THE ROLE OF ROAD INFRASTRUCTURE IN AGRICULTURAL PRODUCTION

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ABSTRACT

Road infrastructure is the backbone of many rural and urban transport systems. Rural transport provides assurance for the supply of the agricultural inputs and facilitates the delivery of the farm outputs to the markets. In rural areas, among other strategies to stimulate agricultural sector development is to improve rural accessibility through the provision of rural road infrastructure and improved transport services. Little is known, however, about the extent of agricultural production improvement following these initiatives. This paper investigates and empirically quantifies the impact of improved rural accessibility on agricultural production of Tanzanian smallholder farmers. Using the Tanzania National Panel Survey (NPS) data of 2012/13, the relationship between transport price, access to the market and crop yield was established. The results show a positive impact on crop yield following the reduction of transport price with an elasticity of -0.291. Farmers who have access to the bigger markets, on average, produce high crop yield. For the development of the agricultural sector, the improvement of rural road infrastructure and transport service should be linked to the roads going to the bigger markets, otherwise, the impact on agricultural sector will be low.

1. INTRODUCTION

The African Development Bank has recognised that investment in infrastructure such as transport, power supply and telecommunication is important for supporting economic growth, reducing poverty and achieving the Millennium Development Goals (MDGs) (Kandiero, 2009). At a macro level, infrastructure investment allows for better private sector activities through lowering production cost, opening up new markets for goods and services and supporting trade (Kandiero, 2009). Road infrastructure improvements, for example, can be expected to raise the output price of the producers and lower production cost through the reduced transportation cost of goods and services (Kiprono & Matsumoto, 2014).

Poor transport infrastructure, high transport cost and missing links in the transport network pose a challenge for market integration and intra-African trade. The level of transport

infrastructure development in African countries is still low; only 30% of the rural population have access to all-weather roads (Kandiero, 2009). Transport prices in Africa are estimated to be twice as high as those of South and East Asia (Kandiero, 2009).

Despite the importance of infrastructure for economic growth in African countries, investment in infrastructures such as transport, power supply and telecommunication account for only 2 – 3% of Gross Domestic Product (GDP) (Kandiero, 2009). Comparing this to China, for instance, during the period 1996 – 2005, infrastructure investment was on average 7.78% of its GDP. This investment was believed to spur a large part of its growth (Davis, 2008).

In many African countries, the agricultural sector is important for economic growth. In Tanzania, the agricultural sector contributes roughly 26% to the national GDP and reported a growth rate of 2.6% in the fourth quarter of the year 2015 (Tanzania National Bureau of Statistics, 2015a). The sector also accounts for more than two-thirds of the total exports of the country (Tanzania National Bureau of Statistics, 2012) and employs more than 75% of the national population (Tanzania National Bureau of Statistics, 2007). In rural areas, among the strategies often adapted to stimulate agricultural development is the provision of proper and adequate transport. Crossley *et al.* (2009) state that transport is a basic component of the agricultural sector; it provides assurance for the supply of the agricultural inputs and facilitates the delivery of the farm outputs to the market. Improvement of the rural roads and transport services are essential to ensure a price reduction for agricultural inputs, improvement of market access for agricultural produce, and improvement of access to agricultural extension services.

In Tanzania, rural roads and transport services are generally characterised by poor infrastructure, high transport cost and charges as well as a low-quality service (Ministry of Communication and Transport, 2003; African Development Bank Group, 2013).

This paper focuses on investigating and empirically quantifying the impact of improved accessibility on the agricultural production of Tanzanian smallholder farmers. The objective of the paper is to establish the relationship between the transport price of agricultural products and the agricultural production of smallholder farmers. The paper also establishes the potential crop production increase that can be realised if transport prices are reduced through road improvement.

2. LITERATURE REVIEW

Road conditions are an important factor in determining transport costs and prices. Hine and Ellis (2001) in comparing transport price to road roughness in Zambia, illustrated that transport price was twice as high on a poor-quality earth road in comparison to transport price on a good-quality gravel road. A survey conducted in Tanzania found that, over a 50 km section of road, an increase in roughness of 50% would increase truck charges by 16% and increase pickup (light duty truck) charges by about twice as much (Ninnin, 1997 as cited in Hine & Ellis, 2001). The situation becomes worse during the wet season. In

Madagascar for example, the passenger fare for taxis, commonly known as “taxis-brousses”, is 70% higher on poor-quality roads during the wet season than during the dry season (Ninnin, 1997 as cited in Hine & Ellis, 2001).

