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Stella Matere. Busienei, J.R and Mbatia, O.L.E

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ADOPTION AND IMPACT OF IMPROVED PIGEON PEAS ON FARMING HOUSEHOLD POVERTY IN SEMI-ARID SOUTH EAST KENYA

[1*]Matere, S.J
University of Nairobi, Department of Agricultural Economics, Kenya
Kenya Agricultural and Livestock Research Organization, Kenya
Corresponding author E-mail:stellamatere@gmail.com

[2]Busienei, J.R
University of Nairobi, Department of Agricultural Economics, Kenya

[3]Mbatia, O.L.E
University of Nairobi, Department of Agricultural Economics, Kenya

Abstract

Purpose: The purpose of the study was to assess the factors influencing adoption of improved pigeon peas in semi-arid South Eastern Kenya and to evaluate the impact of adoption on households' poverty.

Methodology: The study used cross sectional data gathered through household survey to establish the factors influencing improved pigeon pea adoption. Propensity score matching approach was further used to assess the impact of adoption on households' poverty.

Findings: The results show that farmers' access to improved pigeon pea seed, contact with agricultural extension service providers and access to market information significantly influenced adoption ($p< 0.001$). Adopters and non-adopters got an average net farm income of Kenya shillings (KES) 29,570 and 21, 490 per acre per year respectively. Adoption of improved pigeon peas resulted in a decrease of head count poverty by 0.24% and a reduction of poverty gap and poverty severity by 0.30% and 0.20 % respectively.

Contribution to theory, practice and policy: The study recommends that both National and County Government make policies that create enabling environment for private sector participation in production of certified seed to improve farmers' access to improved seed to augment production. Facilitating farmers' improved access to reliable and timely market information will increase production of marketable surplus of the peas that are adaptable to semi-arid areas, increase fall income and contribute to reduction of rural poverty.

Keywords: *Household poverty, pigeon pea, semi-arid areas*

1.0 INTRODUCTION

South Eastern Kenya region is dominated by smallholder farmers experiencing high poverty level emanating from low agricultural production (GoK, 2015; Wambua *et al*., 2017). Pigeon pea (*Cajanus cajan)* is a dryland crop that is well adapted to low rainfall patterns and thrives in low fertility soils. The crop thrives in hot dry environments, its drought tolerance and ability to utilize residual moisture during the dry season making it important in the semi-arid tropics. The crop not only produces edible peas that can be consumed both fresh and dry and nutritious fodder for livestock, its woody stems can be used as fuelwood (GoK, 2015).

Poverty is one of the prime hindrances to human development and economic growth (FAO, 2019). It exposes people to social vulnerability. Most of the poor in the world live in rural areas and depend on agriculture for their income and food security. Climate change is causing serious damage to agriculture all around the world (IPCC, 2018). Agriculture in Sub-Saharan Africa is affected by extreme climate events like droughts and floods, reduced growing seasons, drying and degradation of the soils, increased pest and disease incidence and shifts in suitable areas for growing crops than before which reduces crop yields (Lipper *et al.*, 2014). The resource-poor, rural households located in arid and semi-arid areas are directly experiencing a high decline in incomes due to climate change (Ahmed *et al*, 2014). The IPCC (2014, 2018) emphasizes the importance of agricultural adaptation to climate change to minimize the adverse effects and exploit any benefits brought about by the changes. The Sustainable Development Goal-1 and 2 pay attention to fight poverty, hunger and malnutrition and recognizes tackling climate change as key for lifting people out of poverty.

According to the Kenya Integrated Household Budget Survey 2015/2016, the national poverty headcount rate for individuals was 36.1 percent (KNBS, 2018). The overall poverty rate in rural areas was 40.1 percent compared to 29.4 per cent in core-urban areas. The overall Poverty refers to households and individuals whose monthly adult equivalent total consumption expenditure (that include both food and non-food expenditure) per person was less than Kenya shillings (KES) 3,252 in rural areas, and less than KES 5,995 in core-urban areas. The national food poverty headcount rate in 2015/16 was 32.0 percent. The food poor were unable to consume the minimum daily calorific requirement of 2,250 Kilocalories (Kcal) as per expenditures on food (FAO, 2004). The food poverty rates in rural and core-urban areas was 35.8 percent and 24.4 percent respectively. Food Poverty refers to households and individuals whose monthly adult equivalent food consumption expenditure per person was less than KES 1,954 and KES 2,551 in rural areas and core-urban areas respectively.

