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Socio-economic factors affecting adoption of improved agricultural practices by small scale farmers in South Africa

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Improved crop production forms an integral part of the intervention proposals of the UN Millennium Project to eradicate poverty and hunger in southern Africa. The objective of this study was to collect information on socio-economic aspects and farming practices that could affect adoption of improved agricultural practices. This study highlights the importance of appreciating the complexity of agricultural systems into which development agencies and researchers want to introduce improved technologies. Farmer surveys conducted in dryland and irrigation systems in Limpopo province of South Africa were used to describe the farming communities and identify factors that may affect adoption of improved crop production practices. Surveys involved 367 farmers in seven villages between 2000 and 2003. Surprisingly the incidence of mechanised cultivation was very high. Adoption of new technology in the form of Napier grass trap crops was significantly higher amongst farmers that relied only on farming as a source of income. There were no significant relationships between adoption of improved technologies and farmer age, off-farm income and cultivation methods. These factors are used to illustrate the complexity of agricultural systems and how certain aspects may affect and the role that certain farmer profiles may play in adoption/non-adoption of improved crop production strategies. It is concluded that there may be a lack of need and political will to develop strategies to improve crop production.

Key words: Habitat management, pest management, technology adoption, push-pull.

INTRODUCTION

Farming systems in southern Africa need to become more sustainable and productive to improve livelihoods of smallholder farmers. Improved crop production and irrigation practices form an integral part of the intervention proposals of the UN Millennium Project (Sachs et al., 2004) developed to achieve improved crop production.

The development of improved agricultural practices and the emphasis that various local and international development agencies as well as government agencies put on irrigation system and smallholder agricultural development necessitates a holistic approach to revitalisation of this important agricultural sector in the country. Productivity of subsistence agricultural systems and adoption of improved practices, which contributed to the Green Revolution in large parts of the developing world, may be adversely affected by various components of these farming systems. The failure of the Green Revolution in Africa has been ascribed to the application of new technologies within unsuitable (and often unstable)

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contexts (Hart, 2011), resulting in these improved technologies not being adopted or not being functional. For example, an extremely low number of young people are involved in farming and a large proportion of farmers are older than 60 years with limited farming experience (Bembridge, 1991; Kamara et al., 2001). Although increased age may not seriously impair managerial capability, a significant proportion of farmers may not have the physical ability for carrying out farming operations (Bembridge, 1991) and older farmers have also been reported to be more risk averse (Moscardi and de Janvry, 1977). Technology adoption for example may be affected by the level of off-farm income generation. Off-farm income has indeed been described as part and parcel of what it means to be a subsistence farmer in South Africa (Aliber and Hart, 2010). The adoption of improved technology seems to be influenced by many factors, ranging from environmental factors, farmer type and the methods used by extension agents, to socio-economics (Ndove et al., 2006). Despite the potential benefits of improved technologies such as fertilizer and hybrid seed, farmers are reluctant to invest in them because of high purchase costs (Ndove et al., 2006).

Improved crop production strategies require high levels of expertise from farmers and extensionists in order to be implemented effectively. Poor farmer practices have been shown to constrain performance resulting in low productivity (Crosby et al., 2000). The level of experience and knowledge of farmers regarding technologies such as hybrid seed, fertilizer, and pest management strategies that have been available for decades and which are often taken for granted by scientists and extension services are low. Experiences with poor production of African vegetables also showed that social and agroecological constraints could be improved if the extension services were changed. This could include the use of context specific and low-cost technologies to ensure that crop yields increase their contribution to household food security for resource-poor farmers in semi-arid areas (Hart, 2011).

Limited knowledge of new technologies such as hybrid seed and genetically modified (GM) maize (Assefa and Van den Berg, 2010) as well as lack of skills in crop production among farmers constrains crop production, especially in small holder irrigation systems (Machethe et al., 2004). Infrastructure developments often prove fruitless because human capital is not developed (De Lange et al., 2000). Human capital development and support in all areas of crop production is therefore important to increase agricultural productivity (Crosby et al., 2000; De Lange et al., 2000).

