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Derived demand for African indigenous vegetable seed: implications for farmer-seed entrepreneurship development

RESEARCH ARTICLE

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Abstract

African indigenous vegetables (AIVs) hold potential to address food security and nutrition in Africa. Their production and consumption remain constrained by lack of quality seed. Efforts to promote commercial seed production lack information about the effective demand of AIV seed. This study estimated derived demand for input seed in central Uganda using trans-log production model. Own-price and cross-price elasticities for production inputs were estimated using marginal approach. Seed demand analysis showed that farmers would utilise seed from market sources of approximately 32 tons per year, against current formal supply of 4.4 tons. Estimated price elasticities showed that purchased seed was less sensitive to its own price, implying less significant effect of price change on the quantity of seed demanded over time. Seed production exhibited higher gross margins and returns to labour day compared to vegetable production, suggesting prospects of profitability and sustainability of farmer-seed enterprises as an alternative source of quality seed for farmers.

Keywords: diversification, elasticity, good seed initiative, seed demand, seed entrepreneurship.
JEL code: Q10, Q11, Q13

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1. Background

The 2016 Global Hunger Index shows that the level of hunger in developing countries has fallen by 29% since 2000. Despite this progress, Food and Agriculture Organisation of the United Nations shows that the level of hunger in the world is still 'serious,' with estimated 805 million people continuing to go hungry. Africa has the highest poverty rate in the world, with 47.5% of the population living on $1.25 a day. Chronic hunger has been exacerbated by malnutrition and hidden hunger caused by a deficiency of micronutrients, with an estimated 2 billion people around the world suffering from various forms of malnutrition and hidden hunger (Von Grebmer *et al.*, 2014). Out of 39 countries with the highest burden of undernutrition of under-five, 22 are in Africa, Uganda inclusive (WorldBank, 2013). Micronutrient deficiencies, including in vitamin A and iron, are highly prevalent in women and children. Prevalence of iron deficiency is 53% in children under five and 32% among women of childbearing age (UDHS, 2016). Undernutrition is an underlying cause of 60% of deaths for children under five. Leach and Kilama (2009) report that malnutrition is more common among households which consume diets of mainly carbohydrate-rich staples with low minerals and vitamins, a common scenario in most African countries. This situation has led to increased public awareness of production and consumption of diverse crops and ensuring availability of nutrient-rich foods, including fruits and vegetables. Dietary diversification has been reported as a cost-effective strategy to ameliorate malnutrition (Ghosh-Jerath *et al.*, 2016).

African indigenous vegetables (AIVs) have potential as a sustainable means to address food security and nutrition, particularly for poor urban and rural households. AIVs include all plants that originate on the continent, or have a long history of cultivation and domestication to African conditions and whose leaves, fruits or roots are used as vegetables (Ambrose-Oji, 2012). AIVs have traditionally been a key component in the African diet heritage, and are known to complement staple-based diets. They are an important source of micronutrients, fibre, vitamins and minerals especially calcium, iron and phosphorus, vitamins A and C and proteins (Ghosh-Jerath *et al.*, 2016; Kamga *et al.*, 2013; Yang and Keding, 2009). Empirical evidence shows the positive role of AIVs in increasing dietary diversity (Abang *et al.*, 2014; Ochieng *et al.*, 2016) and reducing food insecurity (Kabunga *et al.,* 2014). AIVs production has also demonstrated higher returns to labour (Kansiime *et al.*, 2016) and higher farm gate values per unit area (Afari-Sefa *et al.*, 2015) compared to a typical cash crop e.g. maize or sunflower, thus significantly contributing to household incomes and food security. Their shorter growing cycles (compared to main staples e.g. maize), little space requirement and ability to maximise scarce water supplies and soil nutrients (Tenkouano, 2011; Weinberger and Lumpkin, 2007) make them amenable to all year round production guaranteeing food availability at the household level. They are also adapted to local agro-ecologies, and farmers have indicated that they integrate local vegetables into their farming systems to respond to climate risks, particularly droughts (Kansiime and Mastenbroek, 2016).