About 83 percent of Kenya is semi-arid and continuous population growth against limiting high potential arable land has led to increased cultivation into the water-stressed areas (UNDP, 2018). The semi-arid areas receive erratic rainfall with variation in onset, intensity and cessation which perennially affects agricultural production and farm income (Gichangi *et al.*, 2015). Most farmers in such areas rely on rain-fed agriculture for their livelihood, however, their farming is characterized by low agricultural productivity that is induced by use of poor quality seeds, limited use of soil fertility enhancing inputs, dependent on low and erratic rainfall (Kwena *et al.*, 2018) which aggravates household poverty. This makes the enhanced farm productivity crucial to ease household poverty.

About 36% of the population in South Eastern Kenya is estimated to be below the poverty line, with majority of the poor living in rural areas, where agriculture is the main source of livelihood. The area is largely semi-arid with a predominant smallholder, rain-fed agricultural production system. Farming is perennially constraint by low and erratic rainfall, low soil fertility and use of poor seeds that result in low yields which aggravates the poverty. Improved pigeon pea varieties were developed and disseminated in South Eastern Kenya to increase productivity and reduce household poverty. However, there is paucity of information on impact of its adoption on household poverty (Gichangi *et al.*, 2015).

Pigeon pea (*Cajanus cajan (L.) Willsp*) is the third most important grain legume worldwide (FAOSTAT, 2019). In Africa, it is grown in more than 33 countries with Malawi leading in production (434,792t), Tanzania 107 (315,837t), Kenya (85, 684t) and Uganda (11,047t) per year. Kenya is ranked the fifth (2.1%) after India 62.7%, Myanmar (21.3%), Malawi (6%) and Tanzania (4.9%) The crop is one of the major staple crops grown in semi-arid of Kenya, it accounts for 67% of the total production in the country (GoK, 2015). USAID (2010) indicated that among the semi-arid districts in South Eastern Kenya, Machakos accounts for about 33 per cent of total national production; Makueni (25 per cent) and Kitui (22 per cent). Nearly 35.5 percent of the population in South Eastern Kenya (SEK) live below the poverty line (KNBS, 2018). Pigeon pea is a leguminous crop with several benefits to the rural poor. It is important for food security, the main food products of the crop are dry grain and green pods produced for both subsistence and sale (Mergeai *et al.* 2001; Shiferaw *et al.*, 2008). The seeds are highly nutritious, mature seeds contain 18.8percent protein, 53percent starch, 2.3percent fat, 6.6percent crude fiber and 250.3 mg per100g minerals (Saxena *et al*., 2010). Biomass from the foliage is used as livestock fodder while the stems are used as fuel wood, the roots fix nitrogen into the soil and release soil-bound phosphorus, thus ameliorating the nitrogen and phosphorus deficiencies that typify most soils in the dry areas in Kenya (Kimiti *et al.*, 2009; Odeny, 2007).

Problem statement

To improve the production of pigeon peas, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kenya Agricultural Research Institute (KARI) currently the Kenya Agricultural and Livestock Research Organization, Winrock International and the University of Nairobi jointly developed improved varieties. The varieties have high-yielding, drought-tolerance and disease resistance traits. Several improved varieties were released and promoted for public production, hinged on the premise that its adoption would increase productivity, improve food security and farm-income in semi-arid areas of Kenya. Despite the seed intervention, limited use of improved varieties is predominant among smallholders (Wambua *et al.,* 2017). Improved early-maturing, drought and disease tolerant, high-yielding pigeon peas were promoted to increase productivity and farmers wellbeing. However, the adoption is low and there is a knowledge gap on impact of adopting the improved pigeon pea varieties on household poverty in the smallholder farming systems.

The annual population growth rate is estimated at 2% in Machakos, 2.35% in Makueni and 2.1% in Kitui counties (KNBS, 2015). Households in Machakos, Makueni and Kitui Counties spent 52.1 %, 59.6% and 62.5% of their total income on food (KNBS, 2018). The population growth means that the composition of children in households is increasing which necessitates efforts to increase food production to meet nutritional needs for the growing population and increase income to cater for other household needs. This justifies need for analysis of adoption of agricultural technologies that increase food supply and income to contribute to alleviation household poverty.

