Livestock, Crop Commercialization and Poverty Reduction in Crop-Livestock Farming Systems in Singida Region, Tanzania

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Abstract
Livestock is an important component of crop-livestock farming systems in Sub-Saharan Africa (SSA). This paper examined the effect of livestock on crop commercialization and poverty reduction among smallholder farmers in crop-livestock farming systems in Singida Region, Tanzania. It was hypothesized that livestock enhances crop commercialization and reduce poverty among smallholder farmers in the Region. Data for the analysis were extracted from the Agricultural Policy Research for Africa (APRA) data set of 600 households selected randomly from random samples of eight and seven villages in Iramba and Mkalama districts respectively. Descriptive statistics were used to compare ownership of livestock, use of ox-plough and livestock manure, crop productivity, crop commercialization and poverty levels across different categories of farmers. Econometric analyses were used to determine if livestock had a significant effect on crop commercialization and poverty levels, controlling for other variables that might have an effect. The results of descriptive analyses show differences in ownership of livestock, use of ox-plough and livestock manure, crop productivity, crop commercialization and poverty levels across different categories of farmers while the results of econometric analysis show that livestock enhanced crop commercialization. Apart from livestock, a range of other factors have worked together with livestock to drive the crop commercialization process. Regarding the impact of commercialization, the findings show that farmers have gained higher productivity (yield), signifying the potential of crop commercialization to reduce poverty. In general, evidence from the results show decline in poverty as crop commercialization increases from zero to medium level. Although crop commercialization has positively impacted on crop productivity (yields) and poverty, the results show existence of socio-economic disparities. Male-headed households (MHH) and households headed by medium-scale farmers (MSF), young farmers and livestock keepers were less poor than their counterpart female-headed households (FHH) and households headed by small-scale farmers (SSFs), older farmers and non-livestock keepers. These social differences are consequences of differences in the use of ox-plough, livestock manure and other productivity enhancing inputs. Exploiting the synergy between crop and livestock in crop-livestock farming systems needs to be recognized and exploited in efforts geared towards enhancing crop commercialization and reducing poverty among smallholder farmers in crop-livestock farming systems in Tanzania and elsewhere in SSA.
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1. Introduction

Agriculture is the mainstay of the majority of rural people in sub-Saharan Africa's (SSA) and has the greatest potential to reduce food insecurity and poverty among smallholder farmer who make up to 80% of the rural population (AGRA, 2014; Pingali et al., 2019). Yet food insecurity and poverty is greatest among rural people in SSA (Giller, 2020, Sasson, 2012). The key cause of food insecurity and poverty is low agricultural productivity and output resulting (Muzari, 2016; Gassner et al., 2019). Commercialization of smallholder agricultural products through increased participation in output markets has been promoted as one of the best strategy to address low agricultural productivity and agricultural output (Awotide, 2016, Ngenoh *et al*., 2019). Addressing low agricultural productivity requires use improved tillage technologies such as tractors and productivity enhancing inputs such as improved seeds and fertilizer (Ahmed *et al*., 2017, Selejio *et al*., 2018). However, access to improved tillage technologies and productivity enhancing inputs among smallholder farmers is constrained by lack of financial capital. Although financial capital can be accessed from commercial banks, smallholder farmers fail to meet the collateral requirements of the commercial banks because of lack of assets that can be used as collateral (Ullah, 2020, Nkilijiwa and Sanka, 2021).

The need for financial capital among smallholder farmers in SSA can be reduced harnessing the synergy between crops and livestock in crop-livestock farming systems. Livestock provide animal draft power that can used to pull tillage implements (e.g. ploughs) for land cultivation and provide manure for fertilizing the soil to improve productivity (Zhou *et al.,* 2018; Guthiga *et al*., 2007). At the same time, crop residues and by-products are a key feed resource for livestock (Asmar and Yayeh, 2018, Onyeonagu and Njoku, 2010). Although the synergy between crops and livestock in mixed crop-livestock farming systems provide opportunities for improving crop productivity and reducing poverty, most smallholder farmers have not been able to harness this synergy. This can largely be attributed to the failure of the famers, policy makers and development partners to recognize the role of livestock in improving household incomes and reduce poverty. Therefore empirical research to inform farmers, policy makers and development partners on the opportunities for reducing poverty among smallholder farmers in rural areas where livestock is an integrated part of the farming system is important.

The use of ox-plough and livestock manure can enhance commercialization of crops in the farming season by expanding land for crop production and increasing crop yield (productivity) respectively. However, livestock production in the crop-livestock farming system provides a new commercialization pathway to crop farmers. Increasing the share of livestock income relative to that from crops would suppress the commercialization tendency for crop-based income sources. Therefore, contrary to the expectation that livestock enhances crop commercialization through the use of ox-plough and livestock manure, income generated from the sale of livestock and livestock products among farmers can have a negative effect on crop commercialization by reducing the need to expand crop production.

While recognizing that the success or failure of the crop commercialization process cannot be attributed to any single factor but a combination of several factors complementing each other, this study examines the effect of livestock on crop commercialization and how the commercialization process has enhanced poverty reduction among smallholder farmers in crop-livestock farming systems of Singida Region. Singida Region forms part of the semi-arid central zone of Tanzania, which experiences low rainfall and short and often erratic rain seasons, with fairly widespread drought every one in four years (Lema and Majule, 2009). Livestock are an integral component of the crop-livestock farming systems in the region, comprising a wide range of crop and livestock enterprises. The crop enterprises include maize, millet, sorghum, paddy, cassava, sweet potatoes, sunflower, cotton, tobacco, wheat, beans, groundnuts, peas and onions while livestock enterprises include cattle, goats, sheep, donkeys and chickens (URT, 2017).

Livestock as an integral part of the farming systems in the Singida Region was hypothesized to have a positive effect on crop commercialization and poverty reduction through the use of ox-plough and livestock manure in crop production. Apart from contributing to the existing empirical literature on the effect of livestock and other factors on crop commercialization as well as the effect of commercialization on poverty, the evidence generated from the study will inform the formulation of policies and strategies for appropriate interventions to enhance commercialization and reduce poverty in crop-livestock farming systems in Tanzania and SSA as a whole. The paper addresses some key policy-relevant questions including: (i) To what extent are households using ox-plough and manure from livestock in crop production?, (ii) Does livestock enhance or inhibit crop commercialization?, (iii) What factors other than livestock influence crop commercialization?, (iv) How does commercialization affect productivity and poverty? and (v) Does commercialization and its effects on poverty differ between different socioeconomic groups?

