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The vegetation and land use of a South African township in Hammanskraal, Gauteng

By

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EXECUTIVE SUMMARY

The world today is faced with major threats to a stable future, such as the greenhouse effect, depletion of fossil fuels, desertification, poverty and the growing gap between rich and poor. People are becoming more aware of the importance of a sustainable relationship between social systems and ecosystems. These systems were investigated in a South African township in Hammanskraal, Gauteng. Fieldwork was done to determine the current land use of the residents, the land use impacts of the residents and the natural resources available to the residents. The current land use of the residents was determined by observations and interviews. The people modified the ecosystem to make decorative gardens, plant food crops and to fence the yards. The land use impact varied over the total area of the selected site. A TWINSPAN analysis divided the ecosystem into two major communities namely the Residential Major-community, which was divided into 5 sub-communities, and the Savanna Major-Community, which was divided into 3 sub-communities. The land use impact was determined for each sub-community of the Savannah Major-Community in terms of species composition, vegetation structure, grass biomass and grazing capacity. The land use impact of the residents is most destructive on the Residential Major-Community, though the impact in each sub-community is similar. The local ecosystem is used to discard waste and to cut trees for firewood. The land use impact of the residents on the local ecosystem is low compared to agricultural activities. It is concluded that the relationship between the social and the ecological systems of the selected site is dysfunctional, because some natural resources needed by the social system are limited or destroyed. These resources include soil, space, water and energy. An interesting question that was investigated is: Why do people plant ornamental plants if they do not have enough resources and food? The relationship between the social and the ecological systems are complex. Technologies are needed to reach sustainable household-based production, without requiring adaptations from the relevant systems. Technologies that were identified from the literature include the principles of plant communities, permaculture, conservation agriculture and intercropping.

1 INTRODUCTION

The world today is faced with major threats to a stable future, such as the greenhouse effect, depletion of fossil fuels, desertification, poverty and the growing gap between rich and poor. People are becoming more aware of the importance of a sustainable relationship between social systems and ecosystems.

This study is specifically concerned with the relationship between the African household and the environment where it lives. Reconciliation between the African household and the ecosystem has many aspects. This study assumes that one aspect would be to establish sustainable and productive vegetation in and around the household i.e. one that would fit into the economical, social and ecological systems involved. This study is the beginning of the process towards such reconciliation, with the vision to establish an African household with sustainable and productive vegetation, following the process indicated in Figure 1.1.

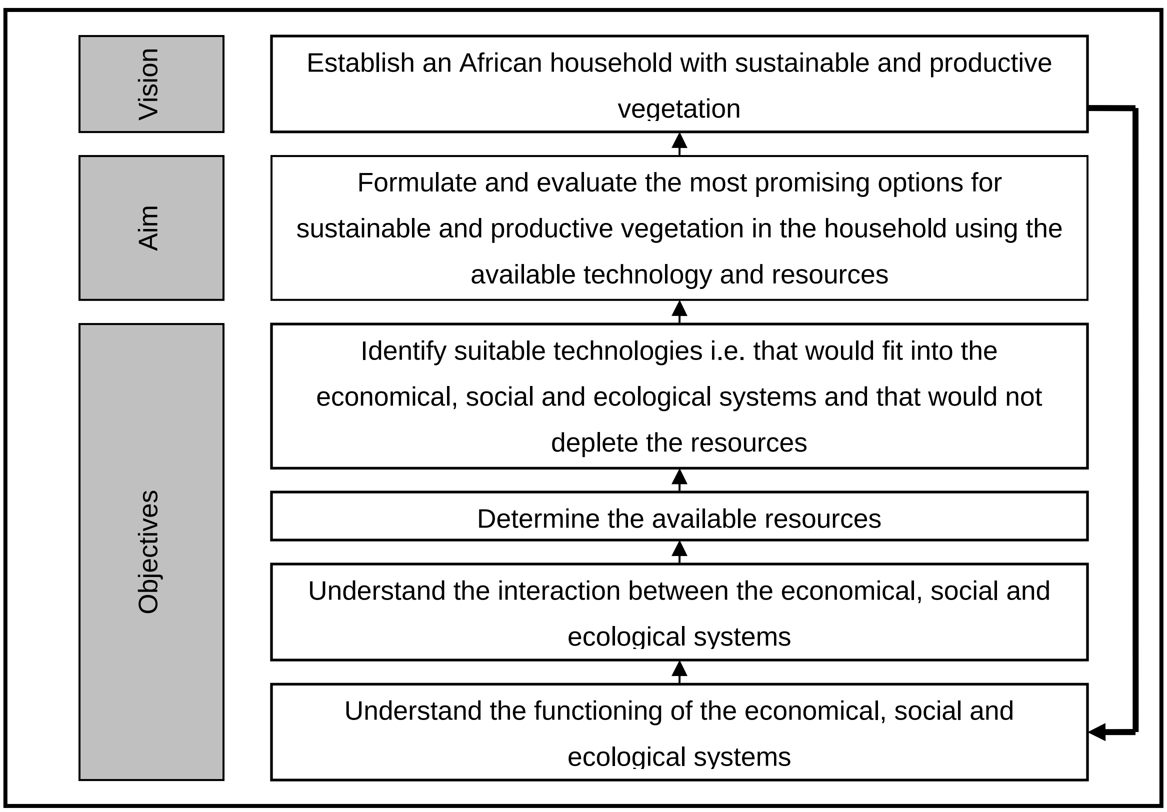

Figure 1-1: The process towards the establishment of sustainable and productive vegetation in an African household

The available resources must determine the technologies that can be used. The technologies should also comply with the requirements of the economical, social and ecological systems. It is therefore important to understand the interactions and the functioning of the economical, social and ecological systems.

In order to establish sustainable and productive vegetation in the household one needs suitable technologies from different specialised fields, such as

- **Plant ecology:** to understand the functioning of a plant community and find suitable plant species to design a sustainable and productive plant community
- **Agriculture:** to find sustainable ways of plant production
- **Human sciences:** to understand and manage the world views and cultural patterns of the human system in its interactions with the other systems
- **Economy:** to understand and manage the economical system

Fieldwork was done to study the interactions between the social system and the ecosystem and to determine the resources available to the people, using a community in Hammanskraal, Gauteng, South Africa, as a community that is representative of a typical South African peri-urban community. A literature study is done to find and evaluate the available technologies, specifically from Botany and Agriculture.

2 BACKGROUND INFORMATION

2.1 TERMINOLOGY

2.1.1 List of Terminology

The following list of terminologies is compiled to clarify some terms used during the study:

Decreaser species Herbaceous species that are abundant if the veld is in a good condition. These grass species would reduce if the veld is overgrazed or undergrazed (Trollope *et al.*, 1990).

Increaser 1 species Herbaceous species that increases if the veld is undergrazed (Trollope *et al.* 1990)

Increaser 2 species Herbaceous species that increases if the veld is overgrazed (Trollope *et al.* 1990)

Increaser 2a species Herbaceous species that increases if overgrazing of the veld is low (Trollope *et al.* 1990)

Increaser 2b species Herbaceous species that increases if overgrazing of the veld is intermediate (Trollope *et al.* 1990)

Increaser 2c species Herbaceous species that increases if overgrazing of the veld is high (Trollope *et al.* 1990)

Land use: The land use is the utilisation of resources from the ecosystem

2.1.2 Confusing Terminology

In this study many terms are used that seem to be closely related and it could create confusion. These terms are defined specifically for the purposes of this study. The following terms are compared and defined to distinguish between them:

- **'Felt needs', 'Real needs' and 'Requirements'**

Felt needs: The residents' perceptions of the necessities required to satisfy fundamental human needs

Real needs Necessities required to satisfy fundamental human needs

Requirements: The rules that a satisfier of a need must comply with, as determined by members of the household as well as role players outside the household

- **'Resources' and 'Technology'**

Resources: Resources can be defined as products of a system that are used by people (Hugo, 2004). For example, a motorcar is usually seen as technology, but in this study it is a resource produced by the social and the economical systems

Technology: Technology should be seen as a tool to increase resources by improving the interaction of the systems. Examples of technologies are methods, philosophies and practices

- **'Human environment', 'Residential environment', 'Natural environment', 'Local ecosystem' and 'Unaffected ecosystem'**

Human environment: The human environment is not defined by a specific area, but it consists of the social and the economical systems. The human environment is usually in a close relationship with the natural environment, but the term excludes the natural environment

Residential environment: The area where people live, including the people, their houses and infrastructures and the natural environment, which consists of soil, water, air, plants, animals etc

Residential ecosystem The ecosystem in the environment where people live, including the natural environment; soil, water, air etc and excluding the people, their houses and infrastructures

Natural environment: The ecosystems where people do not live, including the local ecosystem as well as in the unaffected ecosystem

Local ecosystem: The natural environment outside the boundaries of the residential area, but still in direct contact with the social system of the residential area

Unaffected ecosystem The natural environment outside the boundaries of the residential area, with no direct contact with the social system of the residential area

2.2 SCOPE OF THE PROJECT

The issues dealt with in this study extent over many fields of specialization and require many years of research. This study can only address a fraction of these issues and will form part of a larger project.

2.2.1 Timeframe

The timeframe for the project is illustrated in Figure 2.1. Initially (Phase 2) research and development (R & D) is done with little implementation. At the end of the project (Phase 5) implementation is done and R & D is continued in a small degree. This project is currently in Phase 2.

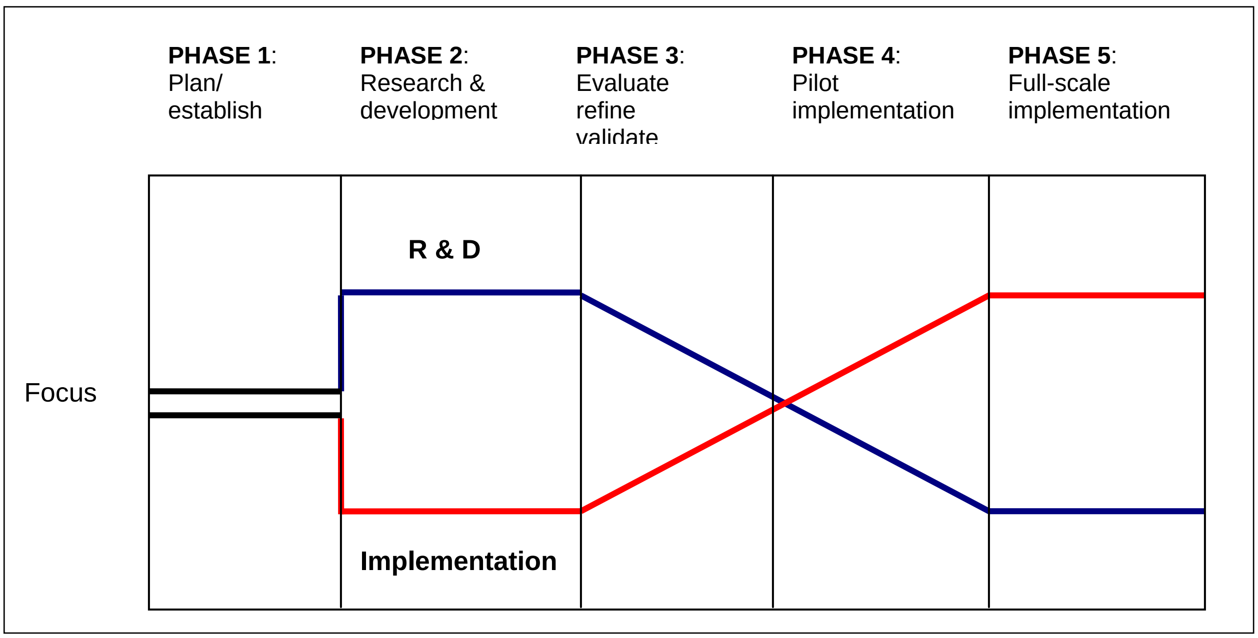

Figure 2-1: Timeframe for a sustainable household-based production project

2.2.2 Vision and Aim

The **long-term vision** to be reached during Phase 5 of the project is to implement sustainable and productive vegetation in the low-income household that will improve the quality of life of the households in a sustainable way.

The **aim** of the current study is to use the available technologies and resources to formulate the most promising options for sustainable and productive vegetation in the household in order to reach the vision

2.2.3 Objectives

This study has three main objectives:

- **Study the functioning of the systems involved and their current interactions with each other;** i.e. the economical system, the social system and the ecological system. This is needed to functionally integrate the systems

- **Determine the needs and the available resources in the low-income household.** This is needed to improve the quality of life of the low-income household

- **Study the available technologies:** The available technologies should be studied that could satisfy the needs of the household and that will fit into the economical, social and ecological systems

2.3 THE TURKANA TRIBE

Human interferences in the past proofed to have unexpected and very negative effects on the larger system. There are numerous examples of how people become involved in dysfunctional systems trying to solve certain problems. Often it is seen that these interferences, though it is done with the best intentions, only magnifies the problems. The Turkana tribe is only one example of many such instances (Harden, 1993).

The East African Turkana was a small nomadic tribe in the semi-desert of northwest Kenya. The tribe was extremely poor and vulnerable, sustained in the harsh conditions of the desert. They were pastoralist, herding cattle, goats, sheep, donkeys and camels. The vegetation in the semi-desert area was not enough to sustain the cattle of the Turkana, and they had to move from one area to the next as soon as the grazing became exhausted. Drought had a direct impact on the Turkana, and caused them to suffer and die of famine. The Turkana was proud, independent and aggressive people. Livestock was a very central part of the culture of Turkana. Livestock was not only a means of livelihood, but it defined them and formed part of their rituals and traditions. Young boys could not become men, or marry without livestock. Livestock allowed them to form part of a network, functioning like an insurance policy during times of drought. During years with sufficient rain people would distribute large amounts of their livestock to relatives experiencing drought. In this way they looked after each other (Harden, 1993).

The suffering of the Turkana has been a point of much concern for many European countries, and Norway specifically funded large projects to improve the living conditions of the tribe. A major fish tank project at Lake Turkana was launched, which seemed to be the ideal solution.

Fish is high in protein and low in cholesterol, it is a renewable source and causes little ecological impacts. If people can eat fish, they would be less dependent on livestock, which has a high ecological impact. The projects also involved building boats and teaching the Turkana to fish. After some investigation they decided that frozen fish fillets would be the most profitable product and they built a $2 million fish plant where the fish could be frozen and stored. The fish fillets could then be sold to the cities in Kenya (Harden, 1993).

Poor research caused this project to fail. The energy needed to freeze the fish fillets cost more than the income generated. They also did not realise that a part of Lake Turkana dried up approximately every 30 years, due to drought. During this time the amount of fish available reduced with 80%. The fish tank failed for another important reason, which involved the culture of the Turkana. Fishermen were considered as failures who could not handle their cattle. Those that did convert to fishing kept their cattle, but now the cattle were concentrated on the riverbanks which became overgrazed and trampled (Harden, 1993).

With better research they would probably have realised that the way of life of the Turkana tribe was not as unsustainable as they thought. If fact, the nomadic ways of the Turkana was much more effective compared to western practices, by tracking the rain patterns and utilising only the young green grass, which is more digestible. Compared to the modern commercial ranches in Australia, the Turkana extracted four times more proteins and six times more energy per hectare (Harden, 1993).

The Norwegians realised that instead of finding new and better technologies to help the people, they should understand their culture and support them in getting what is natural for them. Instead of focusing on the individuals that did not survive, they should rather understand how so many of them did survive (Harden, 1993).

2.4 SUSTAINABILITY

The word sustainable is derived from the Latin word, *sustinere*, which means to keep in existence (Rigby & Cáceres, 2001). According to D' Souza *et al.* (1998) a sustainable system is where current production do not impair future production, i.e. a temporal component, and production at one place do not impair production at another place, i.e. a spatial component. Conway (1987) defines sustainability as an ability of a system to stay productive under some form of stress or a major disturbing force.

In this study, income diversity, rural quality of life and biodiversity are seen as important requirements for sustainability.

2.5 APPROACH

The approach of this study is a systems approach. Systems should interact with each other in a sustainable way. Technology can be used as a tool to reconcile the systems, without disregarding the needs and requirements of each system.

An approach towards sustainability should recognise the presence and functioning of *systems*, the production and use of *resources* and the design and use of *technology*.

2.5.1 Systems

In order to reach sustainability one needs to consider the bigger picture both in time and in space. One should identify different systems involved, the levels of complexity and the driving forces of each system. Then one needs to analyse the interactions between systems and predict the consequences of actions.

The economical requirement of conventional farming is successfully met, but sustainability cannot be limited to economical welfare alone. Three basic systems are viewed as the most integral part of sustainability (Flora & Kroma, 1998):

- **Economical system**, by meeting the basic material needs of all the affected parties
- **Social system**, by meeting needs and requirements of all the affected parties
- **Ecological system**, by living within the ecological limitations

The three systems are complex and the interactions between the systems are even more so. For the purposes of this study these interactions are analysed by the outputs and the required inputs of each system as indicated in Figure 2.2.

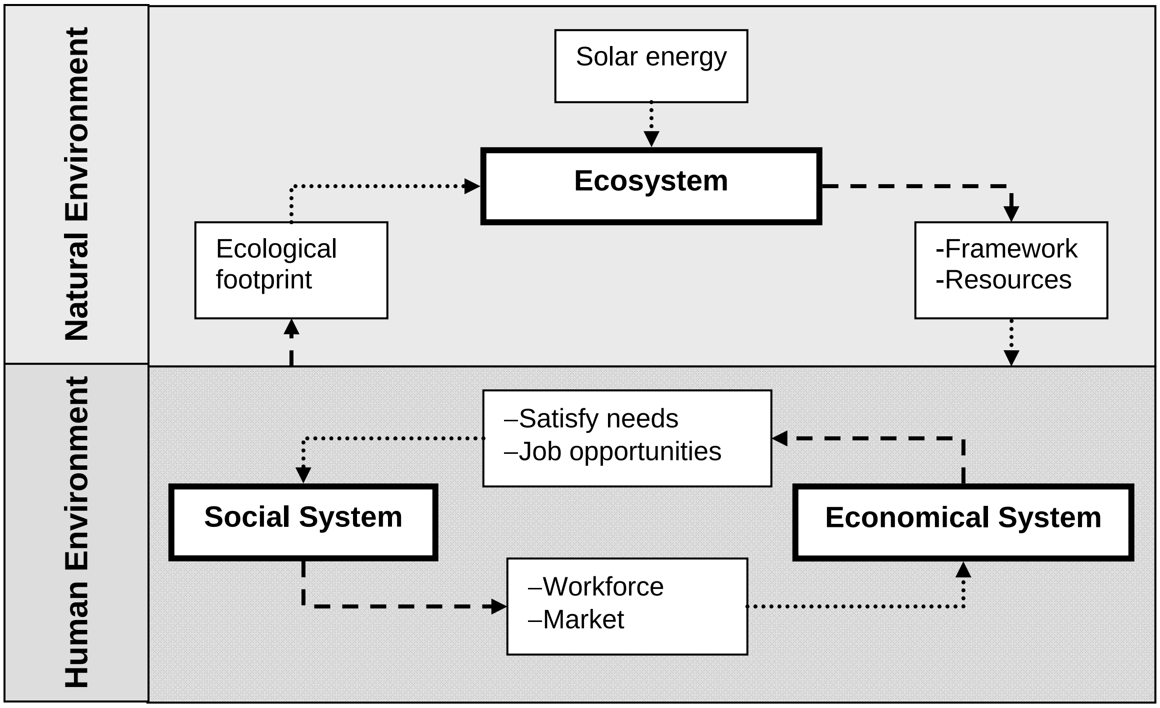

Figure 2-2: A schematic representation of the interactions between the economical system, social system and ecosystem, indicating the inputs and outputs of each system

D' Souza *et al.* (1998) describes the above-mentioned systems as links in the chain of food production. This chain is as strong as the weakest link. Sustainable food production as one link, i.e. economical success, without social or ecological sustainability as another link, does not ensure overall sustainability. The example of the Turkana tribe clearly indicates that disregarding social systems is a serious mistake. According to archaeological records many populations thrived at high population densities but soon declined and disappeared due to the degradation of the ecosystem (Salamon *et al.,* 1998).

The three systems are discussed in subsequent chapters. More research is needed to understand and integrate all systems involved.

2.5.2 Resources

The use of resources is central in understanding sustainable development. It is usually resource limitations causing certain practices to become unsustainable. According to Flora & Kroma (1998) resources can be consumed, stored or invested. *Capital* is resources that are invested in order to generate more resources.

2.5.3 Technology

The functioning of systems and the availability of resources are difficult or impossible to change, but technologies could be changed. Technology should be used to reconcile the economical, social and natural systems, without disregarding the needs and requirements of the systems. Modern technology presents many alternatives to solve global sustainability problems. Research should be done to find technologies that would require the least adaptations from the economical, social and the ecological system.

There are many examples, like the Turkana tribe, where technologies were designed and expected to improve the quality of life of low-income communities, but instead it created more chaos. The role of technology should therefore be contemplated in relation to the systems involved and the resources available.

2.5.4 Summary

A land use becomes unsustainable if resources are depleted faster than being produced. But according to Flora & Kroma (1998) sustainability is a function of systems and not of continuous high production of a resource. Technology should be seen as a tool to increase resources by improving the interaction of the systems, without disregarding the requirements of each system. The relationship between systems, resources and technology is illustrated in Figure 2.3.

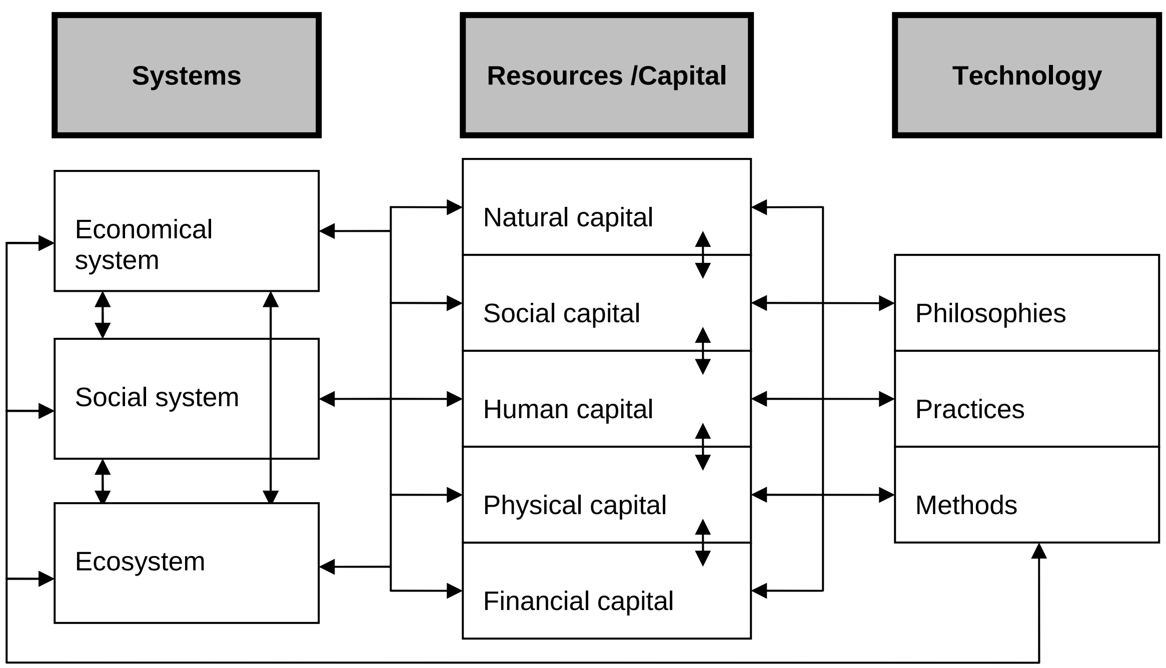

Figure 2-3: An illustration of the interactions between systems, resources and technology.

2.6 SMALL-SCALE PRODUCTION

Creating an environment where the systems interact with each other in a sustainable way is difficult. This study is concerned with the development of technology that would enable the sustainable production of resources on a household scale. The household was chosen as the primary focus of this study because:

- The household is a strategically important place of meeting, where the economical, social and natural systems converge and interact
- The household, specifically rural households, are in a close relationship with the natural environment
- Household-based production are believed to be able to uplift poverty and to empower the marginal poor
- All people are part of a household
- Residential household covers a large area of the world and a successful model could be reiterated over similar areas

3 FIELDWORK

This chapter gives an outline of the planning process and preparation for the fieldwork. The execution of the fieldwork is discussed separately in each of the following chapters.

3.1 AIM OF THE FIELDWORK

The ***aim*** of the fieldwork is to study the functioning of and interactions between the economical, social and ecological systems and the resources that are available.

3.2 SITE AND SITE SELECTION

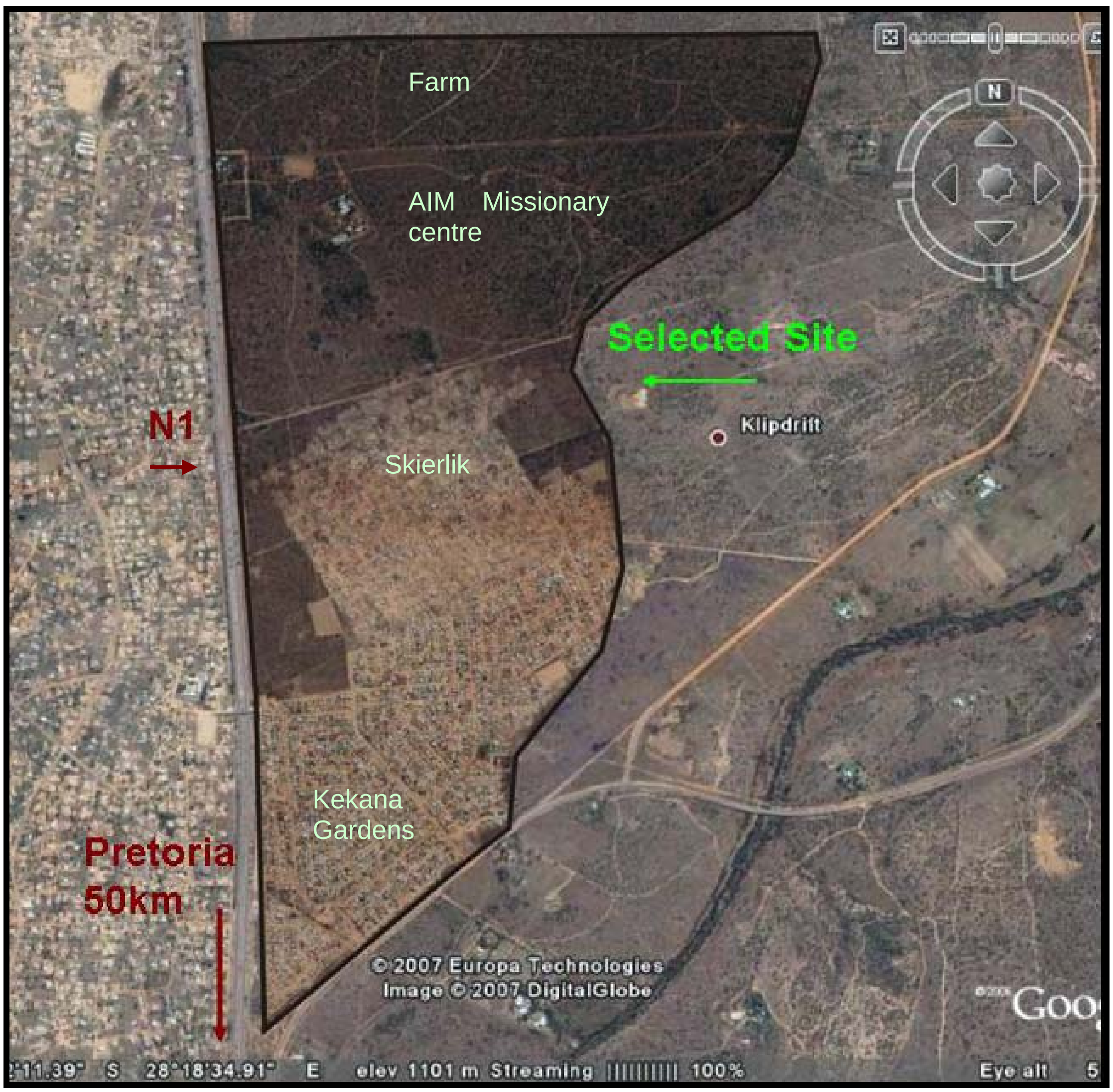

Figure 3-1: Locality map of the selected site in Hammanskraal (Google earth, 2007)

The selected site is a low-income community in Hammanskraal about 50 km north of Pretoria. The N1 highway abuts the western border of the site. Two human settlements are on the site; the permanent residential area, Kekana Gardens and informal housing area, Skierlik. To the North of the human settlements are farms, owned by the Reformed Church. The African Institute of Missiology (AIM) is situated on one of these farms (Figure 3.1).

The site was chosen, because:

- It is a peri-urban environment which is common in South Africa
- The influence of the urban environment on the low-income households is clear
- The influence of humans on the environment is clear
- Different social systems and their land use practices are present

Temperature data of the Pretoria region (25° 44' S; 28° 11' E) for the 30 year period, 1961-1990 is shown in Table 3.1 (SA Weather Service, 1990).