2.0 METHODOLOGY

The study was conducted in South Eastern Kenya region that is made up of Machakos, Makueni and Kitui Counties. Pigeon pea is one of the major staple crops, it is the second most produced legume in the region after the common bean. The study purposively focused on semi-arid zone producing pigeon pea namely: Masinga, Kibwezi West and Kitui South Sub-counties. Primary data was gathered through a semi structured questionnaire. A combination of multi-stage and simple random sampling techniques were used to determine the sample households. A total of 336 farmers were interviewed.

A binary logit model was used to assess the determinant of adoption. Following Greene (2012) Logit model was based on cumulative logit probability function. The logit distribution function of the adoption was specified as:

$$P_i = \frac{1}{(1+ e^{-z_i})} = \frac{e^{z_i}}{(1+e^{z_i})} \quad (1)$$

where: P_i is the probability that the *i*th household will adopt improved pigeon pea varieties which is a binary variable taking the value of 1 for adopters and 0 for non-adopters. The ratio of the probability of adopting to not adopting (odds ratio) was defined by:

$\frac{P_i}{1-P_i} = \frac{1+e^{zi}}{1+e^{zi}} = e^{zi}$, taking the natural log gives:

$$Z_i = In\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + U_t \quad (2)$$

Where $z_i$is a function of n-explanatory variablesX_i which are expressed as:

$$Z_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + U_t.$$

$Z_i$is *ith* value of the dependent variable and $X_i$is the ith value of the independent variable which can be a dummy or a continuous variable. Household, *i* = 1, 2,…. n, are observations on variables for the adoption model and *n* being the number of explanatory variables used in the study.β_0 is an intercept andβ_i are unknown parameters to be estimated in the adoption model. U_t is unobserved error term.

Following Foster (2005) poverty was computed as:

$$P_v = \frac{1}{N} \sum_{i=1}^{N} \left[\frac{Gp_i}{z}\right]^v \quad (3)$$

where : *Pv* is the poverty measure , *N* represents the total number of households, *z* is poverty line. The poverty gap for individual *i* is $Gp_i= z - y_i$ with $Gp_i= 0$ when, $y_i > z$. $y_i$is the expenditure of household *i*. The different measures of poverty were v; (v = 0, 1, and 2) that show the varying range of inequality among the poor. The study evaluated v = 0,1,2 with P_0 as the poverty head count reflecting the percentage of households with household below the poverty line. The poverty line was set at US $1.90 per adult equivalent expenditure per day which was equivalent to KES 5,700 per month. The poverty gap was represented by P_{v1} which is the extent to which an individual falls below the poverty line and P_{v2} is the poverty severity which represents the weighted sum of poverty gaps. For all $v > 0$, the measure shows a decline in living standard that implies that the higher one's standard of living, the lesser the poor one is deemed to be.

Propensity scores and matching algorithm approaches were used to calculate the causal effect. A propensity score was defined as the probability of a farming household adopting improved pigeon peas based on observed characteristics. The nearest neighbor matching method was adopted. The impact of adoption on poverty was estimated by the Average Treatment of the Treated (ATT) approach using matching of the adopting and non-adopting units. The matching was based on two assumptions that selection into adopting group was solely based on observable characteristics and that there was an overlap of observable characteristics between the adopters and non-adopters in the sample. The conditional probability that the *i*th individual will adopt improved pigeon pea conditional on observed characteristics (x_i) was defined by the propensity score, $P(x_i)$and expressed as:

$P(x_i)=P(A_i=1|(x_i))$………………………………………………………………………….. (4)

Where A_i=1 is when the *i*th individual adopts while A_i=0 means no adoption.

