Permaculture as an alternative to present commercial resettlement farming practices in Namibia

Dissertation submitted in partial fulfilment of the requirements for the degree of

MASTER OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE

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Abstract

The current mono-crop farming practices in the Namibian resettlement farms there were visited are unsustainable due to soil nutrient, structure and eventually texture destruction. Furthermore, the aridity of Namibia makes crop and livestock farming difficult.

Permanent agriculture (permaculture) is a way of living sustainably in the environment and it is proposed as an alternative farming method for the mostly poor and illiterate settlers on resettlement farms. It emphasises self-reliance on basic needs and the creation of artificial ecosystems from which nutrition and infrastructure can be attained in a sustainable manner without exploiting or polluting the environment.

Permaculture is not an instant solution but, a long-term sustainable alternative to current agricultural practices in semi-arid and arid areas of Namibia.

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Glossary

The following abbreviations are used in this dissertation:

DEA	Department of Environmental Affairs
EIA	Environmental Impact Assessment
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
IUCN	International Union for the Conservation of Nature and .. . ..
..	Natural Resources
m	meter
NAPCOD	Namibian Programme to Combat Desertification
ppm	parts per million
Spp.	Species
UCT	University of Cape Town
UNEP	United Nations Environmental Programme
WCED	World Commission on Environment and Development.
WWF	World Wide Fund for Nature

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CHAPTER 1

INTRODUCTION

Chapter 1 - Introduction

1.1 Background

Namibia has a extremely uneven distribution of land and wealth, which has resulted in the redistribution of land becoming an issue of major political, social and economic concern. Namibia faced a major challenge after the war of independence with regard to the large number of unemployed and landless people. When the Ministry of Lands, Resettlement and Rehabilitation (MLRR), was established in 1990, and one of its aims was to rectify the problem by purchasing and allocating land, and by providing support services and infrastructure to the landless and poor.

In an attempt to address some of these issues, the Namibian Programme to Combat Desertification (NAPCOD), represented by the Directorate of Environmental Affairs (DEA), commissioned the 1997/98 Masters of philosophy students from the Department of Environmental and Geographical Science at the University of Cape Town to assess the environmental impact of some of the resettlement schemes in the Oshikoto and Omaheke provinces of Namibia (Figure 1.1.).

Six of the M.Phil students undertook a baseline study of five commercial resettlement farms in the Omaheke (Tsintsabus and Excelsior) and Oshikoto (Vasdraai, Drimiopsis, Skoonheid) regions of Namibia from mid January to mid February 1998 as a retrospective assessment of environmental implications for commercial resettlement in Namibia.

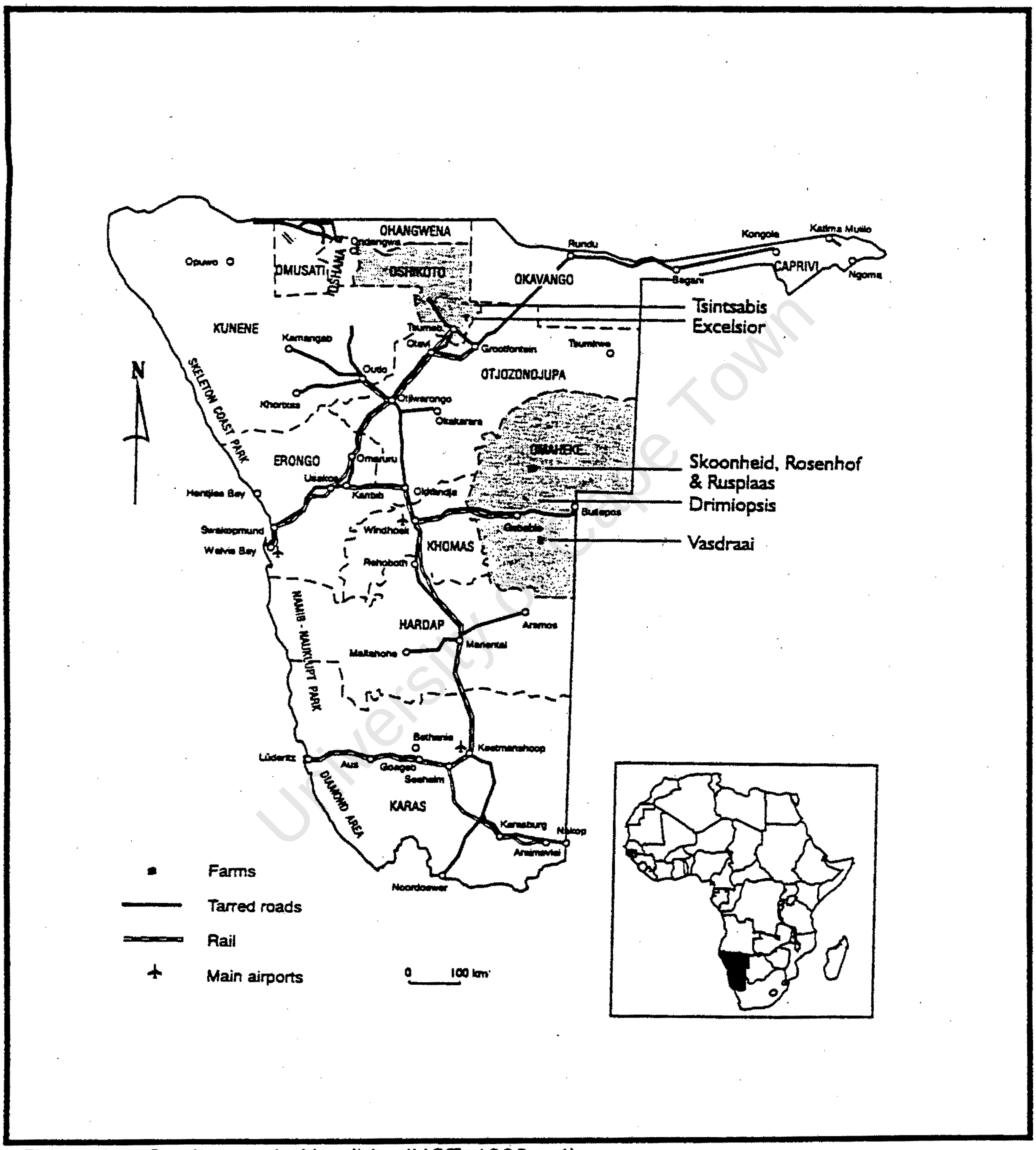


Figure 1.1. Study area in Namibia. (UCT, 1998, p4)

This study was co-ordinated by the Department of Environmental Affairs of Namibia and was funded by the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ).

In addition to the baseline report, individual dissertations were drawn up by each student with the aim of expressing greater understanding and analysing some aspect of the project. This document which contains information gathered from observations and informal discussions on the resettlement farms, together with the individual dissertations, is intended to contribute towards an increased insight into and understanding of commercial resettlement farms in Namibia.

The motivation for the project is the result of recommendations made by NAPCOD in a recent report entitled "Policy factors and Desertification", when it was suggested that research be conducted to analyse the impact of different tenure systems and land-use options. The urgent need for research in this field has also been expressed in the Namibian Environmental Assessment Policy, the National Resettlement Policy and the Lands and Forestry Chapter of the National Development Plan.

Following the visit to the resettlement farms and the research carried out there as well as secondary research, it became apparent that most of the crop-farming methods were not sustainable with regard to yield or sustenance of the settlers and their future generations. The sustainable use of water was also considered.

1.2 Aims and Objectives

This dissertation represents one of the individual dissertations, and it focuses on permaculture as an alternative farming method for commercial resettlement farmers. In the long run, the current unsustainable way of farming will impede the basic element of the resettlement program, which is to provide sustainable occupation and good food production for the poor and destitute. However, the current method of mono-crop farming in arid regions is not sustainable and will lead to the depletion of natural resources in the near future.

Permaculture is proposed as an ecologically, socially, technically and economically sustainable farming method and as an alternative to the current commercial resettlement farming practices in Namibia:

> *"The aim is to create systems that are ecologically-sound and economically viable, which provide for their own needs, do not exploit or pollute, and are therefore sustainable in the long term. Permaculture uses the inherent qualities of plants and animals combined with the natural characteristics of landscapes and structures to produce a life-supporting system for city and country, using the smallest practical area"* (Mollison *et al*, 1997, p1).

In order to implement permaculture, certain objectives need to be formulated:

- To understand the religion, philosophy and ethics.
- To understand the fundamentals of permaculture.

- To discuss the practicalities of permaculture in arid and semi-arid areas of Namibia.
- To test sustainability.
- To understand the impact and results of sustainability and permaculture criteria applied to resettlement farms.
- To understand the utilisation of water as a scarce natural resource.
- To introduce a system whereby the settlers can obtain nutritious resources sustainably in order to function optimally.

The expectations of Namibia's rural resettlement farmers are to become increasingly responsible, over a period of five years for their own individual subsistence. It is therefore hoped that this report will contribute towards providing resettlements with a greater range of alternatives regarding the sustainable development of their farms.

1.3 Methodology

1.3.1 Information Gathering

The following methods were used both by individuals and the group to gather information and data.

Literature Review

Appropriate literature was reviewed with the purpose of providing an in-depth understanding of and theoretical background to permaculture. The literature on permaculture is limited as it is believed to be a new concept in southern Africa and especially in Namibia. The internet was also used to acquire the most up-to-date information but again this was limited.

Interviews

Interviews were conducted with Namibian government officials, non-government organisations (NGO's), as well as private individuals. During the field trip early in 1998, informal interviews were held with settlers to assess their perception of the resettlement issues.

Personal observations

The field trip to Namibia enabled the research team to make first hand observations in the Oshikoto and Omaheke regions, the focus of which was the sustainability of commercial resettlement farms.

1.3.2 Analysis of Information

The first part of this dissertation includes (chapters 1 and 2) an introduction to the study as well as the ethics, philosophy and religion of permaculture. The second part (chapters 3 and 4) establishes a literature basis, describing permaculture as a concept and its practical application in arid areas. The final section (chapter 5 and 6) of the dissertation discusses the application of permaculture. In chapter 5, permaculture is tested for its degree of sustainability, whereas the next chapter focuses on the application of sustainability criteria and permaculture principles to the relevant commercial resettlement farms visited.

1.4 Limitations to the study

The following points may limit the scope of this study:

- There were little primary data available in Namibia and South Africa.
- Communal resettlement farms and normal commercial, communal resettlement farms could not be analysed.
- It was not possible to incorporate questions on permaculture into the field work. There was, therefore, no opportunity to determine the perceptions of settlers on permaculture as an alternative agricultural method.
- Permaculture is a reasonably new concept in southern Africa so that there were no official programmes known to the research team at the time of the field trip. Thus none of the information in this dissertation is based on first-hand experience in Namibia, but on theory from literature studies and personal communication, as well as a visit to the Kommetjie Environmental Awareness Centre in Cape Town.

1.5 Major assumptions

- All five of the farms are in a semi-arid and savannah region.
- The four pillars of sustainability, as presented by Hill *et al* (1997) are valid criteria for sustainability.

In the following chapter, some ethics and philosophy of the environment and permaculture will be discussed in order to understand, in a broader context, the point of departure of permaculture

CHAPTER 2

PHILOSOPHY AND ETHICS OF THE ENVIRONMENT AND PERMACULTURE

industrialisation and urban growth, pollution of air and water, and alienation from nature (Scorer, 1972; Bugler, 1972; Miller, 1998). Since the 1960's, there have been more subtle changes which often affect the whole planet:

- The ozone layer is now less concentrated.
- The average global temperature is rising.
- Rainfall is becoming more acidic.
- Irresponsible agricultural practices are eliminating genetic diversity.
- Harvests from both ecosystems and animal populations have exceeded sustainable yields, (Fuggle *et al*, 1996).

2.2.1 In harmony with the earth

In 1991, the World Conservation Union, in partnership with the United Nations Environmental Program and the World Wildlife Fund for Nature, launched a publication entitled '*Caring for the earth. A strategy for sustainable living*' (IUCN/UNEP/WWF.1991). This document has made a significant contribution worldwide to foster human responsibility for the earth:

> *"Because of the way we live today our civilisation is at risk. The 5,3 billion people alive now, especially the 1 billion in the best-off countries, are misusing natural resources and seriously over stressing the earth's ecosystems. World population may double in 60 years, but the earth would be unable to support everyone unless there is less waste and extravagance, and a more open and equitable alliance between rich and poor. Even then the likelihood of a satisfactory life for all is remote*

unless present rates of population increase are drastically reduced" (IUCN/UNEP/WWF, 1991. p3).

It is seriously argued that there are no easy solutions to this situation and that action is needed on several fronts simultaneously. Fuggle *et al* (1996) state that the two fundamental requirements stressed in *Caring for the earth (IUCN/UNEP/WWF, 1991)* are to secure a widespread and deeply-held commitment to an ethic for sustainable living, and to integrate conservation and development: *"........ conservation to keep our actions within the earth's capacity, and development to enable people everywhere to enjoy long, healthy and fulfilling lives."*

Caring for the earth continues:

> *"........living sustainably depends on accepting a duty to seek harmony with other people and with nature. The guiding rules are that people must share with each other and care for the earth. Humanity must take no more from nature than nature can replenish. This in turn means adopting life-styles and development paths that respect and work within nature's limits. It can be done without rejecting the many benefits that modern technology has bought , provided that technology also work within those limits. This .... is a new approach to the future, not a return to the past."* (IUCN/UNEP/WWF, 1991).

Fuggle *et al* (1996) identified nine principles for building a sustainable society:

i. Respect and care for the community of life.

ii. Improve the quality of human life.

Another reason for the occurrence of environmental problems is their often guileful nature. Problems may arise from the collective impact of a high frequency of small impacts (a smoking chimney, the damming of a river, catching undersize fish, erosion, pesticides). In themselves these may be insignificant but when they are accumulated they pose a dire environmental threat (Fuggle *et al.* 1996).

2.2.3 Ethics of environmental conservation

There is the question: "Why conserve the environment at all?" This is not empirical but normative, seeking a basis for environmental conservation. It is philosophical rather than scientific and there is therefore not one but several possible answers depending from which angle the question is considered (Fuggle *et al.* 1996).

Utilitarianism

The rationale behind the 1970-based credo '*Conservation is for man*' is that nature should be protected on account of its utility to humans (Schaeffer, 1972) and that environmental conservation would offer the most good to man. Utilitarian ethics have considerable appeal in a society where economic values are dominant and no appeal is made to religion. Fuggle *et al* (1996) continues by stating that another attraction of utilitarianism is that moral issues are, in principle, determined by empirical calculations of consequences with grey areas due to technical limitations in assessing what constitutes 'good'. This is in direct contrast to the Christian faith's principle of stewardship and putting God first in all of man's decisions (Fritsch. 1980). Thus, an utilitarian reason for environmental conservation is that such action will produce the greatest good for the greatest number of people for the greatest period of time. Environmental law is therefore often aimed at such issues as pollution and erosion control, and the conservation of natural resources, in order to ensure that the environment remains useful to humans rather than being seen to have a value in its own right (Fuggle *et al.* 1996).

There are, however, other bases for environmental ethics which are not dependent on the utilitarian anthropocentric view. These ethics have been advanced by those who set human beings in a transcendental framework and who believe that mankind and the universe were created by God (Fuggle *et al.* 1996).

Judeo-Christian ethics

Judaism, Christianity and Islam are the world's three major monotheistic religions, each holding that a human is not the ultimate being but a product of God's creation, together with the earth and all the plants and animals. Human beings therefore live in a cosmos created by and belonging to God. They are an integral part of nature. God, not humankind is Lord of all, and all creation glorifies God and not humankind. However, God, humanity and nature should be in harmonious relationship, with nature itself having intrinsic worth before God (Psalm 24: 1. The Holy Bible, 1984) and being witness to God's work (Fritsch, 1980; Rose, 1992.).

we endanger ourselves with our own "*stupidity*" and "*lack of personal responsibility to life*" (Mollison, 1992, p1).

> "*If we become extinct because of factors beyond our control, then we can at least die with pride in ourselves, but to create a mess in which we perish by our own inaction makes nonsense of our claims to consciousness and morality.*" (Mollison, 1992, p1).

Consumptive lifestyles have taken us to the brink of annihilation, while humankind has abused the right to live on the earth by conquering nature. To accumulate wealth, land and power beyond personal need is, in such a limited world, truly immoral. What has been done in the past cannot be undone, but now is the time to change perspective. According to Mollison, the only resource that we need is people, since, if we share our talents and work together, we can solve the problems of our time. It is a brave person who follows the road to peace. Such a person needs courage to live without authority but with personal responsibility. Growth for the sake of personal accumulation of power, status and wealth is an outdated and selfish concept. It is our own and our children's lives that are laid to waste in ecological disasters and consumeristic accumulation frenzy. The primary directive of permaculture therefore is: "*to take responsibility for our own existence and that of our children*" (Mollison, 1992, p1).

Most people would agree with Mollison that mankind has reached the point of an irrevocable decision that can either sustain or destroy life on earth. Information and humanity, as well as science and understanding, are all in transition as we progress through millennia enumerating the wonders of earth. An analysis of our world has also resulted in the development of different sciences, disciplines and technologies. The present situation is that we have a welter of names and a sundering of parts, a proliferation of specialists, and a consequent inability to foresee results or to design integrated systems (Mollison, 1992).

At present, the focus is on how the parts interact with each other and how dissonance or harmony in living systems is achieved. Mollison (1992) believes that life is co-operative rather than competitive, and that life forms of different qualities may interact beneficially with one another and with their physical environment: *"Even the bacteria... live by collaboration, accommodation exchange, and barter"* (Mollison, 1992. p2). Thus the principle of co-operation evolved: *"Co-operation, not competition, is the very basis of existing life systems and of future survival"* (Mollison, 1992, p2).

According to Mollison (1992) we move deeper into both science and mysticism when questioning the purpose and meaning of life. However, for him, life is an open system which is able to take from the energy sources in time and to re-express itself not only as a lifetime but also as a descent and an evolution. He continues that the ideal way to spend time is in perfecting the expression of life, in other words, to lead the most evolved life possible and to assist in and celebrate the existence of life forms other than humans, for all comes from the same seed.

> *"The totality of this outlook leads to a meaningful daily existence, in which one sees each quantum of life eternally trying to perfect an expression towards a future, and possibly transcendental, perfection"* (Mollison, 1992, p2).

It is therefore even more cruel that tribal people whose aim was to develop a conceptual and spiritual existence, have encountered a coarse scientific and material culture whose aim in life is not only unstated but which also relies on pseudo-economic and technological systems for existence.

Mollison believes that there is a need to adopt a sophisticated aboriginal belief system to learn respect for all life, and then we lose our own, not only as a lifetime but also as a future opportunity to evolve our potential.

> "*Whether we continue, without an ethic or a philosophy, ... or whether we create opportunities to achieve maturity, balance and harmony is the only real question that faces the present generation*" (Mollison, 1992, p2).

2.3.1 Ethics of permaculture

Mollison researched community ethics, as adopted by older religions and co-operative groups seeking for universal principles to guide their actions. These can be expressed as three principles:

i. *"Care of the earth: Provision for all life systems to continue and multiply.*
ii. *Care of people: Provision for people to access those resources necessary for their existence.*
iii. *Setting limits to population and consumption: By governing our own needs, we can set resources aside to further the above principles"* (Mollison, 1992, p2).

This ethic leads to self-reliance in individuals and co-operation in groups. Mollison (1992) develops a philosophy similar to Taoism in which the aim is to work with nature rather than against it. Two questions emerge from this statement:

i. "What can I get from this land or person?"

ii. "What does this person or land have to give if I cooperate with them?"

The former approach may lead to war and waste whereas the latter may result in peace and prosperity.

Humans are often led by information, reflection and investigation in order to moderate, abandon or forbid certain behaviours and substances that, in the long run, might threaten our survival, and cautious and conservative rules have thus evolved. This process is the result of many taboos in tribal society. Over time, ways of accounting for our actions have also evolved and these are also necessary for our survival. They include:

i. "*Necessitous Use: - that we leave any natural system alone until we are, of strict necessity, forced to use it.*"

ii. "*Conservative Use: - having found it necessary to use natural resources, we may insist on every attempt to:*"

- Reduce waste and thereby also pollution
- Thoroughly replace minerals that were lost
- Do a careful energy accounting
- Do an EIA (environmental impact assessment) with its mitigation suggestions (Mollison, 1992, p3).

Consideration of the rules of Necessitous Use and Conservative Use may lead us to the fundamental realisation of our interconnectedness with nature – in other words, that we depend on good health of all systems for our survival. The self-interested concept of human survival (based on past experiences of environmental disaster and famine) is thus broadened by the inclusion of the concept of 'the survival of natural systems'. There is also the idea that when we lose plant or animal species we also lose a part of our survival base. Our fates are thus intertwined.

Based on an earth-care ethic we can now turn to our relationship with each other. In this relationship, according to Mollison (1990, p379), a general rule of nature can be observed: "*that co-operative species and associations of self supporting species (like Mycorrhiza on tree roots) make healthy communities.*" Such examples can motivate us to co-operate and play supportive roles in society, and also seek interdependence, which values the individual's contributions rather than forms of opposition or competition.

Initially, helping family or friends may add to survival. We may, however, evolve to what Mollison refers to as a mature ethic that sees all humankind and later all life, as allied associations. We can further extend *people care* to include *species care* for all life has common origins. This is then the meaning of permaculture: mechanisms of pure ethical behaviour or what to do to sustain the earth.

The study of history can identify many ways of achieving permanence and stability in society. Mollison identifies the peasant approach where people hauled nutrients from canals, cesspits and forests to produce an annual grain culture. He describes this as a *feudal permanence* for its method, period and politics. In this system, people were bound to the land by unremitting toil and service to a state or landlord, and were destined for famine and revolution.

Another approach is found on the permanent pasture of the prairies, pampas, and modern Western farms. Here large holdings and few people create a vast grazing expanse, usually for a single species of animal. Mollison describes this as the *baronial permanence* with huge properties operating at the lowest level of land use (pasture or cropland is the least productive use of land). Such systems, once mechanised, destroy whole landscapes and soil complexes and become agricultural deserts.

Tropical forests are at a stable equilibrium and thus provide in its own need for energy (apart from the sun). However, modern-crop agriculture is totally dependent on external energy sources – hence the oil crisis and pollution. According to Mollison (1992, p6) there can be no stable social order other than that created by permanent agriculture.

> *"Thus, the move from productive permanent systems (where land is held in common), to annual, commercial agriculture's where land is regarded as a commodity, involves a departure from low- to high-energy society, the use of land in an exploitative way, and a demand for external energy resources, mainly provided by the third world"* (Mollison, 1992).

This high energy demand is unsustainable. Mollison therefore pleads for permanent agriculture, in order to form a self-supporting and self-sufficient productive system that will sustain all life permanently.

2.4 Conclusion

This chapter covered the need for a change in attitude towards the environment, in order to live in harmony with the earth together with the reasons for environmental deterioration. The section on environmental ethics then considered the question "Why conserve the environment at all?" as well as Utilitarian and Judeo-Christian ethics. The chapter concluded with a discussion of the ethics and philosophy of permaculture.

Having provided a philosophical and ethical overview, the next chapter will focus on the question "What is permaculture?"

CHAPTER 3

WHAT IS PERMACULTURE?

CHAPTER 3 What is Permaculture?

3.1 Introduction

In the previous chapter the fundamental ethics and philosophy of permaculture were examined. This chapter aims to elaborate on the true meaning of permaculture. Definitions are presented followed by a study of the principles. The requirements of permaculture and the aims are then outlined. There is an description of some of the principles to be formulated.

