A QUANTITATIVE APPROACH TO SUSTAINABILITY USING ECOLOGICAL FOOTPRINT AND GEOGRAPHIC INFORMATION SYSTEMS

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The people will wander through the land, discouraged and hungry. They may look up to the sky or stare at the ground, but they will see nothing but trouble and darkness, terrifying darkness into which they are being driven.

ISAIAH 8: 21 – 22

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ABSTRACT

* **A QUANTITATIVE APPROACH TO INSURE SUSTAINABILITY USING ECOLOGICAL FOOTPRINT AND GEOGRAPHIC INFORMATION SYSTEMS**
* **BRAAM OCKERT DU PLOOY**
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Sustainability has become a household word in development. Economic benefits however, overshadow the restraints sustainability places over development (Van Riet, 1989). To take action on unsustainable development, a country should have some sort of measurement tool to determine the condition or progress of unsustainable development. To determine the impact South Africans have on the ecology has been studied intensively but the actual measurements of these impacts have been neglected. This study proposes a practical tool to measure the effect of human impact on the environment.

SAMEVATTING

* **'N KWANTITATIEWE BENADERING TOT EKOLOGIESE VOLHOUBAARHEID DEUR GEBRUIKMAKING VAN EKOLOGIESE VOETAFDRUKANALISE EN GEOGRAFIESE INLIGTINGSTELSELS**
* **BRAAM OCKERT DU PLOOY**
* **MAGISTER ARTIUM**
* **PROF. J.T. HARMSE**

Volhoubaarheid het reeds 'n huishoudelike term in ontwikkeling geword. Ekonomiese voordele oorskadu egter die demper wat volhoubaarheid op ontwikkeling plaas (Van Riet, 1989). Om stappe te neem teen nie volhoubare ontwikkeling, behoort 'n land 'n meetinstrument te hê waarmee die kondisie of progressie van nie volhoubare ontwikkeling gemeet word. Die gevolge van Suid Afrikaners se invloed op die ekologie van die land is reeds omvattend bestudeer. Die meting van sodanige invloed is egter nog baie verwaarloos. Hierdie studie lê 'n praktiese metingsmetode voor om die impak van die mense op die omgewing te meet.

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1. INTRODUCTION

The concept sustainability originated according to Yeld (1993) in German forest management, practiced during the 19^{th} century and popularized in the 1980's.

Sustainability is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Soussan in Mannion and Bowlby, (1992) says that there is today little concern over the effects of resource scarcity on economic processes; rather the great challenge facing the world is to cope with the impact of economic growth on environmental processes. This challenge in emphasis is reflected in the approach which has become known as sustainable development. This is substantial reason to believe that the environmental crisis is inseparably linked to the development crisis and can be resolved only through a revolutionary change in our understanding of the relationship between human economic activity, ecosystem and our perception of the nature of human progress (Goodland, 1992). To conserve the Earth's vitality and diversity, it is essential to curtail pollution, which is defined as the process of over loading the planet's natural capacity to cleanse its ecosystems of damaging materials and waste energy (Fuggle & Rabie, 1994).

The basic implications of the problems and their consequences are common knowledge (Smith, 1971):

* Humans have loaded the earth's atmosphere with pollutants faster than natural processes can reabsorb them, resulting in the thinning of the ozone layer with:
  - Massive climate changes
  - Melting polar ice caps
  - Flood vast coastal areas
  - Desertification
  - Water supply reduction
  - Poisoning of soils (acid rain)

* The soil on which we depend to grow food for an exploding population is being depleted and eroded faster than nature can regenerate it.
* More and more localities face shortages of fresh water
* Garbage is accumulating faster than man can find ways to dispose of it
* Chemical and radioactive wastes are rendering more and more areas of the earth's surface unusable
* Fossil fuels are being exhausted even as humans continue to expand the economic activities dependent on them

An intermediate position between the extremes of no growth versus unlimited growth is according to Robert Repetto sustainable development based on the use of renewable resources in harmony with ecological systems (Cunningham & Saigo, 1992). The goals of sustainable development are defined, but mechanisms to bring about these changes are not.

Goodland et al, (1993) say that the impact (I) of any population or nation upon environmental sources and sinks is a product of its population (P), its level of affluence (A), and the damage done by the particular technologies (T) that support that affluence.

$$I = P \times A \times T$$

More effective sustainability initiatives are required, including tools to stimulate a wider public involvement, evaluate strategies and monitor progress.

One such a tool is an "Ecological Footprint" analysis. This is a concept which accounts for the flows of energy and matter to and from any defined economy and converts these into corresponding land/water area required from nature to support these flows. This is then also important in building public awareness and sustaining decision making. Understanding the ecological constraints will make the sustainability strategies more effective and livable (Nel, 1994).

2. PROBLEM STATEMENT

Unsustainable development and greediness place a burden on South Africa's ecology which grossly exceed the available resources depleting it at a rate hundred fold faster than nature is able to replace it.

3. AIMS OF THE STUDY

The first aim of the study is to determine if development in the country is sustainable or not. The reasons and answers to this will expose development areas that are unsustainable.

By determining and exposure of different development problems, proposals to address these problems are submitted.

A brief outline of the current ecological situation is given as an inspiration to why and if a country like South Africa should give serious thought to sustainable development.

This study also tries to propose a possible, easy-to-use, measuring tool to determine unsustainable development. This quantitative measurement of the impact of a given population on different landuse parameters will be presented as an Ecological Footprint of the population.

The aim then is to determine the ecological deficit of a country using Ecological Footprint Analysis and Geographical Information Systems.

4. PERSPECTIVES ON THE CURRENT ECOLOGICAL SITUATION

Cities are among the most spectacular achievements of human civilization. In every country, cities serve as the social, cultural, communication and commercial centers of national life. If a glass bubble could be placed over a city, for instance Johannesburg, keeping everything that is inside in and outside out. How big will the glass bubble need to be so that the city could sustain itself with its ecosystems needed to produce all the resources it needs, and assimilates wastes? By definition then, the total ecosystem area that is essential to the continued existence of the city is its "de facto" Ecological Footprint on the earth. Because of technology and fast transport it is not necessary to stay in a glass bubble but can the borders of a country be spread all over the earth. An excellent example of this is the Netherlands. One country can utilize a piece of cropland in another country.

These are a few major threads to the sustainability of any ecology. Listed below are globally concerned issues and South African is no exception to this.

* Deserts are encroaching on productive areas at the rate of 6 million hectares per year;
* Deforestation claims 17 million hectares per year ;
* Soil oxidation and erosion exceed soil formation by 26 billion tons per year (Weaver,1989);
* Fisheries are collapsing;
* The draw down and pollution of groundwater accelerate all over the world;
* As many as 17 000 species disappear every year;
* Stratospheric ozone continues to be eroded;
* Industrial society has increased atmospheric carbon dioxide by 28 percent.

All of the above are results of over-expectation and excessive waste generation (Cunningham & Saigo, 1992).

From an ecological perspective, adequate land and associated productive natural capital are fundamental to the prospects for continued human existence on Earth. This always boils down to the question of how much natural capital is enough. Should we strive to conserve or enhance our natural capital stocks ("strong sustainability") or, as many economists believe, are tones of natural capital acceptable if compensated through the substitution of an equivalent amount or value of human made capital ("weak sustainability").

