Strategic Options to Improve Livelihoods in Ganspan Settlement, South Africa: Current Cropping Practices and Options

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MSc Thesis Plant Production Systems

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Abstract

Socio-ecological niche framework followed throughout the study emphasize the importance of involving farmers when bringing new technology. The study has allowed farmers the opportunity to have a voice in the process of finding a way forward suitable to local realities. Current practices in the community are discovered with particular focus on cropping systems, cropping activities, challenges and soil management strategies. Current practices and preferences have given insight on constraints and opportunities for the introduction of alternative crops in the area. Furthermore, the study aimed to identify crops together with farmers and also consider market demands in an multi-disciplinary partnership. Hence various vegetables were recommended to be grown in Ganspan Settlement.

However, local ecological constraints will hinder production of the recommended crops. Identification of crops that are acceptable to the farmers and suitable to agro-ecological conditions and local ecological conditions results in various trade-offs for farmers. Moreover, crop theft has a direct impact on the type of crops selected by farmers. Strategic options are suggested as a way of coping with local constraints and improving livelihoods with emphasis on the integrated management approach. In addition, farmers acknowledge the need for training before recommended crops can be grown. Therefore farmers are only willing to plant these crops after intensive training and collaboration with the Northern Cape Department of Agriculture and Land Reform.

Keywords: small scale farmers, vegetables, partial nutrient balance, livelihoods, options.

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1. Introduction

Diverse biophysical and socio-economic environments throughout Sub-Saharan Africa forces small scale farmers to develop different livelihood strategies. Consequently, livelihood strategies of these farmers are determined by opportunities and challenges that emerge in their respective environments (Tittonell et al., 2010). Furthermore, small scale farmers in Sub-Saharan Africa are faced with challenges of inefficiency, resource limitations and degradation processes (Tittonell et al., 2009). Small scale farmers also adopt land use patterns and agricultural management practices based on agro-ecology, markets and local cultures. As a result, households differ in many aspects hence it is key to acknowledge these differences in a process of introducing new technology. Furthermore, soil fertility is often observed to vary between households due to differences in social status, livestock owners and non-livestock owners. Resource constraints also forces farmers to allocate available labour and nutrient resources differently to certain fields contributing to a new dimension of spatial soil variability [Tittonell 2005b cited in Tittonell et al. (2010)].

According to Adey (2007) South Africa has experienced a decrease in agricultural production from 20% in the 1930's to the current 5% contribution to GDP. Environmental constraints, unreliable rainfalls and drought problems are common challenges facing agricultural production which have added to the current decline in agriculture (Nel and J. Davie, 1999). Furthermore, the apartheid regime which resulted in a developmental backlog through the passage of the 1913 and 1939 Land Act has led to an urgent need to boost agricultural activity among the black rural population in South Africa (Adey, 2007). On the other hand, various challenges need to be addressed prior to development including access to land, provision of infrastructure, technical skills and knowledge, access to financial sources and extension support to farmers (D'Haese et al., 1998).

Some of the problems manifest themselves through low farm productivity as a result of low land productivity, labour resources and types of crops that are grown. Lack of water management also plays a critical role to crop yield as most farmers are faced with unpredictable and unevenly spread rainfall as well as absence or inadequate equipment for irrigation. The poor quality of produce has become a common problem among small scale farmers due to lack of technical skills and knowledge in crop production. Inappropriate cultivars, ill-timed ploughing, little or no use of fertilizer, high pest infestation among other factors plays a significant role to the poor quality of produce by small scale farmers. Such problems can be traced back to lack of technical knowledge, management and access to finances by these farmers. Hence involvement of small scale farmers into the main stream agriculture has become an important part of strategic planning by government in order to overcome such problems and increase agricultural production (D'Haese et al., 1998).

It is estimated that about 48% of the rural households in South Africa depends on wages while half of all South Africans earn less than ZAR 1000 per month (Adey, 2007). According to Taylor & Cairns

(2001) cited in (Adey, 2007), the country is experiencing high unemployment rates with few rural people generating sufficient income from agriculture. Consequently, agriculture is often perceived as the occupation of the poor and avoided by the youth of the country. Furthermore, the end of the apartheid regime in South Africa had led to high expectations towards commercialisation of black small scale farmers. However, the process has been very slow due to various reasons including lack of finance and human resource from the Provincial Department of Agriculture and Land Reform, incoherent rural development programme at National and Provincial levels, high poverty level and slow delivery in transfer of land as stated by Adey et al., 2004 cited in (Adey, 2007).

Ganspan Settlement, a community stricken by most of the current problems in agriculture is located near Jan Kempdorp in the Northern Cape Province. The Northern Cape Department of Agriculture and Land Reform as one of their mandates seeks to improve livelihoods in Ganspan Settlement. Therefore the objective of the study was to explore opportunities for farmers in Ganspan Settlement that will improve productivity and income earned from agriculture. These opportunities were explored by i) Identifying various crops that can be grown in the area based on the selection criteria used by farmers and suitability to agro-ecological and local ecological conditions ii) Identification of constraints under current practices and finally iii) Identification of options that can contribute towards improved livelihoods in Ganspan Settlement.

2. Materials and Method

2.1 Study site

The study was conducted in Ganspan Settlement a community situated 35 km from Warrenton in the Northern Cape Province (see Figure 1). The community has a total area of 792 ha available for residential areas as well as cultivation land and grazing land. From the available area 194 ha has been used as irrigated land while dry land crop production takes place in 44 ha of the land (Hashe et al., 2008). A study that was conducted in the area (Can it be achieved? Partnering towards improving livelihoods in Ganspan Settlement (Hashe et al., 2008) revealed that only a small percentage of the community depends solely on agriculture while a larger percentage combines agriculture with other activities such as part time employment outside the community.

The area has minimum temperature of 9.9^{o}C and maximum temperatures of 32.2^{o}C in summer while in winter minimum temperature reach 0.6^{o}C with a maximum of 19.2^{o}C (Hashe et al., 2008). The area has frost which is expected as early as mid April until mid October in certain cases. Most of the rains occur between October to April with the average annual rainfall of 327 mm. Dominant soil belong to calcisols soil form which is characterized by low clay content making the soil vulnerable to erosion as stated by Venter (2007) cited by (Hashe et al., 2008). According to Badenhorst (2001) cited in (Hashe et al., 2008), most of the area has an average soil depth of less than 1 m and a hard carbonate bank which restrict plant root penetration. Furthermore, Ganspan Settlement has a total of 238 ha available for crop production with 18% of this area allocated for dry land agriculture as mentioned in Badenhorst (2001) cited by (Hashe et al., 2008). At present, the community is using only 178 ha of the land under furrow irrigation and the rest lies fallow.

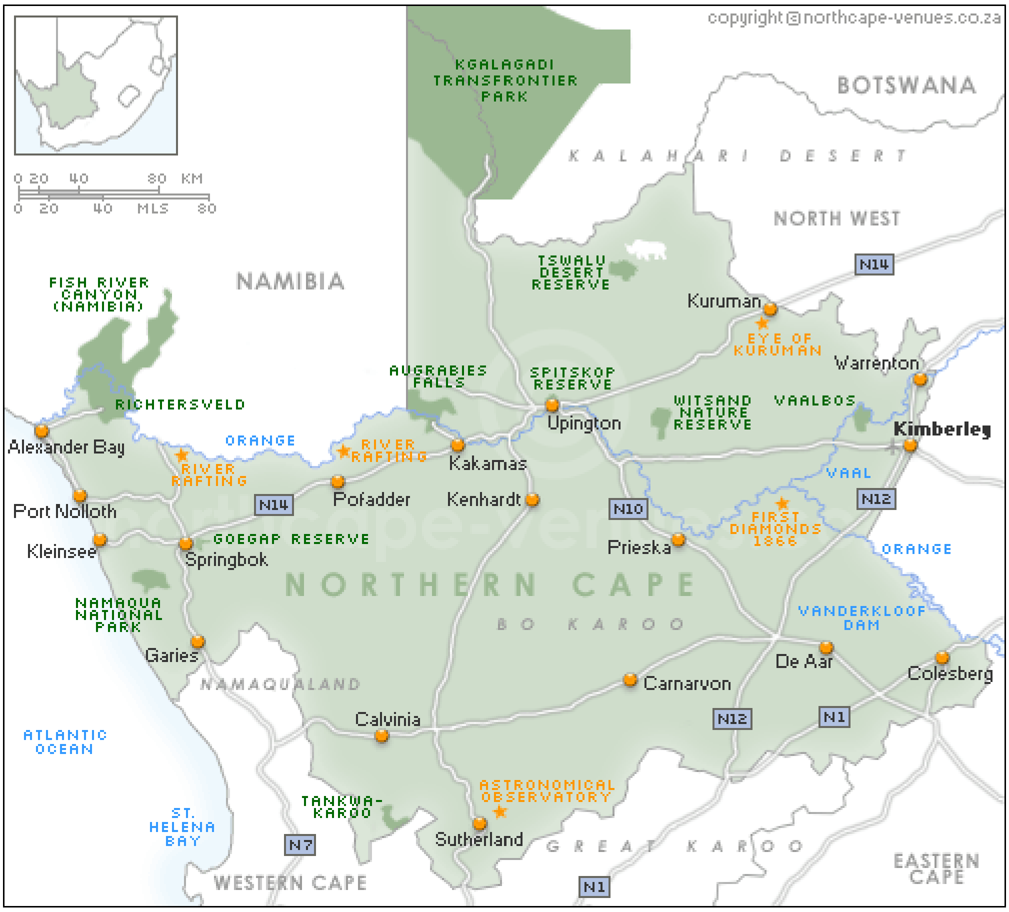

Figure 1. Map of the Northern Cape Province

Source: (North Cape Avenues, 2010)

2.2 Conceptual framework

The socio-ecological niche conceptual framework as illustrated in Figure 2 will be followed in this study (Ojiem et al., 2006). During the selection process of suitable crops various hierarchical factors that influence identification of the niche were used. These factors include agro-ecological factors, local ecological factors which will determine crop suitability to the area as well as socio-cultural factors. Agro-ecological factors will form the basis for manipulating ecological relationships and processes to improve production and produce in a sustainable manner as stated by Gliessman (1998) cited in (Ojiem et al., 2006). While socio-cultural factors emphasize on human values to ensure acceptance of crops that will be selected. A fundamental link between economic and socio-cultural factors in technology development was suggested by Cancian (1972) cited in (Ojiem et al., 2006) as farmers are interested in both economics and their cultural context in decision making.

Details on economic factors within the framework will not be incorporated on this part of the study as this will be the focus of another study focusing on the marketing opportunities for the community. However feedback on both studies will be used in the selection process of suitable crops. Farmers rationalize adoption of a new technology on the basis of prevailing constraints, opportunities, goals and interests. Therefore economic factors such as land, financial capital, labour, input and output markets play a significant role in the process of accepting a new technology. In the case of the Ganspan Settlement access to functional produce markets where small scale farmers can be able to sell their produce would be critical and this was dealt with in detail by the study on the marketing opportunities.