Small-scale farmers play a key role in research regarding improved agricultural practices. Given the complexity of resource-poor agriculture, the context in which it occurs cannot be meaningfully changed to meet the requirements of new technologies (Nederlof and Dangbe´gnon, 2007). Therefore, to be successful, innovations are needed in terms of the contexts in which they are to be applied. The importance of farmers' knowledge of their context is recognized and their involvement in the research and technology adaptation processes is crucial (Nederlof and Dangbe´gnon, 2007). However, in South Africa, acceptance of these two criteria has been rather slow within the public sector agricultural research and extension services (Mazibuko et al., 2008). It is therefore necessary to take cogniscence of their perceptions of specific constraints, their needs and priorities as well as general socio-economic factors prior to planning on-farm research projects. For example, integrated pest management (IPM) which is an important theme in this paper, is considered the most appropriate pest management strategy for smallholder farmers in Africa (Van Huis and Meerman, 1997) but smallholder agriculture has proved resistant to rapid, broad-based changes in this field (Anderson, 1992). A strategy of improved crop management resulting in increased yields and which provide economic incentives for IPM adoption was indicated to be the most likely driver of success in crop protection and adoption of improved crop production practices (Orr and Ritchie, 2004).

Several attempts at developing improved agricultural practices and to initiate research projects have been made during the past decade in the Limpopo province of South Africa. The cost of the improved practices, the extension methods, the age of the farmers and poor rainfall have emerged as the main factors determining adoption in this province (Nederlof and Dangbe´gnon, 2007) and even though several agricultural technologies have been introduced, adoption amongst smallholder farmers in Limpopo is limited (Sasa, 2009). Limpopo is the poorest province in South Africa (Eastwood et al., 2006) and shares borders and ecological zones with Botswana, Mozambique and Zimbabwe. About 80% of the people in the province live in rural areas and the proportion engaged in small-scale subsistence agriculture is very high (GTZ, 1999).

It was also indicated earlier that no coordinated on-farm research was conducted in the eastern part of the province during the 1980's and that some crop management recommendations were far beyond the means of farmers, resulting in limited adoption of recommended technologies (Khuvutlu and Laker, 1993). Very little information existed on farmers' perceptions of pests and actual on-farm pest infestation levels of important staple foods such as grain crops.

During 1998, the Limpopo province Department of Agriculture and Environment with the support of the German Technical Co-operation (GTZ) launched the project on Broadening Agricultural Services and Extension Delivery (BASED) to address the inadequacy of adaptive research and service delivery to smallholders. Its main goal was development of sustainable mixed farming systems involving interactions between crop and livestock systems and the enhancement of economic returns while sustaining food production (GTZ, 2000).

The BASED project was instrumental in initiation of the research on maize sorghum and groundnut in the province. In particular the habitat management strategies for maize stem borers are described subsequently. This habitat management strategy works through the use of selected gramineous and fodder plants that provide a diversionary strategy, whereby stem borers are repelled from the maize by an intercrop and are subsequently attracted to a discard or trap crop (Napier grass) around the field (a 'push-pull' strategy) (Khan et al., 2010) (www.push-pull.net).

The objective of this paper was to indicate the importance of farmer involvement in technology development as well as to collect information on socio-economic aspects and farming practices that could affect adoption of improved agricultural practices.

METHODOLOGY

Study area

Dryland crop production area

The survey was conducted in 2000 and involved questionnaires with farmers in three villages in the central region of the province. These villages were: GaMogano, GaThaba and Spitskop. The number of farmers that participated was 81, 105 and 102 for the three villages respectively. These numbers formed a significant proportion of the total number of households in each village (GTZ, 1999). In the former two villages, these numbers made up 11.6 and 20.5% of the total number of households per village. The total number of households was not determined for the Spitskop village. During the GTZ based project a total of 476 households (20%) were surveyed in two regions of the province (GTZ, 1999). Farmers that were part of village umbrella structures initiated by the GTZ-BASED, as well as farmers that were not part thereof was involved in the study. The questionnaire was discussed individually with farmers and socio-economic data as well as data on farming systems were collected. The questionnaire which focussed largely on farmer perceptions of crop pests also addressed questions regarding the farmer's age and sources of income. The rest of the questionnaire focused on the crops planted, farming practices and livestock production. Information collected on cropping systems, animal husbandry and crop pests are not reported here and only socio-economic aspects that could affect adoption of improved practices are discussed in this paper.

Irrigation area

The survey was conducted in four villages at the Tshiombo irrigation scheme situated in the Tshiombo valley, on the Mutale River. The total area at the irrigation scheme is about 1200 ha and consists of 930 plots, each approximately 1.2 ha in size. This irrigation scheme is typical of irrigation schemes in the Limpopo province. The single most important crop, in terms of area planted, is maize, the staple food, which accounts for 40 to 50% of total cultivated area (Lahiff, 1997). The approximately 900 plot-holders reside in six villages situated alongside the scheme (Lahiff, 1997).