In other words, weak sustainability allows the substitution of equivalent human-made capital for depleted natural capital. From this perspective the loss of the income earning potential of a former forest is no problem if part of the proceeds of liquidation has been invested in factories of equivalent income-earning potential. By contrast "strong sustainability" recognizes the unaccounted ecological services and life support functions performed by many forms of natural capital and the considerable risk associated with their irreversible loss. An economy is sustainable if it saves more (in monetary terms) than the depreciation on its human made and natural capital. What the "rich" countries fail to recognize is that much of the so called rich countries' money savings come from the depletion of other countries' natural capital and exploitation of global common-pool assets.

Monetary analysis is argued fatally flawed in assessing sustainability issues or natural capital constraints. Using money value to signal resource scarcity or natural capital depletion may be misleading according to Wackernagel and Rees, (1996) for at least the following reasons:

* Monetary interpretations of the constant natural capital requirements may mask declining physical stock. Thus constant money income stockvalue may foster the illusion of constant stocks while physical inventories shrink.

* In any event, biophysical or eco-functional scarcity is poorly reflected in the marketplace. Market prices generally say nothing about the size of remaining natural capital stocks (Nel, 1994).
* Monetary analysis is systematically biased against the future by discounting. We regularly sacrifice nature to development because the immediate short-term benefits exceed the (discounted) present value of forgone future benefits. Natural capital to human life will almost certainly increase more rapidly than that of manufactured capital over time, evidence of ecological breakdowns becomes more compelling, whatever today's market tells us. For example, the effective price of stratospheric ozone layer went from zero to near infinity in just a few years in the absence of any market (Park, 1980).
* The utility of monetary indicators is further diminished by market fluctuations, which affect prices but not the ecological value or integrity of natural capital.
* Money values do not distinguish between sustainable goods and complementary goods. All prices are added or subtracted as if goods that are priced the same are of equal importance to human life, for example, fishing boats and factories may be worth as much as all the fish stocks but if the stocks are depleted the boats and factories are worthless.
* The potential for growth of money is theoretically unlimited, which obscures the possibility that there may be biophysical limits to economic growth.
* Perhaps the most serious objection is that there are no markets for many critical natural capital stocks and life-support processes (for example the ozone layer, nitrogen fixation, global heat distribution, climate stability and so on).

What is the carrying capacity then? It is the maximum population of a given species that can be supported indefinitely in a specified habitat without permanently impairing the productivity of that habitat (Barbier et al, 1990). The human "load" has grown to the point where total consumption has already exceeded sustainable natural income. If we calculate the land requirements for all categories of consumption and waste discharge by a defined population, the total area represents the ecological footprint of that population on the earth whether or not that area coincides with the population's present home region. The ecological footprint measures land area required per person (or population), rather than population per unit area (Wackernagel & Rees, 1996).

4.1 The South African context and action

South Africa is a unique country with unique problems. It has a developed world component which has been responsible for some of the worst environmental degradation on record such as air pollution levels in parts of Mpumalanga which – arguably – match or even exceed the worst in industrial Eastern Europe (Council for the Environment, 1989).

Taking the population into account, South Africa is the world's third largest emitter of carbon dioxide. Because of post political policies huge environmental destruction like soil erosion in Kwazulu Natal and former Transkei took place (Hugo & Viljoen, 1992).

Loss of vegetation in the former Ciskei through overcrowding and overstocking took place. Precious ecosystems (like the original wetland in the Tugela basin in Kwazulu Natal) have been destroyed of 90 percent of its original structure (Adler, 1985).

Animals like the quagga are extinct and the wattle cranes may soon follow. Each year during the rain season millions of tons of topsoil are eroded from badly managed productive areas (Rooseboom, 1978).

The country has a duel economic onslaught on the composure of the community. On the one side there is widespread poverty where over-crowded and impoverished communities battle to survive. On the other hand are the extravagant wasteful lifestyles that are not sustainable. Under this dual onslaught of poverty and excess, South Africa's natural resource base is crumbling and its biological diversity dwindling (Sandlund et al, 1992).

Yeld (1993) recommends nine principles that he thinks should be accepted as the philosophical basis for a new way of living. He also says that effective policies have to be advised to give practical effect to the following principles:

* Respect and care for the community of life.

This principle provides the ethical base for the other eight principles, which follow.

- Political negotiations which include environmental issues
- Developing a national strategy for sustainable living
- All sectors of South Africa's community should see how they can contribute to developing the broad philosophy of the world ethic for living sustainably
- Any proposals to harvest wild animals for profit must first be subjected to serious cost-benefit analysis and broad public debate, within the ambit of this first principle for sustainable living.

* Improve the quality of life

The purpose of development is to enable people to enjoy long, healthy and fulfilling lives.

- Services that promote a long and healthy life such as electrification, complete immunization programs, adequate housing, access to clean water and sanitation facilities, and anti-malnutrition programs.
- Attracting increased foreign investment
- Universal primary schooling for all children and adult learning programs.
- Commitment to oppose all chemical, biological or nuclear warfare.
- Military personnel vehicles and equipment and expenditure should be re-deployed for conservation and development projects.

* Conserve the Earth's vitality and diversity

Because of the constant changing of the planet's structure, the life support system that nature provides should be conserved. This means those ecological processes that shape climate, clean the air and water, regulate water flows, recycle essential elements such as nitrogen and oxygen and create and regenerate soil (Alexander, 1988). This also means conserving the diversity of all life on Earth and ensuring that all uses of renewable resources are sustainable.

In South Africa, an estimated 419 million tons of industrial and mining waste, including air emissions and material discharged with wastewater, are generated each year. Of this 1.89 million tons are estimated to be hazardous (Stinner & House, 1989).

South Africa, in spite of its small area in world terms, hosts an estimated ten percent of the world's diversity of plants, birds and fish. It has proportionately, after Indonesia and Brazil, the richest plant and animal life than any country on Earth. These consist of 227 mammal species (5.8 percent of the world's mammal population of 3 927) and more than 700 bird species which is eight percent of the world's 9 000 species. A rich variety of flora, with more than eight percent of the world's higher plants (20 300 species out of a total of 250 000) are found in South Africa. During the past 350 years, the country's dry forests have been reduced by 46 percent in area, grasslands by 62 percent, mangrove swamps by 46 percent, renosterveld vegetation by more than 90 percent (Department of Environmental Affairs, 1992).

* Minimize the depletion of non-renewable resources. Minerals, oil and gas, are non-renewable resources. They cannot be used sustainably. However, their economically viable "life" can be extended by recycling, using less of the resource to manufacture a particular product by applying improved technologies, and by switching to renewable substitutes wherever possible.

Priority actions here are:

- To shift the main focus of South Africa's economy away from its previous dependence on non-renewable resources such as minerals and coal.
- Full integrated environmental management (IEM) procedures must be applied to the proposed development of new mines.
- The exploitation of these non-renewable resources in highly sensitive or valuable areas, where other valuable natural and cultural resources reside, should be avoided.

* Keep within the Earth's carrying capacity

Earth has a finite carrying capacity for its human population and the resources they consume. There is a maximum impact that it can withstand before its life-giving systems start to collapse. To stay within this carrying capacity the government and communities must:

- manage their environmental resources sustainably;
- address the issue of population growth and resource consumption in an integrated way;
- reduce excessive consumption and eliminate wasteful practices;
- provide better information about Earth's carrying capacity and the dangers of over-consumption, using both formal and informal education structures; and
- provide proper health care and family planning services, linked to the education of, and empowerment programs for, woman.