3.2 Definitions of permaculture

The following five definitions for permaculture will be considered:

i. *"Permaculture is the word we have coined for an integrated, evolving system of perennial or self perpetuating plant and animal species useful to man. It is, in essence, a complete agricultural ecosystem, modelled on existing but simpler examples*" (Mollison & Holmgren, 1990, p1).

ii. *"Permaculture (permanent* agri*culture) is an attempt to design an agricultural system that does not depend on finite resources or destroy its own base in natural resources such as water, soil and forests. It is a response to an ecological crisis brought about by deforestation, air and water pollution, desertification and erosion"* (Strange,1983, p88).

iii. Mollison, executive director of the Permaculture Institute in Tyalgum, Australia, defines permaculture as *"the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing food, energy, shelter, and other material and nonmaterial needs in a sustainable way"* (Pleasant, 1988, p43).

iv. "*Permaculture is a design system for creating sustainable human environments*" (Kruger, 1993, p17).

v. "*Permaculture is an encompassing concept for the design and maintenance of agricultural productive systems, which have the diversity, stability and resilience of a natural ecosystem*" (De Waard. 1994, p244).

3.3 Some principles of permaculture

On one level, permaculture deals with plants, animals, buildings and infrastructure. It is however, not only concerned with these elements but also with the relationship we create between them by the way we place them in the environment. The concept is based on the observation of natural ecosystems and the wisdom of traditional farming strategies as well as modern technology. The following principles are inherent in any permaculture design:

- Relative location: every element is placed in such a manner so as to complement and assist the other.

- Each element performs more than one function.
- Each important function is supported by many elements.
- Efficiency in energy use is applied in all elements.
- The use of biological resources over the use of fossil fuel resources is emphasized.
- Energy is recycled on site using incoming natural energies with those generated on site to ensure a complete energy cycle.
- Using and accelerating natural plant succession establishes favourable sites and soils.
- Polyculture and diversity of beneficial species for a productive and interactive system (as opposed to a mono-cropping system) is a feature.
- The edge (ecotone) and natural patterns are used to the best effect (Kruger, 1993).

3.4 Requirements of permaculture

The principles of permaculture are based on natural ecosystems and traditional polycultures. There are at least four requirements to sustain agriculture requirements if it is to work with and not against nature and establish a self-sustaining system (in other words, a type of a cultivated ecosystem):

i. It must produce more energy than it consumes.
ii. It must not destroy its own base.
iii. It must meet local needs.
iv. It must obtain its own nutrients on site.

Natural systems that satisfy these requirements are forests (and tree systems), lakes, swamps and savannahs (Strange, 1983).

3.5 Aims of permaculture

The basic practical aims of permaculture design can be summarized as follows:

- Emphasis on perennial (for example fruit and nuts) rather than annual crops (such as maize and wheat).
- Replacement of annual with perennial crops for animal fodder in the winter and also for human consumption.
- High diversity of species.
- Combination of diverse farming activities: gardening, commercial farming, grazing, poultry, aquaculture, water management, tree and shrub planting.
- Use of small-scale machinery and hand tools.
- Layout which minimizes labour and transportation.
- Recycling of all materials.
- Use of three-dimensional space-plants that use different levels of soil and air.
- Close relationship between land usage and climatic features and the location of design of buildings and their functions. (Strange,1983).

3.6 Description of certain permaculture design principles

The following is a set of significant principles, to be applied in designing sustainable permaculture systems.

3.6.1 Energy accounting

Our planet earth functions on solar energy so that sunlight is in effect the fuel of life on the earth. Solar energy is intercepted by the earth's network of biotic and abiotic elements which is then transformed into matter and is also temporarily stored in matter. *"The planetary household is an energy economy, and sunlight is its currency"* (De Waard, 1994, p245).

Energy accounting is a technique for assessing the performance of a system, in relation to its environment and, all the inputs and outputs of such a system are accounted for in energy terms. For example, the energy accounting for an intensive bio-industrial chicken farm would incorporate the energy used in:

- The mining of mineral resources.
- The manufacturing and transport of materials.
- The production of food.
- The prevention and cure of disease.
- The system management, the disposal of waste.

The total energy input should be weighed up against the energy output, that is the eggs and the meat. In researching the above it is likely that the output/input ratio (or productivity) will dispute the legitimacy of resource use in such a system (De Waard, 1994, p245).

3.6.2 Energy cycling

Natural ecosystem dynamics provide designers with a basic model for the sustainable use of energy. In the first stage of new ecosystem development, colonization takes place by those species that out-compete other plants by consuming the most energy. However, when that ecosystem reaches its climax phase (the most sustainable long-term phase characterized by a dynamic equilibrium), the most successful species is that which make the most efficient use of energy. Since the climax phase of a natural ecosystem represents such a sustainable phase, its structure and internal functioning can be used as a model for designing cultivated ecosystems (De Waard, 1994).

The zero-requirement for sustainable land-use systems is that they care for their own energy needs. In other words, they should satisfy their own needs for growth, reproduction and maintenance by drawing energy from the environment. Furthermore, a sustainable system needs to 'create' energy to produce a surplus to its own needs. Sunlight is free and a system that creates 'edible sunlight' above its own needs can be seen as 'creating' energy (De Waard, 1994).

3.6.3 Synergy

> "*The 'creation' of energy in land use systems is at its most charming in the phenomenon of synergy. When two or more elements work together, there is an extra yield of energy, either because input is saved or because extra output is produced. This extra yield, this synergy, is the extra value of the combination of those elements, none of which could have produced that separately. The whole is more than the sum of its constituents.*" (De Waard, 1994, p247).

Synergy is a reality, it is where "*two and two makes five.*" It is the concept that sustainability is about elements working together, about integration as opposed to separation, and about synergy that is the crux of it. Its application potential is vast and the yield is only limited by the designer's creativity (De Waard, 1994, p247).

3.6.4 Network structure

Life systems, especially those in the climax stage are complex networks consisting of diverse, interrelated elements (Capra,1997). The elements all contribute to the whole, according to their specific capacities and qualities. Life systems work together in universal patterns, recognizable on many levels as the expressions of universal ecological principles. With the design of edible landscapes, the permaculturist strives to organize food production in networks of diverse, interacting elements through which energy and matter are allowed to flow, yielding a surplus to the system's own needs. The principle of relative location emphasises that it is not only an element by itself, but also its placement in relation to other elements that are crucial for its performance. If it can establish beneficial relationships with other elements, synergy is created (De Waard, 1994).

3.6.5 Dimensions

For the most part, conventional agriculture utilizes only two dimensions in space and time so that the other dimensions are all under-utilized. Permaculture sees vertical space as a dimension that can also be utilized optimally for production, thereby maximizing light and dimensional resources. The three-dimensional food garden is essentially copied from home gardens in South-East Asia where all seven forest layers occur: big trees in the canopy, smaller trees below the canopy, then shrubs, the herb layer, creepers on the forest floor, roots beneath it, and finally climbers and epiphytes. Such systems can contain an enormous variety of edible species, each occupying its special niche. A step further in the 'complexity' hierarchy of the system can be achieved through providing specific habitats for pest predators (birds) and beneficial insects (bees). The energy requirements for such a system initially are mainly for its establishment, for preparing and planting. After a couple of years, a forest garden is mainly self-fertilizing, self-watering, self-mulching, self-weed-suppressing, self-pollinating, self-healing, as well as being highly resistant to pests (De Waard, 1994, p248).

Although these tropical forests will probably never occur in Namibia due to the water scarcity and climate, the principles of using space in more than two dimensions still apply. This will be elaborated on in chapter 4.

3.6.6 Multifunctionality

The permaculture rule of thumb is that the elements in a landscape have at least three functions which they fulfill within that landscape. The deliberate use of multifunctional elements is a dynamic way to increase the sustainability of cultivated ecosystems and greater interdependence of elements on each other increases resilience, in terms of both ecology and management options. In addition, overhead expenses of purchase, establishment and maintenance are reduced if one element can be multifunctional (De Waard, 1994).

Trees are therefore important elements in the permaculture system: they are able to yield a diversity of products and perform various other functions that support the yield and wellbeing of other elements in the landscape. Some of their beneficial outputs include:

- Material yields, such as timber, wood fuel, fibre, fruit, fodder, mulch material, nectar, medicine and oxygen.
- Wind and frost protection, shading, erosion control and water buffering, dust traps, offering a condensation area, wildlife habitat and support for other plants and beauty to the visual landscape.

Because trees are of a perennial nature they are very energy-efficient elements in the permaculture system (De Waard, 1994). There is thus a strong argument for a renaissance of agroforestry in all areas.

3.6.7 Concept of edge

The edge is the margin or periphery of an entity, in other words the place where different entities meet. The edge is also where the potential for new progressions and diversity is found: "*Edge zones are the cradles of change*". By increasing the edge there is an increase in sustainability (De Waard, 1994, p250).

The ecological synonym for edge is ecotone and an ecotone is for example where water and land meet. This implies diversity and a possible gradient from wet to moist, as well as temporarily wet to dry soils where each area will have its own unique species. *"The combined concept of synergy and edge implies the possibility of structurally increasing the* *number of opportunities for compatible elements to interact."* The maximization of the ecotone in a system is therefore a sound strategy for increasing sustainability, diversity and yield (De Waard, 1994).

3.6.8 Diversity

Diversity is an important concept in the permaculture system: the higher the diversity, the lower the risk factor. However, the requirement of diversity does not refer only to a large number of different elements. A large number of rarely interacting species for example requires more attention than a few that are well tuned. The determining factor, therefore, is the diversity of the relationships between the elements (De Waard, 1994).

3.6.9 Biological resources

The maximization of biological resources used in the design is recommended because these have many advantages. Live elements have unmatched capacities for growth and reproduction, multifunctionality, adaptation and resilience.

In terms of energy, biological resources also have substantial benefits, in that, in their lifetime, the conversion of energy tends to occur through mechanisms of synergy rather than entropy (De Waard, 1994).

3.6.10 Labour inputs

Permaculture is labour-intensive during establishment and harvesting and the work is described as follows:

"rather than the menial and repetitive labour of sowing, ploughing and reaping in a labour intensive annual crop system, work in the permaculture system usually involves observation and control rather than power functions. This is a more or less continuous process - with few times when the loading is heavy or cropping time critical" (De Waard, 1994, p251).

3.7 Conclusion

Permaculture is based on the observation of natural ecosystems and the wisdom of traditional farming strategies as well as modern technology. In permaculture design, the total energy input should be weighed up against the energy output.

Since the climax phase of a natural ecosystem represents such a sustainable phase, its structure and internal functioning can be used as a model for designing a cultivated ecosystem. In this ecosystem, the sunlight is free and a system that creates 'edible sunlight' over and above its own needs can be seen to be 'creating' energy. This creation of energy, this synergy, occurs when two or more elements work together, and there is an extra yield of energy, either because input is saved or because extra output is produced.

The principle of relative location indicates that it is not an element on its own, but its placement relates to other elements that are crucial for its performance. By increasing the edge, there is further sustainability and the higher the diversity, the lower the risk factor. In terms of energy, biological resources also have substantial benefits in that, in their lifetime, the conversion of energy occurs through mechanisms of synergy rather than entropy.

In this chapter the question 'What is permaculture ?' was addressed, whereas the following chapter describes the actual design of a permaculture farm.

CHAPTER 4

PERMACULTURE – IS IT PRACTICAL IN SEMI-ARID AND ARID REGIONS?

Chapter 4 Permaculture – Is it practical in semi-arid and arid regions?

4.1 Introduction

In the previous chapter, the fundamental elements of permaculture were discussed. In this chapter much of the theoretical base is founded on the work of Mollison (1990, 1992). The reader will thus be exposed to the actual practicalities of permaculture so that one does not only consider the teo-philosophy and objectives. The aim of this chapter is to answer the question: "What does permaculture mean in a practical way when it is applied to the Namibian context?"

The following chapters will build on this foundation. Part of the aim of this dissertation is to generate an attitude of hope for subsistence sustainability in Namibia.

In this chapter, a dwelling in a dryland and the placement of vegetation around it will first be discussed. This will be followed by the desert garden and the concept of corridor farming. The creation of beds, irrigation, soil treatment and plant species are also studied (it should be noted that these plants are merely examples and are by no means comprehensive). Garden irrigation systems, dryland settlement strategies, planting themes, and animals are also covered. The chapter ends with a close look at desertification and the salinization of soils.

4.2 The arid and semi-arid house

Permaculture is not only concerned with living elements, it is also about the infrastructure that serves people and their animals as well as the elements that society consumes. Home is a place where a person spends much time, energy, finances and other resources, so that it is important that the home contributes to health and wellbeing and is not a drain on finances or environmental resources. The two fundamental principles in this regard are:

- Reducing inputs into homes,
- Ensuring that outputs can be contained on site, that they are non-polluting and enhance other functions (Morrow, 1994).

Like sub-tropical houses, the desert house (which may be arid or semi-arid) needs the combined qualities of summer cooling and winter (or night) warmth (Mollison, 1992, Kruger, 1993). Many elements of the desert house resemble those of the sub-tropics and cool temperate houses. For example, the older houses of Iran, Afghanistan, and parts of northern India were all designed with climate in mind, thus offering creative ideas to resettlement housing developments in Namibia. These old houses contain features such as:

- Evaporation strategies from water in tunnels, unglazed pots, tanks, fountains, bark mulch, and coke or hessian 'wicks' for water evaporation
- Use of massive walls painted white as cool surfaces
- Small windows; most of the light is indirect from internal courtyards
- Towers, vanes, and airscoops for ventilation
- Cooking done outside under trellis

- Vines on walls, over roof areas, gardens, store-houses
- Water harvesting from roof runoff
- Roof areas for drying fruit, washing and for pigeon lofts (Mollison, 1992; Slay, 1997).

However, some cultures are accustomed to more space and privacy. In this instance, landscaping is of great importance: planting is needed on the sides of houses to protect them from the sun and to serve as insulation.

Housing in the desert must be efficient and the following offer several ways of providing cool air in the daytime:

- Extensive, fully-enclosed vine arbours with mulch floor and trickle-irrigation. Small courtyards can also be fitted into a single-story dwelling. Arbours are required to use about 30% of the total floor area of the house to be effective. Hanging ferns and other houseplants also aid cooling.
- Open tunnels: a ditch 20m long and 1m deep, with large pipes, half round culverts, or evaporative cooling materials to provided airflow.
- Down draughts: wind scoops on the roof, either fixed or self-steering to force air down into the living areas. At outlets in rooms, these down draught inlets can be fitted with damp hessian (burlap), coke evaporation beds or unglazed pots filled with water. This contributes greatly to cooling and humidifying the air inside.
- Induced cross ventilation: this is achieved by fitting a black-painted sheet-metal solar chimney to open from the ceilings or the roof ridges. As the metal heats up, it effectively

draws air into the rooms from any of the above cool air sources (Mollison, 1992; *et al*, 1997).

According to Mollison (1992; *et al*, 1997) all desert housing should be planned with a garden and trellis as these may not only save the energy used for climate control but may also provide food and shelter. Moreover, an attached shade house may be built as an integral part of the house design as it is a suitable summer living and cooking area. In addition, a sun-side glasshouse has at least four potential advantages in Namibia (Mollison, 1990a, 1992):

- To create a winter heat source
- To draw cool air into the house in the summer
- To plant spring seedlings early, to ripen late autumn plants and to grow greens in the winter
- To dry surplus fruit and vegetables in a safe place

"For both heat and cold, massive walls, edge insulated floors, effective draught-proofing, insulated ceilings or roof areas (if necessary trellised or carpeted with thick vines), and efficient cross ventilation are all essential strategies to moderate the extremes of daily and seasonal temperatures that is typical of desert areas. White-painted exterior walls help to reflect excessive heat, and strategic shade trees, palms, vine trellis, ... assist in buffering heat extremes" (Mollison, 1992, p366).

Small solar chimneys (in cross section) or attached greenhouses (Mollison, 1992, Strange, 1983) on the northern side (since Namibia is in the southern hemisphere) of a house can create a strong cross draught. If a fully-enclosed and totally-vined shade-house is built on the southern side of the house, a cool and humid airflow can result provided that the air can penetrate the house directly and some water is available to supply the vines with evaporative cooling. Air could be cooled 10°C to 15 °C below ambient temperature. The same results could be achieved from earth tunnels. (Mollison, 1990a, 1992).

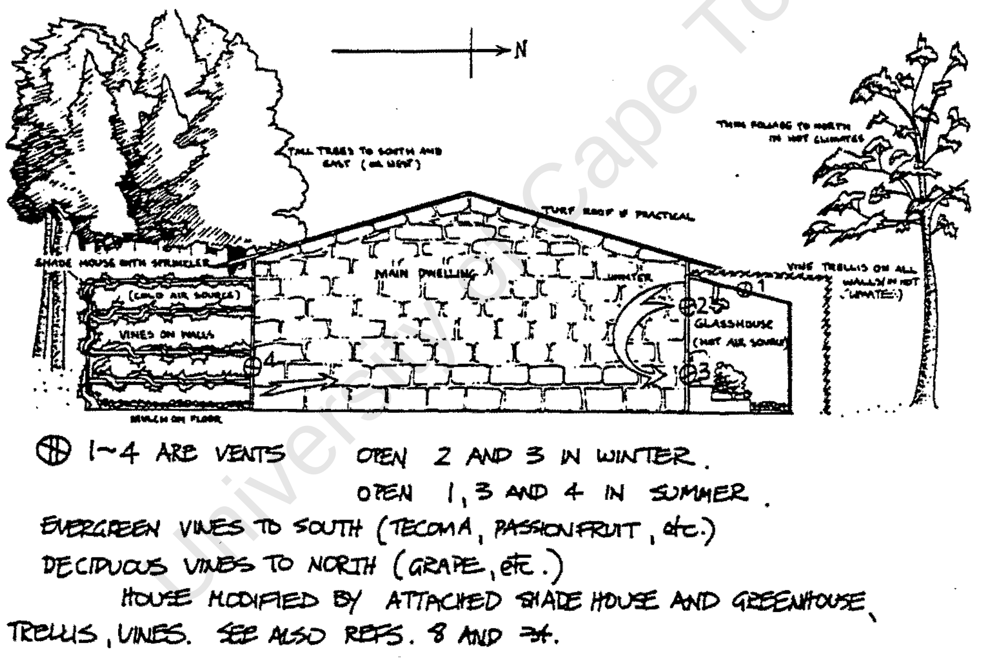


Figure 4.1. House modifications (Mollison, 1990a. p92)

At night or on cold days, it is necessary to close the house and retain the glass-house (Figure 4.1.) heat inside. Such a design saves up to 80% of fuel energy (Fry, 1997). This is of particular importance for low-income groups in Namibia where much energy is spent in collecting fuel. Mollison (1992) stresses that the results of modern houses being constructed without these aids are found in deforestation and the reliance on fossil fuel (and pollution continues). More serious constraints are the financial burden on low-income families, the ill effects of smoky fires, and illness due to cold and fatigue.

4.2.1 Essentials of a desert house

The essentials of a desert house include the following:

- The western wall painted white with no window but shaded by trees and vines.
- A source of cold air.
- Positive hot air exhaust as a solar chimney or small, attached glass-house on the northern side (southern hemisphere).
- Unimpeded through-ventilation for cool air.
- Light, screened or matted walls or very thick, white, fully shaded-walls.
- Insulated ceilings, with thick vine mass over roof area.
- Water harvesting tanks to collect roof runoff water (Pacey *et al,* 1991).

4.2.2 Placement of vegetation around desert dwellings

It is the western sun that heats a house excessively. It is therefore suggested that no windows be placed on the western side of a house. Furthermore, permanent screens of evergreen trees and thick-leafed vines or turf banks should be placed to the west of the house in order to shade or shelter the western wall. The shaded side of the house (southern) is where an enclosed trellis might be built while the eastern side of the house may have small windows and also be shaded by deciduous trees or vines. Glazing is useful on the northern side of the house where up to 25% of the wall surface may be glass. Mollison (1992,1990a) further suggests that houses face north and thus be elongated on the east-west axis so that the winter sun reaches the room floors (heat storage) and, with the correct width of eaves, the summer sun will miss the northern windows and walls. Blinds can also prevent heat entry to the windows on a warm winters' day. Deciduous vines on the northern side of the house may assist as a climate regulator in the summer months.

> Mollison (1992, p368) believes that: *"the emphasis in desert housing should be on developing the arbour for living, and on creating compact and reactive housing mainly for night occupancy and in the rare case of rains."*

In new settlements, the water from washing, toilets and sinks can provide irrigated plantations for all the firewood grown for cooking, provided that it is carefully used in the trickle systems (Mollison, 1992; Morrow, 1993; Nell, 1996; Fry, 1998).It is then stored in non-leaking and covered cisterns.

Low-water use is made possable if washing and hand basin or laundry water is first diverted to the flush tanks of duel flush-toilets, or directly to the garden where flush toilets are not used (Mollison, 1992).

4.3 Desert garden

The following are some of the challenges that need to be overcome in a semi-arid or arid garden in Namibia:

- Water solutes are likely to be factors higher than in humid areas.
- Mineral deficiencies and pH may have a negative influence on health.
- There may be high nitrate levels in water and food.
- Water use is restricted by supply.
- The need to shade plants may be necessary due to restricted water supply.
- Nomadic or wild animals may present problems.

There is generally a low level of resources in Namibia's dryland environment, so that it is unlikely that settlers will be able to afford a fully nutritious lifestyle. Therefore, in order to counteract malnutrition, the home garden can become the primary alleviator. Also unlike cereals and grain legumes, garden leaf, fruit and root products require little cooking and this saves energy. Such a garden encourages family self-reliance as far as food is concerned. Since health in arid areas is directly food-related, the arid garden should be wisely planned with serious commitment.

A careful soil and water analysis is essential. It is possible that phosphorus and zinc, as well as iron and manganese deficiencies, will occur in arid and semi-arid environments. Rain runoff water should therefore be carefully used to flush the soil of the garden if the local water exceeds 800ppm salts. Excess boron from detergents can be a cause of plant failure so that it is preferable for basic soaps to be used where wastewater is used for the garden.

A careful plant sequence for beds to be continually self-shaded by almost constant crop is highly beneficial. It is also advisable to call on the expertise of the local agriculture department. Deep-rooting and high-yielding perennials (asparagus, globe artichoke) are a good standby crop, as are drought-resistant staples such as sweet potato, most cucurbits and the melon family.

A garden in dry areas will function optimally with some staple trees, which are adapted to the periodic droughts that occur in Namibia, and the following are suggested: date palms, olive, doum palm, citrus, avocados, and some vines. It would be an added advantage if the house could be situated near a run-off area, so that water could be harvested in dams and swales (Pacey, *et al*, 1986).

All wastewater can be used in the garden and can be distributed via underground plastic-lined swales or used in soakage fields (Bell, 1994; Nel, 1996; Mollison *et al*, 1997; Morrow, 1994). Most of the vegetables that grow well in tropical and temperate areas will also succeed in Namibia, if these can be planted in small beds (about 3m x 1m) which should be flooded every three to ten days. They should also be mulched and part-shaded by slats, vines or the canopy of a light-crowned leguminous tree.

Wallflowers, marigolds and gladioli are beneficial to *Brassicas, Solanum spp.*, and onions respectively. The beds should be planned for succession to fava beans and peas (both in the cool seasons) and tepary and moth beans (in the warm season). Although yam beans, jicama, sweet potato and sunroot are more reliable yields, even potatoes will grow in boxes (0.5 – 1 meter deep) filled with mulch and organic household scraps.