Following Rosenbaum and Rubin (1983) the Average Treatment Effect on the Treated (ATT), which is the average gain from adoption for individuals who actually adopted is expressed as:

$ATT = E\left(y_{1i} - y_{01}\middle|p(x_i)\right) = E(y_{1i}|p(x_i), A_i = 1) - E(y_{0i}|p(x_i), A_i = 0)$……………..(5)

$ATT = E\ (y_{1i}|A_i=1) - (y_{0i}|A_i=1)$, where $E\ (y_{1i}|A_i=1)$ represents the average outcome of adoption in terms of poverty reduction as observed in survey data while $E\ (y_{0i}|A_i=1)$ is the average outcome of adoption had the farmer not adopted. The nearest neighbour matching method was use

3.0 RESULTS AND DISCUSSIONS

Table 1 provides information on the types of pigeon peas grown in the study area.

Table 1: Pigeon pea varieties grown

Variety	n=336	Percentage responses
Improved peas	104	31
KARI Mbaazi 1	95	28
KAT60/8	51	15
ICEAP 00557	51	13
ICEAP 00554	34	10
KARI mbaazi2	30	09
ICEAP00777	17	05
Indigenous varieties	286	85
Did not grow the peas	11	3.3

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Thirty one percent of the respondents grew improved pigeon peas. About 28 percent of the households grew KARI mbaazi1 variety (Table 1). The results also revealed that between 10-15percent of the farmers grew KAT60/8, ICEAP 00557 and ICEAP 00554. The least grown were KARI mbaazi2 and ICEAP00777 varieties. KARI mbaazi1 was the most produced relative to other varieties which could be attributed to their early maturing and high yielding attributes. The KAT60/8, ICEAP 00557 and ICEAP 00554 are medium maturing while the low adoption rates of KARI Mbaazi2 and ICEAP00777 varieties could be due to their long maturing of 8-9 months. Majority of the farmers (85percent) grew the indigenous varieties and a meagre 3percent did not grow any pigeon pea on their farms. The adoption of improved pigeon pea was not mutually exclusive as some farmers grew more than one improved varieties.

Results in Table 2 presents the factors determining the growing of improved pigeon peas. The overall regression Prob > chi square= 0.000 indicates that several explanatory variables significantly influenced adoption. The Pseudo R square =0.5344 suggests a good explanatory power of the independent variables.

Table 2. Factors influencing farmers' adoption of improved pigeon pea

Variable of household head	Odds Ratio	Std. Err.	z	P>z
Gender	0.776	0.300	-0.65	0.513
Education	1.560	0.276	0.81	0.112
Experience	1.031	0.014	2.30	**0.021**
Household size	1.462	0.127	4.37	**0.000**
Non-farm income	1.248	0.428	0.65	0.518
Farm size	0.726	0.234	-0.72	0.401
Own land cultivated	1.199	1.101	0.84	0.386
Access agric extension services	2.155	0.679	2.44	**0.010**
Access to improved seed	2.703	0.867	3.10	**0.002**
Access credit for farming	1.092	0.209	0.47	0.642
Perceives adaptation	1.872	0.519	2.26	**0.024**
Access climate information	7.978	2.729	6.07	**0.000**
Member of farmers association	3.435	1.165	3.64	**0.000**

n= 336, LR chi square= 310.26, Prob > chi square= 0.000, Pseudo R square =0.5344,

Log likelihood= -135.155, significant variable bold P>z

Table 2 shows that years of farming experience of the household head significantly (5 percent level) influenced adoption of improved pigeon peas. Farming experience was a continuous variable in the regression, measured as the number of years of the farming experience of the household head. Other variables that significantly influenced the adoption were: household size, household access to agricultural extension services, improved pigeon pea seed and climate information and household head's membership in farmers association that were significant at 1 percent level. Household head's perception of production of the improved pigeon peas as an adaptation strategy to climate change significantly influenced adoption at 5 percent level.

Table 3: Impact of adopting improved pigeon pea on household poverty

Outcome	Mean outcome		ATT
	Adopters	Non-Adopters	
Net farm income	29,570	21,490	8,080* (938.6)
Head count poverty	53.07	53.33	-0.263 (0.156)
Poverty depth	5.47	5.83	-0.363 (0.196)
Poverty severity	2.47	2.7	-0.23 (0.095)

T-statistics in parenthesis

The results in Table 3 revealed that the adopters got KES8, 080 per acre per year more than the non-adopters. About 53.07% and 53.33% of adopters and non-adopters of improved pigeon pea respectively were below the poverty line. This means that non-adopters were 0.263 percentage points lower in poverty than non-adopters. Poverty head count provided information on the proportion of adopters and non-adopters that were living on less than KES 190 (US$1.9) per day but did not show how far below the poverty line the poor were. The headcount did not show changes when a very poor person became less poor, nor did it change when a poor person became even poorer.