* Change personal attitudes and practices

Poor people generally do not need to be convinced that a higher standard of living is desirable, for virtually everyone aspires to an improved quality of life. Frequently efforts to escape poverty, through the more concerted exploitation of natural resources, damage the environment. By contrast those people who enjoy higher incomes may accept in principle the need to reduce consumption, but very few would be willing to reduce their standards of living in practice. The following actions are recommended:

- The status of environmental education must be reviewed urgently and it should be introduced into the formal curriculum at all levels.

- Community based organizations must be approached to assist with training, extension of services and demonstrations by qualified workers who can help the users of resources – like farmers, fishermen, forest workers to adopt better and more sustainable practices.
- South Africa's national strategy for sustainable living must include actions to motivate, educate and equip individuals to lead sustainable lives.

* Enable communities to care for their own environments.

To achieve this goal of sustainable living, communities must be empowered to organize themselves and manage local environments for their own benefit. To take actions here the following according to the Department of Environmental Affairs (1992) are applicable:

- Communities and individuals must be provided with secure access to resources, especially land, and an equitable share in managing them.
- There must be open access to information and to the required skills and technologies to understand and deal with environmental issues affecting communities.
- There must be enhanced participation in conservation and development planning.
- Because local governments are key elements in the environmental well being of communities they must be structured effectively and in a politically acceptable form.
- Communities must be provided with proper financial and technical support from the central government.
- The right of "locus standi" must be broadened so that individual citizens and groups can challenge in court matters of environmental significance.

* Provide a national framework for integrating development and conservation.

Through the central government, this ethic must be adopted as the critical element in the country's political philosophy. This means the government must develop a broadly acceptable national environmental framework that encompasses the duties and responsibilities of institutions, the country's economic policies, existing laws and regulations, and an accurate information base (McCaffrey & Lutz, 1978). Until now much of South Africa's environmental policy has been reactive, responding to problems and situations after they have developed. Actions needed here, according to Yeld (1993), are:

- Adoption of an integrated environmental policy with sustainability as the overall goal by the government.
- Overall responsibility for environmental management policy development and planning on a national basis should be vested in a single government department or statutory authority.
- Strategies for sustainability must be developed and implemented directly at national level and through regional and local planning authorities.
- Proposed development projects, policies and programs must be subjected to environmental impact assessment and proper economic appraisal, within the overall application of Integrated Environmental Management procedures.
- South Africa's Environmental Conservation Act must be strengthened, made more comprehensive, and its provisions properly enforced.
- Existing legal and administrative controls which have patently failed to address environmental problems – notably water availability, air and noise pollution, coastal degradation, soil erosion and the disposal of hazardous waste.

- Economic policy must be used as one of the key instruments to attain sustainability.
- Economic incentives must be provided for conservation practices and efforts that promote the goal of sustainability.
- The government must remove any subsidies or other mechanisms that distort the price of natural resources.
- The scientific knowledge base must be maintained and strengthened.

* Create a global alliance

'Think globally, act locally' is a popular phase, but nowadays acting globally is also important. All countries including South Africa, have artificial national boundaries. Yet in environmental terms they are inextricably linked, for ecological processes, environmental features (like oceans and rivers), and wildlife populations do not respect national boundaries (O'Riordon, 1976).

International co-operation is possible. At the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992 – also known as the Earth Summit – 172 of the organization's 178 members reached significant consensus on a number of pressing environmental issues. The following issues were to be addressed:

- Commitment to the many existing international agreements to conserve life support systems and maintain biodiversity, including the Vienna Convention for the protection of the Ozone Layer and its Montreal Protocol; the Geneva Convention an long-range Transboundary Air Pollution, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal; the Rio Conventions on Biological Diversity and Climate Change; the Rio Declaration on Environment and Development in Agenda 21.
- A Universal Declaration and Covenant on Sustainability are urgent international priorities

- South Africa must be a key player in the developing of a comprehensive and integrated conservation regime for the Antarctic and the Southern Ocean.
- Non-government organizations (NGOs) must be recognized in the role they can play.
- South Africa's official debt should be re-negotiated with a view to retiring as much of the debt as possible to help restore the country's economic progress as to address environmental issues.
- Future foreign investments should be subjected to a code of conduct that includes conditions on health, safety and environment.

South Africa has been greatly influenced by the international trends and the Environmental Conservation Act (No 73 of 1989) is according to Fourie and Claasen (1992) a typical example and based on sustainable development principles.

5. ECOLOGICAL FOOTPRINT ANALYSIS AS RESEARCH METHOD

Development will always overshadow environmental concerns, if taken where the environment's place is on modern consciousness. This is the mere root of environmental sustainability problems (Bartelmus, 1994). The environment may be aesthetically pleasing, but it is expendable if economic push comes to shove (Bartelmus, 1980). It seems the premises that a "human society is a subsystem of the ecosphere " and that human beings are embedded in nature, is so simple that it is generally overlooked or dismissed as too obvious to be relevant. The exosphere is where we live; humanity is dependent on nature, not the reverse.

The ecological footprint is then a measure of the load imposed by a given population on nature. It represents the land area necessary to sustain current levels of resource consumption and waste discharge by that population. If the population is then to live sustainable, they must ensure that they consume the essential products and processes of nature no faster than they can be renewed, and that they discharge wastes not at the rate exceeding that they can be absorbed. Ecological Footprint Analysis is an accounting tool that enables the country to estimate the resource consumption and waste assimilation requirements of a defined population or economy in terms of a corresponding productive land area. The Ecological Footprint of a specific population or economy can be defined as the area of ecologically productive land (and water) in various classes. For the scope of this study there would be cropland (wheat and sugar) rangeland, forests, degraded land, conservation areas and energy use. These regimes are then to provide all the energy, material and resources consumed, and to absorb all the waste discharges by the population with prevailing technology, wherever on earth that land is located (Wackernagel & Rees, 1996).

This may be confusing if you take Hong Kong as example and ask why, if Hong Kong is so densely populated with so little natural resources, is so much more prosperous than many African countries or cities? This is a perfect example of people having an impact somewhere even if it is obscured by trade and technology. Indeed, to the extend that trade seems to increase local carrying capacity, it reduces it somewhere else. Ecological Footprint Analysis summarizes a given population's impact on nature by analyzing aggregate consumption (that is: Total Load = Population x Per Capita Consumption) and converting this to a corresponding land area. In worldly terms this means that the fair earthshare (amount of ecological productive land available per person on earth) with apologies to other species amounts to 1.5 hectares (3.7 acres) or 122 meter square per person. Only 0.25 hectare of this is arable according to Wackernagel and Rees, (1996).

As noted previously, the fundamental ecological question for sustainability is whether stocks of natural capital will be adequate to meet anticipated demand. Ecological Footprint Analysis approaches this question directly. It provides a means to compare production by the ecosystem with consumption to the economy, thereby revealing whether there is ecological room for economic expansion or, on the other hand, whether industrialized societies have overshot local (or global) carrying capacity. The Ecological footprint concept provides an intuitive framework for understanding the ecological bottom line of sustainability.

5.1 Methodology of Ecological Footprint Analysis.

* First estimation to the average person's annual consumption of particular items is made from aggregate regional or national data by dividing total consumption by population size. Most statistics on energy, food and forest data are readily available. For many categories, national statistics provide both production and trade figures from which trade-corrected consumption can be assessed:

  Trade corrected consumption = Production + Imports – Exports

* Secondly, estimating the land area appropriated per capita (AA) for the production of each major consumption item (i). This is done by dividing average annual consumption of that item calculated above (C, in kg/capita) by its average annual productivity or yield (P, in kg/Ha).