The remainder of this paper includes a methodology section which describes the conceptual framework, analytical framework and dataset used for the analyses. This is followed by a results section where the findings of the descriptive and econometric analyses are presented and discussed. The discussion section focuses on the effect of livestock and other factors on crop commercialization and the influence of crop commercialization on poverty in Singida. The final section presents the conclusions and recommendations emanating from the major findings of the study.

2. Methodology

2.1 Data Used

The paper uses survey data collected for the APRA sunflower commercialization study in the Iramba and Mkalama districts in the Singida region in Tanzania in 2016/17 agricultural year. The survey involved 600 households (13.6% female-headed and 86.4% male-headed) selected using a two-stage sampling design with stratification. The two strata were Iramba and Mkalama districts from which eight and seven villages respectively were selected separately with probability proportional to size, while 40 households were selected from each village selected in stage by simple random sampling. The Singida region was purposively selected not only because it is a major sunflower producing region but also due to its long history of sunflower production. Meanwhile, the Iramba and Mkalama districts were purposively selected because they have been leading in sunflower production, accounting for nearly 50% of sunflowers produced in the Singida region (NBS, 2017; URT, 2020). Singida is located in central Tanzania, between latitude 30 52’ and 70 34’ south of the equator and longitudes 220 27’ and 350 26’ east of Greenwich. The region has six district councils (Singida rural, Singida urban, Itigi, Manyoni, Mkalama and Iramba). Iramba District Council represents farmers operating on the plateau, above the rift valley while Mkalama District Council represents farmers in the rift valley. Figure 1 is a map showing the study districts.

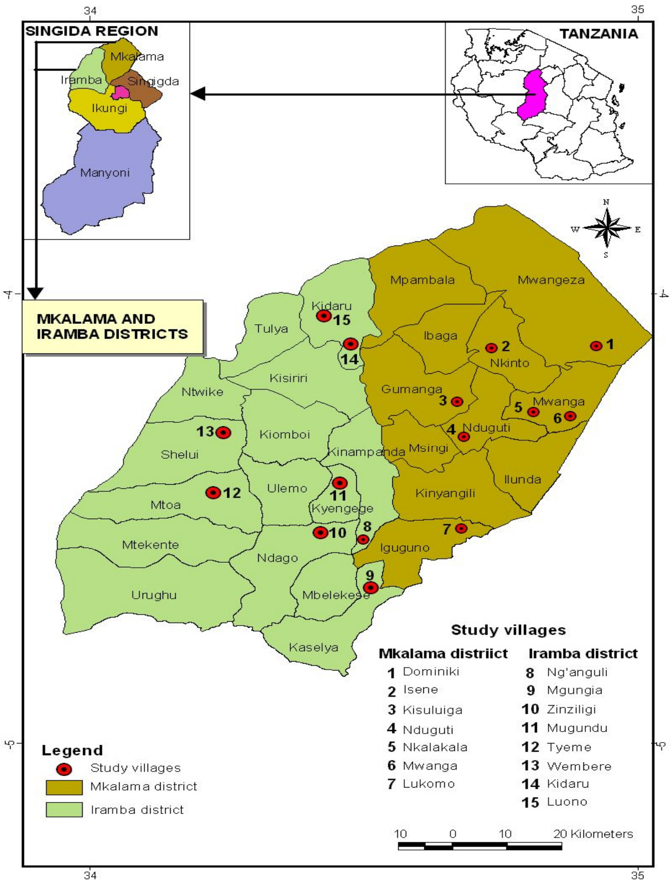

Figure 1: Map of Singida Region Showing the Study Districts and Villages

2.2 Conceptual Framework

Figure 2 presents the major components underlying the analytical framework for our study on the effect of livestock on crop commercialization and livelihoods of rural households in the Singida region. Commercialization of crop production in the mixed crop-livestock farming system in the Singida region has been enhanced by livestock-keeping through the provision of farm power for cropland expansion and manure for fertilizing crops. Both cropland expansion and fertilization lead to high crop output and therefore surplus for the market. On the other hand, the competition for resources such as land for grazing, labor and other resources between livestock and crop production activities can inhibit crop commercialization. In addition, livestock benefit from crop production through the use of crop residues and by-products from cereals and sunflower seed processing. Since livestock production in the mixed crop-livestock farming system provides a new commercialization pathway to crop farming, an increasing share of livestock income relative to that from crops would likely suppress the commercialization tendency for crop-based income sources. Apart from the effects of livestock on crop commercialization, crop commercialization is influenced by a multitude of external factors such as policies, institutions and natural hazards among others (Gupta et al., 2019; Pingali et al., 2019). The last component in our conceptual framework is concerned with the possible impacts of commercialization on farming households. These impacts may include agricultural productivity, household incomes, food security, nutrition and poverty. Empirical evidence shows that the impacts of commercialization can be positive (Hailua et al., 2015; Matenga and Hichaambwa, 2017) or negative (Fischer and Qaim, 2012; Ntakyo and van den Berg, 2019).