Several studies suggest that one of the significant constraints for agricultural development in rural areas is the poor condition of rural infrastructure. A study conducted in the Mhlonto local municipality in South Africa by Chakwizira *et al.* (2010) point out that one of the key constraints to sustainable agricultural and rural development is the poor state of the basic rural infrastructures, including transport and irrigation infrastructure. The poor road condition also affects the transport price of agricultural products. Ikejiofor and Ali (2014) conducted a study in Nigeria and concluded that improved road condition is one of the catalysts for better marketing of agricultural products. They pointed out that improved road condition allow for better access to a wider market and reduce losses and delays in moving the farm produce. If the agricultural produce reaches the market in time, in good quality and at low transport price, the situation will attract more money for the producers (Ikejiofor & Ali, 2014). Oyatoye (1994) as cited in Kassali *et al.* (2012) found that, in Nigeria, an improvement in the quality of the roads allows farmers to realise lower marketing costs and receive a better price for their agricultural produce. Another study conducted in Nigeria by Akangbe *et al.* (2013) indicated that over 70% of the study’s participants confirmed that the poor road condition and road seasonality were the reasons for the high transport prices of agricultural produce. In the same study, road conditions and the remoteness of the area were mentioned as reasons which deny farmers access to the various agriculture-related goods and services. Roughly 78% of the respondents reported not to have access to markets, agricultural extension services, agricultural inputs, agricultural credit and the usage of modern farming techniques and equipment (Akangbe *et al.*, 2013). Yaro *et al.* (2014) argued that in an area where accessibility was good, access to farm inputs was 5.9% more than in an area with poor accessibility. Kiprono and Matsumoto (2014) using longitudinal data from 2004 to 2012 in Kenya indicated an increase in the use of maize hybrid seeds, chemical fertilisers and maize productivity in areas with better road access.

Hine and Ellis (2001) argued that if the transport cost is equivalent to 30% of the farm-gate price, a 20% reduction in the transport cost fully passed to the farmers will result in a 6% increase in farm-gate price. They also point out that if the agricultural production elasticity is +1 (it normally ranges from 0 to 1.5) then the agricultural outputs are estimated to rise by 6%. Dorosh *et al.* (2010) conducted a study on crop production and road connectivity in Sub-Saharan Africa and found that a one percent reduction in travel time to the nearest city would increase crop production by between 1.6 and 4.8%, depending on the population of the nearest city and the type of technology employed in crop production.

Hine *et al*. (1983) conducted a study in Ghana and found that poor accessibility may adversely affect agriculture through the inability to obtain finance. Two related reasons explained the inability to obtain loans i.e. (i) physical measurement of the field/farm (a necessary part of the finance application process) was difficulty due to remoteness; and (ii) the difficulty and higher cost of making follow-up trips for the loan progress. Hine *et al.*

(1983) also indicate that villages located further from major markets experienced lower farm-gate prices due to higher transport charges.
The literature reveals that the condition of the road affects the transport cost of vehicles transporting goods and passengers as well as the price charged by the transport operators. Transport costs and prices, and the level of accessibility of a rural area, also play a significant role in the development of agricultural sector. However, there is still little evidence on the impacts of a reduction in transport costs and transport prices on crop production.

3. DATA

National Panel Survey (NPS) was conducted in Tanzania with the main purpose of providing data to be used by the government and other stakeholders in measuring the progress the National Strategy for Growth and Reduction of Poverty (NSGRP II), as well as assessing the impact of other national policy initiatives (National Strategy for Growth and Reduction of Poverty, 2010; Tanzania National Bureau of Statistics, 2014).

The NPS data for 2012/2013 was collected by the Tanzania National Bureau of Statistics (NBS) (Tanzania National Bureau of Statistics, 2014) and the survey data were obtained from the World Bank database as part of the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) (World Bank, n.d.).