Table 3-1: Temperature data of the Pretoria region taken 1961-1990 (SA Weather Service, 1990)

Month	**Temperature (ºC)**			
	Highest recorded	**Average daily maximum**	**Average daily minimum**	**Lowest recorded**
January	36	29	18	8
February	36	28	17	11
March	35	27	16	6
April	33	24	12	3
May	29	22	8	-1
June	25	19	5	-6
July	26	20	5	-4
August	31	22	8	-1
September	34	26	12	2
October	36	27	14	4
November	36	27	16	7
December	35	28	17	7
Year	36	25	12	-6

3.3 PROCEDURE OF THE FIELDWORK

The procedure of analysing the selected site includes the following steps:

- Scoping process to get a general impression of the area and to plan the fieldwork
- Stratify the vegetation of the study site.
- Select sample plots in each land use zone
- Determine the current land use in different areas of the site (Chapter 5)
- Survey the vegetation in each zone, of the human and the natural environment (Chapter 6)
- Survey the availability of resources, including space, soil, water (Chapter 7)

3.4 SCOPING

Scoping of the area was done in several visits to the site during November 2006. Kekana Gardens is an established residential area and it is in the southern part of the selected site. Figure 3.2 is a household in Kekana Gardens. Skierlik is north of the Kekana Gardens and it is a poor residential area. 'Skierlik' is an Afrikaans word for 'Suddenly', meaning that the houses in this area were established in a very short time. Figure 3.3 is a household in Skierlik. North of Skierlik is the farm of the AIM Missionary Centre of the Reformed Church. Figure 3.4 is a photo of the landscape in this farm. The tree layer between Skierlik and the farm was destroyed for firewood by the residents of Skierlik. North of the farm of the AIM Missionary Centre is another farm where cattle is often seen. Figure 3.5 is a photo of the landscape on this farm.

Figure 3-2: A house in Kekana Gardens

Figure 3-3: A house in Skierlik

Figure 3-4: Trees cut down in the local ecosystem, next to Skierlik

Figure 3-5: The northern boundary of the selected site

3.5 STRATIFICATION OF THE STUDY SITE

For the purposes of this study, the ecosystem is stratified on different levels. The first level of stratification is between the residential environment (Zone 1) and the natural (Zone 2) environment (Figure 3.6).

The second level of stratification divided the site from north to south into four zones based on the land use practices (Figure 3.6):

- Zone 1: The residential environment (Zone 1) is the first zone of impact and is modified due to its intense and direct interaction with the social and economical systems. Zone 1 is subdivided into Zone 1A, Kekana Gardens and Zone 1B, Skierlik

- Zone 2A: The local ecosystem is the second zone of impact. The intensity of the impact from the residential environment decreases as the distance from the residential environment increases. Zone 2A is the farm of the AIM Missionary Centre

- Zone 2B: The unaffected ecosystem represents the ecosystem with the least impact from the residential environment. The unaffected ecosystem does not claim to be a pristine ecosystem, but is merely less affected in terms of a specific impact or land use.

It is important to understand and analyse the land use impact on each zone of the ecosystem for various reasons.

- The household ecosystem (Zone 1) must be studied and modified in order to be ecologically, socially and economically sustainable.

- The local ecosystem, which is the second zone of impact (Zone 2A) must be studied in order to reduce the intensity and extent of the impact from the residential environment.

- The unaffected ecosystem (Zone 2B) must be studied to compare it with the local ecosystem. In this way the land use impact in the local ecosystem becomes clear.

Figure 3.6 is an aerial photograph of the selected site showing the stratification of the area.

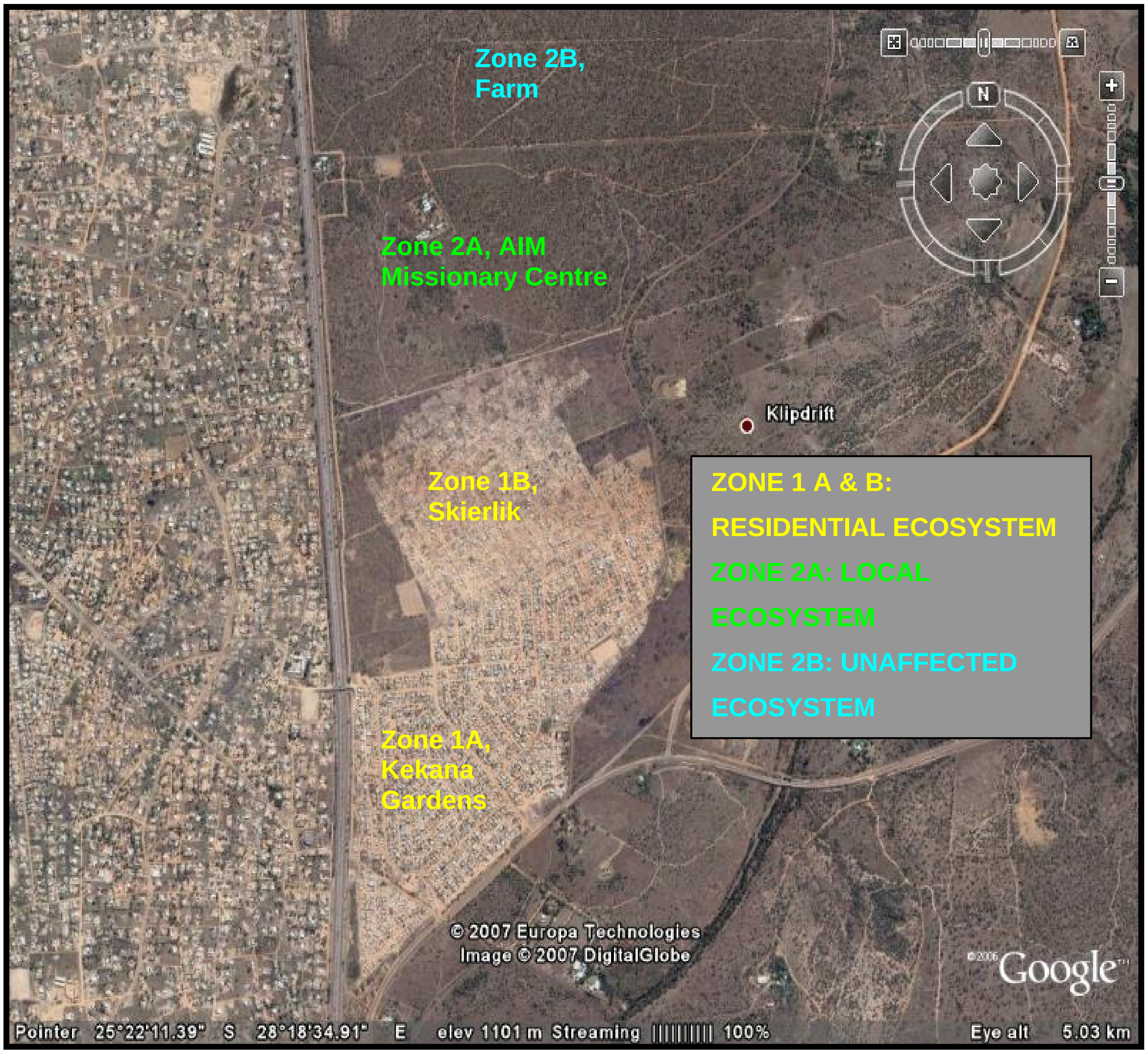

Figure 3-6: Stratification of the study site; Zone 1A & 1B is the residential environment, Zone 2A & 2B is the natural environment (Google earth, 2007)

3.6 SAMPLE PLOTS SELECTION

Sample A (Figure 3.7) consists of 40 households in the residential area, 20 in Kekana Gardens and 20 in Skierlik. Systematic sampling started at the most western point of the main road in Kekana Gardens and every sixth house was sampled. The same procedure was followed in randomly selected roads of Skierlik. Date and GPS data for the selection of Sample A are indicated in Table 3.2. Sample A is used for general observations on the available resources and land use practices in Kekana Gardens and Skierlik.

Table 3-2: Selection of Sample A

Zone	1A	1A	1A	1A	1A	1A	1A	1A	1A	1A
Town	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana
Plot	1	2	3	4	5	6	7	8	9	10
Date	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007
GPS	S 25º22’30.5”; E 28º18’13.0”	S 25º22’34.0”; E 28º18’14.8”	S 25º22’36.3”; E 28º18’16.8”	S 25º22’36.3”; E 28º18’16.8”	S 25º22’39.0”; E 28º18’19.2”	S 25º22’39.0”; E 28º18’19.2”	S 25º22’41.3”; E 28º18’21.5”	S 25º22’41.3”; E 28º18’21.5”	S 25º22’44.5”; E 28º18’24.1”	S 25º22’44.5”; E 28º18’24.1”

Table 3-2 (Continued): Selection of Sample A

Zone	1A	1A	1A	1A	1A	1A	1A	1A	1A	1A
Town	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana
Plot	11	12	13	14	15	16	17	18	19	20
Date	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007
GPS	S 25º22’39.3”; E 28º18’24.7”	S 25º22’39.3”; E 28º18’24.7”	S 25º22’37.9”; E 28º18’26.1”	S 25º22’37.9”; E 28º18’26.1”	S 25º22’35.9”; E 28º18’27.9”	S 25º22’35.9”; E 28º18’27.9”	S 25º22’35.3”; E 28º18’29”	S 25º22’35.3”; E 28º18’29”	S 25º22’33.3”; E 28º18’29.4”	S 25º22’33.3”; E 28º18’29.4”

Table 3-2 (Continued): Selection of Sample A

Zone	1B	1B	1B	1B	1B	1B	1B	1B	1B	1B
Town	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik
Plot	21	22	23	24	25	26	27	28	29	30
Date	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007	28/07/2007
GPS	S 25º22’06.4”; E 28º18’18.9”	S 25º22’06.4”; E 28º18’18.9”	S 25º22’06.7”; E 28º18’17.4”	S 25º22’06.7”; E 28º18’17.4”	S 25º22’07.7”; E 28º18’15.5”	S 25º22’07.7”; E 28º18’15.5”	S 25º22’08.2”; E 28º18’14.4”	S 25º22’08.2”; E 28º18’14.4”	S 25º22’08.6”; E 28º18’11.9”	S 25º22’08.6”; E 28º18’11.9”

Table 3-2 (Continued): Selection of Sample A

Zone	1B	1B	1B	1B	1B	1B	1B	1B	1B	1B
Town	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik	Skierlik
Plot	31	32	33	34	35	36	37	38	39	40
Date	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007	08/05/2007
GPS	S 25º21’51.9”; E 28º18’27.9”	S 25º21’51.9”; E 28º18’27.9”	S 25º21’55.1”; E 28º18’29.7”	S 25º21’55.1”; E 28º18’29.7”	S 25º21’58.6”; E 28º18’31.7”	S 25º21’58.6”; E 28º18’31.7”	S 25º22’01.8”; E 28º18’33.5”	S 25º22’01.8”; E 28º18’33.5”	S 25º22’06.3”; E 28º18’36.2”	S 25º22’06.3”; E 28º18’36.2”

Sample B (Figure 3.7) consists of 10 m x 10 m plots in Zone 2. Sample B is systematically selected plots and is used for a vegetation survey. The plots are along the roads, 450 m apart from each other. The plots of Sample B are numbered consecutive with Sample A for consistency during the TWINSPAN analysis (discussed in Chapter 6). Elevation and GPS data for the selection of Sample B are indicated in Table 3.3.

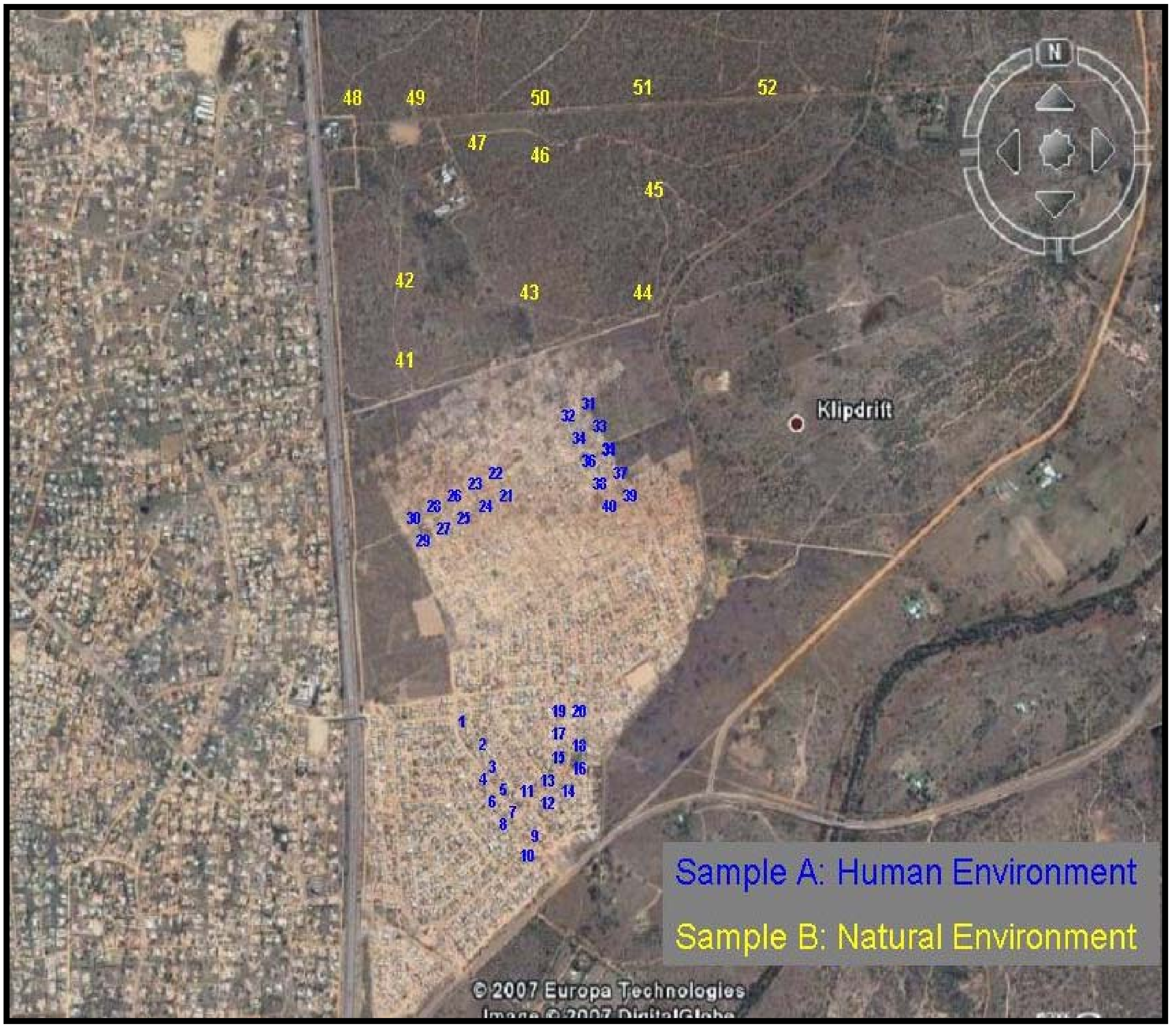

Figure 3-7: An illustration of the selected plots: Sample A and Sample B (Google earth, 2007)

Sample C (Figure 3.8) consists of households in the residential environment. Interviews were done in Sample C. Random houses were chosen for Sample C and interviews were done if people were present. Date and GPS data for the selection of Sample C are indicated in Table 3.4.

Figure 3-8: An illustration of the selected houses in Sample C (Google earth, 2007)

Table 3-3: Sample B Selection

Zone	2A	2A	2A	2A	2A	2A	2A
Plot	41	42	43	44	45	46	47
GPS	25º21'53.8"S; 28º18'08.3"E	25º21'45.6"S; 28º18'06.8"E	25º21'47.1"S; 28º18'26.0"E	25º21'45.6"S; 28º18'39.4"E	25º21'34.0"S; 28º18'40.0"E	25º21'30.7"S; 28º18'29.5"E	25º21'29,6"S; 28º18'15,2"E
Elevation	1091m	1091m	1097m	1093m	1098m	1089m	1086m

Table 3-3 (Continued): Sample B Selection

Zone	2B	2B	2B	2B	2B		
Plot	48	49	50	51	52		
GPS	25º21'25.7"S; 28º18'01.5"E	25º21'25,6"S; 28º18'11,7"E	25º21'25,7"S; 28º18'27.2"E	25º21'25,3"S; 28º18'42.1"E	25º21'24.8"S; 28º18'57.7"E		
Elevation	1090m	1090m	1093m	1095m	1076m		

Table 3-4: Selection of Sample C

Zone	1A	1A	1A	1A	1A	1A	1A	1A	1B	1B
Town	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Kekana	Skierlik	Skierlik
House	1	2	3	4	5	6	7	8	9	10
Date	06/05/2007	06/05/2007	06/05/2007	13/05/2007	13/05/2007	20/05/2007	20/05/2007	20/05/2007	27/05/2007	27/05/2007
GPS	S 25º22'39.5"; E 28º18'22.2"	S 25º22'37.5"; E 28º18'17.8"	S 25º22'35.1"; E 28º18'17.9"	S 25º22'30.0"; E 28º18'13.3"	S 25º22'30.0"; E 28º18'13.3"	S 25º22'27.2"; E 28º18'17.2"	S 25º22'24.8"; E 28º18'17.2"	S 25º22'24.9"; E 28º18'18.7"	S 25º22'17.4"; E 28º18'18.8"	S 25º22'19.1"; E 28º18'14.2"

4 THE ECONOMICAL SYSTEM

The economical system uses the resources of the ecological system to provide products to satisfy the household's needs (Figure 2.2). It is therefore important to develop economical sustainability.

This chapter will shortly discuss the growing gap between rich and poor, which causes economical instability and eco-localism as a proposed idea to reach economical sustainability.

4.1 LEVELS OF COMPLEXITY

For the purposes of this study the economical system are divided into different levels of complexity as indicated in Table 4.1.

Table 4-1: The levels of complexity of the economical system

Scale	Example
International scale	Global economy
National scale	First / third world countries
Local scale	Urban / peri-urban / rural
Household	Living standards measure (Income, material resources, capital etc)
Product group required by system	Functional trait, food, energy, water etc
Product	Bio-diesel, vegetables, etc
Product sub-assembly	Bio-diesel feedstock, maize etc.
Component	Oil, glycerine, starch etc.
Molecules	CO_2, O_2 etc.

4.2 THE GROWING GAP BETWEEN RICH AND POOR

4.2.1 Literature

The gap between rich and poor people in South Africa increases due to a lack in job-creation and education (Leuvennink, 2005). Nürnberger (1987) describes the situation as dangerous and even as a threat to the survival of humans. Economic growth is drawn towards the centres, while the periphery is marginalised and becomes poorer. On a national scale this phenomenon is observed in every country including South Africa. On a global scale, the USA is the industrial centre and the Third World is the periphery (Nürnberger 1987).

This process occurs due to various factors.

- **Population growth in the periphery**: Previously the African culture relied on a high birth rate to counteract the high mortality rate. Many children were a big advantage, because they could work and produce some income when they are older. For African people children are not expensive, because they did not spent money on education, medicine etc. Improved medicinal technology reduced the mortality rate. The birth rate did not reduce, because cultures do not adapt as quickly as the technology changes. This causes an exponential growth in population size (Nürnberger 1987).

- **Economical growth in the centre:** Productive capital is one of the reasons for the exponential growth of the economy in the centre. These capitals can produce improved technologies and machines that work better and faster. The centre has better infrastructures such as roads, methods of communications, water and electrical appliances etc. The centre is also characterised by initiatives, technical, administrative and managerial skills etc. The rural periphery does not have these technologies, infrastructures and skills making it difficult for them to compete with the centre. The periphery is further marginalised (Nürnberger 1987).

- **The historical advantage of the centre:** The development of modern technology extended over millions of years and only now it is accelerating very rapidly. It is therefore not possible for the rural community to catch up with the latest technology in order to compete. People in the centre of the economy are born into a culture that is far ahead in technological development compared to those in the periphery. We are flying space capsules at a speed nearly 30 000 km/h, while some people still use a mule-cart. The people in the periphery are forced to buy the products from outside their own economy, because they simply cannot produce it themselves. The periphery is therefore dependent on the centre (Nürnberger 1987).

- **The power of the centre:** The centre influence the periphery in more subtle ways than many would expect. The centre has power and status, and therefore determines the way of living, the needs, consumption patterns and expectations of the periphery. The culture of the people is forgotten. Often illogical behaviour of people can be explained by their feeling of fitting in with the standards of the centre (Nürnberger 1987).

- **A cyclic process:** The rich will stay rich and the poor will stay poor, because of a cyclic process. The rich bring up their children with much care and all the right medicine and nutrition. The child is stimulated with toys, pictures, books and puzzles. The child has a hard-working father as a role model and then he is sent to the best school with many opportunities. A child born in a poor household might suffer permanent damages due to a lack in proper medicine and food. He herds the cattle from a young age and never plays with stimulating toys. His father is probably a drunkard, if he knows his father at all. Most of these children never finishes school and will become a poor man too (Nürnberger 1987).

The growing gap between rich and poor is a problem because both the rich and the poor has a huge impact on the ecosystem, the rich deplete resources while producing harmful waste products and the growing population numbers of the poor reduces the agricultural potential of a country (Nürnberger 1987).

The growing gap between rich and poor also results in social instability. Crime, poverty and hunger are only a few of the symptoms of the situation.

4.2.2 Fieldwork

The aim of the fieldwork was not to study the economical system of the selected site, but some observations were made on this subject:

- The population density is high and infrastructures and technologies are poorly developed
- It seems as if the urban environment influences the ways and standards of living of the people in the selected site e.g. people want flower gardens in stead of vegetable gardens
- Some have flower gardens, but are still hungry while others do not have the resources to make gardens at all

4.3 ECONOMICAL FEASIBILITY OF SMALL-SCALE PRODUCTION

The concept of sustainability in a functional household system can also be expanded and applied in economical terms. Small farms tend to conserve the aesthetic value of the environment better than large farms. Though it is difficult to quantify the sense of place, it is important for tourism, influencing the economy (D' Souza *et al.*, 1998).

The eco-local economic theory, or eco-localism, argues that sustainability can be reached if communities can be economically independent, while global economies could be unsustainable. The goal of eco-localism is to establish communities that are economically independent (Curtis, 2003).

Eco-localism recognises the unique characteristics of each site, which includes eco-systems, resources and communities of the specific site. Emphasis is placed on locality, because it provides resources and constraints to the local economy and there is a relationship between people and their environment, the environment provides people with stability and safety (Curtis, 2003)

A healthy community economy can be established, but will require the conservation of eco-systems and must comply with social requirements (Curtis, 2003). This is in contrast with the global economy, which moves away from the place and the community. With eco-locality, economic decisions are made by people that understand the needs and requirements of the community and the ecology of the area.

Eco-localism promotes the management of a household in order to improve values such as environmental responsibility, community health, love and loyalty to the place, etc (Curtis, 2003). Other values also include independence and interdependence, security and self-reliance. This is in contrast to views that promote maximum financial success. The benefits from these values cannot be measured in wealth, income and possessions (Curtis, 2003). Other goals should also be reached, such as independence, diversifying local economic capital and improving the knowledge and skills of the local people (Curtis, 2003).

4.3.1 Scale and Efficiency

The concept of scale economies argues that economical output increases faster than economical input. In other words, mass production decreases the cost per item. From an economical viewpoint small-scale production therefore seems to be inefficient (Curtis, 2003). Figure 4.1 indicates the hypothetical effect of farm size on the economical system.

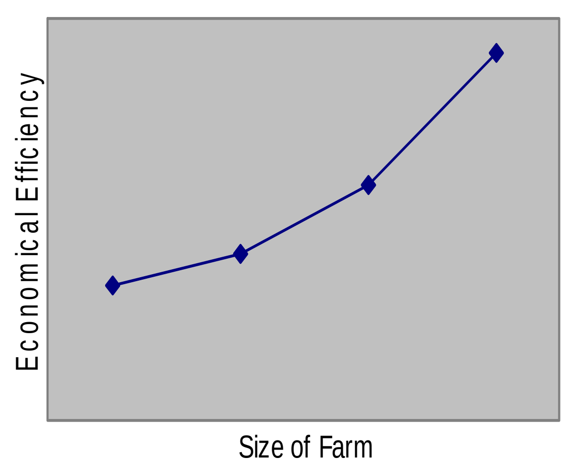

Figure 4-1: The effect of farm size on the economical system (D' Souze *et al.*, 1998)

Eco-localism does not agree with this. Small-scale production on a local scale has reduced transportation, administrative, marketing and communication costs. Global economy requires more input to satisfy the consumer, since the consumer is further away from the producer and the producer does not understand the needs of the consumer. Additionally, the economic efficiency of large-scale production is not due to more efficient production, but large-scale productions are generally subsidised (Curtis, 2003). D' Souza *et al.* (1998) also refers to the potential of diseconomies of size. Beyond a certain threshold, an increase in size reduces economic efficiency.

4.3.2 Consumption

Eco-localism seeks to reduce consumption and the ecological footprint and increases the quality of life. Currently there is a big gap between the consumption of rich and poor. The rich uses their wealth to obtain resources from and deposit their waste in other geographical areas (Curtis, 2003).

Eco-localism limits people to their geographic area, limiting their footprints within their own boundaries. They will be more aware of the damage they cause and will directly be affected by their own damages. Restricting people's consumption to local resources will confine people to their ecological limits (Curtis, 2003).

4.3.3 Trade and Self-Reliance

Self-reliance is an important goal to reach in eco-localism. It improves community building, develops the local social and human capital and improves the quality of life of the community. Trade is still important, because resources are not always available in every local area. By a community should not be dependent on long-distance trade. Curtis (2003) proposes that the basic needs of the community must be locally satisfied, while products in excess can be traded with.

Self-reliance and reduced dependence on trade has certain trade-offs. Local production might not be able to provide the same diversity that could be provided from outside. On the other hand, the locally produced products will suit the local people best and more varieties will probably be unnecessary (Curtis, 2003).

5 THE SOCIAL SYSTEM

This chapter is concerned with the social system in terms of its relationship with the ecosystem. It is important to understand the character of the social system involved, because sustainability is influenced by the social system and land use.

According to Curtis (2003) the community knows and understands the eco-system of the area and how to manage it. It is a question whether this is still true in the present context. The social system is studied in this chapter, focusing on the needs of the household and how these needs are fulfilled by the natural environment.

5.1 LEVELS OF COMPLEXITY

For the purposes of this study the social system is divided into different levels of complexity as indicated in Table 5.1.

Table 5-1: The levels of complexity of the social system

Scale	Level of Complexity
Global scale	The human race
National scale	Nationalities
Local scale	Communities
Small scale	Household
Sub-system	Individual

This study is concerned with finding technologies for the social system on the household level, and seeks to integrate these technologies with the community level.

5.2 SMALL-SCALE PRODUCTION

According to D' Souza *et al.* (1998), the effectiveness of rural development is reduced as the size of the development project increases, as indicated in Figure 5.1.

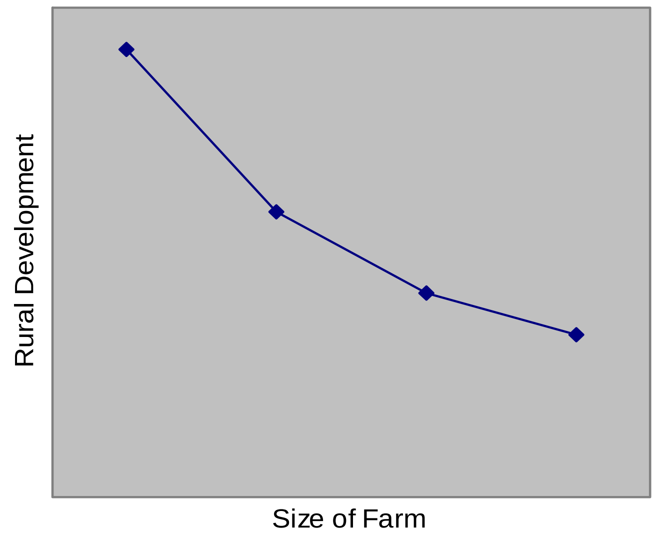

Figure 5-1: The effect of farm size on the effectiveness of rural development (D' Souza *et al.*, 1998)

5.3 NEEDS OF THE HOUSEHOLD

The social system has **real needs** i.e. necessities required to satisfy fundamental human needs. Real needs influence the quality of life of the people. The social system also has **felt needs**, i.e. the residents' perceptions of the necessities required to satisfy fundamental human needs. The real needs could be neglected in order to satisfy the felt needs.

The ecosystem can provide certain inputs to satisfy the needs of the household (see Figure 2.2). Max-Neef (1989) studied human needs and compiled a list of fundamental needs that can be satisfied in different ways in different cultures.

The NOVA institute, an independent research and development organisation has compiled a number of aspects that have to be dealt with properly for a household to function in a healthy way (Figure 5.2).