Despite the multiple benefits of AIVs – improving nutrient intake, household incomes and collateral benefit on environmental sustainability – their production and consumption has been limited by negative perceptions and lack of awareness of their nutritional benefits (Afari-Sefa *et al.*, 2015; Muhanji *et al.*, 2011). In some cultures, they are considered poor people's crop, something to be left behind once one modernises (Yang and Keding, 2009). The substantive, long-term underinvestment in research and development of the horticultural sector, particularly with regard to traditional crops (Afari-Sefa *et al.*, 2012; Vorster *et al.*, 2007), further reduces the status of AIVs in most African countries. The trend is changing amongst many East African consumers due to increasing efforts to promote consumption of AIVs to achieve nutrition and health benefits. Increased awareness has elevated the commercial importance of AIVs and they are currently competing with standard vegetables in supermarkets and retail shops in East Africa (Irungu *et al.*, 2007; Muhanji *et al.*, 2011; Ojiewo *et al.*, 2013). This demand has seen AIVs enter into lucrative markets which have resulted to better incomes for smallholder farmers growing them. In East Africa, popular AIVs in urban markets and rural settings include amaranth, okra, spider plant, jute mallow, celosia, cowpea leaf, African nightshade and African eggplant (Lotter *et al.*, 2014; Olasantan, 2007).

Farmers' capacity to meet a growing demand for these vegetables has been limited by lack of good quality seed of preferred varieties and technical packages (Abukutsa, 2010; Afari-Sefa *et al.*, 2013). The majority of farmers either use seed saved from their crops (usually leftover or deliberately saved over many years), seed from neighbours or from local shops, often with problems of both purity and germination. The absence of good quality seed leads to significant production losses affecting household incomes and food security. A number of seed companies aiming to satisfy this demand in Uganda have resorted to imported seed. CAB International (CABI), under the Good Seed Initiative (GSI) strategy, has been working with partners in Uganda to address this gap by strengthening AIV seed systems. This is done through promotion of farmer seed entrepreneurship – farmers producing quality seed for purposes of sale to other farmers, and promotion of good agricultural practices. Empirical evidence from CABI's previous work shows that farmer-led seed enterprises are critical in successfully unleashing the potential of AIVs to improve livelihoods especially for the most vulnerable populations (Karanja *et al.*, 2011). Other studies also show that farmer-led seed enterprises offer a sustainable solution to the accessibility of good quality and certified seed (Rajendran *et al.*, 2016; Subedi *et al.*, 2013).

However, a general lack of information about the effective demand for AIV seed exists, particularly in the context of Uganda. Without such information, it is difficult to promote commercial seed production. Seed demand is the quantity of seed that buyers are willing and able to purchase at a particular price. This is called effective demand and is different from seed requirement. It is important to understand the quantity of seed farmers will actually buy and how much they would like to buy, in order to guide efforts for promoting seed entrepreneurship. This study, therefore, aimed to generate information to understand characteristics of AIV subsector in Uganda with the view of estimating potential demand for AIV seed. Specifically, the study aimed to achieve the following objectives; (1) establish the most preferred AIVs at household and retail level and ascertain their production system; (2) Examine AIV seed input requirements and demand, and (3) assess opportunities and potentials for market-oriented farmer-seed production. Results are useful in providing guidance on the development of strategies for enhancing AIV subsector performance in order to meet the demand for both seed and vegetables.

2. Methodology

2.1 Research design

The study used descriptive research design, aimed at providing an accurate portrayal of characteristics of the AIV subsector in Uganda. This allowed description of what exists in the AIV subsector in order to quantify the potential demand for AIV seed. The study employed both qualitative and quantitative data collection methods. Data were collected during July-August 2015 from a cross-section of AIV subsector actors: agro-dealers, vegetable producers, seed producers, and vegetable traders. The reference period for the indicators used in this study was March-June 2015 growing season in the region. Data were collected using four main methods; household survey, Focus Group Discussions (FGDs), checklists and observations.

2.2 Study area and sampling design

The study was conducted in Central Uganda. The region has a high level of rainfall (>1,200 mm per year) distributed throughout the year in a bimodal pattern. It's dominated by the banana-coffee farming system (Nkonya *et al.*, 2008). AIVs are also popularly grown in the region, and in some parts of the region are considered to be as important for cash as coffee, the main cash crop for the country (Ssekabembe *et al.,* 2002). Five districts were purposively selected, targeting areas where CABI already had ongoing activities under the GSI promoting farmer seed enterprises. The selected districts were; Buikwe, Kampala, Masaka, Mpigi, and Wakiso.