Celery, onion, *Brassica*, carrot, beet, spinach, globe artichoke and tomato, as well as sweet and chilli pepper can all be planted in arid regions with considerable success and the surplus can be dried. Watermelon, melons and climbing or vine cucurbits all grow well in arid climates. The walls and roofs of homes and other buildings should be seen as a potential vine trellis.

> "*.....the desert garden should also be a corridor plantation down nearby river beds, niche gardens in shaded sites, patch gardens on leach fields, and a spread of very hardy adapted yams, bulbs, and semi-wild fruits, cactus, and palm wherever a site exists or can be made"* (Mollison, 1990. p371).

4.3.1 Corridor farming

Sand-filled waterways usually contain some moisture (Hartley, 1997) and these form corridors of soil and moisture that can be utilised for food production. *"At times, the corridors are rivers* (beds), *dune series on hostile salted or stony pavement, or the floodplains of exotic rivers*" (Mollison, 1990. p371). Corridor farming is very different from normal mono-crop farming: it is necessary to choose and place a complex combination of indigenous (especially endemic plants) and introduced species in order to produce the basic food reserve, fuel and structural timber. It may also be an opportunity for allowing for a good rainy season to broadcast sow into areas, which have already been prepared . Sunflower, millet, sorghum, panicgrass and melons could all grow well in these conditions.

4.4 Matching up earth bed, irrigation, soil treatment and plant species

Gardens offer such an advantage to man that it is worth spending time on their design: intensive bed-by-bed planning is necessary so that companion plants, seasonal succession , bed-soil treatment, and a permanent watering system all play a role.

Where plastic pipes are absent or too costly, adequate replacements can be made such as:

- Unglazed pots.
- Gravel beds.
- Hand-moulded concrete channels on or below the surface, covered with tiles or other flat material.
- Pipes of bamboo, drilled to allow the water to drip.
- Bottles suspended and with their corks perforated to leak.
- Even a bucket may also be used although this might be more laborious.

It should be borne in mind that "*planning a garden repays itself quickly, and a good gardener expects to amortise establishment costs (fences, beds, seed, mulches, micronutrients) in 6-8 months, thereafter gaining a profit in health food and cash*".

The essentials of a desert garden are:

- Small raised, flooded beds, thickly mulched.
- Permanent hardy trees on leach fields or in swales.
- Semi-wild, very hardy bulbs, tubers and yams in selected sites.
- All waste and rain runoff water directed to the garden and leach fields.
- Vines grown on and over any possible trellis, wall, structure and roofs.
- An endless supply of mulch.

4.4.1 Fencing

In many dry land areas, the problem of wild, feral or domestic browsing and grazing animals pose a major threat to home gardens. It is, however,

> " *much cheaper to fence out these devastating and ever hungry animals from settlements and gardens than it is to airlift emergency food aid to starving people, or to withstand the social cost of poverty and famine*" (Mollison, 1990, p377).

4.4.2 Desert mulches

The value of organic material is, as in nature, extremely important (Bell, 1993) and there are many different sources:

- Detritus brought down in floods (which can be trapped with strong mulch fences).
- Tumbleweeds and wisps of plants blown by the wind.
- Mulch grown in the gardens.
- Plants such as *Casuarinas*, reeds, tamarisk , some *Acacias* (there is a need to investigate which plants will be suitable for each specific area) as well as legumes for

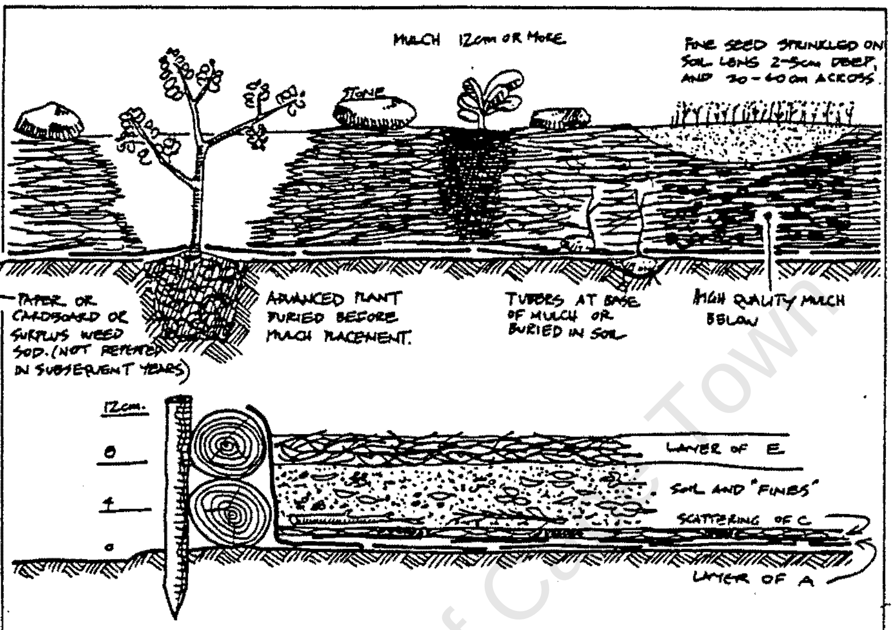
nitrogen fixing (Vandermeer 1989; Rowland 1993; Fry), desert vine and hedge trimmings.

- Household and storage waste.
- Manure from grazers.

Where stones are readily available, they can make a permanent mulch around trees. Stones are beneficial to trees in the following ways:

- By providing shade from intense day heat.
- By releasing stored heat to the soil at night.
- By preventing poultry and small animal damage to roots.
- By preventing wind lifting roots.
- By providing shelter for small soil organisms.
- By letting the water condense on the rocks on particularly cool nights (Mollison, 1990a).

Mulching (Figure 4.2.) also reduces evaporation of the soil moisture, prevents erosion and fertilises the soil. Experiments in Niger showed that, in using the pearl millet's residue as a mulch for the following year's crop, the yield increased by a factor 13. If fertiliser alone was used the yield increase was a factor 14, while both mulching and fertilising increased the crop by a factor of 27 (Rowland, 1993). However, it is interesting to note that if a choice was to be made between fertiliser and mulch, mulch would be preferable for the long term. While fertilisers only work for one season and then need to be bought again in the next season, the benefits of mulching last much longer since not all of the mulch would have been converted to soil yet in the course of one season. Moreover, mulch improves the soil structure and eventually the texture, and this also enhances the water-holding capacity.



MULCHED GARDEN BEDS.
Very thick (18–20 cm) mulch conserves water, produces good humus soils; methods of planting trees, seedlings, fine seeds, tubers are shown. 'Instant' gardens are made this way in drylands: all stages are watered as completed. Mulch is built up as in B.

Figure 4.2. Mulching (Mollison, 1990, p379)

Leaching is delayed and to some extent prevented by mulching the soil. Again, in mulch, there are free-living nitrogen-fixing organisms that supply the plants with nutrients at a steady rate. The greatest losses in tropical dry lands are in the bare soil agriculture where nitrogen, calcium and potassium are leached. Whenever dark green manure, humus or mulches are used, dolomite should be added, as nitrates prevent copper and manganese mobility if no calcium or manganese is provided.

Drought stress in gardens can be greatly alleviated if the plants have mycorrhiza which are root fungi that scavenge for nutrients and can mobilise phosphorus even at low-water levels. In return the fungi receive a habitat and some glucose from the host plant.

Almost without exception, all the vegetables that grow in the humid areas of similar temperatures will also grow in Namibia if they are irrigated. Since space is seldom a problem in Namibia, up to 30% of the area allocated to gardening can be planted with windbreakers such as *Casuarina*. The garden will also benefit from leaves that can be used for mulching material.

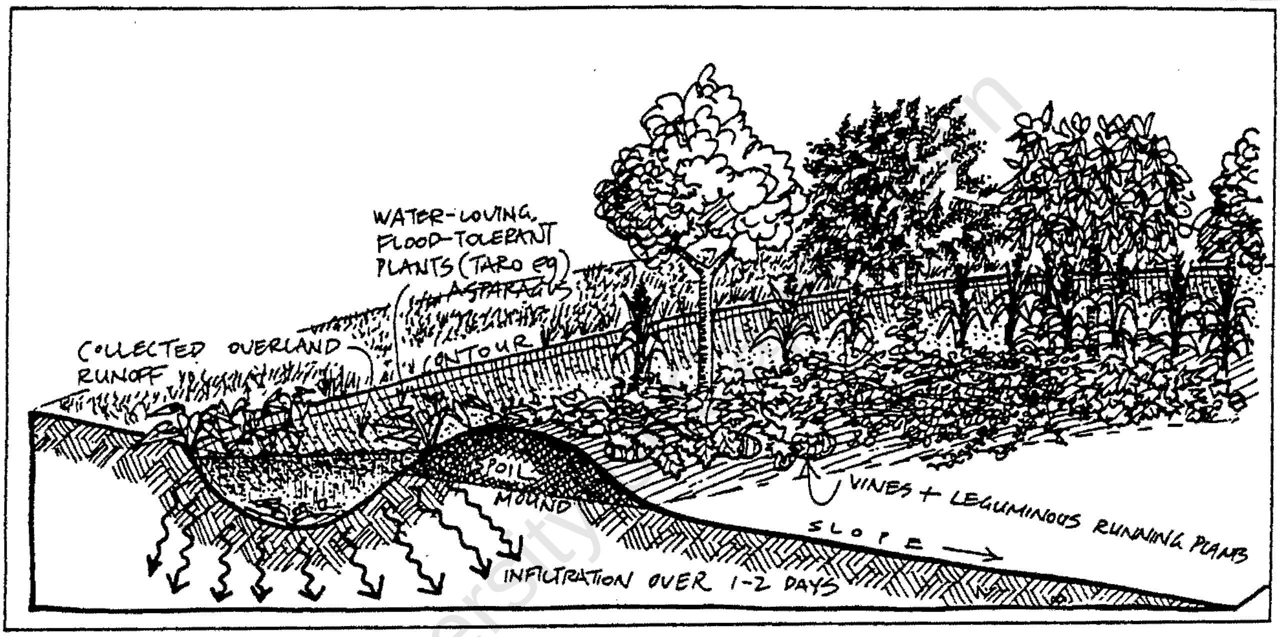
4.4.3 Irrigation systems

There are many irrigation systems on the market, some DIYs and others that are extremely sophisticated with computerised 21st century technology. However, it is not the aim of this thesis to elaborate on the many systems that are available commercially. It is rather suggested that more simple irrigation systems be presented that might be more suitable for the person on a resettlement farm in Namibia.

Subsurface irrigation systems

Underground drip and seep irrigation systems are the most conservative method of irrigation. Drip irrigation is most successful for arid environments because of the limitation of evaporation. When wastewater is used, for the sake of health and infiltration, it is advisable to keep the irrigation system underground. Swales are the best example of cheap subsurface water development:

"Swales are long, level excavations, which can vary greatly in width and treatment from small ridges in gardens, rock-piles thrown across slope, or deliberately excavated hollows in flat lands and low-slope landscapes. .... swales are built on contour or dead level survey lines, as they are not intended to allow water to flow" (Mollison *et al*, 1997, p56)



Swales on contour do not flow; they first stop and then absorb overland water flow. Swales are planted with trees or shrubs on the mound side.

Figure 4.3. Swales. (Mollison et al, 1997, p56)

There are many special irrigation techniques that have been used with success. These are illustrated on the following pages:

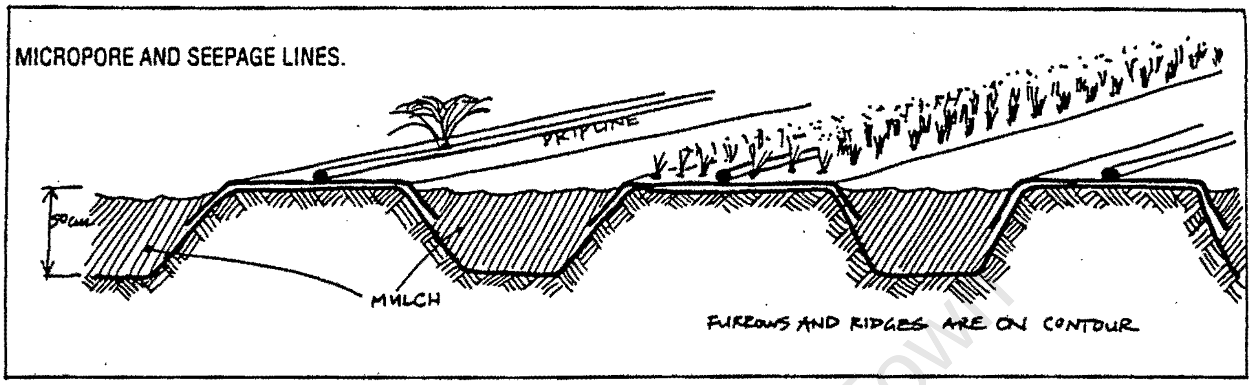


Figure 4.4. Seepage lines (Mollison, 1990, p380)

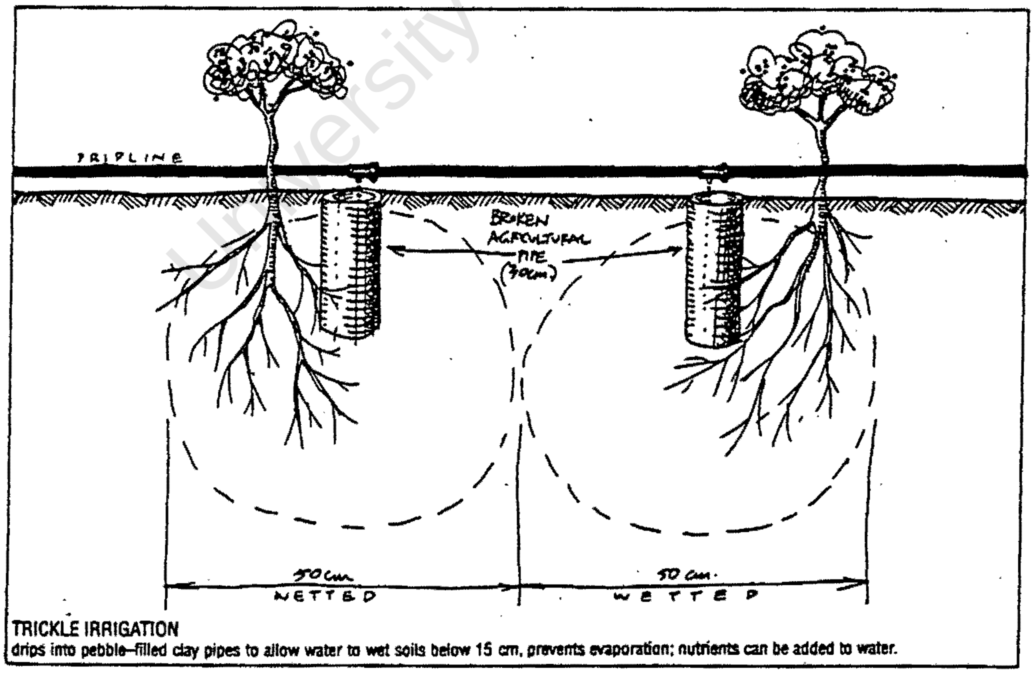
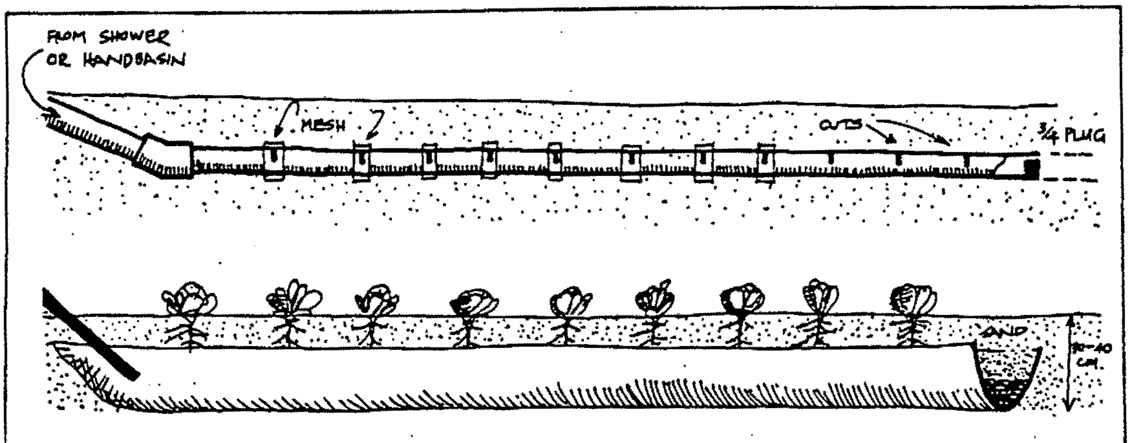
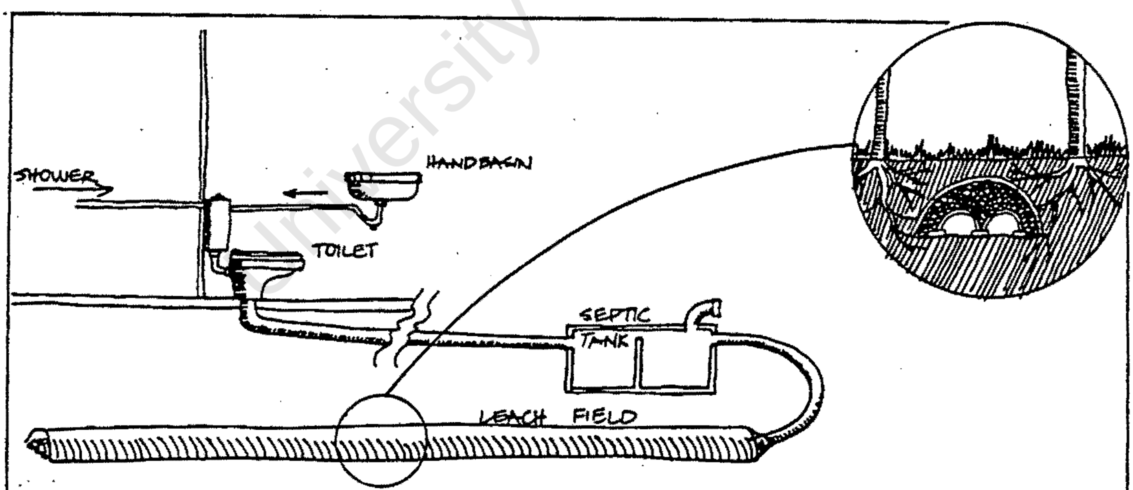


Figure 4.5. Trickle irrigation plus pot or pipe. (Mollison, 1990, p381)



DOMESTIC WASTE WATER CHANNELS.
A level pipe, half cut through at 40 cm intervals and with screens at cuts allows greywater to seep out at root level of vegetables; a plastic-lined trench can help in deep sands. Rigid polythene pipe is good for this method of greywater disposal.

Figure 4.6. Domestic waste water channels. (Mollison, 1990, p382)



ARBOR SYSTEM.
Half-pipes of 20–30 cm diameter, crosswalls at 1.25 m. spacings each 4 cm high enables tree planting beside leach drains with no root clogging of pipes. System is manufactured in South Australia.

Figure 4.7. Arbour system (Mollison, 1990, p382)

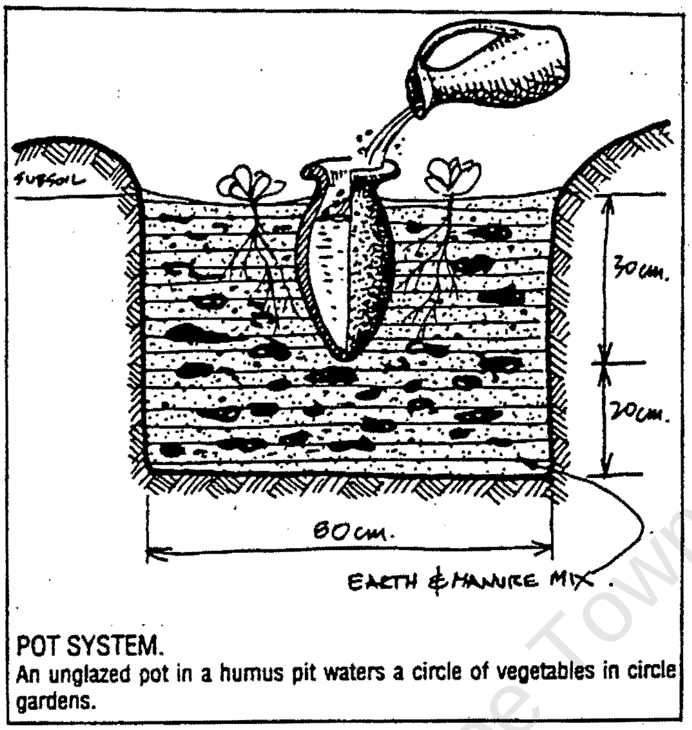


Figure 4.8. Pot system (Mollison, 1990, p383)

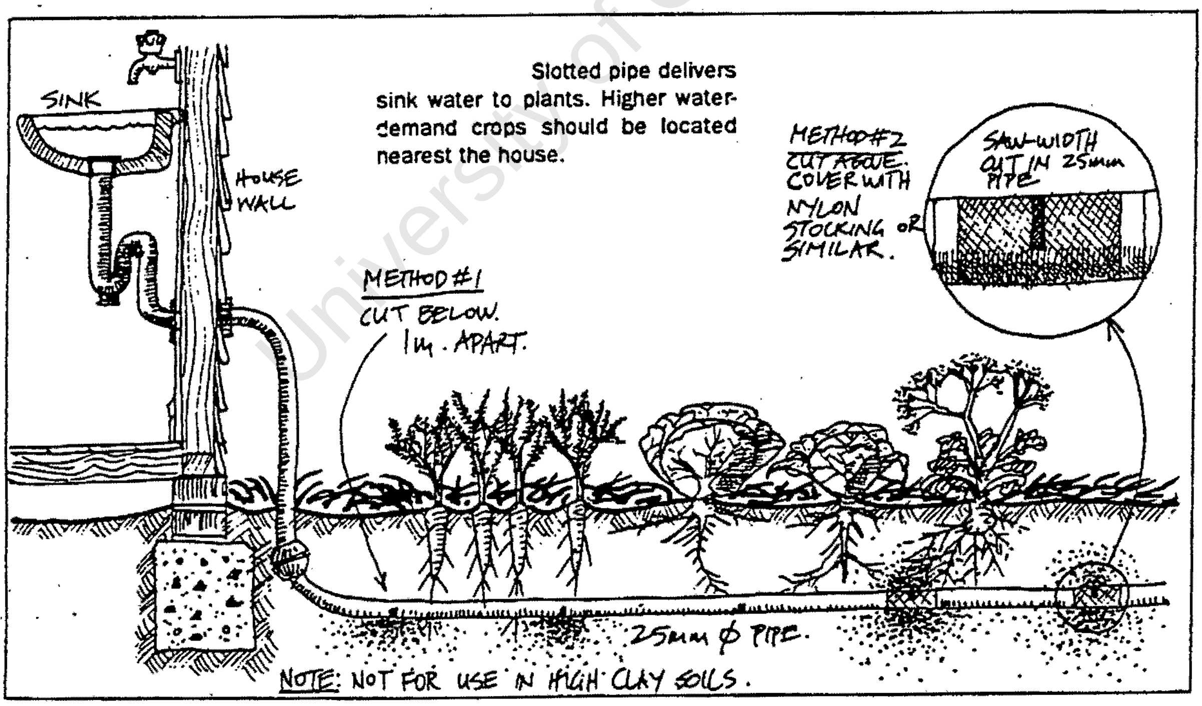
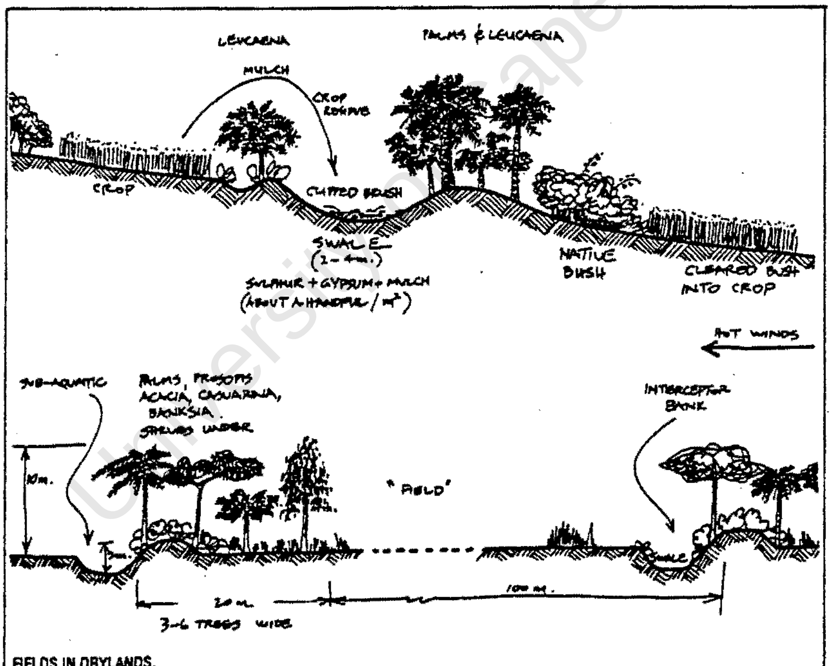


Figure 4.9. Home slot-pipe method (Mollison *et al*, 1997, p119)

4.5. Dry-land settlement strategies

4.5.1 Vegetation in settlements

Lawns in settlements should be minimised as they are an expensive luxury. There are, however, some drought-resistant grasses like *Lippia*. There are also hardy trees that can survive years of near drought. Moreover, normal fruit trees can be grown in swales and/or along roads with water-harvesting infrastructure. Trees provide fuel, mulch, medicines and supplement domestic animal forage, as well as forming the basic shelter from which the rest of the garden can be protected from wind and excessive water loss (Vandermeer, 1989).