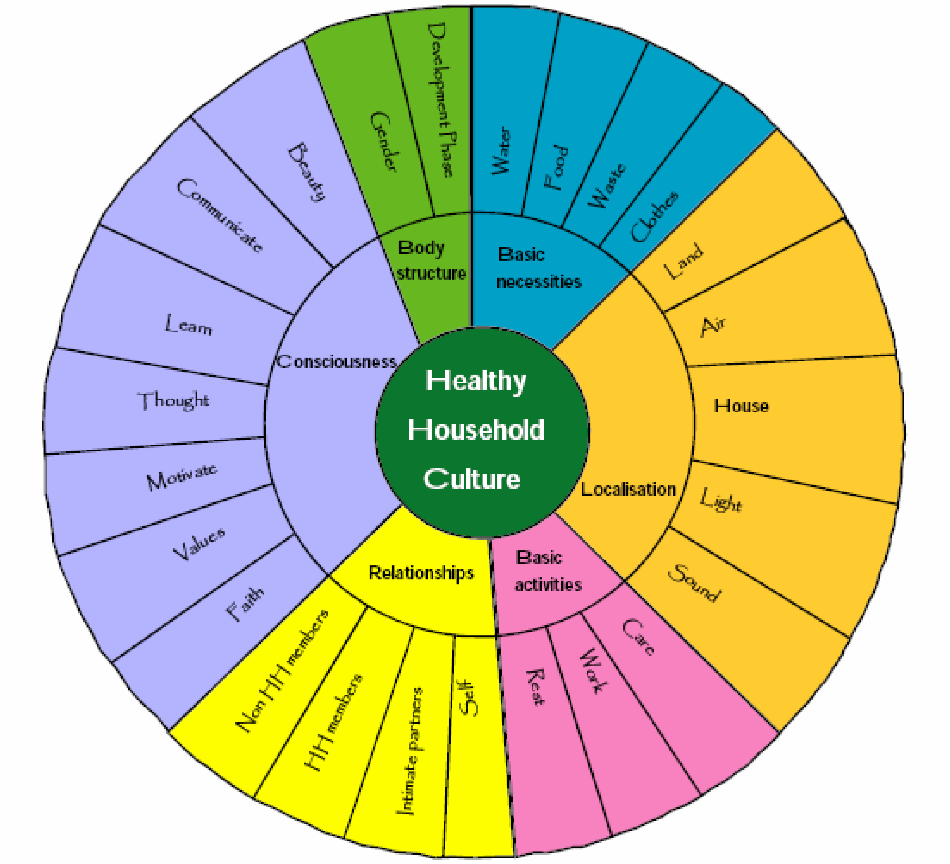

Figure 5-2: Nova's diagram of important aspects of a household

5.4 FIELDWORK

Fieldwork was done in the residential environment of the selected site to determine the current and desired land use. Land use is defined here as the utilisation of resources from the ecosystem. It could be ecologically destructive, but good management could make it more sustainable. During the fieldwork attention was given to the use of space, soil and water.

The land use leaves an ecological footprint, which is seen in this study as the output of the social system in terms of its effect on the ecosystem (refer to Table 2.1). The current land use is therefore a very important part of the relationship between the social system and the ecosystem. Fieldwork was done to form a better understanding of the current land use of the social system and its effect on the ecosystem.

5.4.1 Scoping

The scoping process was done in order to prepare the fieldwork by observations during several visits to the community and discussions with professional people who work in the area.

- **Results from scoping**

The following results from the scoping process influenced the way in which the fieldwork was conducted:

– Space in the yard is subdivided. Vegetable gardens are usually planted at the back of the house, flower gardens and lawns are planted in front of the house

– Large areas of the yards are empty unproductive soil

– In many houses the soil are mostly not covered by plants and are swept clean everyday

– Some gardens seem to be very dry

– Some gardens have many plants and seem to be irrigated regularly

It was concluded that the land use as observed was determined, not only by the ecological and the economical conditions, but also by the meaning people attach to the land and their relationship to the land.

5.4.2 Materials and Methods

One way to determine the underlying meaning that influences their activities and land use practices, is to make observations and do interviews with the residents themselves. The current land use was studied by observations and interviews as discussed below.

- **Observations to determine the current land use**

A household survey was done to collect quantitative information of current land use in 50 households in Sample A and in Sample C. Three main types of land use were identified namely, agriculture, a flower garden with a very small lawn and bare swept soil. All other land uses were noted under a separate category (Table 5.2).

This quantitative survey was followed up by qualitative research done with 10 household in Sample C

Table 5-2: Datasheets used during household survey to determine the current land use

Land use	**Household nr**	
Agriculture	Present	Absent
Garden with lawn	Present	Absent
Bare swept soil	Present	Absent
Other	Present	Absent

- **Interviews to find possible reasons for the current land use**

It is difficult to determine the meaning people attach to resources, because this meaning is at a deeper level than their everyday activities. Interviews were done with 10 household in Sample C (Figure 3.8) to determine this underlying meaning that influences the current land use. The interviews were done to form a better understanding of why certain land uses occur and not to quantify a specific land use. Qualitative methods were therefore applied during the interviews on a small sample of households. A local student from the AIM University was present during the interviews to translate and explain the questions to the people.

Questions were formulated (Table 5.3) according to the results from the scoping process, as discussed above.

Table 5-3: Questions used to guide the interviews on the current land use

QUESTIONS
1. SPACE
Why do you plant your vegetables at the front or back of the house?
Why do you not use all the space in your yard for vegetable production?
2. SOIL
Do you sweep the yard everyday?
Why do you sweep the yard everyday?
3. WATER
Do you irrigate your garden?
Do you have enough water to irrigate your garden?

- **Interviews to get an indication of the desired land use**

A discussion was initiated to form a better understanding of the most desirable way of living, which is directly related to the land use. This discussion was stimulated by showing three photos of different houses during the interviews. The first photo (Figure 5.3) is of a traditional hut, in harmony with the natural environment, with some food crops planted next to the house. The second photo (Figure 5.4) taken in Kekana Gardens has a garden of ornamental plants. The purpose of such a garden is purely aesthetical and no food is produced. This garden also requires high inputs of energy and resources. The third photo (Figure 5.5) is taken in Skierlik. The soil is bare and swept with very few plants. The latter two are both taken on the selected site. The people were asked to choose the most desirable house and to explain why they chose it. Their answers where compared to their current land use.

Figure 5-3: Photo shown during interviews of a traditional hut in harmony with the natural environment and a few crops planted outside the house (Forasté, 2007)

Figure 5-4: Photo shown during interview of an aesthetical garden with no food production

Figure 5-5: Photo shown during interviews of yards where the soil is bare and swept

5.4.3 Results

- **Observations**

The observations on the current land use made in Sample A are indicated in Table 5.4. The most important results on land use practices from Table 5.4 can be summarised by the following:

– 100% of the selected sample had an area of empty unproductive soil, which they sweep everyday

– 25% in both Kekana Gardens and Skierlik had signs of agriculture i.e. where soil is actively tilled and watered

– 35% of the households in Kekana Gardens and 30% of the households in Skierlik had a flower garden or lawn

During the fieldwork additional observations were made, but quantitative information was not collected regarding these observations. These observations could be studied during further research and could be of importance.

– Fruit trees seem to be more popular than vegetables

– All natural vegetation is cleared from the yards, except for a few indigenous trees in some of the households

– Lawns are small, with no apparent use or function

– Lack of water is a major problem in some households, while their neighbours have a complete garden with a lawn, which is an indication of abundant water

– Sometimes if vegetables are planted in front, they are hidden between the flowers

– Many exotic ornamental trees are planted by no indigenous trees

Table 5-4: Observed land use in Sample A

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
Bare swept soil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Agriculture	Yes	Yes	Yes	No	No	No	No	No	No	No
Garden with lawn	No	Lawn only	No	Yes	No	No	No	On pavement only	2 Lawns	No
Other	Rubble	-	-	-	Rubble, Roofing shop, wood & cement	-	Rubble	-	Rubble	Still building, Rubble

Table 5-4 (Continued): Observed land use in Sample A

	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16	Plot 17	Plot 18	Plot 19	Plot 20	Average for Kekana
Bare swept soil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100% Yes
Agriculture	No	No	No	No	Yes, soil is tilled	Yes	No	No	No	No	25% Yes
Garden with lawn	Yes	Yes	No	No	No	No	No	No	Yes	No	35% Yes
Other	-	-	-	-	-	-	-	Rubble, bricks, soil tilled & shop on yard	-	-	30% other land use

Table 5-4 (Continued): Observed land use in Sample A

	Plot 21	Plot 22	Plot 23	Plot 24	Plot 25	Plot 26	Plot 27	Plot 28	Plot 29	Plot 30
Bare swept soil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Agriculture	No	No	No	No	No	No	No	Yes	No	No
Garden with lawn	No	No	No	No	No	No	No	Yes	No	No
Other	-	Loose bricks	-	-	-	-	Loose bricks	-	-	-

Table 5-4 (Continued): Observed land use in Sample A

	Plot 31	Plot 32	Plot 33	Plot 34	Plot 35	Plot 36	Plot 37	Plot 38	Plot 39	Plot 40	Average for Skierlik
Bare swept soil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100% Yes
Agriculture	Yes, soil is tilled	No	No	Yes	Maize in front yard	Yes	No	No	No	No	25% Yes
Garden with lawn	No	Yes	Yes	No	No	38m2 lawn	Grass on pavement, recently planted lawn	No	No	16m2 lawn	30% Yes
Other	-	Fire wood	Soil tilled and dug	Rubble, sand	-	Rubble, sand	Soil tilled	Bricks for building, weedy at back	-	Rubble	45% other land use

- **Interviews**

The answers from the questions (Table 5.3) that were used during the interviews are indicated in Table 5.5. The most important qualitative results are summarised below:

– From the interviews most people indicated that they would plant food in the back yard and not in the front yard

– Some people do not plant more food due to a lack of water

– None of the households produce enough food to sustain themselves

Interesting remarks were also made during conversations. These remarks give important insights to the relationship between the people and the ecosystem and include the following:

Remarks that express fear:

– They plant their food behind the house or between other plants to hide it, because it will be stolen and they want their front yard to be nice (Table 5.5, Household 2 and 7)

– They cleared the natural grasses around the house to get rid of snakes (Table 5.5, Household 9 & 10)

– In traditional villages people planted food in the front yard, because it was not stolen there (Table 5.5, Household 2)

Remarks on the aesthetical value of a garden

– The flower garden is nice, she wants the yard to be nice (Table 5.5, Household 8)

– People with no gardens are poor or lazy (Table 5.5, Household 4)

Remarks on mythical conceptions

– You may not work in the garden on a Saturday, because people are being buried on a Saturday and you must have respect for the soil if people are being buried (Accompanying member)

– Trees are cut down because snakes travel through the air and come to live in the trees. When lightning strikes you can hear the snakes and then they come to your trees (Household 7)

- Ancestors are not bound to the soil where she comes from, if she moves she just tells the ancestors and they will move with her (Table 5.5, Household 9)
- The whole stand is related to the ancestors, they protect her. She also believes in God (Household 8), similar remarks from Household 7 and 9

Remarks that distinguish between indigenous and exotic trees

- She has a lot of trees, but she only likes some of them (Household 8)
- Could not afford indigenous trees (Table 5.5, Household 7)
- They believe in something that can benefit them (Household 7)
- They copied from one another (Household 7)
- People like modern trees more than African trees, people live in two different worlds (Table 5.5, Household 7)

Regarding the preferred land use, every household in Sample C prefers the flower garden above the traditional hut or the garden with clean swept soil (Table 5.6). For some the traditional hut is second best, but nobody liked the area with clean swept soil.

Table 5-5: Interviews on the current land use in Sample C

Question	House 1	House 2	House 3	House 4	House 5	House 6
Use of Space						
Do/would you plant food crops in front or at the back of house?	Back	Back	Back and front	Back	Back	Back
Why?	Protect from animals	Protect from thieves	Safe in front or back (Fence)	How it is supposed to be	How it is supposed to be	How it is supposed to be
Why do you not produce more food in your yard?	Vegetables should only be at back	No money, no water	No water, no plants, children play on bare soil	Like nice gardens. Not dependent on soil, works as police	No water. Not dependent on soil, works in furniture shop	To little water
Use of Soil						
Do you sweep the yard?	Yes	Yes	Yes	Yes	Yes	Yes
Why?	To make it clean	To make it clean	To make it clean	To make it clean	To make it clean	To make it clean
Use of Water						
Do you irrigate your garden?	Yes	Yes	Yes	Yes	No	No
Is there enough water to irrigate your garden?	No	No	No	Yes	No	No
Remarks	Clean water used to irrigate lawn, bath water thrown on bare soil	She would plant vegetables if she has enough money & water. There were no thieves in the traditional villages	0	He has a good job. Enough water to irrigate his garden, people without gardens is lazy / poor. Vegetables needs more attention than fruit trees	Man works in shop,	0

Table 5-5 (Continued): Interviews on the current land use in Sample C

Question	House 7	House 8	House 9	House 10	Summary
Use of Space					
Do/would you plant food crops in front or at the back of house?	Back yard	Back	Back or front	Back	80% would plant food crops at the back, 20% in front& back
Why?	To protect it	Wants a nice garden	Does not matter	Wants a nice garden	40% for protection, 30% due to tradition, 20% for aesthetic value
Why do you not produce more food in your yard?	Interested in garden. Not dependent on soil, work at air force	Wants a nice garden	No water, likes ornamentals	No water	30% is not dependent on food production, 60% due to lack of water
Use of Soil					
Do you sweep the yard?	Yes	Yes	Yes	Yes	100% sweep soil
Why?	To make it clean	To make it clean	To make it clean	To make it clean	100% to make it clean
Use of Water					
Do you irrigate your garden?	Yes	Yes	Yes	Yes	80% Yes
Is there enough water to irrigate your garden?	No	No	No	No	90% No
Remarks	Vegetables in front between flowers. People like modern trees more than African trees, they live in 2 worlds. Snakes travel in the air and when lightning strikes they come to the indigenous trees	Bath water thrown on grass. Not enough food for her family	Cleared the natural vegetation, because they are afraid of snakes	Cleared the natural vegetation, because they are afraid of snakes. Begged for food, money and blankets	0

Table 5-6: Current land use versus the desired land use in Sample C

	House 1	House 2	House 3	House 4	House 5	House 6
Observed Current land use						
Land use						
Bare swept soil	Yes	Yes	Yes	Yes	Yes	Yes
Agriculture	Yes, vegetables	Yes, fruit trees	Yes, vegetables & fruit	Yes, fruit trees	Yes, vegetables & fruit	Yes, fruit trees
Garden with lawn	Yes	No	No	Yes	Yes	Yes
Other		Tree for shade				
Interviews on Desired land use						
Question						
Which house do you prefer (Figure 5.3, 5.4, 5.5)	Flower garden	Flower garden, also the traditional hut	Flower garden, also the traditional hut	Flower garden, also traditional hut	Flower garden	Flower garden
Why?	Its nice	Its nice	Its nice	Its nice	Its nice	Its nice

Table 5-6 (Continued): Current land use versus the desired land use in Sample C

	House 7	House 8	House 9	House 10	Summary
Observed Current land use					
Land use					
Bare swept soil	Yes	Yes	Yes	Yes	All households have bare swept soil
Agriculture	Yes, vegetables & fruit	Yes, fruit trees	Yes, fruit trees	No	Fruit trees are most popular
Garden with lawn	Yes	Yes	No	No	Not all households have garden with lawn
Interviews on Desired land use					
Question					
Which house do you prefer (Figure 5.3, 5.4, 5.5)	Flower garden	Flower garden	Flower garden	Flower garden	All houses preferred flower garden
Why?	Its nice	Its nice	Its nice	Its nice	Because its nice

6 THE ECOLOGICAL SYSTEM

During the previous chapter, research was done to study the social system and its relationship with its environment. This chapter is also concerned with the relationship between the social system and the environment, focusing on the ecosystem. This relationship should be managed to have optimal ecosystem functioning and to improve ecosystem sustainability.

The role of the ecosystem in the residential environment should be contemplated. The ecosystem provides the framework, setting the rules and limitations, but it should also be utilised. Therefore, the research should focus on:

– The functioning and requirements of the ecosystem itself (the framework)

– The relationship between the ecosystem and the social system

A literature review was done to understand the functioning of the ecosystem and fieldwork was done to form a better understanding of the current relationship between the ecosystem and the social system of the selected site.

6.1 LEVELS OF COMPLEXITY

The different levels of complexities of the ecosystem (Table 6.1) form an important part in understanding the functioning of the ecosystem (Kent & Coker, 1992).

Small-scale production in a household system interacts with the ecosystem on the plant community level and all its products. It can also have an effect on the ecosystem at higher levels. The plant community is a fascinating subject, which was debated as early as 1900 by F.E. Clements and H.A. Gleason. They stated the two extreme viewpoints of plant communities (Kent & Coker, 1992).

Table 6-1: The levels of complexity of the ecosystem

Scale	Level of Complexity
International environment	Ecological processes with a global effect such as greenhouse effect, global warming, depletion of fossil fuels and destruction of ozone
National environments	Bioregions
Local environment	From a distance, **growth forms or physiognomy** of vegetation can be distinguished, like forest, grasslands,

	woodlands etc (Kent & Coker, 1992).
Household system	Within a specific growth form more inconspicuous changes are found such as slight changes in colour and species composition. This divides plants with the same growth form into **plant communities** (Kent & Coker, 1992), which is a very important concept in this study.
Product group required by system	Plant communities are composed of **populations** of different species.
Product	A population is many individuals of one **species**, which is the final and most basic level of complexity of vegetation (Kent & Coker, 1992).
Product sub-assembly	A species is composed of individual organisms
Component	An organism is composed of anatomical structures and body parts
Material / Process	Body parts are composed of cells
Elements	Cells are composed of elements e.g. Carbon

6.1.1 The Plant Community Described by Clements

Clements' view of the plant community is known as the *organismic concept* (Kent & Coker, 1992). The community is a strong and stable unit with many associations between the different species. A plant community is such a strong unit, in fact, that it can be seen as one organism, which is stronger than the sum of its individual parts. One must therefore be careful of classifying vegetation as merely the list of species of which it is composed (Bredenkamp, 2001). According to Clements, the plant species associated with each other in one area will probably be associated with each other in all areas with similar climatic conditions. Figure 6.1 is a schematic indication of Clements' view of plant communities (Kent & Coker, 1992).

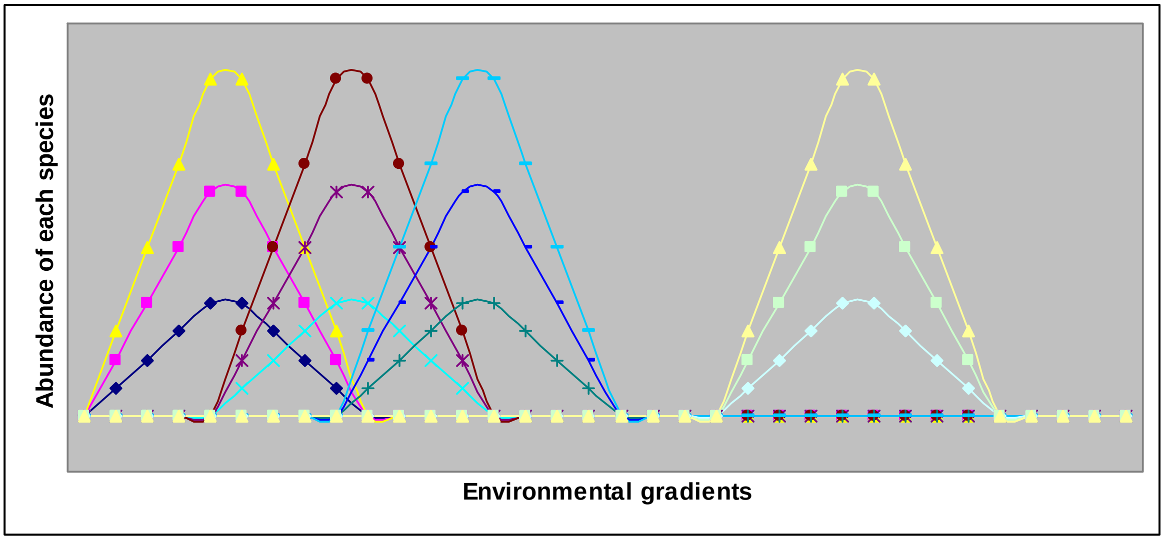

Figure 6-1: Clements' description of plant communities, forming distinctive units

6.1.2 The Plant Community Described by Gleason

Gleason had the opposite approach to plant communities, known as the *individualistic concept*. He believed that plant species are separate entities, growing solely according to external impacts and their tolerance levels. Since the climatic conditions are very variable, you will always get a different combination of species composition (qualitative) and species abundance (quantitative) in any given area. According to Gleason, species abundances changes gradually from one area to the next, according to external gradients, without forming a plant community with distinct edges. Figure 6.2 is a schematic illustration of Gleason's view of plant communities.

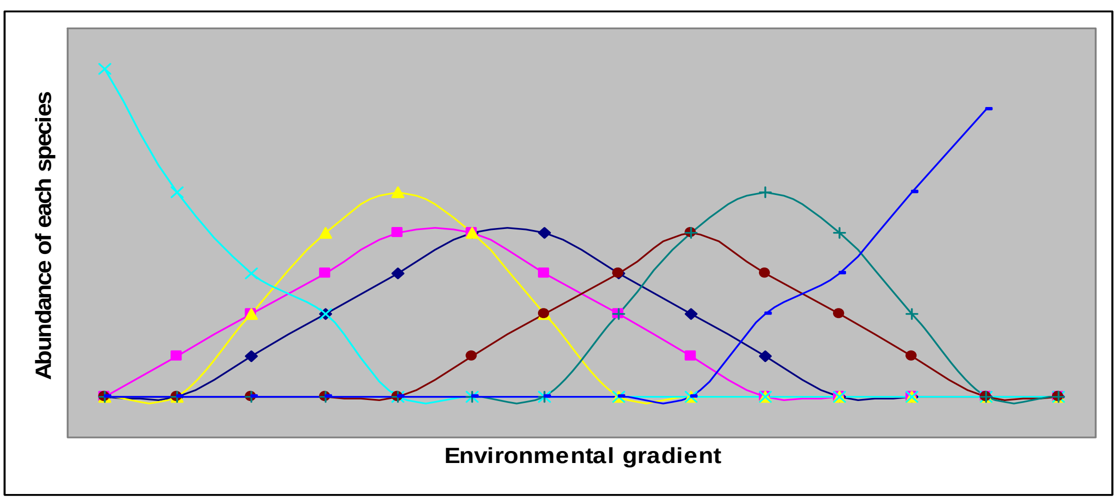

Figure 6-2: Schematic representation of Gleason's approach to plant communities

6.1.3 Formation of Plant Communities

- **Succession**

Plant communities develop by the process of succession, if environmental conditions are stable and favourable, such as high and predictable rainfall. Succession is derived from an equilibrium approach. The first, or pioneer, community which arrives at a disturbed site is usually less diverse and the species invest in reproduction (Fenner, 1985). These species are less compatible and can only survive in areas with less competition, such as disturbed sites. They produce many seeds which are then widely spread, to reach other disturbed areas with little competition (Kent and Coker, 1992).

The early communities at a site are eventually dominated by species that are more competitive. These species grow slower; produce few but more competitive seeds and live longer (Fenner, 1985). Succession will continue until a climax community is established, characterised by a higher diversity in plant species with perennial and highly competitive species. Where succession implies change of vegetation, the climax community is in a dynamic equilibrium. The species composition of the climax community is determined by many different things such as climate, soil, topography, humans and animals (Kent and Coker, 1992).

- **Events driven systems**

Plant communities in arid conditions usually do not have the opportunity to reach a state of equilibrium. In these areas one would typically find non-equilibrium or events-driven systems. In such a system plant communities will be moved from one state to another by a single event such as drought. Therefore abiotic factors directly control these systems, while biotic mechanisms such as grazing have no direct impact. An events-driven system is therefore unpredictable (Bredenkamp & Brown, (2007).

The dynamics in plant communities are mainly dependent on climate, since climate influences the available soil moisture. The dynamics in a plant community are correlated with a gradient in available soil moisture. At the two extremes of the gradient non-equilibrium systems such as events driven systems are usually found in arid environments while equilibrium systems such as succession are found in areas with high water availability. According to Bredenkamp & Brown (2007) environments between the two extremes have different degrees of equilibrium and non-equilibrium systems and this can also change over time. During times of drought, the current system may change into a non-equilibrium system.

The dynamics of the savanna in the selected site, with an annual rainfall of 674mm (refer to Table 7.3) per year, are likely to change in degrees of equilibrium and non-equilibrium systems.

6.2 SUSTAINABILITY OF THE PLANT COMMUNITY

Studying the functioning of the ecosystem can provide insight on how to reach sustainability. Succession tends to develop towards a higher diversity, which is believed to contribute to the stability of the climax community. Higher diversity is also stable, from a genetic point of view, because environmental conditions are variable and uncertain. In certain environmental conditions, such as pest and disease outbreaks, some plants will not be fit to survive, while others will be. This creates a buffer against unpredictable environmental conditions and total destruction of vegetation (Fairbanks and Andersen, 1999). Ecosystems have different ways to increase bio-diversity and prevent the multiplication of a single species:

- If, for example, a certain plant species increases in numbers, the predators of the plant species will increase, due to the availability of food. As the predator numbers increases, the plant species will again decrease in numbers, until equilibrium is reached. In this way, the numbers of species are regulated and diversity increases (Fairbanks and Andersen, 1999).

- In some cases the mother plant utilises the nutrients in the soil that a seedling needs to survive and the predators of the specific plant is concentrated close to the mother plant. These are some of the reasons why the seedlings have a better change to survive if they are distributed far from the mother plant and each other, preventing a concentration of one species on a specific area (Louda, 1989).

According to Kent and Coker (1992), the concept that diversity is needed or ensures stability of a community could not always be applied. There are many examples of communities with low species diversities, which are very stable. There are also examples of communities with high species diversities that are not stable. According to them environmental stability provides stability of the community. The community will develop diversity under stable environmental conditions over time.

6.2.1 Plant Functional Types (PFT)

Previously the road to sustainability was thought to be the establishment of equilibrium within a system. Today it is recognised that a system should be dynamic and adaptable in order to maintain productivity during times of stress (Crabtree 2005). Instead of focusing on the individual, PFT identify the functional traits needed to sustain a community and perform the functions of an ecosystem. Individuals are classified into groups according to these functions.

6.2.2 The Ecological Sustainability of Small-Scale Production

Scale has direct ecological implications on ecosystem sustainability, but it also influence the land use of the site, therefore influencing ecosystem sustainability indirectly.

Ecosystem fragmentation is seen as a threat to biological diversity (Collinge, 1996). Larger ecosystems are more heterogeneous in terms of genetic, species and ecosystem diversity. Fragmentation of ecosystems increases the edges of the habitat and impairs the movement of species, which isolates species in smaller fragments (Collinge, 1996). Small-scale production can therefore be unsustainable, since the fences prevent the movement of organisms and genes. It is therefore very important to manage the fences correctly in order to maximise movement between the ecosystems. Equally important, one should expand and integrate the concepts developed for the household into the higher community level, which can effectively increase the size of the ecosystem.

Smaller farm sizes can indirectly affect the ecosystem, due to different land uses. Large-scale commercial farms are characterised by monocultures, tilling of soil as well as the use of fertilisers and pesticides in order to increase production. According to D' Souza *et al.* (1998), a decrease in farm size results in an increased ecosystem sustainability as indicated in Figure 6.3.

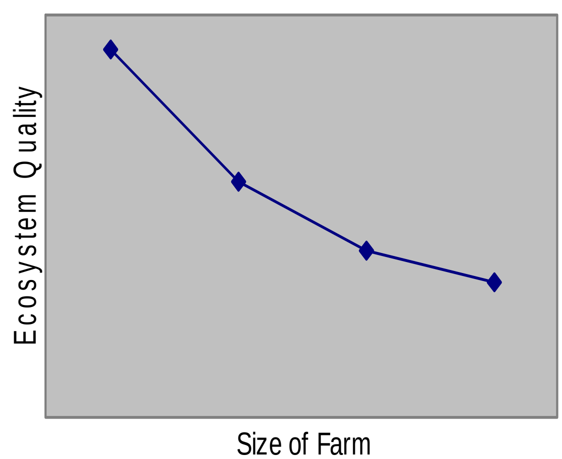

Figure 6-3: The effect of large scale commercial farms on the ecosystem (D' Souza *et al.*, 1998).

This increase in ecosystem quality with the decrease in farm size can be explained by the following:

- **Site specific farming methods**: Small-scale farmers tend to adapt their practices according to the environment, contrasting with commercial farmers, who modify the environment according to the land use. Small-scale farms cause therefore less environmental degradation (D' Souza *et al.*, 1998).

- **Effective management**: Small-scale farmers are able to manage their farms more intensively than large-scale farmers. Thus they are able to implement conservation methods more efficiently. For example, soil degradation on small farms is less severe that on irrigated large farms (D' Souza *et al.*, 1998).

- **Less intensive land use**: The low-income household uses primitive equipment, which causes less damage to the soil and vegetation.

6.3 THE ROLE OF THE ECOSYSTEM

The interaction between ecosystems and the other systems can be analysed by distinguishing between (see Figure 2.2):

- The **inputs** needed by the ecosystems

- The **outputs** of ecosystems

- The **requirements** or the rules of ecosystems

6.3.1 Inputs

Agriculture tends to increase the inputs into an ecosystem in order to increase productivity. Irrigation, fertilisers, pesticides and herbicides are examples of human inputs. Chemicals have adverse effects on the ecosystem as well as the other systems. Industrialisation introduces waste products and pollution.

6.3.2 Outputs

The ecosystem plays the role of the producer, sustaining all species by providing resources. The material outputs of the ecosystem include food, fibre, energy and all other products needed for a healthy economical system. Ecosystems also provide the inputs directly affecting the social system such as, oxygen, water, shade, etc.

If the outputs of ecosystems are exploited beyond their capacity, resources become depleted and ecosystems are destroyed.