Using Bartlett *et al.* (2001) sample determination table, we took a sample of 209 at 0.01 alpha level and 3% margin of error. This sample size was increased to 250 to mitigate a predicted 20%-25% non-response rate. The sample was then distributed equally, targeting 50 households per district. During data collection, however, only 193 households were interviewed mainly in four districts, with a very low response rate in Kampala (Table 1). Our assumption of interviewing urban farmers did not hold as the target numbers were not achievable. Therefore, data analysis and results are based on four districts, less Kampala.

The household survey sought information on household characteristics, AIV production practices (AIVs grown, the area under production, varieties, quantity and type of inputs used), and AIV seed systems (sources of seed, quantities obtained by farmers from various sources). Besides household interviews, we conducted six focus group discussions (81 participants), targeting both vegetable and seed producers (Table 2). Focus group discussions sought information on the most preferred AIVs, trends in production of AIVs, the profitability of vegetable and seed enterprises, and gender participation in AIV production and marketing. Participants in the FGD were of mixed gender and age categories which added value to the discussion to understand perceptions of different social categories with regard to the research questions.

In addition, we interviewed 35 agricultural input dealers and 44 vegetable traders. Information from traders and agro-dealers included; market structure and participants, trends in volumes handled and innovations along the value chain (Table 1).

2.3 Empirical model

Seed input demand model was used to analyse seed demand and factors affecting demand, given that the sector utilises seed (in planting) is in response to final consumer demand for vegetables. First, we estimated the seed requirement (Crissman, 1989). Seed requirement is the seed needed to plant the total AIV production

Table 1. Proportion of study respondents by sex (households).[1]

District	Sub counties	HH respondents			Agro-dealers (#)[2]	Vegetable traders (#)[2]
		Total	% female	% growing AIVs		
Buikwe	Ngongwe, Nkokonjeru	48	54	97	5	7
Kampala[3]	Makindye	3	0	100	15	10
Masaka	Buwunga, Kitengesa,	50	72	96	5	10
Mpigi	Mbizinya, Kamengo, Buwama	48	77	87	3	12
Wakiso	Namayumba, Busukuma	44	64	97	7	5
Total		193	66	96	35	44

[1] HH = household; AIV = African indigenous vegetables.

[2] Respondents were interviewed per district not necessarily by Sub County.

[3] Given the statistically insignificant number of respondents, no further analysis and reference was done on vegetable growers in Kampala, except for information obtained from focus group discussions.

Table 2. Focus group discussions (FGD) participants and their location.

District	Sub-county	Farmer group	Participants at FGD			Category of growers
			Male	Female	Total	
Kampala	Makindye	Shira Women Association	0	10	10	Vegetable
Mpigi	Kamengo	Kiswa Kwekulakulanya Organic	3	11	14	Vegetable
Wakiso	Namayumba	Basooka Kwavula Women's Group	7	5	12	Vegetable
Buikwe	Nkokonjeru	Nkokonjeru Farmers Group	3	12	15	Seed
Masaka	Buwunga	Kabugagali Twegattire Wamu	3	12	15	Seed
Wakiso	Busukuma	Busukuma Farmers Group	4	11	15	Seed
Total			20	61	81	

area. Seed requirement was obtained by multiplying the seed rate per acre by the number of acres (Equation 1). Seed demand was then derived as the quantity of AIV seed that seed users wish to secure from the 'market'. Estimating seed demand involves knowing the rate at which farmers replace their seed stock, seed rate and the area to be planted. Seed demand was computed as in Equation 2, based on the estimation of seed requirement.

$$\textit{Seed requirement} = \textit{crop area} \times \textit{seed rate} \quad (1)$$

$$\textit{Seed demand} = Sa = (A \times Ts) / Tr \quad (2)$$

Where, S_a=seed demand in kg, A=area planted, T_s=seed rate, and T_r=seed renewal rate (years).

However, much as demand for seed may exist, the ability of farmers to actually purchase seed may change during the year due to various economic constraints. The term effective demand is used to emphasise the difference between the desire by farmers to purchase seed and the ability to do it. We, therefore, estimated the seed input function to explain the factors affecting input seed demand for AIVs in Uganda. This analysis also provided information on the interrelatedness of the subsector's derived demand for seed in order to maximise profits.

