ASSESSING THE EFFECT OF CROP INTENSIFICATION IN IMPROVING AGRICULTURAL PRODUCTIVITY IN SMALLHOLDER FARMERS' FIELDS: A CASE STUDY OF NOTHERN KWAZULU-NATAL, SOUTH AFRICA

by

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PREFACE

The research contained in this dissertation was completed by the candidate while based in the discipline of Crop Science, School of Agriculture, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa. The research was supported by the Discipline of Crop Science.

The content of this work have not been submitted in any form to another university and , except where the work of others is acknowledged in the text, the results reported are due to the investigations by candidate.

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Signed: Dr A.O. Odindo

Date:

DECLARATION

I, Hloniphile Mthembu, declare that:

(i) the research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;

(ii) this dissertation has not been submitted in full or in part for any degree or examination to any other university;

(iii) this dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;

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Signed: Hloniphile Mthembu

Date:

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GENERAL ABSTRACT

Crop intensification is adopted by different countries to address their challenges, which may include low standards of food and nutrition security, limited arable land and land degradation. To assess the effect of crop intensification in improving agricultural productivity in smallholder farmers in Northern KwaZulu-Natal, a qualitative study and in-field experiment were conducted. In a qualitative study the Participatory Rural Appraisal (PRA) tools namely, focus group discussions, transect walks and key informant interviews was used. A random purposive sample of 249 smallholder farmers from 5 local municipalities of uMkhanyakude district was undertaken. The following information was explored: different farming systems; landscape; availability of irrigation systems or water sources; classification of farming soil types; perception of soil fertility; planting and rainfall patterns. Smallholder farmers' demographics, socio-economic status, typical farming systems, differences between backyard gardens and crop fields, water sources, knowledge and skills on farming systems and practices, understanding and benefits of mixed farming, crop mixing and intercropping, soil fertility and soil acidity management were also explored. The findings of the study revealed that the age of the smallholder farmers ranged between 40-65 years. About 90% of the smallholder farmers who participated in this study were females. 45% of smallholder farmers' households are headed by females. A typical household of the smallholder farmers, is characterised by more than two dwelling places in one household compound with mixed farming. Water is a serious problem in uMkhanyakude district. 70% of the farmers primarily used indigenous knowledge and acquired their skills on farming systems and practises from generation to generation indigenous knowledge system.

In-field experiment was conducted. It was laid out in a randomized complete block design (RCBD) with three replicates having a net plot size of 3.6m x 5m. The following treatments were evaluated: Maize intercropped with beans (T1), Maize intercropped with pumpkins (T2), Maize intercropped with beans and pumpkins (T3), Maize sole crop control (T4), Beans sole crop control (T5), Pumpkins sole crop control (T6) and Bean intercropped with pumpkins (T7). Productivity was measured using the following indices: Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER), Competition Ratio (CR), Relative Crowding Coefficient (K) and Aggressivity (A), Actual Yield Lost (AYL), Intercropping Advantage (IA) and Monetary Advantage Index (MAI). The study revealed that the intercropping system with three crop species in all three location showed greater values of LER (1.8, 1.9, and 1.7) and ATER (1.8, 1.9, 1.7). The crowding coefficient (K) was the highest in Mtubatuba and Hluhluwe treatment

3 (maize/bean/pumpkin) (80.72 and 61.78) respectively. Intercrops showed positive Agressivity, and greater competition ratio and actual yield loss when compared with the main crops. Intercropping advantage (IA) and monetary advantage (MAI) in treatment 3 (maize/bean/pumpkin in all locations showed greater values (58327, 12850, 5532) and (54573, 59487, 19606) respectively. The productivity of the intercropping system where there are more than two crops is considered greater in terms of land equivalent ratio (LER), area time equivalent ratio, (ATER).

Keywords: *smallholder, intensification, intercropping, mixed farming, crop mixing, Maize, dry bean, Pumpkin, Land equivalent ratio*

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CHAPTER 1: INTRODUCTION

1.1 CROPPING SYSTEMS

Cropping systems can be defined as the pattern of crops occupying a given piece of land, or sequence in which the crops are cultivated on piece of land over a fixed period and their interaction with farm resources and other farm enterprises. Examples of cropping systems include multiple cropping or sole cropping. Multiple cropping is basically growing two or more crops consecutively or at the same time on the same field in the same year. Clearly the number and type of crops planted by farmers in a cropping systems is an important factor that could affect farm productivity and yield. Cropping systems that include two or more crops on the same piece of land can also be described as a form of crop intensification.

Farmers in sub-Saharan Africa including regions such as Northern KwaZulu-Natal plant combinations of crops in their fields, this is a form of crop intensification where farmers plant a variety of crops on the same piece of land. The selection of crop combinations if not done carefully may result in increased inter plant competition for limited resources such as moisture, available nutrients and solar radiation. It is logical that when planting more than one crops simultaneously on the same piece of land the plant population of each crops will be reduced as compared to the sole crop of the same crop. This reduction for plant population and the resultant competition between plants can contribute to further reductions in crop yields. According to Dhima et al. (2007), cited by Muhammad et al. (2008), competition can have a significant impact on the growth rate of the different species used in intercropping. Careful planning of intensification is important and consideration of a number of factors is required. This include good selection of plant species, seeding ratio and planting patterns. According to Banik and Sharma (2009); Cropping systems that combine several crops in the same field/plot such as intercropping maize and legumes are widely practiced and have been shown to increase total productivity per unit area, improve land use efficiency, and increase atmospheric nitrogen fixing ability.

There are several indices that have been developed to describe productivity advantage with regard to competition and economic advantage of intercropping compared to sole cropping. These indices are: land equivalent ratio (LER), competitive ratio (CR): $CR = (CRa + CRb)$, relative crowding coefficient (K): $K = Kab * Kba$ area time equivalent ratio (ATER): $ATER = LER * Dc/Dt$, Agressivity (A): $A = \{Yba/(Ybb * Zba)\} - \{Yab/(Yaa * Zab)\}$, actual yield loss (AYL): $AYL = AYLa + AYLb$, intercropping advantage (IA): $IA = (AYLb) * (Pb)$ and monetary advantage index (MAI): $MAI = (value\ of\ combined\ intercrops) * (LER - 1)/LER$ McGilchrist (1965), Willey (1979), (Banik (1996), and Ghosh (2004). Land Equivalent Ratio is an important tool for evaluation of yield and resource utilization efficiency. Land Equivalent Ratio, providing that all other things are being equal, is a measure of the yield advantage obtained by using this production system compared to growing the same crops in a monoculture system. $LER = \sum(Ypi/Ymi)$, where Ypi is the yield of each crop in the polyculture, and Ym is the yield of each crop in monoculture. A LER value of 1.0, indicating no difference in yield between the polyculture and the collection of monocultures. Any Value greater than 1.0 indicates a yield advantage for intercrop. These indices provide useful tools that can be used to assess the impact of crop intensification in smallholder farmers' fields. These indices provide useful tools that can be used to assess the impact.

1.2 RESEARCH PROBLEM STATEMENT

Factors that may limit production among many smallholder and resource poor farmers include limited land sizes, lack of irrigation facilities, limited rainfall, moisture loss through high evapotranspiration rates and poor soil fertility. Coping strategies in response to these production constraints include cropping systems that combine a number of different crop species on the same piece of land at the same time or sequentially. Such cropping systems may contribute to improved soil fertility through biological nitrogen fixation and soil water conservation depending on the species used. Farmers often plant mixtures of two crops, for example, maize intercropped with beans or groundnuts or cowpeas. In some instances farmers may also plant more than two crops, for example, maize, beans and pumpkin. There is little information regarding the interactions in such crop mixtures with respect to productivity. The reasons why farmers plant more than two crop species in the same piece of land could form part of local indigenous systems, however, the scientific basis for the selection and performance of such crop combinations have not been clearly explained and documented.

1.3 RESEARCH QUESTIONS

This study sought to answer the following questions:

1. What are the underlying reasons that may explain why farmers choose whether to have two or more crops on the same piece of land?

2. Does planting more than two crops (intercropping maize, beans and pumpkins on the same piece of land result into increased productivity compared to sole crops of each species?

1.4 AIMS

The aim of this study was to assess the effect of crop intensification in improving agricultural productivity in smallholder farmers' fields.

1.5 OBJECTIVES

The following specific objectives were pursued in the research:

1. To investigate the reasons why farmers choose to plant more than two crop species in the same piece of land.
2. To compare the productivity of a maize/pumpkin/bean inter-crop with different combinations of maize/bean, maize/pumpkin, bean/pumpkin and sole crops of each species.

1.6 OUTLINE OF DISSERTATION

The dissertation is written in the research paper format.

Chapter 1 is the general introduction which provides the rationale, justification, research questions, aims and objectives of the study.

Chapter 2 is the literature review focusing on the challenges faced by smallholder farmers, crop intensification and intercropping. The chapter reviews information on crop intensification and attempts to identify gaps in knowledge, some of which are addressed in this study.

Chapter 3 is an experimental chapter in which the findings following a focus group discussion on the reasons why farmers decide to plant more than two crop species in the same piece of land are presented and discussed.

Chapter 4 is also an experimental and reports on the productivity of different combinations of maize/bean/pumpkin inter-crops compared with the sole crops of each species.

Chapter 5 is the general discussion and provides the conclusions and recommendations for further research.

1.7 REFFERENCES

Banik P. and Sharma R. C. 2009. Yield and Resource Utilization Efficiency in Baby Corn—Legume Intercropping System in the Eastern Plateau of India. Journal of Sustainable Agriculture. 33:4 Pg 379-395.

Dhima K.V., Lithourgidis I.B. and Dordas C.A. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Research. 100: Pg 249-256.

Ghosh P.K. 2004. Growth, yield, competition, and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Research 88: Pg 227–237.

Hiebsch C.K. and McCollum R.E. 1987. Area x time equivalency ratio: A method for evaluating the productivity of intercrops. Agronomy Journal 79: Pg 15-22.

McGilchrist C.A. 1965. Analysis of competition experiments. Biometrics 21: Pg 975-985.

Muhammad A., Ejaz, M.U. and Abdul K. 2008. Yield and Competition Indices of Intercropping Cotton (*Gossypium hirsutum L.*) Using Different Planting Patterns. Tarim Bilimleri Dergisi 14 (4): Pg 326-333.

Willey R.W. 1979. Intercropping its importance and research needs-I. Competition and yield advantages. Field Crop Research Abstracts 32: Pg 1–10.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Crop intensification is defined as the concentration of inputs upon the same piece of land rather than its distribution among several adjoining pieces of land. According to FAO (2004), crop intensification can be technically defined as an increase in agricultural production per unit of inputs which is labour, land, time, fertilizer and seeds. Crop intensification occurs when there is an increase in the total volume of agricultural production that results from a higher productivity of inputs, or agricultural production is maintained while certain inputs are decreased such as by effective reduction of fertilizer amount, better targeting of plant protection, and mixed or relay cropping on smaller fields. According to Pretty et al. (2011), crop intensification is a concept that has a traditional definition articulated in three different ways: increasing yields per hectare, increasing cropping intensity per unit of land or other inputs (water), and changing land use from low value crops or commodities to those that receive higher market prices. Crop intensification can be achieved by intercropping, where a variety of crop species are planted on the same piece of land. Intercropping diversifies the system by multiple cropping practices which involves growing two or more crop species simultaneously on the same piece of land, Marx et al. (2008).

Smallholder farmers in regions of South Africa such as Northern KwaZulu-Natal are practising crop intensification as the coping strategy to enable them survive under difficult conditions, which include their access to small parcels of land. Cropping systems that combine several crops in the same field/plot such as intercropping corns and legumes are widely practiced and have been shown increase total productivity per unit area, improve land use efficiency, and increase atmospheric nitrogen fixing ability, Banik and Sharma (2009). According to Willey. (1979), productivity in intercropping systems is most often summarised by Land Equivalent Ratios (LERs), which represent how much (more or less) land would be necessary to achieve the same joint output if the crops were grown separately.

2.2 CROP INTENSIFICATION

Crop intensification is adopted by different countries to address their challenges, which may include the following: low standards of food and nutrition security, limited arable land and land degradation. In Lesotho, this country is a small and mountainous. It is also characterized by extensive land degradation and erratic climatic conditions. It has a population of 2 million people of whom 68% live below the poverty line. The country is beset with high unemployment rates and low standards of food and nutrition security. This complex interaction of socio-economic factors and environmental constraints has dramatically affected agricultural productivity. Maize yields have fallen from an average 1.4 ton/ha in the mid-Seventies to a current 0.45 to 0.50 ton/ha in most of the districts. In recent years a growing number of development agencies have been promoting crop intensification as a means to enhance rural livelihoods through sustainable production. Amongst several initiatives the crop intensification based practice that so far has shown the highest potential is a planting basin system, locally called likoti (a Sesotho word for "holes"), FAO (2010). Smallholder farmers in Lesotho producing maize and beans adopted crop intensification. The evaluation conducted on Sustainable Crop Production Intensification by FAO (2006) illustrated the impact of likoti on sustainable crop intensification in the south-eastern highlands of Qacha's Nek district and in the western lowlands of Butha-Buthe and Berea. According to these data, the adoption of likoti has brought about significant advantages. The most important are: (i) higher agricultural productivity, due to improved efficiency in the use of inputs and other resources. (ii) Greater environmental sustainability, due to improved soil structure and enhanced fertility. (iii) Improved livelihoods and social sustainability, due to the accessibility to the technology by all social categories, including the most vulnerable.

In Cameroon, family agriculture includes producers who are smallholder farmers. This production unit is linked to a family structure, with a strong reliance on family labour. In the early 1990s there was a drop in the prices of cocoa and coffee which were then the major commercial farming crops for these farmers. According to Nkongho et al. (2014), many smallholder farmers turned to planting oil palm. However the length of time needed for the oil palm to start producing is 3 to 4 years. This is a major problem for the smallholders who have to invest considerable amounts of money and/or labour before deriving income from their oil palm plantations. Smallholder farmers therefore started testing different options of crop intensification, such as intercropping oil palm with food crops in order to mitigate these costs Nchaji et al. (2015). Smallholder farmers intercropped oil palm during its immature stage with food crops. However this was blamed by Agro-industries for its negative impact on the growth and future yields of palms. They unanimously condemn such practice Nchaji et al. (2015). For smallholders on the contrary, intercropping presents numerous advantages as it not only covers the weeding cost but also provides food and revenue while waiting for the palms to come into production. While such trade-off may be of little interest to an agro-industry. The study that was carried out in seven communities in the Bamuso Sub-division of the South West Region of Cameroon to seeks understanding how smallholder farmers use the intercropping technique during the early stages of oil palm development as a means to improve on their livelihood. Results indicated that, a mean annual wage of 705,000 FCFA was obtained per hectare per household for smallholders practicing crop intensification. In addition to income gained, intercropping significantly reduced the cost of weeding. The study therefore, suggests the need for tactical measures such as food crop choice, planting density amongst others to be taken into consideration when intercropping annual food crops with oil palm so as not to threaten the yield of oil palm at production stage. The finding is of significance for crop intensification encourages poverty reduction for marginalized people especially smallholder farmers with poor access to land. They manage to maximise land use, improve food security status in their households, stabilize yield and profit in smallholders' oil palm plantations. Table 2.1. below is comparing mean annual household income and mean annual farm expenditure for the smallholder farmers when they are intercropping oil palm with food crops and when they are monocropping oil palm.

Table 2.1. Mean annual household return to labour from intercrops

Those involve in oil palm cultivation		**Mean annual household income from total crop production per ha (FCFA)**	**Mean annual farm expenditure (food crop selling and weeding cost) per ha /FCFA**	**Mean annual return to labour (FCFA)**
Smallholders	Intercropping	851 140	146 294	704 846
	No intercropping	0	160 875	160 875

Source: Field survey report (2012)

Even though the intercropping of oil palm with food crops has a negative impact on the yield of the oil palm, but most smallholder farmers are still practicing intercropping for subsistence and to improve on their income levels. This case study revealed that there is a knowledge gap which needs to be bridged for the smallholder farmers in this area on the quality of planting material for the intercrops, crops to promote and crops to avoid, best intercropping techniques, and best management practices for the main crop, oil palm. Furthermore, there is the need to study the effects of different intercropping models on the yields of the oil palm, and also to see how intercropping could be practiced when palms have entered their production stage.