The survey was done during 2003 and focused on general information regarding farmers and their farming systems. Farmers were randomly selected from each village (irrigation section) and individually interviewed, following a structured questionnaire slightly adapted from the one described above. Ten, twenty, thirty and twenty farmers were selected from Blocks 1, 2, 3 and 4, respectively. Block one was the smallest section of the irrigation scheme and therefore only 10 farmers were selected. One questionnaire had to be discarded bringing the total to 79 that were used in this part of the study. The questionnaire also addressed the use of Napier grass as forage crop since this species was introduced into the irrigation scheme as a trap crop for lepidopterous maize stem borers during 2003.

Data collection techniques

Farmer surveys were conducted in two ecologically different areas in the Limpopo province between 2000 and 2003 while pest management research was ongoing till 2008. The one survey involved three villages in the central district where dryland agriculture is practiced while the other involved a typical irrigation scheme in the northern area of the province. Surveys were conducted by the author assisted by Tshivenda and Sesotho speaking field staff and extension officers known to farmers in the villages at the Tshiombo irrigation scheme and the central district (dryland area) of the province respectively.

Data analysis

Questionnaire data were summarized in Excel and for all questions asked during interviews, the percentages calculated were based on the total number of farmers who responded to that particular question. The farmers that did not respond to a particular question were excluded from the calculation of percentage values for that question. When a farmer selected more than one answer or gave more than one method to a question, percentages were calculated for each group of similar answers.

Two-way tables with Chi square (X^2) tests were used to determine if there were significant relationships between adoption of new technologies such as hybrid seed and Napier grass at the irrigation scheme and farmer age, off-farm income and cultivation methods. Due to the very low number of farmers that were younger than 41 years, their numbers were included in the 41 to 50 years age category for the purpose of statistical analyses. For the same reason the two categories with lowest numbers describing land preparation techniques were combined. Data for these categories are however provided separately for each category. Chi square (X^2) tests were also used to determine if there were significant relationships between the ownership of animals and adoption of Napier grass. No statistical analyses of data from the dryland area were done.

RESULTS

Dryland area

A summary of biographic data is provided in Table 1. Seventy one percent of the respondents were female who also indicated that they were solely or largely responsible for farming activities. Seventy percent of the farmers were older than 51 years and a large proportion were older than 61 years (Table 1). Approximately 32% of farmers had less than five years experience in farming. The number of farmers that lived on-farm was low (0-7.8%). The homesteads of between 41 and 51% of

Table 1. Biographic data from survey in three villages in the central semi-arid area of the Limpopo province (April/May 2000).

Biographic information	**Village**			**Mean**
	GaMogano	**GaThaba**	**Spitskop**	
Number of participants	81	105	102	
	%	**%**	**%**	**%**
Male respondents	21.0	36.2	31.4	29.5
Female respondents	79.0	63.8	68.6	70.5
How many farmers belong to village umbrella body?	32.1	55.2	75.5	54.3
How many farmers are independent from umbrella body?	67.9	44.8	24.5	45.7
Age distribution categories (years)				
< 30	0.0	1.0	1.0	0.7
31-40	2.5	14.3	13.7	10.2
41-50	16.0	20.0	20.6	18.8
51-60	49.4	27.6	21.6	32.9
61 +	32.1	37.1	43.1	37.4
How long has respondent been actively farming? (years)				
< 5	37.0	26.7	32.4	32.0
5-10	4.9	10.5	7.8	7.7
11-15	8.6	9.5	9.8	9.3
16-20	11.1	11.4	5.9	9.5
21 +	38.3	41.9	44.1	41.4
What is the distance (km) between homestead and field?				
< 1	4.9	25.7	48.0	26.2
1-2	2.5	4.8	29.4	12.2
2-3	49.4	18.1	6.9	24.8
> 4	40.7	51.4	8.8	33.6
Location of individual farm				
Within larger block of farms	96.3	89.9	79.4	88.5
Farm isolated from others	3.7	10.1	20.6	11.5
Field size (ha)				
< 0.5	2.5	21.0	41.2	21.6
0.5-1.0	45.7	30.5	22.5	32.9
> 1.0	51.9	44.8	29.4	42.0
Proportion of homesteads on farm	2.5	0	7.8	3.4

farmers were more than 4 km away from their fields (Table 1) except for the Spitskop village where 77% lived within 2 km from fields. The majority of farmers' fields were located within larger blocks of fields, separated by footpaths or contours with indigenous grass vegetation. These larger blocks of fields were often fenced off to prevent animals from entering fields and damaging crops during the rainy season. Fields sizes were small with 54.5% of fields being smaller than 1 ha.