  AAi = Ci/Pi

  The total ecological footprint of the average person (EF) is then computed as the per capita footprint by calculating all the ecosystem areas appropriated (AAi) by all purchased items (N) in his or hers annual consumption of goods and services.

EF = Σ AAi

i = 1 ton

Finally, in order to obtain the ecological footprint (EFP) of the study population, the average per capita footprint is multiplied by population size (N):

EFP = N (EF)

Or, if the total area is available from statistics, it is easy to compute the per capita footprint by dividing total area by population.

For the scope of this study landuse and energy consumption will be used. There are roughly eight landuse categories for footprint assessments:

1.	Energy land	: A Land appropriated by fossil fuel energy	{Energy or CO2 land}
2.	Consumed land	: B Built environment	{Degraded land}
3.	Currently used land	: C Gardens	{Reversibility built environment}
		: D Cropland	{Cultivated systems}
		: E Pasture	{Modified systems}
		: F Managed forests	{Modified systems}
4.	Land of limited availability	: G Untouched forests	{Deserts; Icecaps}
		: H Non productive areas	{Deserts; Icecaps}

In this study some of the landuses are going to be used to determine a footprint of South Africa.

Energy land components can be computed to estimate the area that would be required to grow fuel crops to replace our depleting stocks of fossil energy. Fossil fuels are the product of ancient photosynthesis and the accumulation of biomass in forests and swamps that grew over the earth's surface millions of years ago. It took 300 million years for the accumulation of the resource. Humanity is depleting this former productivity in 300 years that is one million times faster than it can be accumulated and that nature is able to replace it.

Most of the energy on which human life depends comes from the sun. In fact, life on earth is powered by a solar flux of about 175 000 terawatts. One terawatt is one trillion (or 1 000 000 000 000) watts or joules per second. This is the same energy required to lift one million tons 100 meters every second. Off the 175 000 terawatts fewer than 150 are transformed into plant biomass by photosynthesis (Barbier & Markandya, 1990). Calculations show that one hectare of average forest could accumulate about 80 gigajoules of recoverable biomass energy per year in the standing timber. Thus the land-for-energy ratio amounts to 80 gigajoules of biomass energy per hectare per year. Therefore a ratio of 1.8 tons carbon emitted each year (one hectare per 100 gigajoules per year) for the land-for-energy ratio for fossil fuel are used (Wachernagel & Rees, 1996).

Thus the method (although not the only available) estimates the land area needed to sequester the carbon dioxide emitted from burning fossil fuel. If we continue to consume excessive quantities of fossil fuel we have a responsibility to manage its wastes products. This approach ensures that we think about the consequences of what we are doing and requires that we calculate the amount of "carbon sink" land required to assimilate the fossil carbon dioxide that we are injecting into the atmosphere. Young to middle aged forests accumulate carbon dioxide at the highest rate over a 50 – 80 year time span. The average forest accumulates approximately 1.8 tons of carbon per hectare per year. This means that one hectare of average forest can sequester annually the carbon dioxide emission generated by the consumption of 100 gigajoules of fossil fuel.

Energy land calculations will then be:

$$\frac{\text{Total consumption in (GJ/Yr)}}{\text{Total Population (South Africans)}} = \text{GJ/Year fossil fuel}$$

Then:

$$\frac{\text{GJ/Year}}{\text{100 GJ/Ha/Yr}} = \text{Ha/cap for sequestering}$$

6. CALCULATION OF SOUTH AFRICA'S ECOLOGICAL FOOTPRINT

The population statistics to be used are for the 1995 census that was provided by the Central Statistics Services.

The land areas to be used are from the ENPAT dataset of 1997.

Agricultural figures were taken from different sources that include Crafford and Nott (1981), Agricultural Guide (1997) and papers delivered at the Veldtrust Conference in 1990.

6.1 Wheat footprint

Production: 1 977 000 tons
Import : 784 545 tons }
Export : 232 357 tons } 552 188 tons

Total consumption 1 977 000t + 552 188t = 2 529 188 000 kg

2 529 188 000 kg / 37 859 000 people = 66.80 kg/capita
1 977 000 000 kg / 19 111 731.95 Ha = 103.44 kg/Ha

The footprint then is consumption divided by production:

60.80 kg/capita
103.44 kg/Ha
0.645 Ha/capita

The landuse can be seen in figure one.

6.2 Sugar cultivation footprint

16 155 857 000 kg / 37 859 000 people = 426.73 kg/cap
16 155 857 000 kg / 974 153.68 Ha = 16 584.50 kg/Ha

The sugar cultivation footprint is then when divided:

426.73 kg/cap
16 584.50 kg/Ha
0.025 Ha/cap

The landuse can be seen in figure two.

6.3 Forestry footprint

17 000 000 000 kg / 37 859 000 people = 449 kg/cap
17 000 000 000 kg / 1 100 000 Ha = 15 454.54 kg/Ha

The forestry footprint when divided is:

449 kg/cap
15 454.54 kg/Ha
0.029 Ha/cap

The forestry landuse can be seen in figure three.

6.4 Rangeland footprint (cattle and sheep)

6 204 000 000 kg / 37 859 000 people = 163.87 kg/cap

6 204 000 000 kg / 46 803 012.50 Ha = 132.55 kg/Ha

The rangeland footprint when divided is:

163.87 kg/cap

132.55 kg/Ha

1.236 Ha/cap

The landuse can be seen in figure four.

