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ADOPTION OF IRRIGATION TECHNOLOGY TO COMBAT HOUSEHOLD FOOD INSECURITY IN THE RESOURCE-CONSTRAINED FARMING SYSTEMS OF THE EASTERN CAPE PROVINCE, SOUTH AFRICA

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ABSTRACT

Sustainable water management has been identified as a powerful tool to combat persistent food insecurity in South Africa's poor rural communities. The irrigation revitalisation scheme was launched in the first decade of post-Apartheid South Africa and focused on smallholder farmers in the former homeland areas. However, the adoption of irrigation technology has been limited, while official data point to worsening poverty rates and food insecurity as agricultural output declines in the face of rising prices. There is thus strong policy interest to ascertain the circumstances in which irrigation adoption can be enhanced. A cross-sectional research design was utilised to collect data from 200 farmers (adopters and non-adopters) selected through a combination of purposive and stratified sampling methods. Probit regression results suggest that irrigation adoption is influenced by distance to the irrigation scheme, age of the farmer, family size, credit access, extension contact, and group membership. Water management programmes that address community access to irrigation water are likely to enhance adoption of irrigation technology, with credit access and extension provided to ensure sustainable use of the technology.

Keywords: Eastern Cape, Extension services, Food insecurity, Irrigation adoption, Smallholder farmers

1. INTRODUCTION

The South African National Water Policy (2013) is underpinned by three fundamental principles for managing water resources which include equity, environmental sustainability, and efficiency (Department of Water Affairs, 2013). According to the Department of Water Affairs (2013), the demand for water would have exceeded supply in Gauteng in 2013, and in the whole of South Africa by 2025. This implies that water use in agriculture needs to improve in order to preserve the resource which is fast declining in South Africa. Irrigation is an age-old means of increasing agricultural productivity. It expands the arable area, improves yield and increases cropping frequency, sometimes enabling two or three crops a year. South African smallholder irrigation schemes are multi-farmer irrigation projects larger than 5 ha in size that were either established in the former homelands or in resource-poor areas by black people or agencies assisting them (Van Averberke & Mohammed, 2006). However, most farmers on irrigation schemes still operate plots below 2.5 ha. In South Africa, 1.5% of the land is under irrigation and producing 30% of the crops in the country (Statistics South Africa, 2008).

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According to Backeberg and Sanewe (2006), approximately 1.3 million hectares are under irrigation with 0.1 million hectares being in the hands of smallholders. Gibb (2004) counted 287 smallholder irrigation schemes in South Africa covering between 46 000 ha and 49 500 ha. Denison and Manona (2007) found a total of 302 smallholder irrigation schemes in the country. Out of these, 90 schemes were non-operational, 206 schemes were operational, and 6 schemes could not be accounted for due to data limitations. Land under smallholder irrigation was held by approximately 31 000 farmers who constitute 15% of the total smallholder population. By comparison, 1.2 million hectares of irrigation schemes under large-scale commercial farmers are in the hands of about 28 350 farmers (Backeberg & Sanewe, 2006).

Smallholder farming plays an important role in the national economy of many countries, especially less developed ones. According to Delgado (1999), in sub-Saharan Africa, smallholder farming accounts for 70% of total employment, 40% of total merchandise exports, and 33% of gross domestic product (GDP). However, the erratic rainfall experienced by most regions implied the unreliability of rain-fed smallholder farming. Therefore, to alleviate the impact of droughts on crop production, irrigation was developed and adopted in many countries (Freeman & Silim, 2001). In Asia, investment in irrigation was a key ingredient of the Green Revolution which created conducive conditions for industrial and economic development (Turral, Svendsen & Faures, 2010). A similar development trajectory for South Africa and other parts of sub-Saharan Africa was seen as viable (Lipton, 1996). Irrigation can lead to a reduction in crop production risk and hence provides greater incentives to increase input use, increase crop yields, intensify crop production, and diversify into higher-valued crops. Consequently, the increase in marketable surplus and commercial activities has the potential to generate increased incomes for farmers (Asayehegn, Yirga & Rajan, 2011).