6.3.3 Requirements

An ecosystem provides the context within which the other systems must function. Other systems must comply with certain requirements of the ecosystem in order to fit into the context of the ecosystem. The requirements of an ecosystem are complex and for this study the following requirements were identified:

- **The rate of resource utilisation should not exceed capacity of the ecosystem to regenerate resources**: Ecosystems set limitations to the utilisation of resources and the population growth of species, due to a limited carrying capacity

- **Communities in changing environments must be diverse in order to be sustainable**: Most ecosystems constantly move towards a point of equilibrium. This equilibrium includes a diversity of species. Communities with low species diversity are found in static environments, but are less common

- **Material products must be circulated:** Substances that are continuously produced must be used again or be broken down. Pollution accumulates and resources deplete, because matter is not effectively circulated

6.4 FIELDWORK

6.4.1 Materials and Methods; Residential environment

Sample A was used to do observations on the modified ecosystem in the residential environment, Kekana Gardens and Skierlik.

- A final phytosociological table was compiled for Sample A. All plant species were identified in the selected plots a Braun-Blanquet cover-abundance value was assigned to each species. This data was incorporated into a vegetation database created in TURBOVEG (Hennekens, 1996). This vegetation data was analysed using TWINSPAN - Two-Way Indicator Species Analysis (Hill, 1979) in the program JUICE version 6.4 (Tichy, 2002). The analysis was done using a high species cut level with values of; 0-2-3-4-8-18-36-68-88 and 6 levels of division.

- The modified ecosystem was divided into the following components, the fence, plants, animals and humans. A datasheet (Table 6.2) was designed to take notes on these components.

As indicated in Table 6.2, the vegetation in the households was classified into four groups:

1. Agricultural fruit trees
2. Agricultural vegetables
3. Horticultural ornamental trees
4. Horticultural ornamental flowers

Table 6-2: Datasheet for analysis of the modified ecosystem in Sample A

Component of the household		**Household x**	
Fence			
Fence/hedge present		Yes	No
What is fence/hedge made of?		Material or plant species	
Animals			
Type		Identify & count animals present	
Enclosed or free roaming		Enclosed	Free roaming
Humans			
Adults or children, male or female		Identify & count humans present	
Vegetation			
Agricultural	Fruit trees	Identify & count fruit trees present	
	Vegetables	Identify & count vegetables present	
Horticultural	Ornamental trees	Identify & count ornamental trees present	
	Ornamental flowers	Identify & count ornamental flowers present	

6.4.2 Results; Residential environment

The results of the survey on the modified ecosystem in Sample A are indicated in Table 6.3.

Table 6-3: Modified ecosystems in the human environment of Sample A

		Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
Fence											
Fence present		Wire fence	Wire fence	Palisade, incomplete	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence
Hedge of plants		No hedge	Granadilla on fence	No hedge	Dodonaea hedge	2 Single Dodonaea plants on fence	No hedge	No hedge	Dodonaea & Creeper	No hedge	No hedge
Number of Plants											
Agricultural	Fruit trees	8	3	3	4	0	3	2	1	2	0
	Vegetables	1	0	25	0	0	0	0	0	0	0
Horticultural	Ornamental trees	1	7	5	0	1	1	2	1	1	2
	Ornamental herbs	4	2	5	0	4	0	0	5	2	1
Alien plants		1	2	0	2	1	0	0	0	2	4
Animals											
Type		0	0	0	0	0	0	0	0	0	0
Enclosed or free roaming		0	0	Chicken shed, no chickens	0	0	0	0	0	0	0
Humans											
Adults or children		1 Women, 2 Children	1 Woman, 1 Child	1 Woman, 1 Child	0	1 Man, 1 Woman	1 Women	0	0	0	2 Men

Colour codes for Table 6.3	
Community 1.1	(orange)
Community 1.2	(blue)
Community 1.3	(light cyan)
Community 1.4	(pink)
Community 1.5	(purple)

Table 6-3 (Continued): Modified ecosystems in the human environment of Sample A

		Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16	Plot 17	Plot 18	Plot 19	Plot 20	Summary of Kekana
Fence												
Fence present		Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	95% Wire, 5% palisade
Hedge of plants		Dodonaea edge	Dodonaea edge	No hedge	Dodonaea hedge	No hedge	No hedge	Ipomoea hedge	No hedge	Canna hedge	No hedge	45% with hedge
Number of Plants												
Agricultural	Fruit trees	1	3	2	1	2	5	5	0	4	2	Average: 2.55
	Vegetables	0	0	0	0	0	0	0	0	0	0	Average:1.3
Horticultural	Ornamental trees	3	3	3	3	2	2	0	1	4	1	Average: 2.15
	Ornamental herbs/flowers	1	6	3	1	2	1	1	0	10	7	Average: 2.75
Alien plants		3	1	2	0	0	2	1	0	5	6	Average: 1.6
Animals												
Type		0	0	0	0	0	0	0	0	0	0	0% animals
Enclosed or free roaming		0	0	0	0	0	0	0	0	0	0	-
Humans												
Adults or children		0	1 Woman, Children	0	0	0	0	0	1 Man	0	0	People present in 40% of households

Colour codes for Table 6.3	
Community 1.1	(orange)
Community 1.2	(blue)
Community 1.3	(light cyan)
Community 1.4	(pink)
Community 1.5	(purple)

Table 6-3 (Continued): Modified ecosystems in the human environment of Sample A

		Plot 21	Plot 22	Plot 23	Plot 24	Plot 25	Plot 26	Plot 27	Plot 28	Plot 29	Plot 30
Fence											
Fence present		Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence	Wire fence
Hedge of plants		Dodonaea edge	No hedge	Dodonaea hedge	No hedge	Passiflora edulis hedge	No hedge	No hedge	No hedge	No hedge	No hedge
Number of Plants											
Agricultural	Number of fruit trees	1	6	4	2	4	1	1	1	0	1
	Vegetables	0	0	0	0	0	0	0	0	0	0
Horticultural	Ornamental trees	1	2	0	1	3	0	2	0	3	3
	Ornamental herbs/flowers	1	1	1	0	1	2	0	3	1	1
Alien plants		0	2	1	0	1	0	0	1	1	0
Animals											
Type		0	0	0	0	0	0	0	0	0	0
Enclosed or free roaming		0	0	0	0	0	0	0	0	0	0
Humans											
Adults or children		0	0	1 Man	0	0	0	0	0	0	1 Woman

Colour codes for Table 6.3	
Community 1.1	(light orange)
Community 1.2	(blue)
Community 1.3	(light cyan)
Community 1.4	(pink)
Community 1.5	(lavender)

Table 6-3 (Continued): Modified ecosystems in the human environment of Sample A

		Plot 31	Plot 32	Plot 33	Plot 34	Plot 35	Plot 36	Plot 37	Plot 38	Plot 39	Plot 40	Summary of Skierlik
Fence												
Fence present		Wire fence	Wire fence	Wire fence	Wire fence	No fence	Wire fence	Wire fence, broken	Wire fence	Wire fence broken & no gate	Poor wire fence	95% wire, 5% no fence
Hedge of plants		Dodonaea hedge	No hedge	No hedge	No hedge	No hedge	No hedge	No hedge	No hedge	No hedge	No hedge	20% with hedge
Number of Plants												
Agricultural	Fruit trees	1	3	4	0	0	6	6	4	0	0	Average: 2.25
	Vegetables	0	0	1	10	10	0	0	0	0	0	Average: 1.05
Horticultural	Ornamental trees	1	1	9	1	6	1	2	1	1	3	Average: 2.05
	Ornamental herb / flowers	1	0	16	2	1	6	7	1	2	3	Average: 2.5
Alien plants		0	2	1	2	0	0	3	0	0	2	Average: 0.8
Animals												
Type		0	0	0	0	Dog	0	0	0	0	0	5% with animal
Enclosed or free roaming		0	0	0	0	Free roaming	0	0	0	0	0	-
Humans												
Adults or children		0	1 Man, 2 Women	1 Man	0	0	0	1 Man	0	0	0	People present in 25% of households

Colour codes for Table 6.3	
Community 1.1	(orange)
Community 1.2	(blue)
Community 1.3	(light cyan)
Community 1.4	(pink)
Community 1.5	(purple)

- **Fences and hedges**

Fences seem to be important, because almost every stand has a fence. From the interviews it is clear that people are afraid of animals and thieves and the fences are for protection. Fences, mostly wire fences are present in 95% of the households in Sample A (refer to Table 6.3). Hedges, mostly *Dodonaea angustifolia* hedges are present in 45% of the houses in Kekana Gardens and in 20% of the houses in Skierlik.

- **Animals**

Very few animals were seen in the households of Sample A, except for a dog. There was a chicken shed in one of the yards but no chickens were seen. Animals, especially chickens were seen in the streets and people complained about animals during the interviews (Table 6.3).

- **Humans**

The presence of the people is influenced by the time of the week and the time of the day. People were present in 45% of the households surveyed on a Tuesday morning (Plots 1-10 and 30-40), while people were present in 20% of the households surveyed on a Saturday morning (Plots 10-30). The people that were present were mostly woman and children. Men were sometimes present, especially if the house is used for a business (Table 6.3).

- **TWINSPAN analysis and vegetation description**

Table 6.4 is the phytosociological table from the TWINSPAN analysis. The first division of the TWINSPAN analysis is between Sample A, the residential environment and Sample B, the natural environment indicating a considerable difference in the vegetation. The plants in the residential environment are classified as Community 1 and the plants in the natural environment are classified as Community 2. These communities are further subdivided into sub-communities. The classification of the plants of each sub-community as fruit trees, vegetables and ornamental trees and flowers are indicated in Table 6.3.

Table 6-4

Community 1; ***Prunus persica – Sterculia* species Residential Major Community:** The natural vegetation in Community 1 is completely destroyed, leaving the soil bare and unproductive with a low diversity of plant species. Community 1 is characterised by Species Group A, which consists of four fruit tree species; *Psidium guajava, Prunus persica, Mangifera indica* and *Carica papaya* and one ornamental tree species, *Sterculia* species. The TWINSPAN analysis subdivided the households in the residential environment, Community 1, into 5 communities as indicated in Table 6.4 and illustrated in Figure 6.4. These communities are discussed below.

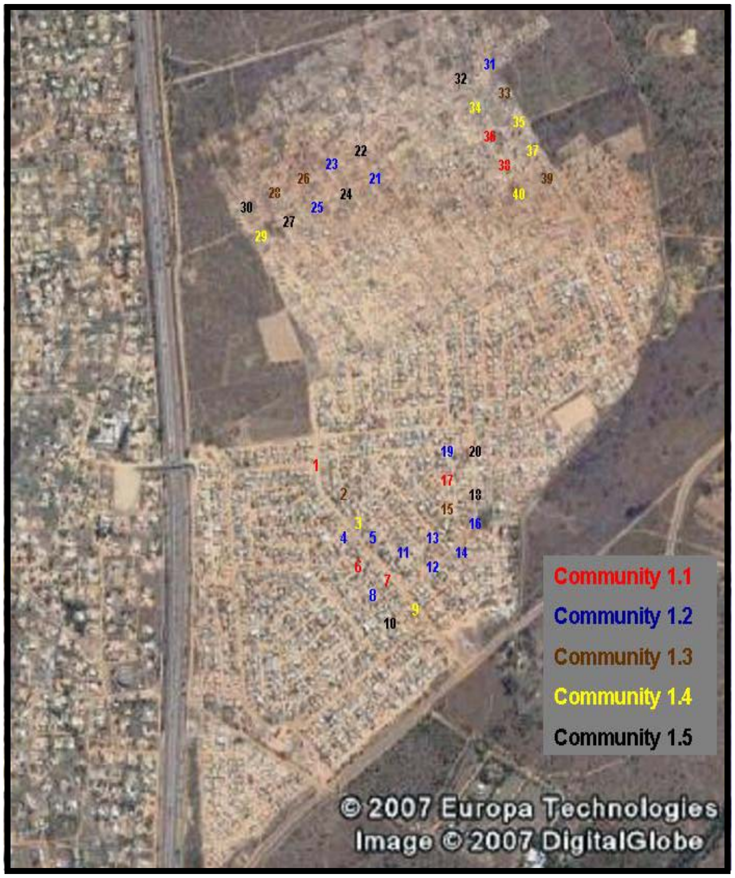

Figure 6-4: Plant communities in the residential area

Community 1.1; *Persea americana – Ensete ventricosum* Residential Sub-Community: Community 1.1 consists of 4 households in Kekana Gardens and 2 households in Skierlik. This community is characterised by Species Group B (Table 6.4): *Ensete ventricosum* and *Persea americana*. It is interesting to note that all the diagnostic plant species of this group are fruit tree species, indicating a dependence on food production.

The results from the household survey, as indicated in Table 6.3, support the impression that fruit trees are important in Community 1.1. Figure 6.5 is derived from the data in Table 6.3, illustrating the number of plants classified as fruit trees, vegetables and ornamental trees and flowers in Community 1.1.

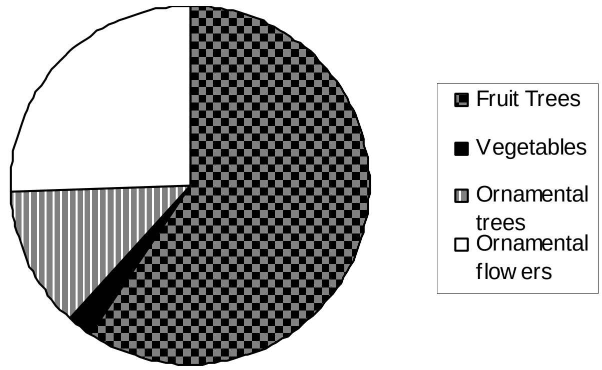

Figure 6-5: The proportions of different plant types in Community 1.1

Community 1.2; *Dodonaea angustifolia – Tecoma stans* Residential Sub-Community: Community 1.2 consists of 9 households in Kekana Gardens and 4 households in Skierlik. This community is characterised by Species Group C (Table 6.4). Diagnostic species of this group are *Dodonaea angustifolia* and *Tecoma stans*, which do not occur in any of the other groups. *Dodonaea angustifolia* is mostly used as an ornamental hedge and *Tecoma stans* is an invader species often used as an ornamental tree.

Figure 6.6 is derived from the data in Table 6.3, illustrating the number of plants classified as fruit trees, vegetables and ornamental trees and flowers in Community 1.2. Figure 6.6 indicates a high proportion of ornamental plants. More or less equal proportions of ornamental trees, ornamental flowers and fruit trees are found in Community 1.2. There are no vegetables planted in Community 1.2. It seems as if ornamental trees and hedges are more important in Kekana Gardens than in Skierlik. The reason for this could be due to a higher living standard and the availability of resources. It could also be due to the higher stability of the residents in Kekana Gardens, which gave them time to work in the garden. Residents in Skierlik are normally temporary in nature and they settled only recently.

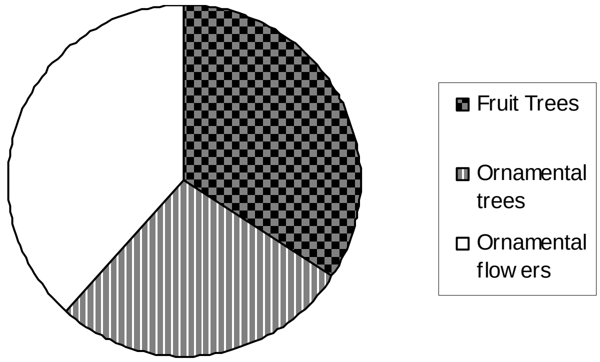

Figure 6-6: The proportions of different plant types in Community 1.2

Community 1.3; *Carpobrotus edulis* – *Pelargonium* species Residential Sub-Community: Community 1.3 consists of 2 households in Kekana Gardens and 4 households in Skierlik and is characterised by Species Group D (Table 6.4): *Carpobrotus edulis* and *Pelargonium sp*. Both these ornamental species are grown easily from cuttings and recently established households have species that are easily grown in their gardens.

Figure 6.7 is derived from the data in Table 6.3, illustrating the number of plants classified as fruit trees, vegetables and ornamental trees and flowers in Community 1.3. Figure 6.7 indicates the importance of horticultural plants in Community 1.3.

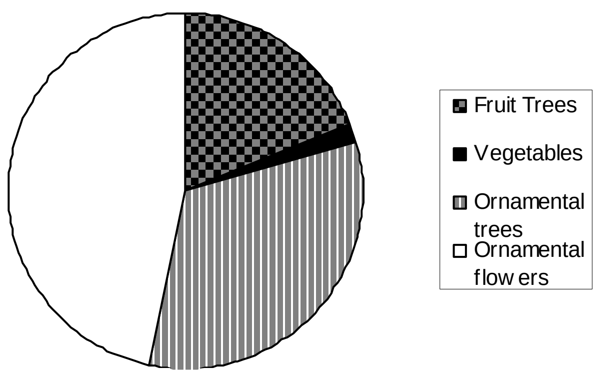

Figure 6-7: The proportions of different plant types in Community 1.3

Community 1.4; *Ipomoea* species – *Cucurbita maxima* Residential Sub-Community: Community 1.4 consists of 5 households in Skierlik and 2 households in Kekana Gardens and is characterised by Species Group E (Table 6.4).

Figure 6.8 is derived from data in Table 6.3 and indicates the proportions of different types of plants in Community 1.4 based on species numbers. In Community 1.4 vegetables play a very important role, but ornamental trees and flowers and fruit trees are often present. Interesting to note is that the majority of Community 1.4 is in the poorer community of Skierlik where vegetables are an important need.

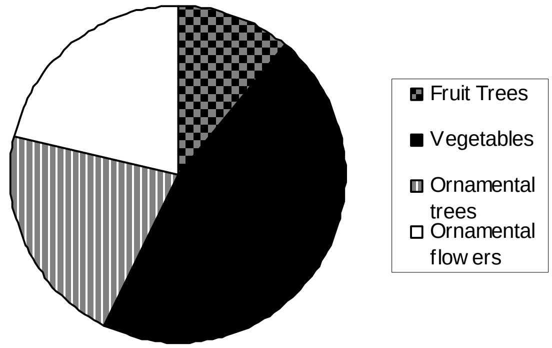

Figure 6-8: The proportions of different plant types in Community 1.4

Community 1.5: Community 1.5 consists of 2 households in Kekana Gardens and 6 Households in Skierlik. Community 1.5 is characterised by plant species from Species Group A of Community 1 while other diagnostic species are absent. The diversity and abundance of plants in the households of Community 1.5 is very low. Since the majority of households in Community 1.5 are in Skierlik, it could be the reason for the low diversity and abundance in plant species. Skierlik was established recently and has very limited resources, especially water.

Figure 6.9 is derived from data in Table 6.3. Interesting to note is that there are no vegetables, but many fruit trees and ornamental trees and flowers. The large proportion of ornamental plants in this community is interesting, seeing that there are large areas of bare soil and few species which is an indication of poverty. This could be an indication of the importance of status in spite of a serious lack of vital resources.

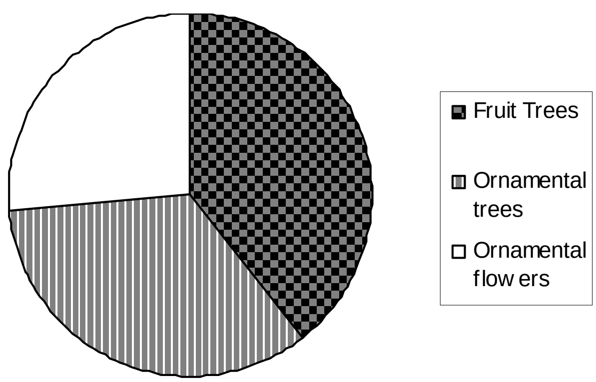

Figure 6-9: The proportions of different plant types in Community 1.5

6.4.3 Materials and Methods; Natural Environment

A vegetation survey was done in Sample B.

- A final phytosociological table was compiled for Sample B. All plant species were identified in the selected plots a Braun-Blanquet cover-abundance value was assigned to each species. The data was incorporated into a vegetation database created in TURBOVEG (Hennekens, 1996). This vegetation data was analysed using TWINSPAN - Two-Way Indicator Species Analysis (Hill, 1979) in the program JUICE version 6.4 (Tichy, 2002). The analysis was done using a high species cut level of 9 (0-2-3-4-8-18-36-68-88) and 6 levels of division.

- The **vegetation structure** was determined by estimating the height (m) and cover (%) of the trees, shrubs, grasses and forbs. Rock cover was additionally estimated as an environmental variable.

- The **biomass** of the grass was determined by taking 10 disk pasture meter readings in each of the plots. An average disc pasture meter reading was determined for each community. These averages were converted to biomass using the following formula from Trollope & Potgieter (1986):

  $$\boldsymbol{y} = 2260\boldsymbol{x} - 3019$$

  y is the estimated grass biomass (kg/ha),
  x is the square root of the average of the disc pasture meter readings (cm)

- The **veld condition** of each plant community was determined in terms of grazing capacity using the program GRAZE (Bredenkamp, 1988). Step point data was collected by taking random steps in the following plots and the plant species at each step were identified:

  - Community 2.1: 150 step points were taken; 50 in Plot 41 and 100 in Plot 44
  - Community 2.2: 100 step points were taken in Plot 46
  - Community 2.3: 100 step points were taken in both Plot 49 and Plot 51

  The identified species were entered into a database and a Decreaser, Increaser 1, Increaser 2a, 2b and 2c value was assigned to each species. The frequencies of Decreaser, Increaser 1, Increaser 2a, 2b and 2c species that were encountered were expressed as a percentage of the total number of step points. A grazing capacity analysis was done on the step point data.

6.4.4 Results; Natural Environment

According to Mucina *et al.* (2005) the vegetation of the selected site are classified as Springbokvlakte Thornveld of the savanna biome. The tree and grass cover varies over short distances due to a difference in land use.

- **Plant community identification**

Table 6.4 is the phytosociological table from the TWINSPAN analysis. The TWINSPAN analysis subdivided Community 2 into three communities as illustrated in Figure 6.10.

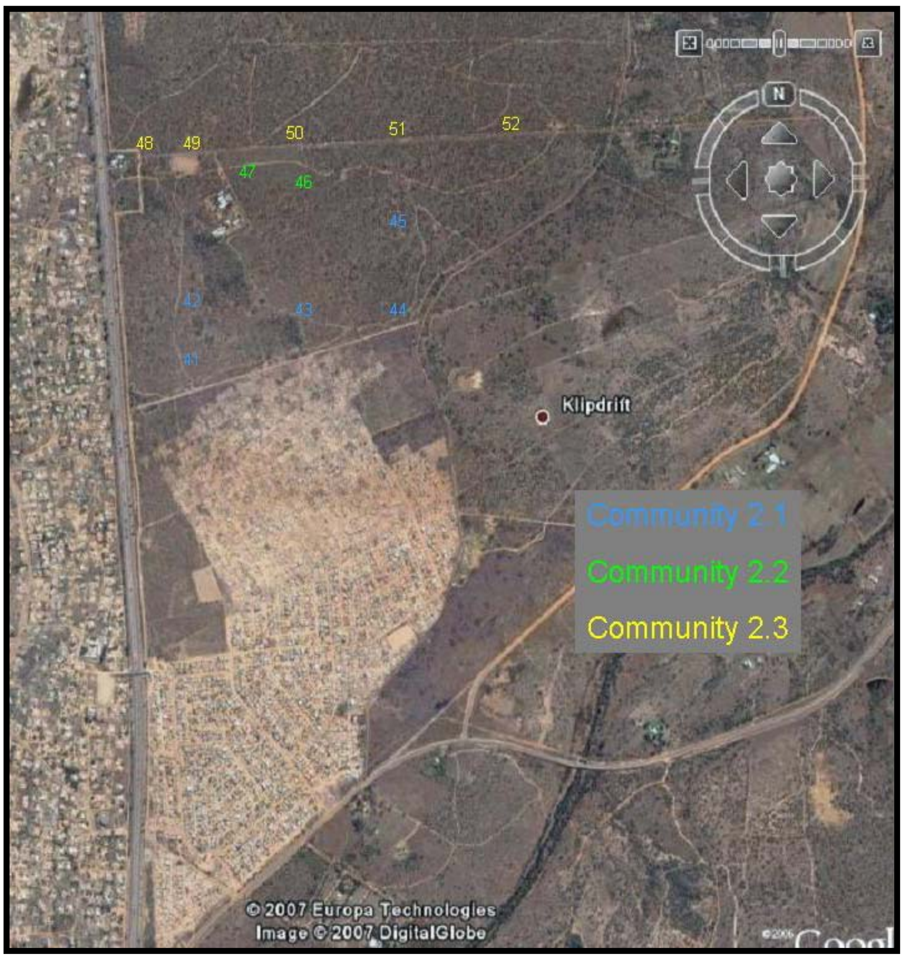

Figure 6-10: Identified plant communities in Sample B (Google earth, 2007)

Community 2; *Eragrostis rigidior – Aloe greatheadii* Savannah Major-Community: As mentioned above, the natural environment is classified as Community 2. This community is characterised by Species Group G of which *Eragrostis rigidior* and *Aloe greatheadii* are the most abundant species (Table 6.4).

The results of the fieldwork in Sample B are indicated in the following Tables and discussed afterwards. Table 6.5 indicates the height and cover values all the selected plots of Sample B. Table 6.6 indicates the disc pasture meter readings of all the selected plots of Sample B. Table 6.7 step point data from Plots 41, 44, 46, 49 and 51 of Sample B. Table 6.8 indicates the graze analysis of each community.