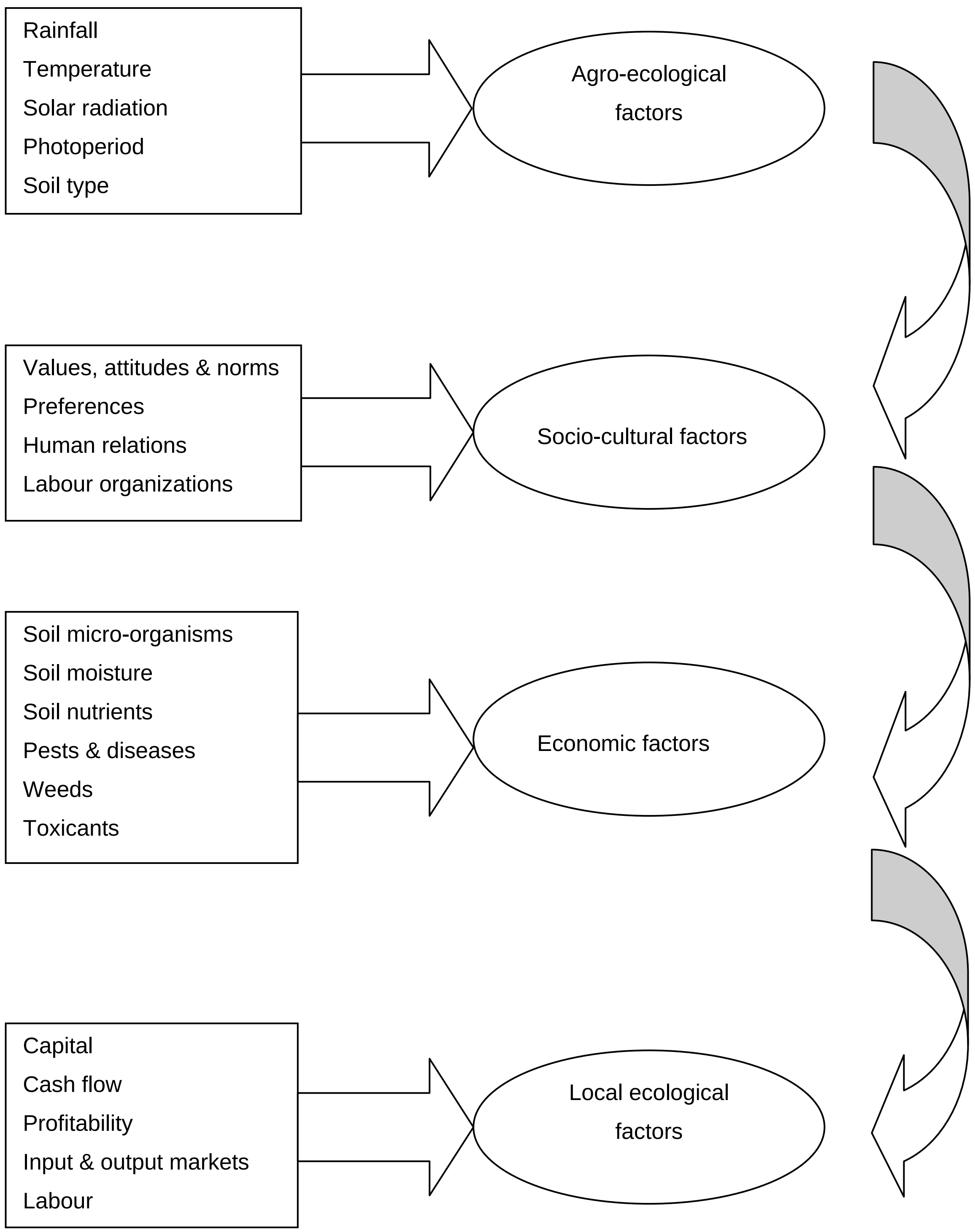

Figure 2: Schematic representation of the socio-ecological niche framework
Adapted from Ojiem *et al*., 2006

2.3 Data Collection

Interviews were conducted with twenty-five farmers between August and October 2009. The selection process of the twenty-five farmers was given to the community during the introduction meeting. However after selection had taken place some community members seemed to be unhappy about the selection. It was later discovered that selected farmers not only included crop farmers but a lot of people that were not even farming their land as yet. Community members who were not actively involved in crop production were so desperate to be interviewed. Some of them created non-existing group names in order to be interviewed. The eagerness to be interviewed was stimulated by the belief that not being interviewed means exclusion. Therefore such an individual would not benefit from any developmental endeavors brought to the community. This confusion led to the need to verify the legitimacy of each member in the farmer committee. Eventually a list of legitimate crop producing farmers was developed and farmers were interviewed at their homes. Semi-structured interviews were conducted with individual farmers which were based on participatory methods.

The study focused on the 24% of the community members that receives income from agriculture as well as in combination with another source of income (Hashe et al., 2008). Data collected was on cropping practices, inputs (such as fertilizer, pesticides and tools), labour needs, prices, criteria for crop selection, yields and finally on views of the farmers concerning recommendations of the study. Furthermore, details on the management of plots and tenure status were also recorded. In order to obtain necessary information on the crop selection criteria a decision making matrix was constructed with each farmer. Participatory budgets were constructed with farmers in order to visualize and understand activities associated with each crop in a year. The participatory budgets were also useful to better understand selected crops by farmers. More information about the farm and challenges throughout the year was also revealed through this exercise as farmers were more engaged during this activity. During this process information on the input and output resource flows and their quantities was also obtained. Farmers also described their farms with particular emphasis on the soil condition, pest and diseases that are problematic on the farm.

Soil samples were taken in the community on randomly selected households on a 0.6 ha plot including plots that were located further away from the houses (see Appendix 1). During sampling an auger was used to dig 20 cm depth for the top soil and 60 cm for sub soil samples. Each sample from a 0.6 ha plot consisted of five sub-samples randomly collected within the plot to represent the plot. While samples that were taken from fields located away from households were made up of ten sub-samples as the area was larger than the 0.6 ha plots. During soil sampling in section A and B six plots were selected for sampling respectively whereas only four plots were sampled in the smallest section, section C. Furthermore, two samples were taken from the additional land corresponding to section A and B while only one sample was taken on the smaller outside land in section C (see Appendix 1). In total twenty-one soil samples were taken in the area which makes forty two soil samples when including top soil and the sub soil samples. Thereafter soil samples were air dried at room temperature for a few days, weighed packed in plastic bags to be sent to the nearest Soil Analysis Laboratory in the Institute for Plant Production, Department of Agriculture in the Western Cape Province for analysis.

2.4 Data Analysis

Genstat 12^{th} edition was used to analyse soil sample results obtained from the laboratory. Furthermore, Excel was used to calculate partial nutrient balance, percentages and graphs for socio-cultural aspects. Interviews that were conducted with the twenty five farmers were qualitatively analysed in order to understand socio-economic dynamics as well as current problems in crop production. During these interviews farmers also quantified input and output flows of resources in their farms and this information was used to calculate partial nutrient balances. Demanded crops in the market were obtained through interviews with supermarkets (Mafuma, 2010). Crops that were frequently mentioned during interviews with supermarkets formed the bases for demanded crops together with farmer preferences. These crops were screened and eliminated based on the agro-ecological and local ecological conditions required by each of the identified crops. Hence a list of suitable crops was developed. Soil samples were analysed for soil pH, total and available phosphorus, potassium, Cation Exchange Capacity (CEC) and micro-nutrients.

3. Current practices

3.1 Cultivated crops

Discussions were conducted with each of the twenty-five farmers selected for the study. During discussions the link between types of crops cultivated by farmers and accessible land was observed. Farmers accessing only 0.6 ha plots often cultivated vegetables alone while farmers with access to additional pieces of land planted other crops in addition to vegetables (see Figure 3). Consequently, available land size was used to distinguish between the different types of farmers. Farmers with small pieces of land ranging between 0.6 ha plots and 2 ha focused mostly on vegetable production. However, a minority of farmers in this group also combined vegetables with groundnuts, wheat or lucerne (see Figure 3).

Therefore, farmers cultivate vegetables as the main crop or in combination with a main crop. Main crops include groundnuts, wheat and lucerne. On the other hand, there was a wide range of vegetables that were planted including cabbage, onion, beetroot, pumpkin, watermelon, spinach, garlic, carrot, tomato, butternut, sweet melon, beans and green pepper. Some of the farmers found it difficult to estimate the amount of vegetables that were harvested and sold to the market. Possibly, this was caused by the fact that most of these vegetables were also used for household consumption. Therefore farmers would not be able to quantify amount of vegetables that were used for household consumption.

Nonetheless, farmers were able to record the amount of seedlings that were transplanted. However, there was a big gap between the amount of seedlings that were transplanted and the yield obtained at the end of the season. Possibly, vegetable farmers suffered yield losses due to pest attacks and water problems as these were constraints often mentioned. Another source of discrepancy in vegetable yields could be the area planted. Farmers do not plant the whole 0.6 ha plot with one kind of vegetable and they often estimated that each vegetable occupied 0.15 ha of their plots. Therefore if the area planted was less than 0.15 ha then yields would be underestimated.

Furthermore, farmers that planted groundnuts, wheat and lucerne remembered yields obtained very well in contrast to vegetable farmers. This might be due to the fact that none of these main crops are used for household consumption. Groundnuts are sold to the nearby cooperative to be processed into peanut butter while lucerne is sold to livestock farmers in the nearby farmers. Farmers that produced groundnuts also had the possibility to obtained inputs from the cooperative when planting in case of insufficient funds. Thereafter, the cooperative would deduct input costs from the income received on selling harvested groundnuts with the cooperative. Therefore groundnut producing farmers were not struggling to obtain seed and fertilizer. However fertilizer application on groundnuts was still not different in comparison to other crops. In some cases groundnut producing farmers have been accused of selling fertilizer obtained from the cooperative to other farmers hence less fertilizer would be applied to groundnuts.

Wheat producing farmers were mostly the same farmers producing groundnuts in rotation with wheat. Farmers producing wheat sold the grain to the nearby cooperative while wheat straw was used to make hay therefore sold to livestock owners. Groundnut residues were also sold to make bails which generated additional income for farmers. However, this was in contrast with findings of (Ncube et al., 2009) where farmers left crop residues for livestock to graze in the field. Farmers in Ganspan Settlement opted to remove crop residues to avoid additional costs of hiring a tractor to incorporate residues into the field. Furthermore, farmers in the area also relied on inorganic fertilizer for soil nutrients which was also in contrast with some of the literature (Ncube et al., 2009). However, use of inorganic fertilizer can be explained by the scarcity of livestock in the area.

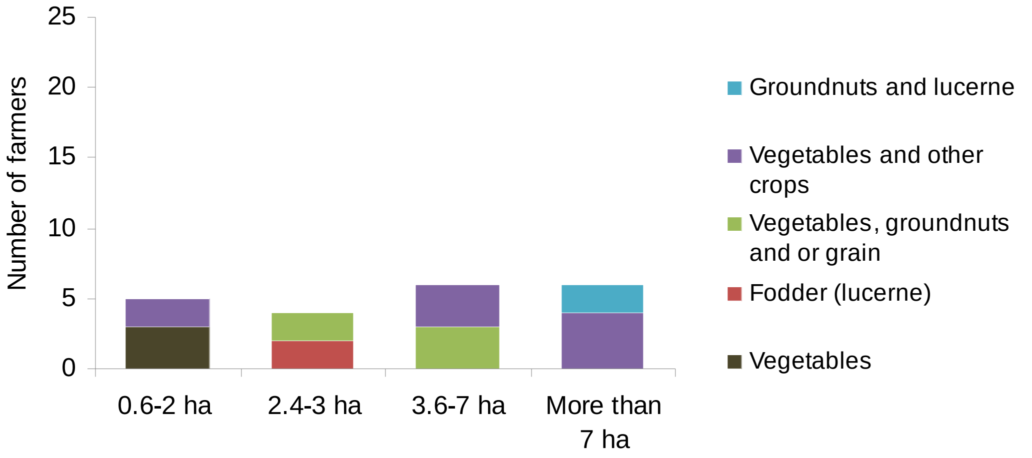

Figure 3 Farmers cultivating respective crops per farmer group

3.2 Cropping calendar

Cropping calendars were developed with individual farmers and combined into one cropping calendar for the whole Ganspan Settlement as shown in Figure 4. Farmers performed weeding throughout the year with August as the only month with the lowest weeding activities (20%). Chemical application for pesticides was done throughout the year with the lowest activity in August. Low chemical application in August can be explained by the fact that most of the vegetables are not yet planted hence no spraying required for pesticides. Furthermore, most cropping activities also begin in this month with more than 30% of farmers planting in August. Highest fertilizer application is in September followed by October and March.

High chemical spraying activities in September is due to the 30% of farmers that have planted vegetables in August and apply chemicals on a monthly basis. Harvesting activities are performed mostly in November, December with the highest harvesting done in December. Vegetable farmers target the month of December for harvesting vegetable since the highest demand for vegetables is in this month. The second planting for vegetables in summer is done around January which explains the April harvest for vegetables. Harvesting in May and June is mostly for groundnuts which are harvested and left to dry for a month in the field and picked afterwards.

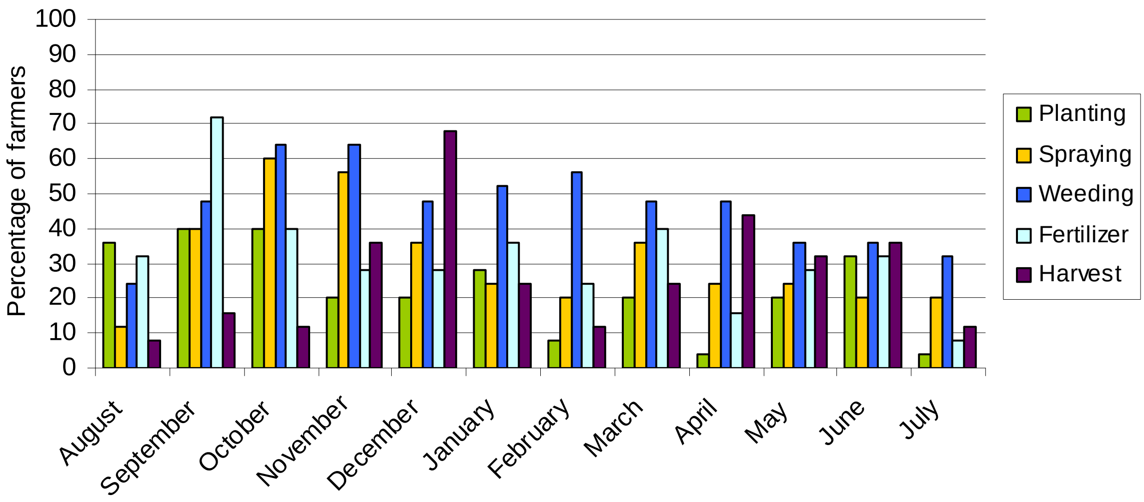

Figure 4 Percentage farmers involved in cropping activities for selected crops by month

On average farmers required eleven labourers to perform various cropping activities mentioned in Figure 4. Although the number of labourers required for the different cropping activities also depends on the size of the land. Furthermore, vegetable growing farmers needed labourers more frequently than other farmers. Farmers that were engaged in vegetable production as their main crop applied pesticides twice a month while fertilizer was applied on a monthly basis. Application intervals for pesticides and fertilizers were followed more stringent by farmers that produced vegetables alone.