According to Cantore (2010), Rwanda agriculture has seen growth in the recent past after implementing Crop Intensification Program (CIP) policy. This policy was aimed at boosting agricultural productivity through an improvement of productive inputs use, irrigation coverage and soil quality. It addresses the following questions: 1. Is the Crop Intensification Program economically profitable and sustainable in a short term and in a long term perspective? 2. What is the environmental impact of the Crop Intensification Program and what could be the consequences for the national budget? The idea behind the Rwanda Crop Intensification Program is very simple and effective from a conceptual point of view: the increase of productive inputs (fertilizers), water use (improvement of irrigation) and a higher level of land use (marshland development) should lead to an increase of production and food security Cantore (2010). The table below shows the Rwanda Crop Intensification Program in the agricultural crops sector.

Table 2.2. Rwanda Crop Intensification Program in the agricultural crops sector.

Target	Action	Cost
Sustainable management of natural resources, water and soil husbandry	52000 ha of additional land protected against soil erosion, using radical and progressive terracing - 70 new valley dams and reservoirs Constructed	158,571,429 FRw
Marshland development	additional 9000 ha of marshlands developed	41,188,900 FRw

Table 2.2. Continues

Irrigation development	**13000 ha of hillside area irrigated (increased from 130 ha) - Legal provision for water user associations and tenure for irrigation systems created.**	**131,190,000 FRw**
Supply and use of agricultural inputs	(increased from 14 MT) -15000 MT production of founded seeds (increased from 3000 MT) - Crop Intensification Program expanded	215,690,211 FRw
Food and nutrition security and vulnerability management	Average availability per day increased from 1,734 kcal to 2150 kcal, 49 g to 55g of protein 8.8 to 23g of lipids - Food and nutrition security monitoring system expanded - 1000 hermetic storage cocoons operational.	17,700,000 FRw

Source: MINAGRI (2010). Investment Plan.

Crop Intensification Program was evaluated whether it is sustainable from an economic point of view in the short term, as it is indicated in table 2.2. The government procured improved seed and fertilizer, which were distributed to smallholder farmers in selected zones chosen for their food crop production potential.

During the first year of the program about 9,000 MT of fertilizer were imported and distributed by the Rwanda Ministry of Agriculture, MINAGRI (2010). Yields of CIP target crops showed encouraging results. Wheat yields more than doubled and maize yields increased by about 90 percent Morris et al. (2007). However it was observed during the evaluation that chemical fertilizers import did not always lead to an increase of the Rwanda crop production.
Table 2.3. shows fertilizers import in relation to crop production in Rwanda since 2006 to 2009. In 2007 the quantity of fertilizers used in 2006 was increased by 8501tons, however the yield decreased. In 2008 the quantity of fertilizers was decreased from 22443tons that was used in 2007 to 17533tons and the yield increased from 7098512Mt to 8234188Mt.

Table 2.3. Fertilizers import in relation to crop production in Rwanda.

Year	Fertilizers import (tons)	Crops Production (Mt)
2006	13942	7166567
2007	22443	7098512
2008	17533	8234188
2009	33500	9261945

Source: RADA (2010) and MINAGRI (2010)

Cantore (2010) concluded that the Crop Intensification Program should incorporate sustainable management practices to balance short term food security needs and long term soil fertility targets.

In India Conventional rice research has frequently insisted on characterizing System of Rice Intensification (SRI) as a technology to be implemented. However certain specific and precisely defined guidelines should be followed in order for this system to be successful, as it applies in intercropping system. According to Stoop (2011), System of Rice Intensification should be viewed as a set of practices to be followed and implemented flexibly and in response to the local agro-ecological and socioeconomic conditions faced by smallholder farmers. System of Rice Intensification was initially developed by de Laulanie´ (1993) in Madagascar for lowland irrigated rice. It is based on the application of the following six practices in order to achieve the best results: 1. The use of very young seedlings (8 to 12 seedlings day old) in transplantation. 2. Transplanting single seedlings per hill quickly, with minimal root disturbance. 3. Widely spaced hills, ranging from 20cm × 20cm up to 50cm × 50cm. 4. An alternate wet and dry soil moisture regime (no permanent flooding) to maintain aerobic soil conditions. 5. The use of organic fertilizers rather than mineral fertilizers; frequent weeding, preferably performed using a surface rotary hoe, during early crop development stages so as to control weeds and aerate the soil. These practices evolved in direct response to biophysical conditions on the Madagascar Plateau and to the socio-economic needs of the small and poor rice farmers in the area. Shortages of rice seeds and of water for irrigation required to keep the fields permanently flooded, were the major local constraints. Smallholder farmers lacked the cash to buy external inputs such as mineral fertilizers and pesticides. The total result of the six general practices as reported by de Laulanie´ (1993), confirmed in many tests throughout the world's rice growing areas, was seen to be the abundantly tillering rice plants that yielded many panicles with heavy individual grains that together added up to large grain yields/ha. This leads to the question as to what lies behind the practices proposed by de Laulanie´ in terms of the fundamental aspects of plant growth and crop development, and which apparently are inadequately appreciated by modern mainstream rice research.

2.2.1. Implications for rice breeding and the selection of System in Crop Intensification

According to Stoop (2011), all formal and informal testing of System Rice Intensification has been done using any locally available rice variety (traditional as well as improved varieties). System Rice Intensification's features have been recorded irrespective of the rice variety used, which emphasises the general validity of the approach. It also indicates that where improved rice varieties were used specifically selected under System Rice Intensification conditions of wide spacing and aerobic soil conditions, substantial further yield gains could be expected. Apart from the physiological functioning of the rice plant as presented above, Thakur et al. (2009), also provided information on how the optimum plant spacing under System Rice Intensification should be adjusted in response to rice varieties of different maturity types (i.e. early maturity, intermediate maturity and late maturity) and of different heights (i.e. overall biomass production). For the full season cultivar, the optimum plant spacing was reached at 25cm × 25cm, while for the early and intermediate maturing materials this was 20cm × 20cm. Stoop (2005) obtained similar result, whereas Mishra and Salokhe (2008) also pointed to the need to adjust plant spacing in response to varieties and their maturity cycles. These results provide important leads for identifying the most desirable plant characteristics to be aimed at in rice cultivars that are specifically selected for their adaptation to System Rice Intensification type systems. These characteristics are a high tillering ability and adaptation to moist, aerobic soil conditions. Depending on the local agro-ecological conditions, intermediate to long duration varieties would be preferable to prolong the tillering phase and process, Stoop (2011). Interesting observation was that the Chinese breeding programme towards a super hybrid, Zhang et al. (2009), and ideotype breeding, including its efforts towards the new plant type, emphasize plant characteristics that are rather different. The plant characteristics emphasized by International Rice Research Institute (IRRI) resulted from plant and crop physiology and morphology knowledge in combination with simulation modelling to define a theoretically efficient plant, Peng et al. (2008). On this basis, a reduced tillering capacity, large panicle size and improved lodging resistance were identified to be most important. The specifically shaped top three leaves and flag leaf, strong stems, reduced plant height and large individual grains were additional selection factors contributing to an increased harvest index. A general aim was to select short to intermediate growth cycles. Neither the Chinese super-hybrid nor International Rice Research Institute’s new plant type breeding programmes appear to have paid any attention to rooting characteristics and root systems, or to possible interrelationships between root health and leaf quality survival. However Lynch (2007) draws attention to the different types of roots and their roles in accessing moisture and nutrients from different soil horizons. He also emphasized the genetic variability that exists in root systems and the architecture that can be exploited through modern plant breeding and selection techniques in developing varieties particularly suited to marginal soil conditions. Samejima et al. (2004) cited by Stoop (2011) emphasized the genetic aspects of the root–shoot interdependence that affect the productivity of new rice lines. That was linked with interdependence to higher cytokinin synthesis by active root systems and its transport in root exudates to above ground shoots. Mishra and Salokhe (2010) confirmed that the development of the rice root system, in the nursery seedbed as well as in the field after transplanting, is greatly affected by the agronomic management of soil moisture and of plant spacing used to determine plant population.

Under the moist, aerobic soil conditions of System Rice Intensification, the early root development becomes much more important than it does under wet soil conditions, Mishra and Salokhe (2008). A larger, deeper, more active root system and vigorous plant is produced by the time the reproductive phase is reached, Mishra and Salokhe (2010). The development of extensive root systems therefore appears to be determined partly by genetic factors and to an even larger extent by complex interrelationships between the below (roots) and above (canopy) ground plant organs. Looking at the development over time of the ratio below ground and above ground plant dry weights for System Rice Intensification compared with the conventional fully irrigated system, distinct differences could be expected. The considerations by Uphoff et al. (2009) about plant and microbial interactions biology, crop rooting and growth would only increase the significance of root systems with regard to overall plant development.

2.2.2. The agronomy of System Rice Intensification

To improve System Rice Intensification agronomy, one has to go back to the agronomic principles introduced in ‘Some basic agronomic principles of crop production ‘section and to the features of local cropping systems, Stoop (2011). The major upland cereal crops, which are pearl millet and sorghum and their main local, photosensitive cultivars respond to early planting by developing an abundant biomass (i.e. the essential source required for subsequently filling the sink). Rice shows a similar feature, but primarily through the tillering process. However rice’s photosensitivity characteristics, as in many local rice cultivars, will further enhance biomass development, upon early planting.

The initial paper on System Rice Intensification by Stoop et al. (2002) elaborated how the rice plant develops during the vegetative growth phase, through a tillering process. de Laulanie´ (1993) identified tillering to be the key feature in the development of a rice crop. During the vegetative phase: every tiller has the potential to develop a new tiller, which amounts to a roughly exponential increase in the number of tillers per individual plant; every new tiller develops adventitious roots at its base that directly support the particular tiller and lead to a very extensive overall root system per plant; potentially every tiller can develop a panicle. The tillering feature becomes particularly striking during the second half of the vegetative phase, when an explosion of tillers occurs roughly from 16 to 32 and from 32 to 64 and beyond, provided soil conditions and plant spacing are favourable. The record number of tillers per rice plant recorded so far was reported from Indonesia and amounted to 220 tillers, Uphoff et al. (2009). Conventional planting methods and spacing i.e. several rice plants per hill and a relatively close hill spacing, resulted in plant populations in excess of 100plants per square meter. Consequently, the tillering and rooting processes of individual plants will be obstructed seriously. System Rice Intensification agronomy exploited the tillering feature by managing two critical elements: 1. Time, this means that the age of the transplanted seedling. 2. Space, this is the spacing between transplants (i.e. plant population) are the key variables to be managed for maximum grain production apart from proper weed control during the early vegetative phase.

Uphoff et al. (2009) proved that the younger the seedlings are at transplantation, the greater will be the total quantity of above ground biomass developed during the vegetative growth phase, as a result of the exponential increase in tillers. Therefore, it becomes imperative to space the individual transplants relatively widely to avoid overcrowding of the field at the time of flowering. When older seedlings have to be used for transplantation, the duration of the vegetative phase and tillering are automatically cut short so as the root system development. Common measures by farmers to counter such situations will be to increase plant densities, Stoop (2011). The effects described above will be compounded by two additional factors. These are: 1. the growth conditions in the nursery, and 2. the overall soil fertility condition of the main field. Under conventional management, seeding rates in nurseries tend to be far higher (5–10 times) than those recommended for System Rice Intensification. When seedlings are kept in crowded nurseries for a considerable period of time prior to transplantation (which is often the case in traditional farming and, to a lesser extent, also under conventional practices), the subsequent vegetative development is likely to be affected and the yield potential of the crop. Furthermore, the general soil fertility condition of the paddy field will always remain a critical factor in determining the optimum plant density. High soil fertility will enhance and accelerate a crop's vegetative development. Individual plants then require a relatively wider spacing than that in the case of less fertile soils, in order to utilize the solar radiation most effectively at the critical periods of flower initiation and grain formation. On the other hand soil constraints such as salinity, iron toxicity or acid sulphate (sub) soils would interfere with the development of an extensive root system, Menete et al. (2008). The resulting reduction in overall above-ground biomass production, due to reduced rates of tillering can then be compensated to a limited extent by increasing the plant density at transplantation to increase the crop's interception of solar radiation.

2.3 INTERCROPPING

Intercropping is defined as the cultivation of two or more plant species in the same field or piece of land at the same time. One important reason intercropping is popular in the developing world is that it is more stable than monocropping. In Africa and South Asia, where environmental stress is common, intercropping is an insurance against total crop failure, Horwith (1985). There are four different types of intercropping, they including the following: (1) mixed intercropping, this is the most basic form of intercropping where the component crops are completely mixed in the available land or plot, (2) row cropping, this type involves the component crops planted in alternate rows, (3) alley cropping, where crops are planted in between rows of trees, and strip cropping, where multiple rows, or a strip, of one crop are alternated with multiple rows of another crop species, (4) temporal intercropping is when a fast-growing crop species is planted with a slow-growing crop species, so that when the fast-growing crop species is harvested before the slow-growing crop species starts to mature, or where the second crop species is planted during the growth, usually near the onset of reproductive development or fruiting of the first planted crop species, so that the first planted crop species is harvested to make room for the full development of the second planted crop species. According to Singh (1990), Intercropping may be further divided into the following four groups. 1. Parallel Cropping: Under this cropping two crops are selected which have different growth habits and have a zero competition between each other and both of them express their full yield potential. Examples are: Green gram or black gram with maize, or green gram or soybean with cotton. 2. Companion Cropping**:** In companion cropping the yield of one crop is not affected by other, In other words, the yield of both the crops is equal to their pure crops. That the standard plant population of both crops is maintained. For examples: Mustard, wheat, potato, with sugarcane Wheat, radish, cabbage, sugar beet, with potato. 3. Multistoried Cropping: or Multi-tire cropping: Growing plants of different height in the same field at the same time is termed as multistoried cropping. It is mostly practiced in orchards and plantation crops for maximum use of solar energy even under high planting density. Examples are: Eucalyptus/Papaya/Berseem. Sometimes it is practiced under field crops such as Sugarcane/ Potato/Onion, or Sugarcane/Mustard/Potato. Or Coconut / Pineapple /Turmeric/Ginger. Multi-tire Cropping: This system of Intercropping is mostly prevalent in plantation crops like coconut and areca nut. The practice different crops of varying heights, rooting pattern and duration are called multi-tire cropping. This cropping system utilize the vertical space more effectively. In this system, the tallest components have foliage tolerant of strong light and high evaporative demand and the shorter component(s) with foliage requiring shade and or relatively high humidity. E.g. Coconut/ black pepper / cocoa /pineapple.

In China, Zhang et al. (2015) examined corn intercropped with either soybeans or red beans and found that both intercropping systems provided a benefit in terms of (1) yield advantage (nearly 1.3x the yield expected from monocultures), (2) economics, and (3) future yield potential of winter wheat (due to increased soil nitrogen accumulation in the legume intercropped soils). Himanen et al. (2016), conclude that in Finland intercropping, with varying spatiotemporal arrangements, management options and genotype combinations, was recognized to have potential as an adaptation strategy for addressing climate change by strengthening farm adaptive capacity and developing multi-benefit climate-smart solutions for agriculture.

2.4 FACTORS THAT ARE CONSIDERED WHEN PLANNING INTERCROPPING SYSTEMS

Carefully planning is required when the farmer have decided to practice intercropping system, i.e. plant spatial arrangements, plant population, maturity dates, plant vegetative growth and its agronomic characteristics. Tall cereals do not cover the soil well because they have upright leaves and they are planted far apart. Short grasses (Brachiaria, Cenchrus, Andropogon), many legumes (lablab, groundnut, cowpea, beans) and cucurbits like pumpkins, cover the ground very quickly after they are planted, Nathan and Hans (2002). Cereals can be intercropped with legumes and /or cucurbits so that they act as the living mulch. These are the benefits of the living mulch: reduce soil erosion, reduce weed pressure, and increase soil organic matter content, decreased water runoff, reduced surface soil temperature and water evaporation. It is very important not to have crops competing with each other for physical space, nutrients, water, or sunlight.