FIELDS IN DRYLANDS.
Need windbreak every 30–60 m, and scattered in crop; swales assist tree survival, and trees decrease 'clothesline' effect of winds; leaves manure fields and swales.

Figure 4.10. Windbreaks. (Mollison, 1990, p388)

The arid regions are hostile, particularly in terms of the effect of advection and evaporation. The advection effect is when a hot dry wind blows and causes vegetation desolation. It is suggested that a tree buffer consisting of a ring of trees about 50m – 100m deep be planted to shelter the gardens. In large fields and gardens, little can be done about evaporation of water through the process of evapo-transpiration in plants and normal evaporation of moisture from the soil and open waterbodies. In smaller gardens, however, protection can be provided in the form of trellises and shade trees like *Prosopis*.

Fuel plantations are essential in permaculture settlements. The fuel forest should be carefully designed and positioned to optimise particularly on wastewater drip irrigation. Hardy trees that can survive on natural rainfall, once established, need to be selected. It is suggested that a matrix of perpetual long-term forests no more than 300m apart, and no less than 8 trees wide, be established. "*In the sheltered spaces so developed, a grid of close spaced trees (2-3 meters) on trickle irrigation pipes....which are harvested in a 4-6 year rotation as coppice*" (Mollison, 1990, p388). Where no sewage or wastewater is available, swales that are 4m - 8m wide and the banks between them 3m - 5m wide are a part of a network of runoff water.

4.6 Plant themes for arid areas

4.6.1 Tree establishment in drylands

Certain important issues should be mentioned regarding dryland tree establishment:

- It is advisable to plant in cool weather and to ensure that the soil is not excessively hot (a soil temperature in excess of 30°C will kill shallow roots).
- Pits around the tree and its roots should be filled with mulch. Alternatively the root area can be stone-mulched (Figure 4.11.).

- The trees should be planted in a long swale or in sloping pits in order to collect moisture (Nel, 1996).
- Gourds, legumes, and ground covers should be planted around the tree so as to keep the roots cool (Vandermeer,1989).
- The tree should be watered for about the first two years until it can shade its own roots.
- The stems should be painted white in order to protect the tree from sunburn until the bark has thickened.
- To enhance each seedling survival, it should be protected from the heat by shade created with dead branches or palm leaves.

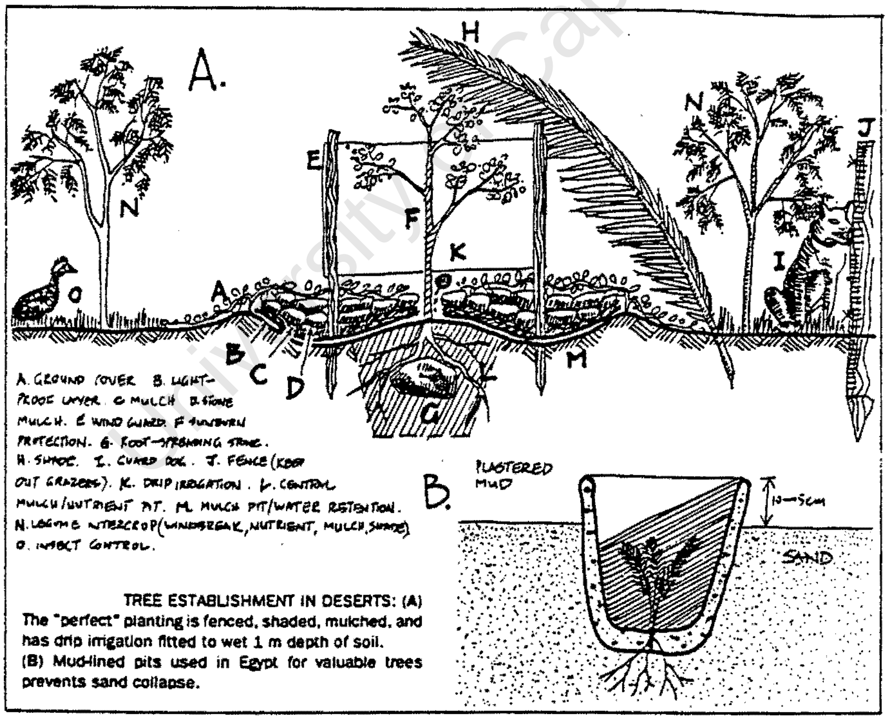


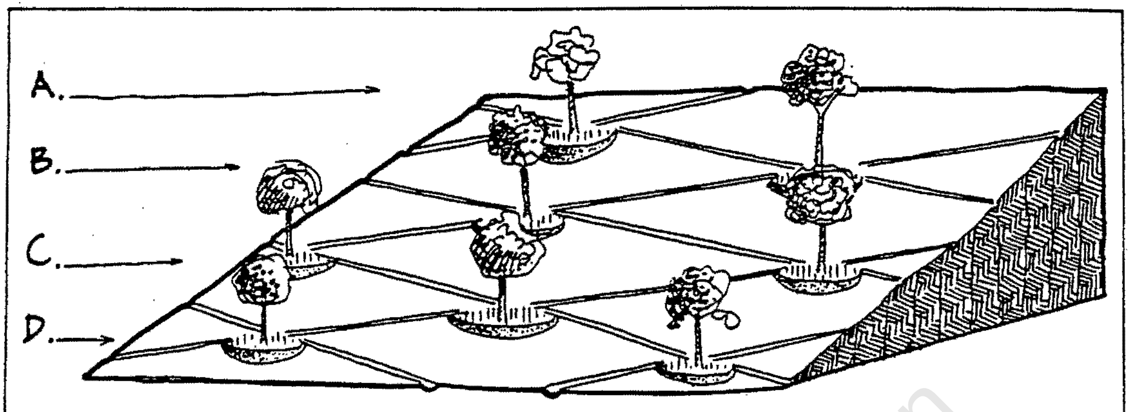
Figure 4.11. Stone mulch (Mollison, 1997, p131)

- Young plantations need to be protected against herbivores.
- Hardy tree legumes can be planted as an inter-crop and they provide shelter from sun and wind also serving as fertiliser and mulch (Vandermeer,1989).

Clay soils that have deep cracks may, with contraction and expansion, break the roots of trees. The roots are left hanging in the air, and the tree eventually dies. A solution to this problem is to put sand into the cracks and plant the trees in these cracks at a time when rain is expected, or after the site is completely drenched with water.

4.6.2 Planting trees in hard soils, and on slopes

To establish vegetation on steep slopes and hard soils, two systems are proposed: the 'net and pan' and the 'boomerang pattern'. Both utilise sheet runoff from the slopes, as well as absorbing flow from active runnels. In the net and pan system (Figure 4.12 and 4.13), the runnels cut across the slope at an angle of about 1:500 (exaggerated in the diagram).
On a more irregular slope small runnels can be blocked to act as silt traps and in due course a small delta of detritus builds up in which a hardy tree can be planted (Figure 4.14). Where larger rills flow, 'boomerangs' can be used to absorb and disperse some of the flow (Figure 4.15).



NET AND PAN (Plan).
Stony hillsides suit "net and pan" tree planting; hardier trees are planted in up–slope skeletal soils, less hardy trees on lower slopes.

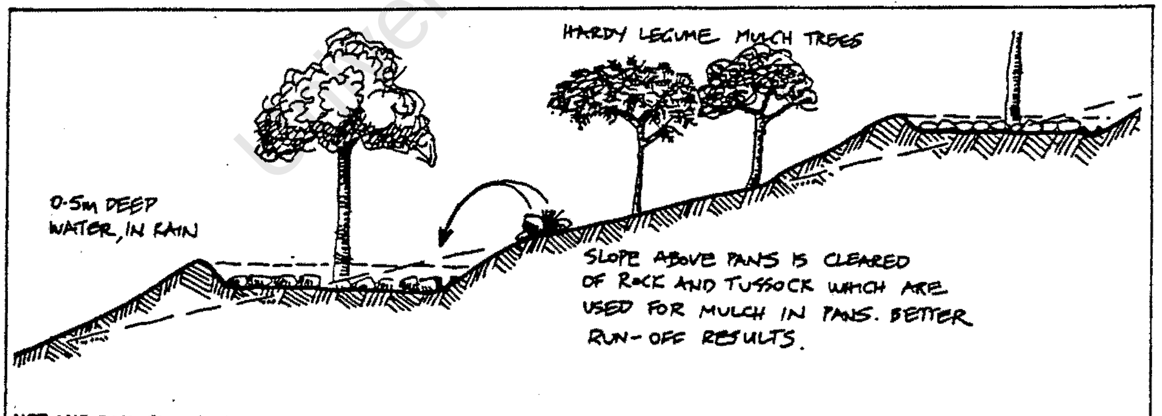
A. Crest trees: hardy needle–leaf species and narrow–leaf trees to suit thin soils, e.g. stone pine, olive, *Casuarina*, *Callitris*, *Acacia*, quandong.

B. Hardy trees with known drought resistance, e.g. fig, pomegranate, *Acacia*.

C–D. Midslope and deeper soils suited to citrus, fig, *Acacia*, pistachio.

E–F. Deep base soils with some humus suited to chestnut, mulberry, raintree, citrus.

Figure 4.12. Net and Pan – Plan (Mollison, 1990, p393)



NET AND PAN (Elevation).

Figure 4.13. Net and Pan - Elevation (Mollison, 1990, p393)

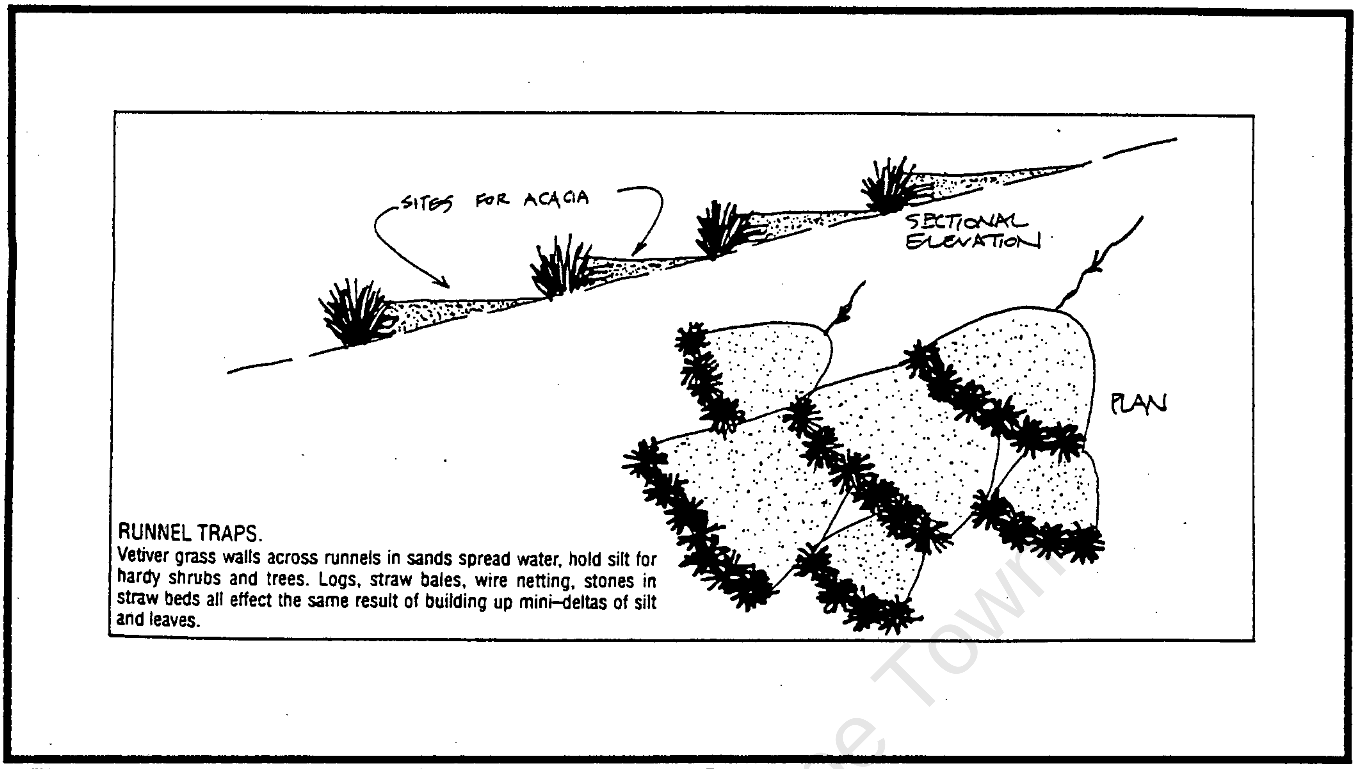


Figure 4.14. Runnel traps. (Mollison, 1990, p395)

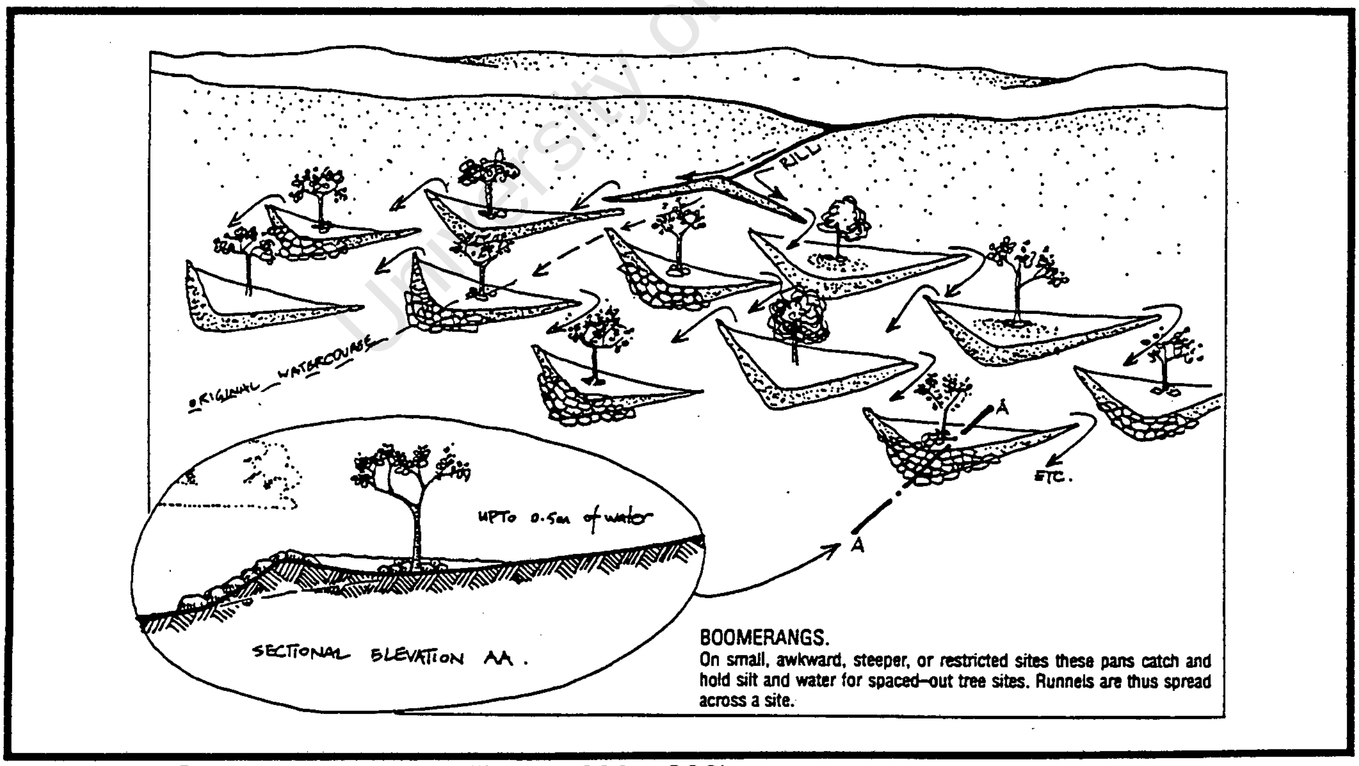


Figure 4.15. Boomerangs. (Mollison, 1990, p396)

4.7 Animals in drylands

Animals, feral or domestic, can ravage the arid and semi-arid environment if not correctly managed and controlled. However, sheep, cattle, donkeys, camels and goats can all thrive in these regions especially if they are herded in about 15 rotated runs, allowing between two and eight years for each run to recover and re-seed. Some Australian sheep farmers allow seven to nine years rest per run and consequently their animals seldom suffer from stress in times of drought (Mollison, 1990, p397)

> "*It is infinitely preferable to run small high value herds on copious range than to risk the inevitable collapse of range and flocks by stressing the vegetation*" (Mollison, 1990, p397).

Another animal resource that can be managed is wildlife, and it is necessary to distinguish between resident and migratory species. Invasive and nomadic species move with the rainfall in order to survive. These nomadic animals should be considered when the livestock carrying capacity of an area is to be determined. It should also be borne in mind that different animals complement one another in the utilisation of environmental resources. For example, cattle graze on tall grasses leaving the shorter grasses for sheep and goats to graze. Grazing at different levels is also found with wildlife.

Some woody and ephemeral plants in arid and semi-arid regions concentrate certain toxic elements in their new growth in the rainy season. Some of these toxic elements are: nitrates, oxalic acids, cyanides, sodium fluro-acetate and poisonous alkaloids which may cause infertility, liver destruction, spasm and eventually death in both domestic and wild browsers. This new growth protection mechanism lasts for about four to six weeks during which time animals need to be intensively managed. On the other hand, mature leaves are for the most part not toxic. Animals in arid and semi-arid areas should be handled with caution since sudden shock or running may cause death. Fire and firewood gathering in hot drylands may also cause such poisonous metabolites in a wide range of woody and ephemeral plants.

4.8 Desertification and the salting of soils

According to Rowland (1993, p38), desertification can be defined as

> *"the extension of desert conditions into formerly more productive areas, or the degradation of dryland environments to less productive states."*

Mollison (1990) refers to Le Huerou (1968) in proposing the following causes of desertification, independently of any long-term cyclical climatic change:

- **Overgrazing**: Overgrazing increased because extra boreholes were drilled. This in turn meant that there was more water and thus more stock could be maintained well into drought times. Previously the amount of livestock was determined by the ecological carrying capacity. Now, however, it was determined by the amount of water. It is also found that the overgrazing occurred close to the borehole sites (Rowland, 1989. University of Cape Town, 1997).

- **Use of wood for fuel**: Timbers used for fuel were not replaced and seasonal fires also devastated the veldt.
- **Use of wood for timber**: Many trees were cut down to fence and build the infrastructure of farms.
- **Settling of nomads**: Some of those who were formerly nomads have settled around wells and boreholes rather than following the rain. This amongst others resulted in over grazing.
- **Cropping**: Often desertification is caused by planting crops in areas where the rainfall is not sufficient. Due to overgrasing the livestock cannot continue to support the people who and therefore attempt to plant food.
- **Extension of clearing natural veldt**: Due to low-crop production the lands are left fallow. The soil becomes compacted and erosion results. More veldt is then cleared in search of more fertile ground (Tisdell, 1991).
- **Excessive water use**: Modern technology has enabled humans to dig deeper wells and to drill boreholes. This process dries up the upper aquifers and the excessive use of local water leads to the salination of surface soils.
- **Surface water depletion**: Drylands become desolate when surface water dries up due to the removal of ground water.

Mollison (1990) contributes more causes to the list:

- **Effect of wind**: The drying effect of wind and the erosion and sandblasting effects on soil and plant can be devastating.

- **Soil degradation**: "*Soil collapse due to deflocculation of clays; hollows and pans develop soil salting due to the above and to the development of hard pans in the B horizon*" (Mollison, 1990, p401).
- **Water problems**: Due to deforestation and agricultural compaction of soils, there is an increase in overland water flow. This causes gullying and salt transport to lower soils and there is also a rise in salt water tables due to deforestation.
- **Saltation of wetlands**: Clay-fraction soils that are commonly found in wetlands are often salted due to the use of water with a high mineral and salt content and because of over-irrigation.

4.8.1 Caution in design of agricultural systems

Given the many possible interactions between salts, evaporation, soils, slope, drainage and land use, designers should exercise caution in designing new agricultural systems. Mollison (1990) encapsulates the approach for dryland systems as follows:

- To experiment with as great a variety of small systems as possible on very limited areas, soil types and slopes.
- Then to monitor infiltration, evaporation, salinity changes and crop health over the next few years.
- Gradually to increase the systems that do not show any salt increase.

- Not to store runoff water where tree roots cannot remove the water. The tree crowns should not shade the water unless if it is subsurface storage in sand basins or sand dams[1].
- To lessen infiltration by flood-water diversion to streams and floodways where ground-water tables are shallow.
- To increase tree cover by increasing local infiltration in swales (where soils are free draining).
- To use ridge trickle irrigation in dry periods in gardens and, where possible, let flood water and rain runoff flush out furrows of accumulated salts.
- "*To favour roof tanks and surface swales rather than wells and bores* (boreholes), *which lower total aquifer resources and create local excesses*" (Mollison, 1990, p408).
- To use 'back-hoe' or 'deep-pit' samples to establish the conditions of drainage locally, and then to proceed with strategies that are based on local conditions (diversion, interception, swale infiltration and crop type).
- To assess potential yields before embarking on any of the above because it is easier to manage a yield than to create one. It is also preferable to manage and increase natural yields than to impose an exotic crop or animal species on a fragile environment.
- To observe every situation where yields are naturally high because these conditions may indicate a safe and tested way of increasing yields with the lowest risk (for example, large trees fringing a dry river bed).