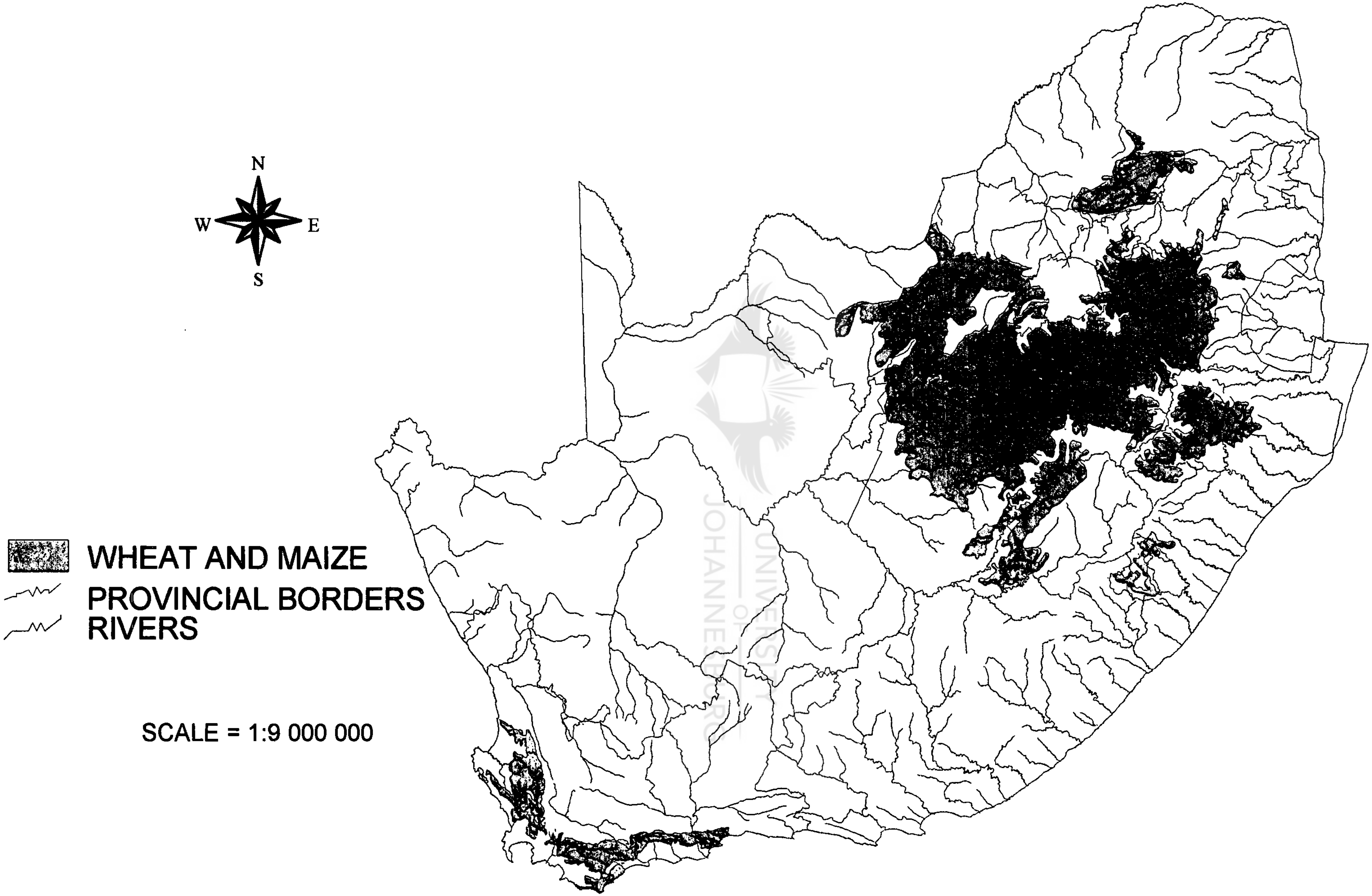

FIGURE 1: LANDUSE WHEAT AND MAIZE

Source: ENPAT 1997

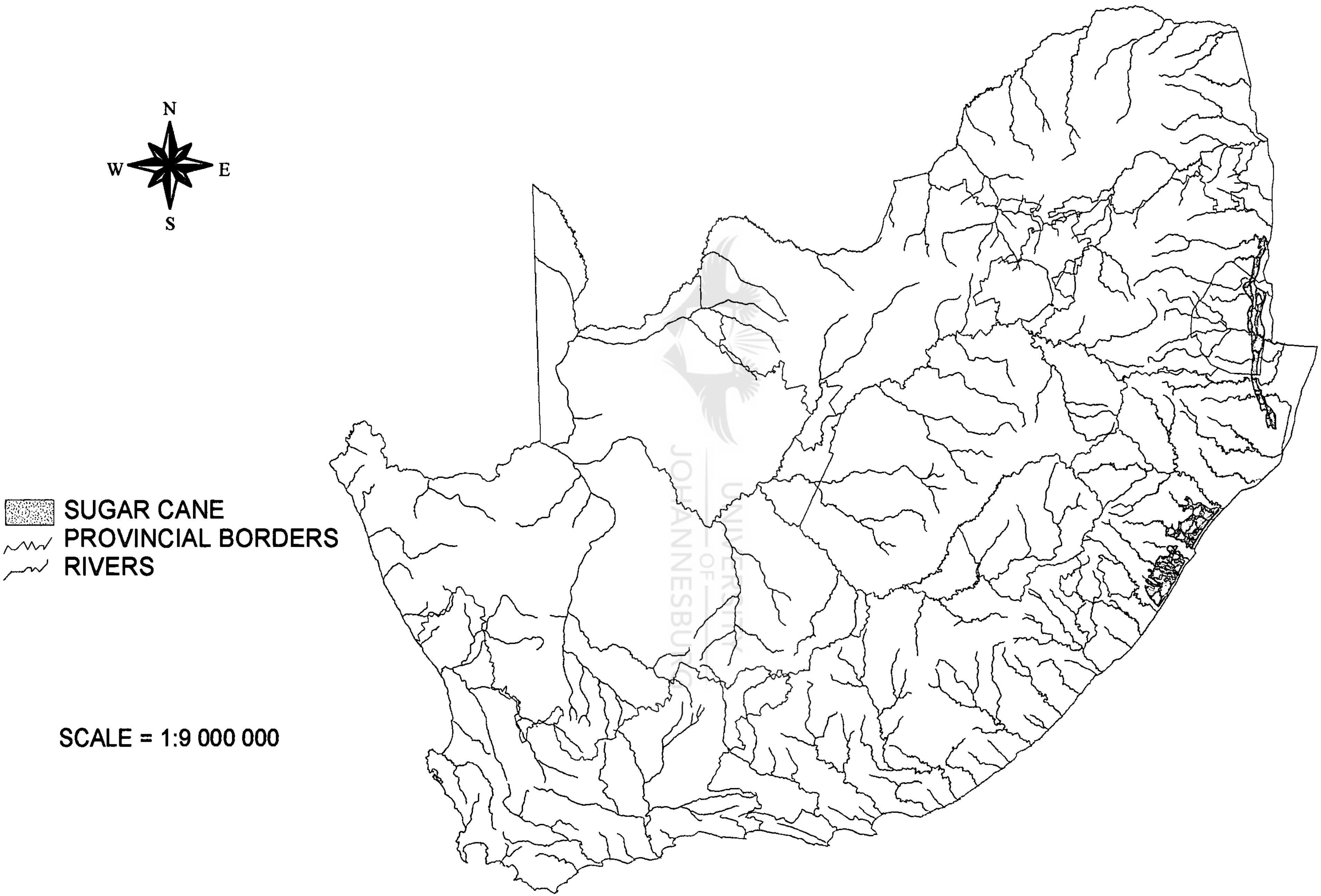

FIGURE 2: LANDUSE SUGAR CANE

Source: ENPAT1997

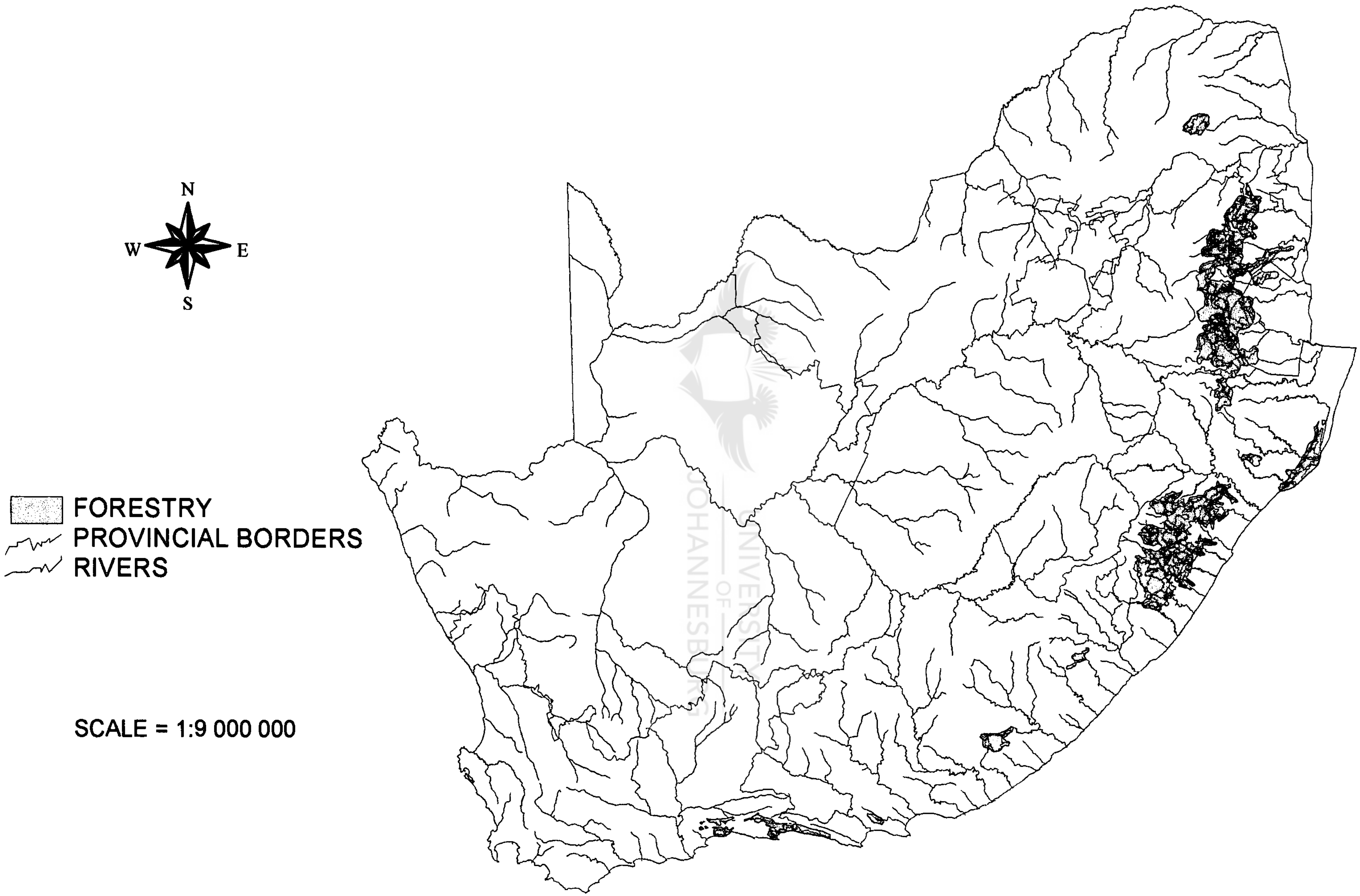

FIGURE 3: LANDUSE FORESTRY

Source: ENPAT1997

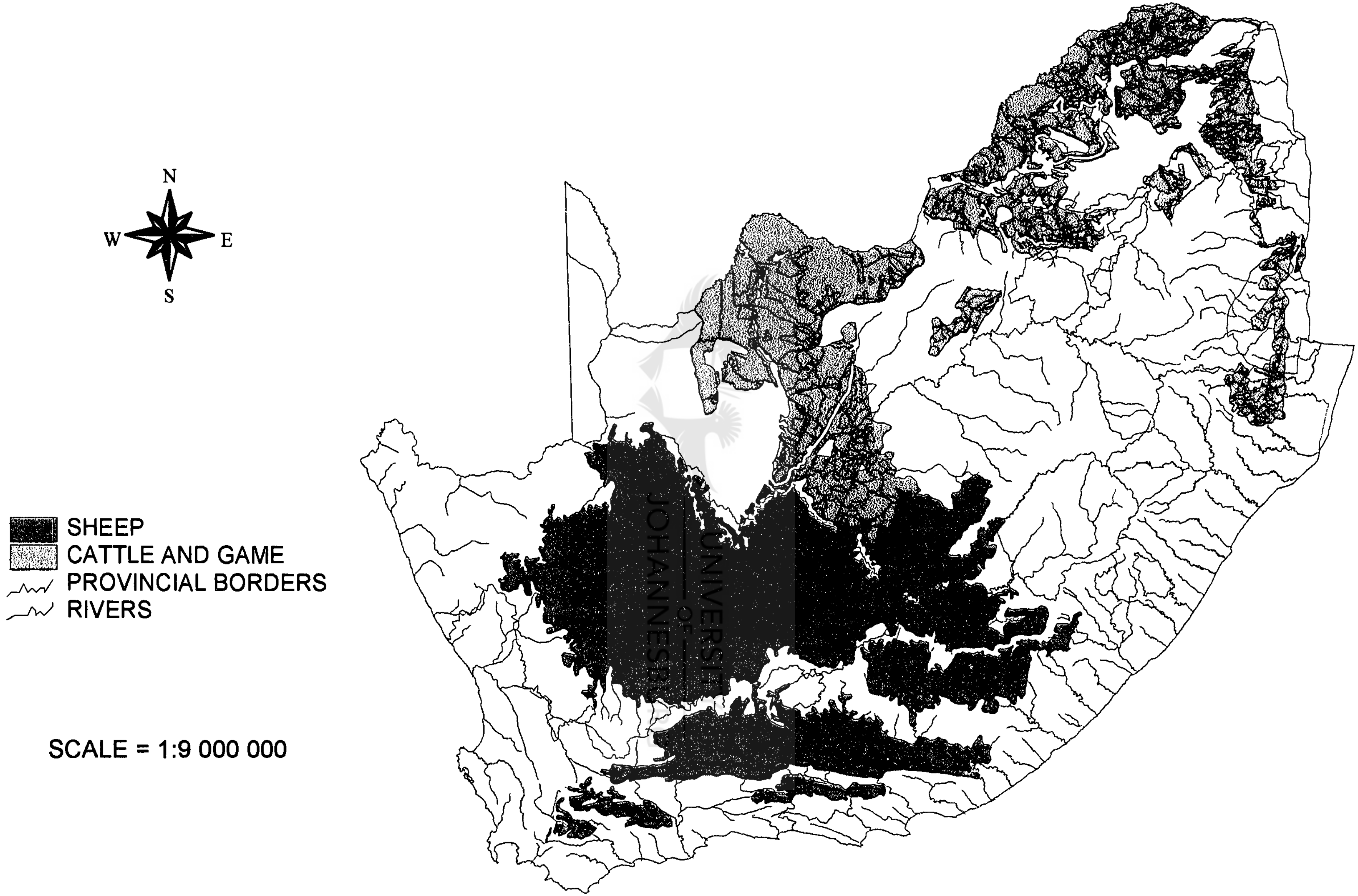

FIGURE 4: LANDUSE RANGELAND

Source: ENPAT1997

6.5 Degraded land footprint

The degraded land footprint comes from land made unusable for production or regeneration processes of nature. The degraded land footprint according to ENPAT (1997) is estimated from:

a) 1 685 towns

b) Sum of 286 228.28 km of roads

It is important to know that this footprint can be much higher if other factors such as mines, strip-mining and slimedams are included in the calculations.

According to Steffen desertification could claim in the region of 2 500 000 Ha of land in South Africa by the turn of the century (World Environmental day, 1991). Mining alone in the Mpumalanga will use 409 500 Ha (McPhee and Smithen, 1984).

Yeld (1993) estimated that there are only 0.4 Ha arable land available per person in South Africa, as desertification has already claimed 2 500 000 Ha.

The degraded land footprint is calculated by using the following statistics:

3 500 000 Ha (2 500 000 Ha deserts and 1 000 000 Ha towns and roads) degraded land divided by the population of 37 859 000 people.

The footprint is then: 0.092 Ha/cap.

In figure five the roads and towns covering the land making those areas "useless" in ecological terms are depicted.