Recent research on small-scale irrigation schemes are now asking questions about how these schemes impact livelihoods. The schemes entail considerable investments of resources to improve the livelihoods of the poor. The emphasis of the United Nation's Millennium Development Goals (MDGs) of reducing poverty and improving livelihoods has often meant that considerable attention is paid to the outcomes without as much attention being paid to the extent to which the process might be constrained by availability of resources and even the nature of the resources at the disposal of the recipients of the support services under these schemes. The observed slow pace of the transformation in many contexts, and the fact that in many cases negative results have been realised, are forcing researchers to re-think the whole basis of the research and policy work that inform interventions. A major driver of this new thinking draws support from the theories on poverty and access to benefit from resources as elaborated by Sen (1981) as well as Ribot and Peluso (2003) to compel consideration of whether access to resources plays a crucial role in whether livelihood benefits are realised. There is now growing interest on sustainable management of the natural resource base of the community as well as their relationships and interactions with other resources and assets in the environment of the small farmer.

However, there is a concern that after more than two decades of implementing various reform measures, small-scale farming practiced in the former independent homelands remains virtually stagnant. Reasons for this are difficult to pinpoint in the quite crowded terrain of farmer support initiatives. In a study conducted in the Eastern Cape, Muchara (2011) observed instances of sub-optimal water utilisation regimes on irrigation schemes as well as individual plots, suggesting that the problem is not solely one of insufficient access. Since, among all the technologies on offer, irrigation is non-negotiable in the light of South Africa's semi-arid status, the present study zeroes in on this technology to ascertain the grounds on which farmers can step up productive water utilisation.

2. OBJECTIVES OF THE STUDY

In light of the foregoing, the objective of the study was to ascertain the circumstances in which irrigation technology adoption can be enhanced to combat household food insecurity in the Eastern Cape Province of South Africa. More specifically, the study aimed to:

1. Examine and describe the socio-economic factors of adopters and non-adopters in the study area.
2. Investigate factors affecting irrigation adoption by smallholder farmers.