The incidence of farmers with cattle and goats was low (Table 2). At GaMogano and GaThaba 100% of the animals were free grazing during summer.

Because many individual fields were often not securely fenced, animals were kept away from crops during

Table 2. Animal husbandry and farm management practices in three villages in the central region of the Limpopo province (April/May 2000).

Farming practices		**Village**			**Mean**
		GaMogano	**GaThaba**	**Spitskop**	
Proportion of farmers owning animals (Actual number of farmers owning animals)		3.7(3)	13.3(14)	32.4(33)	16.5
How are animals kept in summer?	Free grazing	100.0	100.0	90.9	97.0
How are animals kept in winter?	Night in kraal	100.0	78.6	78.8	85.8
Are they fed in winter?	Yes	66.6	85.7	60.6	71.0
How many farmers plant OPV maize?		100.0	94.3	100.0	98.1
How many farmers plant maize hybrids?		0	1.9	3.9	1.9
How many farmers plant indigenous varieties?		42.0	39.0	43.1	41.4
How many farmers plant grain sorghum?		6.2	0.0	0.0	2.1
What is the source of seed that is planted?					
Buy annually		53.1	51.4	55.9	53.5
Keep seed		56.8	61.9	51.0	56.6
How many make use of tractor cultivation?					
Total		100.0	91.4	97.1	96.2
1 x per season		51.9	31.7	36.3	40.0
2 x per season		48.1	53.3	52.9	51.4
3 x per season		0.0	1.0	8.8	3.3
How do farmers plant the seed?					
Hand planting		100.0	90.5	66.7	85.7
Mechanical planter		0.0	9.5	33.3	14.3
How many farmers apply fertilizer?		84.0	80.0	92.2	85.4

summer. Animals were only brought back to homesteads during winter and kept in enclosures during the night. In Spitskop, 9% of farmers kept animals in enclosures during summer where they were fed with maize stalks, grass and other crop residues. At other villages all cattle were free grazing during summer.

The majority of farmers planted open pollinated varieties (OPV's) of maize, such as Kalahari and Border King (Table 2) and 53% of farmers annually bought new OPV seed, produced by commercial companies. A large proportion of farmers indicated that they also kept grain of the harvested crop to be used as seed during the following season. The majority of farmers made use of tractors for soil cultivation (Table 2). Mechanical cultivation of these fields were largely done in one process by a local contractor. Soil cultivation was then followed by hand-planting a few days after ploughing or with farmers walking behind the tractor. Only at Spitskop did a large proportion of farmers make use of tractor-drawn mechanical planters. Hoeing, done by hand, was the responsibility of the farmer who was often assisted by family members, especially during school holidays. Between 8 and 20% of farmers did not use fertilizers.

Approximately 78% of farmers practiced intercropping. Cowpea, dry beans, bambara groundnut and pumpkins were the most common intercrops with maize.

Irrigation area

A summary of biographic data is provided in Table 3. The majority of the farmers were female, even though the households were mainly male headed. Only 3.8% of farmers were younger than 40 years and 31.6% were older than 61 years. Compared to the dryland farming area, the majority of farmers lived within easy walking distance from their fields. Twenty eight percent depended solely on their farming activities for their income while 72% indicated that they received some form of off-farm income. As expected there was a significant ($p = 0.001$) relationship between age group and source of income. This is ascribed to the fact that a large proportion of

Table 3. Biographic data of farmers that participated in the survey at the Tshiombo irrigation scheme (2003 survey).

Number of participants	79
Male respondents	67%
Female respondents	33%
Gender involvement in farming activities	**Farmers (%)**
Female	53.0
Male	25.0
Male and female	22.0
Age distribution categories	
<30	1.3
31-40	2.5
41-50	34.2
51-60	30.4
>61	31.6
What is the distance between homesteads and fields?	
> 500 m	4.0
500 m - 1 km	64.0
1 - 2 km	27.0
2 - 3 km	5.0
What is the main source of household income?	
Pension	51.0
Farming	28.0
Farming and pension	13.0
Farming and employment	4.0
Non-agricultural	4.0
Field size (ha)	
1-2	81.0
2-3	14.0
>3	5.0
What land preparation techniques are used?	
Tractor	79.5
Hand and tractor	14.1
Animal traction and tractor	6.4
What is the source of seed for planting?	
Buy only new seed	97.5
Buy new and keep from harvest	2.5
Keep from harvest	0.0
What is maize stalks/stubble used for?	
Left on field	72.8
Making of compost	12.4
Used for animal feed	8.6
Burned	6.2

farmers (31.6%) were older than 61 years (Table 3) and that older farmers also tended to seek off-farm sources of income. Adoption of new technology in the form of the Napier grass trap was significantly ($p = 0.041$) higher amongst farmers that relied only on farming as a source of income.

