were received by the industry for the periods 1910 to 1971 and 1970 to 2000, respectively. From these graphic representations it is evident that the lease consideration captured the user cost in a highly erratic fashion from 1910 to 1943 the Lease formula was over-efficient and captured more than its fair share of the user cost. From 1944 to 2000 the lease consideration has been highly inefficient and has captured a relatively small proportion of the user cost.

Since 1910 the government has in fact captured 11 per cent of the royalty which means that the other 13 per cent that rightfully belong to Government gas been lost to investors. The problem is that there is no way to monitor the rents or the public instrument designed to capture rents.

There maybe some confusion about the identity of the rightful recipients of rent. As custodians of the national patrimony (the national inventory of mineral assets) government is not only entitled to but responsible for capturing 100 per cent of the mineral rent. Over the years since 1910 it would appear that a 26 per cent capital 74 per cent income component split would have been adequate. In reality there is an approximately equal 50-50 split of mineral rents between government and industry (Cawood and Minnitt, 2002, in press).

## 5 CONCLUSIONS

The lease consideration captured the rent in a highly erratic fashion. From 1917 to 1943 the Lease Formula was over-efficient and captured more than its fair share of the resource rent while from 1944 to 200 the lease consideration has been highly inefficient and captured a relatively small portion of the rent. These data suggest that the exploitation of South Africa's gold deposits has not been undertaken in a fashion that is consistent with the tenets of sustainable development and that surplus rents have flowed to the investors at the expense of income and employment opportunities of the future generations. Consequently the depletion of the gold resources has not been managed in a sustainable fashion.

In their defence it should be noted that investors receive a portion of the resource rents is justified because of the risks faced by the industry and it is the existence of rents and the promise of their capture by mineral developers is what stimulates investment in the first place. The returns to which the investor is entitled are key to understanding mineral investment patterns. If he fails to obtain an appropriate return the mining industry will be systematically starved of capital (Keeton, personal communication). The very reason that the minerals industry is dominated by large corporations is they have the capital for mining investment and are prepared to take the risks associated with investment at this level. In addition this situation has arisen because firstly there is great difficulty in defining what resource rent is and secondly because there is no effective mechanism by which government can capture the resource rents. Furthermore the 47 per cent of resource rents captured by the investor is not for his own personal consumption. As first recipient he is responsible for redistributing the rents to other legitimate claimants who would include the owner, the mineral right holder, indigenous peoples and environmental interest groups (Cawood and Minnitt, 2002, in press). The recent efforts of the sustainable development efforts will probably expand the list and deepen the ability of claimants to extract their rent. One fear is that while these kinds of rents should not be the primary incentive for investment in the mineral industry their potential for being dissipated will certainly detract from the minerals industry as a worthwhile investment location.

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