Root competition of plant species in an intercrop should be avoided. Plants have different root growth patterns; shallow rooted, medium rooted and deep rooted. Therefore plant species in an intercropping system must have different rooting zone to avoid competition for water and nutrients. For example: Corn, broccoli, spinach, cabbage and lettuce are all shallow-rooted crops. Cucumbers, turnips, beans, summer squash, carrots and peas are medium-rooted. Tomatoes, asparagus, winter squash (including pumpkin) and parsnips are deep-rooted. According to Postma and Lynch (2012), maize, bean and squash evolved in polycultures grown by smallholder farmers during their domestication, in the Americas. Polycultures often over yield on low fertility soils, which are a primary production constraint in low-input agriculture. Postma and Lynch (2012) hypothesized that root architectural differences among these crops causes niche complementarity and thereby greater nutrient acquisition than corresponding monocultures. They concluded that spatial niche differentiation caused by differences in root architecture allows polycultures to over yield when plants are competing for mobile soil resources. However direct competition for immobile resources might be negligible in agricultural systems. Interspecies root spacing may also be too large to allow maize to benefit from root exudates of bean or squash. Above ground competition for light may have strong feedbacks on root foraging for immobile nutrients, which may increase cereal growth more than it will decrease the growth of the other crops. It was noted by Willey and Rao (1979) that the order of domestication of crops correlates with increasing nutrient efficiency, rather than production potential. Different crops characteristics need to be considered when planning intercropping in order for it to be successful. Maize has large long leaves while bean has small round leaves which easily occupy gaps in the maize canopy. Squash forms long vines along the ground with large round leaves, occupying the canopy understorey where it forms a living mulch which may conserve water and suppress weed germination

Crops belonging to the same family are not meant to be intercropped as they make for easy targets for pests. Tomatoes, eggplants, peppers and potatoes should not be paired. According to Postma and Lynch (2012), these species have contrasting root architectures, which may be the basis for different, potentially complimentary, strategies for water and nutrient acquisition. Below ground niche complementarity may explain the over yielding of these polycultures under conditions of limited soil fertility, which is prevalent in low-input smallholder farms. For example, bean can supply 20–60 % of its nitrogen through symbiotic nitrogen fixation, while the other two crops rely solely on the uptake of inorganic nitrogen from the soil. Bean and squash may produce more root exudates than maize, allowing them to mobilize sparingly soluble forms of phosphate. Li et al. (2007), suggested that these exudates may facilitate phosphorus uptake by maize in maize/faba bean intercrops. Maize, bean and squash differ strongly in root architecture. These differences in root architecture allow these crops to explore different soil domains with variable intensity. Also crops with common pests should not be planted together. Hence, tomatoes and corn which are attacked by tomato fruit worm/ corn earworm should not be planted together. Squash, cucumbers, pumpkins and melons share the same enemy, the pickleworm, thus should not be planted close by, Nathan and Hans (2002).

2.5 BENEFITS OF CROP INTENSIFICATION

The benefit of crop intensification and diversification include production stability as a result of improved crop protection, and productivity, as well as profitability. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would have been utilized by a single crop. According to McGilchrist (1965), in some cases the yield of a species in an intercrop is increased compared with the yield as a sole crop in a monoculture. There are cases where the yield can be decreased. A species is regarded as a good competitor if the yield generally increases when grown with other species. Cucurbits may be incorporate in addition to maize and legumes, to increasing the variety of food types. Cucurbits may also act as cover crops which suppresses weeds and contribute to soil moisture conservation.

Combination of plants in intercropping system can be beneficial in terms of reducing pests and diseases, out competing weeds, maximising resource utilization, reducing input requirements and providing improved environmental conditions for one or more of the species involved. A plant species in an intercrop system can reduce pests or diseases level through disruptive crop. A plant species can be defined as the disruptive crop if it hinder the progress of the pest or disease through a crop to another crop because of presence of a non-host plant species. An intercropping system can also include plant species that are natural enemies and plant species that may be effective in reducing weed germination. Other benefits of intercropping system include the following: Reduces the amount of fertilizers and chemicals required. Reduces soil erosion if cover crops are part of the system. Diversify the vegetative structure. Increase the productivity of each crop in the system relative to their respective sole crop yields. Reduces management required. Reduces labour, since it is spread more evenly over time. Provides greater variety of products. Reduces risks of crop failure. Provides a living mulch, when legumes or cucurbits is intercropped in a cereal crop.

According to Rusinamhodzi et al. (2012), maize–pigeon pea intercropping can improve productivity and help reduce the area cultivated. In Vanduzi area in Mozambique, the late maturity of pigeon pea means that free-grazing of cattle has to be delayed, which allows farmers to retain crop residues in the fields as mulch if they choose to; this allows the use of no-tillage practises. Rusinamhodzi et al. (2012) concluded that maize–legume intercropping has potential to: (a) reduce the risk of crop failure, (b) improve productivity and income, and (c) increase food security in vulnerable production systems, and is a feasible entry point to ecological intensification. Legumes provide an important pathway to alleviate the constraints related to nitrogen (N) limitations in the soil and improve crop productivity. They can quickly cover the soil surface and reduce soil erosion, suppress weeds, fix atmospheric N2, decrease pests and diseases, spread labour needs and improve the efficiency of land use. Grain legumes are generally preferred by smallholder farmers in the tropics above green manures and cover crops because they ensure food security while improving diet and income. When intercropped with cereals, larger quantities of better quality organic matter inputs are produced leading to greater productivity benefits compared with continuous maize planted in a sole crop production system.

According to Caviglia et al. (2004) the production of dry matter and grain depends on the ability of the crops to capture resources. On an annual basis, farming system focused more on the single crops, which waste large proportions of main inputs including incoming solar radiation and rainfall. Intensive farming comprising of multiple crops per annum could improve resource capture and productivity. The resource productivity can be defined as the ratio between output (biomass or grain yield) and annual input of photosynthetically active radiation or rainfall.

2.6 INDICES FOR ASSESSING THE ADVANTAGES AND DISADVANTAGES OF CROP INTENSIFICATION

Several indices can be used to evaluate the advantages and disadvantages of intercropping systems. These include the following: Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER), Competition Ratio (CR), Relative Crowding coefficient (K), Agressivity (A), Intercropping Advantage (IA), Actual Yield Loss (AYL) and Monetary Advantage Index (MAI).

The following are the formulae that are used to evaluate the advantage and disadvantage of intercropping system:

$$LER = [intercrop\ maize\ yield/sole\ maize\ yield] + [intercrop\ dry\ bean\ yield/sole\ dry\ bean\ yield]$$

where all yields are expressed in ton/ha. LER is the relative land requirements for intercrops compared to sole crops. LER values greater than 1.0 show that intercropping is more productive and those less than 1.0 show that sole cropping is more efficient.

Area Time Equivalent Ratio can be defined as the comparison of the yield advantage of intercropping over sole cropping in terms of time taken by component crops in the intercropping systems.

According to Heibsch (1980), ATER is calculated using the following formula:

$ATER = LER * Dc/Dt.$

Where LER is the land equivalent ratio, Dc is the time taken by the crop in intercropping system, Dt is the time taken by the whole intercropping system.

Competition is evaluated by competitive ratio (CR) using the formula described by Willey and Rao (1980): $CR = (CRa + CRb)$

$$CR = [(LERa/LERb) * (Zba/Zab)] + [(LERb/LERa) * (Zab/Zba)],$$

where CRa is the competitive ratio for the intercrop crop "a" and CRb is the competitive ratio for the intercrop crop "b" and Zba/Zab are the sown proportion of each crop in the mixture. Yield penalty is calculated as the percentage difference in yield. Competitive ratio gives better measure of competitive ability of the crops and is also advantageous as an index over Agressivity and Relative crowding coefficient, Willey and Rao (1980).

Relative crowding coefficient (K) is the measure of relative dominance of one plant species over the other in an intercropping system, De Wit (1960), using the following formula:

$$K = Kab * Kba$$

$$= [(Yab * Zba) \ / \ \{(Yaa - Yab) * Zab\}]*[(Yba * Zab)/\{(Ybb - Yba) * Zba\}]$$

Where Kab and Kba are relative crowding coefficient of crop "a" and crop "b" in an intercropping system, respectively.

Agressivity (A) is the measure of how much relative yield increase in species of crop "a" is greater than that of species of crop "b" in an intercropping system. It measures the intercrop competition by relating to the yield changes of both component crops, McGilchrist (1965). The Agressivity of crop "a" can be determined using the following formula:

$$A = \{Yab/(Yaa * Zab)\} - \{Yba/(Ybb * Zba)\}$$

Where Yab is the Agressivity of crop "a" in an intercropping system, Yba is the Agressivity of intercrop "b" in an intercropping system. If the value of A is zero, that will mean both crop are equal. If the value of A is positive then crop "a" is dominant over crop "b" in an intercropping system. If the value of A is negative then crop "b" is dominant over crop "a" in an intercropping system.

The Agressivity of crop "b" can be determined using the following formula:

$$A = \{Yba/(Ybb * Zba)\} - \{Yab/(Yaa * Zab)\}$$

Where Zab is the sown proportion of crop "a" in the intercropping system.

Zba is the sown proportion of crop "b" in the intercropping system.

Yab is the yield of crop "a" in the intercropping system.

Yba is the yield of crop "b" in the intercropping system

Yaa is the yield of crop "a" in the sole cropping system,

and Ybb is the yield of crop "b" in the sole cropping system

Another index that is used to evaluate the advantage and disadvantage of intercropping system is the Actual Yield Loss (AYL). Banik et al. (2000) reported that the actual yield loss (AYL) index gave more precise information about the competition than the other indices between and within the component crops and the behaviour of each plant species in the intercropping

systems, because it is based on yield per plant. The actual yield loss is the proportionate yield loss or yield gain of intercrops compared to sole crop. Partial actual yield loss represents the proportionate yield loss or gain of each plant species grown in intercropping system in comparison with mono cropping system. The positive or negative values of AYL indicate the advantage or disadvantage of intercropping systems respectively. According to Muhammad et al. (2008), the actual yield loss can be determined using the following formula:
$AYL = AYLa + AYLb$, where AYLa is the actual yield loss of crop "a" and AYLb is the actual yield loss of crop "b"

Intercropping advantage (IA) is another index used to determine intercropping system productivity. According to Muhammad et al. (2008), Intercropping advantage was used by Banik et al. (2000) and Dhima et al. (2007) by the following formula: $IA = (AYLa) * (Pa)$ if calculating Intercroping advantage of crop "a". Where AYLa is the actual yield loss of crop "a" and Pa is the market price of crop "a".
To calculate the actual yield loss of crop "a" in the intercropping system the following formula is used: $AYLa = \{[(Yab/Zab)/(Yaa/Zaa)] - 1\}$
To calculate the actual yield loss of crop "b" in the intercropping system the following formula is used: $AYLb = \{[(Yba/Zba)/(Ybb/Zbb)] - 1\}$

To calculate the Intercropping advantage of crop "b" the following formula is used:
$IA = (AYLb) * (Pb)$.
Where AYLb the actual yield loss of crop "b" and Pb is the market price of crop "b".
According to Muhammad et al. (2008), all competition indices above do not provide any information on the economic advantage of the intercropping system. Economic advantage of the intercropping system can be calculated using the monetary advantage index.

The monetary advantage index is calculated using the following formula:
$MAI = (value\ \ of\ combined\ intercrops) * (LER - 1)/LER$
Where LER is the land equivalent ratio.
According to Ghosh (2004), cited by Muhammad et al. (2008), the higher the monetary advantage index (MAI) value the more profitable is the cropping system.

The table below showed data from IRRI Annual report (1975) where maize and soybean were produced as sole crops and together in an intercropping system. When maize was intercropped with soybean

Table 2.4. Land Equivalent Ratio (LER) of Maize intercropped with Soybean

Crop	Sole Crop Yield (T/ha)	Intercrop Yield (T/ha)	Partial LER
Maize	1.36	1.06	0.779
Soybean	1.23	1.04	0.846
Total LER			1.625

Source: IRR Annual report, 1975

2.7 DISADVANTAGES OF CROP INTENSIFICATION

In most cases crop intensification is achieved by practising intercropping system. The following are the disadvantages of intercropping system:

Yield decreases as the plant species differ in their competitive abilities. Management of intercropping system having different cultural practices seems to be a difficult task. Improved implements cannot be utilized efficiently. This system is labour intensive because most activities need man power, e.g. planting, weeding and harvesting.

There are no implements designed specifically for intercropping system. Harvesting is difficult.

According to Rusinamhodzi et al., (2012) intercropping increased the labour required for weeding by 36% compared with the sole crops, because it became difficult to use chemicals in that farming system. This is the great disadvantage of intercropping system in most areas because farmers are faced with labour constraints. According to Waddington et al., (2007) when legumes are intercropped with cereals, the planting of two or more crops either simultaneously or in relay increases the labour requirements compared with a cereal sole crop; this may limit the widespread use of legumes.

2.8 SUMMARY AND CONCLUSIONS

Crop intensification is adopted by different countries to address their challenges, which may include the following: low standards of food and nutrition security, limited arable land and land degradation. Intercropping is considered as one of crop intensification strategies to increase agricultural productivity per unit area of land. It is the practice of growing two or more crops simultaneously in the same field. Intercropping provides a balanced diet, minimizes risks of crop failure due to adverse effects of pests, improves the use of limited resources, reduces soil erosion, increases yield stability and provides higher returns, Dapaah et al. (2003). Farmers in Northern KwaZulu Natal, South Africa practice different cropping systems to increase productivity and sustainability, Hauggard-Nielson (2001). Cropping system characteristics can fundamentally alter the abiotic and biotic features of an agro-ecosystem and could modify the life cycle of pests such as weeds, Banik (2006). The use of intercropping by smallholder farmers is a common practice since ancient civilization, Dahmardeh (2009) in the tropics and rain-fed areas of the world, Dhima et al. (2007). The advantages of intercropping include soil conservation, lodging resistance, yield increment and weed control over the mono-cropping. When two crops are planted together, intra and/or inter specific competition or facilitation between plants may occur, Zhang (2003). Studies showed that mixtures of cereals and legumes produce higher grain yields than either crop grown alone, Dapaah (2003). Competition among mixture is thought to be a major aspect affecting yield as compared with sole cropping of cereals, Ndakidemi (2006) and a number of indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantages and intercropping advantages are used to describe competition between component crops of intercropping systems.

2.9 REFERENCES

Banik P., Sasmal T., Ghosal P.K and Bagchi D.K. 2000. Evaluation of mustard (Brassica campestris var. Toria) and legume intercropping under 1:1 and 2:1 row-replacement series systems. Crop Science. 185: Pg 9–14.

Banik P. and Sharma R. C. 2009. Yield and Resource Utilization Efficiency in Baby Corn—Legume-Intercropping System in the Eastern Plateau of India. Journal of Sustainable Agriculture 33:4 Pg 379 -395.

Caviglia O.P., Sadras V.O. and Andrade F.H. 2004. Intensification of agriculture in the south-eastern Pampas I. Capture and efficiency in the use of water and radiation in double-cropped wheat–soybean. Field Crops Research 87: Pg 117–129

Cantore N. 2015. The Crop Intensification Program in Rwanda: a sustainability analysis. African Journal of Agricultural Research. 6: Pg 890 – 927.

Dahmardeh M., Ghanbari A., Syasar B. and Ramroudi M. 2009. Effect of intercropping maize with cowpea on green forage yields and quality evaluation. Asian Journal Plant Science 8 (3): Pg 235-239.