[1] A sand storage dam is a dam which "impounds water in sediments caused to accumulate by the dam itself" (Hartley, 1997).

- To bear in mind constantly that the aim is to establish a garden ecosystem in a climax, stable and equilibrium stage.

4.9 Designers' checklist

The following is a checklist for the design of a permaculture garden in dry areas.

4.9.1 Broad Strategies

- Start operations for fresh water infiltration at the top of the catchments, and progress downstream as plants establish.
- First attend to upwind areas for soil pitting and windbreak trees.
- Start plant nucleii at special sites and follow outward with corridor planting.

4.9.2 Garden and food supply

- Establish mulched and shaded gardens.
- Establish successful species along corridors, wadis, water runnels, foothills, niches in rocks, seepages, shaded areas.
- Establish water-harvesting swales that support trees and other plants.

4.9.3 Water supply

- Supply drinking water from rain-water collection from the roofs of buildings.
- Establish gardens and firewood plantation through swales and drip irrigation.
- Establish both windbreak and water harvest for field crops at a ratio of 20 ha run-off to 1 ha sown fields.

- Build safe dams near settlements, preferably in shaded valleys or offstream diverted to drop silt.
- Make use of sand dams and gabion-stabilised terraces.
- Do not waste water, but recycle, reduce and re-use as far as possible.
- Place septic tanks far away from boreholes.
- Do not exhaust boreholes and wells. Test water for salts, radio-actives, nitrates, fluorine, and biological contamination.
- Plant trees to keep salt levels down, where water is infiltrated into the soil.

4.9.4 Health

- Reduce dust with soil pitting and trees to avoid sinus and other respiratory problems.
- Test water where people swim for water-borne diseases.
- Supply main nutritious foods from garden produce.
- Test water, soil, plants and blood for essential mineral levels, especially zinc and iron.
- Rely on locally-produced carbohydrates rather than imports.

4.10 Conclusion

In the dryland house inputs should be reduced and resources re-used and recycled. Vegetation can play a vital role in the sustainability and comfort of dryland dwellings. The dryland garden is an oasis, supporting people and animals in a hostile environment. It can also be a completely nutritious food source that enables the farmer to become independent, and even to make a profit.

Home gardens are often such a huge benefit to humans that it is worth designing them appropriately: intensive bed-by-bed planning is necessary in which companion plants, seasonal succession, soil treatments and a permanent watering method all play an important part. The section on irrigation showed that it can be both inexpensive and effective. Trees that are endemic or indigenous and well adapted to local environments should be used as often as possible.

While trees form the backbone of the dryland settlement, animal contribution is considerable although they need a rotational grazing system and to be kept away from the gardens. Lastly, desertification and saltation of soils can have a devastating effect so that they should be prevented.

In the following chapter permaculture will be accessed to ascertain whether it is sustainable or not in the broader context. This is necessary so that the degree of sustainability can be established before it is applied to the resettlement farms as an alternative method of farming.

CHAPTER 5

TESTING PERMACULTURE AGAINST SUSTAINABLE CONSTRUCTION PRINCIPLES

Chapter 5 Testing permaculture to sustainable construction principles

5.1 Introduction

This chapter aims to determine whether permaculture is actually sustainable as a development concept. This is necessary so that the degree of sustainability can be determined before it is applied to the resettlement farm as a sustainable alternative farming method. It will be weighed up against certain criteria which were developed by Hill and Bowen (1997) (Appendix 1). Since permaculture is concerned with constructing a sustainable ecosystem, it is possible to apply these criteria. The focus in this chapter will therefore be on testing permaculture against the principles of sustainable construction in order to determine whether it is sustainable.

5.2 'Sustainable construction' concept

The term 'sustainable construction' is used to describe the construction industry's responsibility for sustainability and it is seen to be "*creating a healthy built environment using resource-efficient, ecologically-based principles*" (Hill *et al*, 1997, p225). The IUCN describes a sustainable activity as one that can continue infinitely, and stresses that the construction industry cannot attain this specific criterion. Sustainable construction can also include a 'cradle to grave' appraisal, "*which includes managing the serviceability of a building during its life time and eventual deconstruction and recycling of resources to reduce the waste stream usually associated with demolition*" (Hill *et al*, 1997, p226).

The concept of sustainable construction has four criteria, each with a set of principles.

- The first criterion is the *social* component of sustainable construction, which is based on the concept of equity or social justice. It is proposed, however, that poverty reduction be generated from opportunity redistribution and from sharing the focus on development.

- With *economically* sustainable construction, some depletion of non-renewable resources is inevitable when development is undertaken. It should be borne in mind that sustainability is concerned with the substitution of natural for human-made capital.

- Biophysical criteria require improvement in the quality of human life within the carrying capacity of the supporting ecosystem.

- Technical criteria focus on concepts such as performance and the quality and service life of a construction.

5.3 Principles of sustainable construction

It should be emphasised that it is not always possible to conform maximally to these principles and trade-offs and compromises should be negotiated. Values will constantly need to be assessed and it is suggested that these assessments be made by interested and affected parties in the construction project. In complying with each principle, the question should be posed: "*In what way can this principle be practically and most effectively applied in this situation*?" (Hill et al, 1997, p227). In a permaculture context, however, there is another question: "How does permaculture apply these principles in a practical and effective way?" (for a summary of the analysis below, refer to Table 5.1 below).

5.3.1 Testing the social principles

(i) Principle

To improve the quality of human life, including the alleviation of poverty.

Permaculture Response

Permaculture is intensely involved with alleviating poverty and improving the quality of human life through the creation of sustainable structures and gardens. Permaculture provides food, accommodation, education, shelter and, to some extent, health and clothing (basic human needs) in a sustainable way. It is therefore an excellent method of self-sustaining poverty alleviation since the emphasis is on self-reliance and long-term sustainability. The gardens provide food to sustain the family and maintain its members in a healthy manner.

(ii) Principle

To provide for social self-determination and cultural diversity in development planning.

Permaculture Response

Permaculture is an intergenerational, interracial, and intercultural concept concerned with a way of maintaining life now and in the future. It can, thus, accommodate any individual, the only pre requisite being a desire to maintain self (and family). It also promotes social self-determination by allowing each person to garden or farm in his or her own way – the principles are general and the specifics worked out by each person as he/she are seeks self-reliance with nature. A permaculture development is compatible with local institutions because it seeks long-term sustainability and will therefore conform as far as possible with local standards and constraints. With regard to technological compatibility, permaculture remains a simple concept, is based on local knowledge of nature and ecosystems, and its technology itself is so basic that it should not pose a problem even at grass-roots level.

(iii) Principle

To protect and promote human health through a safe working environment.

Permaculture response

Since permaculture focuses on human wellbeing, it promotes healthy food production. As far as the work environment is concerned, the individual will spend a considerable amount of time outside working with farming equipment, and will need to comply with the safety instructions of each implement.

(iv) Principle

To implement skills training and enhance the capacity of disadvantaged people.

Permaculture Response

In permaculture, training skills and capacity building are of paramount importance. It also favours disadvantaged communities since one of its aims is to enable people to be sustainably self-reliant. It is believed that training will ensure that the development of human resources is a lasting legacy of permacultural construction, in addition to the physical presence of facilities and infrastructure.

(v) Principle

To seek fair and equitable distribution of the social costs of construction.

Permaculture Response

There are no public social costs in permaculture as it is the individual who develops his/her own property.

(vi) Principle

To ensure equitable distribution of the social benefits of construction.

Permaculture Response

Permaculture focuses on the individual family's self-reliance on food and fuel, and does not involve the broader public in construction and maintenance. However, when there is a surplus which is sold, the public does benefit from the development. Indirectly, the permacultural development does benefits greater society in that it:

- Provides a pleasing site of shade and greenery
- Helps to trap air pollution in the leaves of the plants
- Makes the permaculturist self-reliant with regards to nutrition.

(vii) Principle

To seek intergenerational equity.

Permaculture response

Permaculture will reach intergenerational equity through the avoidance of excessive resource consumption and also by not overriding the capacity of the environment to absorb wastes. Thus permaculture, being a long-term investment and in seeking sustainability, will provide intergenerational equity.

5.3.2 Testing the economic principles

(i) Principle

To ensure financial affordability for intended beneficiaries.

Permaculture response

Permaculture advocates the utilisation of what is there and tries to propagate simple technologies involving minimal cost.

(ii) Principle

To promote the creation of employment and, in some situations, labour-intensive construction.

Permaculture response

Permaculture is an excellent concept as it provides employment for every person with a small plot of land. In the development and implementation phase, it is particularly labour-intensive but in due course the workload becomes merely harvesting and maintenance. This is not a problem since permaculture produces food, leaving the owner free to be employed elsewhere, without running the risk of being without food.

(iii) Principle

To use full cost accounting and real cost pricing to set prices and tariffs.

Permaculture response

Although not specifically mentioned in the literature review, the researcher believes that this principle is in harmony with the aims of permaculture.

(iv) Principle

To enhance competitiveness in the market place by adopting policies and practices that advance sustainability.

Permaculture response

Permaculture has the capacity to produce a surplus which can then be marketed. It will automatically create competition with other owners selling their surplus and both come from sustainable development.

(v) Principle

To choose environmentally-responsible suppliers and contractors.

Permaculture response

This principle will probably be propagated during permaculture training but in the end depends on the individual's opinion and right to choose

(vi) Principle

To invest certain proceeds from the use of non-renewable resources in social and human made capital, in order to maintain the capacity to meet the needs of future generations.

Permaculture response

Although not specifically mentioned in some permaculture literature, this principle also enhances intergenerational sustainability.

5.3.3 Testing the biophysical principles

At this juncture, the reader is reminded that permaculture is also tested against the biophysical criteria of sustainable construction in order to ascertain to what degree permaculture is sustainable before it is applied to the resettlement farms as a sustainable farming method.

(i) Principle

To extract fossil fuels and minerals, and to produce substances foreign to nature at rates which are not faster than their slow redeposit in the earth's crust.

Permaculture response

Permaculture does not aim to produce substances foreign to nature. It is a way of life in which the vegetative and animal domain of nature predominates. However, the permaculturist will use certain implements and perhaps a tractor, and in this way he/she does not comply with this principle.

It is impossible to comply with this principle because there is no longer a point of no return. It remains for people to work on technologies that will replace the fossil fuels and minerals.

(ii) Principle

To reduce the use of four generic resources used in construction, namely: energy, water, materials and land.

Permaculture response

In permaculture, energy is saved by the use of mulches or green manure's rather than fertilisers. However, although it promotes sustainability (for example, solar and wind energy), it is almost impossible to be 100% sustainable. Water use is reduced by the use of mulches and water harvesting techniques. Permaculturists also strive to reduce waste and recycle and re-use all materials, and are proactive in planting forests for fuel and timber. Moreover, they endeavour to use only the minimum amount of land necessary and to leave the rest to nature.

(iii) Principle

To maximise re-use and/or recycling of resources.

Permaculture response

Permaculture agrees entirely with this statement in that it re-uses or recycles resources which results in reduction in wastes and conservation in resource.

(iv) Principle

To use renewable as opposed to non-renewable resources.

Permaculture response

According to Hill *et al* (1997), this principle can be applied to both energy and materials. For energy, it is suggested that passive thermal design, day-lighting, solar heating and photovoltaics be utilised. With regard to materials, for example wood, only trees produced from a sustainable forest would be used and not the so-called 'old growth' timber if other timber is available. Permaculture respects and agree with this principle and strives to attain it.

(v) Principle

To minimise air, land and water pollution, at global and local levels.

Permaculture response

Permaculture agrees entirely with this statement since it focuses is on sustainability. Permaculture would not attain long-term sustainability if it also polluted the environment. Therefore it encourages recycling, re-use and reduction in the quantity of materials being used.

(vi) Principle

To create a healthy non-toxic environment.

Permaculture response

Permaculture agrees fully with this statement, proposing that natural and environment-friendly herbicides and pesticides be used rather than chemicals. The author believes that it is possible to:

"*create a healthy, non-toxic environment through the elimination or careful and managed use of hazardous and toxic products in the indoor and exterior built environment*" (Hill, *et al*, 1997, p 230).

(vii) Principle

To maintain and restore the earth's vitality and ecological diversity.

Permaculture response

This principle is exactly what permaculture aims to do in that diversity is essential for every permaculture project, mainly because it makes the created ecosystem robust. In addition through permaculture, the earth's vitality could be restored and optimised. It also preserves the natural ecosystems because it promotes the biological banks essential for our survival.

(viii) Principle

To minimise damage to sensitive landscapes, whether scenic, cultural, historical or architectural.

Permaculture response

Although not being explicit, permaculture also aims for the conservation of both artefacts and nature and therefore strives to attain this principle.

5.3.4 Testing the technical principles

(i) Principle

To build durable, reliable and functional structures.

Permaculture response

Permaculture agrees to build durable, reliable and functional structures, because, in striving to attain sustainability, buildings and infrastructure need to have these qualities.

(ii) Principle

To pursue quality in developing the environment.

Permaculture response

Permaculture agrees entirely with this statement striving to create an environmental-friendly built environment that is based on ecologically sustainable principles.

(iii) Principle

To use serviceability to promote sustainable construction.

Permaculture response

To the author's knowledge, permaculturists have not considered this concept in the literature. However, it is likely that they would agree with it since the service life of infrastructure needs to be determined in order to plan for maximum and optimum infrastructure life.

(iv) Principle

To humanise larger buildings.

Permaculture response

Permaculture agrees entirely with this statement since it strives to contextuallise and humanise the environment. However, this principle does not apply in the rural context of resettlement farms.

(v) Principle

Infill and revitalise existing urban infrastructure, focusing on rebuilding mixed-use pedestrian neighbourhoods.

Permaculture response

This principle does not apply in the rural context of resettlement farms.

Table 5.1

Principle	Yes	NO	Debatable	Not applicable
Social sustainability				
Improve the quality of life, including alleviation of poverty	✔			
Make provision for social self-determination and cultural diversity in development planning	✔			
Protect and promote human health through a healthy and safe working-environment	✔			
Implement skills training and enhance capacity of disadvantaged people	✔			
Seek fair and equitable distribution of social costs of construction			✔	
Seek equitable distribution of the social benefits of construction		✔		
Seek intergenerational equity				
Economic sustainability				
Ensure financial affordability of intended beneficiaries	✔			
Promote employment creation and in some situations labour-intensive construction	✔			
Use full cost accounting and real cost pricing to set prices and tariffs	✔			
Enhance competitiveness in the market place by adopting policies and practices that advance sustainability	✔			

Principle	**Yes**	**NO**	**Debatable**	**Not applicable**
Choose environment responsible suppliers and contractors			✔	
Invest some of the proceeds from the use of non-renewable resources in social and human-made capital to maintain the capacity to meet the needs of future generations.	✔			
Biophysical sustainability				
Extract fossil fuels and minerals, and produce persistent substances foreign to nature at rates not faster than their slow redeposit into the earth's crust.			✔	
Reduce the use of the four generic resources used in construction: namely, energy, water, land and materials	✔			
Maximise resource re-use and or recycling	✔			
Use renewable rather than non-renewable resources	✔			
Minimise land air and water pollution at local and global levels	✔			
Create a healthy non-toxic environment	✔			
Maintain and restore the earth's vitality and ecological diversity	✔			
Minimise damage to sensitive landscapes, whether scenic, cultural, historical, or architectural	✔			
Technical sustainability				
Construct durable, reliable, and functional structures	✔			
Pursue quality in creating the built environment	✔			

Principle	**Yes**	**NO**	**Debatable**	**Not applicable**
Use serviceability to promote sustainable construction				✔
Humanise large buildings	✔			
Infill and revitalise existing urban infrastructure focusing on rebuilding mixed-use pedestrian neighbourhoods				✔
Total	**19**	**1**	**3**	**2**

5.4 Conclusion

This chapter introduced the concept of sustainable construction with its four criteria: namely, social, economical, biophysical and technical criteria. Each of these has principles of sustainable construction which were used to analyse permaculture in order to ascertain whether it is sustainable. Of the 25 principles, 19 were 'yes' indicating that permaculture complied with those principles. There was one 'no', three 'debatable' and two 'non-applicable' principles. This result shows that permaculture complied 76% with the sustainability principles, and when the 'non-applicable' principles were discarded permaculture complied 82,6%, which suggests that permaculture is sustainable.

In the next chapter the permacultural theory will be applied to the Namibian resettlement farms in order to ascertain how these farms can be made more sustainable.

CHAPTER 6

SUSTAINABILITY, PERMACULTURE AND THE NAMIBIAN RESETTLEMENT FARMS

Chapter 6 Sustainability, permaculture and the Namibian resettlement farms

6.1 Introduction

In this chapter, the resettlement farms are analysed according to the economic, social, biophysical and technical principles described in the previous chapter (see also Appendix 1) and this analysis leads to the permaculture response as to how the specific principle may be applied to the resettlement farm.

6.2 Applying the social principles of sustainable construction and permaculture to the resettlement farms

(i) Principle

To improve the quality of human life, including the alleviation of poverty.

Resettlement farm

One of the aims of resettlement is to improve the quality of life by ensuring the secure and adequate consumption of basic needs, which include food, shelter, health and education, as well as comfort, identity and choice. However, these needs are currently provided for by the government so that the settler's choice is restricted by a government representative in Windhoek.

Permaculture Response

If the settlers could become self-sustaining, it would be a saving for the government and this would also enhance the settlers' choice, identity and comfort. Permanent agriculture would seem to be a worthwhile alternative to government subsidies, but it is important to plan and design in collaboration with the community, without a top-down approach. Planning should also be integrated and holistic as this would result in a more sustainable solution.

Permaculture addresses the basic needs of the Namibian settlers by focusing on food and shelter and, when these are met, it will enable the settler to attain the other basic human needs (health, clothing, education).

(ii) Principle

To make provision for social self-determination and cultural diversity in development planning.

Resettlement farm

On some farms (Tsintsibus, Skoonheid), people of different ethnic backgrounds were incorporated into the same settlement, which resulted in tension and stressers. Furthermore, the government has often used a top-down approach which inhibited social self-determination and provided for cultural diversity in development planning. It is the author's opinion that every human has a fundamental right to a free choice of association and self-determination.

Permaculture Response

Permaculture literature is not clear on these issues. However, permaculture is intergenerational, interracial, and intercultural. It promotes self-determination since the choices are mere suggestions and the permaculturist him/herself will determine the outcome of the applied principles on the resettlement farms.

(iii) Principle

To protect and promote human health through a healthy and safe working environment.

Resettlement farm

It is believed that the intention of the Namibian government is to promote human health through a healthy and safe working environment. This is also clearly expressed by the government's active provision of primary-health care at each of the five farms. However, it is worth investigating whether the people using machinery such as a tractor have received proper training in order to prevent accidents.

Permaculture response

Permaculture literature is not clear about this principle, although the author believes fundamentalists would agree with it. Permaculture also strives to promote health through the production of nutritious food for both humans and animals.

(iv) Principle

To implement skills training and capacity enhancement of disadvantaged people.

Resettlement farm

The Namibian government promotes and encourages training and capacity enhancement. Knitting, sewing, brick-making and masonry are some of the skills that settlers have received. The agricultural extension officers also promote and assist with agricultural capacity enhancement and training.

Permaculture Response

The author believes that permaculture training can enhance the existing knowledge of the settlers. Permaculture has inherent in its philosophy the concept of continued training and capacity building. It also aims to create self-reliance in a sustainable manner and is thus a good starting point for the alleviation of poverty. Moreover, implementing permaculture will apply skills training and capacity enhancement for each settler, in turn ensuring that human resource development takes place in each resettlement farm project.

(v) Principle

To seek fair and equitable distribution of the social costs of construction.

Resettlement farm

A grant of N$20 million per year for five years, starting in 1995, has been allocated for the buying of farms for resettlement in Namibia. Meanwhile, the cost of establishing a settler on a farm is approximately N$200 000 which excludes the provision of health services, infrastructure, food distribution and education (UCT, 1998).

Although the original farm owners are fairly compensated for the sale of their farms, the public taxpayer is paying for the high cost of the resettlement program. It should therefore be considered whether it is fair and equitable for certain of the poor, who are fortunate to settle on a farm, to receive the equivalent of +N$ 200 000 from the government while others receive nothing. Moreover, the long-term sustainability of these hand-outs should be questioned. Arguably the government might produce more employment opportunities by using the N$20 million each year and investing it in the creation of work through establishing industries and urban resettlement projects.

Permaculture Response

Social costs, such as pollution from some farming implements and animals, are minimal and are not long-term risks. Apart from these and perhaps a few of other impacts, permaculture does not present major social costs since it is using renewable resources in a sustainable manner. Permaculture will also free the taxpayer from paying for food distribution in the 'food for work' programme since it can produce nearly all the nutrition requirements.

(vi) Principle

To seek equitable distribution of the social benefits of construction.

Resettlement farm

The aim is for the settlers to be self-sustaining in five years and this would be of social benefit since the settlement would not need to be supported as heavily after the first five years. However, this social benefit should be weighed up against the social costs already discussed. The author believes that these costs far outweigh the social benefits and that, seen in totality, the current resettlement programme is risky financially.

Permaculture Response

The social benefits of permaculture are that any person can establish a permaculture garden and, if the garden produces a surplus and the owner decides to share it with the wider community, then it also benefits that community. It is also a sustainable way of alleviating poverty which results in a social benefit.

(vii) Principle

To seek intergenerational equity.

Resettlement farms.

At present, in a worst possible case scenario, the biophysical costs of constructing a resettlement area would be overgrazing, depletion of natural resources such as trees for fuel, excessive use of boreholes and bush encroachment. The next generation would inherit desolation, no finance, and little social means to uplift themselves.

Permaculture response

In the future, in a best possible, case scenario, only small plots have been utilised as cropping areas, with the rest of the farms managed in a sustainable

Permaculture response

Permaculture propagates the use of simple technologies with low-cost practicality. For instance, permaculture proposes that the farmer use mulch instead of commonly used hi-tech fertilisers. Also, the irrigation systems suggested for arid countries like Namibia use gravity as a water propellant rather than hi-tech pump-driven irrigation systems.

(ii) Principle

To promote the creation of employment and, in some situations, labour-intensive construction.

Resettlement farm

This is one of the major aims of the Namibian government in the resettlement schemes, and in some respects it has been successful. On some farms (for example, Tsintsibus), the settlers made their bricks and built their own houses. However, farming provides the main employment and this activity is a part of the food-for-work program. This program works with varying degrees of success: when the five farms were visited, the impression gained was that it was not successful and that some settlers did not work although they still received food. This can be attributed to various factors and reasons which are not directly relevant to the current discussion.

Permaculture response

Permaculture is an excellent concept as it provides employment for every person with a small plot of land. In the development and implementation phase, it is particularly labour-intensive but in due course the workload consists merely of harvesting and maintenance. This is not a problem since permaculture produces food, leaving the owner free to be employed elsewhere.

(iii) Principle

To use full cost accounting and real cost pricing to set prices and tariffs for goods and services that fully reflect social and biophysical costs.

Resettlement farm

The Namibian government does not apply this principle since politics determines the money that is spent on resettlement and not real-cost pricing. Moreover this principle is not applied since it is usually the extremely poor who are being resettled and they cannot afford the capital and running costs of such a project. However, the long-term sustainability of this way of resettlement needs to be assessed and considered, especially with factors like overgrazing, bush encroachment, deforestation and slow aquifer recharge.