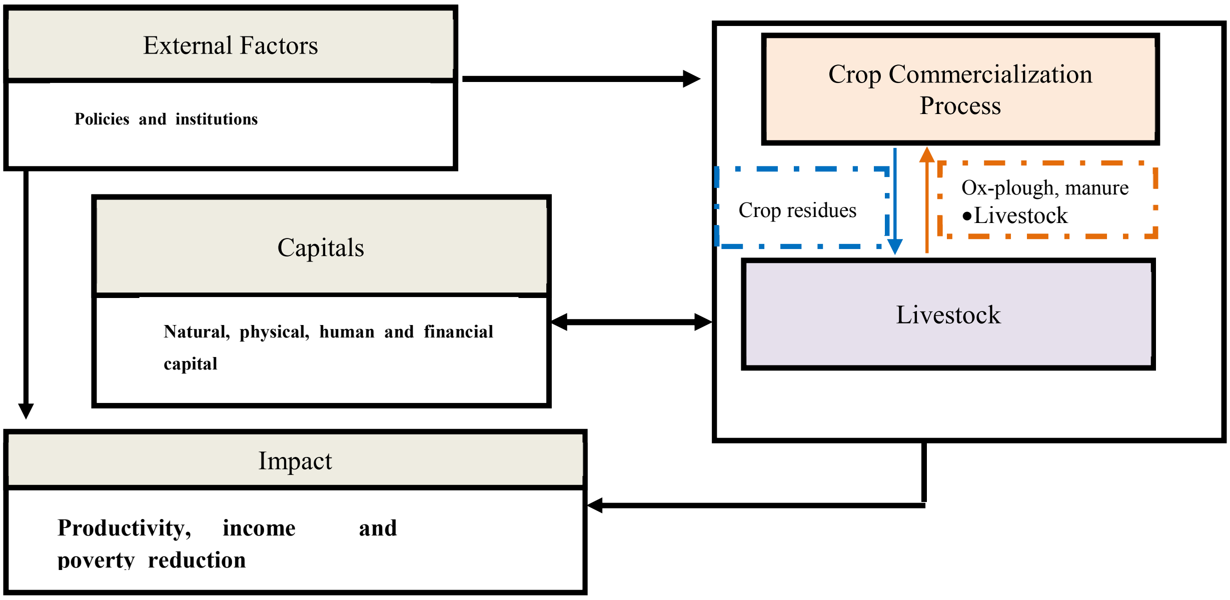

Figure 2 : Conceptual framework
Source: Modified from Mutabazi et al. (2013)

2.3 Analytical Framework

2.3.1 Determining the Effect of Livestock on Crop Commercialization

The effect of livestock on crop commercialization was determined by first establishing an indicator of crop commercialization and analyzing the influence of livestock on crop commercialization after controlling for other factors as described below.

2.3.1.1 Measuring Crop Commercialization

Agricultural commercialization has been measured either by examining the extent of the use of purchased inputs (Hagos and Geta, 2016, Kibiti et al., 2016) and/or volume and value of agricultural output (Muriithi and Matz, 2015; Dube and Guveya, 2016;). In this paper, we follow Rahut et al. (2010), defining the crop commercialization index as:

$CCI = GVS_{ij} / GVP_{ij}$

Where:

CCI = Crop Commercialization Index of the ith household

GVS_{ij} = Gross value of major crop sales for the ith household during j*th* season

GVP_{ij} = Gross value of major crop production for the i*th* household during j*th* season

More than 10 different crops are produced in the Singida region, but only seven major crops in the two sample districts of Iramba and Mkalama were used in the computation of CCI. The seven crops chosen were grown by more than 30% of the sample farmers and at least 30% of the output was marketed, and thus these crops provide a more reliable representation of commercialization in the region. The crops were maize, sunflower, rice, common bean, sorghum, pearl millet and groundnuts. The computed commercialization index varies from 0% where no crop output was sold to 100% where all harvested crop output was sold. The sample was divided into four CCI categories, namely a category of no sales (0%) and terciles for the remaining households with low commercialization as first tercile, medium commercialization as second terciles and high commercialization as the third tercile. To examine the effect of livestock and other factors on different groups of farmers, the commercialization levels were compared for the following categories of households: (i) livestock-keeping and non-livestock-keeping households, (ii) small and medium farmers, (iii) young and old farmers and (iv) MHH and FHH. The results of these comparisons are presented in the next chapter.

2.3.1.2 Determinants of Crop Commercialization

Crop commercialization index can be expressed either in proportions or in percentages. Both forms of presentation lead to a continuous interval from 0 to 1 and 0 to 100% with both limits included. A two limit Tobit model is appropriate as a corner solution model if there is a pile up at both limits with positive probability. However, according to Wooldridge (2010) if the interest is to estimate the conditional mean of the dependent variable, then a two limit Tobit model can lead to inconsistent parameter estimates. Although a two limit model has been used in similar studies such as Dube and Guveya (2016) and Bekele and Alemu (2015), we followed Wooldridge's specification of a model for conditional mean based on logistic or probit function which leads to consistent parameter estimates. The model has been applied in similar studies by Ogunleye et al. (2018). The fractional probit regression model is specified as in equation 1.

$$E(y|x) = \Theta(x\beta),\ \ 0 \leq y \leq 1 \qquad (1)$$

Where:
y = the fraction or proportion of crops commercialized
E(y|x) = Population conditional mean proportion of crops commercialized
Θ (xβ) = normal cumulative distribution function
B = vector of parameters to be estimated

The vector x represents explanatory and control variables categorized into household and household head factors (sex of household head, age of household, education of household head, household size, total crop land, non-farm income), an information technology variable (use of mobile phone), physical factors (distance to nearest all weather road) and agricultural technology variables (use of modern tillage implements such as animal traction and tractor, use of purchased seed, use of inorganic fertilizers, use of organic fertilizer or manure, and use of pesticides). The aim is to determine the partial effects of the x variables on the mean proportion of crops commercialized. The parameters of equation 1 are estimated by Bernoulli Quasi Maximum Likelihood Estimation fractional probit regression. The specification of the variables used for the fractional probit regression is presented in Table 1.

Table 1: Specification of Explanatory Variables used in the Fractional Probit Model for Determinants of Crop Commercialisation

Variable	Description	Expected sign
Sex of household head (dummy)	Sex category of household head: 1 if male, 0 if female	+/-
Age of farmer (dummy)	Age category of famer: 1 if young and 0 if old farmer	+/-
Education of household head	Year of schooling for household head	+
Household size	Number of people in a household	+/-
Total crop land	Hectares (ha) of land planted with crops	+
Livestock kept	Number of livestock kept in TLU	+
Use of tractor	1 if farmer uses tractor as tillage implement, 0 if hand hoe	+
Use of animal traction	1 if farmer uses animal traction as tillage implement, 0 if hand hoe	+
Access to extension	1 if farmer has access to extension services, 0 otherwise	+
Use of purchased seed	1 if farmer used purchased seed, 0 otherwise	+
Use of inorganic fertilizer	1 if farmer used of inorganic fertilizer, 0 otherwise	+
Use of organic fertilizer	1 if farmer used organic fertilizer, 0 otherwise	+
Use of pesticide	1 if farmer used pesticide, 0 otherwise	+
Non-farm income	Non-farm income earned by the household in Tanzanian shillings (TSh)	-
Distance to nearest motorable road	Distance in kilometres from farm to motorable road as a proxy of market access	-

Source: Authors' own

2.3.2 Determining the Effect of Livestock and Other Factors on Household Poverty

The determination of the effect of livestock and other factors on the livelihoods of rural households comprised of two steps. The first step was the development of livelihood indicators while the second step involved the measurement of the effect of livestock and other factors on the livelihoods of the sample households.