Dapaah H..K., Asafu-Agyei J.N., Ennin S.A. and Yamoah C.Y. 2003. Yield stability of cassava, maize, soybean and cowpea intercrops. The Journal of Agricultural Science. 140: Pg 73–82.

de Laulaníe H. 1993. Technical presentation on the System of Rice Intensification, based on Katayama's tillering model. Tropicultura (Brussels) 11: Pg 110-114.

De Witt, C.T. 1960. On competition. Verslag LandbouwKundige. Onderzoek 66: Pg 1-28.

Dhima K.V., Lithourgidis I.B. and Dordas C.A. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Research. 100: Pg 249-256

FAO. 2004. Statistics. Food and Agriculture Organization. Rome.

FAO. 2006. The State of Food Security in the World. Rome.

FAO. 2010. Global Forest Resources Assessment. Food and Agriculture Organization. Rome.

Field survey report. 2012. Australian Journal of Crop Science. 5 (4): Pg 396-410

Ghosh P.K. 2004. Growth yield competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Research 88: Pg 227–237.

Hauggaard-Nielsen H., Ambus P. and Jensen E.S. 2001. Interspecific competition, N use and interference with weeds in pea–barley intercropping. Field Crops Research. 70: Pg 101–109.

Hiebsch C.K. 1980. Principles of intercropping. Effect of N fertilization and crop duration on equivalency ratios in intercrops versus monoculture comparisons. PhD Thesis. North Carolina State University. Raleigh. USA.

Himanen S.J., Mäkinen H., Rimhanen K. and Savikko R. 2016. Engaging Farmers in Climate Change Adaptation Planning: Assessing Intercropping as a Means to Support Farm Adaptive Capacity. Agriculture 6: Pg 34-47.

Li L., Li S.M. and Sun J.H. 2007. Diversity enhances agricultural productivity via rhizosphere phosphorus facilitation on phosphorus-deficient soils. Proceedings of the National Academy of Sciences of the USA 104: Pg 11192–11196

Lynch J. P. 2007. Roots of the second Green Revolution Australian Journal of Botany 55: Pg 493-512.

Marx K. and Engels F. 2008. Collected works 2nd ed. vol. 25. Part 2. Pg 227.

McGilchrist C.A. 1965. Analysis of competition experiments. Biometrics 21: Pg 975-985.

Menete M. Z. L., van Es H. M., Brito R. M. L., DeGloria S. D. and Famba S. 2008. Evaluation of system of rice intensification (SRI) component practices and their synergies on salt-affected soils. Field Crops Research 109: Pg 34–44.

MINAGRI. 2010. Agriculture sector investment plan 2009 – 2012. MINAGRI document.

Mishra A. and Salokhe V. M. 2008. Seedling characteristics and the early growth of transplanted rice under different water regimes. Experimental Agriculture 44: Pg 1–19.

Mishra A. and Salokhe V. 2010. The effects of planting pattern and water regime on root morphology, physiology and grain yield of rice. Effects of some SRI practices on rice growth. Journal of Agronomy and Crop Science 196: Pg 368–378.

Morris M., Ronchi L., Rohrbach D. 2007. Building sustainable fertilizers markets in Africa. World Bank Report.

Muhammad A. Ejaz M.U. and Abdul K. 2008. Yield and Competition Indices of Intercropping Cotton (*Gossypium hirsutum L.*) Using Different Planting Patterns. Tarim Bilimleri Dergisi 14 (4): Pg 326-333.

Nathan L. H and Hans U. A. 2002. Cover crops and living mulches. Weed Science 50 (6): Pg 688- 699.

Nchanji Y.K., Nkongho R.N., Mala W.A . and Levang P. 2015. Efficacy of oil palm intercropping by smallholders. Case study in South-West Cameroon. Agroforest Systems 90:Pg 509-519.

Ndakidemi P.A. 2006. Manipulating legume/cereal mixtures to optimize the above and below ground interactions in the traditional African cropping systems. African Journal Biotechnology. 5 (25): Pg 2526-2533.

Nkongho R. N., Feintrenie L. and Levang P. 2014. Strengths and weaknesses of the oil palm Agroforest Systems 90: Pg 609–619.

Peng S.B., Khush G.S., Virk P., Tang Q.Y. and Zou Y.B. 2008. Progress in ideotype breeding to increase rice yield potential. Field Crops Research. 108: Pg 32–38.

Pretty J., Toulmin C. and Williams S. 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability 9 (1): Pg 5-24

Postma J. A. and Lynch J. P. 2012. Complementarity in root architecture for nutrient uptake in ancient maize/bean and maize/bean/squash polycultures. Annals of Botany 110 (2): Pg 521-534.

RADA. 2010. UNEP – African Development Bank – African Development Fund publication.

Rusinamhodzia L. Corbeelsc M., Nyamangarad J.and Giller K.E. 2012. Maize-grain legume intercropping as an alternative option for ecological intensification that reduces climate risk for small-holder farmers in Central Mozambique. Elsevier 12: Pg 45-60.

Samejima H., Kondo M., Ito O., Nozoe T., Shinano T. and Osaki, M. 2004. Root-shoot interaction as a limiting factor of biomass productivity in new tropical rice lines. Soil Science and Plant Nutrition. 50 (4) Pg 545–554.

Singh M. 1990. Productivity and risk evaluation in contrasting intercropping systems. Field Crop Research. 23: Pg 279-293

Smith B.D. 2006. Eastern North America as an independent center of plant domestication. Proceedings of the National Academy of Sciences of the USA 103: Pg 12223–12228.

Stoop W.A., Uphoff, N. and Kassam A. 2002. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. Agricultural Systems 71 Pg 249-274.

Stoop W. A. 2005. The System of Rice Intensification. Wageningen Journal of Life Sciences 59 (1): Pg 61-62

Stoop W.A. 2011. The scientific case for system of rice intensification and its relevance for sustainable crop intensification, International Journal of Agricultural Sustainability 9 (3): Pg 443-455.

Thakur A. K., Choudhari S. K., Singh R. and Kumar A. 2009. Performance of rice varieties at different spacing grown by the system of rice intensification (SRI) in eastern India. Indian Journal of Agricultural Sciences 79 (6): Pg 443-447.

Uphoff N., Anas I., Rupela O. P. Thakur A. K. and Thyagarajan T. M. 2009. Learning about positive plant-microbial interactions from the system of rice intensification (SRI). Aspects Applied Biology 98: Pg 29–54.

Waddington S..R., Mekuria M., Siziba S. and Karigwindi J. 2007. Long-term yield sustainability and financial returns from grain legume-maize intercrops on a sandy soil in sub humid north central Zimbabwe. Experimantal Agriculture. 43: Pg 489-503.

Willey R.W. 1979. Intercropping-It's Important and Research Needs. Part 1. Competition and Yield Advantages. Field Crop Abstracts 32: Pg 1-10.

Willey R.W. and Rao M.R. 1980. A competitive ratio for qualifying competition between intercrops. Experimental Agriculture 9: Pg 117–125.

Zhang Y., Tang Q., Zou Y., Li D., Qin J., Yang S., Chen L., Xia B. and Peng, S. 2009. Yield potential and radiation use efficiency of 'super' hybrid rice grown under subtropical conditions. Field Crops Research. 114: Pg 91–98.

Zhang Y., Liu J., Zhang J., Liu H., Liu S. and Zhai L. 2015. Row Ratios of Intercropping Maize and Soybean Can Affect Agronomic Efficiency of the System and Subsequent Wheat. PLoS ONE 10 (6): Pg 129-165

CHAPTER 3: AGRICULTURAL SYSTEM OF INTENSIFICATION IN SMALLHOLDER FARMING SYSTEMS OF MKHANYAKUDE SMALLHODER FARMERS, KWAZULU-NATAL PROVINCE, SOUTH AFRICA

3.1 ABSTRACT

Farmers practice various forms of crop intensification by planting more than two crop species on the same piece of land to add on to the diversity of their food procurement systems and improve on food security. However the reasons why farmers plant more than two crop species in the same piece of land could form part of local indigenous systems, however, the scientific basis for the selection and performance of such crop combinations have not been clearly explained and documented. The objective of the study is to investigate the reasons why farmers choose to plant more than two crop species in the same piece of land. A qualitative study using Participatory Rural Appraisal (PRA) tools namely, focus group discussions, transect walks and key informant interviews was done. A random purposive sample of 249 smallholder farmers from 5 local municipalities of uMkhanyakude district, namely, 67 farmers from Hlabisa, 57 farmers from Mtubatuba, 46 farmers from The Big 5 False Bay, 40 farmers from Jozini and 39 farmers from uMhlabuyalingana was undertaken. The following information was explored: The transect walks explored and observed the different farming systems; landscape; availability of irrigation systems or water sources; classification of farming soil types; perception of soil fertility; planting and rainfall patterns. The focus group discussions explored smallholder farmers' demographics, socio-economic status, typical farming systems, differences between backyard gardens and crop fields, water sources, knowledge and skills on farming systems and practices, understanding and benefits of mixed farming, crop mixing and intercropping, soil fertility and soil acidity management. The findings of the study revealed that the age of the smallholder farmers ranged between 40-65 years. About 90% of the smallholder farmers who participated in this study were females. 45% of smallholder farmers' households are headed by females. A typical household of the smallholder farmers, is characterised by more than two dwelling places in one household compound with mixed farming. Water is a serious problem in uMkhanyakude district. 70% of the farmers primarily used indigenous knowledge and acquired their skills on farming systems and practises from generation to generation indigenous knowledge system.

Keywords: *smallholder, intensification, intercropping, mixed farming, crop mixing*

3.2 INTRODUCTION

The majority of smallholder farmers generally have small land parcels. These lands are not enough to sustain production of a variety of produce in sufficient quantities to ensure food security. Various challenges such as access to irrigation facilities and rainfall are often experienced by these farmers. The little water which becomes available from the rain is often lost via evapotranspiration because of the high summer temperatures prevalent in these regions. Poor soil fertility is often cited as another major challenge because these farmers cannot afford chemical commercial fertilisers which are very expensive. Even when fertilizers are applied losses occur as a result of volatilization and denitrification. The crop may use 30 to 50% of the inorganic fertilizer applied, the rest is lost by volatilization, denitrification, or leaching as nitrate into groundwater, Khan (2005).

Farmers in these regions such as Northern KwaZulu-Natal have developed a number of coping strategies to enable them to adapt and survive under these conditions. These include practices that allow them to diversify and/or intensify crop production. Cropping systems that combine several crops in the same field/plot such as intercropping corns and legumes are widely practiced and have been shown increase total productivity per unit area, improve land use efficiency, and increase atmospheric nitrogen fixing ability, Banik and Sharma (2009). Although some of these strategies are widely used worldwide the reasons why local farmers in Northern KwaZulu-Natal choose certain crops and plant them in combination have not been studied. The scientific basis for such cropping system combinations are not well -understood. The objective of the study is to investigate the reasons why farmers choose to plant more than two crop species in the same piece of land.

3.3 MATERIALS AND METHODS

3.3.1 DESCRIPTION OF THE STUDY AREA

The study was conducted in the UMkhanyakude is located in the far north of the KwaZulu-Natal province. It shares its borders with Swaziland and Mozambique as it appears on the figure 3.1 below. Agriculture is one of the main economic sectors in this district. It is the second-largest district in the province. The size of this district municipality is 12818 km^2. The population size is 625846 of which 76% is youth. The unemployment rate is 43%. About 57.3% of the population survive on less than eight rand per month. The poverty status in this district municipality is very high, UMkhanyakude IDP (2015/16).

The region is characterized by disadvantaged rural communities and it ranks higher in terms of poverty and malnutrition compared with other districts within KwaZulu Natal province. These communities rely on farming for food security and to generate income with surplus and livestock sold to neighbours. The land sizes are generally small, these farmers lack of irrigation facilities and rainfall is often limited and erratic. Soil moisture losses occur through high evapotranspiration rates and soils have low fertility and are low in nutrients and organic matter. Weather variability causes planting to be delayed and sometimes farmers miss the planting season because of the delayed first rains. Drought spell and unusual rainfall pattern often cause high occurrences of pest and diseases that destroy the crops and worsen the yield even further.

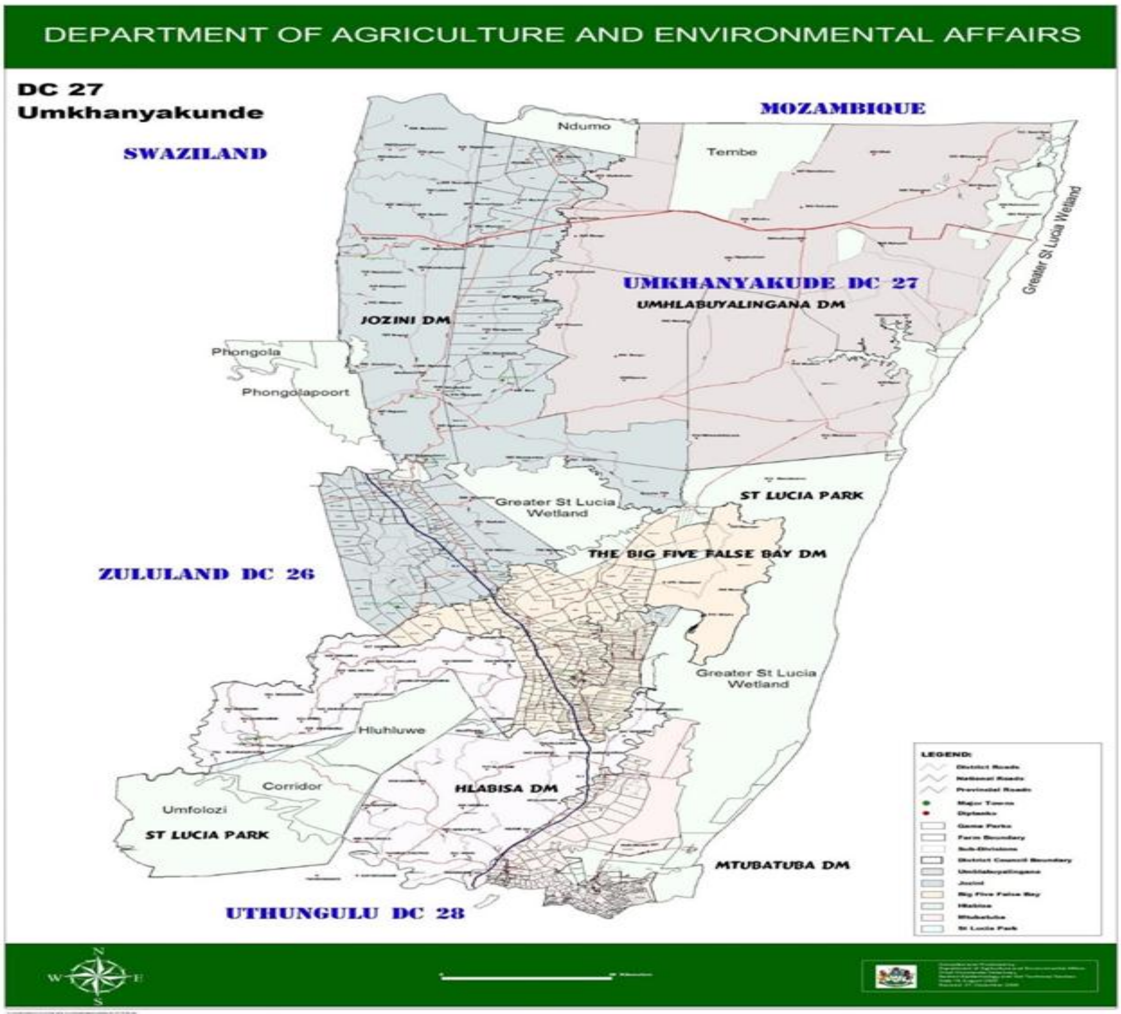

Figure 3.1: Map showing uMkhanyakude District Municipality. Source: DARD BRU

3.3.2 DATA COLLECTION

The Participatory Rural Appraisal (PRA) approach method was used to obtain data from smallholder farmers. A series of 10 focus group discussions and 5 transect walks from each local municipalities (see Table 3.1). These activities were complemented by key informant interviews held with the local extension officers and 'Izinduna' *(Headmen).* (See Appendix 1. –Focus Group Discussion guide). Focus group discussions are an approach used to gain in-depth information useful for exploring people's knowledge and experiences and can be used to examine not only what people think but how they think and why they think that way, Rennekamp and Nall (2004). A trained facilitator conducted the FGDs and 3 local people were trained to be fieldworkers playing a role as note takers during FGDs and tape recorder operators. Smallholder farmers were asked to draw a typical household, showing the farming area. From the drawing questions were probed on farming system and practices, mixing farming, crop mixing and intercropping. They were asked to do comparisons between the above concepts, to give benefits, and or disadvantages of intercropping systems. They were asked where they got information or skills on farming systems and practices. Questions were probed on what value their practices have to them, and how do you manage the soil fertility in your field. On the other hand the transect walks (a combination of observations and interviews) were conducted to obtain a better understanding of the farming systems, crop intensification, agricultural practices and management from the farmers' perspective. Secondary data obtained from FGDs were used to verify and justify information obtained from the PRA tools. These different data sources triangulated each other to establish reliability, trustworthiness and validity of the multiple PRA tools.