A small group of farmers were also employed outside of agriculture. Most of the farms were between 1 and 2 ha. Cultivation was largely done by means of tractor-drawn ploughs, although animal draught power and hand cultivation was also used (Table 3). Mechanical soil cultivation was followed by hand-planting. There were no significant ($p>0.05$) relationships between adoption of improved cultivation technology (tractor cultivation) and farmer age or off-farm income. The majority of farmers bought hybrid seed from co-operative stores and a few planted seed saved from the previous harvest. Hybrid maize which was planted by most farmers was available at the local co-operative stores. The locally produced OPV (ZM521) was planted by 7.2% of farmers that were interviewed (data not shown). There were no significant ($p > 0.05$) relationships between age of farmers and adoption of improved technology in the form hybrid seed. Most farmers planted crops in long strip-plots formed by several adjacent small blocks of approximately 4 m long with 10 to 15 rows interspaced between 0.7 and 0.9 m. These small blocks facilitate flood irrigation. Only 29.5% of farmers indicated that they practiced intercropping. Intercropping in this regard does not refer to mixed cropping, but cultivation of small blocks varying in size (approximately 10-20 m long and 5-10 m long) of different crops adjacent to one another in the same strip plot. The crops most planted in order of importance are maize, groundnut, sweet potato and cabbage (Van der Walt, 2008).

Only 23% of farmers kept animals with cattle, goats and chickens being the most important (Table 4). During the summer, most of the cattle and goats were allowed to graze freely outside of cropping areas, while in the winter they were kept in enclosures close to homesteads where they were fed. The types of feed provided to animals are summarized in Table 4. The cut grass fed to cattle and draught-animals refers to Napier grass that was cut from contours planted as trap crop for stem borers. There were no significant ($p > 0.05$) relationships between age of farmers and adoption of Napier grass technology. The relationship between the adoption of Napier grass and use of crop residues (stubble) was nearly significant ($p = 0.05$).

DISCUSSION

In order to improve small scale farm productivity, the above mentioned aspects need to be addressed effectively and strategies developed to overcome these constraints. Improved productivity on small scale farms

Table 4. Animal husbandry practices and types of animals kept by farmers at the Tshiombo irrigation scheme (2003 survey).

Type of animals	Farmers (%)
Cattle	43.3
Chickens	30.0
Goat	16.7
Pigs	6.7
Donkeys	3.3
Where do farmers keep animals in summer?	
Free grazing	53.3
Kraal	46.7
Where do farmers keep animals in winter?	
Kraal	50.0
Free grazing but brought in at night	27.8
Free grazing	22.2
What do farmers feed their animals?	
Cut Napier grass (in kraal)	17.6
Free grazing	47.1
Residues of maize/sweet potato crop	23.5
Other (wheat bran, tree leaves, wild grass)	11.7

will only become a reality once the factors that could prohibit adoption of improved agricultural practices are identified and understood. It is essential to understand the interactions between system components when planning interventions such as introduction of new crop production strategies.

Certain farming practices, demographics and aspects of village life may affect development and adoption of pest and crop management technologies. While poor performance of smallholder irrigation schemes in South Africa has been attributed to socio-economic, political, climatic, edaphic and design factors (Bembridge, 2000); farmers who are on irrigation projects are more likely to be food secure than dry-land farmers (Oni et al., 2011). Farmer practices have however also contribute to poor performance and low yields on irrigation systems (Crosby et al., 2000). A study done in the Eastern Cape Province (Fanadzo et al., 2010) also indicated that poor crop management practices compromised yields achieved in several different crops grown in an irrigation system. Main limiting factors were reported to be poor weed, fertiliser and water management, low plant populations, poor cultivar selection and late planting (Fanadzo et al., 2010).