3. MATERIALS AND METHODS

3.1 Study areas

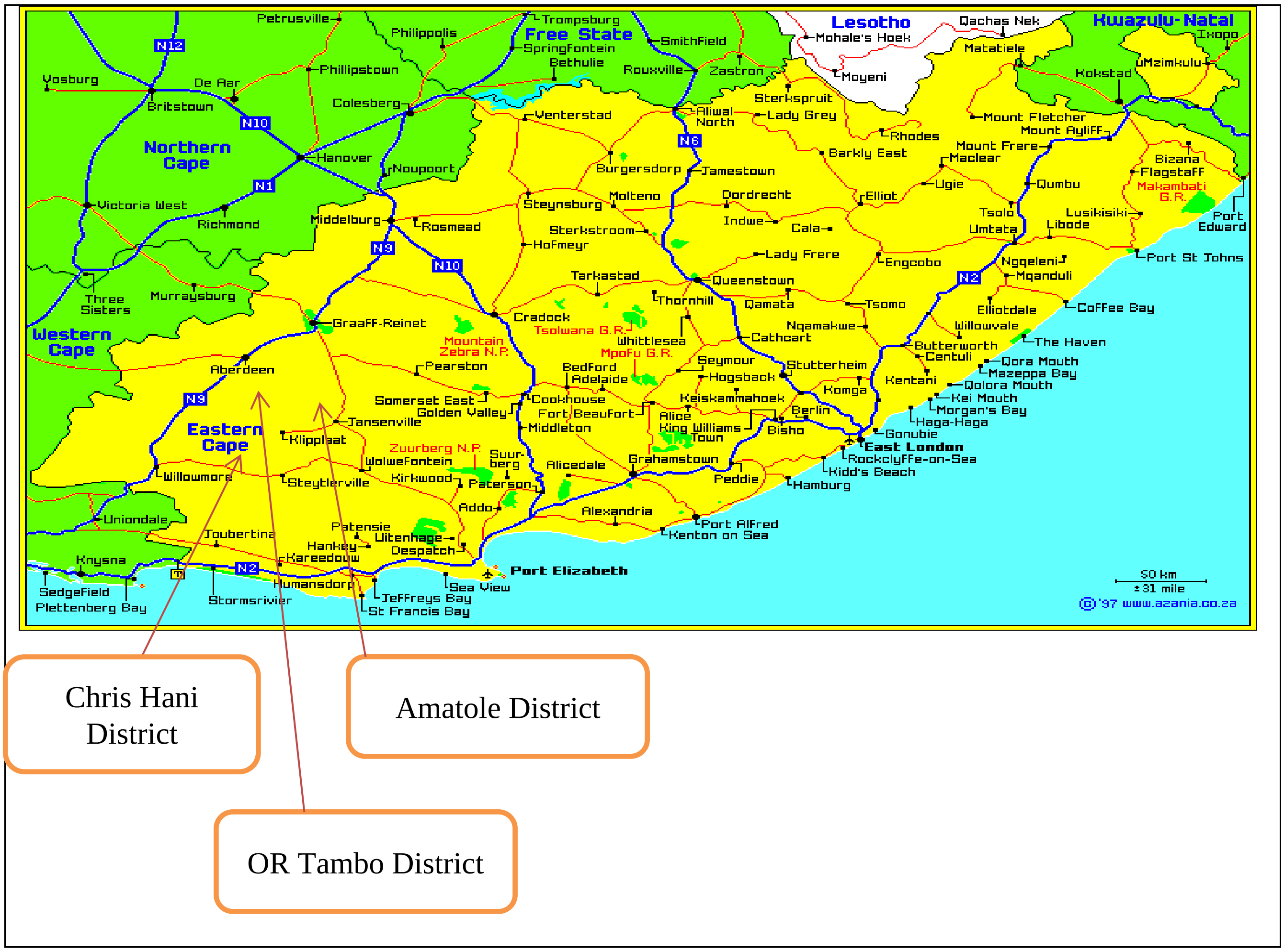

Figure 1: Map of the study areas
Source: Google maps, 2016

The Eastern Cape Province is easily poorest, the situation being worse in the former homelands of Transkei and Ciskei (Jacobs, 2010). The province's average poverty level was estimated at

74.9% in four districts which include O.R. Tambo, Alfred Nzo, Joe Gqabi and Chris Hani. Unemployment rate stood at 35% in 2016 and social grant recipients were substantial.

3.2 Irrigation schemes

3.2.1 Qamata irrigation scheme

Qamata irrigation scheme is located in Intsika Yethu Municipality, part of Chris Hani District in the Eastern Cape Province. In 1968, the construction of Lubisi dam was completed to serve Qamata irrigation scheme. Initially the scheme was divided into two portions, namely the individual food plots of 0.25 ha to 2.5 ha based on the size of land owned by the household before the establishment of the irrigation scheme. For each household that joined the scheme, their land tenure needed to be converted into communal land tenure systems administered by traditional leaders (Kodua-Agyekum, 2009). The second category of farmers was regarded as commercial farmers who owned land of more than 5 ha in size. In addition, a highly mechanised Lanti commercial farm was established on over 225 ha of land to create employment and generate income used to subsidize inputs for household food plots. The major crops grown on the Lanti commercial farm included maize, lucerne and cabbage. Lanti farm used a vertical integration approach, where most of the produce harvested was sorted, graded and carefully packed, ready to be sold in formal markets (Kodua-Agyekum, 2009). However, the scheme failed to realise its objectives of reducing poverty, increasing employment and improving the general livelihoods of farmers at the scheme (Kodua-Agyekum, 2009).

3.2.2 Tyefu irrigation scheme

Tyefu irrigation scheme is located 30 km in the western part of Peddi along banks of the lower Great Fish River in the Eastern Cape Province of South Africa (Sishuta, 2005). The scheme was using approximately 25 km of the Great Fish River waters that served five sections. These sections include Ndlambe, Pikoli, Ndwayana, Kaliken and Glenmore. In 1997, the scheme was reported to cover approximately 694 ha with a future potential of expansion to 1000 ha of irrigated land. The area is faced with multiple agricultural challenges which include intensive droughts, low soil fertility, irregular rain fall, poor water quality, high rates of evaporation, and extreme temperatures (Sishuta, 2005). Communities surrounding Tyefu irrigation scheme lack access to credit/ finance support and extension services, and are also challenged with poor infrastructures that limit movement of produce from farms to markets. Soil erosion and veld degradation makes land unsuitable for farming. Sishuta (2005) reported that Tyefu area has a potential of commercial crop production, though more suitable for extensive and semi-intensive livestock production. Large blocks of uncultivated farmland can be observed in Tyefu communities, and this may be due to the aforementioned challenges that are beyond farmers' control (Sishuta, 2005).