Data from the 2012 population and housing census indicated a total of 9 276 997 households in Tanzania. Of these 66.7% are located in rural areas and 33.3% in urban areas (Tanzania National Bureau of Statistics, 2015b). For the 2012/2013 NPS, a total of 5 015 households were used as the representative sample of the population (Tanzania National Bureau of Statistics, 2014).

The National Panel Survey included four types of instruments for data collection: a household questionnaire, an agricultural questionnaire, a livestock/fishery questionnaire and a community questionnaire (World Bank, n.d.). Each questionnaire was divided into different sections. For the purpose of this paper, most of the required information such as household agricultural production, sales, types of crops cultivated and transportation charges were obtained from the agriculture questionnaire.

The data set comprised of 15 different files with agricultural information. Merging of the files and aggregation of the data were done for each household, as presented in Figure 1. The process involved identifying the number of plots cultivated by each household and the types of crops planted on each plot. A household can plant the same crop on more than one plot. It can also plant multiple crops on the same plot. The crops from different plots were aggregated to get the total amount of cultivated crops per household. The final data set comprised of 5 010 households and 8 487 cases.

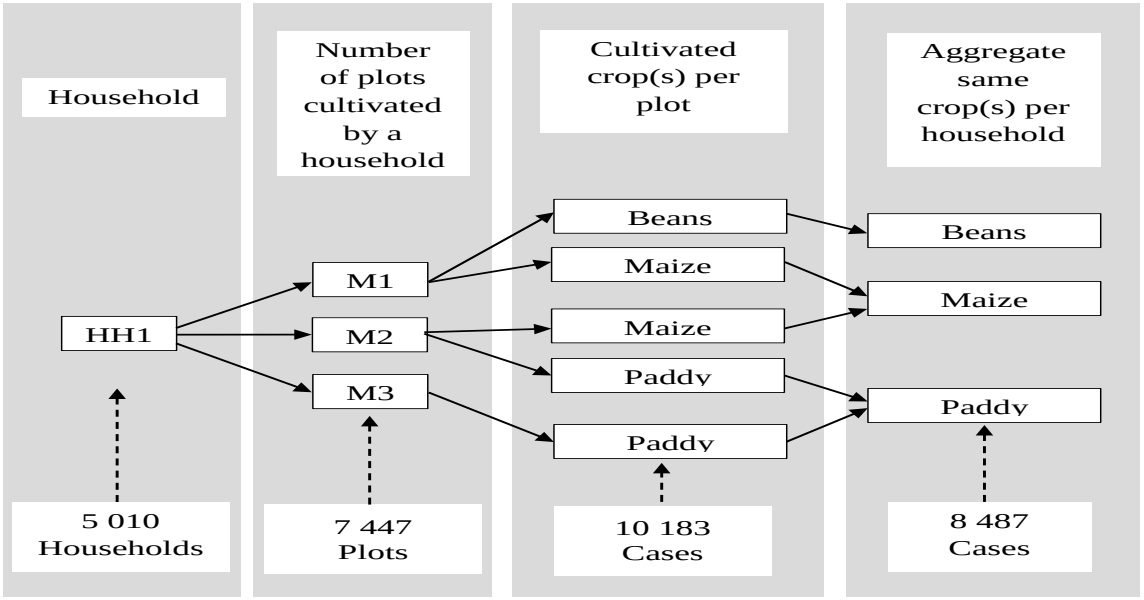

Figure 1: Merging and aggregation process

4. DATA ANALYSIS AND RESULTS

4.1. Descriptive statistics at household level

The aggregated data set provided crop information at the household level (Figure 1). The data set provided 64 different types of crops and a household may cultivate more than one type of crop.

4.1.1. Crop selling and transportation

A household may sell part of the harvested crops or not sell at all. Among those who sold their crops, some of the households reported transporting their crops to the markets. Table 1 indicates that 38% of cultivated crops (per households, see Figure 1) were sold, of which 30.6% were reported to be transported to the markets. Of the 30.6% who transported their crops to the markets, 62.8% reported paying nothing for the transportation of the crops. This may indicate that family labour was used (see Section 4.2.2). A further analysis revealed that only 4.3% (n=261) of the total number of harvested crops (n=6 070) involved payment for transportation to the market. Generally, these results suggest that most of the farmers engage in subsistence farming; only a few sold their crops.