Table 3.1: Number of uMkhanyakude District Municipality smallholder farmers who participated in FGDs and Transect walks

Local Municipality	**Number of farmers participated in the FGD**	**Number of farmers participated in a transect walk**
Hlabisa	21*(2FGDs)*	46 *(5 transect walks)*
Mtubatuba	18 *(2FGDs)*	39 *(5 transect walks)*
The Big 5 False Bay	18 *(2FGDs)*	28 (5 transect walks)
Jozini	18 *(2FGDs)*	22 (5 transect walks)
UMhlabuyalingana	24 *(2FGDs)*	15 *(3 transect walks)*
Total	**99**	**150**

The transect walks explored and observed the different farming systems; landscape; availability of irrigation systems or water sources; classification of farming soil types; perception of soil fertility; planting and rainfall patterns.

3.3.3 DATA ANALYSIS

Both FGDs and transect walk narrative data was processed using content analysis through systematic coding. The flip chart notes, note taker's notes and the recorded discussions were transcribed to identify themes, concepts and trends. Verbatim quotes were identified and are reported to highlight and capture the truthful perspective relayed.

3.3.4 SAMPLING TECHNIQUE

A random purposive sample of rural-based and resource poor practising intensification for crop production were identified with the aid from the local extension officers. The list was also used to randomly draw transect walk participants. Every 5th farmer on the list was selected. For FGDs participation, the invitation was purely voluntary, the invitation was sent out to the smallholder farmers through the extension officers.

3.3.5 GAINING ENTRY TO THE COMMUNITY AND ETHICS

Meetings were held with the local extension officers of each local municipality to gain entry to the community. These extension officers acted as gatekeepers who also organised meeting and venues on behalf of the researcher. Before all the FGD sessions the smallholder farmers were reminded that their participation was voluntarily and confidential. They were informed that they could withdraw at any time if they felt uncomfortable to continue with FGD. It should be mentioned that extension officers were strictly used as gatekeepers and were excluded in the research activities to avoid bias.

3.4 RESULTS AND DISCUSSION

3.4.1 DEMOGRAPHICS OF THE SMALLHOLDER FARMERS

The age of the smallholder farmers ranged between 40-65 years. About 90% of the smallholder farmers who participated in this study were mainly females who are producing for household consumption. This concur with Hart and Aliber (2012) findings, they also show that women exceed the number of men, when producing for household consumption as compared to an almost balanced number when cash crops are produced for marketing. Smallholder farming has not yet transformed, as it is still gender biased. More so the age of the smallholder farmers are mainly of the age group that just come off from the economic active bracket to the senior age group. When planning and delivering agricultural services these dynamics should be of primary consideration. Table 3.2 shows demographics of smallholder farmers.

Table 3.2: Distribution of smallholder farmers participated in the study by gender, age group, educational level and source of income.

Gender	**Female**	**Males**		
	89%	11%		
Age Group	**40 – 54**	**55 – 65**		
	84%	16%		
Education Level	**No Schooling**	**Primary to Secondary**	**Std 10 / Grade 12**	**Higher**
	41%	44%	15%	0%
	Salaries / Wages	**Sales of agric produce only**	**Grants and or pension only**	**Sales of agric produce + grants/pension**
	0%	**45%**	**16%**	**39%**

3.4.2 THE SOCIO-ECONOMIC STATUS OF THE SMALLHOLDER FARMERS

About 45% of smallholder farmers' households are headed by females because the males are working in big cities away from home. The male (father of the household) sends small amount of money once a month for them to buy households needs and sometimes agricultural production inputs. This concurs with Stats SA (2011), 43.8% of the households for black Africans are headed by females. The results of the study also showed that, smallholder farmers have poor access to resources because they occupy marginal areas that are less favourable for agricultural production. It was also observed that most of the smallholder farmers are unemployed. Their main source of income is agriculture and government social grants. They do not have ownership of the land that they are occupying and this makes it difficult for them to access credit facilities. According to Olowu (2013), there is an increasing number of female headed household struggling to make a livelihood. In South African rural areas almost all the land is communally owned and administered by a Traditional Authority (TA), and it is mainly for subsistence purposes. According to Jacobs (2008), most smallholder farmers in South Africa are socio-economically poor, less educated and reside in rural communities with less developed infrastructure which locates them in the so called second economy. Thamaga-Chitja (2014), reported that many of these communities are usually governed by male traditional chiefs, while up to 80% of the active producers are females FAO (2002).

3.4.3 DESCRIPTION OF A TYPICAL SMALLHOLDER FARMING SYSTEM IN UMKHANYAKUDE DISTRICT

A typical household of the smallholder farmers, is characterised by more than two dwelling places in one household compound. As seen in Figure 3.1 a backyard garden, chicken kraal, cow kraal, goats' kraal and water tanks were viewed as the main components that make up a household system. Kraal manure and chicken litter are used as fertilizers in backyard gardens. When picking the produce the crop residues are used to feed chicken and other livestock in the household. Cows are also used for ploughing. This concur with Perry (2011), who reported that the homestead, can be characterised as having several huts (or residential sites), a garden plot adjacent to the huts, a cattle kraal and livestock. According to Galhena, Freed and Maredia., (2013), this type of setting resembles and maintains a symbiotic relations between human, livestock, crops and water. The backyard gardens sizes varied between 15m^2-1ha. The backyard gardens were also characterised by mixed cropping with maize taking (60-70%) of the garden as shown in Figure 3.2.

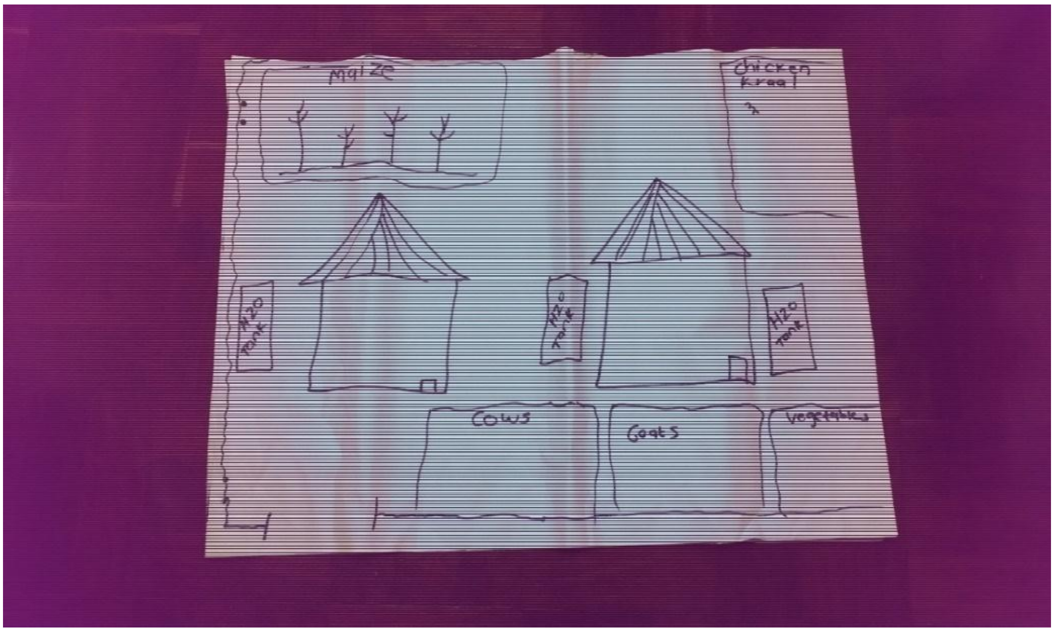

Figure 3.2: Typical household of smallholder farmers in uMkhanyakude

Almost every household own a piece of land for crop production purposes. The field sizes were between 0.25-5ha. This concur with Lewu and Assafa (2009) one member of a rural household has access to a homestead plot and practices farming to provide for the household. They found that smallholder farmers have access to highly variable plot sizes that ranges from at least 0.2ha to 1.9ha, with an average plot size of 1.6ha. Intercropping was practised on bigger fields planting maize taking about 70%, 20% beans and 10% cucurbits of the planting land. Table 3.3 below presents the overall key distinct characteristics of the different backyard and field crop systems. This concurs with Landon-Lane (2004) he found that the location of the garden is close to the home in order to reduce the risk of food losses from foraging wild animals and from theft. He reported that, in the household farming system, most staple foods are usually supplied by one or more fields demarcated for crop production. Such fields are typically at a distance from the smallholder farmers' home.

Table 3.3: The difference between backyard gardens and crop fields

Characteristic	Practice – Back Yard	Practice – Field
Location	About 5m from the household	Away from household ±3km
Extent	0.25-1ha	1ha -5ha
Production objective	Day to day picking of the ready produce when cooking	The produce is harvested when ready and the yield is kept in indigenous silos.
Labour source	Females and children	Females, children and Males (household head) and group of neighbours helping without expecting payment but in exchange for that group to work on their farm as well. (Ilima)
Cropping pattern	Mixed cropping	Intercropping
Technology	Indigenous knowledge	Indigenous knowledge, knowledge from government extension officers and NGOs.
Input cost	Ranges from R100 to R300. It will cover the seed/seedling costs only	Ranges from R2000 – R7000. It covers land preparation, fertilizers, hiring of tractors and other implements and seeds.
Assistance	Government extension officer and NGOs	Government extension officer, seed suppliers and NGOs

3.4.4 WATER SOURCES

Smallholder farmers in UMkhanyakude district mainly relied on rainfed agriculture. However, due to climate change variations, the area has been experiencing drought spells and is currently adapting to rain water harvesting. Even though most areas such as uMhlabayalingana, Jozini, The Big Five False Bay and Hlabisa were using communal water supply, the communal taps were at a distance and unreliable. These water sources were mainly for household consumption and irrigation of crops was not allowed.

The drought spells resulted into unexpected costs to households and farmers, they were forced to buy water:

Farmers' quotation: 3.1.

"Each tank (2000l) costs us R600.00 what can we do, farming is our life, waiting for government is not helping us. Because they promise without any delivery; the communal taps are not within our reach and they are unreliable"

According to Machethe (2011), Water problems in South Africa, include decreasing quality of water, water scarcity, and dysfunctional municipal water infrastructures.

3.4.5 SMALLHOLDERS' KNOWLEDGE AND SKILLS ON FARMING SYSTEMS AND PRACTICES

About 70% of the farmers primarily used indigenous knowledge and acquired their skills on farming systems and practises from generation to generation indigenous knowledge system. Only a low proportion (5-10%) obtained knowledge and skills from government extension officers, liaisons officers, NGOs extension officers (Table 3.4). Rankoana (2015) findings also showed that huge percentage of smallholder farmers use their indigenous farming practices such as planting on different soil types, soil fertilization, selection and storage of seeds and maintenance of crops.

Table 3.4: Knowledge and skills acquisition on farming systems and practises for smallholder farmers

Knowledge and skills acquisition	Percentage (%)
Indigenous knowledge and skills that was obtained from their elders.	70 %
Information days, demonstration and agricultural shows conducted by extension officers from department of agriculture.	10%
Information and skills on improved technologies and new improved seed cultivars farmers obtained from seed suppliers liaison officers.	10%
Farmers get information and skills by trying and experimenting different things in field. Farmers Own Innovation	5%
Extension officers from NGOs operating in the area.	5 %

The findings of the study revealed that smallholder farmers valued their indigenous knowledge and skills learnt from forefathers. This concur with Seleti and Tlhompho (2014) subsistence agriculture is mostly based on local (indigenous) knowledge. Women were involved in almost all aspects of farming, that is from seed selection, planting, harvesting, weeding to grain storage.

Furthermore the focus group discussions revealed a shared perception that smallholder farmers lacked trust of the extension officer's knowledge as they believed farming came with experience and that was what made them knowledgeable:

Farmers' quotation: 3.2.

"where were you when I have started farming, you were not even born; what can you tell me about farming?"

Consequently, farmers were selective and only took what they thought would improve their farming systems and practices. There seems to be a fundamental challenge that implies stagnant progression in the smallholder farming system. There is inefficiency from extension and institution support to provide farmers with new relevant information. Extension services are supposed to improve the decision-making, farming practices and management, Mkandawire (1993).

According to Mkandawire (1993), a major problem in sub-Saharan Africa is that year after year extension workers who are hardly afforded in-service training, and are loosely linked to research, continue to disseminate the same messages repeatedly to the same audience. Muzari et al. (2012) reported that, a situation has consequently arisen where the disseminated messages to the majority of the extension audience, have become technically redundant and obsolete. An additional problem is that most extension services tend to perceive farmers as simply agents of change. According to Nguluu et al. (1996), studies in some areas have shown that smallholder farmers do not adopt all components of "packaged" technologies. When exposed to innovations, smallholder farmers only take those components that they perceive as useful and economically within their reach.

3.4.6 PERCEIVED UNDERSTANDING OF MIXED FARMING, CROP MIXING AND INTERCROPPING

According to smallholder farmers' responses, there was a distinct difference between the three farming system concepts; that is mixed farming, crop mixing and intercropping. Distinct differences in these farming systems are in terms of on-farm biodiversity, planting patterns, cropping system and whether planting of various crops is taking placing simultaneously or in different times (Table 3.5). These findings indicate that smallholder farmers have clear understanding of the different farming systems.

Table 3.5: Key characteristic between the smallholder farming systems

Criteria for comparisons	**Mixed farming**	**Crop mixing**	**Intercropping**
On-farm biodiversity	There is combination of livestock and plant production *(crops, vegetables and fruits)* taking place in one farm or household compound.	There is a variety of crop production taking place in the same piece of land or farm.	There is a variety of crop production taking place in the same piece of land or farm.
Planting patterns	There is no specific pattern followed.	There are no specific patterns followed.	There are specific inter-row and intra-row spacing to be considered.
Cropping system	Farm plan or household arrangement is per individual farmer's preferences.	It can be as a result of mixing two or more different seeds and broadcast them across the same piece of land; It can be arranged in plots, i.e. each plot with different crop. It can be in lines, one line of one crop and another line of other crop.	There is main crop *(usually maize)* and then other crop/s *(usually legume and /or cucurbit).*
Planting decision	Production can take place either simultaneously or in different times but within the household or farm.	Production can take place either simultaneously or in different times but within the same piece of land.	Planting takes place simultaneously

Mixed farming resembles the ecosystem, where there is interaction of organisms and their environment. According to Galhena, Freed and Maredia (2013) this type of setting resembles and maintains a symbiotic relationship between human, livestock, crops and water. As shown in Table 3.5. There were certain perceived similarities between crop mixing and intercropping, however the planting patterns, cropping system and planting decision varies. According to smallholder farmers' response, in mixing farming, there is a high level of crop-livestock integration. Livestock is a dominant part of the farm's cash income and gross margin. The main outputs of cattle were intermediate products used as inputs into the crop production enterprise, such as draught power for land cultivation and crop threshing, and manure for fertilizer. However Van der Pol (1992) finding showed that, the role of livestock in mixed farming systems and the interactions between the crop and livestock components was poorly understood by smallholder farmers.