Permaculture response

Although not specifically mentioned in permaculture literature, the author believes that full-cost accounting and real-cost pricing is in harmony with the aims of permaculture.

(iv) Principle

To enhance competitiveness in the market place by adopting policies and practices that advance sustainability.

Resettlement farm

Some settlers commented that, in some seasons, they produce enough vegetables to sell on the local market and thereby compete with other producers. However, the type of mono-crop farming, in some instances using fertilisers, is not a sustainable long-term farming method and permaculture is proposed as an alternative.

Permaculture response

Although it is not the intent of permaculture to produce a surplus, this occurs frequently and the surplus can then be sold on competitive markets. The important point is that it is produced in a sustainable manner that will enable future generations to continue producing a surplus.

(v) Principle

To choose environmentally-responsible suppliers and contractors.

Resettlement farm

As far as can be ascertained, it is not known whether the Namibian government applies this principle.

Permaculture response

This principle is in harmony with permaculture but ultimately each person needs to choose for him/herself. In other words the settlers and agricultural extension officers will decide which supplier they choose according to their own conciseness and education. Education is therefore of the utmost importance.

(vi) Principle

To invest some of the proceeds from the use of non-renewable resources in social and human-made capital to maintain the capacity to meet the needs of future generations.

Resettlement farm

The author is not aware of any proceeds from the use of non-renewable resources that have been reinvested in capacity enhancement and building on any of the five farms he visited. Although the children, and in some cases the adults, do receive education, it is not the result of their subsidy but rather that of the government.

Permaculture response

Permaculture supports this principle since it is a fundamental principle that the permaculturist is continually learning, for example, how to manage the created ecosystem. However, the settlers are generally poor and cannot afford this idea. Although it would be beneficial if a small amount could be deposited each month from each household, which could later be invested in society. In the beginning of the process, this need not be a huge investment but can be so small as to buy the agricultural extension officers a small gift to show appreciation for the work they do. It is the concept of meeting the needs of the future generation by investing in social and human capital that needs to be understood and achieved.

6.4 Testing the biophysical principles of sustainable construction with regard to permaculture

(i) Principle

To extract fossil fuels and minerals, and produce persistent substances foreign to nature at rates not faster than their slow redeposit in the earth's crust.

Resettlement farms

The resettlement farms do not mine minerals directly or extract fossil fuels or produce substances foreign to nature, although, indirectly, they do so through the use of implements such as tractors. Therefore, although it is on a very limited scale, it does not comply with this principle. Moreover, crops use soil nutrients which, in most cases, are not replenished by mulching. There were some comments that in Tsintsibus they had not yet received fertilisers, but it is not a sustainable way of replenishing soil fertility and does not improve soil texture and structure.

Permaculture response

It is *".....suggested that the implementation of these two conditions requires answers to the following question: In what way can your organisation systematically decrease its dependence on these substances?"* (Hill *et al.* 1997.

p229). Using animals rather than of first-world implements would in part follow this principle. It should be stated that the use of domesticated animals for farming purposes should not be looked down on but should be considered rationally. For example, it is not possible for the settlers to buy or even maintain a tractor on their respective current incomes. In any event, since the areas that need implements are so small, it does not justify such a purchase. In other words, it is a question of 'economy of scale'.

Furthermore it is suggested that mulches, as already described, be used and made integral to farming strategies. In certain instances, fertiliser might be used to initiate the green mulching process but this should then be minimised as it is not a sustainable farming method.

(ii) Principle

To reduce the use of four generic resources used in construction: namely, energy, water, materials and land.

Resettlement farms

- Energy for households is mainly firewood as there is no electricity on most of the farms. The settlers complained (UCT, 1998) that they had to walk increasing distances to collect firewood so that they were using more and more energy to generate energy (fire). Moreover, the amount of wood is diminishing, which means that the settlers may deplete their energy resources in the future.

- Water is central to any settlement in Namibia. At Excelsior farm, the water table is high and is thus easily accessed with boreholes. Furthermore, each settlement is developed around a borehole. However, the sustainability of these boreholes has not been determined throughout and some have been utilised regardless. In addition, since settlements are around boreholes, the areas around them are overgrazed and denuded.

- The main construction materials in resettlement schemes are for the building of houses: bricks, steel, corrugated iron, cement, water and sand. Of these, the steel, corrugated iron and cement have to be imported to the site. Timber is also used for fencing and making kraals.

- Land is vital to the resettlement program but, in some instances, the garden plots are far from the settlements. Most of the farms were under-utilised for grazing and it seems that bush encroachment is a common phenomenon. Not all the farms were assessed before being purchased for resettlement and this resulted in the purchase of some marginal land.

Permaculture response

- Settlers need to create a fuel forest bank. This should be a continuous process – as the trees grow tall and are chopped down for firewood, new trees should be planted. The fuel forest should also be closer to the settlers homes so that walking and collecting time is reduced. This would enable the women to have more time for self-actualisation.

- Since water is vital to the settlements, it should be treated with care and wisdom. The first step towards saving water is to apply water-harvesting techniques which would also alleviate the sole dependence on the borehole. Boreholes could deplete the upper aquifers of all their water which would have a devastating effect on the flora and fauna of the area, regardless of human life.

- The materials that need to be imported to construct the houses make building unsustainable. The existing houses are too hot during the day and too cold (cement floor) at night, and there are no sanitation facilities or running water or a kitchen. Mud and timber structures with a thatched roof, which are suited for Namibia's climate, would almost certainly be better. These are thermally suitable, can be erected anywhere and are biodegradable and environment-friendly especially if they are constructed from self-grown timber. Furthermore, not all the houses faced north. As suggested, these structures need to be well designed and thought through and the planting of vines, trees and embankments can all contribute towards counteracting the climatical problems (see chapter 4).

- Farms need to be assessed and their sustainability determined before purchase. The houses and garden plots should be close together so that as little energy as possible is wasted. Bush encroachment is an expensive problem, and clearing it, whether manually or chemically, is extremely costly. Fortunately, most of the settlers are not dependent on grazing for animals. The bush can, however, be used for mulching especially if some of the younger bush is shredded.

Bricks, corrugated steel and tractors (plus implements) are non-renewable resources, which are in demand on the resettlement farms. However, some of the farms (for example, Skoonheid and Tsintsibus) make use of solar-powered borehole pumps for some of their water needs.

Permaculture response

Water harvesting is suggested as well as the monitoring of all boreholes. Bricks can be replaced with mud and straw, or mud and timber and the corrugated iron sheets can be successfully replaced by thatch. These solutions should not be regarded as degrading or as housing for the disadvantaged, since there are whole cities with multiple-storey buildings constructed out of mud and timber (International Centre for Earth Construction – School of Architecture, Grenoble, France). Moreover, soil as a building material, especially in Africa's extreme climatic conditions, is optimally applicable. The tractor can be replaced by oxen or donkeys which are more economical and sustainable for the low-intensity agriculture of the resettlement farms.

(v) Principle

To minimise air, land and water pollution, at global and local levels.

Resettlement farm

The resettlement farms are most efficient as far as air pollution is concerned. Only the tractor, diesel engines for water and electricity, fires for cooking, and animals (methane) pollute the air, and on such a small scale the pollution that is being propagated has minimal impact locally and globally. However, if the settlers make a fire inside the house for warmth or cooking, then the smoke may become lethal. Fortunately this is not common practice.

None of the farms visited was situated close to a river, so that there is minimal surface-water pollution. However, there were some farms where the pit toilets were close to a borehole (Drimiopsis). This could become a problem, since a shallow aquifer might be polluted by the sewage effluent.

Land pollution is mostly limited to litter on the settlements, but on account of unsatisfactory ablution facilities, the surrounding veldt of some settlements is strewn with human excrement. Dust pollution is also a problem due to construction as well as settlers' activities and overgrazing, especially close to settlements and boreholes.

Permaculture response

The air pollution caused by resettlement settlements is so localised that it should not become a problem in Namibia. However, it is suggested that solar-powered borehole pumps replace the diesel engines as and when they no longer function or when they fall into disrepair. Solar pumps not only save energy; they also do not pollute the environment.

In addition, the animals' methane production is not a cause for concern since there are few animals on a huge surface area (the average carrying capacity is 30-15Ha/live stock unit).

substances should be discarded carefully so as not to pollute the air, soil or ground water, and even plastics and glass should be discarded in a responsible way. Pesticides can be made from many common plants and are equally as effective as chemical pesticides, as well as being biodegradable and environment-friendly.

(vii) Principle

To maintain and restore the earth's vitality and ecological diversity.

Resettlement Farm

Aquifers are being used with no knowledge of their carrying capacity. Currently, essential soil nutrients are not being recycled and soil creation and regeneration are not being achieved. Due to overgrazing, firewood, "veldkos" gathering and hunting, some ecosystems are not renewing themselves or conserving the biodiversity of plants and animals. While the range of genetic stock within each species is not protected, rare and endangered species are, on the other hand, protected but it is difficult to enforce the law.

Permaculture response

Permaculturists emphasise the use of runoff rain water and the re-use of domestic waste water and minimal dependence on underground water. Swales and other water-harvesting techniques are also proposed, whereas soil creation, regeneration, and nutrient recycling can be achieved through mulching. 'Veldt kos' and firewood collection, overgrazing and excessive-hunting are the result of overriding the carrying capacity of the farms and are also a management problem. 'Veldt kos' collection can, however, be alleviated by the establishment of a permaculture garden. Wood for fuel and timber should be produced on the farms by establishing plantations, but overgrazing remains a management problem. The amount of livestock needs to be limited according to the carrying capacity of each farm, and this should be investigated urgently since the farms will be rendered useless as a result of desertification and bush encroachment. The farms also need to be managed with a well-planned rotational system for livestock so that the veldt has time to recover. Once the gardens are established, pigs, poultry and other animals can be used to replace the need to hunt and gather 'veldt kos'. This, in turn, would help the ecosystem to renew itself and to conserve biodiversity of both fauna and flora. In this way, the range of genetic stock will be protected to some extent.

These issues, as well as the need to protect endangered and threatened species, should be communicated to the settlers so that the rationale behind the action is understood. It is hoped that, through education, the attitude towards particular environmental resources will be one of conservation and intergenerational sustainability.

(viii) Principle

To minimise damage to sensitive landscapes, including scenic, cultural, historical and architectural.

Resettlement farm

The author is not aware of any sensitive sites that have been damaged or protected on the five farms he visited.

Permaculture response

In permaculture, sensitive sites are preserved, and development only continues as far as is necessary for self-sustenance.

6.5. Applying the technical principles of sustainable construction and permaculture to the resettlement farms

(i) Principle

To construct durable, reliable and functional structures.

Resettlement farm

The main activity is the construction of houses which are durable and reliable structures. However, their functionality is questionable since they are not suitable for the hot days and cold nights of Namibia, and ablution and cooking facilities are inadequate. Many of the prefabricated houses are not subdivided into smaller rooms and some houses do not face north.

Permaculture response

Houses need insulation although trees and vines can be grown to assist the insulation in altering the thermo-dynamics of the resettlement houses. The houses also need to face north and to have the appropriate roof overhang to protect the dwelling from the summer sun. Small windows should be placed on the east side of the house. A pergola covered by a vine would significantly improve the living conditions of the settlers, if planned for as a part of the resettlement house. This could then serve as a cooking area as well as outdoor living space.

(ii) Principle

To pursue quality in creating the built environment.

Resettlement farm

During the research early in 1998, it was found that the settlers are usually grateful for their new homes on the resettlement farms, which are mostly well kept and looked after even though they do not fulfil all their needs. However, the following questions may be asked. What will the situation and emotion about the houses and settlements be after 20, 30 or 50 years? Will these dwellings last for centuries? Are they adaptable for other uses? Although the answers to these questions at this stage are merely speculative, they should nevertheless be considered when striving for quality in creating the built environment.

Permaculture response

As explained in chapter three, permaculture, as the name suggests, is the design of permanent agricultural settlements and its aim is to develop an integrated, self-sustainable and long-term ecosystem. Integrated into this ecosystem are the structures (house, outbuildings and infrastructure) that form a complete system of

6.6 Conclusion

In this chapter the resettlement farms have been analysed according to the principles of sustainable construction and possible permaculture responses have been offered as to how the resettlement farming community may wish to alter their existing farming methods in order to reach sustainability and self-sufficiency.

CHAPTER 7

CONCLUSION

7 Conclusion

7.1 Background

This dissertation has looked at permaculture as an alternative farming method for commercial resettlement farms in Namibia. To understand and place permaculture in a broader context, religion, philosophy and ethics as well as its fundamental principles have been discussed. Some practicalities were then studied and the degree of permacultures sustainability was determined. This was necessary since the over arching aim of the dissertation is to encourage and motivate the achievement of sustainability on the resettlement farms and permaculture had first to be analysed to determine whether it is sustainable before being applied to the resettlement farms. Permaculture was applied to the resettlement farms within a framework of sustainable constructions criteria and their principles. Following are a number of recommendations.

7.2 Recommendations

Permaculture, as the name suggests, is the design of permanent agricultural settlements and its aim is to develop an integrated self-sustaining and long-term ecosystem. It is proposed that future resettlement farms be designed properly by environmental designers and landscape architects. In such a designed ecosystem the aims of ensuring the secure and adequate consumption of basic needs can be achieved by practical planning and implementation. Furthermore, the aim is to create self-reliance in a sustainable manner and it is thus a good starting point for the alleviation of poverty.

However it is necessary to consider whether it is fair and equitable for some of the poor who are fortunate enough to be settled on a farm to receive the equivalent of +N$ 200

000 from the government and while others receive nothing. On the other hand what is the long-term sustainability of these handouts? It is worth investigating whether the government perhaps would not produce more employment by using the N$20 million each year and investing it in the creation of work through establishing industries and urban resettlement projects. The author believes that the social costs far outweigh the benefits and that, seen in totality, the current resettlement programme is not financially viable?

If sustainability criteria were not applied to the current resettlement farms, a possible worst case scenario would be the biophysical costs of constructing a resettlement area, for example overgrazing, depletion of natural resources like trees for fuel, excessive use of boreholes and bush encroachment leaving desolation to the next generation. Financially the next generation would be left with marginal land with no finance and little social capacity to uplift themselves. It is therefore necessary to have an environmental conscience and integrity. It is suggested that this be thought in schools and adult workshops.

The Namibian Government should perhaps reassess its technology support strategy in order to apply the appropriate level which will most likely be a lower but more practical level of technology for the disadvantaged. However, this should not be viewed as providing a lower quality of service to the settlers, but is merely as a technology level that will be manageable by many of the illiterate settlers.

The use of domesticated animals for farming purposes should not be looked down on but should be considered rationally. For example, it is not possible for the settlers to buy or even maintain a tractor on their current income and, since the areas that need implements are so small, it does not justify the purchase of such an implement. In the end it is a question of 'economy of scale'.

Since water is vital to the settlements, it should be treated with care and wisdom. The first step towards saving water is to apply water-harvesting techniques which would also alleviate sole dependence on the borehole.

As far as housing is concerned, bricks can be replaced with mud and straw or mud and timber, and the corrugated iron sheets can be successfully replaced by thatch. These solutions should not be regarded as degrading or as housing for the disadvantaged, since there are whole cities with multiple-storey buildings constructed out of mud and timber (International Centre for Earth Construction – School of Architecture, 1998, Grenoble France).

The pollution of land, due to human defecation, should be assessed urgently. There are numerous pit toilets on the market in South Africa that are considered to be human and environment-friendly. However these need to be strategically placed as not to pollute shallow aquifers. Dust pollution can be limited by the provision of wind breaks and the covering of bare soils by plants.

Toxic substances should be discarded carefully to avoid polluting the air, soil or ground water and even plastics and glass should be discarded in a responsible way. Pesticides can be made from many common plants and are equally as effective as commercial chemical pesticides, as well as being biodegradable and environment-friendly.

Furthermore, soil creation, regeneration, and nutrient recycling can be achieved through mulching. The farms also need to be managed with a well-planned rotational system for livestock so that the veldt has time to recover.

These issues, as well as the need to protect endangered and threatened species, should be communicated to the settlers so that the rationale behind the action is understood. It is hoped that, through education, the attitude, particularly towards environmental resources, will be one of conservation and intergenerational sustainability.

Houses need insulation, although trees and vines can be grown to assist the insulation by altering the thermo-dynamics of the resettlement houses. The houses also need to face north and to have the appropriate roof overhang to protect the dwelling from the summer sun, while small windows should be placed on the east side of the house. A pergola covered by a vine would significantly improve the living conditions of the settlers if allowed for as a part of the resettlement house. This could then serve as a cooking area as well as outdoor living space.

It is difficult to assess but important to consider what the situation and emotion about the houses and settlements will be after 20, 30 or 50 years? Will these dwellings last for centuries? Are they adaptable for other uses? These factors need to be kept in mind when resettlement farms are planed.

7.3 Concluding remarks

In conclusion the aim of permaculture is reviewed:

> *"The aim is to create systems that are ecologically-sound and economically viable, which provide for their own needs, do not exploit or pollute, and are therefore sustainable in the long term. Permaculture uses the inherent qualities of plants and animals combined with the natural characteristics of landscapes and structures to produce a life-supporting system for city and country, using the smallest practical area*" (Mollison *et al*, 1997, p1).

Permaculture, if applied correctly, has the power to transform Namibia's resettlements. However, it would never materialise unless it is applied.

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Appendix 1

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Sustainable construction: principles and a framework for attainment

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The evolution of the concept of sustainable development is used as a basis for advancing understanding of sustainable construction. Principles of sustainable construction are developed and divided into four 'pillars' – social, economic, biophysical and technical – with a set of over-arching, process-oriented principles, to be used as a checklist in practice. A multi-stage framework is proposed which requires the application of Environmental Assessment and Environmental Management Systems for construction projects.

Keywords: Sustainable, development, environment, assessment, management

Introduction

Development efforts which seek to address social needs while taking care to minimize potential negative environmental impacts have been called sustainable development. Given the fact that the concept of sustainable development has been open to a wide range of interpretations, it would seem appropriate to summarize the evolution of the concept within the context of the environmental movement, and to propose a practical framework for the attainment of this concept in the construction industry. The purpose of this paper, then, is to: outline the evolution of the concept of sustainable development; advance understanding of the concept of sustainable construction; enunciate principles to be upheld in order to attain sustainable construction; and to propose a practical framework for the attainment of sustainable construction.

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Evolution of the concept of sustainable development within the environmental movement

The concept of sustainability was probably intuitively understood by early human civilizations such as the South African Bushmen. These hunter-gatherer people recognized the importance of utilizing the resources provided by nature on a sustainable basis and had practical experience of the fact that humans are dependent on the Earth's life support systems for survival (Van der Post and Taylor, 1984). The World Commission on Environment and Development (WCED) observed that, while modern cultures have only now begun to search for sustainable forms of development, traditional cultures have practised sustainable resource use for millennia (WCED, 1987).

Over the course of this century, the rapid advance of scientific and technological knowledge has provided humankind with the power to drastically alter planetary systems. This new-found power, together with increasing human numbers, has led to the excessive exploitation of renewable natural resources such as fish, wildlife and forests. There is growing scientific consensus that vast stocks of biological diversity are in danger of disappearing just as science is learning how to exploit this diversity through genetic engineering (WCED, 1987).

By the middle of this century, people were starting to question the capability of the earth to sustain the affluent lifestyle of the developed world. This questioning was based on the view that technology, far from providing answers to the issues facing society, was actually responsible for the escalation of environmental degradation. Writers such as Leopold (1949) and Carson (1962) called for people to embrace a lifestyle which showed more consideration for the environment and which sought to reduce the environmental impacts caused by material- and energy-intensive development. Such writers sowed the seeds of the environmental movement by advocating qualitative forms of development which gave precedence to spiritual and psychological needs over material wants, the so-called 'post-materialistic society' (Gardner, 1989).

In the developed world, public concern for the environment increased throughout the decade of the 1960s, and the first Earth Day was celebrated in April 1970 in Vermont, United States of America (Fuggle *et al.*, 1992). International concern was reflected in the United Nations Conference on the Human Environment which was held in Stockholm in 1972. The idea of ecodevelopment emerged from this conference as 'an approach to development aimed at harmonising social and economic objectives with ecologically sound management' (Gardner, 1989, citing Sachs, 1978). Ecodevelopment was the precursor of the concept of sustainable development.

In the same year as the Stockholm Conference, the Club of Rome published *The Limits to Growth*, a document which emphasized that concerns about pollution, environmental degradation and natural resource depletion were crucial to the long-term future of humanity (Meadows *et al.*, 1972). The limits-to-growth perspective challenged the pro-growth perspective of the previous decades, and, because this threatened important ideas and interests, reaction was intense. A synthesis of these conflicting perspectives eventually emerged in the perspective of sustainable development (Stockdale, 1989). This synthesis may be more usefully described as a continuum of perspectives in the middle ground between the extremes of the limits-to-growth perspective and the pro-growth perspective. Differing perspectives of sustainable development have been grasped by both environmentalists and the proponents of development to bolster their respective viewpoints. This clearly illustrates that the concept of sustainable development is value laden.

In the 1970s, the practice of nature conservation still largely embraced a preservationist philosophy, which held that nature could and should be conserved within the neatly demarcated boundaries of conservation areas. Development and conservation were seen as two ideals which were in direct conflict with one another. In 1980, the International Union for the Conservation of Nature and Natural Resources (IUCN) published the *World Conservation Strategy* (IUCN, 1980). The Strategy marked a significant shift in conservation, from focusing solely on the practice of fencing off nature reserves to viewing conservation and development as integrated concepts. The Strategy defined development as 'modification to the biosphere to satisfy human needs', and conservation as 'the management of human use of the biosphere to yield the greatest sustainable benefit to present and future generations' (IUCN, 1980).

On a practical level, the *World Conservation Society* translated a concern for the conservation of life support systems, ecological processes and genetic diversity into priorities for action. The priority requirements for the conservation of genetic diversity were founded on the notion of the *Genetic Management Iceberg* (IUCN, 1980), which has important implications for the concept of sustainable construction. The Strategy used the 'iceberg' to illustrate that efforts to conserve biodiversity in zoos, botanical gardens, seed and sperm banks, and even in National Parks and nature reserves, only reflect the tip of the 'iceberg', and that, if one wants to make a meaningful contribution to conserving genetic diversity and ecological processes, one should also focus efforts on the bulk of the 'iceberg', hidden from view, which represents areas outside of conservation management – the areas where most construction projects are implemented. In these areas, the Strategy urged that all development should aim to achieve 'sound planning, allocation and management of water and land uses' (IUCN, 1980). The message was that development and construction activities can make an important contribution to the conservation of biodiversity by applying environmental management in the execution of projects.

In 1987, the World Commission on Environment and Development (WCED) produced a publication entitled *Our Common Future* (WCED, 1987), which is referred to as the 'Brundtland Report'. The Commission stated that the essential needs of vast numbers of people were not being met, and warned that a world where poverty and inequity were endemic would be prone to ecological and other crises. The publication described the concept of sustainable development as meeting the basic needs of all people and extending to all the opportunity to satisfy their aspirations for a better life without compromising the ability of future generations to meet their own needs. In contrast to the limits-to-growth perspective, sustainable development placed more emphasis on the social and economic goals of society, particularly in the developing countries, but stressed that the attainment of these goals was interconnected with the achievement of environmental goals.