On the other hand, farmers that produced vegetables in addition to the main crop applied pesticides and fertilizers once in a while. Some of the vegetable farmers also applied herbicides in case of watermelon and pumpkin although weeds were removed manually in other vegetables. Farmers that produced groundnuts and wheat did not apply fertilizers and pesticides as frequently as vegetable growing farmers. Furthermore, weeding in groundnuts and wheat was done manually without any herbicide application unlike in certain vegetable crops. Lucerne farmers applied fertilizers once at the beginning of the season and were not applying any pesticides and herbicides. Lucerne production did not involve many cropping activities.

Lucerne producing farmers were only watering and cutting lucerne throughout the season. Watering of lucerne begins in August until the end of the season in April. Therefore lucerne cutting begins in September until end of April although some of the farmers try to cut lucerne even in May. Labour required throughout the cropping calendar that was constructed by farmers for lucerne indicated that only three labourers were used throughout the season for lucerne. Consequently lucerne production

was not considered in the cropping calendar in figure 4 due to minimum activities taking place throughout the year.
All crops in the cropping calendar had to be irrigated at least twice a month. However in the case of vegetables irrigation was more frequent than in other crops. Most of the vegetable growing farmers irrigated vegetables twice a week. Irrigation of crops required the same amount of labourers for all the farmers irrespective of the crop. Hence watering was not included as an activity since all farmers used two labourers to irrigate crops irrespective of the type of crops. Soil preparation was done by one person driving the tractor and an additional person to assist the person driving the tractor. Therefore soil preparation was also not included in the cropping calendar due to low labour demands.

3.3 Land and social relations

Households in Ganspan Settlement have access to the 0.6 ha plots in front of their houses. However not all the community members are interested in agriculture. Community members that are not engaged in agriculture offer the 0.6 ha plots to those that are interested to farm. Farmers that are able to pay rent for additional land cultivate crops in their respective 0.6 ha plots and in the rented 0.6 ha plots. When renting a 0.6 ha plot to produce vegetables the farmer has to pay ZAR 200 after selling harvested vegetables. Therefore the land owner would receive rent every three months in case of vegetable production.

Farmers producing lucerne on rented land paid ZAR 100 after each cutting for a period of eight months in a year. Meaning that land owners that gave 0.6 ha plots to lucerne growers would generate money for eight months in a year. Therefore community members would favour lucerne farmers when renting out their land. Furthermore, Ganspan Settlement had extra land which was given to few farmers by the local municipality. Addition land that was given to selected farmers by the municipality ranged between 2 ha per person to more than 10 ha for a group of farmers in a project.

3.4 Current challenges

3.4.1 Pest management

During interviews farmers often mentioned problems with pests particularly the cabbage aphid which was mentioned by most farmers. Other pests such as the diamondback moth, red spidermites, african bollworm and root-knot nematodes also occur in the area. However, some of the pests were not discovered through conversations with farmers alone. Perhaps some of the pests were not as easy to describe as the cabbage aphid which was often referred to as the ‘lice’ during interviews with farmers. Nonetheless, discussion with other informants in the area including nursery owners for vegetable seedlings has assisted in the understanding of major pest problems in Ganspan Settlement.
Furthermore, weeds were also a problem in the area with particular emphasis on *cynodon dactylon* (quick grass) as the most problematic weed to control. Most farmers controlled weeds by hoeing while few mentioned the use of herbicides (round-up) in case of quick grass. Knowledge on the kind of

chemical to be applied as well as the importance of the right dosage seemed to be a major issue. Most of these farmers have mentioned that they always apply half the recommended chemical dosage by the dealer in the co-operative where they buy these chemicals. Application of less than the recommended dosages of chemicals can lead to the built up of resistance and ineffective pest control. Financial constraints have been the major reason for these farmers to apply chemicals below recommended dosages. Furthermore, selection of chemicals based on financial constraints and not what is best for application raises concerns.

Experiences from other countries showed that small scale farmers opt for the cheapest chemicals posing a health hazard when these vegetables are consumed. In addition, pesticide application was higher for vegetable farmers than other crops similarly to trend that have been observed in other countries such as Ghana. According to (Dinham, 2003) there are 87% vegetable farmers applying pesticides in Ghana. In Ganspan Settlement pesticide application differed among farmers while farmers that produced cabbage applied pesticides most frequently (twice a week). Some farmers applied pesticides twice a month while most farmers only applied pesticides on observation of pest attack. Most of the farmers were not able to remember the type of chemicals applied on their crops. However few farmers that focused on vegetable production were able to mention names of the chemicals that were used.

3.4.2 Labour demands

Farmers that were not part of the groups in Ganspan Settlement used family members as the source of labour for farming activities and hired labour when necessary. On the other hand farmers that collaborated with other farmers to share land could collectively perform required agricultural activities. Farmers required labour during planting especially for vegetables which were transplanted in the 0.6 ha plots. Most labour demands in Ganspan Settlement were for weed control since most farmers did not apply herbicides. Farmers paid a standard amount of ZAR 40. 00 per person employed for a day. Labourers were hired mostly for weeding, planting and harvesting in case of groundnuts. Farmers did not complain about the labour supply therefore it is reasonable to assume ample labour supply in the area.

3.4.3 Theft

All farmers in Ganspan Settlement have access to the 0.6 ha plot in front of their houses. However, some of the farmers also have access to additional land situated at a distance from the houses. Additional land situated further away from the houses does not allow farmers to watch over their crops during the night. The land is situated near an informal settlement where a number of people have settled illegally near these fields and do not partake in any agricultural activities. Consequently farmers in Ganspan Settlement attribute the stealing problem to the illegal inhabitants located near to their fields.

Because of crop theft farmers have to plant crops that cannot be stolen in fields further away from the houses. Crops that are not stolen in the community include groundnuts, wheat and lucerne. Hence these crops are the only crops that are considered for planting in the land located away from the houses. Consequently, vegetable cultivation occurs mainly in the 0.6 ha plots in front of the houses. Although farmers cultivating watermelons in the 0.6 ha plots still have to guard against thieves at night. Some of the farmers cultivating watermelons in the 0.6 ha plots have even opted to employ security guards during the night. Furthermore, recent studies in literature have reported similar behaviour in other countries affecting among other factors cropping patterns, food availability and soil nutrient management activities .

3.4.4 Water allocation

Ganspan Settlement forms part of Vaalharts irrigation scheme which was recently privatised. Now, the irrigation scheme is under the control of the local Water User's Association. Therefore farmers in the area including farmers in Ganspan Settlement are responsible for paying for their own water. Farmers in Ganspan Settlement have to pay a fee of ZAR 15 before they can receive water for irrigation purposes. Farmers in Ganspan Settlement use floor irrigation for watering their crops. The local water committee in Ganspan Settlement is responsible for distributing water through water canals into the plot of a farmer.

However, some farmers avoid paying the cost for irrigation and divert water that was meant for other farmers. Therefore, these farmers illegally irrigate their land with water that has been paid by another farmer. Consequently, less water than was intended would be distributed to the farmer that has paid. Hence conflicts in relation to water allocation have emerged among farmers. Some farmers have even claimed reduced crop yields due to the problem water distribution problem. As a result some farmers have decided to avoid crops that require frequent watering including vegetables. Farmers preferred cultivating groundnuts or lucerne because of lower water demands. Therefore crop selection in Ganspan Settlement has been to a large extent influenced by the water allocation problem.

3.5 Preferences

Important factors considered by farmers when selecting a crop were determined through individual interviews with the farmers. Figure 5 shows six factors that were frequently mentioned by farmers during interviews. Most farmers were concerned about planting a crop that can be sold in the market. Hence this was the first criteria that had to be met when selecting a crop. According to farmers crops that are easy to sell are those that are commonly seen in the market. Meaning, farmers do not secure a market first but prefer to plant crops that are commonly found in the market. Most farmers assumed that it is easy to sell a crop that is common to find in the market. The tendency to follow market trends was also seen in the decision to cultivate vegetables that were included in the highly demanded 'vegetable mix'. The vegetable mix as it is called by farmers included popular vegetables such as green pepper, onions, tomatoes, cabbage and half of a pumpkin.

Profitability of the crop was the second factor considered by farmers which referred more on the amount of money received per selling unit of a crop. Nevertheless, one can argue that there is a connection between the market criterion and the profitability criterion. Amount of money generated by a crop is an important criterion for the farmers considering that most of the interviewed farmers depended on agriculture as a source of family income. Crop utility was the third factor mentioned which includes household consumption purposes.

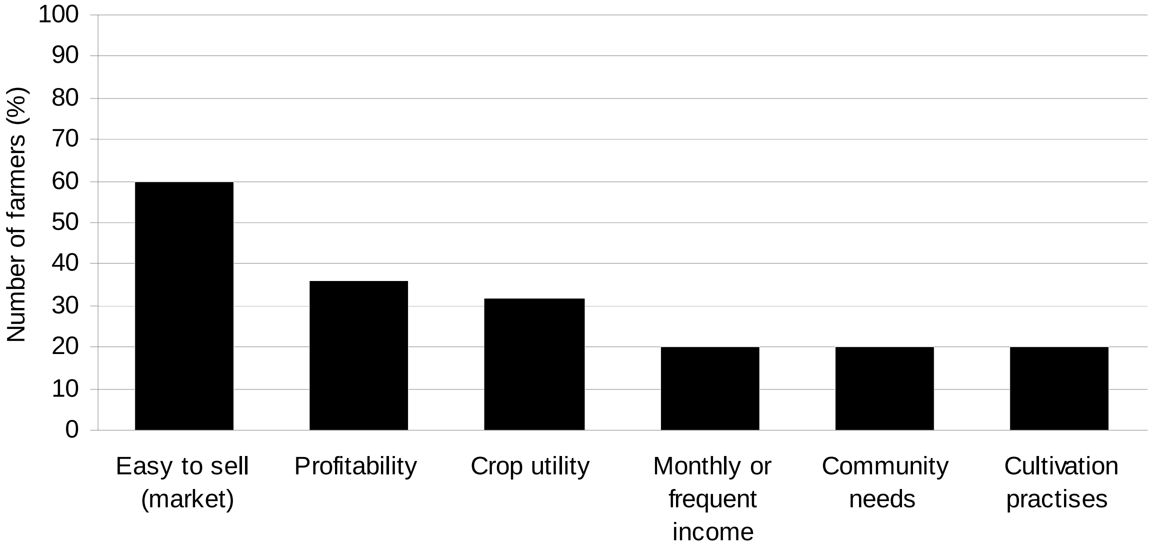

Figure 5 Percentage of farmers using respective criteria when selecting a crop

The last three factors were seen as equally important by farmers including frequency of the income received, meeting community needs and the cultivation practices required by the crop. In case of frequent income generation farmers want to plant a crop that will result in monthly income like is the case with lucerne. Farmers in the area cut lucerne for eight months in a season while vegetables provided income every three months. Community needs with particular reference to job creation and poverty alleviation were mentioned as well. Furthermore some of these needs included giving vegetables to HIV/Aids patients within the community and selling the remaining vegetables. Some of the farmers that were interested in planting vegetables to assist HIV/Aids patients were individuals that were members of care groups for HIV/Aids patients.

The last criterion was cultivation practices which encompassed various issues. In this criterion farmers were concerned about the required implements in planting a certain crop, water requirements and labour demands. Most farmers did not have a lot of implements and they try to avoid additional costs of hiring machinery from neighbouring commercial farmers. Labour demands were also a concern for individual farmers that were not part of a group of farmers. Farmers that were also involved in farming groups were not concerned with labour since the whole group would assist during planting, weeding, watering and harvesting.

Furthermore, some of the male famers considered vegetable production as a women activity while man focused on other crops. However, the connection between gender and crop selection criteria was not explored in this study. Detailed criteria which includes some of the less prominent factors considered by farmers during crop selection can be found in Appendix 2. Furthermore, the selection criteria revealed that farmers select a crop mainly because it is easy to market and generate profit for the household. Farmers are also looking for other benefits when selecting a crop such as household consumption in addition to the profit earned. Therefore crops with multiple benefits are most preferred by the farmers as is the case with groundnuts. Groundnuts in the area were sold as peanuts and crop residue was sold as fodder.