Table 6-5: Height and cover values of the natural vegetation

Community 2.1					
	Trees	**Shrubs**	**Grass**	**Forbes**	**Rocks**
Minimum height (m)					
Plot 41	0	0.5	0.6	0.3	0
Plot 42	0	0.5	0.6	0.2	0
Plot 43	0	0.5	0.5	0.2	0
Plot 44	7	0.5	0.4	0.2	0
Plot 45	6	0.5	0.4	0.2	0
Average minimum height (m)	6.5	0.5	0.5	0.22	0
Maximum height (m)					
Plot 41	0	3	0.6	0.3	0
Plot 42	0	3	0.6	0.2	0
Plot 43	0	3	0.7	0.2	0
Plot 44	7	3	2	0.3	0
Plot 45	6	3	0.6	0.3	0
Average maximum height (m)	6.5	3	0.9	0.26	0
Cover (%)					
Plot 41	0	30	45	1	0
Plot 42	0	20	50	1	0
Plot 43	0	10	45	1	0
Plot 44	1	20	45	1	0
Plot 45	3	20	55	2	0
Average cover (%)	0.8	20	48	1.2	0
Total cover of vegetation in Community 2.1	70%				

Table 6-5 (Continued): Height and cover values of the natural vegetation

Community 2.2					
	Trees	**Shrubs**	**Grass**	**Forbes**	**Rocks**
Minimum height (m)					
Plot 46	4	0.5	0.5	0.2	0
Plot 47	6	0.5	0.5	0.3	0
Average minimum height (m)	5	0.5	0.5	0.25	0
Maximum height (m)					
Plot 46	7	3	0.6	0.3	0
Plot 47	6	2	0.8	0.3	0
Average maximum height (m)	6.5	2.5	0.7	0.3	0
Cover (%)					
Plot 46	3	10	55	1	0
Plot 47	5	15	50	5	0
Average cover (%)	4	12.5	52.5	3	0
Total cover of vegetation in Community 2.2	72				

Table 6-5 (Continued): Height and cover values of the natural vegetation

Community 2.3					
	Trees	**Shrubs**	**Grass**	**Forbes**	**Rocks**
Minimum height (m)					
Plot 48	3	0.5	0.1	0.2	0
Plot 49	4	0.5	0.1	0.2	0
Plot 50	4	0.5	0.1	0.3	0
Plot 51	4	0.5	0.2	0.2	0
Plot 52	5	3	0.1	0.2	0
Average minimum height (m)	4	1	0.12	0.22	0
Maximum height (m)					
Plot 48	5	3	0.5	0.2	0
Plot 49	6	3	0.5	0.3	0
Plot 50	5	3	0.5	0.3	0
Plot 51	7	3	0.5	0.3	0
Plot 52	5	3	0.3	0.3	0
Average maximum height (m)	5.6	3	0.46	0.28	0
Cover (%)					
Plot 48	5	25	20	1	0
Plot 49	10	15	15	1	0
Plot 50	5	10	20	1	0
Plot 51	25	5	20	10	0
Plot 52	20	5	15	10	0
Average cover (%)	13	12	18	4.6	0
Total cover of vegetation in Community 2.3	47.6				

Table 6-6: Average disk pasture meter data in Sample B

Plot	Disc Pasture Meter Reading (cm)	Grass Biomass (Kg / ha)
Community 2.1		
41	7.2	3045.2
42	7.9	3333.2
43	10.4	4269.3
44	7.2	3045.2
45	7.1	3003.0
Average	**7.96**	**3357.2**
Community 2.2		
46	5.8	2423.8
47	5.8	2423.8
Average	**7.42**	**3137.2**
Community 2.3		
48	4.6	1828.2
49	3.6	1269.0
50	3.5	1209.1
51	3.6	1269.0
52	3.1	960.1
Average	**3.68**	**1316.4**

Table 6-7: Step Points in Community 2.1

Species	Increaser (I)/ decreaser (D) value	Nr of encounters Plot 41	Nr of encounters Plot 44	Total encounters in Plot 41 &44	Percentage encounters in Plot 41& 44
Digitaria eriantha	D	3	6	9	6
Themeda triandra	D	2	8	10	6.7
Schmidtia pappophoroides	D	3		3	2
Panicum coloratum	D	5		5	3.3
Setaria sphacelata	D		3	3	2
Total D		**13**	**17**	**30**	**20**
Schizachyrium sanguineum	I1		16	16	10.7
Loudetia simplex	I1		4	4	2.7
Total I1			**20**	**20**	**13.3**
Heteropogon contortus	I2a	4	8	12	8
Eragrostis curvula	I2a	1	2	3	2
Total I2a		**5**	**10**	**15**	**10**
Elionurus muticus	I2b		7	7	4.7
Eragrostis superba	I2b		2	2	1.3
Total I2b			**9**	**9**	**6**
Aristida congesta	I2c	2	14	16	10.7
Eragrostis rigidior	I2c	20	10	30	20
Aristida canescens	I2c	10	11	21	14
Pogonarthria squarrosa	I2c		9	9	6
Total I2c		**32**	**44**	**76**	**50.7**

Table 6-7 (Continued): Step Points in Community 2.2

Species	Increaser (I) / decreaser (D) value	Nr of encounters Plot 46
Digitaria eriantha	D	9
Themeda triandra	D	4
Schmidtia pappophoroides	D	1
Panicum coloratum	D	2
Total D		**16**
Schizachyrium sanguineum	I1	0
Loudetia simplex	I1	0
Total I1		**0**
Heteropogon contortus	I2a	14
Eragrostis curvula	I2a	4
Total I2a		**18**
Elionurus muticus	I2b	7
Total I2b		**7**
Aristida congesta	I2c	3
Eragrostis rigidior	I2c	39
Aristida canescens	I2c	9
Tricholaena monachne	I2c	1
Enneapogon scoparius	I2c	1
Pogonarthria squarrosa	I2c	6
Total I2c		**59**

Table 6-7 (Continued): Step points in Community 2.3

Species	Increaser / decreaser value	Nr of encounters Plot 49	Nr of encounters Plot 51	Total encounters in Plot 49 and Plot 51	Percentage encounters in Plot 49 & 51
Digitaria eriantha	D	14	10	24	12
Themeda triandra	D	20	31	51	25.5
Total D		**34**	**41**	**75**	**37.5**
Heteropogon contortus	I2a	4	2	6	3
Eragrostis curvula	I2a	11	4	15	7.5
Total I2a		**15**	**6**	**21**	**10.5**
Elionurus muticus	I2b	16	27	43	21.5
Hyparrhenia hirta	I2b	1	0	1	0.5
Eragrostis superba	I2b	0	4	4	2
Total I2b		**17**	**31**	**48**	**24**
Aristida congesta	I2c	12	3	15	7.5
Eragrostis rigidior	I2c	22	9	31	15.5
Aristida canescens	I2c	0	10	10	5
Total I2c		**34**	**22**	**56**	**28**

Table 6-8: An analysis of the step point data as an indicator for the veld condition of three communities in the natural vegetation

Community (C)	**C 2.1**	**C 2.2**	**C 2.3**	**Total**
Size (ha)	100.00	100.00	100.00	300
Trees %	1	4	13	
Shrubs %	20	13	12	
Bush factor	0.93	0.93	0.87	
Decreasers	20	16	38	
Increasers 1	13	0	0	
Increasers 2a	10	18	11	
Increasers 2b	6	7	24	
Increasers 2c	51	59	28	
Encroachers	0	0	0	
Bare soil	0	0	0	
Total	100	100	100	
Veld Condition Index %	**41.8**	**33.7**	**55.2**	
Grass cover %	48	53	18	
Rainfall (mm/yr)	674	674	674	
Accessibility	1.0	1.0	1.0	
Fire (0.8\1)	1	1	1	
Grazing capacity				
In a normal year				
ha/LSU Cattle	5.2	5.8	6.1	
ha/LSU Game	8.7	9.7	9.7	
Number Cattle	**19.2**	**17.3**	**16.5**	**52.9**
Number LSU Game	**11.5**	**10.3**	**10.4**	**32.2**
Grazing capacity				
In a bad year				
ha/LSU Cattle	8.4	9.6	10.8	
ha/LSU Game	14.1	16.1	17.2	
Number Cattle	**11.9**	**10.4**	**9.2**	**31.5**
Number LSU Game	**7.1**	**6.2**	**5.8**	**19.1**

Community 2.1; *Dicoma anomala* – *Acacia nilotica* Savanna Sub-Community: Community 2.1 is represented by Plots 41, 42, 43, 44 and 45 and is characterised by Species Group H (Table 6.4). Within Community 2.1 Plots 41 and 45 are more strongly related, while Plots 42, 43 and 44 are more strongly related. On average the altitude of Community 2.1 is higher than the other communities ranging from 1091 m to 1098 m. Figure 6.11 is a photo of the vegetation taken in Community 2.1.

Figure 6-11: The typical vegetation of Community 2.1

The height and cover values of trees, shrubs, grass, forbs and rocks in Community 2.1 are indicated in Table 6.5. Community 2.1 is adjacent to Skierlik and consequently the main disturbance of the site is from the residential area. The site, especially Plots 41 and 43, is littered by waste and rubble.

Many trees have been chopped for firewood resulting in a low tree cover of 0.8%. These trees resprout to form shrubs, resulting in a relatively high shrub cover of 20%. The average minimum and maximum height of the shrubs ranges from 0.5m to 3m (Table 6.5).

Grazing in the area is insignificant, which explains the high grass cover of 48% (Table 6.5). The grass is relatively tall with an average height ranging from 0.5m to 0.9m. The average disc pasture meter reading in Community 2.1 is 7.96cm (Table 6.6), representing a biomass of 3357.2 kg/ha (Trollope & Potgieter, 1986).

The cover of rocks in Community 2.1 is 0%. The cover of the forbs is 1.2% with an average height ranging from 0.22m to 0.26m. The total cover of the vegetation in Community 2.1 is 72%.

The results from the step points are indicated in Table 6.7. The grazing capacity of Community 2.1 in a year with sufficient rainfall is 5.2 ha / LSU[1], for cattle and 8.7 ha / LSU for game. In a bad year the grazing capacity is 8.4 ha / LSU for cattle and 14.1 ha / LSU for game (refer to Table 6.8).

Community 2.2; *Enneapogon scoparius – Schmidtia pappophoroides* Savanna Sub-Community: Community 2.2 is represented by Plots 46 and 47 and is characterised by Species Group I (Table 6.4). The altitude of Community 2.2 is relatively low with Plot 46 at 1089 m and Plot 47 at 1086 m. Community 2.2 is locally situated between Community 2.1 and Community 2.3. Therefore the disturbing factors present in both Community 2.1 and Community 2.3 are also present in Community 2.2. Figure 6.12 is a photo taken in Community 2.2 indicating the typical vegetation of this community.

Figure 6-12: The typical vegetation found in Community 2.2

Rubble is not dumped in Community 2.2 as it is in Community 2.1. The height and cover values of trees, shrubs, grass, forbs and rocks in Community 2.2 are indicated in Table 6.5.

[1] LSU stands for livestock unit. 8.4 ha/LSU Cattle means that 8.4 hectares are needed to sustain one LSU

The total cover of the woody layer in Community 2.2 is slightly lower than the cover of the woody layer in Community 2.1. The trees in Community 2.2 are chopped for firewood and *Combretum apiculatum* resprout, therefore many shrubs are found (see Figure 6.12). The tree cover of 4% is slightly higher than in Community 2.1. The average height of the trees ranges from 5m to 6.5m in the sample plots. The shrubs have a cover value of 12.5% and an average height ranging from 0.5m to 2.5m (refer to Table 6.5).

Tracks and droppings of cattle are found in this community. The grass species composition is poorer compared to Community 2.3, indicating previous overgrazing. Community 2.2 has the highest grass cover of 52% (see Figure 6.12). The average height of the grass ranges from 0.5m to 0.7m in the sample plots (refer to Table 6.5). The average disk pasture meter reading of 7.42cm in Community 2.2 is slightly lower compared to Community 2.1 (Table 6.6). It represents a biomass of 3 137.2 kg/ha (Trollope & Potgieter, 1986).

The average cover of forbs in Community 2.2 is 3% with an average height ranging from 0.25m to 0.3m. The cover of rocks is 0%. The total cover of the vegetation in Community 2.2 is 72% (Table 6.5).

The results from the step points are indicated in Table 6.7. The grazing capacity of Community 2.1 in a year with sufficient rainfall is 5.8 ha / LSU for cattle and 9.7 ha / LSU for game. In a bad year the grazing capacity is 9.6 ha / LSU for cattle and 16.1 ha / LSU for game (refer to Table 6.8).

Community 2.3; *Ozoroa paniculosa – Grewia flava* Savanna Sub-Community: Community 2.3 is represented by Plots 48, 49, 50, 51 and 52 and is characterised by Species Group J (Table 6.4). The five plots are in a straight line along the gravel road leading to the AIM Missionary centre. The altitude increases from Plot 48 at 1090 m to Plot 52 at 1096 m with a slight dip in altitude at Plot 49 at 1089 m. Figure 6.13 is a photo taken in Community 2.3 and represents the typical vegetation of this community.

Figure 6-13: The typical vegetation found in Community 2.3

Community 2.3 is furthest from the residential areas and fewer trees were chopped, resulting in the relatively high tree cover of 13%. The average height of the trees ranges from 4m to 5.6m in the sample plots. *Combretum apiculatum* is found mostly as trees, although some have been chopped and have regrown. Trees were more chopped on the eastern plots compared to the rest of the plots in Community 2.3. The cover of the shrubs in Community 2.3 is 12% with an average height ranging from 1m to 3m. Figure 6.14 is a photo taken in Plot 48 where the trees were chopped and resprout as shrubs.

Figure 6-14: *Combretum apiculatum* shrubs in Plot 48 of Community 2.3

The veld in Community 2.3 is heavily overgrazed and cattle are often seen in this community. This is probably the reason for the relatively low grass cover of 18%. The average height of the grass ranges from 0.12m to 0.46m (see Figures 6.13 and 6.14), which is considerably lower than the height of the grass in the other communities. The disc pasture meter readings of 3.68cm (Table 6.6) are relatively low for this community and represent a biomass of 1 316.4 kg/ha (Trollope & Potgieter, 1986).

The average cover of the forbs is 4.6% with an average height of 0.22m and 0.28m. The cover of the rocks is 0%. The average cover of 48% of the vegetation in Community 2.3 is much lower than the vegetation cover in the other communities. There is a high percentage of bare soil in this community, as is clear from Figure 6.13 and 6.14.

The results from the step points are indicated in Table 6.7. The grazing capacity of Community 2.1 in a good year is 6.1 ha / LSU for cattle and 9.7 ha / LSU for game. In a bad year the grazing capacity is 10.8 ha / LSU for cattle and 17.2 ha / LSU for game (refer to Table 6.8).

7 RESOURCES

Resource limitations are a major concern in rural areas. Space, soil and water are natural resources that inhibit crop production. Resources can be defined as products of a system that are used by people (Hugo, 2004). Resources are a very general term and could be classified in different ways. Natural resources are illustrated by Hugo (2004) and this illustration is expanded with information from the literature to include human and material resources as in Figure 7.1.

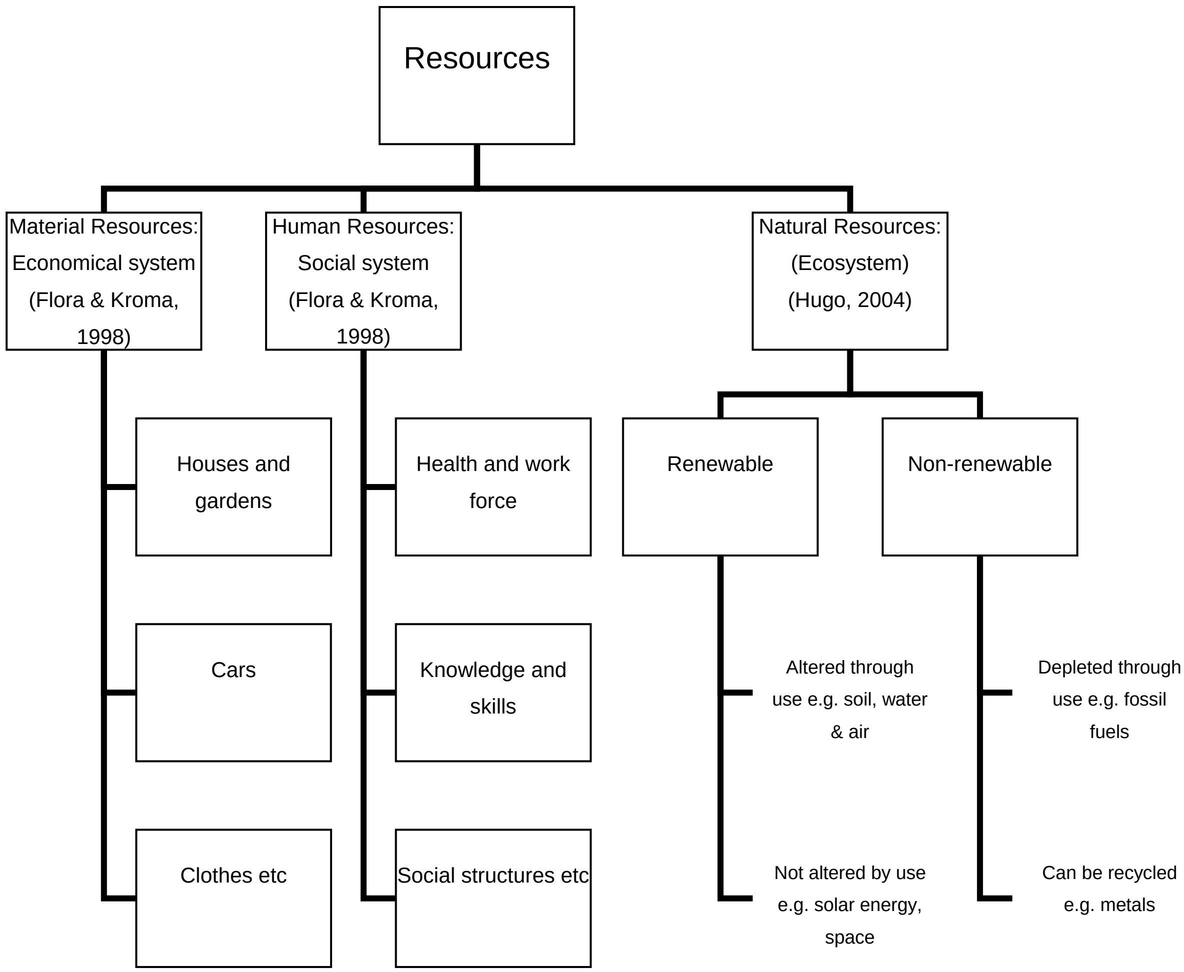

Figure 7-1: A simple classification of resources

In the low-income household resources must be studied for two reasons, firstly because the people are dependent on resources and secondly the household can become a producer of resources to the larger economy.

Resources are produced within a functional system. Resources are depleted if the system is dysfunctional. A practice within a system is unsustainable if a resource is being depleted faster than it is generated. The correct use of resources is one way to increase the sustainability of a system. Another way is to invest resources, known as capital, in order to produce more resources.

The different resources needed to fulfil the needs of the household on a small scale are very complex. It is therefore only possible to study the most important natural resources. Natural resources could come from the local ecosystem or the local household environment. The resources that are chosen should be limiting resources i.e. those that restrain production. During the scoping process the limiting abiotic resources in the low-income household were identified as soil, space and water and energy. Biotic resources would include all animal and plant species, but for this study only bio-diesel producing plant species are discussed.

7.1 RESOURCES AND AFRICA

Natural resources and the earth have a certain cultural and religious meaning for the African household. Prof Thakatso Mofokeng expresses the importance of land in the African culture:

> "As far as the Black cultural tradition is concerned, land is the mother and Black people are 'sons and daughters of the soil'. It gives Black people an identity and in turn receives an identity from them … Land is the source of livelihood … It is also of religious significance as the location of sacred places where we dialogue with the hounding fathers of the Black community … Tearing these people away from this land is sacreligious (sic). The land is also socially and psychologically significant … We always come back to our roots … The land is also the bedroom where we put our departed loved ones to bed. It is also the house of our ancestors. We always go back to have our dialogue with them, to retain and promote our sense of community and history. Without them and their land we float like a ship without an anchor and compass on a stormy sea…" (Mofokeng, 1987)

Earth, mother, Africa and night are united in other African literature. Europe and Africa is opposed to one another as day and night. Being black is to be clean from the contagions of civilized men. Identity will be found in a spiritual return to Africa, in the mythical landscape where the ancestors are buried, in the memories of childhood and the presence of the mother. The black woman is the key to the return to the African world. Death is seen as a rebirth into a new and better life. To be buried in the soil of Mother Earth is to be planted like a seed. 'The African night stands in opposition to the light of Europe: at this hour, at the call of the woman, the Earth Mother, the ancestors gather to talk to their children' (Awoonor, 1976).

The modern Western lifestyle promoting productivity is seen as an alienation from the land. This approach to maximum productivity regards land merely as a means to production. In the African literature, the approach to productivity is a mythical or religious view of fertility and productivity. Women and the earth are united in the concept of fertility and productivity. Women and the earth ensure the perseverance of the mankind, and mankind should ensure the perseverance of the earth (Cartey, 1969). Mankind should ensure the perseverance of the earth by having a good relationship with the ancestors. The ancestors will then provide rain and good crops (Kenyatta, 1985).

7.2 SOIL

Information on the soil types was found from the literature. The selected site falls within a single land type, Bb18, the soil of which is described as dystrophic and/or mesotrophic and red soils is not wide spread (Chief Director of Surveys and Mapping, 1978)

- **Terrain unit**

The land type Bb18 is divided into four terrain units, 1, 3, 4, and 5. Terrain unit 5 is the lowest point in the land type at 1100m above sea level. The elevations of the plots are close to or below 1100m (refer to Table 3.3). It is therefore concluded that the selected site falls within Terrain unit 5. The slope of Terrain unit 5 is 0-1 % and the form of the slope is concave. Terrain unit 5 has little to no mechanical limitations, such as stones, that could impair agricultural activities (Schoeman, 1986).

- **Terrain type**

The terrain type of land type Bb18 is identified as A3 (Schoeman, 1986). The 'A' indicates that 80% of the area does not have steep slopes i.e. 80% of the surface area has slopes of less than 8%. The '3' indicates that the difference between the highest and the lowest point in the landscape is between 90m and 150m (Land Type Survey Staff, 1987). The lowest point in the landscape is 1100m above sea level (Schoeman, 1986). Therefore, the highest point in the landscape would be between 1190m and 1250m above sea level.

- **Geology**

The geology of the area is identified as sandstone, shale and grit of the Ecca group and Nebo granite (Schoeman, 1986).

- **Soil**

Terrain unit 5 is characterised by the following soil series:

– 15% Longlands Lo21 with a soil depth of 450 mm – 750 mm. The clay content of Longlands Lo21 is 8% - 20% in the A-horizon, 6% - 15% in the E-horizon and 25% - 35% in the B21-horizon (Schoeman, 1986)

– 30% Jozini Oa36 with a soil depth of more than 900 mm. The clay content of Jozini Oa36 is 10% - 20% in the A-horizon and 15% - 30% in the B21-horizon (Schoeman, 1986)

– 30% Lindley Va41 with a soil depth of 300 mm – 400 mm. The clay content of Lindley Va41 is 20% - 30% in the A-horizon and 35% - 50% in the B21-horizon (Schoeman, 1986)

– 25% Balfour Es 35 and Uitvlugt Es 34 (Schoeman, 1986) with a soil dept of 400 mm – 500 mm. The clay content of these soil series is 10% - 20% in the A-horizon, 10% - 15% in the E-horizon and 35% - 50% in the B21-horizon (Schoeman, 1986)

7.3 SPACE

The available space presents a limit to the production of crops. It is therefore important to measure the available space in order to determine where this upper limit to small-scale production is.

7.3.1 Materials and Methods

General observations were made of the households in Sample A to determine the available space using data sheets as indicated in Table 7.1.

Table 7-1: Datasheet for observations of available space of Sample A

Area	Measurement
Plot size	
House size	
Size of front yard	
Size of back yard	
Number of buildings	
Building material used	

7.3.2 Results

The results on the available space are indicated in Table 7.2 and it is summarised below:

- The average plot size for households in Kekana Gardens and Skierlik is 232.5m^2 and 230.45m^2 respectively
- The average house size in Kekana and in Skierlik is 52.8m^2 and 33.1m^2 respectively
- The average size of the front yard in Kekana Gardens and in Skierlik is 113.25m^2 and 118.9m^2 respectively
- The average size of the back yard in Kekana Gardens and in Skierlik is 44.74m^2 and 36.3m^2 respectively

Therefore, the average plot sizes are almost the same in Kekana Gardens and in Skierlik, but the average sizes of the houses are much larger in Kekana Gardens than in Skierlik. The size of the average front yard in both Kekana Gardens and in Skierlik is much larger than the average back yard. Buildings that are often found in the yard include the house, a toilet and sometimes a store or a shop.

Table 7-2: Observed building and plot sizes of Sample A

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
Plot size (m^2)	225	225	450	225	225	225	225	225	225	225
Size of front yard (m^2)	120	75	300	150	90	165	45	45	150	60
Size of back yard (m^2)	75	60	30	15	15	60	15	180	75	60
Number of buildings	4	2	2	1	2	2	1	1	2	1
House size (m^2)	80	27	50	16	44	33	150	12	30	144
Building material used	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Bricks & Corrugated iron	Wood & Corrugated iron	Bricks, still being build	Corrugated iron	Corrugated iron	Modern bricks

Table 7-2 (Continued): Observed building and plot sizes of Sample A

	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16	Plot 17	Plot 18	Plot 19	Plot 20	Average for Kekana
Plot size (m^2)	225	225	225	225	150	225	150	300	225	225	232.5
Size of front yard (m^2)	105	60	120	135	90	120	60	120	120	135	113.25
Size of back yard (m^2)	15	20	15	45	20	30	15	75	30	-	44.74
Number of buildings	1	1	1	1	2	1	1	2	1	1	1.5
House size (m^2)	80	48	42	21	16	54	35	80	40	54	52.8
Building material used	Bricks	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Modern bricks	80% Corrugated. Iron, 25% Bricks, 5% Wood

Table 7-2 (Continued): Observed building and plot sizes of Sample A

	Plot 21	Plot 22	Plot 23	Plot 24	Plot 25	Plot 26	Plot 27	Plot 28	Plot 29	Plot 30
Plot size (m^2)	225	450	150	225	225	225	450	225	150	225
Size of front yard (m^2)	150	240	80	75	120	90	135	120	100	30
Size of back yard (m^2)	30	45	20	45	30	57	15	30	0	105
Number of buildings	1	2	1	2	2	1	1	2	1	2
House size (m^2)	21	40	21	50	34	28	40	25	40	60
Building material used	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron & bricks	Corrugated iron, wood & material	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron

Table 7-2 (Continued): Observed building and plot sizes of Sample A

	Plot 31	Plot 32	Plot 33	Plot 34	Plot 35	Plot 36	Plot 37	Plot 38	Plot 39	Plot 40	Averages for Skierlik
Plot size (m^2)	150	144	225	240	150	375	225	225	100	225	230.45
Size of front yard (m^2)	130	120	213	100	100	100	150	150	40	135	118.9
Size of back yard (m^2)	0	24	0	100	0	50	0	75	10	90	36.3
Number of buildings	1	3	1	1	1	1	1	2	2	2	1.5
House size (m^2)	20	20	8	24	12	72	50	64	15	18	33.1
Building material used	Corrugated iron	Corrugated iron	Corrugated iron	Corrugated iron, bricks at back for future building	Corrugated iron	Concrete slabs	Corrugated iron & wood	Bricks, modern. New one under construction	Corrugated iron	Corrugated iron	90% Corrugated. Iron, 15% Bricks, 10% Wood, 5% Concrete, 5% Material

7.4 WATER

During the interview in Sample C some people indicated that water is a limiting factor for food production. Water availability was researched during the fieldwork. Water is provided by rainfall and municipal servitudes.

Precipitation data of the Pretoria region (25° 44' S; 28° 11' E) for the 30 year period, 1961-1990 is shown in Table 7.3 (SA Weather Service, 1990).

Table 7-3: Precipitation data of the Pretoria region taken 1961-1990 (SA Weather Service, 1990)

Month	Precipitation		
	Average monthly (mm)	**Average number of days with >= 1mm**	**Highest 24 hour rainfall (mm)**
January	136	14	160
February	75	11	95
March	82	10	84
April	51	7	72
May	13	3	40
June	7	1	32
July	3	1	18
August	6	2	15
September	22	3	43
October	71	9	108
November	98	12	67
December	110	15	50
Year	674	87	160

7.4.1 Scoping

The scoping process was done in order to prepare the fieldwork by observations during several visits to the community and discussions with professional people who work in the area.

- **Results from scoping**

The following results from the scoping process influenced the way in which the fieldwork was conducted:

– There are communal water points in the streets and children fetch buckets of water

- Some people have taps in the yard
- Many people do laundry in buckets outside the house

From these observations it seemed as if some people have to walk far for water, while other have taps in their yards. It seems as if doing laundry is important, seeing that many people must walk far to get water.

7.4.2 Materials and Methods

Interviews were done in Sample C to determine the availability of water in the households of the selected site. Questions were prepared based on observations made during the scoping process to guide during the fieldwork.

- Do you have a tap on the yard?
- How far is the communal tap?
- Is there always water in the taps?
- Do you have enough water?
- How much water do you use in a week? (Litres/week)
- How much water do you use in a day if you do laundry? (Litres/day)
- How much water do you use on a normal day? (Litres/day)
- How many days in a week do you do laundry (Days/week)
- Remarks

7.4.3 Results

The results on the available water are indicated in Table 7.4 and it is summarised below:

Table 7-4: Water availability as investigated during interviews in Sample C

Question	House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10	Summary
Do you have a tap on the yard?	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Some people have taps in the yard, others don't
How far is the communal tap?	Right outside	Very far	Do not use it	Do not use it	15m from house	Do not know	Do not use it	Do not use it	Do not know	Do not know	Some people need to walk very far for water
Is there always water in the taps?	No	23:00-4:00	Mostly not	20:00-5:00	Not always	No	At night	At night	No	No	Water usually just available at night
Do you have enough water?	No	No	No	Yes	No	No	No	No	No	No	Household 4 has a lot of water, others have a serious need
Water used on a laundry day (liters/day)	300	125	Do not know	Do not know	150	Do not know	Do not know	Do not know	Do not know	Do not know	Household 2 can do laundry with as 125 liter
Water used on a normal day (liters/day)	225	60	Do not know	Do not know	75	Do not know	Do not know	Do not know	75-100	100-150	Household 2 survive with 60 liters/day
Nr of days to wash laundry (days/week)	2	2	Do not know	Do not know	1	Do not know	Do not know	Do not know	Do not know	Do not know	
Weekly water usage (liters)	1725*	550	Do not know	Do not know, uses a hosepipe	600	Do not know	Do not know	Do not know	875	700	Household 2 can survive with as little as 550 liters a week
Remarks		Sometimes she walks far for water.	People steel the head of the tap to make jewelry	Water leaks from the hosepipe during the interview.	He fetches water daily						

The following interesting remarks regarding water were made during the interviews (refer to Table 7.4):

- Some people can only get water at night
- Many people in Sample C are not satisfied with their water supply
- The soil in the yards is empty and swept each day, because they do not have enough water to make a garden

Water seems to be the main limitation to household-based production of crops. Space is also a significant limitation, but the presence of open spaces, not cultivated due to a lack of water, indicates that water is the limiting factor for production. The lack of water is further increased by the evaporation of water from the soil due to the exposure to the sun.

During the interviews, some confusing remarks were made on the availability of water. Most households in Sample C felt that there is not enough water to irrigate their gardens. Some do have vegetables but cannot maintain it due to draught. They have to walk far for water and sometimes they do not have any water at all. The households with gardens and lawns have no problems with water. They get water from their taps and irrigate their gardens with a hosepipe. According to them other people do not have gardens, because they are too lazy. It is concluded that water is overall a major limiting factor, but there is an unequal distribution of water within the community.

7.5 Jatropha curcas

Energy sources in rural environments are limited and people mostly depend on human labour and to a lesser extent on animals. Chemicals for weed and pest control are mostly unavailable (Fowler & Rockstrom, 2001). Discussions during the scoping process indicated that people cut the trees of the natural environment for firewood. Bio-diesel could provide an alternative energy source in the household. Four possible energy crops for household-based production are discussed.

Jatropha curcas, also known as the physic nut, is a member of the family Euphorbiaceae. It has a lifespan of up to 50 years (Heller, 1996).

It is a multipurpose plant. The oil can be used for soap production, which yields a higher income than bio-diesel. The phorbolesters in the oil and seed have insecticidal value (Wink *et. al*, 1997).

J. curcas has medicinal value. Traditionally the latex was used to stop bleeding, prevent infection and to heal septic gums. The leaves were used against malaria (Henning, 1997) and to sooth the pain caused by rheumatism (Trabi *et. al*, 1997). The seeds and the oil can be used as a purgative and to treat scabies, gout and dropsy (Trabi *et. al*, 1997). The press cake can be used as a fertilizer, since its nitrogen content is equivalent to chicken manure (Henning, 1997).