2.3.2.1 Measuring Household Poverty

The common approaches in the literature to measure the level of poverty use income, assets, food security, subjective well-being, or multidimensional poverty (Alkire *et al*., 2015). This paper uses the Multidimensional Poverty Index (MPI) as proposed by Alkire *et al*.(2015) and Alkire and Santos (2014). The MPI uses a set of vulnerability indicators to determine the incidence of poverty (headcount) and the intensity of poverty (degree of deprivation). At the population level these two indicators are combined to compute the MPI. A poverty cut-off point of 33.3% identified people whose deprivation score exceeds this threshold as 'multidimensional poor' (Alkire *et al*., 2015). A household is considered "MPI poor" if its score is above the 0.33 (or 33%) cut-off point, and not MPI poor otherwise. Hence, the overall MPI represents a proportion of the sample which is poor. Being representative of the population from which the sample is drawn, higher scores represent more deprivation, hence deeper poverty. The entire list of indicators that were used to compute the MPI is summarized in Annexes 1.

2.3.3 Determinants of Household Poverty Status

The influence of livestock on household poverty status can take the following pathways: the productivity pathway through provision of organic fertilizer or animal traction and income pathway through the sale of live animals and livestock products. Given the limitations of recall in estimating livestock income we used Tropical Livestock Units

(TLU) under the assumption that they have a high correlation with livestock income. According to Engida et al. (2015), livestock assets provide a flow of income from sales of animals and products such as meat, eggs and milk, but to fully account for livestock income, it is necessary to include value of non-monetary exchanges (barter) and household consumption less the expenditure related to livestock production in the form of labour, feeds and veterinary services (Pica-Camara et al., 2011). While in absolute terms it is expected that the higher the livestock assets owned the higher the income flow, there is no clear evidence that the share of livestock income to total livestock income is dependent on the size of livestock assets (Pica-Camara et al., 2011). The technology variables are reflected in the commercialization index and are therefore not included in the model. A probit model is used to determine the likelihood of a household being MPI poor given a set of attributes as specified below. A latent model indicating the household poverty status is presented in equation 2.
V* is unobservable and is linked to MPI as follows"

$$p(MPI = 1|x) = p(v^* < 0|x) = p[(x\beta + \mu)|x < 0] = p(\mu < -x\beta|x) = \Theta(-x\beta) \quad (3)$$

$$v *= x\beta + u;\ u|x \sim N(0, \sigma^2) \quad (2)$$

Where:
Θ (-xβ) = the standard normal cumulative distribution function.
x = vector of explanatory variables whose details are presented in Table 2. The probit model presented in equation 3 is estimated by Maximum Likelihood method.

Table 2: Explanatory Variables for Estimating the Probit Model for MPI and their Expected Signs

Variable	Description	Expected sign
Sex of household head (dummy)	Sex category of household head: 1 if male, 0 if female	+
Age of farmer (dummy)	Age category of farmer: 1 if young and 0 if old farmer	+/-
Education of household head	Year of schooling for household head	+
Household size	Number of people in a household	-
Total crop land	Hectares (ha) of land planted with crops	+
Livestock kept	Number of livestock kept in TLU	+
Non-farm income	Non-farm income earned by the household in Tanzanian shillings (TSh)	
Level of crop commercialization	Modelled as commercialization tercile dummies, with low commercialization tercile as reference category	
Second tercile (CC_T2)	1 if second tercile and 0 otherwise	-
Third tercile (CC_T3)	1 if third tercile and 0 otherwise	-

Source: Authors' own

3 Results and Discussion

3.1 Descriptive Statistics

3.1.1 Livestock Keeping, Ownership and Use

As highlighted in the introduction, livestock keeping is an integral part of the farming systems in the Singida Region. Local chickens were the most common livestock type, raised by 80% of the sampled households. Cattle, goats, sheep and pigs were raised by approximately 70%, 45%, 36% and 4% of the sampled households respectively. With respect to cattle, two categories of cattle keepers exist in Singida Region, owners and caretakers who do not own but raise the cattle on behalf of the owners. Owners and caretakers account for 92.1% and 7.9% of the livestock keeping households, respectively. Evidence from focus group discussions and key informant interviews showed that livestock, especially cattle, are kept as store of wealth. Apart from keeping cattle as store of wealth, the owners of cattle under caretakers benefit from cattle sales and saving herding labour costs. The decision to sell cattle occurs when the cattle owner needs cash income for farming and/or other household needs. On the other hand, the cattle caretakers benefit from drinking and selling milk as well as draft power and cattle manure for crop production (Isinika *and* Mwajombe, 2019).

Imbalance in ownership of livestock was evident in this study. For example, FHHs, households headed by SSF, and young farmers seemed to be more disadvantaged in terms of the number of animals/birds per household than MHH and households headed by MSF and older farmers (Table 3). The pattern was the same with respect to percentages of households owning the different types of livestock, except in the case of farm size category where the percentages of SSFs owning different types of livestock is significantly higher than MMFs (Table 4).