When considering the poverty gap, adopters had an average of 5.47 percentage points lower than the poverty line while the non-adopters were deeper in poverty by a 5.83 percentage points. The results were generated by dividing the total sum of all the poverty shortfalls below the poverty line by the total adult equivalent in the sample. Poverty severity for adopters was 2.47 percentage points among adopters and 2.7 percentage points in non-adopters.

4.0 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

The results revealed years of farming experience of household's head coefficient was positive and significantly influenced adoption. This is because with increasing years of farming, it is expected that farmers acquire more experience, knowledge and skills about the appropriate use and operation of the technology which translates into higher productivity. The increased productivity translates into improved agricultural income and reduction of household poverty as higher productivity means higher yields, more food, more livestock feed from crop residues and more marketable surplus from own harvest.

Farmers' access to agricultural extension services positively influenced adoption. Agricultural extension service is useful for incentivizing the adoption of technologies, it provides farmers with information on seeds suited to the various agro-ecological zones, availability of farm inputs and good crop husbandry. The results imply that public agricultural extension service provision is a strong conduit for providing both information and technical skills on improved agricultural production especially among those who cannot afford to pay for the private service provision. The results agree with development experts noted the importance of agricultural extension services in achieving agricultural development, poverty reduction, and food security (Feder *et al.*, 2003; Feleke and Zegeye, 2005; Lambert *et al*; 2015).

Access to pigeon pea seed positively influenced adoption of the technology. This implies that access to seed is a necessary condition to adoption of improved pigeon peas. The recurrent drought in SEK region and resultant crop failure is a precursor to exhaustion of seed stock in most resource-poor households. This is due to the tendency of the households converting the seed into food whenever there is drought and hunger. Frequent replenishment of seed stock by increasing its availability and improving farmers' access in terms of location and affordability is thus inevitable if production of improved pigeon pea varieties in SEK is to be increased. The published studies of Audi *et al.,* (2009) and Asfaw *et al.,* 2012 found access to seeds crucial for adoption of improved pigeon peas among smallholders, they reported formal sector pigeon pea seed supply constraints affecting adoption.

Farmers' access to climate change information is crucial especially in in an area with erratic rainfall. This could be because farmers need information on onset and cessation of rainfall and the distribution to be able to plan their farming activities. Information on expected temperature range is also important for farmers to prepare on the pigeon pea husbandry. During very high temperatures the pest infestation is high and farmers need to be aware of the likely weather changes for risk management. Farmers access to advance information about the rainfall during the forthcoming season has the potential to help farmers in these areas make advantageous decisions about farm investments and adopt management practices that make best use of the season and reverse the current food and poverty situation The results corroborate those of (Kenkel and Norris, 1995; Shankar *et al.,* 2011; Tadesse *et al.,* 2009; WMO, 2015) who found that Seasonal climate forecasts speed up the adoption rate of high yielding and climatic risks reducing technologies and activities. Information about the onset of the rainy season can help farmers choose the crop cultivars that are more suited with the season. Farmers can choose late or early maturing cultivars in order to mitigate climatic risks.

Farmers' access to market information had a positive coefficient and significantly influenced adoption. This could be because farmers are usually receptive of a technology when they are informed on how to sell what is produced in excess of home consumption or when they are sure that what they produce has ready market. Market information is inevitable for farmers who aspire to practice farming as an agri-business to increase farm income. Information on how much to produce, when, where to sell what quantities and which price is usually needed by farmers to make informed decision on production. Simtowe *et al.* (2016) found access to the market in terms of distance to the market and market information as a crucial factor determining adoption of improved pigeon peas in Tanzania.