The most widely used functional form to represent technological relationship between the amounts of two or more inputs and the amount of output that can be produced by those inputs is the Cob-Douglas production function (Abedin, 1985). This, however, has some disadvantages as the own price elasticities are always price elastic and the cross-price elasticities of each input are equal, due to the constant unitary elasticity of substitution among all input pairs. The trans-log form does not maintain additivity or unitary elasticities of substitution and thus considered less restrictive than the Cobb-Douglas form (Christensen *et al.,* 1973). The trans-log cost function is particularly the most useful function for estimating the factor demand functions (Obare *et al.,* 2003). It has been applied to both time series or panel data and cross-sectional data (Abedin, 1985; Assa *et al.*, 2014). For this study, we employed trans-log production function with one output and three inputs to estimate the derived demand for seed (Wang and Lall, 1999) (Equation 3);

$$\begin{aligned} lnY = {} & \alpha_0 + \alpha_{ps}\, lnPS + \alpha_{AS}\, lnAS + \alpha_F\, lnF \\ & + 0.5\,\beta_{PS}\,(lnPS)^2 + 0.5\beta_{AS}\,(ln\,AS)^2 + 0.5\beta_F\,(ln\,F)^2 \\ & + \gamma_{PS\times AS}\, lnPS \times lnAS + \gamma_{PS\times F}\, lnPS \times lnF + \gamma_{AS\times F}\, lnAS \times lnF + u_i \end{aligned} \quad (3)$$

Where; ln is the natural logarithm, Y is the aggregate quantity of AIVs produced by a household, PS, AS and F are vectors of quantity of purchased AIV seed, aggregate AIV seed (irrespective of source) and fertiliser used respectively. α_0 is the intercept, α_{ps}, α_{AS}, α_F are first derivatives, β_{PS}, β_{AS}, β_F are own second derivatives and $\gamma_{PS\times AS}$, $\gamma_{PS\times F}$, $\gamma_{AS\times F}$ are cross second derivatives, and u_i is a normally distributed error term. The quantity of output and input are measured in kg per year. The amount of land allocated to AIV production and labour were assumed to be constant in the short run, thus not included in the model estimate.

Marginal productivity analysis provides output elasticity with respect to each factor, which is estimated by taking the partial derivative of the trans-log production function with respect to the factor under consideration (Equation 4). This gives us a set of equations for differentiating the trans-log production function with respect to each factor input;

$$\begin{aligned} \sigma_{PS} &= dlnY / dlnPS = \beta_{PS} + \beta_{PS} \ln PS + \beta_{PS\times AS}\, lnAS + \beta_{PS\times F}\, lnF \\ \sigma_{AS} &= dlnY / dlnAS = \beta_{AS} + \beta_{AS} \ln AS + \beta_{AS\times PS}\, lnPS + \beta_{AS\times F}\, lnF \\ \sigma_F &= dlnY / dlnF = \beta_F + \beta_F \ln F + \beta_{F\times PS}\, lnPS + \beta_{F\times AS}\, lnAS \end{aligned} \quad (4)$$

Using the assumption that agricultural producers pursue profit maximisation as their primary objective and perfect competition exist in the market; the marginal cost of a factor of production equals its market price. Thus, the marginal values of each factor of production can be estimated as (Equation 5);

$$\varphi_i = \frac{\partial Y}{\partial \mathrm{i}} = \frac{\partial lnY}{\partial \ln(i)} \times \frac{Y}{i} = \sigma_i \times \frac{Y}{i} \tag{5}$$

Where i are factor inputs: purchased seed, aggregate seed, and fertiliser. Parameter estimates of Equation 5 are used to estimate elasticities related to variable input demands. They indicate different impacts that exogenous price variables have within and across input demands. Own price and cross-price elasticity of demand for the inputs can, therefore, be calculated as in Equation 6 (Argüello *et al.*, 2015).

$$\varepsilon_{ii} = \frac{\sigma_i}{\beta_i + \sigma_i^2 - \sigma_i} \qquad \varepsilon_{ij} = \frac{\sigma_j}{\gamma_{ij} + \sigma_j} \tag{6}$$

The model was estimated using two-step feasible generalised least squares.