Table 1: Descriptive statistics: Crop selling and transportation, 2012/13 NPS data

	Frequency						
	YES	**Percent**	**NO**	**Percent**	**Sub Total (N value)**	**Missing Data**	**Total**
Did you sell crops?	2 302	38	3 768	62	6 070	2 417	8 487
Did you transport crops for selling?	704	30.6	1 598	69.4	2 302	6 185	8 487
Pay for transport service?	261	37.2	443	62.8	704	7 783	8 487

The results in Table 2 show that, on average, those who sold crops had significantly bigger farm sizes and higher quantity harvested. However, there was no significant difference in crop yield between the two groups. The results also show that bigger farms were further from the road and from the local market. It is normal to have people reside close to the road (residential areas), and they may have relatively small farms near their homes and bigger farms further from their homes.

Table 2: Difference in farm size, crop production and distance variables, 2012/2013 NPS data

Variable description	Did you sell crops?		
	YES (N value = 2 302)	NO (N value = 3 768)	P value
Average area harvested (acres)*	2.5	1.5	0.000
Average quantity harvested (kg)*	906	310	0.000
Average crop yield (kg/acres)*	552	445	0.445
Average distance from the farm to the road (km)	3.0	2.0	0.000
Average distance from the farm to the local market (km)	12.5	10.2	0.000

*Values for all crops

The results in Table 3 show that those who sold but did not transport their crops for selling had a significantly higher crop yield, however, there was no significant difference in the quantity they harvested and the quantity they sold when compared to those who reported transporting their crops to market for selling. The data set, however, did not reveal how the farmer's products reach the market. Therefore, not much can be said about the agricultural production of these farmers in the context of road infrastructure and associated transport prices involved in transporting their crops to the market. The average crop price was significantly higher for those who transported their crops compared to those who did not. Looking at the distance variables, it was also found that there is no significant difference between the average distances from the farm to the road and from the farm to the local market between these two groups of farmers.

Table 3: The differences between transported vs non-transported crops, 2012/2013 NPS data

Variable description	Transported crops for selling?		
	YES (N value =704)	NO (N value = 1598)	P value
Average area harvested (acres)*	2.7	2.3	0.041
Average quantity harvested (kg)*	883	917	0.747
Average crop yield (kg/acres)*	462	592	0.004
Average quantity sold (kg)*	565	547	0.729
Average crop price (Tsh/kg)*	819	696	0.000
Average distance from the farm to the road (km)	2.7	3.0	0.337
Average distance from the farm to the local market (km)	12.9	12.3	0.400

*Values for all crops

The results in Table 4 show that those who paid for transport services, transported their crops to a more distant market for selling, compared with those who did not pay. Those who paid for transport service had farms significantly further from the local market. There was no significant difference for the distance from the farm to the road between these two groups. Those who paid for transport services had a significantly higher crop yield, crop price and quantity sold.

Table 4: Differences between those who pay and those who did not pay for transport services, 2012/2013 NPS data

Variable description	Did you pay for transport services?		
	YES (N value = 261)	NO (N value = 443)	P value
Average area harvested (acres)*	2.7	2.8	0.737
Average quantity harvested (kg)*	1 074	769	0.073
Average crop yield (kg/acres)*	578	393	0.001
Average quantity sold (kg)*	820	414	0.000
Average crop price (Tsh/kg)*	909	767	0.017
Average distance from the farm to the road (km)	3.2	2.3	0.077
Average distance from the farm to the local market (km)	16.4	10.7	0.000
Average distance to the market for selling (km)	22.5	6.9	0.000

*Values for all crops

4.1.2. Mode of transport

Four different modes of transport were reported to be used to transport crops to the market (Table 5). The results indicate that, on average, the Non-Motorised Transport (NMT) trips are shorter compared to car trips. NMT includes walking, cycling or the use of animals. The results also show almost all those who reported not paying for transport services use NMT modes. This may indicate that family members together with animals or bicycles were used. Cars were more frequently used by the farmers who reported to pay for transport services. Table 5 also shows that in some instances where hired NMT modes were used, they charge a higher transport price than that of the usage of cars.