3.2.3 Ntshongweni irrigation scheme

Ntshongweni irrigation scheme is located in Qumbu of the O.R. Tambo District Municipality in the Eastern Cape Province of South Africa. Qumbu is a rural town which is 61 km north of Mthatha. The scheme was initiated in 2013 by the smallholder farmers of Ntshongweni rural community. The scheme is about 30 ha owned and managed by community villagers.

3.2.4 Pendu irrigation scheme

Pendu irrigation scheme is located in King Sabatha Dalindyebo Local Municipality in Mqanduli town. Mqanduli is situated about 30 km south of Mthatha. Pendu irrigation consists of 30 households farming on 58 ha for maize production. The scheme was initiated in 2013 by the Department of Agricultural Ministry under the leadership of Zoleka Chapa.

3.3 Research design

This study used a cross sectional survey design where data were collected at a single point in time. Qualitative and quantitative data were collected from the four irrigation schemes using a combination of methods such as a survey, focus groups and key informant interviews.

3.4 Sampling technique and sample size

A combination of purposive and stratified sampling techniques was used to select farmers in the study areas. The farmers were stratified into two strata, namely irrigation users and non-users. From each stratum, random sampling was conducted to obtain 100 irrigators and 100 non-irrigators. Data collection was done through structured surveys using a close-ended questionnaire. Since the number of household heads in the two groups is proportional, an equal number of participants was drawn from each group, in other words, 100 household heads were selected from each group. In total, 200 household heads were interviewed.

3.5 Empirical model for irrigation adoption

Production risk factors are important in household decisions to adopt irrigation. This is because farmers in low income countries are risk averse (Dercon, 2004). The probit regression model was chosen as there is no rule compelling the choice of models (Gujarati, 2004). The general formula for the probit regression model is specified as:

$$Y_i = \alpha_0 + \alpha_1 x_i + \alpha_2 x_i + \alpha_3 x_i + \alpha_4 x_i + \alpha_n x_n + \varepsilon \quad \text{……………………………………………..….(1)}$$

Where, $\varepsilon \sim N(0, 1)$

Y_i is the dependent variable, is equal to one when a farmer adopted irrigation during 2014-2015 period, and equal to zero if the farmer did not. The constant or intercept term is depicted by α_0 while $\alpha_1, \alpha_2, \alpha_3,, \alpha_4$ and…….. α_n represent the parameters to be estimated and ε is the stochastic disturbance term. The probit regression model adds the condition of normally distributed variables that can be specified as:

$$P\left(Y = \frac{1}{X}\right) = F(Ii) = \frac{1}{\sqrt{2\pi}} \int_{\alpha}^{Ji} e^{\frac{-z^2}{2}} dz \quad \text{…………………………………………………………(2)}$$

Where,

$I_i = \alpha_0 + \alpha_1 x_i$ ……………………………….+ $\alpha_n x_n$ = utility index (latent variable), $P\left(Y = \frac{1}{X}\right)$ = the probability of irrigation adoption; Z = the standard normal variable, and F is the standard normal CDF. Gujarati (2004) explains the behaviour of a dichotomous dependent variable as we need to use a suitable Cumulative distribution function (CDF). The independent variables that condition of adoption behaviour are age, gender, level of education, household size, farm

size, off farm income, access to extension services, access to credit, primary occupation, member of a group, and distance to irrigation scheme.
3.5.1 Definition of variables and hypotheses

In this study, adoption of irrigation technology is the dependent variable calibrated as a binary response that is coded 1 if a farmer adopts and 0 otherwise. It is assumed that the household's behaviour is explained by different demographic, socio-economic and institutional factors. Variables explain adoption behaviour, how calibrated/ defined, and hypothesized relationship with dependent variable are presented in Table 1.