Mixed farming occurred when the farmer kept more than one type of livestock i.e. chicken, cattle, goats, sheep, pigs this should be complemented by crop within the household and/ or fruit production. In this farming system there is resources recycling, e.g. livestock feed on crop residues and their manure is used as fertilizer for crop production. Animals such as cattle and donkeys are used to prepare land for crop production. Smallholder farmers identified four advantages and two disadvantages of mixed farming (Table 3.6). According to their response it was observed that they prefer mixed farming system because of the exchange of resources between livestock and crop production. According to FAO (2001) Mixed farming system requires a special approach to make a success, however what counts the most to farmers is the yield of the whole system. This system is mainly addressing the issue of restricted resources.

Table 3.6: Mixed farming advantages and disadvantages

Advantages	Disadvantages
1. Manure and compost from livestock	Livestock can destroy crops when there is poor fencing
2. Diversified food for food security	Livestock can cause soil compaction when feeding on residues
3. Livestock feeds on crop residues after harvesting	
4. Farmers investment (produce can be sold to make cash)	

According to the farmers crop diversification (planting two or more crops at the same time on the same piece of land) was reconsidered as an insurance against crop failure because of weather conditions. This concur with Clements at al. (2011) finding, that the main aim of crop diversification is to increase crop range so that farmers are not depending on a single crop for food security or to generate income. The second chief advantage was that it improved soil fertility and increased yield. Table 3.7 summaries advantages and disadvantages of intercropping and crop mixing as perceived by uMkhanyakude smallholder farmers. Most farmers interviewed were not able to identify any disadvantages of mixed farming and or intercropping.

Table 3.7: Intercropping farming and crop mixing advantages and disadvantages

Advantages	Disadvantages
1. Intercropping saves farmers' time: "One weeding operation is done for all three varieties of crops"	None
2. It saves farmers money that is paid for land preparation one portion of land is prepared instead of two or three.	None
3. Diversification of produce is attained in a relatively small portion of land.	None
4. Enhances food diversity; Farmers get balanced nutrition from their fields.	None
5. Crops benefits from each other e.g. legumes fixed nitrogen and improve soil fertility.	None
6. It reduces weeds since other crops like legumes and cucurbits act as the cover crops.	None
7. Retains soil moisture	None
8. Inhibits the weeds most importantly intercropping with cowpea inhibits witchweeds (Striga asiatica (L))	None
9. It minimizes chances of soil erosion because cucurbits and other legumes covered the soil	None

Farmers did not associate intercropping and crop mixing with any disadvantage, however according to Gebru (2015), disadvantages in intercropping systems includes yield reduction of the main crop, loss of productivity during drought periods, and high labour inputs in regions where labour is scarce and expensive. Gebru (2015) further argued that, it is well documented that in most cases the main crop in an intercropping system will not reach its high yield as in a monoculture, because there is competition among intercropped plants for light, soil nutrients and water.

In this study the major concern raised by the farmers who were using herbicides, was the suspicion that the recommended herbicide applications for the maize crop was observed and reported to destroy legumes and cucurbits (Table 3.8). As a coping strategy to avoid the situation, the farmers used these strategies:

Farmers' quotation: 3.3.

"We plant maize first as the main crop, when the maize is at the knee height (approximately 6 weeks after germination) herbicides are applied and then after that beans and cucurbits are planted";.

Other farmers:

Farmers' quotation: 3.4.

"We use old buckets and dishes as protectors, we cover the legumes and cucurbits plants before applying herbicide"

According to Akobundu (1980b) in maize-cassava, maize-yam, and maize-cassava-yam intercropping systems, a single application of an atrazine-metolachlor herbicide mixture was observed to be as effective as three hand weeding in minimizing weed competition. However it can be concluded according to Gianessi and Williams (2011), that smallholder farmers can spray herbicides before planting to remove weeds from a field, applied directly to soil at planting for residual control of germinating weed seeds. This results revealed that there is great need to expose and train farmers on the use of herbicides.

3.4.7 SMALLHOLDER FARMING PRACTICES

Rural households in uMkhanyakude district used various farming practices. Table 3.8 summarises the different farming practices used and it also elaborates on why these practices were of value to the UMkhanyakude district smallholder farmers.

Table 3.8: The importance of different farming practices in UMkhanyakude district

Themes	Explanation provided by smallholder farmers
Minimal tillage	89% use minimum tillage **Reason**: to conserve soil and moisture and reduce labour costs.
Weed control	Glyphosate herbicide is applied (only 25% of the farmers used this practice) **Reason**: to kill the weeds 2 weeks prior planting date.
Manual tillage	11% Still use hoes , span of oxen and donkeys for cultivation Reason: Limited access and availability of tractors
Fertiliser application	72% In the strip-tilled lines fertilizer is applied, covered by soil and the seed is planted Reason: to provide nutrients
Planting patterns	100% plant maize as the main crop - planted in larger portion compared to other crops that are intercropped. Reason: Maize is used as staple food and can be processed into various food types

This study revealed that 89% of uMkhanyakude smallholder farmers use minimum tillage because it conserve moisture and reduces labour costs, this is because of uncertain rainfall patterns and restricted resources (Table 3.8). However Ngoma et al. (2016) revealed that there is lower adoption of minimum tillage by smallholder farmers in sub-Saharan Africa.

Smallholder farmers valued and appreciated chemical weeding but found it to be costly compared to manual weeding:

Farmers' quotation: 3.5.

> *"We value technology as it minimizes man-labour but it increases the production costs; hence some of us are still using manual weeding"*

The South Africa government has realised the cost implications mentioned by the smallholder farmers, subsequently developed a programme to support farmers with production inputs and mechanisation. However, smallholder farmers reported that these services were limited and insufficient, thus were not reaching nor servicing the smallholder farmers:

Farmers' quotation: 3.6.

> *"the government has tractors but they are not servicing us; if your field is on a slope you lose out on the service because the tractors cannot reach it"*

Giller et al. (2009) reported that, within the conservation agriculture community weeds were the big problem as weed control is often laborious and costly in the first years, with a greater requirement for herbicides than with conventional tillage. On the other hand, some proponents of conservation agriculture argued that with good ground cover resulting from mulching or cover crops, there is less weed pressure with conservation agriculture. Manual cropping systems, land preparation and weeding are very labour intensive (Table 3.8). Not tilling the soil and planting directly into a mulch of crop residues can reduce labour requirements at a critical time in the agricultural calendar, particularly in mechanized systems when a direct-seeding machine is used. However this study also revealed that the government mechanization program is not service all smallholder farmers because of poor access to their fields (Table 3.8). There is a need for agricultural interventions to be accessible and be suitable to the smallholder farmers' environment.

3.4.8 SOIL FERTILITY AND SOIL ACIDITY MANAGEMENT

This study revealed that smallholder farmers in uMkhanyakude district lacked the skills to analyse soil fertility and acidity thus mainly relied on their indigenous knowledge. Habby and Leonard (2005) emphasized that, soil acidity and fertility management are critical for crop production. The farmers were however, clear and aware that not all soils have the same quality, therefore soil's nutrient supplying capacity is essential for the quality plant production. According to Qamar (2005), several factors such as insufficient extension services, far distance of soil analysis institutions, the cost fees and impractical recommendations received from extension officers influenced their lack of interest in engaging in soil fertility analysis. For soil acidity, they used the physical attribute component (Table 3.9):

Farmers' quotation: 3.7.

"the types of weed that will grow e.g. Striga asiatica grow in a soil with low pH meaning that there will be poor plant growth and yield".

Farmers outlined that soil acidity could be corrected by crop rotating with cowpeas and application of lime. UMkhanyakude district smallholder farmers used specific soil fertility management process, table 3.9 summarises how the farmers managed their soil fertility.

Table 3.9: Soil fertility management process for uMkhanyakude smallholder farmers

Question	Theme	Quote
How do you ensure soil fertility?	Conservation tillage using organic matter	*" We leave the crop residues in field, cover the soil and protect it from direct sunlight to retain moisture and decompose and fertilize the soil"* *"We broadcast available grasses and weeds allow it to decompose in field"* *"We broadcast kraal manure in winter and plough it into the soil."*
	Crop residue management	*"If tractors are available, the crop residues are ploughed into the soil in winter"*
Cover cropping	*"By planting cover crops like cucurbits and legume."*	
Nutrient management	*"Applying inorganic fertilizers."*	
Intercropping with leguminous plant	*" Increasing atmospheric nitrogen fixing ability"*	

In Mhlabuyalingana crop production was under dry land and they did not apply any fertilisers. According to smallholder farmers in this area there is no need for supplying soil nutrients because the production is under dryland therefore there is very low soil moisture to dissolve inorganic fertilizers. Their soil management process includes crop residue management, their soils are very sandy. However Boul et al. (2003) classified sandy soils as very fragile with respect to agricultural production due to their very low nutrients and organic matter content. Yanai et al. (2005) reported that, there is limited information available on the fertility status of sandy soils especially with reference to soil-plant relationship. The results of this study revealed the importance of evaluating sandy soils fertility status.

According to DARD BRU (2011), soil at uMhlabuyalingana are classified as follows: Soil forms are Clovelly and Fernwood. The soil ecotypes in this area are B.3.1 The soil ecotype is used to estimate the production potential of the soil. A soil ecotype is a class of land defined in terms of soil form, texture, depth, wetness, slope and soil surface characteristics. An ecotype is defined by soil texture, clay percentage, depth, slope and rockiness. Therefore, ecotype B.3.1. and B.3.2. are soils that are well drained, with clay percentage <15%, > 800m soil depth. This soil ecotype represent the moderate potential soil class and have a moderate crop potential. These are sandy soil. DARD BRU (2011). Table 3.10 summarises the distribution of annual rainfall in uMhlabuyalingana area. June to August showed the least median and mean rainfall. The median and mean annual rainfall is 504mm and 588mm respectively DARD BRU (2011).

Table 3.10 uMhlabuyalingana Rainfall in mm.

	Annual	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Median	504	82	76	62	30	14	4	4	6	22	60	71	73
Mean	588	91	87	78	40	19	7	9	11	40	54	77	75

Source: DARD Bio Resource Unit

According to uMkhanyakude smallholder farmers, they are using their indigenous knowledge wisdom (IKW) to analyse their soil fertility by the following characteristics: soil colour, presence of worms, cracks, salts, sandy and gravel as well as drying up characteristics. This concur with Mowo et al. (2004), reported that in Tanzania and Benin the local soil analysis system or indicators used by smallholder farmers are soil colour, presence of worms, cracks, salts, sand and gravel and drying up characteristics. These results revealed that, even though farmers' knowledge of soil fertility analysis might be limited but they could strictly distinct between fertile and infertile soils by fertility making reference and association with what was growing around or on those soils. The scientists and researchers need to work together with farmers so that farmers' indigenous knowledge is made the foundation of all scientific developments. Mowo et al. (2004) concluded that, farmers have developed their own theory and philosophies based on indigenous knowledge wisdom (IKW) to asses soil fertility, however discourse emerges as their knowledge does not provide any strong scientific justification at times it does not agree with formal scientific knowledge. According to Sommer et al. (2013) knowledge of land condition and soil health constraints is necessary to plan management options and apply necessary soil fertility enhancing interventions.

3.5 CONCLUSION AND RECOMMENDATIONS

The findings of this study revealed that smallholder farmers at uMkhanyakude district are practising crop intensification because they have limited resources, namely: land, water, mechanization and production inputs such as fertilizers and chemicals. They believe that intercropping saves them time, e.g. one weeding operation is done for all three varieties of crops. It saves them money that is paid for land preparation- one portion of land is prepared instead of two or three.

There is the great need to expose farmers on the proper selection of crops when planning crop intensification. It is recommended that smallholder farmers be exposed and trained on different skills and methods of water harvesting and herbicides application. Government need to support smallholder farmers with irrigation infrastructures that are suitable to their needs.

3.7 REFERENCES

Akobundu O. 1980b. Weed Science Research at the International Institute of Tropical Agriculture and Research Needs in Africa. Weed Science. 28 (4): Pg 439-445.

Banik P. and Sharma R. C. 2009. Yield and Resource Utilization Efficiency in Baby Corn—Legume-Intercropping System in the Eastern Plateau of India. Journal of Sustainable Agriculture 33:4 Pg 379 -395.

Boul S. W., Southard R. J., Graham R. C. and McDaniel P. A. 2003. Soil genesis and classification 5: Pg 494.

Clement R., Haggard J., Quezada A. and Torres J. 2011. Technologies for climate change adaptation. Agriculture Sector X Zhu edition. UNEP RISO Centre.

Khan M.A. 2005. Effect of phosphorus levels on growth and yield of maize cultivars under saline conditions. International Journal. Agricultural Biology 7 Pg 511-514.

KZN Department of Agriculture and Rural Development. BioResource Unit. 2011.

FAO. 2001. Mixed crop-livestock farming. Agriculture and Consumer Protection. Rome: Food and Agriculture Organisation.

FAO. 2002. The State of Food Insecurity in the World. Rome: Food and Agriculture Organisation.

FAO. 2013. Investing in smallholder agriculture for food security. Rome: Food and Agriculture Organisation.

Galhena D.H., Freed R. and Maredia K.M. 2013. Home gardens: a promising approach to enhance household food security and wellbeing. Agriculture and Food Security 2. (8) Pg 112-138.

Gebru H. 2015. A review on the comparative advantages of intercropping to mono cropping system. Journal of Biology, Agriculture and Healthcare 5 (9): Pg 1-9

Gianessi L. and Williams A. 2011. Insecticide Use in West Africa Means More Cocoa Beans for Chocolate and Less Destruction of Rain Forests. International Pesticide Benefits. Case 4. CropLife Foundation. Crop Protection Research Institute

Giller K.E., Witter E., Corbeels M.and Tittonell P. 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. Field Crops Research 114: Pg 23–34.

Habby V.A. and Leonard A.T. 2005. Sustainable Alfafa production on coastal plain soils of United States. Communications in Soil Science and Plant Analysis 36 (1): Pg 47-63.

Hart T. and Aliber M. 2012. Inequalities in Agricultural support for women in South Africa. Policy Brief. Human Sciences Research Council.

Jacobs P. 2008. Market Development and Smallholder Farmers-A Selective Literature Survey. Human Sciences Research Council: Durban

Landan-Lane C. 2004. Livelihoods grow in garden: Diversifying rural incomes through home garden. Rome. Food and Agriculture Organisation of the United Nations.

Lewu F.B. and Assefa Y. 2009. Farmers' knowledge in the cropping systems of Northern kwaZulu-Natal: Current challenges and solution for sustainable future food production. African Journal Agriculture Research. 4 (11): Pg 1148-1153.

Machethe E.M. 2011. The causes and impact of water shortage on the households of Ga-Kgapane Township in the Limpompo Province. University of Limpompo South Africa.

Mkandawire R.M. 1993. Smallholder survival strategies, perception and responsiveness to extension and credit in Salima. Agricultural Extension and Rural Development 9 (9): Pg 185-199.

Mowo J.G., Janseen B.H. and Oenema, O. 2014. Soil fertility evaluation and management by smallholder farmer communities in Northern Tanzania. Agricultural ecosystem and environment 122: Pg 1-19.

Muzari W., Gatsi W. and Muvhunzi S. 2012. The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: Journal of Sustainable Development 5 (8): Pg 1913-1963.

Ngoma H., Mulenga B.P. and Jayne T.S. 2016. Minimum tillage uptake and uptake intensity by smallholder farmers in Zambia. African Journal of Agricultural and Resource Economics 11 (4) Pg 21-31.

Nguluu S. N., Ransom J. K., Ariithi C. C. K. and Muhammad L. 1996. Adoption of Improved maize technology in Eastern Kenya following a community based Farmer Training Project.