3.6. Soil Fertility Management Strategies and Partial Nutrient Balances

Partial nutrient balances are calculated by estimating all nutrient inputs entering the farm by means of inorganic fertilizers and organic fertilizer such as animal manure. Thereafter, outputs are calculated and these include crop yields harvested which will be sold to the market and exported crop residues when applicable. Furthermore, partial nutrient balances exclude some of the more difficult to measure nutrient inputs (such as atmospheric nitrogen deposition) and outputs such as gaseous losses of nitrogen and nutrients that leached. On the other complete nutrient balances capture the full nutrient cycles within a farm.

In agricultural production systems the full nutrient balance serves as an important indicator of sustainability in agricultural production systems. While partial nutrient balances serves as a mere indicator of management practices and provide insight into sustainability of the farm. When partial nutrient balances are negative, then we can be confident that the full nutrient balances are even more negative. Furthermore, partial nutrient balances were calculated for major crops and two commonly used vegetables in Ganspan Settlement. However, the partial nutrient balances reflect management practices rather than sustainability *per se,* but they can provide useful insights into the longer term sustainability of the cropping system.

Furthermore, nutrient availability can influence productivity as insufficient amounts of nutrient application affects productivity. Therefore, an understanding of the current nutrient status in Ganspan Settlement can assist in making future management improvements. Major crops in the area include groundnuts, lucerne and wheat production while vegetables that were chosen include cabbage and onion. In this study farmers were divided into groups based on the accessible land area. However, there were no major differences in the amount of fertilizers used per group. Therefore fertilizer application used in the calculations was taken to be the average from the different groups of farmers with different land sizes. Details on the inputs used for partial nutrient balances can be found in Appendix 3. While output quantities used in the calculation of partial nutrient balances can be found in Appendix 4.

3.6.1 Partial Nutrient Balance for Groundnuts

Farmers cultivating groundnuts on large pieces of land cultivated wheat as well in a crop rotation. Nonetheless few farmers were involved in groundnut, wheat crop rotation. Most of the farmers would only cultivate groundnuts and alternate with a different crop. The only source of soil nutrients for groundnuts was a compound fertilizer 2:3:4 in 50 kg bags. Farmers applied on average 6 kg N ha^{-1}, 4 kg P ha^{-1} and 3 kg K ha^{-1}. Nitrogen fixation by groundnuts was 198.78 kg N ha^{-1} which is similar to ranges found by Toomsan et al., (1995) which increased the nitrogen input dramatically. Therefore total nitrogen input was above 200 kg N ha^{-1} while less than 5 kg ha^{-1} of phosphorus and potassium was applied as seen in Figure 6. Fertilizer application was done two days before planting groundnuts with less than the recommended amounts. Farmers harvested 3853.55 kg ha^{-1} marketable grain of groundnuts at the end of the season. Furthermore, groundnut residues were also harvested and sold as animal feed.

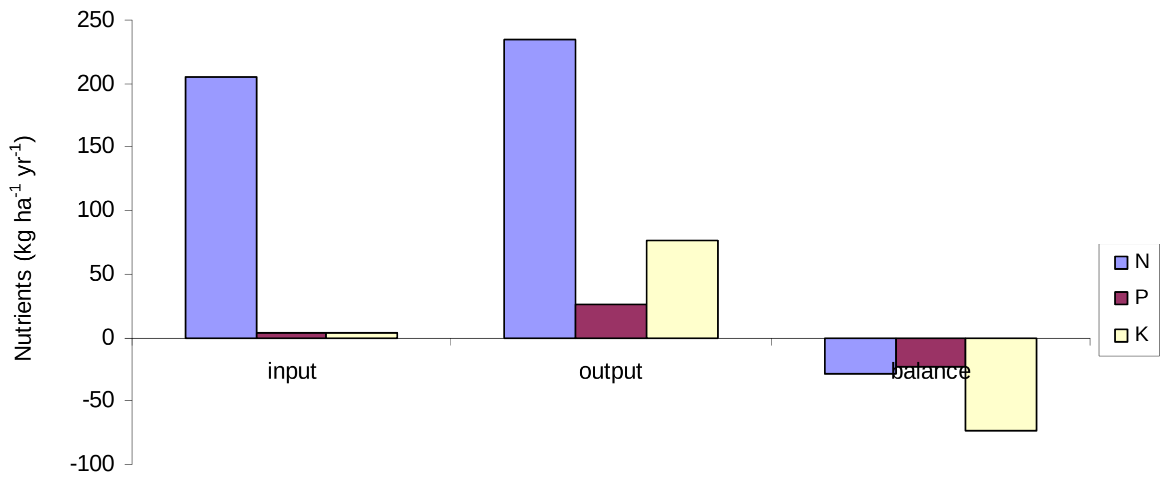

Figure 6 Partial nutrient balance for Groundnuts

Hence there was a complete removal of N, P and K during harvesting of groundnuts as grains and pod shells. Due to large amounts of nitrogen exported out of the farm by means of peanuts and pod shells there was no nitrogen remaining in the soil from the nitrogen that was applied. Negative balances were also observed in phosphorus and potassium (Figure 6).

Negative partial nutrient balance indicates that farmers in the area are practising nutrient mining. More nutrients are taken out of the cropping system than nutrients that are brought into the cropping system. Nutrients can be brought into the system in several ways including sufficient amounts of inorganic fertilizer or organic fertilizers, or through biological nitrogen fixation. In the case of Ganspan Settlement farmers are exporting both the peanut and crop residues out of the cropping system. Therefore farmers can improve soil fertility by incorporating crop residues into the soil.

3.6.2 Partial Nutrient Balance for Lucerne

Lucerne production plays an important role in improving soil structure and as a source of biological nitrogen through nitrogen fixation (Summers, 1998). Lucerne is produced under irrigation in Ganspan Settlement and cut eight times in a season. In a year 20400 kg ha^{-1}season^{-1} of lucerne is sold by farmers. Most lucerne farmers cultivated lucerne alone for a period of five years thereafter farmers would start planting lucerne again or opt for a different crop. Farmers applied small amounts of Lime Ammonium Nitrate LAN (28) in 25 kg bags. Fertilizer application was 21 kg N ha^{-1} in a year without any application of phosphorus and potassium. Nitrogen fixation (382.5 kg N ha^{-1}) by lucerne also contributed to the nitrogen input per season. Some farmers applied table salt to the lucerne when in short of capital which they believe to contribute the same as fertilizer on lucerne growth. Farmers did not apply any other macro nutrients in addition to nitrogen. Phosphorus should have been applied in a form of a single fertilizer or any other fertilizer that is high in phosphorus. Phosphorus plays an important role in nitrogen fixation in legumes, stimulates root growth and plays a role during flowering and seed setting process.

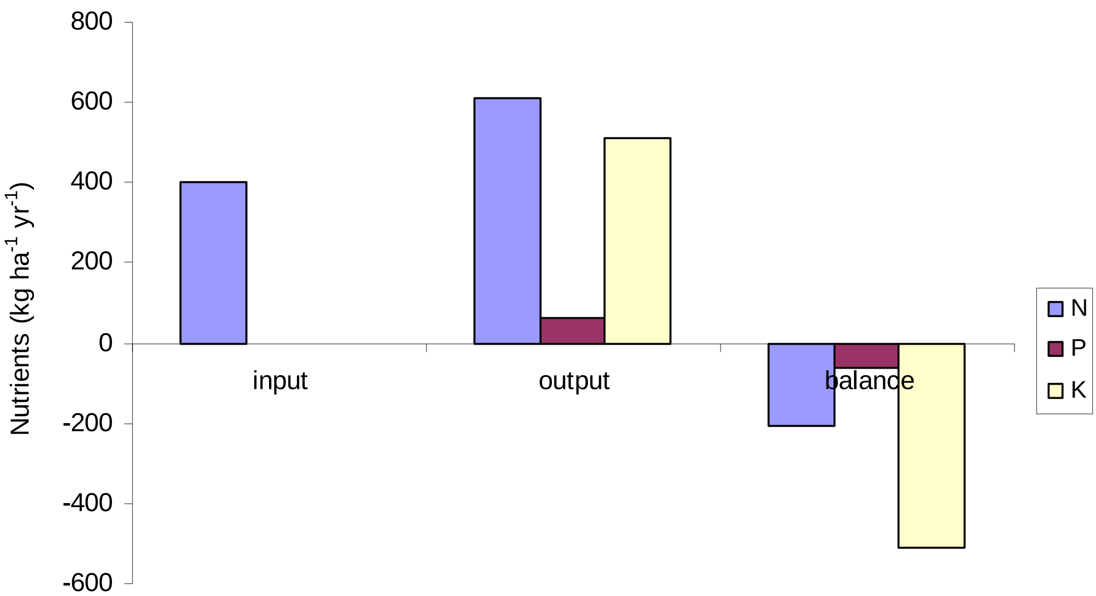

Figure 7 Partial nutrient balance for Lucerne

There was little nitrogen application as compared to the amount of nitrogen exported out of the system (Figure 7). Large amounts of potassium were exported from the cropping system while no potassium was applied. In contrast to other nutrients, there was little phosphorus removal from the soil. Hence the small negative value for phosphorus in the balance in comparison to nitrogen and potassium. Considering the amount of inorganic fertilizer applied by farmers it was not surprising to find negative partial nutrient balances. Therefore lucerne farmers are depleting soil fertility by applying less fertilizer than amounts removed through lucerne bails.

3.6.3 Partial Nutrient Balance for Wheat

The few farmers that cultivated wheat in Ganspan Settlement usually planted it in rotation with groundnuts. Wheat farmers harvested 870 kg ha^{-1} of grain. Wheat straw was exported out of the field to be used in making hay that to be sold to livestock farmers. Therefore both grain and wheat straw were exported from the system. Farmers applied to wheat the same compound fertilizer that was applied to groundnuts. Wheat farmers applied one 50 kg bag of fertilizer per hectare. Fertilizer applied was 6 kg N ha^{-1}, 4 kg P ha^{-1} and 3 kg K ha^{-1}. On the other hand fertilizer recommendations for wheat indicated 30 kg N ha^{-1}, 40 kg P ha^{-1} and 4 kg K ha^{-1} should be applied during the season.
Therefore farmers in Ganspan Settlement applied fertilizer that was much less than the recommended amounts of fertilizer. The partial nutrient balance (Figure 8) also shows insufficient amounts of nitrogen and potassium. Phosphorus application was interestingly sufficient to balance the rate of removal and showed a positive partial nutrient balance in the cropping system. However, in the case of the other main crops (groundnuts, lucerne) this nutrient was insufficient.

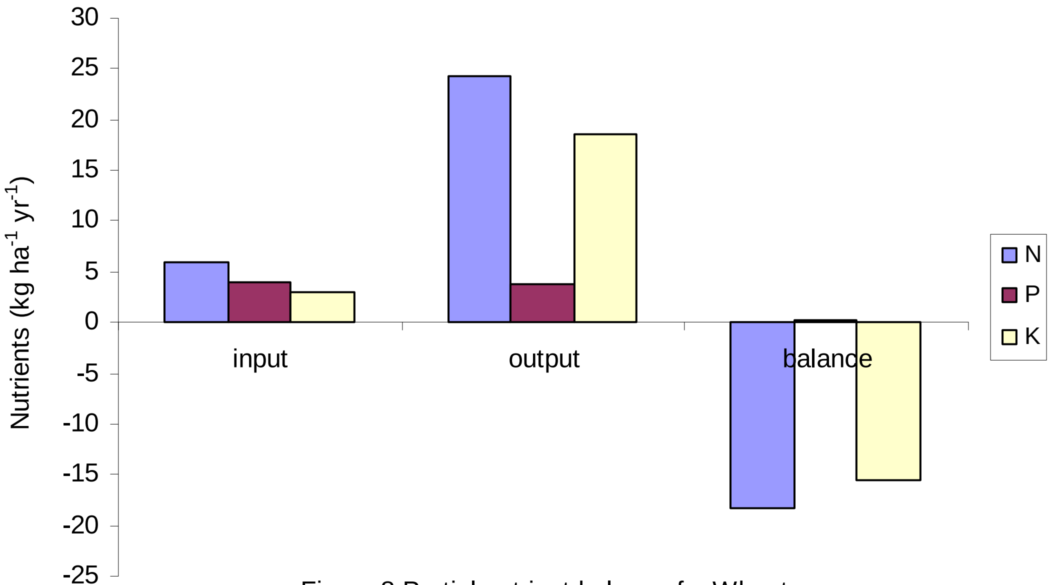

Figure 8 Partial nutrient balance for Wheat

3.6.4 Partial Nutrient Balance for Cabbage

Cabbage is an important crop in the South African diet especially for the poor community (Semuli, 2005). Cabbage producing farmers in Ganspan Settlement harvest 21.67 t ha^{-1} after planting. Furthermore, farmers can plant cabbage twice in a season meaning that some farmers can double the 21.67 t ha^{-1} in a year. Production of cabbage is most popular with the farmers although it is also one vegetable that is mostly attacked by pests. Farmers applied three different types of fertilizer in large amounts as compared to the main crops. Commonly used fertilizers were the compound fertilizer 2:3:4 (24), Urea and LAN (28) in fertilizer bags of 50 kg. Fertilizer applied was 88.3 kg N ha^{-1}, 10 kg P ha^{-1} and 7.5 kg K ha^{-1}. In cabbage production the only nutrient that was insufficient was potassium as indicated in the partial nutrient balance (Figure 9).