Table 5: Mode of transport, distance, payment for transport service, 2012/13 NPS data

Means of transport	Pay for transport service (N value = 261)		Not pay for transport service (%) (N value = 443)	Average distance to the market for selling (km) (N value = 704)
	(%)	Transport price (Tsh/ton-km)		
On Foot	2.3	4 229	28.7	5
Bicycle	21.4	3 353	51.4	8
Animal	17.6	2 806	14.0	6
Car	42.7	2 220	0.5	44
Other	16.0		5.4	
Total	100		100	

(Exchange rate, 2013: 1USD = Ths 1600)

4.2. Agriculture production and transport service

Considering the effect of transport infrastructure and transport service on the agricultural sector, four aspects were examined:

(i) The price of transporting agricultural products.

(ii) The distance from the farm to the road.

(iii) The distance the crop is transported to the *market for selling* (market for selling can be a physical local market or any other market or a place where farmers sell their crops to individual buyers or institutions).

(iv) The distance from the farm to the *local market*.

Crop yield (i.e. crop produced per unit area of land cultivation) was used to determine the relationship between agricultural production and transport services. The analysis included only the farmers who reported transporting their crops to the market and paying for the transport service, which constituted 261 cases, equivalent to 4.3% of the total number of harvested crops (Table 1 and Figure 2).

4.2.1. Crop yield and transport service

Crop yield may be influenced by, among other things, the use of the agricultural inputs, the available technology, weather conditions and the soil type. This paper examines the relationship between road infrastructure, transport services and crop yield. Ordinary least squares (OLS) regression was used to empirically quantify this relationship.

The OLS model comprises of six independent variables with crop yield as the dependent variable. The list below presents a brief description of the independent variables used in the analysis:

(i) **Agricultural inputs** such as inorganic fertiliser, herbicides/pesticides and improved seeds are not manufactured in the rural areas and have to be transported from the area of production to the rural areas. The transport service and associated transport cost during the transportation of the agricultural inputs may, in one way or another, affect the usage of the inputs and eventually the crop yield.