The coefficient on membership in farmers' association was positive and significant. This could be attributed to farmer group meetings that are local fora for interactive knowledge exchange which enhance adoption of agricultural technologies. Membership in farmers associations enables farmers benefit from economies of scale by purchasing farm inputs in bulk at a discounted rates and marketing in bulk that reduces the marketing transaction cost and increase their marketing margins. The published studies results (Abebaw *et al*., 2013; Bernard and Spielman, 2009; Pingali *et al*., 2005; Shiferaw *et al*., 2011) found that targeting farmer groups as an appropriate channel to achieve successful dissemination and adoption of agricultural technologies. Farmer groups have the capabilities to internalize transaction costs, facilitate efficient information flow, and reduce both farmers' risk aversion toward new technologies and income shocks through collective risk management.

The results showed a positive, but insignificant impact of adoption of the technology on poverty reduction. This probably could be because of the small increase in household expenditure per capita that could not induce a significant reduction of poverty in the study area. This was contributed by the small acreage under improved pigeon peas. In SEK, most of the farmers cultivate less than 2 hectares (Kwena *et al*., 2018, Wambua *et al.,* 2017), the rapid population growth, land fragmentation that reduce land size while low and erratic rainfall constraints crop production to increase poverty in agriculture-dependent households. The limited access to improved seed, sub-optimal use of soil fertility enhancing inputs constraint the objective of increased yield, food supply, farm income and poverty reduction in smallholder pigeon pea production system. The constraint is aggravated by the common practice of selling multiple, small quantities by individual farmers that increases the transaction cost in marketing (Pambo *et al.,* 2014), and lowers prices from farmers' low bargaining power that reduces the farm income.

Harris and Orr (2014) argue that crop production as a direct pathway from poverty is weak as the additional income from new technology, even if adopted is not sufficient to lift a typical smallholder farm above the poverty line. However, Gwata (2010) found that adoption of tropical legumes contribute to poverty reduction by improving food supply and incomes of smallholder farmers in Africa. Mathenge *et al.,* (2014), Smale & Mason (2014), Verkaart *et al.,* (2017) reported positive but insignificant reduction in poverty that corroborate this study on positive impact of technology adoption on household poverty reduction.

The results on poverty gap provides the mean aggregate expenditure shortfall relative to the poverty line across the all households interviewed. This provided information on how far an average household was from the poverty line. Adoption of the technology reduced the variation in net farm income among adopters compared to non-adopters, the poverty gap can be used by County Governments to measure the minimum amount of resources that would be required to eradicate poverty in a specific pigeon pea production location.

The reduction in poverty head count, poverty gap and poverty severity in adopting households relative to the non-adopters suggests that production of improved pigeon pea varieties had a quantifiable impact of reducing the percentage of farmers below the poverty line, narrowing the gap of the poor below the poverty line (depth of poverty) and reducing the inequality of the poor below the poverty line (severity). The results are an indication of adoption of the technology contributing towards improving the farmers' wellbeing through poverty reduction.

Conclusions

Farmers adopt a technology when there is easy access to the required inputs and reliable market information for the output. The results also showed that adoption of improved pigeon pea was associated with reduction of household poverty which raises the need to find mechanisms for extending improved pigeon pea production to other semi-arid areas in Kenya.

Recommendations

An individual cannot be brought out of poverty unless the quality and productivity of the resources on which that livelihood depends are addressed. Interventions to promote adoption of improved pigeon pea production on *fanya juu* terraced farms should exploit the opportunities available and address the circumstances under which decisions are made. The specific recommendations are:

(a) Policy at County level should strengthen and leverage government extension services to promote and create awareness about the existing improved pigeon pea varieties and its integration in soil and water management practices to enhance farmers' resilience to climate variability and change. There is need for County governments concerned to take the lead in technology promotion and dissemination at the initial stages and in creating an enabling environment for effective participation of the private sector. Awareness campaigns for improved varieties, combined with improved availability of improved seeds at subsidized prices would offer the most promising policy mix to accelerate and expand adoption.
(b) The County Governments of Machakos, Makueni and Kitui should establish a farmer-based seed production program and improve farmers' skills in seed multiplication. The farmers should be facilitated in certification of the seed with KEPHIS to increase seed supply within communities.
(c) County Government should take a lead role in provision of market information, as a step in facilitating the level of aggregation required for smallholder participation in markets. Institutional arrangements should be created under which farmers can enter into developing marketing channels – related to enforcement of contracts, including product grades and standards, access to credit, insurance and technical information through extension services.

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