Table 3: Ownership of Livestock by Farmer Category

Type of livestock	SSF	MSF	FHH	MHH	Young farmer (≤ 35 yrs)	Older farmer (≥ 35 yrs)	Whole sample
Cattle	5.3	18.1***	3.5	8.2***	5.8	8.0	7.5
Goats	3.2	9.1***	1.8	4.6***	2.8	4.6**	4.2
Sheep	1.5	6.4***	1.0	2.5**	1.3	2.6	2.3
Pigs	0.1	0.3***	0.12	0.14	0.02	0.2***	0.1
Chickens	7.8	12.9***	6.5	9.1	8.4	8.8	8.7

Note: * = difference is significant at P = 0.1; ** = difference is significant at P = 0.05; *** = difference is significant at P = 0.01

Table 4: Percentage of Households Owning Livestock by Farmer Category

Cattle	64.6	94.3***	44.6	73.4***	65.6	70.6	69.4
Goats	41.65	64.8***	25.6	48.6***	48.4	35.4**	45.5
Sheep	31.5	55.2***	18.3	38.4***	21.5	39.7***	35.7
Pigs	2.7	11.4***	4.9	4.1	1.5	4.9**	4.2
Chickens	78.6	86.7*	69.5	81.7**	75.6	81.4	80.0

Note: * = difference is significant at P = 0.1; ** = difference is significant at P = 0.05; *** = difference is significant at P = 0.01

In the study area, livestock had different uses. In general, livestock produced meat, milk and eggs that could be consumed by livestock keeping households to improve their food security and nutrition or sold to generate income. They also provided farmyard manure and draft power for pulling farm implements such as ploughs, weeding implements and carts for tillage, weeding and transportation respectively.

3.1.2 Use of Ox-ploughs and Tractors as Tillage Implements

Use of ox-plough to till land for growing crops is relatively higher than the use of tractor as evidenced by the percentages of sample households using them (Table 5). Differences were found in the use of ox-plough and tractor across farmer categories. The percentages of FHHs and households headed by SSF, young farmers and non-livestock keepers that used ox-plough and tractor were significantly lower than those of MHHs and households headed by old farmers and livestock keepers (Table 5). This suggests a higher likelihood of these households tilling smaller land areas for growing crops than the MHHs and households headed by old farmers and livestock keepers.

Table 5: **Percentage of Households Using Ox-plough and Tractor**

Tillage implement	Farm size category		Gender of household head		Age category		Livestock keeping category	
	SSF	MSF	FHH	MHH	Young farmers	Old farmers	Livestock keeper	Non-livestock keepers
Ox-plough	35.0	50.7	45.8	63.3***	48.1	48.5	63.3	24.6***
Tractor	7.4	13.5	4.9	8.9	7.7	8.6	6.5	12.5**

Note: * = difference is significant at P = 0.1; ** = difference is significant at P = 0.05; *** = difference is significant at P = 0.01

3.1.3 Use of Livestock Manure and Other Productivity Enhancing inputs and Extension Service

With the exception of purchased seeds and livestock manure, use of other productivity enhancing inputs and extension service was quite low as evidenced by the percentages of sample households using them (Table 6). Apart from low use, the percentages of FHHs and households headed by SSF, young farmers and non-livestock keepers that used productivity enhancing inputs were significantly lower than those of MHHs and households headed by older farmers and livestock keepers (Table 6). This suggests a higher likelihood of these households achieving lower crop productivity (yield) than the MHHs and households headed by old farmers and livestock keepers. However, it is interesting to note that crop yields achieved by FHHs were significantly higher than those achieved by MHHs as indicated in Section 3.1.4. This is contrary to the findings of many previous studies. Most studies report higher yields for MHHs than FHH (Challa and Mahendran, 2015; Oseni et al., 2015; Slavchevska, 2015; Gebre et al., 2021;) while few studies report insignificant differences in crop yields between MHHs and FHHs (Masterson, 2007; Croppenstedt *et al*., 2013). The relatively higher crop yields obtained by FHHs compared with MHHs might be due to differences in crop husbandry practices such as planting time, spacing and weeding frequency and timely weeding.

Table 6: Percentage of Households Using Livestock Manure, Other Productivity Enhancing Inputs and Extension Service

Item	Farm size category		Gender of household head		Age category		Livestock keeping category	
	SSF	MSF	FHH	MHH	Young farmers	Old farmers	Livestock keeper	Non-livestock keepers
Purchased seeds	84.2	88.2	74.6	86.7**	84.1	87.8	84.3	86.5
Manure	37.4	50.5**	29.3	41.3**	32.3	41.6**	46.0	25.0***
Inorganic fertilizer	85.6	86.7	12.2	14.4	15.3	13.8	12.6	17.8*
Pesticides	14.0	19.0	12.3	15.4	13.0	15.6	14.5	16.1
Extension service	16.5	21.0	16.3	17.5	14.7	18.1	17.3	17.5

Note: * = difference is significant at P = 0.1; ** = difference is significant at P = 0.05; *** = difference is significant at P = 0.01

3.1.4 Crop Productivity

Like the use of ox-plough, tractor and productivity enhancing inputs, productivity (yields) of crops achieved in the 2017/18 farming season varied across different categories of famers (Table 7). However, the difference was not significant for most crops and farmer categories except rice where yields achieved by FHHs were significantly higher than those achieved by MHHs and groundnuts. Yields achieved by old farmers were significantly higher than those achieved by young farmers.

Table 7: Crop Yields (kg/ha) for Major Crops Grown by Farmer Category

Item	Farm size category		Gender of household head		Age category		Livestock keeping category	
	SSF	MSF	FHH	MHH	Young farmers	Old farmers	Livestock keepers	Non-livestock keepers
Maize	1022.4	1071.1	1184.7	1005.3	990.0	1041.3	996.3	1118.1
Rice	2068.6	2335.4	3481.5	2019.6**	2420.9	2018.4	2110.5	2358.0
Sorghum	691.5	568.7	727.2	658.5	258.7	341.6	696.8	588.9
Pear millet	712.5	750.8	657.7	731.0	704.8	721.9	694.6	837.5
Sunflower	654.4	553.4	475.3	657.6	658.9	622.6	641.9	602.6
Groundnuts	373.5	335.3	258.0	380.6	119.2	399.5**	356.6	383.4
Common beans	306.1	405.5	163.0	334.7	258.7	341.6	351.1	268.0

Note: ** = difference is significant at P = 0.05

3.1.5 Crop Commercialization

This section presents commercialization levels of individual major crops in the study area and an overall CCI. The individual crop commercialization levels varied across crops and across different categories of farmers (Table 8). Sunflower appeared to be the highest commercialized crop with commercialization levels above 60% across all farmer categories. Commercialization levels of all other crops were below 50%. In general, FHH and households headed by SSF, old farmers and non-livestock keepers had relatively lower commercialization levels than MHH and households headed by MSF, young farmers and livestock keepers.