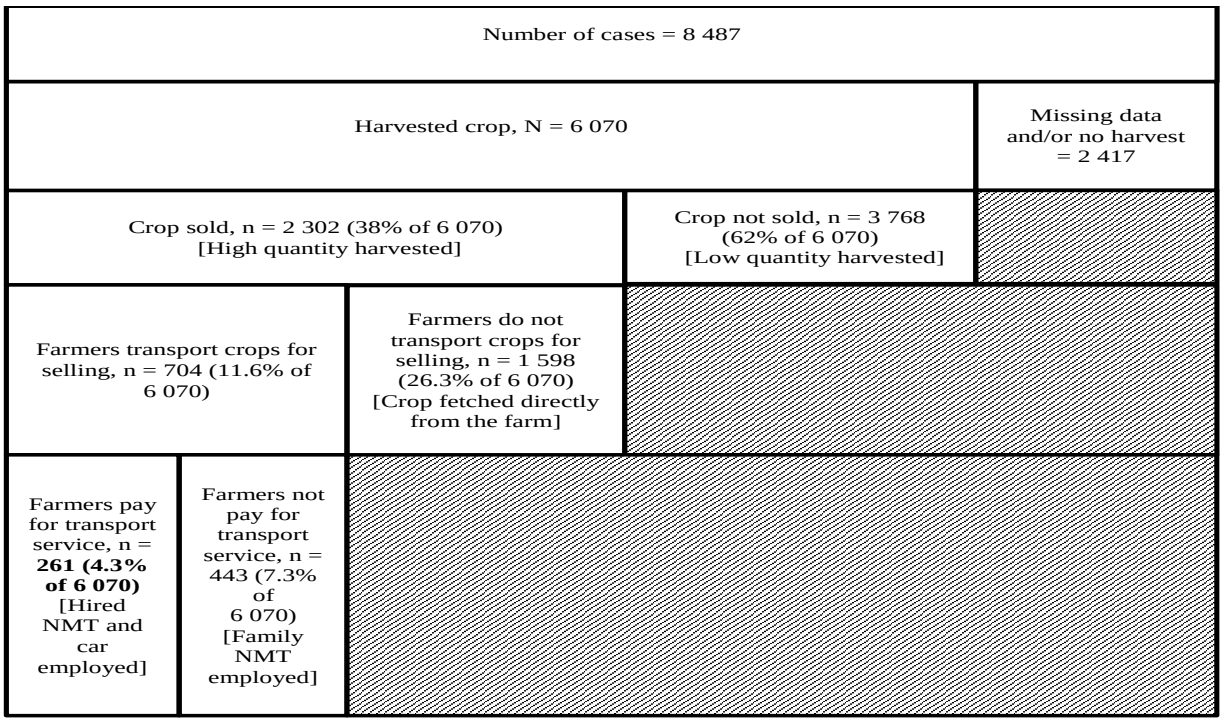

Figure 2: Sub-sample used in the regression analysis

(ii) **Crop market prices** act as an incentive/disincentive to the farmers in relation to the crop yield. Higher crop prices may motivate the farmer to produce more and vice versa. The cost associated with transporting the crops to the market will impact the market price.

(iii) The **distance from the farm to the road** was used to measure the influence of road infrastructure availability on crop yield.

(iv) The **distance the crops were transported to the market for selling** was used to measure the influence of the distance travelled by farmers to sell their crops on crop yield.

(v) The **distance from the farm to the local market** was used to measure the influence of local market vicinity on crop yield.

(vi) **Transport price** was obtained by dividing the amount paid to transport crops by the quantity transported and was included in the variable list in order to measure the direct effect on crop yield.

The empirical model is presented in Equation 1:

Quantity produced per unit land = f(Quantity of input per unit land, market crop price, transport price, distance from the farm to the road, distance from the farm to the local market, distance crop transported to the market for selling) (1)

Each crop has a range of expected harvest per unit of land cultivated (i.e. yield). In order to control for the effect of the different crop yields, the crops were divided into 14 groups, and 13 dummy variables were created. The groups are: (i) sesame; (ii) tobacco; (iii) cotton; (iv) pigeon peas; (v) cow peas; (vi) chickpeas; (vii) green grams; (viii) sorghum; (ix) maize; (x) beans; (xi) paddy/rice; (xii) groundnuts; (xiii) tomatoes; and (xiv) vegetables and roots and tubers. Table 6 provides a list with units of all variables used in the model. All the variables were log-transformed to reduce skewness and to ensure a more normally distributed variable. The final empirical model is presented in Equation 2:

$$ln(Y) = \beta_1 + \beta_2 ln(X_2) + \cdots \beta_n\, ln(X_n) + \alpha_1 D_1 + \cdots \alpha_n D_k + \mu, \quad (2)$$

where:

- *Y = Crop yield;*
- *$X_2, X_3, ..., X_n$ = Factors that may affect crop yield;*
- *$\beta_2, \beta_3, \ldots, \beta_n$ = Coefficients;*
- *$\alpha_1, \alpha_2, \ldots, \alpha_n$ = Dummy variables coefficients;*
- *$D_1, D_2, \ldots, D_k$ = Dummy variables for different types of crops; and*
- *μ = Error term.*

Table 6: Variables used in the crop yield model

	Variables	Units	Observation (N)
Dependent variable	*ln(Crop yield)*	Kilogramme per acre (kg/acre)	261
Independent variables	*ln(Quantity of input per acre)*	Kilogramme per acre (kg/acre)	261
	ln(Market crop price)	Tanzanian Shilling per kilogramme(Tsh/kg)	261
	ln(Transport price per trip)	Tanzanian Shilling per tonne-trip (Tsh/ton-trip)	261
	ln(Distance from the farm to the road)	Kilometre (km)	261
	ln(Distance from the farm to the local market)	Kilometre (km)	261
	ln(Distance crop transported to the market for selling)	Kilometre (km)	261
	Dummies		

The results of the model (Table 7) are statistically significant with an adjusted R-square value of 0.435, meaning that 44% of the variation in crop yield is explained by the linear regression model. Transport price showed a negative relationship with crop yield with an elasticity of -0.291, implying that a one percent reduction in the transport price is associated with an increase in the crop yield by 0.291%. These results corresponded well with the results suggested by Hine and Ellis (2001) which showed that a 20% reduction in transport cost, fully passed on to farmers, will raise the agricultural output by 6%, or stated differently, that a one percent reduction in the transport cost will raise the agricultural output by 0.3%.