Socio-economic aspects that may affect adoption of improved crop production technologies

Age structures, farming experience and off-farm income

Several possible constraints to adoption of new technologies were highlighted in this study. Although there was no significant relationship between farmer age and adoption of technology at the irrigation scheme, various other factors are interrelated with the ages of farmers reported in this and other studies. While an extremely low number of young people were involved in farming, a large proportion of farmers were women older than 60 years which had limited farming experience. Similar results were reported in another region of the province where the average age of farmers was found to be between 53 and 61 years on different irrigation schemes (Kamara et al., 2001), with the oldest farmers around 90 years of age. Another study reported that 23% of farmers in the Vuwani district of the Limpopo province were older than 61 years and 31% had less than five years of farming experience (Mphinyane and Terblanché, 2005). Less experienced farmers were less inclined to use hybrid maize and that 69% of farmers had no knowledge of pest control methods on maize (Mphinyane and Terblanché, 2005). Similar observations on age structure of farming communities were made in the Eastern Cape region and it was concluded that although increased age may not seriously impair managerial capability but that physical ability for carrying out farming operations may become a limiting factor (Bembridge, 1991). Results from these surveys show that the profile of farmers is such that adoption of new strategies, especially high-input activities will be slow or none at all. For example, lack of farming experience and managerial capacity could lead to poor compliance to specific requirements associated with cultivation of GM crops, resulting in farmers loosing the benefits of this new technology (Assefa and Van den Berg, 2010). Furthermore, it has also been shown that older farmers tend to be more risk averse, which could affect their decision-making on adoption of new technology which they may see as high-risk and older farmers have also been reported to be more risk averse (Moscardi and de Janvry, 1977)

A further limitation to technology adoption may be the relatively high off-farm income contribution from sources outside of agriculture, which could influence the way that farmers approach the adoption of high input technologies. The significant relationship observed in this study between adoption of Napier grass as pest management tool (and source of forage) and reliance on farming as only source of income, indicates the significant role that off-farm income could play in non-adoption of new technologies. This finding is supported by the findings of Eastwood et al. (2006) and Sasa (2009). The low level of reliance on own-farm income may contribute to low adoption rates of technologies that result in increased complexity of farming systems and that are perceived to add to labour requirements. An example thereof is the planting and maintaining of Napier grass on contours as part of a pest management system (Van den Berg et al., 2001) and the addition of components such as dairy animals in order to attain a level that would make the system more productive and sustainable. Furthermore, developing and maintaining a niche market for forage produced as a “by-product” of a pest management strategy such as the stem borer habitat management system requires continuous high labour and managerial inputs. This lack of participation in the markets is a common feature of small-scale farming systems worldwide has also been identified as a constraint by Bie´nabe and Vermeulen (2011). Small farmers generally have low incomes and lack capital, and their attempts to market their products, is adversely affected by poor infrastructure and communication (Bie´nabe and Vermeulen, 2011).

High remittances might also influence whether or not farmers decide to join in contract farming ventures for extra benefits in terms of increased income (Anim, 2011). While irrigation systems were reported to be comparatively more profitable farming systems (Oni et al., 2011), it is significant to note that on such a small holder irrigation system (Thulamela, Limpopo Province), only 20% of the homesteads had a farmer livelihood type, meaning that they derived at least half of their income from agriculture. Other plot holders also farmed, but derived most of their income from sources other than farming (Van Averbeke et al., 2011). In South Africa the contribution of gross farm income on smallholder irrigation schemes to total homestead income range between 2.8 and 81.2% (Van Averbeke et al., 2011).

Off-farm income has also been shown to be an important factor affecting technology adoption in other countries. In Botswana there is frequent competition between off-farm wage employment and arable production as well as interactions between different components of cropping systems and between crop and livestock production (Edwards, 1993). Wage earners have a dramatic impact on crop production practices. It is well appreciated that many farmers in sub-Saharan Africa survive largely through remittances from family members working in industries unrelated to agriculture (Van Huis and Meerman, 1997). Wage earners remit money which can be used to hire tractors, while their absence may also result in labour shortages at critical periods during the production season (e.g. planting and weeding) (Edwards, 1993). The high incidence of tractor use reported in this study was also observed in KwaZulu-Natal (Lewu and Assefa, 2010) and it was pointed out that the high incidence of mechanical cultivation by small scale farmers may be unique to South Africa. Although a high level of mechanization by small scale farmers may be encouraging (Lewu and Assefa, 2010) it may also limit adoption of certain crop management strategies aimed at improving soil nutrient status, control of parasitic weeds and stem borer pests of maize and sorghum (Khan et al., 2010). For example, in this study high level of mechanization was directly responsible for discontinuation of certain components of the stem borer habitat management strategy introduced into farming systems in the Limpopo province. While off-farm income may on the one hand contribute positively to farm productivity through the financing of the renting of tractors for soil cultivation, the lack of finances to afford mechanization may have additional negative impacts on livelihoods of already poor farmers. For example, another study conducted in the Limpopo province showed that a significant number of farmers were elderly people experiencing low yields and high production costs due to hired labour or tractor services that they financed through their pension (Bie´nabe and Vermeulen, 2011).