The individual crop commercialization indices were used to compute the CCI as described in the methodology. The mean CCI for the whole sample was 59.2%. The CCI varied significantly across different categories of farmers. As indicated in Table 9, the CCI for MHH and households headed by MSF, young farmers and livestock keepers were significantly higher than the CCI for FHH and households headed by SSF, old farmers and non-livestock keepers. The major reason for the difference in CCI is probably low productivity resulting from differences in the use of productivity enhancing inputs such as improved seeds and fertilizer as well as the use of modern farm implements as indicated earlier. These results support the findings by Mdoe et al. (2020) and Mutabazi *et al.*, (2013).

Table 8: Mean Commercialisation Indices (%) for Major Crops Grown by Farmer Category

Item	Farm size category		Sex category of household head		Age category of farmer		Livestock keeping category	
	SSF	MSF	FHH	MHH	Young	Olds	Livestock keeper	Non-livestock keeper
Maize	14.9	22.6***	13.7	16.6	20.0	15.1	17.2	14.0
Rice	28.6	46.1*	21.1	34.8	52.8	24.8*	36.7	18.8*
Sorghum	11.8	5.5**	9.7	10.7	15.7	9.5*	9.4	13.8*
Pear millet	12.0	28.9**	13.0	15.6	15.1	15.1	17.1	4.6
Sunflower	68.4	73.9	64.4	70.6	70.9	69.7	71.5	64.4
Groundnuts	8.7	15.4	3.4	11.6	16.7	9.6	9.4	15.6
Common beans	8.3	17.9*	4.7	11.0	19.4	9.4	11.5	7.7

Note: * = difference is significant at P = 0.1; ** = difference is significant at P = 0.05; *** = difference is significant at P = 0.01

Table 9: Overall Crop Commercialization Indices (%) by Farmer Category

Farmer category	Mean	Median	Significance of the effect
Farm size category:			
SSF	38.5	38.0	F = 15.989***
MSF	51.1	54.1	
Sex of household head:			
FHH	33.4	28.5	F = 5.621**
MHH	41.8	41.6	
Age category of farmer:			
Young	48.2	51.0	F = 10.824***
Old	38.6	37.7	
Livestock keeping category:			
Livestock keepers	42.2	42.7	
Non-livestock keepers	37.1	30.7	F = 3.586*
Whole sample	59.2	65.2	

Note: F = *; implies F value is significant at p<0.1. F = ***; implies F value is significant at p<0.01.

3.1.6 Household Poverty Status across Different Categories of Farmers

Poverty level differed across different categories of farmers. As depicted in Table 10, the percentage of MHH and households headed by MSF, livestock keepers that had a high level of deprivation (MPI poor) was significantly lower than those of FHH and households headed by SSF and non-livestock keepers. Regarding the level of poverty across households with different CCI, the percentage of households with low level of deprivation (MPI poor) decreased from 89.1% for farmers who did not commercialize to 22.2% for farmers with a medium crop commercialization level and then increased to 28.8% for farmers with a high level of crop commercialization (Table 10). The decline in poverty can be associated with some cultural factors. It was evident during the focus group discussions that some agro-pastoralists who ranked highly in terms of number of cattle-ownership ranked low in terms of quality of housing, clothing and children's education, which are the criteria considered important in defining the quality of life in the study area (Isinika and Mwajombe, 2019). Additionally, agro-pastoralists rarely sell livestock to build modern houses and/or purchase physical assets besides livestock which unfortunately were not among the assets used in the computation of MPI as a measure of poverty in this paper.

Table 10: Percentage of Households by Poverty Level (MPI) and Farmer Category

Farmer category	MPI poor (high level of deprivation)	MPI not poor (low level of deprivation)	χ2
Farm size category:			
SSF	79.7	20.3	14.672***
MSF	59.5	40.5	
Sex of household head:			
FHH	78.6	21.4	18.307***
MHH	24.9	75.1	
Age category of farmer:			
Young	69.9	30.1	1.569ns
Old	76.8	23.2	
Livestock keeping category:			
Livestock keepers	75.6	26.5	2.695*
Non-livestock keepers	81.6	18.4	
Crop commercialization level:			
Zero	89.1	10.9	9.1**
Low	28.9	71.1	
Median	22.2	77.8	
High	28.8	71.2	
Whole sample	24.2	75.8	

Note: F = *; implies F value is significant at p<0.1. F = ***; implies F value is significant at p<0.01.

3.2 Econometric Results

3.2.1 The effect of Livestock on Crop Commercialization: Results of the Fractional Probit Model

Livestock as an integral part of the farming systems in Singida was hypothesized to have a positive effect on crop commercialization through the use of animal traction and manure from livestock in crop production. Table 11 presents the results of the fractional probit regression analysis on the influence of livestock and other factors on crop commercialization in the Singida region. The model represents a good fit for the data based on the log likelihood, pseudo R-Square and corresponding F-value. The number of livestock kept per household was measured using TLU[1] which appeared to have a negative effect on crop commercialization (Table 11). The marginal effect of TLU of -0.0002 implies that increasing the livestock herd by one more TLU is likely to reduce crop commercialization by 0.02%. This likelihood of crop commercialization reductions stems from the fact that livestock production in the mixed crop-livestock farming system provides a new commercialization pathway to crop farming. An increasing share of livestock income relative to that from crops would likely suppress the commercialization tendency for crop based income sources. Factors other than livestock which had a positive effect on crop commercialization were age category of farmer, education, land planted with crops, use of modern tillage implements such as animal traction and tractors, mobile phones, purchased seeds, inorganic fertilizers, organic fertilizers (livestock manure) and pesticides. Among these factors, age of farmer, land planted with crops and the use of pesticides to control pests had a significant positive effect on crop commercialization. The remaining factors had an insignificant positive effect on crop commercialization. Being a young household head had a higher marginal effect than the other factors with a positive influence on rice commercialization. The marginal effect of 0.116 for youth indicates that the level of crop commercialization is likely to increase by approximately 12% for an additional household head by a young farmer compared with an increase of about 3% for an additional ha of land planted with crops. This suggests significant gains in crop commercialization if a household is headed by a young farmer instead of an old farmer. This finding is consistent with the results of previous studies that young farmers are more commercially oriented than old farmers (Hall *et al*., 2017; Liu *et al*., 2018; Mariyono, 2019).