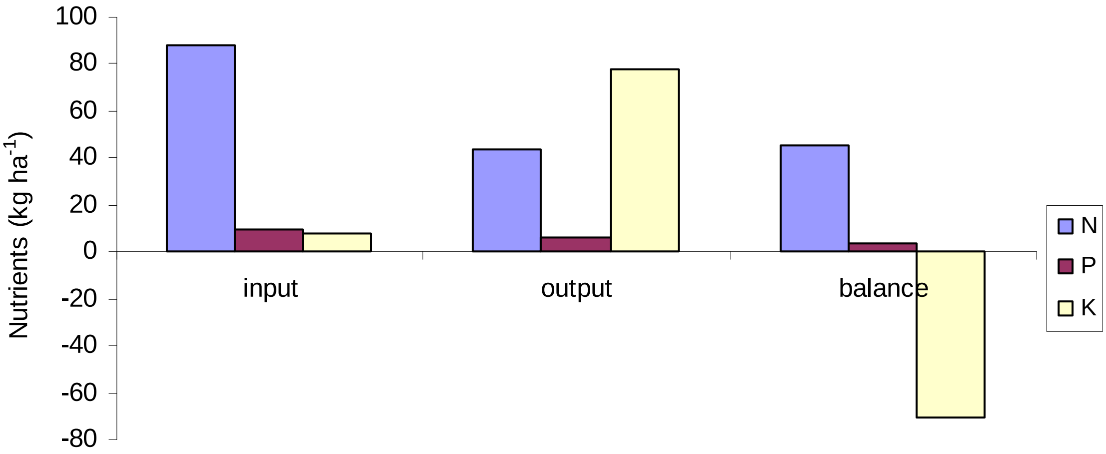

Figure 9 Partial nutrient balance for Cabbage

3.6.5 Partial Nutrient Balance for Onions

Onion is an important vegetable in Africa, it is used in preparing most dishes. In some African countries onion supply has been inadequate due to climatic conditions and selected varieties among other problems (Rouamba and Currah, 2005). Furthermore, farmers in Ganspan Settlement have indicated very low yields from onion production. Farmers in Ganspan Settlement applied 70.6 kg N ha^{-1}, 8 kg P ha^{-1} and 6 kg K ha^{-1} as seen in Figure 10. However, fertilizer amounts that were applied were still lower than the amounts applied in cabbage production. Fertilizers used in onion were compound fertilizer 2:3:4, Urea and Ammonium Nitrate.

Due to extremely small amounts of yields recorded from farmers it was decided to calculate yield based on the number of transplanted onions. Farmers had kept good records of the amount of seedlings that were bought to be transplanted hence this was a better option to improve yield accuracy. However, there was an assumed 20% reduction in the amounts of transplants which were harvested as onion. Meaning the yield obtained was 20% less than the original onion transplants that were bought from the nursery. Consequently, onion yield of 4.37 t ha^{-1} was obtained which was still lower than the lowest recorded onion yield from other African countries. In literature, onion yields recorded in West Africa ranged between 8 t ha^{-1} and 20 t ha^{-1} which differed immensely from the yields obtained in Ganspan Settlement (Rouamba and Currah, 2005). Nonetheless, partial nutrient balance has shown that the only insufficient nutrient application was potassium in onion production.

Potassium deficiency was also observed for cabbage production. However in onion production the amount of potassium that is negative is much smaller than in the cabbage partial nutrient balance.

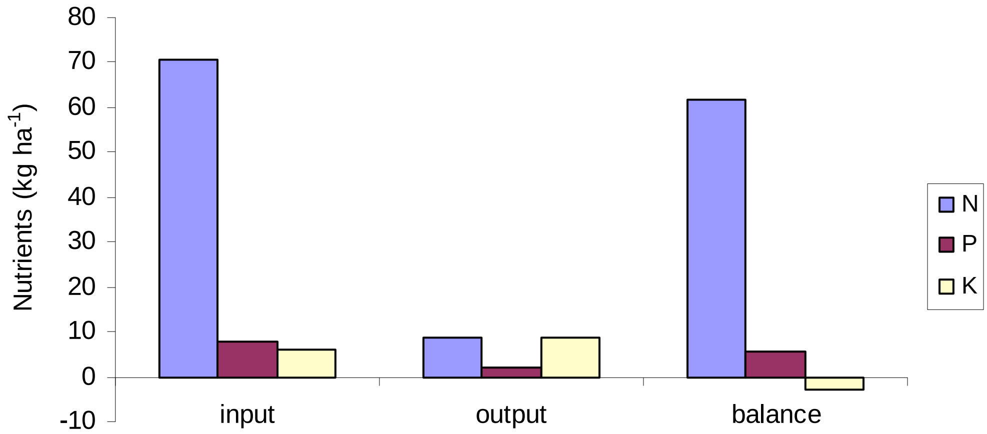

Figure 10 Partial nutrient balance for Onion

3.6.6 Differences in crop management

Farmers in Ganspan Settlement are usually engaged in vegetable production in addition to one or more main crops. However, some farmers are only focusing on vegetable production and have better management of vegetables as this is their only source of income. In Ganspan Settlement it was clear that farmers applied more fertilizer in vegetable production than in main crops as they expect more returns from vegetables. The trend of more fertilizer application in vegetables is in agreement with what has been observed in literature for small scale farmers. Clearly, crop production contributes to large amounts of nutrients that are exported when selling crops to the market. Farmers who cultivate large pieces of land export more nutrients from the farm (Esilaba et al., 2005). Therefore the same practice was observed in Ganspan Settlement. There were no differences found in amounts of fertilizer applied in main crops by farmers belonging to different farmer groups. Meaning, nutrient depletion was exacerbated in large pieces of land and farmers that had access to more land were contributing more to nutrient mining than a farmer accessing 0.6-2.4 ha of land.

In groundnuts production, partial nutrient balance did not show any nitrogen deficiency while there was -6 kg P ha $^{-1}$ year^{-1} and -23 kg K ha $^{-1}$ year^{-1}. In addition to low amounts of fertilizer applied in groundnut the removal of pod shells contributed to a negative partial nutrient balance. Although farmer perception on soil fertility management was not pursued in detail, farmers did not show much concerned for sustaining soil fertility. Farmers were much more concerned with generating additional income from residues of groundnuts and wheat. Wheat production showed a partial nutrient balance that was negative only for nitrogen and potassium. There was -4 kg N ha $^{-1}$year^{-1} and -3. 9 kg K ha $^{-1}$year^{-1} that required to be added into the system to maintain the system in balance. Wheat production contributed least to nutrient mining followed by groundnuts and then lucerne. Lucerne production in the area exports the most nutrients contributing to poor soil fertility. Eight cuttings in a season resulted in large amounts of nutrients exported while small amounts of nutrients were imported into the system. Therefore the problem of nutrient mining was more prominent under lucerne production.

Lucerne production resulted in a negative partial nutrient balance for all nutrients. Nitrogen was deficient by -209 kg $ha^{-1}year^{-1}$ while -33 kg $ha^{-1}year^{-1}$ of phosphorus was needed. Potassium was deficient by -244 kg $ha^{-1}year^{-1}$ and needed to be supplemented. Small amounts of phosphorus were exported in lucerne production while large amounts of nitrogen and potassium were exported. Therefore lucerne contributes the most in nutrient mining due to several cuttings in a season and less fertilizer application. It was clear that farmers producing lucerne are depleting soil nutrients and should consider other management practices that will incorporate more nutrients into the soil.

4. Alternative crops

The purpose of this study was to identify crops that can be grown in Ganspan Settlement. However, the importance of involving farmers in the whole process of identifying possible crops was acknowledged. Hence, determining farmer preference was the first step towards identification of these crops and this was established in the previous chapter. Therefore acceptability by farmers would ensure acceptability of new technology which is crops in this case. Furthermore, there is no point in identifying crops without a market. Hence this study was conducted in collaboration with another study focusing on marketing strategies (Mafuma, 2010). Through the marketing study various crops that were demanded in the market were identified and presented in this study. However, crop production is more than selecting crops that would be accepted by the community and marketable. Agro-ecological and local ecological conditions need to be taken into account throughout the process. Hence agro-ecological and local ecological conditions were evaluated to determine suitability of the crops that were demanded in the market.

4.1 Demanded crops

Demanded crops were obtained from the study conducted by (Mafuma, 2010) in collaboration with the current study. Therefore further details on the marketing strategies can be found in (Mafuma, 2010). Different types of crops that were frequently mentioned as demanded from the marketing study are shown in Table 1. Therefore crops that were demanded in the market in combination with farmer preferences formed the bases for the selection of suitable crops. Some of the crops that were demanded in the market such as garlic, green pepper, pumpkin, tomatoes and onion were already grown by some of the farmers. However farmers are frequently not satisfied with the quality of their produce and often incur losses due to lack of market access.

Farmers also mentioned some crops that were demanded in the market based on their observations. These were crops which formed part of what is locally known as a ‘vegetable mix’. The vegetable mix is a plastic bag consisting of various vegetables and weighs approximately 8 kg. Vegetables included in the vegetable mix include half of a pumpkin, an onion, half of a pepper, two tomatoes, half of a cabbage and four potatoes. As a result farmers try to produce vegetables that will be used in this vegetable mix due to high demand in the market. Furthermore, crops that were demanded based on the marketing study conducted by (Mafuma, 2010) had to be evaluated for suitability in the area. Hence a selection process looking at agro-ecological factors and local ecological factors had to be conducted. Therefore the agro-ecological and local ecological conditions will be the most determining factors for crop suitability in the area.

Table 1. Crops that are demanded in the market in close proximity to Ganspan Settlement

Highly demanded in the market	Demanded	Difficult to find
Lettuce *Compositae* (*Lactuca sativa*)	Garlic *Alliaceae* (*Allium sativum*)	Broccoli *Cruciferae* (*Brassica oleracea*)
Cucumber *Cucurbitaceae* (*Cucumis sativus*)	Peppers *Solanaceae* (*Capsicum annuum*	Patty pans *Cucurbitaceae* (*Cucurbita pepo*)
Tomatoes *Solanaceae* (*Lycopersicon esculentum*)	Radish *Cruciferae* (*Raphanus sativus*	Cauliflower *Cruciferae* (*Brassica oleracea*)
Potato *Solanaceae* (*Solanum tuberosum*) not considered	Parsley *Apiaceae* (*Petroselinum crispum*)	Marrows *Cucurbitaceae* (*Cucurbita pepo*)
Onion *Alliaceae* (*Allium cepa*)	Pumpkins *Cruciferae* (*Cucurbita pepo*)	Red onion *Alliaceae* (*Allium cepa*)
Sweet potato *Convolvulaceae* (*Ipomoea batatas*)		

4.2 Agro-ecological and Local Ecological Conditions

4.2.1 Current soil conditions

Soil analysis results were sub-divided into three sections that were found in Ganspan Settlement as seen in Table 2. Soil analysis was performed to determine soil fertility in the area which is important for crop productivity in cropping systems (Makoi and Ndakidemi, 2008). Soil fertility indicators include soil pH, soil organic matter, Cation Exchange Capacity (CEC), exchangeable bases, salinity and sodicity status. Furthermore, exchangeable mineral nutrients such as extractable N, P, K, Mg and Ca are also regarded as key soil fertility indicators (Makoi and Ndakidemi, 2008). In case of Ganspan Settlement it was important to establish current soil fertility status before introducing new crops. Soil analysis results showed that soil pH in Ganspan Settlement is moderate with a minimum of 6.01 and a maximum of 6.26 (Table 2).

Phosphorus levels in all three sections were below critical levels. Furthermore, phosphorus is known to determine uptake and utilisation of nitrogen. Phosphorus deficiency is often accompanied by calcium deficiency in acid soils (Giller, 2001). Acute phosphorus deficiency is a problem as it hinders nodulation by legumes. The current phosphorus levels can limit crop production. Therefore supplementation of phosphorus is required. Low Ca concentration shown in Table 2 indicate higher bondage of Ca to phosphorus at high soil reactions (Makoi and Ndakidemi, 2008). This means that calcium supplementation is also necessary. As for Potassium, supplementation is only required in Section A.