An understanding of interactions between system components is therefore essential before planning interventions. In a study on adoption of farming practices in conservation farming systems (Düvel, 1990), it was shown that “needs are the cause of all adoption behavior and that most behavior can be deferred as goal-orientated”. Off-farm income, may therefore adversely affect the need for adoption of certain crop production practices. Low farm productivity and off-farm income are therefore inter-related. Poor farm productivity may result in abandonment of farming activities and subsequent total reliance on off-farm sources of income (Baiphethi and Jacobs, 2009). Due to low farm productivity in the Vhembe district of the Limpopo Province, many farmers are only involved in farming on a part time basis and have to generate off-farm income (Oni et al., 2010). The relevance of new or improved technologies to farmers and the need of the farmers to improve their situation are therefore important driving factors of adoption (Ndove et al., 2006). This observation is supported by evidence from this study which indicated that farmers that did not generate off-farm income were the ones that were inclined to adopt a technology that contributed towards pest management and also provided forage for cattle. Low adoption rates of new pest management and other technologies due to ineffective technology transfer but also socio-economic constraints such as lack of money to purchase hybrid seed and pesticides was also reported in Mozambique (Van den Oever and Segeren, 1989). Technology transfer generally proves ineffective for resource-poor farmers in harsh environments, often because the complexity of the ecological and social issues involved is greater than anything addressed by researchers (Richards, 1989).

Seed systems

While farmers in the dryland area indicated that they largely planted OPV’s of maize and kept back grain as seed for the next season, those at the irrigation scheme, nearly without exception, bought hybrid seed annually. While nearly all farmers at the irrigation scheme bought seed annually, a high incidence of OPV use was reported in the nearby Vuwani district where only 43% of farmers use hybrid maize seed (Mphinyane and Terblanché, 2005). This shows that farming practices can vary largely within small geographical areas. These results indicate that the most likely locations for introduction of advanced technologies such as new hybrids, GM maize and higher fertilizer rates would be irrigation schemes where farmers are used to buying hybrid seed and where the incidence of hold-back of grain for use as seed is low. This study also pointed out that the practice of holding back of seed, which is not allowed in the case of GM crops, is relatively common in certain small farming systems.

Integrated pest management

Experiences gained during pest management research, particularly on the stem borer habitat management system, provide insights into possible effects that farming systems may have on adoption of improved crop production practices. Although, the methods of data collection in this study does not allow for direct comparison between irrigation and dryland farming systems, a general tendency seems to show that differences in demographics, production constraints, farmer perceptions of pests as well as on-farm pest levels may contribute to non-adoption of the recommended pest management approaches in certain areas. In dryland areas where very few farmers showed interest in adopting the planting of Napier grass as trap crop, they lived far from fields, had few or no animals and cultivated their fields with tractor-drawn implements. These observations were made at the start of the project and no monitoring of adoption rates was subsequently done. Farmers at the villages where animal husbandry was not important did not express further interest in using Napier grass as pest management tool. On the other hand, in irrigation systems where farmers had access to resources, had more animals, lived closer to fields and perceived stem borers to be serious pests of maize, more farmers adopted the Napier grass technology.

In the dryland area, animal husbandry formed an important component of farming only at the Spitskop village. These animals were largely free grazing in summer but were kept in enclosures where they were fed during winter months. Because of the relative importance of animals in the Spitskop village compared to the other two villages, this locality was selected as an entry point for a habitat management system in which Napier grass was used (GTZ, 1999). Adoption rate until the end of the project was very low but during follow-up visits in 2010 it was observed that approximately 30% of farmers successfully used this grass as forage for cattle and goats (personal observations).

The high level of mechanization did not only affect adoption of the mentioned pest management strategy but also the spatial arrangement that farmers were willing to adopt for planting of Napier grass. Farmers were not willing to plant Napier grass as a barrier around fields but only planted it on contours between fields. The reason advanced for this was that it would prevent effective cultivation of fields by tractors and that it may also damage implements. The method of planting of Napier grass as barriers on all sides of the field as used in east Africa, was therefore adapted by farmers to the local farming system in which the use of tractors is common (Krüger, 2006).