Factors with negative effects on crop commercialization included household size, non-farm income and distance to nearest road, however these effects were insignificant. The negative coefficient for household size indicates that the crop commercialization level declines with increase in the household size. The marginal effect of household size of -0.0103 implies that increasing the household size by one more person is likely to decrease crop commercialization by 1.03% (Table 11). Increase in household size reduces marketable surplus due to increase in household consumption (Owagbemi et al., 2016; Turaa *et al*., 2016; Kyaw *et al.*, 2018). The negative coefficient for distance to nearest motorable road as a proxy of market access suggests that crop farmers close to a motorable road will likely be more commercialized than farmers in remote areas. Improvement in market access is an incentive for farmers to increase agricultural productivity and hence increase in marketable surplus (Linderhof

[1]Tropical Livestock Unit (TLU) is defined as a mature animal weighing an average weight of 175 kg (Jahnke, 1982). Livestock conversion factors are 0.70 TLU for cattle, 01 TLU for goats and sheep, 0.2 for pigs and 0.01 for chickens.

et al., 2019; Ntakyo and van den Berg, 2019; Ogutu *et al*., 2020).

Table 11: Determinants of Crop Commercialization in Singida Region: Results of the Fractional Probit Regression (CCI ≤1)

Independent variable	Coefficient	Robust se	Marginal effect	p>|z|
Sex category of household head (1 = male head)	0.0009	0.1399	-0.0003	0.995
Age category of farmer (1 = young farmer)	0.2946***	0.1003	0.1157	0.003
Education (years of schooling)	0.0223	0.0182	0.0088	0.220
Household size	-0.0253	0.0160	-0.0099	0.114
Total land planted with crops (ha)	0.0726***	0.0165	0.0285	0.000
Number of livestock kept (TLU)	-0.0005	0.0069	-0.0002	0.933
Use of modern tillage implement (1 = yes)	0.0195	0.0755	0.0076	0.796
Use of mobile phone (1 = yes)	0.0247	0.1013	0.0097	0.807
Use of purchased seed (1 = yes)	0.0904	0.1058	0.0355	0.393
Use of inorganic fertilizer (1 = yes)	0.1318	0.1143	0.0518	0.249
Use of organic fertilizer (1 = yes)	0.0014	0.0791	0.0006	0.986
Use of pesticide (1 = yes)	0.1941*	0.1075	0.0762	0.071
Non-farm income (100,000 Tsh)	-0.0061	0.0040	-0.0024	0.127
Distance to nearest road	-0.0111	0.0118	-0.0043	0.351
Constant	-0.5595***	0.1888		0.003

N=354, Wald $\chi^2_{(15)}$=54.67, p>χ^2=0.000 and Pseudo R^2=0.0345

Notes: * significant at p<0.1, ** significant at p<0.05 and *** significant atp<0.01

3.2.2 The Effect of Livestock on Household Poverty: Results of the Probit Model

Table 12 presents the estimates of the effects of livestock and other factors on household poverty measured in terms of MPI as indicated in the methodology. As indicated in Table 12, the number of livestock measured in terms of TLU is negatively related to the MPI as expected, implying that livestock in crop-livestock farming systems of the Singida region increases the probability of reducing poverty among crop-producing households. This result is consistent with the findings by Sarkar (2020) and Hegde (2019).

Factors other than livestock found to have a significant effect on MPI included education, non-farm income and the second crop commercialization tercile (CCI_T_2). The coefficient for education of household head was negative, suggesting a high likelihood of decline in poverty in a household as the education level of the household head increases. The decline in poverty with increase in education is associated with improvement of agricultural productivity resulting from better understanding of improved farming practices among educated farmers (Maiyo, 2015; Wanka and Rena, 2019). As expected, non-farm income had a significant negative effect on MPI. The negative effect on MPI suggests the likelihood of reducing household poverty as the household earns more non-farm income. The role of non-farm income in reducing household poverty in rural area is widely reported (see for example Rantšo, 2014; Alobo-Loison, 2015; Idris and Siwar, 2017). The effect of crop commercialization was determined using dummy variables assigned to the terciles. The first tercile was used as a base. As indicated in Table 9, the coefficients of both the second and third tercile had the expected negative sign but only the coefficient of the second tercile was significant. The negative coefficients suggest that crop commercialization is likely to reduce household poverty as reported by several studies on the effect of agricultural commercialization on poverty (See for example Hailua *et al*., 2015; Muriithi and Matz, 2015; Ochieng and Hepelwa, 2018; Cazzuffi *et al*., 2020).

Coefficients for sex of household head, age category of the farmer, household size and total cropland are insignificant. Regarding the sex of household head, being a male had a significant positive effect on MPI. The positive effect on MPI suggests a high likelihood of an MHH being poor. This result supports the finding by Majeed and Malik (2015) but contradicts the findings that FHH are likely to be more impoverished than MHH (Buvinic, Gupta and Casabonne, 2009; Mitiku, 2014; Isinika et al., 2020; Mdoe et al., 2020). The coefficient of age category is negative, suggesting that households headed by young farmers are more likely to be less poor than households headed by old farmers. This result supports similar findings from numerous studies that show households are likely to be poor as the age of the household head increases (Rahman, 2013; Mdoe et al., 2020).

As in the case of the sex of household head, household size had a positive effect on MPI, suggesting that household poverty is likely to increase as the household size increases because of a higher dependency ratio, as reported by previous studies that have examined the effect of household size on household poverty (see for example Meyer and Nishimwe-Niyimbanira, 2016; Mdoe et al., 2020). As expected, total cropland had a negative effect on MPI, implying the likelihood of reducing household poverty as total cropland increases. This finding is consistent with results of previous studies that have examined the effect of farm size on poverty that household poverty is likely to decline as the farm size increases (Gassner et al., 2019; Onuche and Oladipo, 2021).