Table 1: Variables included in the model

Variables	Definition	Hypothesized Sign
Age (X_1)	Actual number of years	+
Gender (X_2)	Gender of the farming household head (Male =1, Female = 0)	+/-
Marital status (X_3)	Marital status of the farming household head (Single = 1, Married = 2, Divorced = 3, Widowed = 4)	+
Number of years spent at school (X_4)	Education level of the farming household head	+
Household size (X_5)	Number of persons	+
Farm size (X_6)	Number in hectares	
Other groups' membership (X_7)	Member of community club (Yes = 1, No = 2)	+
Credit accessibility (X_8)	(Yes = 1, No = 0)	+
Distance to the irrigation scheme (X_9)	(Number in km)	-
Contact with extension officers (X_{11})	Actual number of visits	+
Income from off/ non-farm activities (X_{12})	Amount in Rands (R)	+

4. RESULTS AND DISCUSSION

Descriptive statistics of the variables and the estimation results of the probit regression are presented to yield insights on the factors that influence the decision to adopt irrigation schemes.

4.1 Demographic and socio-economic status of farmers

Adopters were classified as farmers who were members of irrigation schemes and non-adopters are those who were not members of irrigation schemes during the years 2014 and 2015. The results show that 63% of the households were male headed. The average age was 60 years and there were no significant differences between the two groups in respect to age. The average household size was five persons. Education level of the household head was expressed as the number of years of schooling. The results indicated that the average number of years of schooling for the farmers in the sample was 7.25 years and there was no difference between

the two groups. The average farming experience was 10.5 years. Adopters had more farming experience (11 years) than their counterparts (10 years).
There were significant differences in terms of access to credit between adopters and non-adopters. For example, the proportion of farmers reported to have access to credit in 2014/15 was significantly higher among adopters (30.3%) than among non-adopters (16.2%). The results also indicated that 47% of farmers were members of rural/ farmer associations. However, a significantly larger proportion of adopters (63%) were members compared to 32% for non-adopters.

The pooled data shows that only 19.6% of the respondents in the study area accessed extension. This result suggests that respondents in the study area had difficulty in accessing government extension services and this might have a significant adverse impact on improving their level of production. It was also observed that irrigators had higher household off-farm incomes of R2 944 than for non-irrigators at R2 345.

Table 2: Demographic, institutional and socio-economic characteristics of members

Variable	**Description**	**Adopters**	**Non-Adopters**	**Overall sample**
		Mean Value	Mean Value	Average Mean
Age	Years	62	58	60
Household size	Number of persons	5.8	4.17	4.99
Level of education	Years in school	7.3	7.2	7.25
Farming experience	Years in farming	11	10	10.5
Off-farm income	In Rands	2944.50	2345.79	2645.145
		Percentage (%)	**Percentage (%)**	**Overall sample**
Gender	Male	66	59	63
	Female	34	41	37
Access to credit	Yes	30.3	16.2	23.25
	No	69.7	83.8	76.75
Contact with extension	Yes	18.9	20.3	19.6
	No	81.1	79.7	80.4
Member of society group	Yes	63	32	47.5
	No	37	68	52.5
Farmers perception about irrigation	Positive	98	28	63
	Negative	2	72	37
Farmers attitude towards irrigation	Good	82	20	51
	Bad	18	80	49

Source: Field survey, 2015

From the discussions, the two groups of farmers had mixed perceptions with regards to irrigation schemes. For instance, 98% of adopters agreed that irrigation was good compared to

28% of non-adopters. Furthermore, the focus group discussions indicated that the adoption group unanimously accepted the need of irrigation to supplement rainfed agriculture. Adopting farmers had a positive attitude towards new technologies with the majority (82%) being first-time adopters. Only 18% had never applied the technology in the three years preceding the study. However, for non-adopters, only 20% indicated that they had adopted some of the technology, while as much as 80% had never adopted any technology, including irrigation technology.

4.2 Modelling irrigation adoption decision

The variables included in the model are age of the household head, gender of the household head, years of schooling, marital status, household size, farming experience, size of cultivated land, perceived land quality, mode of acquiring land, member of another community organisation, distance to the scheme, legibility to participate in scheme, access to extension services, access to market, and access to credit. The probit model was estimated to determine the household characteristics and resource endowments that affect farmers' adoption of irrigation technology. The results indicate that collectively, all estimated coefficients are statistically significant since the LR statistic has a *p*-value less than 1%. The pseudo R value is 61% which is high for cross sectional data. The model also correctly predicted about 81% of the cases, confirming that the model fits the data well.