7.5.1 Morphology

J. curcas is a small tree or a large shrub and it can grow up to 8 m. The stems are succulent. Like any member of the Euphorbiaceae family, the stems contain latex (Heller, 1996). The leaves are lobed and alternately arranged (Figure 7.2).

Figure 7-2: The leaves of *J. curcas* are lobed

Inflorescences are a complicated cyme and occur terminally on branches (Figure 7.3). Flowers are usually unisexual and plants are monoecious (Heller, 1996). Staminate and pistillate flowers are produced on the same inflorescence (Aker, 1997). If pistillate flowers are present they are located on the tips of the branches, while the staminate flowers are located lower down. The petals of both the staminate and pistillate flowers are small and greenish or pale yellow (Aker, 1997). *J. curcas* is pollinated by insects. Staminate flowers open later than pistillate flowers of the same inflorescence, in this way cross-pollination is promoted (Heller, 1996).

Figure 7-3: The inflorescence of *J. curcas*

The fruit is a trilocular capsule (Figure 7.4). The colour of the fruit changes from green to yellow and eventually it becomes brown (Aker, 1997).

Figure 7-4: The fruit of *J. curcas*

The seeds of *J. curcas* are black and they are 2 cm long and 1 cm thick. The seeds attract the most attention, since it contains a high percentage of oil that can be used for bio-diesel production (Heller, 1996).

The tree has a tap root system, but plants propagated by vegetative reproduction do not have taproots. The roots grow close to the surface of the ground anchoring the soil and creating small dikes. These dikes slow water runoff and water penetrates the soil more effectively (Henning, 1997). In this way *J. curcas* increases crop production.

7.5.2 Distribution

J. curcas originates in Mexico and Central America (Figure 7.5), where it occurs naturally in forests in coastal regions. In Africa and Asia, the plant has been cultivated and used as a fence for a very long time (Heller, 1996).

Figure 7-5: The distribution of *J. curcas* and the centre of origin (Heller, 1996)

7.5.3 Ecology

- **Habitat**

J. curcas grows successfully on well-drained, aerated soil, with a low nutrient content. It is found at altitudes below 500m (Heller, 1996).

J. curcas has a succulent stem and sheds its leaves in times of drought. It is adapted to dry areas and occurs mainly in areas with a rainfall of 300mm to 1000 mm per year. *J. curcas* are adapted to high temperatures above 20 ºC. It does not grow well in cold climates and can only withstand slight frost (Heller, 1996).

- **Effect of *J. curcas* on the environment**

– Influence on other plants: increase food production

- *J. curcas* is a toxic plant and not browsed by animals. Therefore, although the plant is not an effective food source, it can protect vegetable gardens from grazing animals (Henning, 1997).

- It is said that *J. curcas* improves soil conditions, by reducing water runoff and increasing soil fertility. Furthermore, *J. curcas* reduces soil erosion (Henning, 1997).

- The seed meal of *J. curcas* can be used as an effective fertilizer, since it has nitrogen content similar to chicken manure (Henning, 1997).

7.5.4 Bio-diesel Production

Bio-diesel can be produced from the oil of the seeds of the plant. After a transesterification reaction the oil from the seed of the plant can serve as bio-diesel in any normal diesel engine. The low-income household could provide the bio-diesel feedstock to the industry and the industry will process it to produce bio-diesel (Heller, 1996).

According to Sharma (2007) dry seed production can vary between 4 and 12 tons per hectare per year. Minengu (2007) measures a dry seed yield of 7, 5 ton per hectare per year from ten year old *J. curcas* hedges. According to Iglesias (2007) 2, 2 kg of seed yield 1 litre of oil. In this study it is assumed to be a standard for all seeds.

7.5.5 Concerns

- It is expected that *J. curcas* will produce a high amount of oil without irrigation and while growing in poor soil. This is not the experience or expectations of many scientists

- *J. curcas* is not indigenous to South Africa, and people have great concerns about its invasive potential

- According to the literature, *J. curcas* has very few insect pests with economic value, due to the toxicity of all the parts of the plant. But the opposite is mostly experienced especially in large monocultures. There are a few true bugs that feed on the fruits. *Leptoglossus zonatus* and *Pachycoris klugii* are the two most common species found on trees in Nicaragua. The species damage developing fruit, causing abortion and malformation of the seeds (Grimm, 1997)

- The biggest concern about *J. curcas* is the toxic compounds it contains. These compounds are phorbolesters, curcin, trypsin inhibitors and phytates (Makkar & Becker, 1997)

7.6 Moringa oleifera

M. olifera, also known as the never-die-tree, is from the family Moringaceae. It is a promising alternative diesel-plant and seems to be suitable to be cultivated in low-income households (Francis *et al.*, 2002).

M. oleifera is a multipurpose tree. The oil is eatable and can be used as a lubricant for delicate machines such as watches (Duke, 1983).

Different parts of the plant can be used as medicine. The flowers, leaves and roots are used against tumours and the seeds are specifically used against abdominal tumours. In Nicaragua a decoction are made of the roots that can be used against dropsy. The leaves are applied as a bandage to sores, rubbed on the temples for headache and it contains purgative properties. The roots, bark and leaves promote digestion. The oil is applied externally for skin diseases. The bark exudes a gum that can be used for diarrhoea (Duke, 1983).

7.6.1 Morphology

M. oleifera is a deciduous, perennial tree that can grow up to 10m tall, but usually it is short. The main root is thick. The bark becomes thick, greedy and corky after 4 years. The leaves are trifoliolate and pale green.

The flowers are white to creamy-white (Figure 7.6). *M. oleifera* bears legumes (Figure 7.7), which are brown and triangular and it splits into three parts when dry. There are about twenty seeds in each legume. The seeds are dark brown with three papery wings. In Sri Lanka fruit production is in May and April (Duke, 1983).

Figure 7-6: The flower of *M. oleifera* (Olson, 1999)

Figure 7-7: The legumes of *M. oleifera* (Simons, 2007)

7.6.2 Distribution

M oleifera originates in north-west India and is distributed in different countries in Africa, Arabia, South East Asia, South America and the Pacific and Caribbean Islands (Francis *et al.*, 2002).

7.6.3 Ecology

- **Habitat**

M. oleifera grows in tropical and sub-tropical conditions (Francis *et al.*, 2002). It is distributed throughout Africa as a living fence. It has a shallow root system, which can prevent water erosion to a certain extent. If the trees are not pruned, it is susceptible to wind damage. The canopy of the tree is not dense and allows sunlight to penetrate to the ground. In this way, crops can be planted underneath the canopy of a *M. oleifera* tree (Pratt *et al.*, 2002).

M. oleifera is drought tolerant and it grows optimally in areas with an annual rainfall of 250-1500 mm. It grows in many different soil types but prefers well-drained sandy soil or loamy soils. The plant can grow in slightly alkaline soil with a pH of up to 9. *M. oleifera* can tolerate light frost (Francis *et al.*, 2002). The plant will need additional fertilization and in dry years it needs irrigation, to produce optimally.

It is a fast growing tree producing flowers and fruit continuously (Francis *et al.*, 2002). It yields seeds after 1-2 years.

- **Effect of *M. oleifera* on the environment**

Interaction between *M. oleifera* and other plants can improve crop production. The trees are planted as live hedges (Duke, 1983). When *M. oleifera* fences protect vegetable gardens, crop production can be increased.

The cultivation of *M. oleifera* improves soil conditions and consequently increases crop production. Nitrogen production from the association with mycorrhiza can improve soil fertility. The seed cake can be used as a fertiliser (Pratt *et al*., 2002).

M. oleifera can provide food to humans and animals. Most parts of the plant are eatable. The seeds are eaten like peanuts in Malaya. The leaves can be eaten in salads and other dishes as seasoning. Thickened roots are used instead of horseradish. The oil is also eatable containing 76% monounsaturated fatty acids, which is mostly oleic acid. Livestock eat the leaves and young branches (Duke, 1983).

A water extract of the kernels is useful as a water-purifying agent.

7.6.4 Bio-diesel Production

The seed kernels consist of an average of 40% oil in terms of weight. The oil can be used for bio-diesel. The plant yields approximately 3.0 tons of seeds per hectare. It produces fruit within 6 to 8 months after being planted and continues production for 30 to 40 years (Francis *et al.*, 2002).

7.6.5 Concerns

- M. oleifera is not indigenous to South Africa, and might have possible impacts on the environment
- The seeds do not produce as much oil as the other alternatives, and economical feasibility should be investigated
- Information on oil yield under stressful conditions is not available, but will probably be lower

7.7 Ximenia caffra

X. caffra, also called the large sourplum, belongs to the family Olacaceae. It is indigenous to South Africa (Baloyi & Reynolds, 2004). *X. caffra* has two varieties, var. *caffra* and var. *natalensis*. The two varieties differ slightly in morphology and distribution.

The plant has various medicinal uses against diarrhoea, inflamed eyes, tonsillitis etc (Baloyi & Reynolds, 2004). Cold infusions of the leaves can be used as and anti-inflammatory and as an eye lotion. In Africa the roots are used against fever and diarrhoea. An infusion of the roots is used against syphilis and ancylostomiasis (Watt & Breyer-brandwijk, 1962). The wood is used in construction and to make handles for tools and spoons. The wood is also used for firewood. Traditionally the oil is used to soften animal hides and bow strings. The oil is also used as a body ointment (Palmer & Pitman, 1972).

7.7.1 Morphology

X. caffra is a shrub or a small tree and it can grow up to 6 m tall. The bark is dark grey and rough. The leaves are simple, dark green and leathery. The leaves of var. *caffra* have red brownish hair, while var. *natalensis* is not hairy (Palgrave, 2002). The midrib of the leaf is prominent and the leaves are inclined to fold inwards (Palmer & Pitman, 1972).

The flowers are small and creamy white (Palgrave, 2002). It is hairy with four petals and has a sweet scent (Palmer & Pitman, 1972). The sexes are separate and on different plants (van Wyk & van Wyk, 1997)

The fruit are fleshy and about 2.5 cm long (Figure 7.8). The fruits are red with white spots and it is edible, though it has a very sour taste (Palgrave, 2002). Every fruit contains one seed (Palmer & Pitman, 1972).

Figure 7-8: The fruit of *X. caffra* (Nichols, 2004)

7.7.2 Distribution

The distribution of *X. caffra* in South Africa is described in different sources. As indicated in Figure 7.9, it is distributed in the northern areas of South Africa and along the coast (Palgrave, 2002). According to Palmer and Pitman (1972), the rocky hillsides in the Magaliesberg are the southern edge of *X. caffra*. It also occurs westwards to Botswana and South West Africa. *X. caffra* extends northwards to tropical areas in Africa.

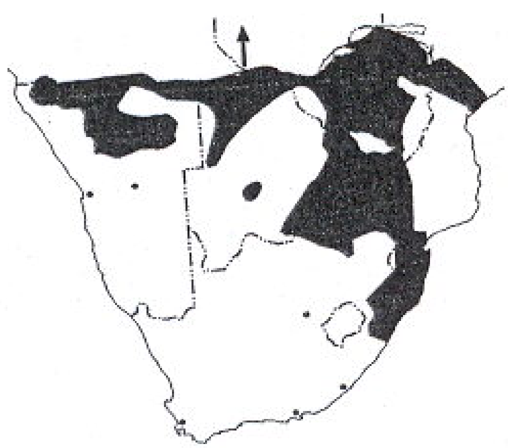

Figure 7-9: The distribution of *X. caffra* (Palgrave, 2002)

7.7.3 Ecology

- **Habitat**

X. caffra occurs in dry wooded bushland and wooded grassland, but it is more abundant in dry coastal and lowland woodlands. It also occurs on rocky outcrops and on termite mounds (Baloyi & Reynolds, 2004). According to the literature, *X. caffra* prefers soils such as clays, clay loams, sandy clay loams and compacted sandy loams. In contrast to this, PRU-herbarium specimens of *X. caffra* occur mostly on well-drained sandy soils (HGWJ Schweickerdt herbarium).

X. caffra needs full sun and it is drought resistant (Baloyi & Reynolds, 2004). It requires a minimum rainfall of 250 mm and a maximum rainfall of 1270 mm. The plant requires minimum temperatures of 14 ºC and the temperature should not exceed 30 ºC. The minimum altitude, where *X. caffra* grows, is 15 m and the maximum altitude is 2000 m.

The plant is partly parasitic and the roots need to make contact with other plant roots (Baloyi & Reynolds, 2004).

- ***X. caffra* in the ecosystem**

The fruit of *X. caffra* are edible drupes. Animals, people and birds such as bulbuls, barbets and starlings eat the ripe fruits. Animals such as, giraffe, impala, kudu, grey duiker, steenbok, bushbuck and eland eat the leaves. A big variety of butterflies also feed on the leaves (Baloyi & Reynolds, 2004).

The nutritional value of *X. caffra* is indicated in Table 7.5. The fruits of *X. caffra* have a high ash and mineral content and low fat, fibre and carbohydrate levels. The Ca and Mg content of *X. caffra* are low (Saka & Msonthi, 1994).

Table 7-5: The nutritional value of *X. caffra* fruit (Saka & Msonthi, 1994)

Dry matter (%)	Ash (%)	Crude protein (%)	Fat (%)	Fibre (%)	Total carbo-hydrate (%)	Energy value (kJ / 100g)	Mineral (μg / g)					
							P	Ca	Mg	Fe	K	Na
17.2	11.0	7.6	5.2	2.3	78.8	1506	1674	29	459	366	41791	198

The oil of *X. caffra* has a high quality and it is very nutritious, containing 58.7% oleic acid, a little palmitic acid and linoleic acid.

7.7.4 Bio-diesel Production

The seeds contain 65, 7% of high quality oil (Ligthelm *et al.*, 1954).

7.7.5 Concerns

- Unfortunately *X. caffra* only produces seed after 5 years, and it will take a long time to establish the trees for bio-diesel production (Baloyi & Reynolds, 2004)

- The semi-parasitic nature of *X. caffra* will require a host plant, and might cause damage to the host. Combining *X. caffra* with other diesel-plants might reduce the oil production of the other plants

7.8 Pappea capensis

P. capensis (Figure 7.10), also known as the Jacket-plum, belongs to the family Sapindaceae. It is the only example that is indigenous to the local ecosystem of the selected site. Except for potentially producing bio-diesel, *P. capensis* have many uses. The oil is edible, can be used medicinally and to produce soap. The bark also has medicinal value (van Wyk & van Wyk, 1997).

Figure 7-10: *P. capensis* (Hankey, 2004)

7.8.1 Morphology

P. capensis is an evergreen tree with a height of 2-8m. The leaves are simple and tough and the fruits are green on the outside with a bright red flesh and black seed as seen in Figure 7.11 (Hankey, 2004).

There are two varieties of *P. capensis* in South Africa. The variety growing in moister conditions are bigger trees, with bigger leaves and the leaves are hairy. The variety growing in arid areas is smaller and less hairy (Hankey, 2004).

Figure 7-11: The fruit of *P. capensis* (Hankey, 2004)

7.8.2 Distribution

P. capensis is widely distributed throughout southern Africa as indicated in Figure 7.12 (van Wyk & van Wyk, 1997). The two South African varieties differ mostly in distribution. One variety occurs in the eastern and northern part of the South Africa, which is a moister area. The other variety occurs in arid areas such as the Karoo (Palmer & Pitman, 1972).

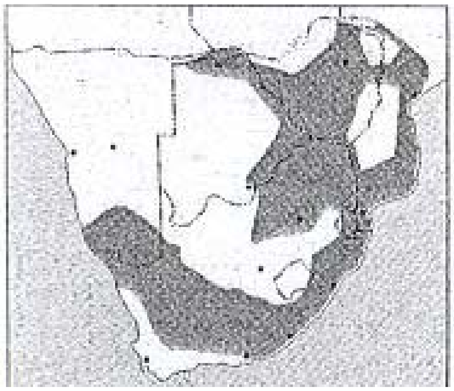

Figure 7-12: The distribution of *P. capensis* (van Wyk & van Wyk, 1997)

7.8.3 Ecology

- **Habitat**

The two varieties of *P. capensis* in South Africa differ in habitat requirements. One variety occurs in moist areas and the other variety in arid areas. The variety growing in the arid regions produces very little seeds (Palgrave, 2002).

- ***P. capensis* in the ecosystem**

Animals such as, giraffe, elephant and domestic stock heavily graze the leaves of *P. capensis*. Bees are attracted to the sweet scent of the flowers. *Leptocoris hexophtalma*, a small red sucking bug, is associated with *P. capensis*. The bug sucks the oil from the seeds on the ground (Palgrave, 2002). *P. capensis* also provides a good shade for animals (Palgrave, 2002).

In the Karoo environment, *P. capensis* trees are associated with *Boscia oleoides* and on rocky slopes it is associated with *Portulacaria afra* and *Euclea undulate* (Palgrave, 2002).

7.8.4 Bio-diesel Production

The seeds of *P. capensis* have a very high oil content that can be used for bio-diesel production. The oil yield per area is not known (Palgrave, 2002).

7.8.5 Concerns

- In arid areas the trees do not produce enough seeds and additional irrigation will be necessary

- The fruits are very small and production potential should be determined

7.9 CAPITAL

Capitals are resources that are invested to produce more resources and are crucial for the sustainability of a system (Flora & Kroma, 1998). All capitals can be divided into five categories (Flora & Kroma, 1998).

7.9.1 Natural Capital

The natural capital is the local eco-system including biodiversity of the flora and fauna, resources like air quality, water and soil quality and quantity, the landscape and services such as decomposition (Flora & Kroma, 1998). The natural capital forms the basis of sustainability. It should also be noted that natural capital is site specific and is very variable (Curtis, 2003).

7.9.2 Social Capital

Social capital is aspects of the social structures that facilitate coordination, teamwork and mutual aid. Building a community is very important to achieve social capital (Flora & Kroma, 1998).

The local community has control over the eco-system, and needs to conserve it. The community knows and understands the eco-system of the area and how to manage it. This knowledge must also be passed on to next generations. Sustainability is dependent on social systems and it is important to understand the character of the social system involved (Curtis, 2003).

7.9.3 Human Capital

Human capital includes the capability of the individual, the individual's skills like business skills, knowledge in different fields such as agriculture and community development skills such as judgment, patience, consideration etc (Curtis, 2003).

7.9.4 Physical Capital

According to Flora & Kroma, (1998) the physical capital includes the tools and machinery, infrastructures, water and waste systems and other municipal services, energy systems, houses, buildings, pesticides, fertilisers etc. These tools should be designed in such a way that sustainability increases, energy is not wasted and renewed etc. Permaculture proposes good concepts on how to manage physical capital (Curtis, 2003).

7.9.5 Financial Capital

Financial capital is money and all the instruments needed to make investments such as credit. Individuals acquire financial capital from salaries, loans, wages from investments etc (Flora & Kroma, 1998).

The economy in the African context is a limiting factor for development. Being a third world country, South Africa does not have this essential resource of development. Low-cost agriculture needs to be designed to overcome this limitation (Fowler & Rockstrom, 2001).

8 TECHNOLOGY

Traditional western agriculture was introduced in South Africa based on European technologies. These agricultural practices were characterised by large-scale commercial cultivation, irrigation and powerful equipment, pesticides and fertilisers. These farming practices degraded soil properties and structures, reduced water holding capacity and cation exchange capacity of the soil and destroyed organic matter and soil organisms. These damages caused soil erosion and desertification, reducing the agricultural potential of the soil (Fowler & Rockstrom, 2001).

The conclusion is that more sustainable methods are not only desirable but crucial. Sustainable agriculture is needed that would maintain its productivity over the long-term, support the social system, that would not destroy the ecosystem or deplete resources and it should be economically feasible and commercially competitive.

The concept of sustainability is very debatable. Large-scale commercial cultivation is not the only unsustainable way of agriculture; low-income communities with minimum inputs, such as fertilisers and pesticides, tend to cause the same amount of damage. Therefore, sustainability cannot be measured as a function of the amount of input (Rigby & Cáceres, 2001). Rigby & Cáceres, (2001) goes further to say that sustainable agriculture does not correspond to low production. A decrease in production will lead to an increase in cultivation area, leading to the destruction of even more natural habitats.

The concept of sustainability also faces the problem of scale. The agricultural practices of an organic farmer such as crop rotation and less input of chemicals can be locally sustainable, but still he uses non-renewable energy sources that are unsustainable on the global scale. According to Curtis (2003) small-scale, labour intensive agriculture therefore seems to be the most sustainable option.

Different sustainable agricultural methods were designed with the purpose to improve the sustainability of agricultural methods, many of these incorporates ecological principles. This chapter is a literature study on sustainable agricultural methods. *Permaculture* is a holistic approach, based on ecological principles, focusing on the establishment of sustainable production systems including humans, animals, plants, soil etc. *Conservation agriculture* focuses on the conservation of natural resources such as soil, water, soil biota etc. *Intercropping* increases plant diversity in order to increase the stability of the system. *Organic farming* has a set of standards to which farming systems must comply with, and can be characterised by the reduction of inputs such as fertilisers and pesticides and crop rotation etc.

The different sustainable agricultural methods give insight in the path to sustainability, and should be used as guidelines instead of a set of rules. Sustainable agriculture will be achieved in different ways at different times and places. Reaching sustainability is a process of trail and error and time is critical in achieving success.

8.1 PERMACULTURE

The word permaculture is derived from 'permanent agriculture'. The concept was developed by Australian ecologists, Bill Mollison and his student David Holmgren (Diver 2002).

Permaculture is an alternative farming system, which incorporates ecological principles to human settlements and food productions. The aim is to design a sustainable system, reducing energy input and waste production. Permaculture focuses on the relationship between the different components of an ecosystem. Ideas of permaculture designs are often found in nature (Diver, 2002). According to Diver (2002) the following are characteristics of permaculture:

- Permaculture is a holistic and integrated system, integrating all aspects of an ecosystem such as soil and soil organisms, water, annual and perennial plants, animals and humans into stable and productive communities
- Permaculture can be applied as productive systems or to restore degraded land
- Permaculture uses traditional experience and knowledge if possible
- Permaculture approves organic agricultural methods that do not use pesticides or pollutants
- Permaculture promotes symbiotic and synergistic relationships between the different components
- Permaculture can be used in urban planning and rural land design
- Permaculture designs are developed specific to the site and the culture of the people

8.1.1 Ethics of Permaculture

Ethics were identified which represents the broad moral values. The ethics according to Diver (2002) are in short:

- **Care for the Earth:** This includes plants, animals, water, air, soil etc.

– **Care for People:** Permaculture should help people to be independent and responsible to their community

– **Setting Limits to the Population Growth and Consumption:** Excess time, money, labour, information and energy are given away.

– **Conservation:** Every living thing has an intrinsic worth and must be conserved

8.1.2 Principles of a Permaculture Design

The following universally applicable principles are set to guide one when designing a permaculture system:

- **Design with nature:**

Biological or natural alternatives must be considered for everything that needs to be accomplished in the system (Jackson, 1984).

- **Plan the physical layout:**

According to Jackson (1984) the physical layout can be divided in three ways, zonation, sector planning and relative location.

Zonation: Different zones can be identified around the household within which the different components of the garden will be located. It can be envisioned as concentric circles with the house as the centre point. The component which requires the most energy is located close to the door of the house. The component that requires the least energy is located in the zone far from the house.

Sector planning: The site is divided in wedge shaped segments, radiating from the house as the centre point. Every segment is identified, in terms of fire risk, view, noise etc. These are the external inputs that need to be managed within every segment, which can either be beneficial or needs to be mitigated.

Relative location: The location of each component on the site relative to other components must reduce energy and resource input requirements. The components with similar requirements must be clustered together. For example, if all the components requiring water are close to each other, water installation requirements will be reduced.

- **Each element performs multiple functions.**

Jackson (1984) explains this with the example of chickens. A chicken is not only used for its eggs, meat and feathers, it also excretes nitrogen which improves soil conditions, it eats seeds of weeds and insect pests and it prepares the soil for planting by scratching in the ground.

- **Each function in the system is supported by different components.**

This is important for in case one component is in short supply, then the function can be supported by other components Diver (2002).

- **Other principles**

Permaculture has other the principles as well: energy efficient planning and energy cycling, use of biological resources, small-scale intensive systems, natural plant succession, diversity of species and observing and replicating natural patterns (Diver 2002).

8.1.3 Designing a Permaculture Garden

A permaculture system needs to be well planned and designed. The application of permaculture will differ from site to site, depending on the ecology of the area and the social and cultural aspects of the people. According to Raders and Raders (2006) the following steps should be followed before implementation.

- **Observation**

First you need to observe the site. Note everything that you see.

- **Analyse the site**

– Map the boundaries and study the upstream and upwind activities. The proximity of servitudes, rivers, towns etc

– Determine the topography, the slope of the area, valleys and ridges as well as the aspect of the slope

– Determine the temperature and precipitation (climate), microclimates and the wind strength and direction

– Analyse the soil and geology as well as the hydrology of the area

- Sense of place, where would time be spent most and how is the view from there?
- Utilities: their situation in terms of electricity, water availability, sewerage, telephones etc
- Council activities, waste removal, public transport, recycling etc
- The traffic intensity, heavy vehicles and pedestrian traffic etc
- Housing, build environment, shacks etc
- Ecology, animal populations. Vegetation, plant communities, indigenous plants, exotic species, poisonous plants
- Previous land-use activities: abandoned agricultural land, pasture, geomorphologic hazards
- Rules and Regulations, current land-use and zoning
- Future land-use: Subdivisions, industry, mining, tourism etc
- Problems and Hazards: Fire events, floods, pollution (air, visual or noise)
- Assets and Potential: Waterfalls, rock outcrops etc
- Resources of the Neighbourhood: Shops, schools, hospitals, factories etc
- Imports and Exports: Food, building materials, fossil fuels etc

- **Social and cultural analysis**

Interview every individual in the household as far as possible and determine the following:

- Names, ages and occupation of everyone in the household
- Any pets present
- Their needs, such as food, water, etc
- Their dreams, goals, etc
- Lifestyle: Likes, dislikes, hobbies, values, etc
- Resources: Finances, skills, knowledge, health etc

- Communities relations: Friends, church relation, community involvement
- Favourites: Food, past time, activities, interests etc

- **Draw a base plan**

Draw a map containing al the information you collected i.e. the status quo. Put the map into scale by indicating north

- **Concept**

Formulate the different goals and prioritize them: Income production, production to sustain, aesthetic value and sense of place, ecological sustainability etc.

- **Lay out zones**

Create the different zones around the household. The gardens requiring the least attention are far from the house, while the gardens requiring most attention are placed close to the door of the house.

- **Earthworks**

Do all the earthworks, like buildings, dams, walls, drains etc.

- **Species Selection**

Decide which species is needed according to the needs of the household and the ecological system. Locate the animals and the vegetables.

8.1.4 Permaculture in the Low-Income Household

The household is a place where different systems interact and resources are produced and needed. Therefore a holistic approach such as permaculture seems to be the best approach for the household.

The theory and aims of permaculture is well developed and well formulated. Permaculture is already a few steps ahead by focusing on the systems, rather than on the production of resources. Finding a method to reconcile all the systems present is difficult and the right approach is essential. Using nature as a template for designing such a system is a good approach.

The concept of permaculture sketches an ideal situation, which would probably work in a predictable system. Systems are very dynamic and difficult to predict and the application of permaculture would probably not be as simple. Applications of permaculture in the Africa-context present many challenges and one might be forced to settle with a system not entirely flawless.

8.2 CONSERVATION AGRICULTURE (CA)

Conservation agriculture is an alternative agricultural method that can be used on different scales, from household-based production to large-scale commercial farms. The aim of CA is to conserve natural resources and to sustain the environment, while generating a high profit. CA is based on the following basic principles (FAO, 2006):

- Tillage is avoided
- The soil is permanently covered
- Annual crops are rotated while perennial plants are diversified

8.2.1 Conservation Tillage (CT)

Tillage is the preparation of the soil for planting crops by ploughing and loosening the soil. CT is a soil management system promoting minimum soil disturbance. CT restrains from ploughing or disturbing the soil as a natural resource. Other natural resources that are also conserved include water, energy, time and money (Fowler and Rockstrom, 2001).

- **Water conservation**

Water is generally the most limiting factor in African crop production and soil conditions have a big influence on soil water conservation (Fowler & Rockstrom, 2001). Ploughing and working of the soil destroys the soil cover and exposes the soil. Soil water is lost due to exposure to high temperatures and wind (FAO, 2006).

Conservation tillage increases the soil water content, especially in dry areas, by improving the organic matter content of the soil and by changing the pore sizes of the soil. Plants and residues covering the soil surface reduce water evaporation and increases infiltration of water by reducing water run-off (Bescansa *et al.*, 2006).

- **Soil conservation**

Soil degradation is a worldwide concern. Of all the space available for crop production, 70 % are already degraded. Topsoil is lost at an alarming rate. Soil erosion follows, leading to a loss in soil fertility (Fowler & Rockstrom, 2001).

Except for the soil water content, CT also improves physical soil properties like soil aggregation and stability of aggregates. CT also improves chemical soil properties, such as increasing organic matter, quality of the organic matter and nutrient status. In some cases CT can restore saline soils, reducing the electrical conductivity. The improved conditions and stability of the soils due to CT reduces soil erosion (Bescansa *et al.*, 2006).

8.2.2 Permanent Soil Cover

A permanent soil cover is crucial for CA and can either be reached by leaving the residues of the previous crops on the soil or by planting a covering crop. Severely degraded soils with no vegetation cover are exposed to erosion and crust formation. These conditions increases water run-off and decreases water retention (FAO, 2006).