Although the concept of sustainable development was now firmly entrenched within the environmental movement, debate continued on appropriate definitions for, and uses of, the concept. One attempt to define the meaning of 'sustainability' was proposed by resource managers in the term 'sustainable utilization' of natural resources. However, in response to this notion, the question was raised as to how non-renewable resources, such as oil and minerals, could be exploited on a sustainable basis. The term 'sustainable utilization' was deemed, therefore, by some to be limited in applicability to renewable natural resources, for example, to water resources, plants and animals, and implied using them at rates within their capacity for renewal.

In the 1991 update to the World Conservation Strategy, entitled *Caring for the Earth* (IUCN, 1991), the World Conservation Union stated that the term 'sustainable development' had been criticized as ambiguous and open to a range of interpretations, many of which were contradictory. The authors suggested that this was because the term had been used interchangeably with 'sustainable growth'. They stated that sustainable growth is a contradiction in terms because nothing physical can grow indefinitely. *Caring for the Earth* defined 'sustainable development' as development which 'improves the quality of human life while living within the carrying capacity of supporting eco-systems'.

The operationalization of this concept remains contentious because of difficulties in determining the 'carrying capacity of supporting ecosystems' and difficulties in identifying the actions undermining ecosystems. Accusations between the nations of the North and the South over who is overextending the carrying capacity of local and global systems have become habitual, and formed the topic of heated debate at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro.

A comprehensive and 'an almost practical step toward sustainability' was proposed by the economist Solow (1993). Solow argued that development will inevitably cause at least some drawdown of current stocks of non-renewable resources, and that sustainability should mean more than just the preservation of natural resources. To maintain the capacity to meet the needs of future generations, concern is required for society's total capital, taking into account the substitution possibilities between natural and other forms of capital. Solow proposed that fairness towards future generations requires that some of the proceeds from the exploitation and depletion of non-renewable resources should be invested in other assets, which could include social or human-made capital (e.g. education and factories), to maintain productive capacity to meet the needs of future generations (Solow, 1993).

The divergence of opinions relating to the term proves that 'sustainability' is so broad an idea that a single definition cannot adequately capture all the nuances of the concept. It is probably true that the dichotomy of the development/environment debate in the 1970s and the 1980s has been replaced by a sustainable development synthesis, in that there is general agreement that uncontrolled exploitation of natural resources is not beneficial to humankind in the long term.

Advancing understanding of 'sustainable construction'

Having discussed, albeit briefly, the evolution and uses of the term 'sustainable development', the purpose of this section of the paper is to discuss the concept of sustainability as it relates to the construction industry and to advance understanding of the term 'sustainable construction'. For the purposes of this paper, the construction industry is deemed to comprise the civil engineering and building construction industries.

The environmental impacts of the construction industry are extensive. The November 1994 issue of the journal *World Watch* noted that *Homo sapiens* has become a super species through the use of buildings, capable of adapting to life anywhere on the planet. This ability to shape one's surroundings has obvious financial and environmental costs. According to *World Watch*, one-tenth of the global economy is dedicated to constructing, operating and equipping homes and offices. This activity accounts for roughly 40% of the materials flow entering the world economy, with much of the rest destined for roads, bridges and vehicles to connect the buildings (Roodman and Lenssen, 1994).

The term 'sustainable construction' was originally proposed to describe the responsibility of the construction industry in attaining 'sustainability'. November 1994 saw the holding of the First International Conference on Sustainable Construction in Tampa, Florida, United States of America. A major objective of the conference was 'to assess progress in the new discipline that might be called "sustainable construction" or "green construction"' (Kibert, 1994a). The conference convener, Kibert (1994b), proposed that sustainable construction means 'creating a healthy built environment using resource-efficient, ecologically-based principles'.

It is inevitable that the term 'sustainable construction' will initiate a number of semantic problems. When one considers that the IUCN (1991) described a sustainable activity as one which can continue forever, it is clear that a construction project cannot fall within this category of sustainable activities. To compound the problem, the term 'sustainable construction' is generally used to describe a process which starts well before construction *per se* (in the planning and design stages) and continues after the construction team have left the site. Wyatt (1994) has deemed sustainable construction to include 'cradle to grave' appraisal, which includes managing the serviceability of a building during its lifetime and eventual deconstruction and recycling of resources to reduce the waste stream usually associated with demolition.

One response to the confusion inherent in the term 'sustainable construction' would be to revert to the use of the term 'sustainable development'. In applying this suggestion, one would seek to ensure, for example, that the construction of a building, house or road satisfies the principles of sustainable development. However, sustainable development is such a broad term that it may well be useful to distinguish between general and specific applications such as 'sustainable construction'.

Semantic considerations aside, the various definitions of sustainability hitherto proposed need to be examined in an attempt to find common ground between the ideals of 'sustainability' in general, and those of 'sustainable construction' in particular. Four attributes of sustainability – social, economic, biophysical and technical – have been singled out to advance understanding of the concept of sustainable construction. Because these attributes underpin and support the attainment of sustainability, they have been conceptualized in this paper as the four 'pillars' of sustainable construction. Thus, the formulation of solutions, to the range of issues inherent in these four attributes, might be viewed as the construction, 'stone' by 'stone', of the 'pillars' of sustainable construction.

The social 'pillar' of sustainable construction is based on the notion of equity or social justice. This notion, which formed a cornerstone of the Brundtland Report (WCED, 1987), requires what has been described as 'opportunity redistribution on a massive scale' (Gladwin *et al.*, 1995). This necessarily requires more than the IUCN's general call for improving the quality of human life (IUCN, 1991) – it calls specifically for addressing poverty and inequity. The issue of social justice has been given scant attention in most of the literature on sustainable construction, which seems to focus mainly on the biophysical environment and technical issues (see for example: Kibert, 1994c; Roodman and Lenssen, 1994, 1995; *Environmental Building News*, undated; Loftness *et al.*, 1994). According to Kirkby *et al.* (1995), social sustainability requires, *inter alia*, a return to the high ideals of Brundtland which they suggest were diluted at the Rio Conference when the 'north turned "green" and the south was turned away'. Although Brundtland called for reviving growth as a way to reduce poverty, Goodland (1995) has proposed that poverty reduction has to come from, *inter alia*, redistribution and sharing, with a focus on development (as realizing potentialities) rather than from Brundtland's emphasis on throughput growth. Goodland (1995) noted that 'our planet develops over time without growing', and suggests that our economy, as a subsystem of the earth, must eventually adapt to a similar pattern in seeking 'development' rather than 'growth' as an objective. The social justice perspective of sustainable construction is perhaps the most difficult component to address in individual projects. Although the achievement of global social sustainability is an awesome task, some practical and attainable suggestions for construction projects are presented in the following section of this paper, under the heading 'Social principles of sustainable construction'.

The concept of sustainability proposed by Solow (1993) is a key element in the economic 'pillar' of sustainable construction. While accepting that some depletion of non-renewable resources is inevitable when development is undertaken, Solow suggests that sustainability is concerned with the substitution of natural to human-made capital. As the construction industry is constantly involved in this substitution, it is feasible to describe the industry as involved in operations which are supportive of sustainable development, although there is much debate around the issue of the degree to which human-made capital can provide substitutes for natural capital (Goodland, 1995).

The biophysical 'pillar' of sustainable construction is founded on the second part of the definition of sustainability proposed by the IUCN (1991). The IUCN stated that sustainability requires the improvement of the quality of human life within the carrying capacity of supporting ecosystems. As construction is largely involved with improving the quality of human life, if construction could demonstrate a responsible approach towards operating within the carrying capacity of supporting ecosystems, the ideals of sustainability could feasibly be attained from a biophysical perspective.

Consideration of the technical 'pillar' of sustainable construction does not necessarily mean constructing buildings or structures that will last for a few thousand years, like some ancient Roman aqueducts or Greek temples. One can argue that such structures were economically inefficient in that resources used for their construction were tied up for generations after they ceased to be useful. In our rapidly changing age, some structures may only have a limited economic life, after which they become redundant (Wyatt, 1994, citing Switzer, 1967). The technical 'pillar' of sustainability has been used in this paper to group a number of concepts, including concepts that relate to the performance, quality and service life of a building or structure.

Having introduced the concept of sustainable construction and its relationship with sustainable development, the following section of the paper develops and discusses principles for the attainment of sustainable construction.

Principles of sustainable construction

This section of the paper outlines a number of principles whose application would make the construction industry more sustainable. The principles are divided into the four main 'pillars' of sustainability – social, economic, biophysical, and technical – with a set of over-arching, process-oriented principles. These process-oriented principles suggest approaches to be followed in deciding the emphasis to be given to each of the four 'pillars' of sustainability, and each associated principle, in a particular situation.

Before introducing the principles of sustainable construction, it is necessary to give an indication of how these might be used in practice. It should be noted that optimization of all the listed principles is not always possible, and that trade-offs and compromises may be necessary. Indeed, some of the principles cannot be considered immediate priorities, but this does not mean that they should be ignored. The choice of which principles to apply to a particular construction project, and the decision on the extent to which each chosen principle should be applied, reflect value judgements, i.e. whether to apply weak, strong, or very strong sustainability. It is best if these judgements are made by the interested and affected parties involved in a project. The emphasis, therefore, should be on implementing a process which seeks to achieve consensus among interested parties on which principles are more, and which are less, important.

Because the guidance offered on implementing the principles is limited to recommendations on matters of process, this paper may be criticized for not providing quantitative standards to determine whether an action meets the sustainability criterion for a certain principle, or not. Absolute standards are not provided for two reasons. The first reason is to avoid the proselytizing and prescriptive nature of much writing on sustainability. The second reason is the recognition that trade-offs are sometimes required between the different 'pillars' of sustainability. This recognition should not, however, hinder the search for creative solutions which satisfy as many of the seemingly conflicting principles as possible. The interested parties involved in a project should use the principles listed for each 'pillar' of sustainability as a checklist, and then themselves make the important decisions on which should not be applied, which should, and the extent of application.

The principles of sustainable construction are summarized in Figure 1 and discussed below. The question to be asked for each principle is: In what way can this principle be practically and most effectively applied in this situation?

Social principles of sustainable construction

This section outlines social principles of sustainability. Some of the principles listed below could be categorized as either 'social' or 'economic', or both: these principles have been allocated to the 'pillar' that reflects the most prominent attribute of the principle. The social 'pillar' of sustainable construction requires that practitioners seek to:

- Improve the quality of human life by ensuring secure and adequate consumption of basic needs, which are food, clothing, shelter, health, education, and beyond that by ensuring comfort, identity and choice (Yap, 1989). The first step towards achieving this goal is poverty alleviation.
- Make provision for social self determination and cultural diversity in development planning (Gardner, 1989), and ensure that the operation of development (after the construction process is complete) is compatible with local human institutions and technology (Yap, 1989).
- Protect and promote human health through a healthy and safe working environment. Plan and manage the construction process to reduce the risk of accidents, and carefully manage the use of substances which are hazardous to human health.
- Implement skills training and capacity enhancement of disadvantaged people to allow them to meaningfully participate in a project. Such training and participation should ensure that development of human resources is a lasting legacy of construction, in addition to the physical presence of facilities.
- Seek fair or equitable distribution of the social costs of construction and, where this is not achieved, determine fair compensation for people adversely affected by construction operations. This principle and the following two principles can be applied at local, regional, and international scale where, for example, large inequities exist between developed and less-developed countries in terms of access to resources.

PROCESS-ORIENTED PRINCIPLES OF SUSTAINABLE CONSTRUCTION

Over-arching principles indicating approaches to be followed in evaluating the applicability and importance of each 'pillar', and its associated principles, to a particular project.

- Undertake prior assessments of proposed activities
- Timeously involve people potentially affected by proposed activities in the decision-making process
- Promote interdisciplinary collaborations and multi-stakeholder partnerships
- Recognize the necessity of comparing alternative courses of action
- Utilize a life cycle framework
- Utilize a systems approach
- Exercise prudence
- Comply with relevant legislation and regulations
- Establish a voluntary commitment to continual improvement of performance
- Manage activities through the setting of targets, monitoring, evaluation, feedback and self-regulation of progress
- Identify synergies between the environment and development

PILLAR ONE: SOCIAL SUSTAINABILITY

- Improve the quality of human life, including poverty alleviation
- Make provision for social self determination and cultural diversity in development planning
- Protect and promote human health through a healthy and safe working environment
- Implement skills training and capacity enhancement of disadvantaged people
- Seek fair or equitable distribution of the social costs of construction
- Seek equitable distribution of the social benefits of construction
- Seek intergenerational equity

PILLAR TWO: ECONOMIC SUSTAINABILITY

- Ensure financial affordablity for intended beneficiaries
- Promote employment creation and, in some situations, labour intensive construction
- Use full-cost accounting and real-cost pricing to set prices and tariffs
- Enhance competitiveness in the market place by adopting policies and practices that advance sustainability
- Choose environmentally responsible suppliers and contractors
- Invest some of the proceeds from the use of non-renewable resources in social and human-made capital, to maintain the capacity to meet the needs of future generations

PILLAR THREE: BIOPHYSICAL SUSTAINABILITY

- Extract fossil fuels and minerals, and produce persistent substances foreign to nature, at rates which are not faster than their slow redeposit into the Earth's crust
- Reduce the use of the four generic resources used in construction, namely, energy, water, materials and land
- Maximize resource reuse, and/or recycling
- Use renewable resources in preference to non-renewable resources
- Minimize air, land and water pollution, at global and local levels
- Create a healthy, non-toxic environment
- Maintain and restore the Earth's vitality and ecological diversity
- Minimize damage to sensitive landscapes, including scenic, cultural, historical, and architectural

PILLAR FOUR: TECHNICAL SUSTAINABILITY

- Construct durable, reliable, and functional structures
- Pursue quality in creating the built environment
- Use serviceability to promote sustainable construction
- Humanize larger buildings
- Infill and revitalize existing urban infrastructure with a focus on rebuilding mixed-use pedestrian neighbourhoods

Figure 1 Principles of sustainable construction

- Seek equitable distribution of the social benefits of construction and, where this is not achieved in the intended use of a facility, seek to optimize benefits which arise during the construction process, such as employment opportunities.
- Seek intergenerational equity so that significant social, biophysical and financial costs of current construction are not passed on to future generations. This requires, *inter alia*, the avoidance of excessive resource consumption (from environmental sources) and not overtaxing the assimilative capacity of the environment to absorb wastes (the environmental 'sinks'). Injudicious use of these environmental 'goods and services' forecloses options for future generations. Sustainability requires a change in consumption patterns, and a concern for managing or constraining the flow of natural capital in the form of energy and materials (Goodland, 1995). This principle aptly demonstrates the linkages between social, economic and biophysical sustainability.

Economic principles of sustainable construction

This section lists principles of economic sustainability. The economic 'pillar' of sustainable construction requires that practitioners seek to:

- Ensure financial affordability for intended beneficiaries by reducing the overemphasis on technical sustainability. For example, appropriate sets of minimum housing and associated service standards need to be developed to promote the acquisition of affordable formal housing.
- Promote employment creation and, in some situation, labour intensive construction for disadvantaged communities as this should result in a significant portion of the financial contribution of a project remaining and circulating in local hands.
- Use full-cost accounting and real-cost pricing to set prices and tariffs, for goods and services, that fully reflect social and biophysical costs. This seeks to achieve more equitable development and more efficient use of resources. Liddle (1994) contends that, while legal control was the primary vehicle for managing the environment under the paradigm of environmentalism, the emphasis under the paradigm of sustainability is on economic approaches.
- Enhance competitiveness in the market place by adopting policies and practices that advance issues of sustainability.
- Choose environmentally responsible suppliers and contractors who can demonstrate environmental performance.
- Invest some of the proceeds from the use of non-renewable resources in social and human-made capital, to maintain the capacity to meet the needs of future generations.

Biophysical principles of sustainable construction

This section lists the principles that constitute the biophysical 'pillar' of sustainable construction. The term 'biophysical' is used to include the atmosphere, land, underground resources, the marine environment, flora, fauna and the built environment. The biophysical 'pillar' of sustainable construction requires that practitioners seek to:

- Extract fossil fuels and minerals, and produce persistent substances foreign to nature, at rates which are not faster than their slow redeposit into the Earth's crust (Robèrt, 1995). This principle contains two elements which are discussed together in the following text. Robèrt (1995) has proposed four system conditions which represent very strong sustainability. These were derived from a systems perspective of planet Earth in considering flows of matter and energy in terms of the laws of thermodynamics. Robèrt therefore considers that these conditions allow one to 'strive for an absolute as opposed to a relative frame of reference'. The first two of these system conditions require that substances from the Earth's crust (minerals and fossil fuels) and substances produced by society (persistent compounds foreign to nature) should not be produced at rates faster than their slow redeposit into the Earth's crust, i.e. such substances should not systematically increase in nature. Robèrt (1995) suggests that the implementation of these two conditions requires answers to the following question: 'In what ways can your organisation systematically decrease its economical dependence on these substances?' The third and fourth of Robèrt's conditions are to phase out diminishment of the productivity and biodiversity of nature and seek resource-savings methods to meet human needs, both of which are discussed in subsequent principles for biophysical sustainability.
- Reduce the use of the four generic resources used in construction, namely, energy, water, materials, and land, at each stage in the project life cycle (Kibert, 1994c). This principle addresses the underlying causes of much environmental degradation – overconsumption of resources (Kibert, 1994c).

  Optimization of this principle for energy requires reduction of both embodied and operating energy (Loftness *et al.*, 1994). Embodied energy of building materials and products is the total energy used in the processes of production, from extraction of raw materials to final delivery. Operating energy includes that used to cool/warm and light rooms and heat water.

The adoption of the conservation principle for water is of particular importance to South Africa, where it is a limiting resource for development. Examples include: roof-top rain-water harvesting for outdoor watering; water efficiency in buildings through the specification of conserving fixtures such as low-flow showerheads, tap aerators and water conserving toilets; and indigenous, drought resistant plants for landscaping. Such planting also optimizes for the principle on creating a healthy, non-toxic environment through reducing the need for potentially polluting pesticides, herbicides, and fertilizers.

- Maximize resource reuse, and/or recycling as this leads to a reduction in waste thereby prolonging the life of landfill facilities and reducing the need to select new landfill sites. It also reduces the need for raw materials thereby contributing to the attainment of the second principle of reducing resource consumption.

Examples of reuse include the renovation of existing buildings and refurbishment for a new purpose. This requires that buildings are designed and constructed with adaptability in mind (Roodman and Lenssen, 1994). Where demolition is absolutely necessary, this principle requires the implementation of salvage which necessitates the reinstitution of hand-wrecking and, importantly, planning for disassembly or deconstruction (Wyatt and Gilleard, 1994). The aim should be to reuse as much of the structure as possible on another project and to recycle what cannot be directly reused. Central to this is the need for planning for disassembly, entailing the requirement that fixing details allow for the non-destructive separation of different materials at the end of the life of a building (Wyatt and Gilleard, 1994).

Recycling is different from reuse in that existing items are not used intact but are reduced to raw materials and used in new products (Kibert, 1994c). On the construction site, recycling requires educating workers about recycling procedures and instituting on-site sorting of usable waste into bins clearly marked for different types of waste.

Extra attention should be given to the 3Rs (Reduce, Reuse, Recycle) when considering the use of non-renewable resources. While non-renewable resources cannot be used sustainably, their 'life' can be extended by reducing their use in product manufacture, reusing a product a number of times rather than discarding after using once, recycling of the resource at the end of the usable life of the product, and switching to renewable substitutes where possible (IUCN, 1991).

- Use renewable resources in preference to non-renewable resources. This principle can be applied to both building materials and energy. For energy, this indicates the use of passive thermal design, daylighting, solar heating of water, and the use of photovoltaics to generate energy. Passive thermal design, defined as '. . . building in harmony with the local climate, obtaining indoor thermal comfort with minimal recourse to artificial heating or cooling' (National Energy Council, undated), includes con-siderations of building orientation, the use of breezes for natural cooling, solar warming of buildings, and even the siting of buildings to benefit from existing and planned vegetation. For materials, using wood as an example, this implies the use of sustainably-managed forests and avoiding the use of so-called 'old growth' timber when other alternatives are available (*Environmental Building News*, 1994).
- Minimize air, land and water pollution. This principle can be applied to various environmental concerns, which may vary from global to local, at one or more stages in the life cycle of projects. As for global concerns, it can include the reduction or elimination of pollutants causing ozone depletion and global warming. At a local level, it requires the development of operational procedures for controlling various activities including emergencies, and the management of noise, odour, dust, vibration, chemical and particulate emissions, and solid and sanitary waste during construction operations.
- Create a healthy, non-toxic environment through the elimination or careful and managed use of hazardous and toxic products in the indoor and exterior built environment (Kibert, 1994c). This includes minimization of the use of solvent-based finishes, adhesives, carpeting, and particleboard which release formaldehyde and volatile organic compounds into the air (*Enviromental Building News*, undated). These chemicals can affect the health of workers and occupants and contribute to 'sick building syndrome' (Roodman and Lenssen, 1994). This principle can also be applied in day-to-day management of the use and disposal of hazardous wastes, such as metal polish, paint thinners, ammonia-based cleaners and chlorine bleach, which should not be discarded down the sink or drain. Outdoors this principle requires minimizing and managing the use of pesticides and other persistent toxic chemicals to prevent soil and water contamination.
- Maintain and restore the Earth's vitality and ecological diversity, through:
  i) conserving life support systems, which are the ecological processes which shape the climate,

cleanse air and water, regulate water flow, recycle essential nutrients, create and regenerate soil and enable ecosystems to renew themselves.

ii) conserving the biodiversity of plants, animals and other organisms, the range of genetic stock within each species, and the variety of ecosystems, with special attention to protecting rare and endangered species and ecosystems.

iii) minimizing damage to renewable resources such as soil, wild and domesticated organisms, forests, rangelands, cultivated land, and the marine and freshwater ecosystems that support fisheries (IUCN, 1991).

iv) restoring ecological processes that have been disrupted by past human activities. UNEP (1994) proposes that current activities should be judged in terms of whether they contribute towards improvements in indicators of environmental health, such as biodiversity, and not only on whether they have maintained the current, in many cases, inadequate situation.

The application of the first three of the above-mentioned components of this principle has hitherto formed the focus of most efforts to achieve sustainable construction in South Africa. This has been through the evaluation of alternative sites to avoid sensitive environments and the on-site protection of vegetation, topsoil and river water quality during construction. These efforts should be extended to consider the ecological impacts, often at remote locations, caused by extraction, processing and transport of materials to the construction site.

- Minimize damage to sensitive landscapes, including areas which are valuable from a scenic, cultural, historical, or architectural point of view, and minimize intrusion into wilderness areas.