Table 12: Determinants of household poverty status: probit estimates

Independent variable	Coefficient	Robust se	Marginal effect	p>|z|
Sex category of household head (1 = male head)	0.2655	0.2334	0.0842	0.255
Age category of farmer (1 = young farmer)	-0.2847	0.1883	-0.0903	0.131
Education (years of schooling)	-0.0693*	0.0386	-0.0219	0.072
Household size	0.0105	0.0309	0.0033	0.735
Total crop land (ha)	-0.0414	0.0333	-0.0131	0.214
Number of livestock kept (TLU))	-0.029**6	0.0139	-0.0094	0.034
Non-farm income (100,000Tsh)	-0.0296**	0.00937	-0.00643	0.031
CCI_T_2	-0.3910**	0.1945	-0.1239	0.044
CCI_T_3	-0.1306	0.1921	-0.439	0.497
Constant	1.4069***	0.3319		0.000

N=357, Wald $\chi^2_{(9)}$=31.91, p>χ^2=0.0002 and Pseudo R^2=0.0917

Notes: * significant at p<0.1, ** significant at p<0.05 and *** significant at p<0.01

4.0 Conclusions and Recommendations

This paper examined the effect of livestock on crop commercialization and farmers' livelihoods in the Singida region, Tanzania. Quantitative data for the analysis were extracted from the APRA data set of 600 households selected randomly from random samples of eight and seven villages in Iramba and Mkalama districts respectively. The quantitative data were complemented with qualitative data collected through focus group discussions and key informant interviews. As hypothesized, the results show that livestock has enhanced crop commercialization and increases the probability of reducing poverty among crop-producing households. This enhancement stems from the provision of livestock manure for soil fertility improvement and ox-plough as a tillage technology. Apart from livestock, a range of other factors have worked together with livestock to drive the crop commercialization process and reduce poverty. These include use of tractor as a tillage implement, total land planted with crops, farmer's education level, access to markets and the use of productivity (yield) enhancing inputs such as improved seed, inorganic fertilizers and pesticides.

Although livestock and the other factors have positive effect on commercialization and poverty reduction, social disparities exist. MHH, households headed by MSF, households headed by young farmers and households with livestock fared well in terms of level of commercialization and poverty reduction, being above their counterparts, including FHH, households headed by SSF, households headed by old farmers and households without livestock. These social differences are the consequences of differences in the use of livestock manure, ox-plough, tractor and other productivity enhancing inputs like inorganic fertilizer. For example, MHH had more access to land for commercial crop production compared to their FHH counterparts while households headed by MSF had more access to land than households headed by SSF. In addition to more access to land, use of ox-plough, tractor, manure and other productivity enhancing inputs was higher among MHH and households headed by MSF than FHH and households headed by SSF

The above findings point to the need for farmers, local government authorities and development practitioners to recognize and enhance the complementarity between crop and livestock in the crop-livestock farming systems. Specifically, efforts should be made to promote (i) use of manure for fertility improvement, (ii) use of animal power not only for land preparation but also for weeding and transportation of harvested crops to homesteads/warehouses/market and, (iii) promote use of crop residues and by-products from crop farms as livestock feed to sustain availability of livestock manure and animal power. This should go hand in hand with encouraging livestock keepers to control livestock numbers to avoid land degradation. The promotion of animal traction should go hand in hand with ensuring timely availability and application of fertilizers to complement the use of manure to enhance crop yields. Meanwhile, some factors were obstacles to crop commercialization which, if addressed, could accelerate the crop commercialization processes. These include but are not limited to household size – which increases subsistence consumption at the expense of marketable surplus – and poor access to crop markets due to the absence of good roads that link the crop producing villages to crop markets. Interventions to promote crop commercialization should go hand in hand with efforts to increase access to family planning and reproductive health services in rural areas. This will address the decline in marketable surplus due to high household consumption in big households and hence reduce marketable surplus. Regarding market access, the government has made commendable improvements in major roads connecting regional and district headquarters in the country through Tanzania National Roads Agency (TANROADS). Although the government has established Tanzania Rural and Urban Roads Agency (TARURA), much remains to be done to improve and maintain roads connecting district headquarters to villages. TARURA should be given annual budget allocation by the central government. This should be complemented by funds from respective district councils when needs arise.

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Annexes

Annex 1: **Indicators Used to Compute Multi Poverty Index (MPI)**

S/N	Indicator	Measurement
1	Years of schooling	Assigned 1 for a household that did not have any member who has at least five years of schooling and 0 otherwise
2	School attendance	Assigned 1 for a school-age child out of school, and 0 otherwise
3	Child mortality	Assigned 1 for a household that reported a death of a child in the household during the past ten years, and 0 for a household that had not
4	Nutrition	Used the Food Insecurity Experience Scale with a cut-off point of five, where those scoring five and above out of nine were considered to be deprived nutritionally (See list of food insecurity situation in Annex 2b below).
5	Living standards:	
6	Electricity	Assigned 1 for a household that did not have electricity, and 0 for one that had electricity
7	Drinking water	Assigned 1 for a household that did not have access to clean water, i.e. use unprotected sources, and 0 for a household that had access to clean drinking water.
8	Sanitation	Assigned 1 for a household that did not have adequate sanitation (i.e. no toilet facility, go to bush or field, use pan or bucket, use traditional pit latrine), and 0 for a household that had a ventilated improved pit latrine and a flush toilet
9	Flooring	Assigned 1 for a household that had dirty, earth, dung floor etc, and 0 to a household that had a tiled, cemented, concrete floor
10	Cooking fuel	Assigned 1 for a household that cooked with wood, charcoal or dung, and 0 was given to a household that used gas, electricity or paraffin as the main source of cooking energy
11	Asset ownership	Assigned 1 for a household that did not own did not own a car or tractor, or more than one of the following: radio, TV, telephone, bicycle, motorcycle, or refrigerator; the value of 0 was given to a household that owned more than one of the listed assets

Source: Authors' own