Table 3: Determinants of irrigation adoption decision

Variables	Coefficients	Standard Error	Z	P>|z|
Constant	-1.003	2.309	0.367	0.664
Gender of HH head	-0.599	0.659	0.549	0.363
Age of HH head	0.048	0.022	1.050	0.031**
Level of education	0.092	0.077	1.097	0.232
Household size	0.123	0.111	1.131	0.267
Farming experience	0.045	0.057	1.046	0.426
Farm size (Ha)	0.015	0.199	1.015	0.942
Access to extension	0.677	1.666	1.968	0.684
Member of club	-4.250	1.687	70.117	0.012**
Access to credit	0.959	0.592	2.610	0.105*
Access to market	1.078	0.899	2.940	0.130*
Distance to the scheme	-0.341	0.067	0.711	0.000***
Probit model		Number of Observ =		200
		Prob > Chi^2 =		0.000
Log likelihood = 88.961		Pseudo R^2 =		0.813

Note: ***, ** and * means significant at 1%, 5% and 10% levels, respectively.
Source: Results from SPSS (Version 20) generated from field survey, 2015

The estimates indicate that age of the household head significantly influenced adoption at the 5% level, suggesting that an increase in age leads to a possible 3% increase in irrigation adoption. These results closely mirror Daniel (2011) and Salome and Rotimi (2013) who established that age was significant in the household head decision to adopt new technologies.

On the contrary, a study by Mattee and Gebreyes (2013) indicated that younger household heads are more innovative in terms of technology participation and are more likely to take risks than older household heads.

Access to credit had a positive and statistically significant effect on adoption at the 10% significance level, suggesting that farmers who could easily access credit have a greater likelihood of adopting. Access to credit support ensures that farmers can secure inputs in time, resulting in increased farm income. Adoption of irrigation technology is also associated with the use of a range of complementary inputs that are sourced through the market. Machete *et al* (2004) suggest that one of the most critical problems threatening the viability of irrigation is the lack of credit to meet the additional cash obligations of technology adopting farmers. The results agree with the findings of Daniel (2011) that access to credit plays an important role in improving household livelihoods.

Distance to irrigation schemes significantly influences the decision to adopt. However, the relationship is negative, which means that the further the households are from the scheme, the less likely they are to participate as compared to households that are located within a close proximity. As the distance from a scheme increases by one kilometre, household participation declines. In this study, results suggest that a decline in participation of up to 34% can be observed. In contrast, Asayehegn *et al* (2011) found that distance had no impact on participation in Ethiopia.

Moreover, membership of farmer groups had a significantly negative effect on adoption. The decision to adopt irrigation by households who are members of other community groups was less. This is an important finding considering the infrastructure situation in many communities and the fact that most schemes are known to draw clientele from residents in their immediate vicinities while the rest of the communities are virtually isolated. A scheme in the neighbourhood has a demonstration effect which will produce positive responses from farmers.

5. CONCLUSION AND RECOMMENDATIONS

Smallholder farmers in the Eastern Cape could potentially contribute to economic growth and development, but this depends crucially on the extent of technology use, among other factors. The revitalisation of small-scale irrigation schemes undertaken early in the reform era was expected to enhance agricultural production, yet adoption of the technology has been limited which is probably due to a range of institutional, technical and socio-economic constraints. The finding that distance to irrigation schemes negatively influences adoption of irrigation technology is an important one. At one level, it reflects the infrastructure profile of much of the rural Eastern Cape where locational constraints are sometimes severe to the point of communities being isolated and virtually excluded from civilisation. At another level, it is one factor that is amenable to policy intervention since it is possible to do something about where a scheme is located. Furthermore, the distance to a scheme will affect other factors, particularly extension access as well as credit access, both of which individually and collectively have important practical implications for technology adoption. As the current debate on agricultural restructuring rages, it is important to pay attention to these relationships to the extent that technology adoption is crucial to the agricultural transformation process and is crucial to the attainment of food security and improvement of rural livelihoods through poverty reduction.

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