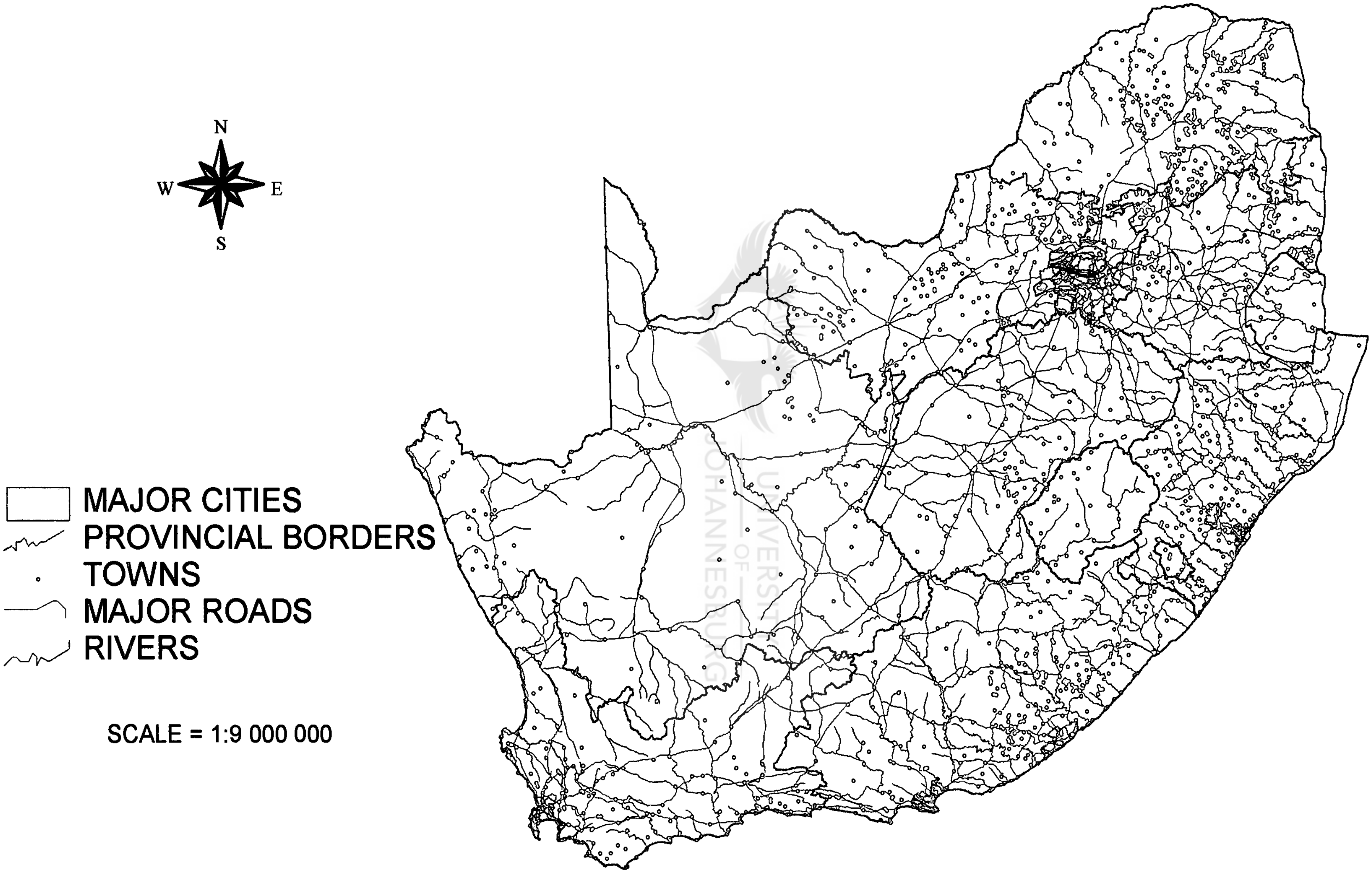

FIGURE 5: DEGRADED LAND

Source: ENPAT1997

6.6 Energy footprint

The total energy usage according to the Department of Mineral and Energy Affairs (1997) is:

Total production = 541 064 961 Tera joules
Import = 60 934 822 Tera joules
Export = 170 636 766 Tera joules

Consumption is then 431 662 017 Tera joules which is 4 316 620 170 Giga joules.

4 316 620 170 Giga joules / yr
37 859 000 South Africans
114.0 (GJ/year) fossil fuel per annum

As calculated earlier the average 1 Ha forest can sequester annually the carbon dioxide emission generated by the consumption of 100 gigajoules of fossil fuel. This 100 gigajoules of fossil fuel is then divided in the 114 (GJ/year) fossil fuel per annum which amounts to the amount of forest South Africa needs to purpose a sink for the fossil fuel emissions.

Then: 114 GJ/year / 100 = 1.14 Ha/cap

Although South Africa has only 4% of the land area and 7% of the population of Africa it consumes about 53% of the total energy used in Africa (Holland, 1982). South Africa has rich coal reserves (115×10^9 tons) of which 58×10^9 tons are recoverable, this is 11% of the world reserves (Department of Environmental Affairs, 1992). These however, if not used sustainable, will not last forever.

6.7 Conservation footprint

Because South Africa has such a high diversity in plant and animal communities it is important to include this footprint. South African flora, which is 80% endemic to the country comprises 8.4% of the world's total. The animal life is as impressive with 2% of the world's total amphibians, 4.6% of the world's reptiles, 6.7% of the world's birds and 5.7% of the world's mammals. Many of these are also endemic (Meadows, 1985).

Conservation land in South Africa comprises of 6 454 053.56 Ha according to EMPAT (1997).

The conservation footprint is then

6 454 053.56 Ha
37 859 000.00 people
0.17 Ha/cap

Figure six shows the land allocated to conservation.

The total footprint then for the parameters above is:

Wheat	: 0.645 Ha/cap
Sugar	: 0.025 Ha/cap
Forestry	: 0.029 Ha/cap
Rangeland	: 1.236 Ha/cap
Degraded land	: 0.092 Ha/cap
Energy	: 1.14 Ha/cap
Conservation	: 0.17 Ha/cap
	3.337 Ha/cap

If only these parameters are used then total land needed by South Africans comes to 3.337 Ha/cap x 37 859 000 people which are 126 335 483 Ha.

South Africa's total land surface comprises 126 725 201 Ha (ENPAT, 1997).