Perry A. 2011. Rural homestead design and permaculture. The transformation Journal 12: Pg 32-55.

Olowu D. 2013. Gender aspects of food security in Lesotho: implications for an integrative Rights-Based Approach. Nigeria: Centre for Psychological Studies.

Qamar M.K. 2005. Recent developments in Agricultural Extension. Research Extension Division Sustainable Development. FAO. Rome Pg 199-207.

Rankoana S.A. 2015. The use of indigenous knowledge in subsistence farming. African Journal for Physical Health Education. 1: Pg 272-278.

Rennakamp R.A. and Nall M.A. 2004. Using focus groups in program evaluation. University of Kentucky Co-operative Extension.

Seleti Y.N. and Tlhompho G. 2014. Rural women subsistence farmers, Indigenous knowledge system and agricultural research in South Africa. Journal of human Ecology, 48 (1): Pg33-41.

Statistics South Africa. 2011. General Household Survey Series 4 (3) Pg 18-30. Food Security and Agriculture (2011-2012): In Depth analysis of General Household Survey. Statistics South Africa: Pretoria.

Sommer, R.; Bossio, D.; Desta, L.; Dimes, J.; Kihara, J.; Koala, S.; Mango, N.; Rodriguez, D.; Thierfelder, C.; Winowiecki, L. 2013. Profitable and sustainable nutrient management systems for East and Southern African smallholder farming systems: challenges and opportunities: a synthesis of the Eastern and Southern Africa situation in terms of past experiences, present and future opportunities in promoting nutrients use in Africa. The University of Queensland. QAAFI. CIMMYT

Thamaga-Chitja J.M. and Morojele P. 2014. The context of smallholder farming in South Africa: Towards a livelihood asset building framework. Journal of Human Ecology 45 (2): Pg 147-155.

UMkhanyakude District Municipality. 2015. Integrated Development Plan. 2015/16. UMkhanyakude District Municipality

Van Der Pol F. 1992. Soil Mining: An Unseen Contributor to Farm Income in Southern Mali. Royal Tropical Institute. Amsterdam. 325: Pg 48.

Yanai J., Nakata S., Funakawa S., Nawata E., Tulaphitak T., Katawatin R. and Kosaki T. 2005. Re-evaluation of fertility status of sandy soil in Northeast Thailand with reference to soil-plant nutrient budgets. Kyoto Prefectural Universit.

CHAPTER 4: EVALUATION OF PRODUCTIVITY LEVEL OF MAIZE-DRY BEAN-PUMPKIN INTERCROPPING

4.1 ABSTRACT

Crop intensification can be achieved by intercropping, where a variety of crop species are planted on the same piece of land. In some instances farmers plant more than two crops, however there is little information regarding the interactions in such crop mixtures with respect to productivity. The reasons why farmers plant more than two crop species in the same piece of land could form part of local indigenous systems, however, the scientific basis for the selection and performance of such crop combinations have not been clearly explained and documented. This study was carried out to compare the productivity of a maize/pumpkin/bean inter-crop with different combinations of maize/bean, maize pumpkin, bean/pumpkin and sole crops of each species. The experiment was laid out in a randomized complete block design (RCBD) with three replicates having a net plot size of 3.6m x 5m. The following treatments were evaluated: Maize intercropped with beans (T1), Maize intercropped with pumpkins (T2), Maize intercropped with beans and pumpkins (T3), Maize sole crop control (T4), Beans sole crop control (T5), Pumpkins sole crop control (T6) and Bean intercropped with pumpkins (T7). Productivity was measured using the following indices: Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER), Competition Ratio (CR), Relative Crowding Coefficient (K) and Aggressivity (A), Actual Yield Lost (AYL), Intercropping Advantage (IA) and Monetary Advantage Index (MAI). The study revealed that the intercropping system with three crop species in all three location showed greater values of LER (1.8, 1.9, and 1.7) and ATER (1.8, 1.9, 1.7). The crowding coefficient (K) was the highest in Mtubatuba and Hluhluwe treatment 3 (maize/bean/pumpkin) (80.72 and 61.78) respectively. Intercrops showed positive Agressivity, and greater competition ratio and actual yield loss when compared with the main crops. Intercropping advantage (IA) and monetary advantage (MAI) in treatment 3 (maize/bean/pumpkin in all locations showed greater values (58327, 12850, 5532) and (54573, 59487, 19606) respectively. It can be concluded that the productivity of the intercropping system where there are more than two crops is considered greater in terms of land equivalent ratio (LER), area time equivalent ratio, (ATER).

Keywords: *Maize, dry bean, Pumpkin, Intercropping, Land equivalent ratio, Competitive ratio, Relative crowding, Agressivity, Actual yield loss, Intercropping advantage and monetary advantage index*

4.2 INTRODUCTION

Crop intensification can be technically defined as an increase in agricultural production per unit of inputs. Input may be labour, land, time, fertilizer, and seed FAO (2004). For practical purposes, intensification occurs when there is an increase in the total volume of agricultural production that results from a higher productivity of inputs. Intensification can also occurs when agricultural production is maintained while certain inputs are decreased, such as by more effective delivery of smaller amounts of fertilizer, better targeting of plant or animal protection, and mixed or relay cropping on smaller fields. Marx et al. (2008), defines crop intensification as the concentration of capital upon the same plot rather than its distribution among several adjoining pieces of land. Crop intensification can be achieved by intercropping, where a variety of crop species are planted on the same piece of land. Intercropping diversifies the system by multiple cropping practices which involves growing two or more crop species simultaneously on the same piece of land. According to Ouma and Jeruto (2010), intercropping is a multiple cropping practice involving growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise not be utilized by a single crop Staller et al. (2006). Careful planning is required, taking into account the soil, climate, crops, and varieties. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop, or planting a tall crop with a shorter crop that requires partial shade Miguel and Nicholls (2004). Planting two crops in close proximity can especially be beneficial when the two plants interact in a way that increases one or both of the plant's fitness and therefore yield. For example, plants that are prone to tip over in wind or heavy rain (lodging-prone plants), may be given structural support by their companion crop. Climbing plants can also benefit from structural support. Some plants are used to suppress weeds or provide nutrients. Delicate or light-sensitive plants may be given shade or protection, or otherwise wasted space can be utilized. An example is the tropical multi-tier system where coconut occupies the upper tier, banana the middle tier, and pineapple, ginger, or leguminous fodder, medicinal or aromatic plants occupy the lowest tier Poveda et al (2008). Intercropping of compatible plants can also encourage biodiversity, by providing a habitat for a variety of insects and soil organisms that would not be present in a single-crop environment. These organisms may provide crops valuable nutrients, such as through nitrogen fixation Poveda et al. (2008).

The objective of this study is to compare the productivity of a maize/pumpkin/bean inter-crop with different combinations of maize/bean, maize pumpkin, bean/pumpkin and sole crops of each species.

4.3 MATERIALS AND METHODS

4.3.1 SITE DESCRIPTION

The study was done Hluhluwe (28^0 01'70.91" S, 32^0 16'23.12" E), Mtubatuba (28^0 24'50.24" S, 32^0 11'23.65" E) and Hlabisa (28^0 08'38.46" S, 32^0 11'23.65" E) areas in KwaZulu Natal, South Africa. These areas are situated in the north of KwaZulu Natal. All three municipalities fall under the uMkhanyakude district manucipality.

4.3.2 CLIMATIC FACTORS

The area has an annual mean rainfall of 928 mm, indicating a good rainfall and the incidence of frost is rare. The rainfall and temperature regimes experienced on the farm are as follows:

Table 4.1 Rainfall (mm) and Temperature (˚C) of uMkhanyakude

	Annual	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Rainfall (mm)													
Median rainfall (mm)	693	87	92	83	50	35	21	18	23	44	73	80	87
Mean rainfall (mm)	928	121	127	111	70	52	37	33	33	56	84	100	104
Mean daily temperatures (^{0}C)													
Average (^{0}C)	21.9	25.5	25.8	24.7	22.6	20.1	17.6	17.7	19.1	20.8	21.5	23.0	24.4
Minimum (^{0}C)	16.7	20.7	21.0	19.7	17.4	14.4	11.4	11.6	13.4	15.7	16.8	18.2	19.7
Maximum (^{0}C)	27.1	30.3	30.6	29.7	27.8	25.9	23.8	23.7	24.7	25.9	26.3	27.8	29.1

Sourced: DARD Bio Resource Unit

4.3.4 EXPERIMENTAL DESIGN

The production systems of maize/bean/pumpkin intercropped were evaluated in 2015/16 planting season. The experiments were laid out using a randomized complete block design (RCBD) with three replicates. The treatments were as follows: maize intercropped with beans (T1), maize intercropped with pumpkins (T2), maize intercropped with beans and pumpkins

(T3), maize alone control (T4), beans alone control (T5), pumpkins alone control (T6) and bean intercropped with pumpkins (T7). The crops were planted in plots measuring 2m x 3m. The trials were planted at three sites, namely Hluhluwe and Mtubatuba which were under sprinkle irrigation and at Hlabisa which was under rain-fed conditions. Before planting, soil samples were collected randomly from each plot to determine the fertility status. Sampling was done using 3-4 subsamples collected from each plot, at 3 sampling depths (0-10, 10-20 and 20-30 cm). The following mineral elements carbon (C), nitrogen (N), phosphorus (P), Potassium (K) and sulphur (S), exchangeable bases (calcium (Ca), magnesium (Mg) and sodium (Na) and micronutrients boron (B), zinc (Zn), molybdenum (Mo) and iron (Fe) Soil pH and texture were analysed.

Maize seeds were planted at 1m inter row and 30cm intra row spacing and plant population per hectare was 33 000 (T4), bean seeds were planted at 7.5cm inter row and 90 cm intra row spacing and plant population per hectare was 148 000 (T5), pumpkin seeds were planted at 2m inter row spacing and 50cm intra row spacing and plant population per hectare was 4 000 (T6). In (T1) maize plant population was 24 750, bean plant population was 44 400. In (T2) maize plant population was 24 750, pumpkin plant population was 1 200. In (T3) maize plant population was 24 750, pumpkin plant population was 600 and bean was 22 200. In (T7) bean plant population was 111 000, pumpkin plant population was 1 200.

4.3.5 AGRONOMIC PRACTICES

Fertilizer was applied according to recommendations based on soil samples analysis. Weed control was done by hand at week 3. Kemprin 200 EC pesticide was applied at 2 weeks interval until week 8 to control pests.

4.3.6 DATA COLLECTION

At the time of harvesting grain yield data of maize and bean were recorded, in order to assess the advantages and/or disadvantages of intercropping using the competition indices. Bean was harvested at week 15 after planting. Maize and pumpkin were harvested at week 18 after planting. Ten plants (maize and bean) per treatment were sampled to determine grain moisture content. The grain moisture meter (MMG 608 manufactured by Merlin technology) was used to determine maize grain and bean grain moisture content.

The following competition indices were used as the criterion to measure efficiency of intercropping advantage in utilizing the resources:

Land Equivalent Ratio; $LER = [intercrop\ maize\ yield/sole\ maize\ yield] + [intercrop\ dry\ bean\ yield/sole\ dry\ bean\ yield]$ where all yields are expressed in ton/ha. Mead and Willey (1980).

Area Time Equivalent Ratio was calculated using the following formula:

$ATER = LER * Dc/Dt.$

Where LER was the land equivalent ratio, Dc was the time taken by the crop in intercropping system, Dt is the time taken by the whole intercropping system.

Competition was evaluated using competitive ratio (CR), the formula described by Willey and Rao (1980): $CR = (CRa + CRb)$

$$CR = [(LERa/LERb) * (Zba/Zab)] + [(LERb/LERa) * (Zab/Zba)],$$

Where CRa was the competitive ratio for the intercrop crop "a" and CRb was the competitive ratio for the intercrop crop "b" and Zy was the sown proportion of each crop in the mixture. Yield penalty was calculated as the percentage difference in yield.

Relative crowding coefficient (RCC or K) was the measure of relative dominance of one crop over the other in the intercropping system, de Wit (1960).

The K was calculated as follows:

$$K = Kab * Kba$$

$= [(Yab * Zba)/[(Yaa - Yab) * Zab] * [(Yba * Zab)]/[(Ybb - Yba) * Zba]$, where Kab and Kba are relative crowding coefficients for maize and bean intercrops respectively.

Aggressivity (A) gave a simple measure of how much relative yield increase in species of ‘a’ was greater than that for species ‘b’ in an intercropping system. It measured the intercop competition by relating the changes of all components crops and it was calculated, McGilchrist (1965), as:

$Yab = [\{Yab/(Yaa * Zab)\} - \{Yba/(Ybb * Zba)\}]$ where Yab was the aggressivity of intercrop maize.

Where Yab is the Agressivity of crop "a" in an intercropping system, Yba is the Agressivity of intercrop "b" in an intercropping system. If the value of A is zero, that will mean both crop are equal. If the value of A is positive then crop "a" is dominant over crop "b" in an intercropping system. If the value of A is negative then crop "b" is dominant over crop "a" in an intercropping system.

The Agressivity of crop "b" can be determined using the following formula:

$A = \{Yba/(Ybb * Zba)\} - \{Yab/(Yaa * Zab)\}$

Where Zab is the sown proportion of crop "a" in the intercropping system.

Zba is the sown proportion of crop "b" in the intercropping system.

Yab is the yield of crop "a" in the intercropping system.

Yba is the yield of crop "b" in the intercropping system

Yaa is the yield of crop "a" in the sole cropping system,

and Ybb is the yield of crop "b" in the sole cropping system

Another index that was used to evaluate the advantage and disadvantage of intercropping system was the actual yield loss (AYL).

$AYL = AYLa + AYLb$

Where AYLa is the actual yield loss of crop "a" and AYLb is the actual yield loss of crop "b"

Intercropping advantage (IA) is another index that was used to determine intercropping system productivity. According to Muhammad et al. (2008), Intercropping advantage was used by Banik et al. (2000) and Dhima et al. (2007) by the following formula: $IA = (AYLa) * (Pa)$ if calculating Intercroping advantage of crop "a". Where AYLa is the actual yield loss of crop "a" and Pa is is the market price of crop "a".

To calculate the actual yield loss of crop "a" in the intercropping system the following formula is used:

$AYLa = \{[(Yab/Zab)/(Yaa/Zaa)] - 1\}$

To calculate the actual yield loss of crop "b" in the intercropping system the following formula is used:

$AYLb = \{[(Yba/Zba)/(Ybb/Zbb)] - 1\}$

To calculate the Intercropping advantage of crop "b" the following formula is used:

$IA = (AYLb) * (Pb)$.

Where $AYLb$ the actual yield loss of crop "b" and Pb is is the market price of crop "b".

According to Muhammad et al. (2008), all competition indices above do not provide any information on of economic advantage of the intercropping system. Economic advantage of the intercropping system can be calculated using the monetary advantage index. The monetary advantage index is calculated using the following formula:

$MAI = (value\ \ of\ combined\ intercrops) * (LER - 1)/LER$

Where LER is the land equivalent ratio.

According to Ghosh, (2004), cited by Muhammad et al., (2008), the higher the monetary advantage index (MAI) value the more profitable is the cropping system.

4.3.7 STATISTICAL ANALYSIS

Data was subjected to analysis of variance (ANOVA) using Genstat version 16. Means we separated using LSD at 5% level.

4.4 RESULTS AND DISCUSSIONS

4.4.1 MAIZE, BEAN AND PUMPKIN YIELDS

At harvesting the bean grain moisture was 12.5% dry mass basis while maize was 13 % across all locations. Yield results obtained in the current study showed that there were highly significant differences (P<0.001) with respect to treatments and locations (Table 4.2).