Table 7: Crop yield, regression model results

Dependant variable: ln(Crop yield)	*Coefficients*	*P-values*	*Significant F*	*Adjusted R square*
(Constant)	7.559	.000	.000	.435
ln(Transport price-Tsh/ton-trip)	-.291	.000		
ln(Market crop price-Tsh/kg)	.056	.462		
ln(quantity of input per acre)	.080	.008		
ln(Distance from the farm to the road – km)	-.014	.684		
ln(Distance from the farm to the local market – km)	.058	.235		
ln(Distance crop transported to market for selling – km)	.161	.002		
Dummy (Beans)	-.497	.054		
Dummy (Chick Peas)	-1.427	.110		
Dummy (Cotton)	-.431	.072		
Dummy (Cow Peas)	-.171	.791		
Dummy (Green Gram)	-1.876	.000		
Dummy (Groundnuts)	-.596	.040		
Dummy (Maize)	.503	.019		
Dummy (Paddy)	.842	.002		
Dummy (Pigeon Peas)	-.715	.027		
Dummy (Sesame)	-.849	.011		
Dummy (Sorghum)	.308	.635		
Dummy (Tobacco)	-.048	.878		
Dummy (Tomato)	1.285	.001		

The distance that crops are transported to the market for selling showed a positive relationship with crop yield, with an elasticity of 0.161. These results imply that a one percent increase in the distance farmers transport their crops to the market for selling will increase the crop yield by 0.161%. This finding is surprising, as one would expect that those who sell at the nearby markets will have fewer market access problems and lower transport charges, both of which may impact positively on crop yield. Two possible reasons may be associated with these results:

(i) Those who sell their crops at more distant (relatively larger) markets have a higher chance of accessing goods and services which may not be available locally. These include agricultural inputs, advice from extension officers and people they meet which in turn may facilitate the increase in crop yields.

(ii) Selling at more distant markets is associated with a lower unit transport price measured in *per ton-km* (see Fungo & Krygsman, 2017), as well as a higher crop price (see Table 4). Longer routes have the advantage of economy of distance; the road conditions are relatively good (secondary roads go to the bigger markets) and the use efficient modes of transport (longer trips use cars as opposed to walking and cycling). Relatively speaking, those who sell at more distant markets are better off in terms of transport price and crop price, which in turn may facilitate an increase in crop yield.

The quantity of inputs per acre showed a positive relationship with crop yield, with an elasticity of 0.080. A one percent increase in the quantity of input per acre will increase the

crop yield by 0.08%. The analysis showed no statistically significant relationship between crop yield and market crop price.

It is expected that if the farm is closer to the road, there are benefits such as lower transport prices and ease of access to the market, which may be associated with higher crop yield. However, the analysis showed no statistically significant relationship between the distance from the farm to the road and crop yield. This could be due to the fact that most of the tertiary roads near the farms are of poor quality and do not provide sufficient transport services required to lower the transport price.

The distance from the farm to the local market also reveals no statistically significant relationship with crop yield. As discussed, farmers who sell their crops at a more distant market experience an increased crop yield. The fact that the distance from the farm to the local market was not statistically significant indicates that the local market alone is not providing sufficient goods and services required by the farmers to facilitate the increase in crop yields.

Dummy variables coefficients showed the expected results, with the highest coefficient for tomatoes, 1.285, and lowest for green grams, -1.876.

5. CONCLUSION AND RECOMMENDATIONS

Figure 3 summarises the findings of the paper. A reduction in the transport price to transport agricultural products has a positive impact on the agricultural yield. The elasticity of this impact is -0.29, i.e. a one percent reduction in transport price increases crop yield by 0.291%. Investing in road infrastructure in order to reduce transport costs and prices will, therefore, benefit the agricultural sector.