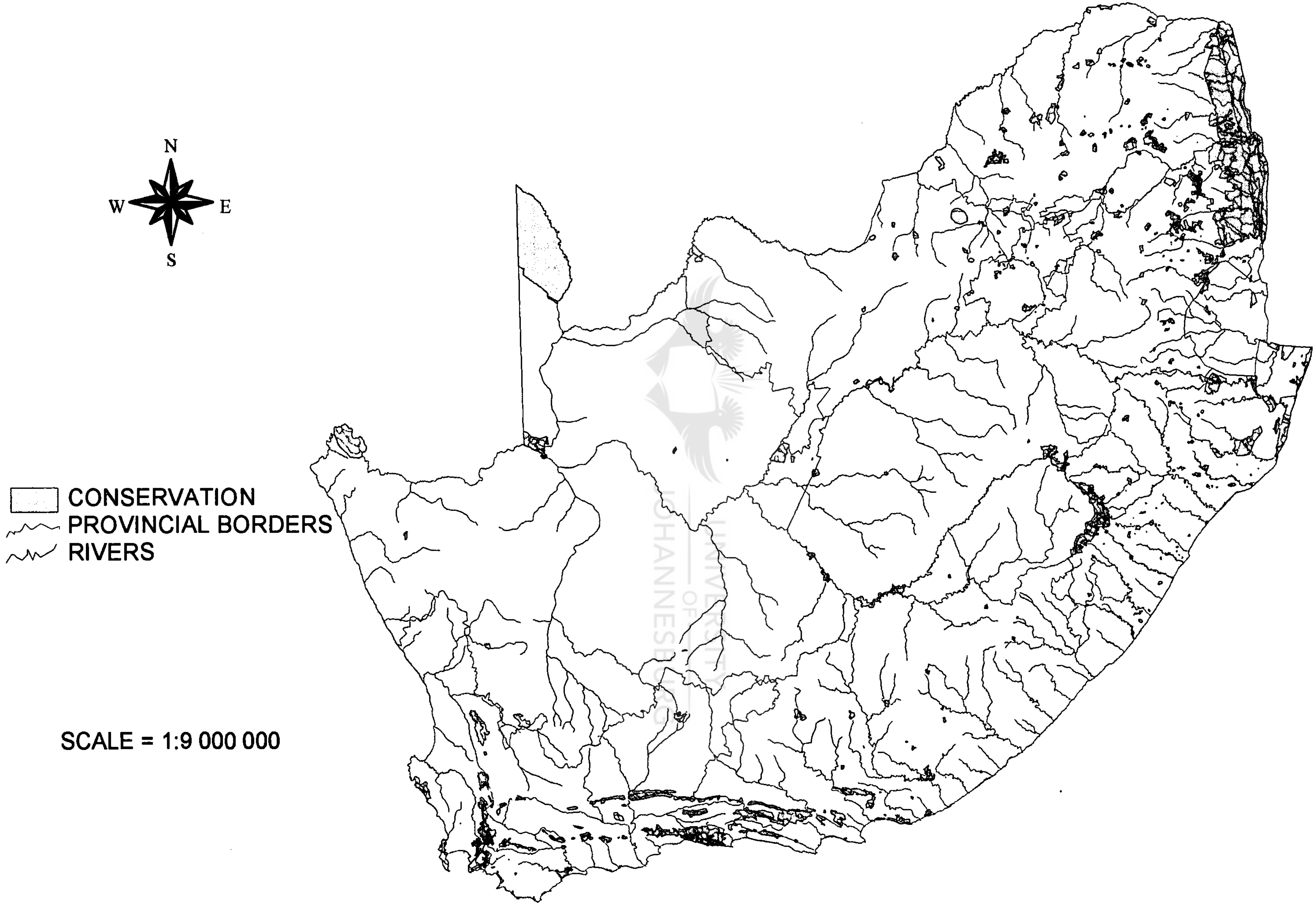

FIGURE 6: LANDUSE CONSERVATION

Source: ENPAT1997

7. EVALUATION AND DISCUSSION

It is unfortunate that a country like South Africa with its fast ecological resources lack so intensely in sustainable development plans and proposals. That the people of South Africa over-utilize its natural resources at a suicidal rate is demonstrated in the study.

It seems that a global concern to sustainable development lack not of plans and enthusiasm but the education of developers, the monetary problems therein and the education of the "common people" are left behind.

It does not take much to get people to agree that sustainable development needs to foregone environmental impact studies but supplying money to enforce this seems to never come available.

The measurement tool in Ecological Footprint Analysis is practical and easy to use, which gives a means to determine unsustainable development.

The ecological deficit measured in the final analysis shows an alarming figure of just how much 'damage' is being done.

The strength of the Ecological Footprint Analysis is its ability to communicate simply and graphically the general nature and magnitude of the biophysical "connectiveness" between humankind and the ecosphere. Ecological Footprint Analysis calculations are static. They provide an ecological snapshot of the economy - land relationships at a particular point in time. However, historical trends can be captured. This can be done by reconstructing and calculating the Ecological Footprint of an entity for a series of such snapshot points.

The Ecological Footprints of a country can be reduced with technology, thus by ignoring technology Ecological Footprint Analysis allows us to compare current ecological requirements and constraints with those that would result if specified technology improvements were widely implemented. Ecological Footprint Analysis can even provide a dynamic picture of changing conditions. It also provides an incentive to determine an estimate of how far we have to go to achieve sustainability and a yardstick to monitor the economy's progress towards reducing its load on nature (Wackernagel & Rees, 1996).

The load on nature always results in waste, and sustainability means to handle the waste produced. In South Africa high amounts of wastes are produced and in table one the tonnage of solid wastes produced is shown.

Table 1: South Africa's total waste stream in 1991 (t/yr.)$^{-1}$

330 million	Mining waste
29 million	Coal ash
15 million	Urban waste
20 million	Agricultural waste
12 million	Sewage sludge
6.8 million	Non-metallurgical waste
5.5 million	Metallurgical industry waste

(Source: Department Environmental Affairs, 1992, 101)

The waste handling is important because of health reasons. For the scope of this study land was allocated to this variable making the Ecological Footprint of South Africa even bigger.

8. CONCLUSION

According to Yeld (1993) the arable land left for each South African is 0.4 Ha/person. This gives a total of 15 143 600 hectares.

The following figures are applicable:

South Africa's total land : 126 725 201 Ha
Ecological footprint : 126 335 483 Ha
Available arable land : 15 143 600 Ha

To estimate the Ecological deficit of South Africa Wackernagel and Rees (1996) supply the following formula (table 2):

Table 2: Ecological Deficit

	Ecological Productive land a $x10^2$	Population 1995 b $X10^3$	Ecological Productive Land per cap. c = a/b	National ecological deficit per capita	
				(in hectares) d = footprint – c	(in % available) e = d/c
				* footprint = 3.337	
Total arable land available	151 436	37 859	0.4	**2.937**	834%

Where the above figures are compared to those of some other countries, it is clearly demonstrated that industrialized countries run significantly high ecological deficits (table 3).

Table 3: Ecological deficits: A comparison in countries

Country	National Ecological deficit per capita	
	In hectares	In % available
Japan	1.76	730%
Austria	2.15	250%
Belgium	2.80	1400%
Switzerland	2.56	580%
Australia	28.44	760%
United States	2.29	80%
South Africa	1.709	834%

(Source: Wackernagel & Rees, 1996)

This implies that South Africa is greatly over-utilizing its resources. The ecological footprint stretches well over the country's borders and South Africans have a significant impact on other countries as well.

The Ecological Footprint is aimed to be a tool used to determine certain factors and trends. This is a decision-making tool and states problem aspects as they are converted into real figures so that the decisionmaker's tasks are easier. Ecological Footprint Analysis is a tool adding facts to sustainable plans and support ecological trends in such a way that on the spot analysis can be made as well as trends on an ongoing basis.

According to Maruma (date unknown) the present government does not adopt an anti-growth stance, it rather adopts a pro-development position. This emphasizes the importance of monitoring tools like the Ecological Footprint Analysis to be used as a pro-development tool. South Africa, as any other country, should make full use of all the technology available to live more sustainable because it all boils down to one fact which is that we only have one earth.

This study exposes the importance of hard ecological restructuring in South Africa. Development should be done under the guidance of Integrated Environmental Management. The study proposes a means to determine ecological impacts on different entities. It gives opportunity to study ecological impacts on from a small scale up to determining ecological deficits of a whole country. The Ecological Footprint Analysis is an easy-to-use-tool and can be implemented on a very simplistic scale. For example in a high school Geography project the children can determine how many trees should be planted to support the paper need of the local newspaper. More complex studies in ecological impact assessments could be conducted. Because no previous Ecological Footprint Analysis has been done on South Africa exposes a wide variety of entities to conduct this analysis on. Waste assimilation and water usage are only two entities on which an in depth Footprint Analysis can be conducted.

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