Table 4.2 Yield (ton/ha) in different treatments in 3 different location

	Hluhluwe			Mtubatuba			Hlabisa		
Treatments	maize	Bean	pumpkin	maize	beans	pumpkin	maize	beans	Pumpkin
maize/bean	3.9	1.9		3.7	1.9		2.1	0.6	
maize/pumpkin	3.9		30.3	3.5		29.3	2.1		10.3
maize/bean/pumpkin	3.6	0.6	28.3	3.6	0.7	28.3	2.1	0.3	10.0
maize	4.3			4.1			2.5		
Bean		2.5			2.4			1.1	
Pumpkin			39.0			38.7			19.7
Bean/pumpkin		1.8	28.7		1.9	27.7		0.8	11.3
LSD	0.2			0.15			2.2		
CV %	3.6			6.6			5.2		
Significance (Location x treatment)	P< 0.001			P< 0.001			P< 0.001		

With respect to individual locations, the current findings indicated that there were no significant difference (P>0.05) in mean maize yield within treatments in Hluhluwe and Mtubatuba, however in Hlabisa the mean maize yield was significantly low in all treatments where there maize, when compared with treatments in Hluhluwe and Mtubatuba. This was expected since the trial in Hlabisa was under rain-fed area whereas trials in Hluhluwe and Mtubatuba were under irrigation. Treatment 4 (maize) mean maize yield was slightly higher when compared with other treatments in all locations.

There was significant difference (P<0.05) in mean bean yield within treatments in all locations. That was because in T1 (maize/bean), bean plant population was reduced to 22 200 when compared with plant population in T5 (bean), in T3 (maize/bean/pumpkin), bean plant population was reduced to 22 200 as compared to T5 (bean). In T7 (bean/pumpkin), bean plant population was reduced to 111 000. In all treatments in Hlabisa the mean bean yield was significantly low when compared with treatments in Hluhluwe and Mtubatuba. The reason for that was, in Hlabisa the trial was under rain-fed area whereas trials in Hluhluwe and Mtubatuba were under irrigation.

There was significant difference (P>0.001) in mean pumpkin yield within treatments in all locations. Treatment 6 (pumpkin), mean pumpkin yield was significant higher when compared with other treatments where there was pumpkins in all locations, that was because in T2 (maize/pumpkin), pumpkin plant population was reduced to 1 200 when compared with plant population in T6 (pumpkin), in T3 (maize/bean/pumpkin), pumpkin plant population was reduced to 600. In T7 (bean/pumpkin), pumpkin plant population was 1 200. In all treatments in Hlabisa the mean pumpkin yield was significantly low when compared with treatments in Hluhluwe and Mtubatuba. That was expected since the trial in Hlabisa was under rain-fed area whereas trials in Hluhluwe and Mtubatuba were under irrigation.

4.4.2 COMPETITION INDICES

Table 4.3 that partial LER of maize in the intercropping system was more than LER of intercrops in all three location. That is because maize was the main crop therefore its plant population was higher than that of intercrops. This concur with Banik and Sharma (2009). It was reported that in all intercropping systems, baby corn (main crop) recorded highest LER values. All treatments in an intercropping system showed LER that was greater than 1, however treatment 3 in all locations showed greater LER than all other treatments. That means intercropping system showed yield advantage compared to mono cropping system. This was also reported by Shakur and Nasrollhzadeh (2014) and Muhammed et al. (2008). They reported that LER of the intercropping systems substantially exceeded that of sole cropping systems. Treatment 3 (maize/bean/pumpkin) in all location showed extra yield advantage than all treatments. The results at Hluhluwe showed 70% for treatments 1 and 2, 80% for treatment 3 and 50% for treatment 7. Mtubatuba trial results showed 70% for treatment 1, 60% for treatment 2, 90% for treatment 3 and 30% for treatment 7. Hlabisa trial results showed 40% for treatments 1 and 2, 70% for treatment 3 and 30% for treatment 7. This showed area would be required by a sole cropping system to recover the yield of intercropping system, Miyda et al. (2005). ATER values were found greater in treatment 3 in all location. ATER value provides more realistic comparison of yield advantage of intercropping over sole cropping in terms of variation in time taken by component crops of different intercropping system, Muhammed et al. (2008). ATER values showed an advantage of 30 to 90% under irrigation trials and 20 to 60% under rain-fed trial. That concurred with LER in that treatment 3 showed extra yield advantage than all treatments.

Partial K values for the main crop were minimum in all treatments when compared with intercrops, that means intercrops were more competitive than the main crop. Table 4.4 showed the K values of treatment 3 (maize/bean/pumpkin) in location 1 and 2 were greater than the K value in all other treatments. The results of Agressivity (A) showed that the intercrops were dominant species in an intercropping system with the positive values, over the main crop which had negative values. The values for CR in all treatments in all locations also showed the similar trend of dominant behaviour of intercrops over the main crop. CR values for intercrops in intercropping systems were higher in all treatments in all locations. However Muhammed et al. (2008) reported that the main crop (cotton) showed dominance in terms of K, A and CR over intercrops. This is dependent on the plant species character in terms of relative crowding coefficient, Agressivity and competitive ratio.

Table 4.5 showed the positive partial actual yield loss (AYL) index for both main crop and intercrops in the intercropping system, except for treatment 7 (bean/pumpkin) in location 1 and 3 where the main crop showed negative AYL. The intercrops showed the greater AYL. This means there was extra yield advantage in intercrops when compared with the main crop in all treatments in all locations. Partial intercropping advantage (IA) results showed positive IA for main crops and intercrops in all locations except for treatment 7 (bean/pumpkin) in location 1 and 3 where the main crop showed negative IA. The IA for intercrops showed greater values in all locations than IA of the main crops. That indicates the economic intercropping advantage of intercrops.

Table 4.3 LER and ATER in different treatments in 3 different location

	Hluhluwe						Mtubatuba						Hlabisa					
Treatments	P LER main crop	P LER intercrops	LER	P $ATER$ main crop	P $ATER$ intercrops	$ATER$	P LER main crop	P LER intercrops	LER	P $ATER$ main crop	P $ATER$ intercrops	$ATER$	P LER main crop	P LER intercrops	LER	P $ATER$ main crop	P $ATER$ intercrops	$ATER$
maize/bean	0.91	0.76	1.7	0.91	0.64	1.6	0.90	0.79	1.7	0.90	0.66	1.6	0.84	0.55	1.4	0.84	0.46	1.3
Maize/ pumpkin	0.91	0.78	1.7	0.91	0.78	1.7	0.85	0.76	1.6	0.85	0.64	1.6	0.84	0.52	1.4	0.84	0.52	1.4
Maize/bean/ pumpkin	0.84	0.24	1.8	0.84	0.93	1.8	0.88	0.30	1.9	0.88	0.98	1.9	0.84	0.27	1.7	0.84	0.71	1.6
maize	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0
bean	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0
pumpkin	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0	1.00		1.0
Bean/pumpkin	0.72	0.74	1.5	0.60	0.74	1.3	0.79	0.72	1.5	0.66	0.72	1.4	0.73	0.57	1.3	0.61	0.57	1.2

Table 4.4 Relative crowding coefficience (K), agressivity (A) and competitive ratio (CR) in different treatments in 3 different location

Treatments	Hluhluwe					Mtubatuba					Hlabisa				
	K	Agressivity (A)		Competitive ratio (CR)		K	Agressivity (A)		Competitive ratio (CR)		K	Agressivity (A)		Competitive ratio (CR)	
		A main crop	A intercrops	CR main crop	CR intercrops		A main crop	A intercrops	CR main crop	CR intercrops		A main crop	A intercrops	CR main crop	CR intercrops
Maize/bean	30.88	-1.32	1.32	0.48	2.11	35.15	-1.44	1.44	0.46	2.19	6.30	-0.70	0.70	0.61	1.64
Maize/pumpkin	33.57	-1.38	1.38	0.46	2.14	18.11	-1.40	1.40	0.45	2.24	5.80	-0.57	0.57	0.65	1.55
Maize/bean/pumpkin	61.78	-1.21	1.21	0.35	2.88	80.72	-1.18	1.18	0.34	2.96	0.02	-0.53	0.53	0.43	2.32
Bean/pumpkin	7.20	-1.50	1.50	0.40	2.58	9.60	-1.33	1.33	0.44	2.28	3.60	-0.94	0.94	0.51	1.95

Table 4.5 Actual yield loss (AYL) and intercropping advantage (IA) in different treatments in 3 different location

Treatments	Hluhluwe						Mtubatuba						Hlabisa					
	Actual yield loss (AYL)			Intercropping advantage (IA)			Actual yield loss (AYL)			Intercropping advantage (IA)			Actual yield loss (AYL)			Intercropping advantage (IA)		
	AYL main crop	AYL intercrops	AYL	IA main crop	IA intercrops	IA	AYL main crop	AYL inter crops	AYL	IA main crop	IA intercrops	IA	AYL main crop	AYL intercrops	AYL	IA main crop	IA inter crops	IA
Maize/bean	0.21	1.53	1.74	1680	21420	23100	0.20	1.64	1.84	1600	22960	24560	0.12	0.81	0.93	960	11340	12300
Maize/pumpkin	0.21	1.60	1.81	1680	4837	6517	0.14	1.52	1.66	1120	4595	5715	0.12	0.74	0.86	960	2237	3197
Maize/bean/pumpkin	0.12	6.74	6.86	960	57367	58327	0.17	1.35	1.52	1360	11490	12850	0.12	0.65	0.77	960	5532	6492
Bean/pumpkin	-0.04	1.45	1.41	-560	4382	3822	0.05	1.40	1.45	700	4232	4932	-0.03	0.91	0.88	-240	2751	2511

Table 4.6 showed the positive monetary advantage index (MAI) values and that indicated a definite yield advantage in all intercropping systems over mono cropping. The results concurred with the findings of Ghosh (2004) who found that when the LER and K were higher in that intercropping system, there was also significant economic benefit expressed with higher MAI values.

Table 4.6 Monetary advantage index (MAI) in different treatments in 3 different location

Treatments	Hluhluwe	Mtubatuba	Hlabisa
Maize/bean	23 800	22 344	7 071
Maize/pumpkin	50 562	44 166	12 689
Maize/bean/pumpkin	54 573	59 487	19 606
Bean/pumpkin	35 274	37 333	9 360

The results obtained from this study indicated that the intercropping system where there were more than two crops showed higher land equivalent ratio (LER) and area time equivalent ratio, (ATER). This indicates yield advantage of the intercropping system. It was also indicated that intercropping advantage and monetary advantage where more than two crops were planted showed greater values.

4.5 CONCLUSION

Based on the results of this study it can be concluded that the productivity of the intercropping system where there are more than two crops is considered greater in terms of land equivalent ratio (LER), area time equivalent ratio, (ATER). This indicates yield advantage of the intercropping system. The economic feasibility indicators favoured the intercropping system where there are more than two crops, this is intercropping advantage (IA) and monetary advantage index (MAI).

4.6 REFERENCES

Banik P. and Sharma R. C. 2009. Yield and Resource Utilization Efficiency in Baby Corn-Legume Intercropping System in the Eastern Plateau of India. Journal of Sustainable Agriculture. 33 (4): Pg 379-395.

Dhima K.V., Lithourgidis I.B. and Dordas, C.A. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Research. 100: Pg 249-256

FAO. 2004. Statistics. Food and Agriculture Organization. Rome.

Ghosh P.K. 2004. Growth, yield, competition, and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Research 88: Pg 227–237.

Marx K. and Engels F. 2008. Collected works 2nd ed. vol. 25. Part 2. Pg 227.

McGilchrist C.A. 1965. Analysis of competition experiments. Biometrics 21: Pg 975-985.

Miguel A.A. and Nicholls C.I. 2004. Biodiversity and Pest Management in Agroecosystems, Second Edition. Psychology Press.

Miyda A., Bhattacharjee K., Ghose S.S. and Banik P. 2005. Deffered seeding of blackgram (*Phaseolus mungo L*) and rice (*Oryza sativa L*) field on yield advantages and mothering of weeds. Crop Science. 191: Pg 195-201.

Muhammad A., Ejaz M.U. and Abdul K. 2008. Yield and Competition Indices of Intercropping Cotton (*Gossypium hirsutum L.*) Using Different Planting Patterns. Tarim Bilimleri Dergisi 14 (4): Pg 326-333.

Ouma G. and Jeruto P. 2010. Sustainable horticultural crop production through intercropping: The case of fruits and vegetable crops: A review Agriculture and Biology Journal of North America. 1 (5): Pg 1098–1105.

Poveda K.; Gómez M.I. and Martínez E. 2008. Diversification practices: their effect on pest regulation and production. Revista Colombiana de Entomología. 34 (2): Pg 131–144.

Shakur C.H. and Nasrollhzadeh G.B. 2014. Root distribution and yield responses of wheat/ maize intercropping to alternate irrigation in the arid areas of North West China. Plant soil Enviromental. 56: Pg 253-262.

Staller J. E; Robert H. and Tykot B.F. 2006. Histories of maize: Multidisciplinary approaches to the prehistory, linguistics, biogeography, domestication, and evolution of maize. Amsterdam. Pg 529–537.

Willey R.W. and Rao M.R. 1980. A competitive ratio for qualifying competition between intercrops. Experimental Agriculture 9: Pg 117–125.

CHAPTER 5: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Based on the results of this study it can be concluded that the productivity of the intercropping system where there are more than two crops is considered greater in terms of land equivalent ratio (LER), area time equivalent ratio, (ATER). This indicates yield advantage of the intercropping system. The economic feasibility indicators favoured the intercropping system where there are more than two crops, i.e. intercropping advantage (IA) and monetary advantage index (MAI).

Smallholder farmers can be advised to practice intercropping where the system will include three crop species, however there are no production guidelines that are stating the plant population that is ideal if you want to achieve maximum productivity of the intercropping system. It was discovered during this study that intercropping is labour intensive therefore there is the need for developing agricultural machinery and implements that are suitable for intercropping in order to allow intercropping to be implementable even at a larger scale.

Further research is required on developing production guidelines that take into consideration plant populations (seed rate) of main crop and intercrops. This can give guidance of inter-row and intra-row spacing. These guidelines can inform the development of agricultural machinery and implements that are suitable for intercropping system.

APPENDIX 1

UNIVERSITY OF KWAZULU-NATAL, SCHOOL OF AGRICULTURE, EARTH AND ENVIRONMENTAL SCIENCES

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE

FOCUS GROUP DISCUSSION GUIDE

1. In a form of drawing, describe your typical household, showing the farming area (crop and livestock; houses). On the drawing indicate the parts that take bigger portions of land and justify the allocation.

a. Probe on farming system and practices

b. Probe on mixing farming, crop mixing and intercropping

c. Probe for comparisons between the above concepts

d. With regards to intercropping systems what are its benefits, and or disadvantages?

e. Where did they get information or skills on farming systems and practices?

Probe on what value their practices have to them.

2. How do you manage the soil fertility in your field?

a. Probe on types of fertilizers used and the application rate.

3. Does the soil acidity mean anything to you? If yes, explain what and if No, explain why not

a. Probe on how much do they know about soil acidity, its effects and how to correct it

4. In your own opinion and observation, is there any difference in yield of your crops over the past three years?

a. Make the farmers draw a seasonal map showing the following:

Year	Crop	Months planted	Indication of yield decrease, constant or increase per crop	Justification	Quote

a. What crops are planted every season and why?

b. Probe on whether the planting have changed over time

c. Probe on the perceived reason/causes of change

d. Probe on whether the crops planted today are still the same as the past ones, why?

(You may give a certain period that will be related to the age group of farmers)

5. What is the smallholder farmer’s perception of climate change?

a. What is their understanding of climate change concept? (you need to determine if the farmers are aware of climate change concept, then try to explain without leading them, then pose questions)

b. What has been their observations over the years (10-20 years) challenges, changes etc

c. Has it affected their practices and production management in any way? Justify or elaborate how?

d. What kind of coping strategies have they adopted?

e. Probe on gender dynamics (who does what on the field and why)

6. What inform your decisions of what crops to plant?

a. Probe on who makes the decisions on what to be planted, Justify why?

b. What factors influences the type of crops to be planted?

7. What crops do you plant every planting season? (Who makes that decision and Why?)