Technical principles of sustainable construction

This section lists the principles that constitute the technical 'pillar' of sustainable construction. The term 'technical' has been chosen to describe those principles that relate to the performance and quality of a building or structure, but also includes a principle which requires humanizing larger buildings because, although this might be seen as a social concern, it requires the application of technology to achieve the desired outcome. This illustrates the somewhat artificial separation of principles into the four 'pillars', in that one principle could incorporate elements which relate to more than one 'pillar'. The technical 'pillar' of sustainable construction requires that practitioners seek to:

- Construct durable, reliable and functional structures. Considerations of technical sustainability start with the requirement that structures are able to withstand the destructive forces of nature. Beyond this, Keoleian and Menerey (1994) note that product life extension is at the top of a hierarchy of life cycle design strategies. A durable building that lasts, due to competent design, manufacturing and construction procedures (Halliday, 1994a), and one that reliably and continuously fulfils its intended purpose, usually saves energy (because manufacturing and construction are energy intensive) and also contributes less to solid waste problems. For consumer products, Keoleian and Menerey (1994) have proposed that durability should not be enhanced beyond the expected useful life of a product as this can be wasteful. The applicability of such limitations on the life of a building (although discussed in the principle on reuse and recycling) may be questionable, however, given the focus of the next principle on pursuing quality. Brand (1994) has suggested that the real test of a building is how it serves its users as they constantly adapt and alter it. He also states that the most significant failing of contemporary architecture is its focus on style at the expense of good function.
- Pursue quality in creating the built environment. This traditional criterion (taken from Kibert, 1994c) is important for sustainability because cherished spaces are cared for and maintained while dehumanizing structures are prone to vandalism. Loftness *et al.* (1994) suggest that the pursuit of sustainability requires a shift away from 'maximum quick-profit financing' and 'tight-fit designs' to buildings that 'are designed for life cycle value', and which embody 'generous design', 'modifiability through modularity' (see principle on reuse) and 'cherishable delight and craftsmanship' (Loftness *et al.*, 1994). The creation of buildings that imbue users with a sense of well-being does tend to ensure that such buildings are modified to meet changing needs without resorting to demolition. Such treasured buildings can have life spans measured in centuries rather than decades, and will be defended vigorously against demolition.
- Use serviceability to promote sustainable construction. According to Wyatt (1994), serviceability provides an approach to life assessment quality from the pre-briefing stage of a project to its final deconstruction. In essence, serviceability accepts and recognizes that each constituent part of any building and its systems possesses its own unique decay curve, and hence service life, that, in some cases, can be extended through replacement, renovation and other such measures. In this regard, there is a

need to understand serviceability loss, whether attributable to deterioration, failure or outright obsolescence.

Wyatt (1994), citing Masters (1984), has gone some way to developing the serviceability discipline. In time, an approach to designing for sustainability, using target and design service life profiling, within defined reliability parameters, will be possible. The concept of serviceability necessitates determining each building's unique quality decline tree and at what point to extract part of an element, building system or component from service to replace it. Consideration should also be given to an upgrading strategy to be effected in the future.

- Humanize larger buildings so that individual users can control indoor environmental conditions (which requires a move away from centralized, uniform control). Loftness *et al.* (1994) suggest that this challenge should be tackled through a combination of: the use of 'thin' buildings (which optimize inside-outside contact, i.e. contact with nature, by avoiding large central areas which do not have contact with the building perimeter); and the use of low-resource solutions of the past (windows that open) together with advanced 'distributed, user-controlled, environmental conditioning and networking systems' (Loftness *et al.*, 1994).
- Infill and revitalize existing urban infrastructure with a focus on rebuilding mixed-use pedestrian neighbourhoods which integrate housing, retail space, and work places (Loftness *et al.*, 1994; Calthorpe, 1996; and Downs, 1996). Halliday (1994a) has expressed this principle as a requirement to enhance living, working, and leisure environments. While infrastructure and buildings themselves obviously play an important role in considerations of sustainability, the interrelationships between buildings and the quality of the intervening spaces also deserve attention. Loftness *et al.* (1994) bemoan the over-emphasis on the development of single-use suburban development and rural office, school, and shopping 'parks'. Such low-density urban sprawl consumes valuable open space, in the form of both agricultural land and natural habitat, and produces excessive dependency on the private car for transportation. The environmental impacts inherent in increasing populations of cars and the increasing annual distance travelled by each vehicle are multifarious. According to Goodland *et al.* (1993), the impact of the worldwide annual production of 48 million cars 'vastly exceeds' the impact of the human population growth of 90 million. Impacts of car use include energy inefficiency, in terms of energy consumption per passenger per kilometre, air pollution and congestion. Various authors (e.g. Lofthouse *et al.*, 1994; Calthorpe, 1996; and Downs, 1996) have motivated the need for a new vision and a new development model. Calthorpe (1996) envisions 'new communities as more finely integrated, walkable neighbourhoods with a strong local identity and convivial public spaces'.

Process-oriented principles of sustainable construction

As previously mentioned, the principles outlined above are divided into four main 'pillars' of sustainability – social, economic, biophysical and technical. The principles outlined in this section of the paper may be conceptualized as a set of over-arching, process-oriented principles. These process-oriented principles suggest approaches to be followed in considering the applicability of, and importance allocated to, each of the four 'pillars' of sustainability, and to each of the principles embodied in these 'pillars'. The process-oriented principles require that sustainable construction is characterized by approaches that:

- Undertake prior assessments of proposed activities, to integrate information concerning social, economic, biophysical and technical factors in decision-making.
- Timeously involve people potentially affected by proposed activities and present equal access to such people in the decision-making process (World Commission on Environment and Development, 1987).
- Promote interdisciplinary collaborations and multi-stakeholder partnerships between government, industry, consultants, contractors, non-government organizations and the general public (Gardner, 1989), in a process that is participatory, interactive and consensual. This principle also suggests the need for international cooperation to accelerate the attainment of sustainability.
- Recognize the complexity and multiplicity of objectives inherent in the concept of sustainability, and the necessity of comparing alternative courses of action, in terms of the extent to which each alternative satisfies a range of objectives and stakeholders (Pètry, 1990), at each stage in the project life cycle.
- Utilize a life cycle framework, which recognizes the need to consider all of the principles of sustainable construction at each and every stage in planning, assessment, design, construction, operation and decommissioning of projects.
- Utilize a systems approach, which recognizes the interconnections between economics and the environment.
- Exercise prudence or caution in the face of uncertainty, unpredictability and risk (Goodland, 1995).

- Comply with relevant legislation and regulations. This is a minimum requirement, and compliance could extend to professional and industry codes of practice; agreements with public authorities; and non-regulatory guidelines (ISO, 1995).
- Establish a voluntary commitment to continual improvement of performance, in striving to attain sustainable construction, which goes beyond compliance with legal requirements. The rate and extent of such improvement would be decided for each project and would be influenced by economic and other circumstances (ISO, 1995).
- Manage activities through the setting of targets, monitoring, evaluation, feedback and self-regulation of progress (Gardner, 1989), in a process that is iterative and adaptive in nature. This process can be applied both within a specific contract and in ensuring that knowledge from one contract is integrated into future contracts, essentially what Boye-Moller and Larsen (1994) call a 'continuous learning process'.
- Identify synergies between the environment and development rather than trade-offs (Liddle, 1994). An example of this is the concept of 'eco-efficiency' (Gladwin *et al.*, 1995), in which reducing the use of resources and pollution prevention at source rather than clean-up can lead to increased economic efficiency. Liddle (1994) contends that the search for synergies is what distinguishes the paradigm of sustainability from that of environmentalism which is locked into the view that development and environmental quality are inherently contradictory outcomes, i.e. more of one must necessarily mean less of the other.

While the lists of principles for sustainable construction outlined in this paper are not exhaustive, they do indicate the wide range of principles that should be considered in determining a more sustainable course of action for individual construction projects.

A framework for the attainment of sustainable construction

Where previous sections of this paper have developed the concept and principles of sustainable construction (the 'what'), this section presents a framework for the attainment of sustainable construction (the 'how to'). The process-oriented principles listed in the previous section can be satisfied in the implementation of a proposed multi-stage framework (Hill *et al.*, 1994) which requires:

- application of Environmental Assessment (EA) during the planning and design stages of projects, provided that the traditional EA is expanded to include assessment of all four 'pillars' of sustainable construction and is undertaken in accordance with the process-oriented principles of sustainable construction, and,
- implementation of Environmental Management Systems (EMS), as described in the specification prepared by the International Organization for Standardization (ISO, 1995), within construction organizations, and for each project, during construction, operation and, where appropriate, even decommissioning.

The framework and its components are summarized in Figure 2 and discussed below.

In this paper, a broad meaning is given to the term 'environment', to include the physical, biological, social, and economic circumstances that affect the existence and development of an individual or group (Department of Environment Affairs, 1992). Given this definition, an 'Environmental Assessment' could include assessment of all four 'pillars' of sustainable construction, although a Sustainability Assessment might be a more appropriate term. However, for ease of recognition this paper will continue to use the existing term of EA.

The remainder of this section of the paper outlines the role of both EA and EMS in achieving sustainable construction, with emphasis (and more detail) on the role of EMS during construction. This emphasis has been chosen because the role and objectives of EA are well documented (e.g. Brown and Hill, 1995) whereas the use of EMS in the construction industry has not been adequately discussed in the literature.

Environmental assessment in the planning and design stages

In the planning and design stages of projects, sustainable construction can be achieved by applying the principles, procedures and methods of Environmental Assessment (or Environmental Impact Assessment). The South African procedure for environmental assessment and management has been called Integrated Environmental Management (IEM). The IEM procedure was 'designed to ensure that the environmental consequences of development proposals are understood and adequately considered in the planning process. . . . The purpose of IEM is to resolve or mitigate any negative impacts and to enhance the positive aspects of development proposals' (Department of Environment Affairs, 1992).

The IEM procedure makes provision for an Environmental Assessment to: identify potential impacts, resulting from actions at each stage of the project life cycle; formulate and evaluate alternatives,

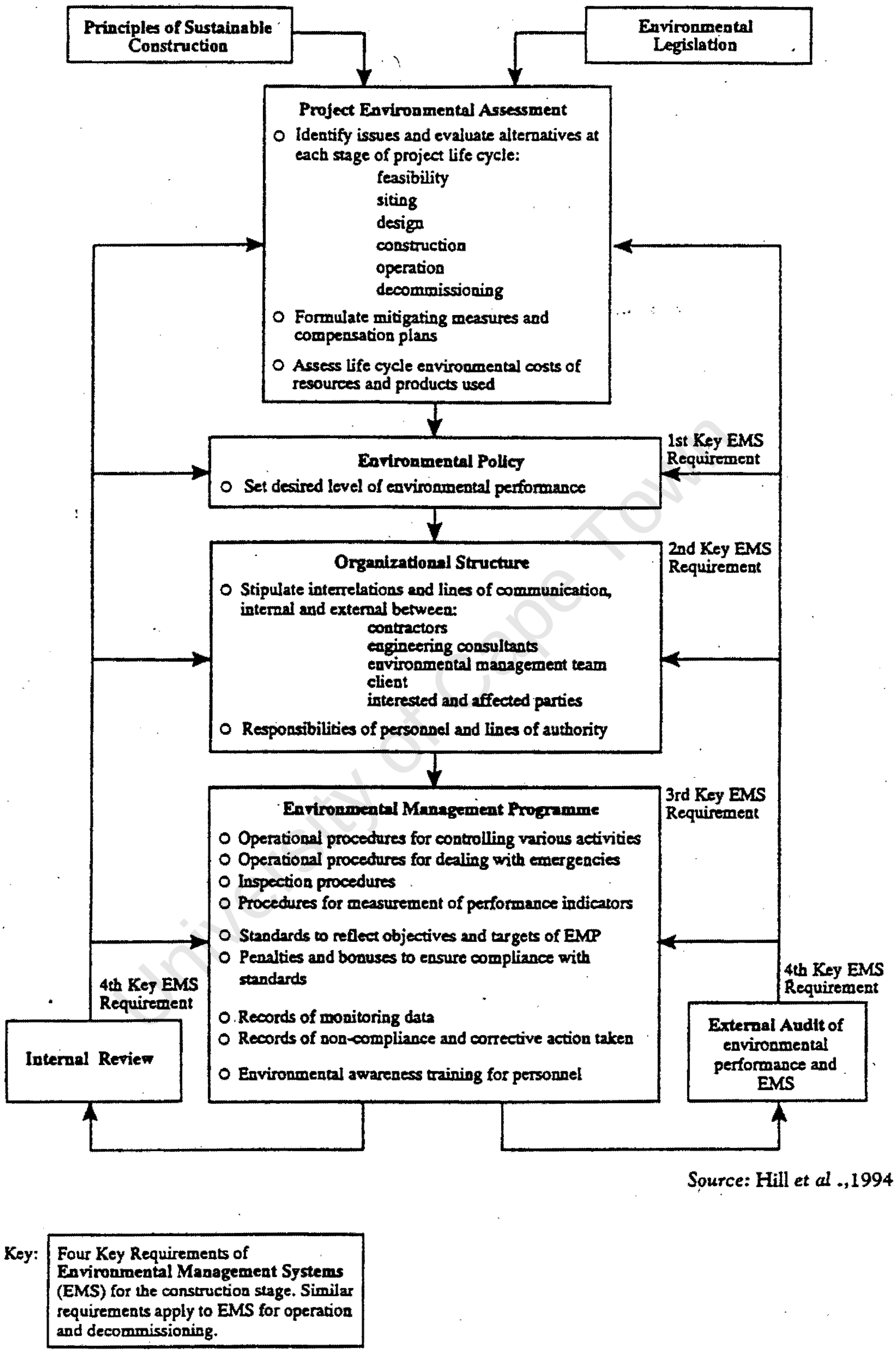

Figure 2 A framework for sustainable construction

in order to identify the preferred option at each stage (Brown and Hill, 1995); and, formulate mitigating measures to reduce impacts and develop compensation plans and monitoring programmes for residual impacts which cannot be mitigated to insignificance (see 'Project Environmental Assessment' in Figure 2).

A comprehensive traditional EA would evaluate alternatives for the sourcing of certain materials, such as the siting of quarries for stone aggregate, but would be unlikely to consider the life cycle environmental costs of most materials and products used in the construction process. The traditional EA should be expanded to consider life cycle assessment of alternative materials and products which could be used in the construction process. In addition, the EA should ensure that efficiency is a key criterion in the use of water, energy and land. The results of such a life cycle assessment should influence the purchasing specifications for materials and products to be used. These examples illustrate how application of the principles of sustainable construction would expand the practice of EA towards the goal of attaining sustainability.

The approach and methods of EA should also be applied, not only when evaluating siting, design, and material and product alternatives, but also during the stage when the planning and formulation of construction activities is undertaken. For instance, the choice of site for a concrete batching plant should be subject to the same rigour in assessing alternative sitings as is the case for the structure to be constructed.

After the EAs at each stage of planning and design are complete, the IEM procedure stresses the importance of formulating environmental management plans and the drawing up of an environmental contract to ensure implementation of the management plan, during project construction, operation and, where appropriate, even decommissioning. The IEM procedure provides few details as to how this should be done, and this is where specifications for Environmental Management Systems are more helpful.

Environmental management systems in sustainable construction

In discussing the use of Environmental Management Systems (EMS) as part of a framework for the attainment of sustainable construction, this paper draws on the *Code of Practice for Environmental Management Systems* published by the South African Bureau of Standards (SABS, 1993). In the preface to this Code of Practice, the SABS acknowledges the valuable assistance derived from the *Specification for Environmental Management Systems*, published by the British Standards Institution (BSI, 1992). These national specifications are to be superseded by the new international specification for EMS which has recently been developed by the International Organization for Standardization (ISO, 1995). The international specification has structured its model for EMS under five headings which represent consecutive stages in the planning, implementation and review of an EMS. The key requirements of an EMS for construction projects used in this paper are all contained in the ISO specification.

In South Africa, most formal EMS instituted to date have been implemented by large industrial or business organizations. The environmental management that has been implemented in a few major South African construction projects did not, in most cases, initially use an EMS specification for guidance. Such specifications nevertheless provide comprehensive checklists that should improve the practice of environmental management of construction. The implementation of EMS is essentially a voluntary and proactive approach which should afford construction companies a far better chance of addressing the issues of sustainable construction and testing solutions before legislative involvement by government.

Implementation of Environmental Management Systems (EMS) as part of a framework for attaining sustainable construction starts with the adoption of an EMS within a construction organization. This organization-wide EMS would make provision for the application of project specific EMS for each new construction activity. After construction, when a facility is handed over to the client, a new organization usually takes over management of the facility and yet another EMS could be developed to deal with the operation of the facility. A final EMS could be developed, where appropriate, for facility decommissioning. The use of EMS for the operation and decommissioning of facilities constitutes an essential part of the framework, given the definition of sustainable construction to include facility maintenance and deconstruction. However, because the application of EMS to the operation of existing facilities forms the focus of most of the literature on the subject of EMS, the use of EMS in operation and decommissioning is not addressed further in this paper, and the chosen focus is on the environmental management of the construction process.

In this paper, the components of an EMS are grouped under four key requirements for the sake of improving clarity (see Figure 2). In order to ensure implementation of environmental management during a construction project, these components should be documented as requirements in the contract specifications and bills of quantities. The purpose of this section of the paper is to outline these key requirements of Environmental Management Systems.

The first key requirement in developing an EMS is to determine an environmental policy to judge all the activities which are to be managed. Such a policy would set the desired level of environmental performance (see 'Environmental Policy' in Figure 2). Construction organizations could adopt a general environmental policy which could inform policies for specific projects. For instance, Shimizu Corporation, a Japanese construction company, adopted a Global Environmental Charter in 1991 (Miyatake, 1994). This Charter commits the company to six key policies which include 'evaluating environmental impact at each stage of construction', and 'harmonisation with the community'. At the level of individual construction projects, environmental polity would emanate from: company policy, if available; relevant legal requirements, and the EA for the project, which would identify those principles of sustainable construction deemed relevant to the project through consultation with interested parties at an early stage in the EA.

The second key requirement is to provide an organizational structure and to determine the responsibilities, authority, lines of communication and the resources needed to implement the EMS (see 'Organizational Structure' in Figure 2). At company level, this could necessitate, *inter alia*, a number of committees, each constituted to address a particular environmental issue. For example, in 1994, the Global Environment Committee of Shimizu Corporation had a subcommittee which had been tasked with reducing the usage of tropical wood composite boards for concrete formwork. Another committee was tasked with research and development of waste disposal technology (Miyatake, 1994). At the level of a particular construction project, a range of different organizations interact in the undertaking, and an EMS would need to define the required interactions between the various contractors, consultants and clients involved in the project. Similarly, lines of communication should link the organizations involved, and should also provide a connection with a range of interested and affected parties external to the construction process. With the exception of the management representative charged with implementing an EMS and those carrying out specialized environmental management functions, many of the personnel within the implementing organizations would need exposure to environmental awareness training.

The third key requirement is to develop an environmental management programme (EMP) that stipulates environmental objectives and targets to be met and work instructions and controls to be applied in order to achieve compliance with the environmental policy (see 'Environmental Management Programme' in Figure 2). For example, the Shimizu Corporation has set targets for three different types of construction waste. The reduction target for mixed wastes is 70% of the 1990 volume in the year 2000, and other targets are provided for concrete debris and construction sludge (Miyatake, 1994). At project level, the EMP would contain operational procedures for controlling various activities, which would include: work instructions for defining the manner of conducting an activity; inspection procedures to ensure that mitigating measures are applied; procedures for dealing with accidents and emergencies; and, procedures for the measurement of performance indicators, for example, accidental and controlled release indicators, and site impact indicators. Documentation plays an important role in the implementation of an EMP: in addition to an environmental management manual describing procedures, records should be kept of the monitoring data collected to test the effectiveness of mitigation measures and impact controls. Data collected to monitor performance indicators would be compared with standards chosen to reflect the objectives and targets of the EMP. These standards should be quantified as far as possible to facilitate verification of objectives. In construction, where the primary goals of the contractor and the environmental management team may be different, the EMP may need to rely on penalties and bonuses to ensure compliance with standards. Records should also contain details of incidents of non-compliance with stipulated policy and standards, and should describe corrective action taken. Records should also be kept of environmental training activities.

The fourth key requirement is to undertake periodic audits of the environmental performance of the construction team and the effectiveness of the Environmental Management System. An audit report provides an essential information feedback loop to management who can take corrective action to address the identified weaknesses of the EMS. For some years there has been debate as to whether environmental auditing should be a voluntary internal management tool or a compulsory external reporting mechanism (Soutter and Möhr, 1993). Auditing of an EMS for a construction project could be done internally by the environmental managers or externally by a consultant. Typically, an external audit would be preferred for a large construction project of extended duration with potential to cause significant environmental impacts. Ongoing internal review of the environmental performance of the construction team and the functioning of the EMS would complement the periodic audits (see 'Internal Review' and 'External Audit' in Figure 2). The results of company-wide and project specific environmental audits could be incorporated in the annual company report, which could eventually evolve into what UNEP (1994) has called annual 'sustainable development reporting'.

Complementary measures for the attainment of sustainable construction

In order for this framework to be successfully implemented, the professionals involved will need continuing education so that they can master the evolving concept, principles and applications of sustainable construction. Many of these professionals will also need to enhance their capacity to work in inter-disciplinary teams. Much information on the application of sustainable construction can be gleaned from sources such as the UK Building Services Research and Information Associations' *Environmental Code of Practice for Buildings and their Services* (Halliday, 1994b), and the American Institute of Architect's (1992) *Environmental Resource Guide*. In addition, the requirements of environmental labelling systems and voluntary rating systems for buildings can be applied in the design and construction of facilities (Roodman and Lenssen, 1995), and, in so doing, should improve the professionals' understanding of the issues involved. Roodman and Lenssen (1995) also note that 'sustainable building' design contests have been valuable in educating both professionals and the public about the issues of sustainable construction because of the high profile attached to such competitions. Another educational opportunity, which is only starting to receive appropriate recognition, is the educational role of Environmental Assessment (Brown and Hill, 1995). In assessing the sustainability of projects, the EA process fulfils a critical role in the education of developers, planners, architects, engineers, decision-makers and the public.

A further *caveat* to the successful implementation of the proposed framework relates to the financial and fiscal measures which are needed to sustain its technical implementation. Roodman and Lenssen (1995) report many examples of financial institutions giving preferential lending rates for the construction of sustainable buildings, and water and electricity supply utilities offering fee rebates on payment for services used in water and energy efficient buildings. As for fiscal policies, governments could tax pollution and the use of raw materials in production, and use part of the revenue to support research and development of sustainable technologies (Roodman and Lenssen, 1995). Such measures would complement the implementation of the framework in the quest for the attainment of sustainable construction.

Conclusions and recommendations

Consensus has not been reached on definitions for the terms 'sustainability' and 'sustainable development'. It is probably true, however, that the dichotomy of the development/environment debate in the 1970s and the 1980s has been replaced by a sustainable development synthesis, although this synthesis may be better described as a continuum of perspectives representing differing degrees of sustainability.

The term 'sustainable construction' is generally used to describe a process which starts well before construction *per se* (in the planning and design stages) and continues after the construction team have left the site. Sustainable construction includes managing the serviceability of a building during its lifetime and eventual deconstruction and recycling of resources to reduce the waste stream usually associated with demolition.

The principles of sustainable construction outlined in the paper are divided into four 'pillars' of sustainability – social, economic, biophysical and technical – with a set of over-arching, process-oriented principles. It is recommended that the interested and affected parties involved in a particular construction project use the list of principles for each 'pillar' as a checklist, and then seek consensus and compromises in reaching decisions on: the emphasis to be given to each of the four 'pillars' of sustainability; which principles to apply; and the extent to which each chosen principle should be applied. These decisions reflect value judgements which are best made by the interested and affected parties in the context of the project under consideration. It is suggested that these decisions are most likely to satisfy the different sustainability objectives of a range of interested parties, if the decisions are the outcome of a process which is managed in accordance with the process-oriented principles of sustainable construction.

A multi-stage framework for sustainable construction is proposed which requires application of Environmental Assessment (EA) during the planning and design stages of projects, and implementation of Environ-mental Management Systems (EMS) within construction organizations, and for each project, during construction, operation and, where appropriate, even decommissioning. In order to ensure implementation of environmental management during the construction stage of a project, it is recommended that these components are documented as requirements in the contract specifications and bills of quantities.

The application of the principles listed in this paper and the implementation of the framework, together with the complementary implementation of continuing education for construction professionals, should facilitate the attainment of sustainable construction.

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