Magnesium concentration in all the sections was below recommended values from literature (Table 2). In literature recommended ration of Calcium to Magnesium was between 3 and 5. However, Ca:Mg in Ganspan Settlement was below the recommended range due to low Ca. Furthermore, the ratio suggests that soil conditions are not favourable for most crops due to restricted nutrient uptake (Makoi and Ndakidemi, 2008). Calcium and Mg deficiency is typical of acid soils due to insufficient amounts of these cations and secondary effect of high hydrogen ions present in high concentrations. Hence uptake of these cations by plants will be inhibited as stated by Andrew (1978) as cited by (Giller, 2001). Sodium values are low and therefore not detrimental to crop production (FSSA, 2003).

Copper and Zinc values that are less than 1 mg kg^{-1} needed to be supplemented. In Ganspan Settlement Cu was below the critical value in Section A and Section B. Therefore Cu should be supplemented in these soils. On the other hand, Section C had a Cu value that was just above the critical value. When compared to the values found in literature soils in Ganspan Settlement have very low values for Copper. Furthermore, Cu was significantly different between section A, section B and section C. In the case of Zinc, critical value required in the soil is 1 mg kg^{-1} and this was exceeded in Ganspan Settlement.

Generally the soils had high Mn concentration which exceeded the critical value. However Mn concentration was still within the range literature values stated by Mandiringana (2005). Boron values were above the critical value shown in Table 2 in case of Section A and Section B. However, in Section C Boron was deficient and required to be supplemented. Cation Exchange Capacity was below suggested ranges in literature. High CEC is generally more desirable and indicates that the soil can retain mineral elements while a low CEC is associated with low organic matter resulting in low yields for most agricultural soils (Makoi and Ndakidemi, 2008).

Table 2. Chemical composition of selected soils under agricultural production in Ganspan Settlement

Sample ID	pH (KCl)	Olsen P (mg kg^{-1})	K (mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	Na (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	B (mg kg^{-1})	Ca:Mg	CEC (cmol kg^{-1})
Section A (n=8)												
Topsoil	6.10	2.00	125.6	1.92	1.02	13.87	0.60	1.69	103.0	0.18	1.88	3.32
Subsoil	6.25	2.37	80.60	1.46	0.93	5.12	0.44	0.18	89.2	0.23	1.56	2.61
Section B (n=8)												
Topsoil	6.01	3.00	147.3	2.10	0.93	11.00	0.59	1.13	119.9	0.18	2.25	3.45
Subsoil	6.05	1.00	78.10	1.50	0.95	5.12	0.47	0.14	103.3	0.27	1.57	2.67
Section C (n=5)												
Topsoil	6.26	3.8	158.4	2.38	1.33	25.80	1.14	2.08	149.6	0.23	1.78	4.22
Subsoil	6.20	2.20	95.20	2.01	1.33	6.48	0.98	0.31	146.9	0.27	1.51	3.61
Critical values[a]		5	140	5	2	69-161	1	1	10	0.5		6-12
Ranges from literature[b]	5.0-7.0	5-15	80-200	4-10	0.33-0.66	23-460	10-80	10-300	20-3000	7.0-80	3-5	12
SE	0.39	1.59	23.79	0.45	0.18	14.50	0.46	0.99	29.72	0.05		
CV%	6.48	69.02	21.17	24.47	17.35	64.26	71.25	112.42	25.98	23.40		

[a]Critical values for topsoil (Makoi and Ndakidemi, 2008; Kruger, 2009).

[b]Ranges common in mineral soils as given in literature (Makoi and Ndakidemi, 2008).

Soil analysis results with particular emphasis on soil pH influenced the crop selection process. In combination to soil conditions, temperature requirements of the respective crops also played a role in determining potential crops. Furthermore, local ecological factors had to be taken into account in the process of recommending crops that can be grown. Hence current pest problems in the area that can affect potential crops needed to be considered.

4.2.2 Current pests

During interviews that were conducted with farmers, problematic pests in the area were mentioned by farmers. Therefore farmers in Ganspan Settlement struggle to control cabbage aphid, diamondback moth, red spidermites, african bollworm and root-knot nematodes. Nonetheless, some of the pests were not discovered through conversations with farmers alone. Some of the informants in the area including the nursery owner that sells seedlings to farmers shared information on the problematic pests. Furthermore, data obtained from a nematode survey conducted by the Agricultural Research Council (ARC) in the Northern Cape Province clearly indicated the dominance of *Meloidogne javanica* in the area (Van Biljon, 2010).

The survey identified nematode species that exist in the eastern parts of Northern Cape Province. Eastern parts of the Northern Cape Province also include Ganspan Settlement which is the focus of this study. Furthermore, root-knot nematodes particularly *M. javanica* attacks all vegetables hence it is a constraint to vegetable production. Furthermore, pest attack on vegetables leads to poor quality produce making it difficult for farmers to meet quality standards specified by the respective supermarkets.

4.3 Screening of potential crops

Determining farmer preference in Ganspan Settlement was the first step in determining alternative crops followed by the identification of demanded crops in the market. Market demanded crops were screened for suitability under current conditions in Ganspan Settlement. Hence all the selected crops were evaluated per crop family based on agro-ecological and local ecological conditions. The screening process will eliminate any crops that will not be suitable in the area due to various factors such as climatic requirements, pest and disease and soil pH.

4.3.1 *Cruciferae* family

Cauliflower and broccoli were among the crops that were difficult to find in the market although there was a demand. Therefore farmers in Ganspan Settlement can have a market for cauliflower and broccoli. Both crops belong to the *Cruciferae* family that also includes cabbage which has been grown by farmers in the Settlement. Therefore cauliflower, broccoli and cabbage require similar climatic and soil conditions. However, cabbage production has been linked to pest and disease problems in the area particularly aphids. In this case cauliflower and broccoli can also be expected to have similar problems with pest and disease as cabbage. Cauliflower is also a cool season crop with temperatures ranging between 16^{o}C to 18^{o}C. Contrarily temperatures in the area can vary from 9.9^{o}C to 32^{o}C. Cauliflower can survive minimum temperature of 7^{o}C and a maximum of 24^{o}C which are below maximum temperatures in the area. The area has high temperatures which exceed temperature tolerance for cauliflower of 21^{o}C to 24^{o}C. Consequently quality of the cauliflower will be affected at high temperatures leading to defects called 'leafy, ricy, loose or yellowed curds'. Furthermore cauliflower requires rich soils with adequate irrigation which can be a challenge in the area as water allocation has been a problem (Mc Gillivray, 1953).

Likewise, broccoli grows under similar climatic conditions as cabbage and requires cool, moist conditions with optimum temperatures between 16^{o}C to 18^{o}C. It can tolerate cold temperatures as low as 4^{o}C and maximum temperatures of 24^{o}C. However pest and disease which are a problem for cabbage will also be a problem for broccoli. Farmers have complained about aphids affecting the quality of the cabbage and even considered to discontinue with cabbage production. Therefore the same problem can occur in broccoli production. Broccoli production in the area can only be possible with proper knowledge in controlling pest and disease. Without sufficient knowledge in pest and disease control farmers will struggle to produce broccoli according to market requirements for quality.
Radish was also demanded in the market and grows under similar climatic conditions as those of the *Cruciferae* family. However a major problem for this crop will be aphids which will need proper control measures.

4.3.2 *Compositae* family

Lettuce was identified as one of the highly demanded crops in the market. However lettuce production in the area would be inhibited by aphids as this is a major pest for the crop. Downy mildew will also need to be controlled (Scherm et al., 1995). Water requirements for the whole season are much higher for lettuce (Mc Gillivray, 1953) and this can be a problem in the area. High water demands would force farmers to irrigate frequently while farmers prefered crops that do not require a lot of watering due to problems experienced with water allocation. Climatic requirements for lettuce are the same as cauliflower. The crop is unsuitable to be cultivated under these high temperatures conditions as bitter flavour and seeding will be experienced (Mc Gillivray, 1953).

4.3.3 *Cucurbitaceae* family

Cucumber was also highly demanded in the market but melon aphids which are a problem for both cucumber and squash can hinder cucumber production. Insects and diseases attacking pumpkin and watermelon planted in the area would also be problematic for cucumber which belongs to the same *Cucurbitaceae* family. The same holds for patty pans and marrows which are also belong to the same family. Furthermore pumpkins planted in the area have experienced sudden death and farmers are generally not happy with their harvest. During cucumber production aphids which can be carriers of viral diseases would need to be controlled properly. There are various diseases that attack

Cucurbitaceae therefore proper control measures for pests and disease would need to be in place in order to successfully grow these crops (MacGillivray, 1953).

4.3.4 *Convolvulaceae* family

Sweet potato was highly demanded from the market and has the same climatic requirements as watermelon. Farmers in the area have produced good quality watermelon for several years. However nematodes are known to be a problem in the surrounding farms and might be a problem in sweet potato production.

4.3.5 *Apiaceae* family

The demand for parsley was also identified although it was clear that only small quantities of parsley were demanded. Furthermore parsley requires the same climatic conditions as cabbage which already grows in the area.

4.3.6 *Solanaceae* family

Sweet pepper has been cultivated in the area even though temperatures can sometimes exceed optimum temperatures for sweet pepper. Climatic requirements for sweet pepper are the same as those of tomato which has been successfully grown by some of the farmers. The crops that were identified in the market as demanded were then evaluated for suitability in the area. Hence some of the crops that were identified cannot be selected due to unfavourable conditions in the area. Therefore crops were selected based on the local and agro-ecological conditions.

4.4 Selection of suitable crops

Crops that were found suitable for the area during the screening process are the only crops that can be recommended for cultivation in Ganspan Settlement. However, pest and disease are a prominent constraint in the area that needs to be addressed even in the production of selected crops. Recommended crops in the area include sweet pepper, garlic, red onion, parsley, broccoli, cucumber, radish, patty pans and sweet potato. However, all these vegetables are attacked by root-knot nematodes particularly *Meloidogyne javanica* which injures vegetables. Hence production of the recommended vegetables without sufficient pest and disease control measures will lead to major yield losses and poor quality.

Furthermore, it was established from (Mafuma, 2010) that the quality of the product was a key determinant whether or not to buy from a farmer. Consequently, supply of poor quality vegetables by farmers in Ganspan Settlement will lead to termination of contracts by local supermarkets. In addition, vegetable production requires frequent watering and the community has problems with water distribution. Therefore the conflicts with water distribution need to be properly addressed before the cultivation of recommended crops. The community needs to come together and reach an agreement on how to properly facilitate water allocation.

5. Setting a different scene

5.1 Current constraints

Partial nutrient balances that were calculated for groundnuts, lucerne, wheat, cabbage and onion were used as an indication of management practices. All crops that were selected for partial nutrient balances depended on mineral fertilizer for nutrients. Therefore no manure application was done. Partial nutrient balances for main crops clearly indicated that farmers apply less fertilizer than what was withdrawn by the crops. On the other hand, large amounts of fertilizer were applied in vegetable production as compared with main crops (groundnuts, wheat and lucerne). However, it should be noted that vegetable production only takes place in small plots as compared to the area used for main crops.

Furthermore, negative partial nutrient balances were observed with lucerne experiencing the most negative partial nutrient balance compared to wheat and groundnuts. In groundnuts, potassium was the most negative nutrient in partial nutrient balances. Phosphorus which is regarded as an important nutrient for plant growth was below the critical value of 5 mg $kg^{-}1$ in all three sections (A, B and C) as seen in Table 2 from Section 4.2.1. Furthermore, phosphorus is used as a soil fertility indicator and in this case it shows poor soil fertility in Ganspan Settlement (Makoi and Ndakidemi, 2008).

Calcium concentration was below the recommended threshold for most crops. Soils that are limited in calcium are generally expected to produce lower yields. Calcium is a crucial regulator of growth and development in plants (Hepler, 2005). Together with potassium and magnesium, calcium plays an important role in soil-plant relationships. These three elements should be present in the soil in adequate amounts and in suitable proportions to one another as well as with other exchangeable cations, such as aluminium, hydrogen and NH_4^+ in order to create a suitable medium for plant-root development. Low magnesium concentration was observed in all sections of Ganspan Settlement with the minimum value obtained in section C. Consequently low crop yields can be expected in the long term due to low nutrient concentration than critical values. Although there are other factors that also contribute to poor crop yields in the area.

Vegetable production has problems with pest and disease attack which forces farmers to use chemicals in order to obtain good quality crops. Likewise, farmers in Ganspan Settlement are faced with pests such as the cabbage aphid, diamondback moth, red spidermites, african bollworm and root-knot nematodes. Pest attack on vegetables leads to poor quality produce. In such situations farmers can no longer meet quality standards specified by the respective supermarkets. Therefore, the pest problem on vegetables exacerbates the problem of not finding markets for their produce.