A vegetation cover protects the soil from high temperatures and evaporation of water, creating a suitable habitat for soil organisms. Soil organisms have different ways to create macro pores in the soil, which increases water holding capacity (Fowler & Rockstrom, 2001).

According to FAO (2006) cover crops have the following advantages:

- It protects the soil, especially from temperature fluctuations and water loss
- It retains nitrogen in organic form ($-NH_2$) preventing it from leaching from the soil. Available nitrogen is increased if legume plants are used as a cover crop
- It increases the organic content of the soil
- It inhibits the growth of weeds and repels soil borne pests
- It prevents and reduces soil compaction, while increasing soil porosity

Cover crops have the following disadvantages (FAO 2006):

- It requires very good management

– At the beginning of the growing season, the decomposition of the cover crops might reduce nitrogen in the soil

The cover crop should be properly managed. This includes correct spacing and timely sowing of the crop. Organic residues covering the soil should be evenly distributed over the soil surface, otherwise it could result in uneven germination of seeds (FAO, 2006).

Research must be done to choose a suitable cover crop. The first year of CA one must start with a cover crop producing residues that will decompose slowly, covering the soil for longer. Grasses and cereals are suitable for this stage. Legume plants can be incorporated at a later stage, though it decomposes quickly, but it improves the soil conditions and the nitrogen content. At later stages, the cover crops can have an economic value of its own such as livestock fodder (FAO, 2006).

8.2.3 Crop Rotation

Crop rotation is a basic and very important part of CA. The effect of crop rotation includes (FAO, 2006):

– Plant diversity increases providing a diversity in human and animal nutrition

– Reduces the risk of pest and weed infestations, since the density of a single species reduces

– Macro pores form at different levels of the soil profile

– Water and nutrients are distributed better throughout the soil profile and plants can exploit different levels of the soil profile for optimal water and nutrients uptake

– Increase humus formation and nitrogen fixation

8.2.4 CA in the Household

CA has the following benefits:

- **Low impact on the environment**

The global greenhouse effect has become a major concern and is caused by an increase in atmospheric CO_2, CH_4, NO_x, SO_x etc. Soil biota plays a major role in absorbing these compounds from the atmosphere, changing it into available forms for plants to absorb (Fowler & Rockstrom, 2001).

The conservation of soil micro-organisms in CA and CT practices increases fixation of compounds such as NO_x into plant available forms (Fowler & Rockstrom, 2001).

- **Economically feasible**

The improved soil conditions due to CA practices requires a lower input for successful production of crops. No tillage reduces the labour intensity reduces the cost of production (Fowler & Rockstrom, 2001).

- **Technically feasible**

The physical capital needed for CA is reduced, since disturbance of the soil requiring expensive machinery is avoided.

One disadvantage of CA is the social acceptability of the method (Fowler & Rockstrom, 2001). CA requires very good management in order to be successful. Furthermore it might require a paradigm shift, since the gardens do not look neat and tidy as many people are used to.

8.3 INTERCROPPING

Monocultures are not natural systems and experience instability, requires more input to succeed and destroy bio-diversity. Intercropping, also known as poly-cultures, is the practice of growing two or more crops in combination. This method is an imitation of the natural system, which is inclined to higher diversity. Higher bio-diversity generally improves the stability of the system (Sullivan 2003).

In the process certain other benefits become clear. Plants could affect each other in a positive way. Plants could, for example, improve soil conditions, repel insects and provide structure to other plants. According to Sullivan (2003), co-existence in plant communities is more common than competition. It is therefore possible that the production of plants in a mixed crop will be higher than the production in a monoculture.

8.3.1 Implementation of Intercropping

Even though intercropping presents many benefits, it is more difficult to manage. The crops must be combined in such a way that cooperation is maximised and competition is minimised for optimal production. Therefore the following things need to be considered (Sullivan, 2003):

- **Spatial Arrangement**

The spatial arrangements can be varied in four main ways:

– *Row intercropping*; two or more crops are planted with at least one crop planted in rows

– *Strip intercropping*; two or more crops are planted in rows, far enough for machines to harvest the crops separately and close enough to facilitate interactions between the crops

– *Mixed intercropping*; two or more crops are planted with no arrangement

– *Relay intercropping*; crops are planted at different times. The second crop is planted when the first crop has reached its reproductive stage but before it is harvested (Sullivan, 2003)

- **Plant Density**

Intercropping will not succeed if the crops are planted to dense. The seedling rate of both crops should be reduced in order to prevent overcrowding. Priority could be given to a specific crop, and the density could be reduced with only 20% while the density of the other crop is reduced with 80% (Sullivan, 2003).

- **Maturity Dates**

Resource requirements peak at a certain stage of the lifecycle of all crops. Crops can be planted at different times in such a way that their stages of highest resource requirements occur at different times of the year (Sullivan, 2003).

- **Plant Architecture**

The architecture of a plant must be considered for several reasons. For example, one plant could cast a shadow over other crops. The architecture of plants could also supply a structure for climbers etc (Sullivan, 2003).

8.3.2 Evaluation of the Success of Intercropping

In order to determine the success of the intercropping, the percentage yield of the different crops in monoculture will be compared to their yield if they are intercropped. The success of an intercrop is determined by an LER value. An LER value will be calculated using the equation (Sullivan, 2003):

LER = (intercrop diesel-plant / pure diesel-plant) + (intercrop vegetable / pure vegetables).

8.3.3 Intercropping in the Household

Intercropping could have many advantages for a small-scale farmer because, compared to a monoculture, it is at a higher level of complexity. A variety of plants could for instance satisfy different needs of a household, it could provide stability in production and it could provide food for a larger period of the year. A small-scale farmer could maintain an intercropping system easier than a large-scale farmer, because and intercropping system is labour intensive and difficult to harvest with large machines.

8.4 ORGANIC FARMING (OF)

Many scientists regard organic farming as synonymous to sustainable agriculture, while others feel it is two different concepts. This problem arises because of the many definitions for both sustainable agriculture and organic farming. The concept of organic farming was also motivated by the concept of sustainability, regarding concerns like soil structure and health, the environmental impacts of fertilisers and human health issues (Rigby & Cáceres, 2001).

8.4.1 Principle Aims of OF

The International Federation of Organic Agriculture Movements published the principle aims of organic agriculture and processing (IFOAM, 1998):

- To produce high quality food in adequate quantities
- To interact positively with natural systems. Promote natural systems and cycles within the farming system
- To consider social and ecological impacts caused by the production of food
- To develop an aquatic ecosystem, which will conserve water resources as well as the living organisms in the water
- To maintain and increase the fertility of the soil over the long term
- To conserve genetic diversity in the farming system and the surrounding system
- Strive towards using renewable resources
- Minimise every form of pollution and produce fully degradable organic products

8.4.2 Published Standards

The aims of organic farming mentioned above, seems to correlate with sustainable agricultural practices. Organic farming, in theory, goes beyond the point of reducing input (Rigby & Cáceres, 2001).

The one thing distinguishing organic farming from other sustainable agricultural practices is probably the published standards to which producers must comply with in order to classify their products as organic. These standards must be clear and cannot leave space for vagueness. Food either complies with these standards or they don't. On the one hand the set standards are useful, but on the other hand it creates some problems (Rigby & Cáceres, 2001).

Some of the set standards which organic farming needs to comply with are difficult to quantify. The restriction of inputs such as fertilisers and pesticides are easy to quantify and universally applicable standards can be created. But how would one quantify the social and ecological impacts? Therefore organic farming, though in theory they include socially and ecologically acceptable practices, in practice these aspects are neglected. The standards, therefore, focus on the exclusion of agricultural inputs, such as fertilisers and pesticides (Rigby & Cáceres, 2001).

The use of set, well-defined standards in organic farming is also difficult to apply over time and space. Sustainable agriculture is site specific, since social and ecological systems are dynamic and varies in time and space. One set of standards is therefore not sufficient to be applied universally (Rigby & Cáceres, 2001).

8.4.3 The Negative Effects of OF

Organic farming can also have negative environmental effects, like (Rigby & Cáceres, 2001):

– Nitrates leaching from under legumes

– Livestock waste accumulates causing ammonia to volatilise

– Certain practices causes heavy metals to accumulate in the soil

8.4.4 The Success of OF

The effect of organic farming compared to traditional western farming on different aspects of the environment can be summarised as follows (Rigby & Cáceres, 2001):

– **Ecosystem:** Organic farming conserves faunal and floral diversity better than western farming systems, but direct conservation depended on individual farmers

– **Soil:** Organic farming improves soil fertility and stability, though no difference can be noted concerning soil structure

– **Energy efficiency:** Energy is used more efficiently in organic farming

8.4.5 OF in the Household

Organic farming has positive aims and if it is applied successfully it could be beneficial.

A household is a very dynamic system, because there the social system and the ecosystem are in close contact with the production practices. It will be difficult to apply set standards in such a dynamic system. A set of standards will probably be easier to apply in a large-scale farm that are more isolated from the social and the natural environment.

9 DISCUSSION

In this chapter the objectives of this study as formulated in Chapter 2 are discussed and used to formulate the most promising options for sustainable and productive vegetation in the household, which is the aim of the study.

9.1 THE FUNCTIONING OF THE SYSTEMS

Systems have different levels of complexity, which is important to study when dealing with the functioning of a system. The functioning of a system is analysed by the inputs needed by the system, the outputs of the system (Table 2.2) and the requirements of the system.

9.1.1 Economical System

The residential area of the selected site can clearly be divided into different economical groups. From their gardens and buildings it seems as if some are rich, while others are extremely poor. Further research is needed to understand the functioning of the economical system in the African household.

9.1.2 Social System

The functioning of the social system was studied on a household-scale. The ecosystem can provide necessities required to satisfy fundamental human needs (see Figure 2.2). The requirements of the household set the rules for the technologies that are used to acquire the resources from the ecosystem that would satisfy the needs of the household. The output of the social system in this context is seen as the footprint on the ecosystem and is discussed under the interaction between the social and the ecosystem.

- **Needs of the social system:**

In Figure 2.2 it is seen that the inputs needed by the social system ultimately come from resources provided by the ecosystem. The ecosystem can improve the quality of life of the low-income household by providing the following elements that are required to fulfil their fundamental human needs:

- Food including proteins, starch, vitamins, minerals etc. Crop production needs protection against thieves, animals, soil erosion etc
- Energy like firewood
- Animal feed

– Fertiliser

– Medicine

– Shade

– Income

- **Requirements**

In the context of this study, the word "requirement" refers to those things that a satisfier of a need must comply with, as determined by members of the household as well as role players outside the household. Household-based production technology will only be used by household members if it complies with the requirements of the household. Crops are required to have certain properties in order to be cultivated successfully by a low-income community with low expertise. These properties include the following:

– The crop should be easy to cultivate and not be knowledge, labour and capital intensive

– The crops need to be tough plants, resistant to fungi and marginal environmental conditions

– The crops should not endanger the health of the people. The toxicity of the plant should be investigated

Other role-players may also have requirements, e.g. that the no invader species must be introduced to an area. Such requirements must be complied with, even if the household members are not concerned about it.

9.1.3 The Ecosystem

On a global scale, the only input needed by the planetary ecosystem to be maintained is sunlight energy. This ecosystem supports all other systems and provides resources as an output (Table 2.2).

The levels of complexities in the ecosystem are important to understand ecosystem functioning. An important concept is found in Ecology, which is the concept of the plant community, which is at a relatively high level of complexity. The functioning of the plant community gives a person good insight in the way sustainability could be maintained. Ecology recognises that a higher level of complexity, like the plant community, is more stable than the lower level of complexity, like the monoculture (Kent & Coker, 1992). This study assumes and seeks to proof that a household ecosystem at a higher level of complexity can also increase the stability of the social and economical systems. In this way global problems in the systems like ecosystem destruction, poverty and the growing gap between rich and poor might be solved.

9.2 THE INTERACTIONS BETWEEN THE SYSTEMS

The relationship between African people and the ecosystem or the land is very complex, as is clear from the African literature. The mythical connotation to life, land and productivity seems irrational to the modern western culture. Our technological and economical solutions to problems in the African household do not always succeed, since we do not understand this way of thinking, as in the example of the Turkana Tribe. The research that is done for this study helps one to form a better understanding of the meaning these people attach to the ecosystem.

9.2.1 The Social System and the Economy

Many indications were found during the fieldwork of the influence of the Western economy on the African households. The following interesting remarks were mentioned during the interviews (refer to Chapter 5):

- The flower garden is nice, she wants the yard to be nice (Table 5.5, Household 8)
- People with no gardens are poor or lazy (Table 5.5, Household 4)
- People like modern trees more than African trees, people live in two different worlds (Table 5.5, Household 7)

The jobs that people do, such as police men, business men etc are also an indication of the influence of the Western culture and their dependence on money. The woman in Household 10 of Sample C begged for food, money and blankets. She therefore seeks her solution solely in the economical system.

9.2.2 The Ecological and Social System

The interaction between the social system and the ecosystem takes place in the land use, as determined in Chapter 5, and its ecological implications, as determined in Chapter 6. It is also seen as the outputs or the footprint of the social system on the ecosystem.

- **Land use**

The social system utilises the ecosystem in a particular way, which influences the availability of resources. The current land use was studied in terms of the utilisation of space, soil and water.

Space: It was found that the actual space for crop production is reduced by the utilisation of space. The space available for crop production is limited to the back yard, since the people do not prefer planting crops in the front yard. Possible reasons for this were found during the interviews:

– **Fear:** During the interviews most people would say that it is to protect the vegetables against stealing (refer to Table 5.5)

– **Aesthetic value:** People want a pretty garden that is visible from the street. Some remarks were made that support this idea: 'I want it to look nice' and 'flowers are supposed to be in front and vegetables are supposed to be at the back' (refer to Table 5.5, Households 6 and 8)

– **Symbols:** They are close to Pretoria and often see the pretty gardens of rich people. This is a standard to which they constantly strive in spite of their poverty. The lawns in most of the yards are too small to be functional and are probably a symbol of a high living standard

Soil: Areas of bare swept soil are seen in 100% of the households of Sample A and all the households in Sample C. Firstly the soil is not covered or protected from the sun, wind or water. The soil dries out quickly because of the heat during the day. Micro-organisms die in this temperature fluctuations and very little organic matter is formed in the soil. The soil forms a crust and water cannot infiltrate the soil, leading to runoff and erosion.

The question is: Why do people spend time and energy in utilising the soil in an environmentally destructive way, if they do not benefit from this? The reason for sweeping the soil was investigated during the interviews. A few reasons were identified:

– The **influence of the Western culture:** They want their yard to be neat and clean (refer to Table 5.5)

– **Resource limitation:** There is not enough water to plant anything in the yard (refer to Table 5.5)

– **Fear:** People are afraid of snakes. There are many snakes in the grasses and the natural vegetation (refer to Table 5.5, House 9 & 10)

– **Functionality:** The children play on the bare soil, they do not want the children to play in the flowers (refer to Table 5.5, House 3)

Water: Water is used to irrigate gardens, for laundry and for other household activities. Some people water the yard with used water, but others use clean water because they believe the soap is bad for the plants. A lot of water is wasted, because of broken pipes and negligence around the communal taps.

Some people have to walk far for water and some have taps in the yard. Water is usually just available late at night. During the interviews it was clear that some households have a lot of water (refer to Table 7.4, Household 4), while other people have a serious need of water.

In this study the minimum water requirement of a household is assumed to be 550 litres per week, because Household 2 of Sample C survives with that amount of water.

Plants: The natural vegetation is destroyed and exotic species are introduced. Some reasons for this are identified:

– **Religion:** Mythical conceptions such as the remarks that snakes travel through the air and come to the indigenous trees indicates the religious connotation of plants (refer to Table 5.5, House 7)

– **Fear:** People are afraid of real snakes. There are many snakes in the grasses and the natural vegetation (refer to Table 5.5, House 9 & 10)

– **Identity:** People struggle between the Western identity and the African identity, 'people like modern trees more than African trees, they live in two different worlds' (Table 5.5 House 7)

Preferred Land Use

Is the current land use the desired land use? When the three photos were showed to residents, all the households in Sample C preferred the flower garden in Figure 5.4. A few also liked the traditional hut in Figure 5.3. Nobody in Sample C wanted the yard with the bare soil in Figure 5.5, though they all had a large area of bare soil. The sample size is too small to conclude that the flower garden is the desired land use for all people. However, it can be said that the current land use of Sample C does not correspond with their desired land use.

The discussions during the interviews raised a few interesting questions. First one should understand the meaning of the three households shown in Figure 5.3, 5.4 and 5.5. Figure 5.3 and Figure 5.4 represents a specific identity. Figure 5.3 is the traditional African identity. Before

Western influences the African culture used to be harsh with a high mortality rate. But the population numbers were controlled by environmental limitation and the African way of life was sustainable. Figure 5.4 represents the Western identity. It is a life of comfort, wealth and progress. The Western life is seen as 'easy', as the 'soft life of the whites' and as if people have a high quality of life. But the Western culture is from an ecological point of view not sustainable. It relies heavily on environmental resources and consumes limited resources.

People strive towards a Western identity, because it represents a prosperous life. But unfortunately it does not always improve their quality of life. They spend a lot of resources, energy and time making beautiful gardens, but they still do not have enough to eat. It is even likely that the extensive use of water in some gardens further increases the lack of water in other gardens.

The question that arises here is what identity is represented by Figure 5.5? Everybody has at least a piece of bare soil in their gardens, though it is a land use that nobody in Sample C prefers. If asked people would say they sweep the floor to keep it clean and the soil is bare because they do not have enough water. Why do they not leave the natural vegetation as in Figure 5.3 in stead of the bare soil? It is possible that Figure 5.5 is a result of people striving towards the Western standard, but they do not have the resources to reach it. Household 9 and 10 of Sample C gave another possible answer for this. There are many snakes in the area, which they are afraid of. If the tall grasses are cleared, the snakes cannot hide in the grass.

- **The land use impact on the vegetation**

The human impacts on the ecosystem differ with each Zone of Impact (see Figure 3.6). From the communities, which were identified during the fieldwork, Communities 1.1 to 1.5 falls within different areas of Zone 1A and Zone 1B. Communities 2.1 and 2.2 fall within the 'local ecosystem', Zone 2A. Community 3 falls within the 'unaffected ecosystem', Zone 2B. The impacts are discussed separately for each community

Community 1: The residential environment

The ecosystem is negatively affected by the social system where the two systems are in direct contact with each other, like in the residential environment. In Community 1 the diverse plant communities of the natural environment is destroyed and reduced to a simple system with a low species diversity and little biomass. Large areas of the soil are in most households completely bare and unproductive. Every unit is fenced with wire, some with a hedge of plants.

As seen in Table 6.3, the plants in the households include indigenous and alien plant species, agricultural fruit trees and vegetables as well as ornamental trees and flowers. The results can be summarised as follow:

- The ornamental flowers are the most popular with an average of 2.75 individual flowering plants per household in Kekana Gardens and 2.5 individual flowering plants per household in Skierlik
- After the ornamental flowers the fruit trees are most popular, with an average of 2.55 individual trees per household in Kekana Gardens and 2.25 individual trees per household in Skierlik
- An average of 2.15 ornamental trees per household are found in Kekana Gardens and an average of 2.05 ornamental trees per household are found in Skierlik
- Vegetables seem to be unpopular, with an average of 1.3 and 1.05 individuals per household in Kekana Gardens and Skierlik respectively. Interesting to note is that 47% of the number of plants in Community 1.4 is vegetables.
- The ornamental flowers have the highest diversity with 32 identified species. Of the fruit trees, vegetables and ornamental trees respectively 10, 5 and 20 species were identified (Table 6.4).

Community 2: The ecological environment

During the fieldwork it was found that the ecosystem of the selected site is modified by two different social systems, the residential environment and the agricultural environment. The social system influences different properties of the ecosystem, such as species composition, vegetation structure, grass biomass and grazing capacity.

Table 6.4 is the phytosociological table of the TWINSPAN analysis. The **species compositions** of Community 2.1, 2.2 and 2.3 are indicated in Table 6.4. Community 2.3 is in the zone that is least affected by the residential environment. The quality of the species in Community 2.3 is poor in relation to the quality of the species in the Communities 2.1 and 2.2. For example, *Opuntia ficus-indica* is an invader species, indicating poor veld conditions and *Acacia nilotica* is a bush encroachment species, which increases when the veld is overgrazed. The poor quality of the species in Community 2.3 is due to overgrazing by cattle from the agricultural environment, which is much less in the areas close to the residential environment. Impacts from the residential environment on the quality of the species on the local ecosystem are therefore smaller than the impact from the agricultural environment. Please note, the local ecosystem exclude the ecosystem within the residential environment and only include Communities 2.1 and 2.2 of the Savanna Major-Community.

The **vegetation structure** is indicated by the height and cover of the trees, shrubs, grasses and forbs. The highest trees are found in the selected plots in Communities 2.1 and 2.2 with a maximum average height of 6.5m. The trees in Community 2.3 have a maximum average height of 5.6m (Table 6.5). The shrubs in Communities 2.1 and 2.2 have an average minimum height of 0.5m and an average maximum height of 3m and 2.5m respectively. The shrubs are taller in Community 2.3 with an average minimum height of 1m and an average maximum height of 3m (Table 6.5). Grasses are tallest in Community 2.1 with an average maximum height of 0.9m. The average maximum height of grasses in the selected plots in Community 2.2 is 0.7m and the grass in Community 2.3 has a low average maximum height of 4.7m (Table 6.5). The average maximum and minimum heights of the forbs in the selected plots of Communities 2.1, 2.2 and 2.3 range between 0.2m and 3m (Table 6.5).

The total cover of the vegetation is 72% in Community 2.2, 70% in Community 2.1 and 47% in Community 2.3 (Table 6.5). Table 9.2 compares the cover of the grass and woody layer of the selected plots in Community 2.1, 2.2 and 2.3. Figure 9.1 and Figure 9.2 is derived from Table 9.2.

Table 9-1: Cover of the grass and the woody layer of Communities 2.1, 2.2 and 2.3

Community 2.1				
Cover value (%)	**Grass**	**Trees**	**Shrubs**	**Woody**
Plot 41	45	0	30	30
Plot 42	50	0	20	20
Plot 43	45	0	10	10
Plot 44	45	1	20	21
Plot 45	55	3	20	23
Average	48	0.8	20	21
Community 2.2				
Cover value (%)	**Grass**	**Trees**	**Shrubs**	**Woody**
Plot 46	55	3	10	13
Plot 47	50	5	15	20
Average	52.5	4	13	17
Community 2.3				
Cover value (%)	**Grass**	**Trees**	**Shrubs**	**Woody**
Plot 48	20	5	25	30
Plot 49	15	10	15	25
Plot 50	20	5	10	15
Plot 51	20	25	5	30
Plot 52	15	20	5	25
Average	18	13	12	25

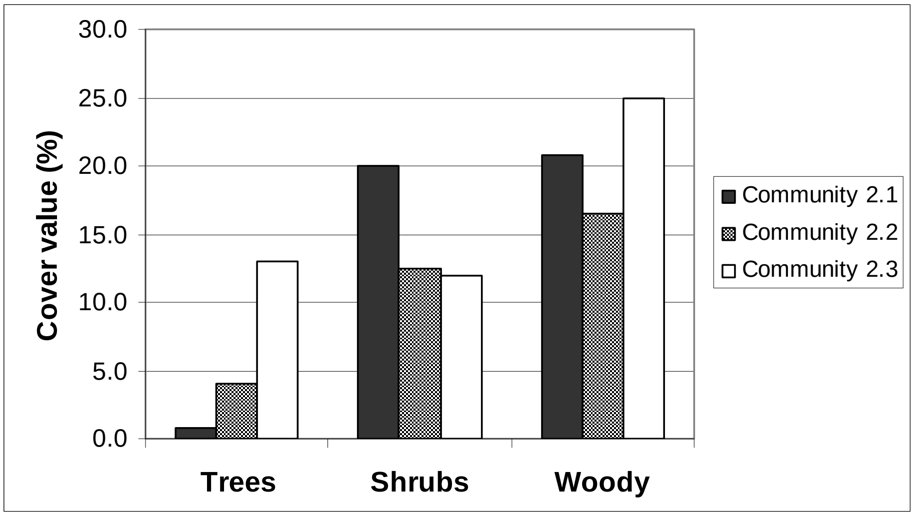

Figure 9-1: Comparison between the woody layers of Communities 2.1, 2.2 and 2.3

The tree cover of the selected plots increases as the distance from the residential area increases (Figure 9.1). The total shrub cover of the selected plots decreases as the distance from the residential environment increases (Figure 9.1). This is due to the chopping of trees for firewood, which is much more severe close to the residential area. The total cover of the woody layer, i.e. the cover of the trees and shrubs, are higher in the selected plots of Community 2.3 compared to Communities 2.1 and 2.2 (Figure 9.1). Therefore the chopping of the trees reduces the total cover of the woody species.

Figure 9.2 compares the grass cover with the woody cover in each community. The grass cover is highest in Community 2.2 and lowest in Community 2.3. The woody cover, which includes the tree and shrub cover, is highest in Community 2.3 and lowest in Community 2.2. Community 2.3 is the only community where the grass cover is lower than the woody cover, which is a possible indication of overgrazing.

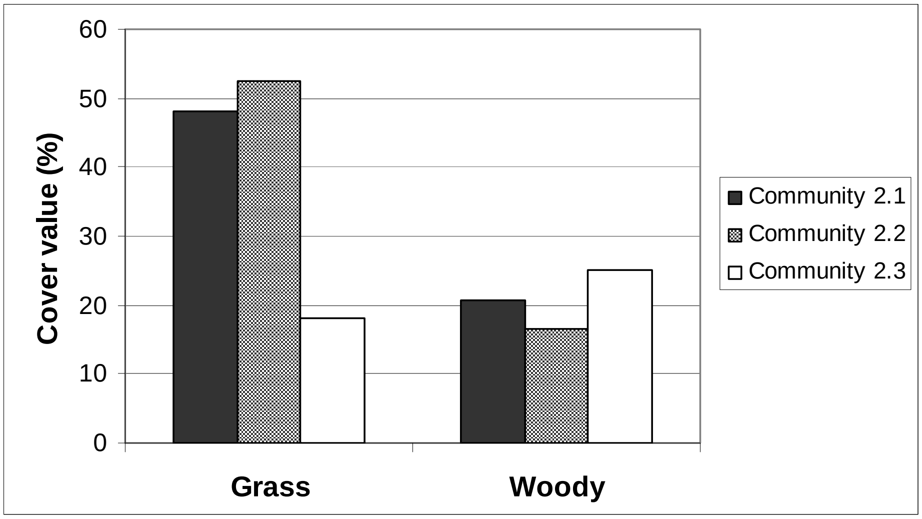

Figure 9-2: Comparison between the woody and grass layer of Communities 2.1, 2.2 and 2.3

Therefore, the vegetation structure is affected by the different land use practices. The height of the trees is lowest in the selected plots of Community 2.3, but the cover of the woody species is slightly higher compared to Communities 2.1 and 2.2. The height and cover of the grass is short in Community 2.3 compared to Communities 2.1 and 2.2. The total cover of vegetation in Community 2.3 is low compared to Communities 2.1 and 2.2. The over-grazing in Community 2.3 reduces the height and cover of the grass, leaving larger areas of bare soil.

The **grass biomass**, as indicated by the disc pasture meter data (Table 6.6), is higher in Communities 2.1 and 2.2 which is close to the residential environment. The grass biomass in Community 2.3 is very low. This could be explained by the competition between the trees and the grass. The trees next to the residential environment are destroyed giving the grass a better chance to grow due to more space and less competition. Secondly the cover of the grass layer in Community 2.1 could be higher because of less grazing by cattle, which affects the grass layer of Community 2.3. The low grass biomass in Community 2.3 could be an indication of current overgrazing. The residents have a relatively low impact on the grass biomass of the local ecosystem in Communities 2.1 and 2.2, if compared to the grazing pressure in Community 2.3.

The results of the **grazing capacity analysis** from the step point data are shown in Table 6.8. Figure 9.3 compares the hectares per livestock unit (ha / LSU) needed to support cattle in each of the three zones in the ecosystem. The grazing capacity is highest for Community 2.1 and lowest for Community 2.3. Therefore, the grazing capacity is higher in the plant communities closer to the residential environment compared to the plant communities closer to the agricultural environment.

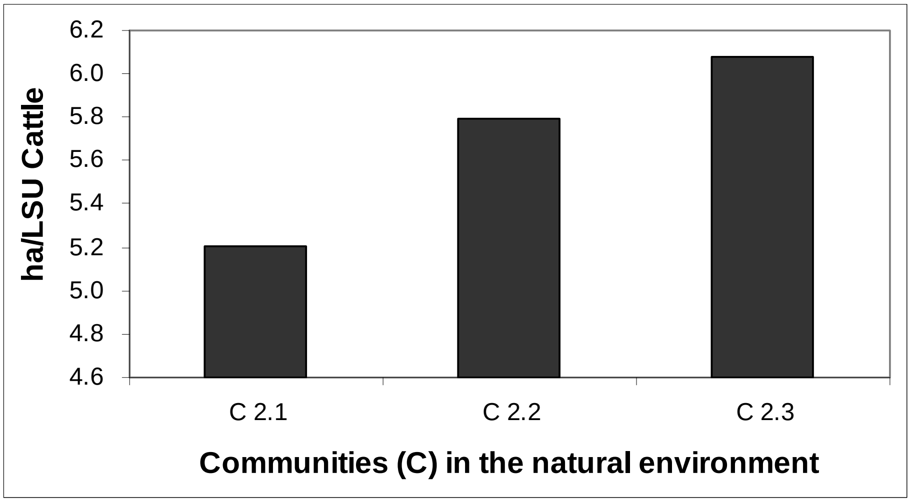

Figure 9-3: An illustration of the differences in grazing capacity of the three communities of the ecosystem

The residents have a relatively low impact on the grazing capacity of the local ecosystem in Communities 2.1 and 2.2, if compared to the grazing pressure in Community 2.3.