Introducing the cut-and-carry of fodder which is common in east Africa, for example, may not be feasible in South Africa for families in which adults are often absent, working off-farm, or where they live long distances away from fields. Distance between homesteads and fields have also been reported to affect adoption of other technologies. For example, a study conducted in northern KwaZulu-Natal showed that fields situated far from homesteads received fewer inputs such as manure mainly because of labor shortages and lack of finances to pay for transport (Lewu and Assefa, 2010). Furthermore, the re-introduction of cattle into arable areas after harvest makes it difficult for individual farmers to adopt and manage fodder production practices since land is seen as communal and for anybody's cattle to graze on. Competition for labour and functional interactions between system components can lead to farmers implementing practices differently than what researchers would expect (Edwards, 1993). For example in certain areas in Botswana cattle are excluded from arable areas and are only brought back into these areas after harvest. The demarcation of land is therefore only seasonal and after harvest all available land is used for grazing. Most of the farmers in these areas practice mixed farming and crop production is only a component of a system in which livestock production and especially off-farm income are most important. The inter-relationships between livestock and cropping are multi-faceted and particularly tied to availability of labour (Anderson, 1992). Farmers therefore make decisions concerning allocation of resources between different activities according to the nature of the season and the circumstances of the individual household (Edwards, 1993). Attempts to improve on the status quo must take these interactions into account. In South Africa similar aspects have been pointed out by farmers who were involved in the pest management system which produces fodder as a by-product. Few farmers owned land that was fenced in and where Napier grass could be planted without the concern of cattle eating it. The lack of fencing has previously also been shown to have a negative effect on vegetable production since the absence thereof allowed animals to enter fields (Cairns and Lea, 1990). Factors such as damage caused by animals to crops (due to absence of fences) as well as high production costs and unpredictable yields cast doubt on the capacity of external intervention to promote changes among elderly people and substantially improve their farming systems (Bie´nabe and Vermeulen, 2011). These factors are important in any area where farmers adopt technologies such as trap crops that are valuable as forage and where no fences are present to keep animals out of fields.

Challenges to extension services

This study showed that the profile of farmers may affect adoption of new technologies. The level of experience and knowledge of farmers regarding technologies such as hybrid seed, fertilizer, and pest management strategies that have been available for decades and which are often taken for granted by scientists and extension services are low. The above mentioned types of pest management strategies would however require high levels of expertise from farmers and extensionists in order to be implemented effectively.

This study and others quoted herein do not only point out socio-economic factors that may affect adoption of new technologies, but also to the lack of efficient extension services in the region. Not only is a new paradigm needed for schooling of farmers, but also for training of extension personnel in basic technologies used in modern farming. One possible solution to address this problem amongst farmers is the adoption of an alternative extension paradigm such as farmer field schools. This approach has previously been advocated in the Limpopo region (Lewu and Assefa, 2010) as well as the rest of Africa (Van Huis and Meerman, 1997). Extension programs aimed at increasing knowledge have potential to increase adoption of technology (Sasa, 2009), and increased frequency of extension visits to impart information could result in increased productivity and income generation (Ackello-Ogutu, 2011). In addition education and extension training are essential for farmers to adopt new technologies (Oni et al., 2011).

Ultimately, adoption of technology by farmers as well as the political will to take on the responsibility of development is affected by need of farmers, extension services and politicians responsible for this task, since, as it was aptly put, “needs are the cause of all adoption behavior” (Düvel, 1990).

Successes will ultimately be determined by political will to create an enabling environment for small scale farmers to improve productivity. Government initiatives need to focus on improvement of all aspects related to these farming systems in order to improve rural livelihoods (Oni et al., 2010). Unfortunately the extent to which agricultural reform and revitalization of agricultural practice (the “green revolution”) is a priority in southern Africa, is limited (Ngomane, 2005). Similar to West Africa (Arokoyo, 1998), the poor performance of the agricultural sector in South Africa can be viewed as a system problem, which is prevalent within the research – extension – farmer – input system.

Conclusions

This study highlighted the lack of coordinated crop protection and crop production research in the region and that improved technologies cannot be introduced without prior involvement of farmers and understanding of the driving factors for adoption. It is *per sé* the farmers that need to implement the improved technologies, making it part of their daily practices. Many socio-economic factors and aspects of the daily livelihoods of farmers that affect adoption of improved agricultural practices throughout southern Africa have been listed and discussed in this paper. The main factors are the high age of farmers, high incidence of tractor use, access to land, high off-farm income and poor extension services.

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