Moreover, vegetable cultivation in areas subject to pest attack also results in major yield losses due to severe pest attack. Major yield losses make it impossible for small scale farmers to provide required volumes by supermarkets. According to Slinger & Bird (1977) cited in (Wesemael and Moens, 2008), 43% yield losses were experienced in carrot production due to attack by root-knot nematodes. Such losses would lead to termination of contracts by supermarkets in case of Ganspan Settlement. Furthermore, poor quality of produce harvested under pest attack has direct implications on the profit received by farmers. Vegetables that have been injured by pests will not be bought for the same price as good quality vegetables. In such cases farmers are forced to settle for low prices offered by supermarkets. Consequently, less money would be available for household expenditures. Thus, cultivation of crops that will not be of inferior quality on the market is of utmost importance towards improving livelihoods.

5.2 Farmer's perspective

In the final stages of the research a meeting with all the farmers that were part of this study was conducted. During the meeting crops that were recommended after the screening process of the identified crops were introduced to the farmers. The whole process of introducing a new crop was discussed in detail with farmers. Farmers shared their views about the recommended crops and their views differed depending on the group of farmers.

During the meeting, farmers who were identified in this study were sub-divided into four groups. Farmers who belonged to the first group (0.6 ha – 2 ha) were pessimistic about the recommended crops and did not see the point of stopping to plant current vegetables. This group of farmers did not even try to think of circumstances that would require them to plant different vegetables recommended in this research. Farmers in this group are currently focused on vegetable production. Furthermore, some of these farmers had experiences of crop failure with some of the recommended crops. This can be an indication of the current pest and disease problem although these farmers could not identify the cause of crop failure. Most of the farmers in the first group relied solely on vegetable production as their source of income and this can result in reluctance to try new things. On the other hand, other groups of farmers with more access to land were more optimistic about planting recommended crops.

Farmers that belonged to group two (2.3 ha- 3 ha) and those that were in group three (3.6 ha -7 ha) were willing to plant recommended vegetable crops although they were concerned about the growing period. Farmers did not want to plant vegetables that would require a longer growing season than the current vegetables. Perhaps this concerned emerged from the criteria of frequent income from crops. However, all the farmers acknowledged the need for assistance from crop experts in order to pursue recommended crops. The last group of farmers (more than 7 ha) consisted of farmers that farm together in groups hence accessing more land. Although there are few farmer groups in the area these farmers were enthusiastic about planting new crops. They were eager to plant them although they clearly mentioned conditions that needed to be fulfilled before they can plant these crops.

Farmers mentioned various challenges that needed to be addressed before cultivating recommended crops.

5.2.1 Market

Farmers in Ganspan Settlement are currently struggling to find markets for their vegetables. Hence the market was an important aspect that needs to be secured before cultivating recommended crops. Farmers expected the Department of Agriculture and Land Reform to be involved and assist them to find markets for the recommended crops.

5.2.2 Transport

Vegetables are transported to the local market in order to sell in supermarkets or along the road. However, it is a cost for farmers to transport vegetables to other areas and farmers do not always receive expected returns from the market. Hence farmers wanted assistance with transportation of their produce to the market. In some cases farmers could get a market for their current crops but struggle to take crops to the market. Farmers attribute crop losses to transportation problems as in some cases vegetables would get spoiled from the field due to lack of finances for transportation. Therefore transport for vegetables is an important aspect of crop production in the area. Furthermore, some of the supermarkets expect frequent delivery of fresh vegetables which is often too expensive for small scale farmers.

5.2.3 Small water reservoir

Farmers have mentioned conflicts in the community about water distribution which has also limited the type of crop cultivated by some farmers. Hence in final discussions with farmers the water problem was mentioned once again. According to farmers the current water reservoir is not enough for the whole community. Therefore farmers think it would be better to have another water reservoir.

5.2.3 Training

All farmers acknowledged the fact that there was insufficient knowledge in the community for pest and disease control. Therefore farmers were not willing to plant other crops until they were trained in pest and disease management. Farmers often mentioned the need for training concerning fertilizer application, types of fertilizers that are useful for respective crops and quantities required. Furthermore, the problem of weeds that was identified in the cropping calendar in Section 3.2 came up again. Cropping calendar constructed from the community has shown that farmers spend most of their time weeding their fields. Therefore farmers are concerned about proper control measures for weed infestation and require workshops on pest and disease, fertilizer application and weed control. Furthermore, farmers had no idea about the recommended crops and had never eaten them before. Therefore in case of household consumption this would also be another aspect needing training on different uses of the recommended crops.

5.3 Strategic options

It is not uncommon to find vegetable growing farmers in areas that are infested with pests such as aphids and nematodes. There are several countries in the world that are faced particularly with nematode problems under vegetable production. Countries like Australia have similar ecological and agro-ecological conditions as South Africa and more precisely Northern Cape Province. Nonetheless Australian farmers continue to produce vegetables for large supermarkets (Stirling and Pattison, 2008) and farmers in Ganspan Settlement can learn from their experiences. Different management practices that suit the area need to be put in place to ensure minimum crop losses. Therefore it is not impossible to cultivate vegetables in spite of pests.

Small scale farmers in developing countries lack training in pest management techniques (Dinham, 2003). Likewise, farmers in Ganspan Settlement struggle with pest control measures with particular emphasis on the type of chemicals, timing and correct quantities. Therefore lack of training in pest control observed in literature is also a problem for farmers in Ganspan Settlement. Farmers need to be thoroughly trained on the possible pest control measures. In order to continue with crop production under current pest constraints three options have been developed for Ganspan Settlement.

Suggested options are considered as strategies that can be used for crop production in the area. Furthermore, opportunities and constraints of each option are stated. The following strategic options need to be taken into account before deciding on cultivating selected vegetable crops.

5.3.1 Alternative crops that are not vegetables

Root knot-nematodes occur in large population numbers in the Northern Cape Province including Ganspan Settlement. In particular, *Meloidogne javanica* dominates the area and attacks all vegetable crops. Consequently all recommended vegetables for Ganspan Settlement are subject to attack by *M. javanica*. Vegetables that were recommended based on discussions with the community and market demand include sweet pepper, garlic, red onion, parsley, broccoli, cucumber, radish, patty pans and sweet potato. Nematode injuries degrade the quality of vegetables although severe nematode attack can lead to complete crop loss. When vegetables have been attacked by nematodes the poor quality of the crop makes it difficult for farmers to make profit. Hence farmers in Ganspan Settlement should look for alternative crops which are not vegetable crops.

Constraints:

- Alternative crops to vegetables will need to be identified together with the community.
- New market studies have to be performed to determine the demand of these crops.
- Crops will still need to be screened for suitability in the area and perhaps it will later be found that they are also not suitable for the area.

- Farmers in Ganspan Settlement preferred crops that can be consumed for household food security. Alternative crops to vegetables might not fulfil this requirement.
- Willingness of farmers to abandon vegetables which play an important role in household food security.
- Time and financial resources to repeat the whole process of crop identification.
- Different pest and disease problems may arise with different kinds of crops. Ultimately costs can still be incurred for pest and disease control.

Opportunities:

- Grow crops that are not susceptible to the current pests and disease. Therefore save costs in buying pesticides.
- Possibility of growing crops that can generate high profit than current crops.
- Grow crops that are rare to find in the market.
- Explore new markets that may not currently be in existence.

5.3.2 Organic agriculture

Small scale farmers often do not apply mineral fertilizer yet these farmers are not practising organic agriculture. Farmers that are not opting for management practices that enhance the presence of natural enemies to control pest and disease cannot be classified as organic farmers (Scialabba, 2000). According to (Goldberger, 2007) to be able to qualify as an organic farmer the use of mineral fertilizer, pesticides, growth regulators, genetically modified organisms, livestock feed and additives should all be avoided. An initiative from the Ministry of Food and Agriculture and Ghana Organic Agriculture Network in Ghana has indicated that organic farming is a better alternative for some small scale farmers. The practice as such reduces costs in pesticides, generate employment and minimize health and environmental hazards (Scialabba, 2000).

In Ganspan Settlement farmers have often indicated that they apply small amounts of pesticides and mineral fertilizers to vegetables in particular yet this is not organic agriculture. Therefore farmers are currently using mineral fertilizer and pesticides in crops that generate high profits from the market like is the case with vegetable farmers (see Section 3.6.4 and Section 3.6.5). Organic agriculture makes use of management practices that will attract natural enemies of problematic pests in a cropping system. Furthermore, genetically modified crops are also not used under organic agriculture although farmers in Ganspan Settlement have not been using genetically modified crops. Clearly, farmers in Ganspan Settlement would need to be trained on specific procedures that need to be followed in order to become organic farmers.

Constraints:

- Registration and the certification procedure that might not be easily followed and understood by small scale farmers.
- Pest control on the recommended vegetable crops is only limited to biological control measures.
- Alternative sources of fertilizers to mineral fertilizers would need to be used.
- Partial nutrient balances for various crops in Ganspan Settlement have indicated reliance on mineral fertilizers alone. Therefore it will take a while to shift mindset of farmers.
- Farmers do not own livestock and therefore there is a shortage of kraal manure as an alternative to mineral fertilizer.
- Compost required might not be sufficient resulting in some cost implications for compost.
- Demand for organic products was estimated by (Mafuma, 2010) complementing identified crops. There was no strong demand for organic products in the surrounding supermarkets. Therefore the market for organic products is not yet established in this area.

Opportunities:

- Vegetable crops that were recommended in this study can still be planted although the market was not for organic products.
- Improve soil fertility through practice of crop rotation with crops that can contribute to improved soil fertility according to Parrot & Marsden (2002) as cited by (Goldberger, 2007).
- Environmentally friendly alternative resulting in less chemical emissions to the environment.
- Could reduce input costs by using available alternative sources to mineral fertilizer and pesticides.
- Organic market has not been fully explored and this can be used to the advantage of the farmers in Ganspan Settlement. Local supermarkets are aiming to increase supply of organic products in the future.

5.3.3 Integrated management approach

Nematode problems are often controlled through the use of soil fumigants. According to Toyota *et al*., (1999) and Ibekwe *et al*., (2001) cited in Aires et al., (2009), soil fumigants such as metham sodium have been proven to reduce soil microbial populations leading to reduced soil processes such as nitrogen and carbon mineralization. Consequently, alternative methods to chemical application or in combination with some level of chemical application can improve soil fertility. Chemicals are expensive and often not affordable to small scale farmers. Hence the use of biological control in combination with a certain level of chemicals would be appropriate. In western India maize was grown as a staple food yet low productivity resulted in maize deficits for many families. Hence it was necessary for researchers to intervene and introduce intercropping techniques. Researchers together with farmers planted trials and intercropped maize with horsegram (*Macrotyloma uniflorum*).

Introduction of horsegram in an intercrop would increase maize yields and also introduce farmers to intercropping practice. Farmers participated by planting maize with horsegram and exchanged their views with researchers throughout the process. At completion of the trials farmers saw the benefit of reduced labour due to less weeding activities that were required in an intercrop. Consequently farmers were keen to adopt the new technology. The market for the new crop which was horsegram was still poor but increased supply and coordinated marketing among farmers would improve profits. Therefore using participatory approaches to introduce new technology allows farmers to judge attractiveness of the technology and decide for themselves either to adopt or not to adopt (Witcombe, 2008).

Similarly, farmers in Ganspan Settlement farmers are struggling to control aphids and other pests. Farmers lack knowledge on the type of chemicals, timing, dosage and various techniques that can be used in pest control. Moreover, farmers in Ganspan Settlement practice crop rotation using groundnuts-wheat while others continuously cultivate the same vegetables and lucerne. Thus, cover crops used as green manures can be an opportunity for farmers to improve soil fertility, control pest and diseases. In literature there are various studies that show the potential of the *Brassicacea* family in controlling nematode problems which are also a problem in Ganspan Settlement. Nematode suppression also depends on the type of extract and concentration used (Aires et al., 2009).

Furthermore, resistant crop varieties can also be used in this option in combination with sequential cropping. Crop rotation plays an important role in controlling pest and disease. Therefore farmers in Ganspan Settlement should plant recommended vegetables in rotation with crops that are not susceptible to the current pest problems. Farmers will require training and involvement through trials focusing on the different possibilities of using an integrated approach in their cropping systems. Vegetables that have been recommended in this study can therefore be grown in rotation with poor host crops for nematodes among other possibilities. An integrated approach to control current pest problems is more likely to be adopted by farmers in Ganspan Settlement as it has multiple benefits.

Constraints:

- Crop theft particularly in watermelons and maize which are commonly used for household consumption is a restriction in Ganspan Settlement. It has been shown that farmers avoid to plant crops that are easily stolen as discussed in Section 3.4.3. Hence crop theft can be a restriction on the adoption of potential crops that can be used in rotation with recommended vegetables.
- Cultivation of green manures have input cost implications for buying seeds, hire labour to plant green manures, watering costs and tractor for the incorporation of the green manure into the soil. In-depth investigation on the type of green manures that will be suitable for Ganspan Settlement still needs to be undertaken.