The paper has also revealed that those farmers who sell their crops at a more distant (relatively larger) market have higher crop yield compared to those who sell at a nearby (local) market, with an elasticity of 0.161.

If a farm is close to the road, it to some extent facilitates access to the local market as well as to the bigger market. However, due to the poor condition of most of these tertiary rural roads, the presence of the road is not enough to ensure access to the bigger market as well as lower transport price.

The established empirical relationship between transport price and crop yield can be used during the road appraisal processes to quantify the expected increase in agricultural yields following the road infrastructure investment. Road infrastructure investment lowers transport cost and transport price (Fungo & Krygsman, 2017). However, in order to improve agricultural yield and production, an improved rural road network must be linked to the secondary roads going to the bigger markets (improve access to bigger market); otherwise, it will not have the necessary impact on the agricultural sector.

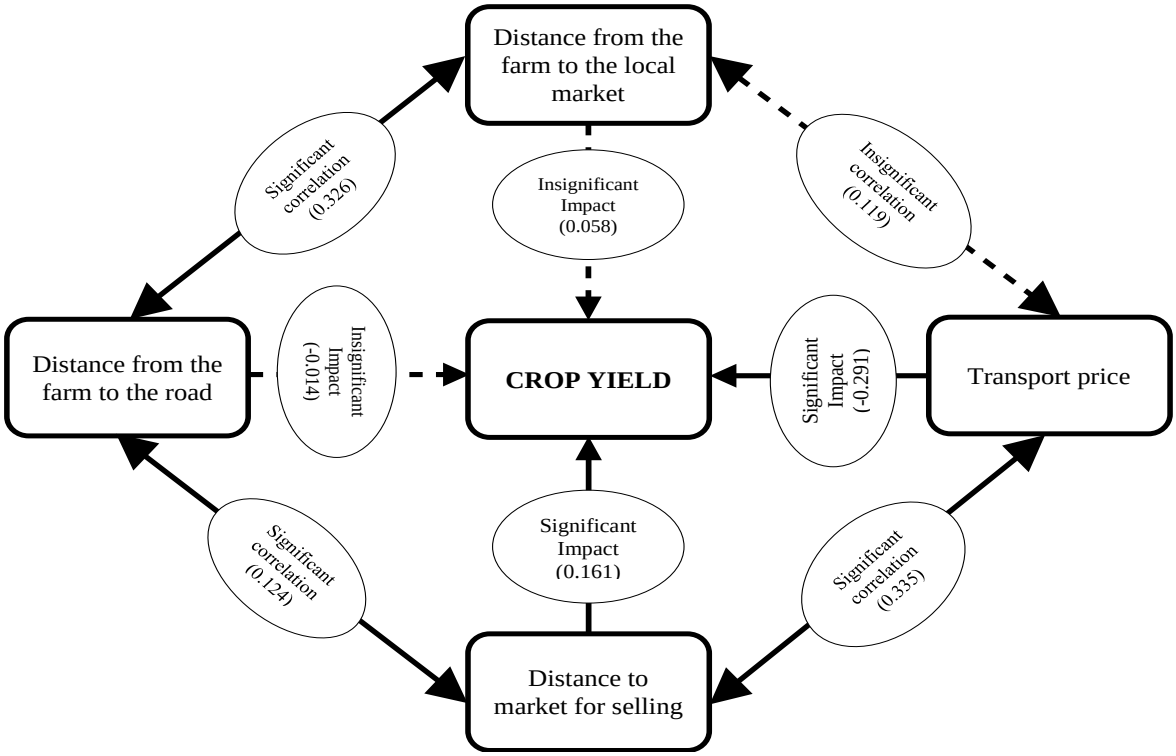

Figure 3 : Relationship between crop yield, road infrastructure and transport service

Despite the fact that improved road infrastructure and transport services are necessary they are not the only factors to ensure agriculture development and sustainable poverty reduction in rural areas (Chakwizira *et al.*, 2010). Road infrastructure investment should preferably complement other rural development programmes such as investment in irrigation systems and post-harvest storage technology as well as provision of extension services and financial support.

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