9.3 AVAILABLE RESOURCES

The availability of resources is controlled by the functioning and interactions of the systems. Resource limitations are a serious problem in African households. Many attempts have been made to provide additional resources from external sources, but the management of the available resources is still neglected. With good resource management one can reduce the resource limitations considerably. This management plan should consider the economical, social and ecological systems.

9.3.1 Current Availability of Space

For a small-scale farmer space is a limitation. In Sample A of the selected site it was found that the average size of a plot in Kekana Gardens is 232.5 m^2 and the average size of a plot in Skierlik is 230.45 m^2, which is very small. This space is divided into the buildings, the front and the back yard. The people further reduce the space available for food production by planting food crops only in the back yard.

9.3.2 Current Soil Conditions

The soil is unproductive and dry. Crust formation causes poor water infiltration and results in water runoff and erosion.

9.3.3 Current Availability of Water

Water in the residential environment is provided by servitudes and rain. Some people catch rainwater in buckets. Many people complain of too little water to plant any food crops, which seem to be a definite problem. Water is only available at night, sometimes there is no water at all and some people need to walk very far to fetch water.

9.4 THE SUITABLE TECHNOLOGIES

Technologies are needed to improve production in the household. Important technologies from ecology and agriculture were identified for this purpose.

9.4.1 Plant Community Concept

In plant ecology the plant community is regarded as an important concept in reaching sustainable production on a household scale. The use of a plant community in household-based production of crops would include the following advantages:

- The diversity of species would satisfy different needs of the household

- The diversity of species could provide stability in production, i.e. production throughout the year and stable production in spite of changing environmental conditions (Fairbanks and Andersen, 1999).

- The interactions between species could be mutualistic, increasing the production of each other e.g. insect repelling crops, nitrogen fixing bacteria on legume plants etc (Sullivan 2003).

9.4.2 Sustainable Agricultural Methods

From agriculture a few important technologies came forth, such as permaculture, intercropping, conservation tillage and organic farming. An interesting observation can be made that most sustainable agricultural methods are based on some principles in ecology. Permaculture is the most holistic concept applying every possible aspect of an ecosystem including humans. Permaculture is the only school of thought incorporating the establishment of systems with no waste production and minimal energy input. Intercropping focuses on the increase in diversity. Conservation tillage reduces disturbance to its minimal and conserves soil and its micro-organisms. Organic farming substitutes inputs like chemicals with natural alternatives.

9.4.3 Alternative Uses of Space

The current use of space limits production of crops and an alternative way is needed to increase the available space used for production. Presently the space is also not used productively and the possibility of introducing a productive crop is also considered.

- **The permaculture approach**

A permaculture design would divide space in such a way that energy and resources are used optimally. Seeing that production is the aim of this project, one should find a way to increase the space available for production, while considering the social system as an invariable.

A permaculture design should consider the following suggestions in order to increase the amount of space used for energy or food production:

– Give the people energy producing crops with beautiful flowers that they can plant in the front yard

– Build the houses closer to the street in order to increase the area of the back yard

– Use a bio-diesel or crop producing plant with thorns as an hedge to protect the household

- **The use of space for bio-diesel production**

Bio-diesel production and yield from *Jatropha curcas* is variable. Average seed yield of 5-year old plants in various soil types ranges from 4 tons / hectare / year to more than 12 tons / hectare / year. Twelve tons / hectare / year are reached under favourable conditions, like irrigation and fertilisation of the soil (Sharma, 2007). The poor soil conditions and draught in the selected site in Hammanskraal will result in a low seed yield. For the prediction of bio-diesel production under natural conditions, it is therefore assumed that *J. curcas* will produce 4 tons / hectare / year in the selected site.

The average household in Kekana Gardens is 232.5 m^2 (refer to Table 7.2). The annual dry seed yield of 5-year old plants could be predicted as follows:

If **4000 kg** (4 tons) dry seed are produced on **10 000 m^2** (1 ha);

Then **93kg** of dry seed will be produced on **232.5 m^2** (an average plot).

Therefore one can produce 93 kg of dry seed, if you use the entire plot for *J. curcas* production. Since the people in the selected site produce crops only in the back yard, the average space available for *J. curcas* production in Kekana Gardens is 44.74 m^2 (refer to Table 7.2). The predicted dry seed yield would therefore be 17.9 kg per year.

According to Iglesias (2007) 2, 2 kg of seed yield 1 litre of oil. With 17.9 kg seed one will therefore produce 8.1 litres of oil in a year. This predicted oil yield can be increased by improved irrigation and fertilisation.

9.4.4 Alternative Uses of Soil

The current sweeping of the soil is not a sustainable or productive land use. Alternative land uses would include a return to the natural state or a new and sustainable method. The current land use, the natural state and alternative land uses are compared in Table 9.3

Table 9- 2: A comparison between the outputs and the required inputs of three land uses

Land use	Required inputs	Advantage & disadvantage of the outputs
Current Situation, Clean swept soil	High energy inputs, no knowledge inputs	Unsustainable & unproductive
Previous Land Use, Natural Vegetation	No energy or knowledge inputs	Sustainable & unproductive
Optimal Land Use, Permaculture, Conservation Agriculture	High energy and knowledge inputs.	Sustainable & productive

- **Return to the natural state**

Compared to the current situation where the soil is bare and unproductive, the natural vegetation seems like a much better alternative. The natural vegetation does not require any management or irrigation, it reduces dust, it looks prettier and it conserves the soil and the soil water. Some of the households during the interviews liked the traditional hut with the natural vegetation in tact, while nobody liked the house with the bare swept soil.

On the other hand, though the natural vegetation is good for soil management, it does not provide food or energy and it provides a hiding place for snakes and other animals.

- **New methods; Conservation Agriculture and permaculture**

One should consider ways to utilise the soil in a sustainable way, keeping in mind that production is the aim of this project. According to Conservation Agriculture the best management of the soil would be to cover the soil with a cover crop or some residue. This management would increase crop production by increasing the fertility and the water content of the soil.

From a permaculture approach, which is the holistic approach, the soil use is not an individual aspect of the household, but is integrated with every other aspect. It is therefore very important to approach soil use in the context of the social and environmental system as well. The reasons for their current land use identified as water limitations, the influence of the Western culture, the fear for snakes and the functionality of the bare soil should all be considered in a holistic permaculture approach to improve their living conditions.

9.4.5 Alternative Uses of Water

The optimal use of water would be to have enough water for household activities and human sustenance, with extra water to produce food and energy.

During the interviews people complained that the water is too scarce to grow plants in the yard. As mentioned above, the exposure of the soil could contribute much to the loss of soil water and it is also important to cover the soil as a way to manage water availability. To cover the current unproductive soil, one can consider either to leave the natural vegetation in tact or to find productive plants with a low water requirement.

- **Rainwater catchments**

Water saving and recycling practices should be implemented in order to increase the water available for the household activities and human sustenance. One way would be to catch rainwater on the roof. The amount of rainwater gained if it is caught on the roof can be calculated. According to the SA Weather Service, 1990, the average rainfall of the area is 674 mm/year or 0.674 m/year (refer to Table 3.1). The average size of the houses, therefore the roof area, of Kekana Gardens in Sample A is 52.8 m^2 (Table 7.2). The amount of water caught on the roof in a year is therefore 0.674 m x 52.8 m^2 = 35.6 m^3 or 35.6 litres. The average size of the houses in Skierlik is only 33.1 m^2 and they will only catch 22.3 litres or rainwater in a year. The minimum water needed by a household is assumed to be 550 litres/week as in Household 2 of Sample C (refer to Table 7.4). Seeing that one cannot catch enough rainwater in a year to satisfy the needs of a household for one week, it is therefore not a feasible solution. It might be beneficial to catch rainwater in combination with other water management practices.

- **Return to the natural state**

In the past, before the servitudes were established, people were more directly dependent of the rainwater. Contrasting to the residential environment, the local natural ecosystem is sustained solely by rainwater. It can therefore be said that a resource limitation is dependent on the land use. As with the management of the soil, the natural ecosystem requires no human inputs in terms of water. If the people do not destroy the natural ecosystem in the first place, the rainwater would sustain the natural vegetation and the soil would not be bare. If the soil is covered, less water would evaporate. As with soil management, this requires less energy inputs, it is ecologically less destructive and the soil would be covered. But again the natural vegetation does not provide food for the people.

- **Introduce productive plants**

If the natural ecosystem could be sustained solely by rainwater, then there might be food and energy crops that could also be sustained by rainwater. If one could find such plants it would easily grow without any additional water inputs. Conservation Agricultural practices can protect soil water.

9.4.6 Management of Energy Resources

At this stage, some suggestions can be made on how to manage energy resources.

- **Renewable energy** sources such as bio-diesel, solar and wind energy etc. should be exploited instead of non-renewable sources

- Human resources such as knowledge and skills should be used to **reduce the dependency on an external supply of energy**

- A **diversity** of the resources should be used instead of an over-exploitation of one resource

9.5 POSSIBLE LAYOUTS FOR A SUSTAINABLE PLANT COMMUNITY

9.5.1 Requirements of the Design

This study considered the current functioning of and interactions between the relevant systems as well as the available resources and technologies in the rural residential area of the selected site. Possible layouts for a sustainable plant community in the household could now be formulated, based on the results of this study. Such a design should functionally integrate all the relevant systems by satisfying the needs of all of the social system (Refer to Chapter 5.3) and complying with the requirements of each system.

The design must comply with all the following requirements as identified during the study:

- The implementation of the model must be sustainable

- The implementation of the model must be economically feasible
- The implementation of the model should require minimum external inputs such as knowledge, capital and labour
- The implementation of the model should have a low ecological impact and minimum waste production
- Renewable energy sources must be produced and used in the household

9.5.2 Components of the Current Low-Income Household

General components in many of the current low-income households, as seen during the field work include:

- The built house
- A pit-toilet outside
- Fences, either wire fences or plant fences
- Taps or boreholes
- Waste dumping sites where the organic and inorganic waste is burned, few houses have compost heaps
- Vegetable gardens and orchards
- Chicken shelter with chickens
- Cattle and dogs

The following significant components, where not seen in the current low-income households during fieldwork:

- Water catchments or dams
- Soil cover, biotic or abiotic
- Structures to obtain renewable energy such as solar or wind energy
- Trees planted specifically for shadow

9.5.3 Interactions between the Components of the Household

The household consist of many components that can potentially improve the growth and vitality of the other components. In different situations components could either be beneficial or it could be harmful to other components. Examples of current negative interactions that could be positive under different conditions are:

- A compost heap is an excellent way to introduce organic material into the soil. Unfortunately, if the soil is transferred from the compost heap to the vegetable garden, the soil is tilled and disturbed. In the process of digging soil from the compost heap, seeds in the soil are exposed to air and light. When this soil is watered in the vegetable garden, the seeds start to germinate with a possibility of weeds. Transferring soil from the compost heap to the vegetable garden is also very labour intensive.

- Weeds reduce the success of vegetable production, but at the same time it is a useful soil cover during the times that crops are not planted.

- Chickens are very destructive in a vegetable garden. This is unfortunate, because they could be a potential benefit for food production. If they would rather eat the seeds of the weeds, instead of the vegetables, they would improve the growth of the vegetables. Furthermore, their droppings are an excellent source of nitrogen and therefore a natural fertiliser.

Components could be separated from each other spatially or temporally. If components are completely separated over space and time there will be no interactions, excluding also the positive interactions. A design could use a combination of spatial and temporal separations in order to eliminate the negative interactions, but still promote the positive interactions, for example:

- Annual crops could be planted on the soil of the compost heap of the previous year. This will be less labour intensive and it will reduce the disturbance of the soil. If chickens are allowed in the compost heap before the crops are planted, it might remove some of the weeds.

- With the correct management, weeds can protect the soil and if it is mechanically destroyed before planting vegetables, it could provide a mulch to cover the soil while the vegetables are grown.

- Temporal and spatial separation of the chickens and the crops could be managed in such a way that the chickens prepare the soil before the vegetables are planted. Annual crops could therefore be planted on the space where the chicken shelter was the previous year. If the chicken shelter is spatially separate from the vegetable garden, the chicken manure must physically be transferred to the vegetable garden, increasing the labour intensity.

9.5.4 The Labour-and-Energy-Efficient Layout

The focus of this model is to reduce labour and energy inputs. Instead of carrying resources from one place to another, rotation could be used. This will reduce labour intensity and it will diversify the utilisation of specific areas within the garden. The proposed layout is illustrated in Figure 9.4.

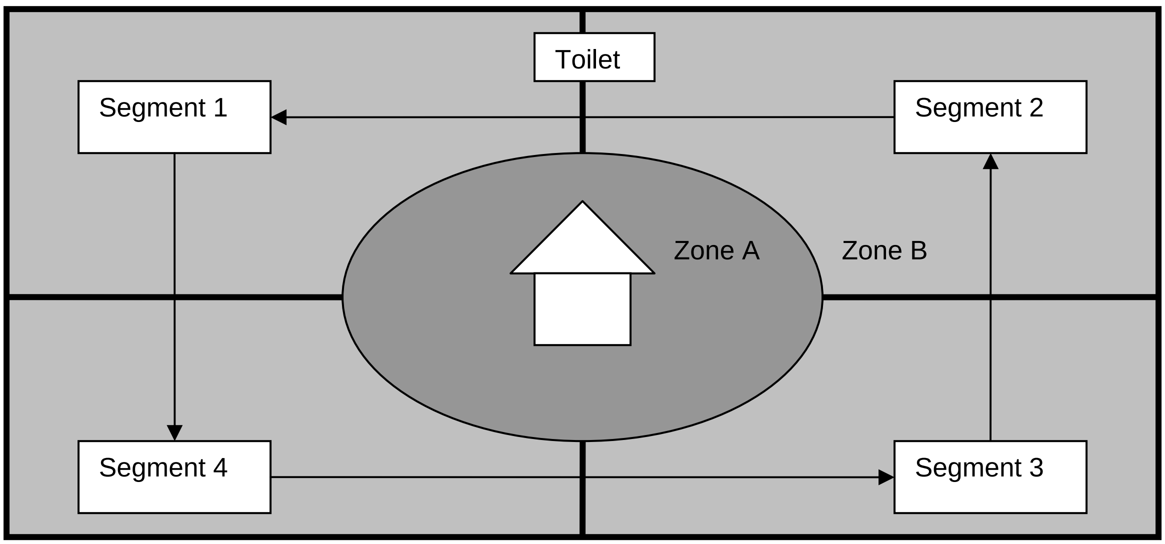

Figure 9-4: The labour-and-energy-efficient-layout

As illustrated in Figure 9.4, a sustainable and productive household is firstly divided into two circular zones and Zone B is subdivided into four segments. The layout is done using the methods of permaculture.

Zone A is close to the house, and crops planted in this zone are those that require more attention. The features in this zone should also benefit the household directly, like a big tree for shade and water catchments, supplying water for the household.

Zone B is the outermost zone and the components of the garden requiring less attention will be based here. These components are the chicken shelter, the compost heap and two vegetable gardens. Each of these components should be planted in a different segment and each year it is rotated counter clockwise.

– During the first year, for example, Segment 1 will contain the compost heap. Organic material increases in the soil and some seeds germinate. Vegetables that grow spontaneously on the compost heap are planted into a vegetable garden in another segment. At the end of the year, the compost heap and any weeds that are present are maintained as a soil cover, while a new compost heap is formed in Segment 4.

- Segment 2 contains the chicken shelter, which is moved to Segment 1 during the following year. The chickens are allowed to eat the weeds in the segment. As they stray around in the segment, their excretions increase the nitrogen content of the soil.

- Segment 3 contains a vegetable garden. The vegetable garden is moved to Segment 2 during the following year and the segment is prepared by physically destroying all the weeds that are still present. The weeds are then left on the soil to decompose and to form a soil covering mulch. This vegetable garden can contain vegetables that have shallow root systems, because the organic matter is expected to be higher up in the soil profile. The soil has been prepared for the vegetables firstly by the compost heap that increased the organic matter content of the soil, and secondly by the chickens that removed some weeds and spread chicken manure.

- Segment 4 has a vegetable garden that is moved to Segment 3 during the following year. These vegetables have deeper root systems, in order to explore other layers of the soil profile. It can be expected that by this time some of the nutrients are leached further down into the soil profile, and these plants are needed to recover those nutrients.

The black lines separating the zones and segments are hedges made of perennial bio-diesel plants such as *M. oleifera*. These edges must be secured with a wire fence to keep the chickens from leaving their section. It will take some capital to install the structures, but then it should only be maintained, since *M. oleifera* lives up to 50 years.

The pit toilet is in Zone B where it can be far from the house. Next to the toilet, deep rooted leguminous plants must be planted to retrieve nitrogen from human excretions.

9.5.5 The Social-System-Driven Layout

During the interviews it was clear that people prefer their front yard to look nice. From the interviews it seems as if the people would or do plant their crops only in the back yard (Table 5.5). Three reasons were identified for this; fear of animals and thieves, tradition and aesthetic value (Table 5.5).

Improved fences could address the fear of the people, but tradition and the need to make the yard look nice cannot be changed. A layout driven by the current patterns in the social system would therefore include a garden in the front yard. One must accept the fact that current social patterns cannot be changed, even if it means a loss of resources with no gain in productivity.

The challenge is to optimise production within the framework of the social system. One possibility could be to plant crops with flowers in the front yard. This will satisfy the people in that the garden looks nice from the street, but it does not address their fear that crops will be stolen. Another possibility would be to build the house close to the street, reducing the size of the front yard and increasing the size of the back yard as in Figure 9.5. The same rotation system could be used as in the labour-and-energy-efficient-layout.

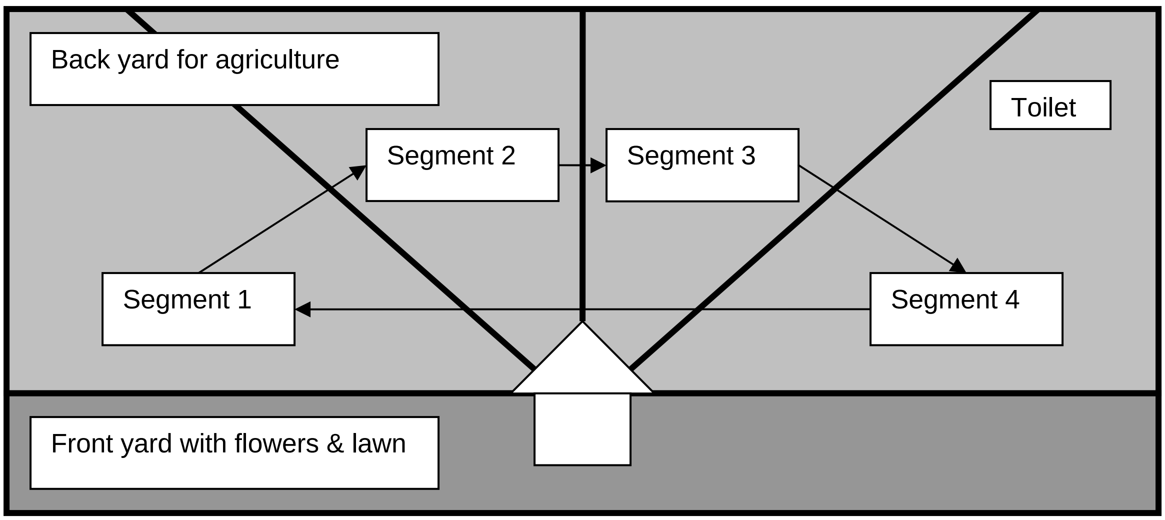

Figure 9-5: The social-system-driven-layout

10 CONCLUSION

10.1 THE CURRENT LAND USE

The first step of this study is to understand the way in which the relevant macro-systems functions and how they interact and combine. The systems involved in the selected site are identified as the economical, social and ecological systems. This study focused on the relationship between the social system and the ecosystem. The social system needs resources that are produced by the ecosystem, and a dysfunctional relationship between the two systems would result in resource limitations. In turn the social system has an impact on the ecosystem. Technologies are needed to reconcile the social system and the ecosystem in such a way that resources are supplied in a sustainable way.

The land use of the residential area has different degrees of ecological impacts, depending on the distance of the residential area from the ecosystems. The ecosystem was divided into three zones of impact according to the degree of impact from the residential environment. The TWINSPAN analysis supported this division, since the communities identified by TWINSPAN coincide with these zones of impact. The first zone of impact is the residential ecosystem, which coincides with Community 1, the Residential Major-Community from TWINSPAN. The second zone of impact is the local ecosystem, which coincides with Savanna Sub-Communities 2.1 and 2.2 from TWINSPAN. The third zone of impact is the unaffected ecosystem, which coincides with the Savanna Sub-Community 2.3 from TWINSPAN. The land use of the residential environment and the land use impact were studied for each zone of impact.

The **residential ecosystem**, Zone 1, is in direct contact with the human environment. The households are small with fences or hedges. The natural vegetation is cleared and ornamental plants, of which many are aliens, are planted in their place. Large areas of bare swept soil are very common and lawns are usually small and not functional. Ornamental flowers are very popular and planted in the front yard. Vegetables are mostly planted in the back yard because it will not be stolen there and the front yard should look ‘nice’.

Resources from the ecosystem such as soil, space, water and energy are limited. Soil is in a poor condition due to the constant sweeping and exposure of the soil. Water is not equally distributed among the households. The households in Kekana Gardens are more established and have more resources than the households in Skierlik.

The vegetation of the **local ecosystem**, Zone 2A is affected by two social systems, the residential environment to the south and an agricultural environment to the north. People from the residential environment discard their rubble and waste in the local ecosystem, but the rubble and waste does not seem to affect the species composition (refer to Table 6.4), vegetation structure (refer to Table 6.5) and grass biomass (refer to Table 6.6) of the local ecosystem. The local ecosystem provides one resource to the residential environment, energy in the form of firewood. The people cut down trees in the local ecosystem for firewood. When these trees resprout they form shrubs, which are more abundant closer to the residential environment. Compared to the agricultural environment, the residential area has a low impact on the total vegetation cover, the grass biomass and the grazing capacity of the local ecosystem because the residents do not have animals that graze there. The cover of the woody species is reduced due to the cutting of the trees by the people from the residential environment.

The **unaffected ecosystem**, Zone 2B, is not heavily utilised by the residential environment but the agricultural environment uses this area for grazing. In terms of species composition, grass cover, grass biomass and grazing capacity, this vegetation is in a poorer condition compared to the vegetation of the local ecosystem.

10.2 DYSFUNCTIONAL RELATIONSHIP

A broad framework can now be formulated for the dysfunctional relationship between the social system and the ecosystem (Figure 10.1).

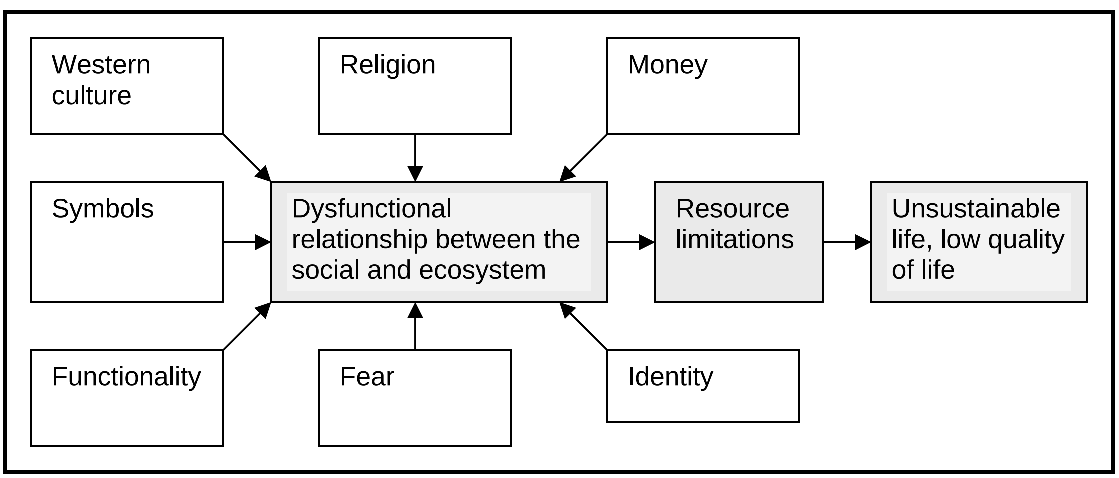

Figure 10-1: A broad framework for the dysfunctional relationship between the social and ecological system

Due to the resource limitations it is concluded that the relationship between the social and the ecosystem is dysfunctional to a certain degree. After the fieldwork and interviews have been done a few causes have been identified for the dysfunctional relationship between the social system and the ecosystem. These causes include the western culture, religion, money, symbols, functionality, fear and identity. For example, the western culture sets a very attractive and powerful standard of living that people aspire to reach. This does not ensure a quality of life, because most people are unable to afford this standard. For many it has become more important to satisfy their felt needs, in this case a high standard of living, than the real needs, which is a high quality of life.

10.3 FUNCTIONAL RELATIONSHIP

A functional relationship would be reached if the real needs of the people are satisfied, and the felt needs of the people are understood and managed or satisfied. This should be done by using the economical system, by using and conserving the ecosystem and by designing suitable or functional technologies. Technology is easily adaptable, because it is not a system, while the other systems are not easily changed. Therefore technologies, such as methods, designs, artefacts and procedures, should be designed in such a way that it would not require changes from any of the systems (Figure 10.2).

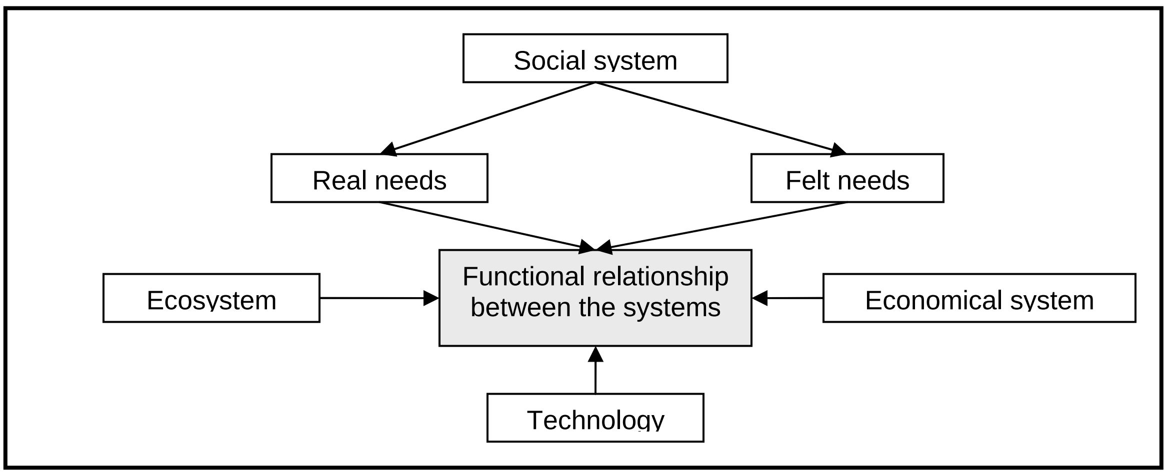

Figure 10-2: An illustration of the approach to reach a functional relationship between the social and ecological system

Technologies that have high potential to facilitate healthy interaction between the prevailing systems have been identified. The functional interactions and sustainability of a plant community sets the standard that needs to be reached in the low-income household. Permaculture designs should be used to reconcile the systems, because it is the most holistic approach. Conservation Agriculture (CA) and intercropping should be used in combination with permaculture designs, because these methods could conserve the natural resources that are currently limited. Organic farming will not be successful, because a set standard will not fit into a dynamic system such as the household. However, the principles of organic farming are interesting to note.

10.4 LAYOUTS FOR A HOUSEHOLD

Two alternative layouts for a household with sustainable and productive plants were proposed. These layouts are based on principles that were determined during this study. These principles can be summarised as follow:

- Manage the culture and fulfil the real and the felt needs of the social system as far as possible. The importance of this principle is revealed by previous examples from the literature, such as the Turkana Tribe.

- Each component in the household must have different functions. This is a principle from permaculture, but the same conclusion was reached during this study. As seen in Figure 10.1 the households have various needs that must be satisfied and from the fieldwork it is seen that all the needs are not always satisfied. A plant that could satisfy different needs, such as providing food, protection and decoration, could therefore fulfil different needs of the household, and it could potentially increase the area utilised for production of food.

- Manage the different components of the household to interact in a positive way. Spatial and temporal separations could be used to maximise positive interactions and to minimise negative interactions. Positive interactions could be used in such a way that production is increased and sustainability is reached.

- Produce resources from waste. This is a principle from permaculture, and also relevant for the selected site. In the selected site resources are limited and waste is produced. Certain waste products such as organic material can be recycled in a compost heap to improve the nutrient contents of the degraded soil.

- Use sustainable agricultural methods to conserve the ecosystem and the resources supplied by the ecosystem. For example, the sweeping and exposure of the soil causes evaporation of water, which is a resource that limits production.

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