- Consequently a cost-benefit analysis would need to be performed before recommending suppressive crops to be able to determine that the benefits exceeds additional costs of these control measures.
- Potential crops that can be used in a rotation have not been tested under local conditions. Therefore suppressive effect of such crops on nematode populations under local ecological conditions is not yet known.
- Willingness of farmers to plant another crop on a limited size of land which could mean there is no available land for vegetables used for household consumption.
- This is clearly a shift from the current practices in Ganspan Settlement. Therefore, intensive training on the identification and enhancing presence of natural enemies for pests and disease problems will be required.

Opportunities:

- Experiments conducted with maize have shown that maize is a poor host of the root-knot nematode which makes it a potential crop to include in a rotation as stated by Kimenju *et al*., 1999 cited in Mweke et al., (2008). Sweetcorn and babycorn can be included in a crop rotation to suppress root-knot nematodes (Mweke et al., 2008). These crops can also be used for household consumption and sold to the market. Therefore, planting sweet corn and baby corn in rotation with recommended vegetables is still in line with farmer preferences.
- Vegetable crops that have been selected in this study can be cultivated in combination with different pest control management practices.
- Reduce negative impact on the environment and humans
- Various methods for suppressing nematode population have been shown including *Brassicaceae* family as an alternative in green manures.
- Some of the crops within the *Brassicaceae* family that can be used to suppress nematodes include watercress and cauliflower (Aires et al., 2009).
- Sorghum, millet and guar (*Cyamopsis tetragonoloba*) have also shown suppressive effect on root-knot nematodes as shown by Morris & Walker, 2002; Wang *et al*., (2002) and (2003) cited in (Mweke et al., 2008). Therefore these crops can also be considered for controlling nematode problems.
- According to George et al (2009) diamondback moth (*Plutella xylostella*) which is also a problematic pest in Ganspan Settlement can be controlled using trap crops including Indian mustard (*Brassica juncea* L.), cabbage (*Brassica oleracea*) which is a different variety than the main crop, rocket (*Barbarea vulgaris* L.) and collard (*Brassica oleracea*).
- Possible research trials to be conducted in the community and involve farmers in the evaluation of new technologies. Farmers would be involved in practising new technology in trials and therefore gain the necessary knowledge for their management practices. Furthermore, farmers can evaluate the benefits of the new technology and likely to adopt new technology when they observe benefits (Witcombe, 2008).

- Allow for soil fertility improvement while reducing chemical emissions to the environment. Farmers will be in a position to manage their cropping systems in such a way that enhance the presence of natural enemies to control pests. Crop rotation and or antagonistic crops to pests particularly root-knot nematodes will be the focus of this approach.

6. Conclusion and recommendations

Farmer preferences were the main drivers during the crop selection process in combination with market demanded crops. Therefore crops that can be used for household consumption and generate frequent income were selected. Consequently, high value crops recommended in this study include sweet pepper, garlic, red onion, parsley, broccoli, cucumber, radish, patty pans and sweet potato. However, sweet pepper and garlic recommended in this study are already grown in the area but in very small scale. Furthermore, partial nutrient balances have indicated poor soil management practices in Ganspan Settlement. Soil analysis results indicated some nutrient concentrations that were below critical values and needed to be supplemented. Therefore deficiencies in certain nutrients can and might have contributed to low crop yields experienced in the area. Therefore management practices aimed at improving soil fertility are necessary. Besides soil fertility problems there are other challenges faced by farmers in Ganspan Settlement.

Some of the challenges include water distribution conflicts which needs to be addressed before production of the recommended crops. Pests such as the cabbage aphid, diamondback moth, red spidermites, african bollworm and root-knot nematodes are major challenges for farmers in the area. Current pest problems limit production of recommended crops hence it is necessary to improve pest management practices. Therefore, training of farmers on various pest control measures will play a significant role in improving income earned from crop production. Possible management practices that deals with the pest problems creates a dilemma between farmer preferences and methods used to deal with pest problems. Crop rotation or use of green manures can lead to the introduction of crops that do not fit preferences of the farmers. Farmers prefer crops that can be used for household consumption. However not all crops suggested for pest control can be used for household food security.

Consequently, there are trade-offs between food security and pest control that needs consideration by farmers. Farmers can choose to focus only on vegetables which will fulfil their household food demands. On the other hand introduction of other crops as green manures might not have direct benefits for food security but can increase yields through improved soil fertility. This study has identified three options as possible means of dealing with the current pest constraints in Ganspan Settlement. First option suggest cultivation of different crops which would require more investigation on other possible crops.

The second option of organic agriculture has some level of overlaps with the last option. The main difference between organic agriculture and integrated management approach option is the complete exclusion of mineral fertilizer and pesticides. The two extremes from relying solely on chemicals in the case of vegetable farmers to the use of biological control measures alone is rather drastic in the short-term. Hence the last option which merges the option of organic agriculture with some degree of chemical application in crop production is more likely to be adopted in the area.

Among the three options that were considered in this study for dealing with pest problems only one option was recommended. Integrated approach to pest management and soil fertility is recommended for implementation in Ganspan Settlement. An integrated management approach gives the possibility of combining chemicals, and biological control measures. In this option the use of sweet corn and baby corn in a crop rotation with vegetables has been suggested and this was the most suitable option for food security needs generate high income. On the other hand, introduction of this crop can be limited by crop theft in the area. Therefore farmers have to find ways to deal with crop theft. Farmers might have to come up with other control measures such as high fencing since some plots are not fenced and form groups that guard against thieves during the night.

Farmers in Ganspan Settlement should participate together with researchers in finding suitable options that can be integrated with current practices resulting in better pest control management strategies. Hence further investigations should be conducted on the performance of some of the suggested crops for use in crop rotation and as green manures. The two studies conducted in Ganspan Settlement one being the current study focusing on finding crops that can be grown while the second study focused on the marketing strategies (Mafuma, 2010) should be used jointly for further developments in Ganspan Settlement. Further studies can also look at cost-benefit analysis of growing recommended vegetables in rotation with other crops or green manures. The study should be seen as a point of reference for further research work to the bigger problem of finding better management practices to control pests in Ganspan Settlement.

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Appendixes

I. Soil sampling locations within Ganspan Settlement

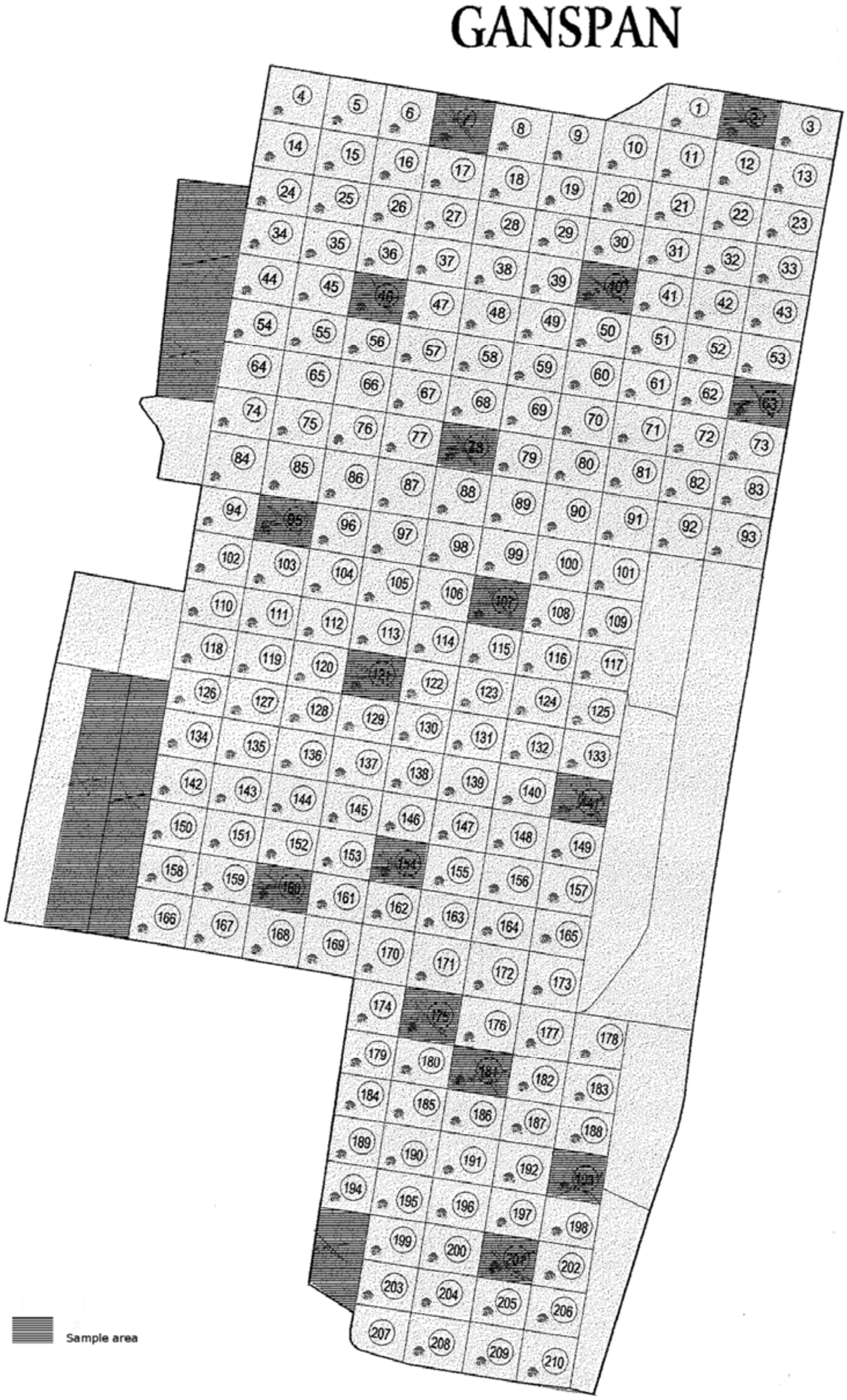

Figure 1 Households and fields selected for soil samples

II. Detailed crop selection criteria

Table 1 Crop selection criteria used by farmers

Detailed criteria	Number of farmers in (%)
Easy to sell crop (market)	60
Profitability of crop	36
Production costs (min costs)	12
Crop utility (consumption, by-products, feed)	32
People preferences ('vegetable mix')	12
Stealing (cannot steal lucerne)	8
Scarce crops, planted later in season	16
Crops that can generate monthly or frequent income	20
Crop characteristics (yield, shelf life, growing period)	16
Crops that can fit in a crop rotation with main crop	8
Local conditions (pests and disease problems)	8
Community needs (Aids patients, job creation, poverty)	20
Cultivation practices (labour, implements, water demands, knowledge)	20

III. Inputs used for partial nutrient balances

Table 2 Input data used in partial nutrient balance calculations for selected crops

Selected crops	Assumptions	Mineral fertilizer	Nitrogen fixed
Groundnuts (kg ha^{-1})	4 % N content in grain and 2% N content in podshells 75% N is fixed by crop (Giller, 2001)		
N		6.00	198.78
P		4.00	
K		3.00	
Lucerne (kg ha^{-1} season^{-1})	Assumed 2.5 % N in biomass		
N		21.00	382.50
P		0.00	
K		0.00	
Wheat (kg ha^{-1})			
N		6.00	-
P		4.00	
K		3.00	
Cabbage (kg ha^{-1})			
N		88.33	-
P		10.00	
K		7.50	
Onion (kg ha^{-1})			
N		70.67	-
P		8.00	
K		6.00	

- Not applicable

IV. Outputs used for partial nutrient balances

Table 3 Output data used in partial nutrient balance calculations for selected crops

	Assumptions	Harvest Index (Chiwona-Karltun)	FM	Yield	Crop withdrawal amounts			Source
Crops		%			**N**	**P**	**K**	
Groundnuts **:**	Assumed 41% FHI (because grain and podshells are removed from the field) Moisture content 7.5%	41.00						(Van Duivenboden, 1992).
Nuts (kg ha^{-1})			4166.67	3853.55	154.14	14.25	23.12	
Vines (kg ha^{-1})				5545.35	79.85	12.19	53.23	
Lucerne (kg ha^{-1} season^{-1})	Moisture content 15% Assumed 10% yield loss during cutting Eight cuts in a season	-	26666.67	20400	612.00	61.20	510.00	Agricultural Handbook (Grusenmeyer) cited Agronomic rate determination by crop (2010).

Continued

Crops	Assumptions	Harvest Index (Chiwona-Karltun)	Fresh Biomass	Yield	Crop withdrawal amounts			Source
		%			**N**	**P**	**K**	
***Wheat*:**	Moisture content 13%	42.00						(Van Duivenboden, 1992).
Grain (kg ha^{-1})			1000.00	870.00	17.40	2.95	3.65	
Straw (kg ha^{-1})				1201.43	6.96	0.84	14.89	
Cabbage (t ha^{-1})		-	-	21.67	43.33	6.50	78	(FSSA, 2003).
Onion (t ha^{-1})	Yield based on amount of transplanted seedlings Assumed 20% losses in transplanted seedlings	-	-	4.37	8.76	2.19	8.75	(FSSA, 2003).

- Not applicable