In addition, we assessed the profitability of seed enterprises to alleviate concerns over the profitability of AIV seed production for smallholder farmers. Data was based on records provided by current local seed businesses and vegetable producers, aggregated to an average production of a 0.25 acre. Profitability indicators used were; benefit-cost ratio, gross margin analysis and returns per labour day. Benefit-cost ratio was computed as the ratio of benefits to costs. Gross margins were computed as the difference between benefits and costs associated with the production of seed or vegetables. Returns to labour day were computed as the ratio of gross revenue less non-labour costs of production to the number of labour days. Participants were asked how many days on average they would spend on a particular production activity e.g. land opening, sowing, weeding, harvesting, and processing. The number of labour input days was average and used in the computation of returns to labour day. Returns to labour day indicate the opportunity cost of labour if allocated to vegetable production compared to other activities.

3. Results

3.1. Importance of African indigenous vegetables in central Uganda

The study identified a number of indigenous vegetables grown and marketed in central Uganda (Table 3). Observations at farm and market level clearly indicated that Nakati (*Solanum aethiopicum*) was the most preferred AIV. *S. aethiopicum* was also the most abundant in the market in terms of volumes handled, and the number of traders dealing in this vegetable. Other preferred AIVs by the proportion of both producers and traders were Bugga (*Amaranthus lividus*), Ntula (*Solanum gilo*) and Jjobyo (*Cleome gynandra*).

Farmers selected and grew AIVs that they considered important in achieving food and income (Table 4). Awareness of nutritional and medicinal values and market demand followed as other major reasons for farmers' selection of various AIVs. From the farmers' perspective, various AIVs have different attributes. For example, while farmers believed that Doodo (*Amaranthus dubius*) was a good source of food and income, its marketability was perceived to be low, probably explaining the low level of engagement in its cultivation. Considerably, *S. aethiopicum* was perceived to contribute to food and income, and also highly

Table 3. Common African indigenous vegetables (AIV) grown and marketed in central Uganda.

No.	Scientific name	Common English name	Local name[1]	Growers (%)	Sellers (%)[2]
1	*Amaranthus dubius*	Green amaranth	Doodo	20	48
2	*Amaranthus lividus*	Red amaranth	Bugga	56	75
3	*Brassica oleracea*	Kale	Sukuma wiki	1	8
4	*Corchorus species*	Jute mallow	Mlende	0	2
5	*Cucurbita maxima*	Pumpkin leaves	Sunsa	1	0
6	*Gynandropsis (Cloeme) gynandra*	Spider plant	Jjobyo	23	57
7	*Hibiscus esculentus*	Okra	Bamia	0	2
8	*Hibiscus sabdariffa*	Hibiscus	Malakwang	0	9
9	*Solanum aethiopicum*	Scarlet eggplant	Nakati	92	91
10	*Solanum aethiopicum (gilo)*	African eggplant	Ntula	30	18
11	*Solanum indicum*	Bitter berries	Katunkuma	1	1
12	*Solanum nigrum*	Nightshade	Nsuga	2	7
13	*Vigna unguiculata*	Cow peas	Gobe	1	14

[1] Commonly used local name for the vegetable in central Uganda.

[2] Proportion of AIV traders selling a particular AIV on interview day.

Table 4. Farmers' and traders' reasons for dealing in the most common African indigenous vegetables (AIVs).

Reasons	Proportion of farmers/traders dealing in AIVs					
	***A. lividus* (green amaranth)**	***A. dubius* (red amaranth)**	***Cleome* (spider plant)**	***S. aethiopicum* (scarlet eggplant)**	***S. gilo* (African eggplant)**	**Overall**
Farmers						
For food and income	30	47	32	30	29	32
Nutrition and medicinal value	24	19	25	18	33	26
High demand and marketable	15	6	22	27	19	22
Easy to cultivate	28	19	19	19	9	11
Good taste and palatable	1	3	0	4	10	7
Seed is available	2	6	2	2	0	2
Traders						
Most preferred by consumers	49	41	44	57	45	55
Mostly grown by farmers	19	6	9	25	13	10
Easy to handle in the market	19	29	17	5	34	22
Mostly preferred and grown	13	24	30	13	8	13

marketable. From focus group discussions, farmers indicated that there was no problem of oversupply with *S. aethiopicum*, which made it easy to market at all times.

At the retail level, the main reason for dealing in particular AIVs was the demand from consumers. Traders also indicated the ease of handling AIVs in the market as another important reason for trading in the various AIVs. For example, *S. gilo* was considered easy to handle compared to leafy vegetables that are relatively more bulky and perishable.

3.2 African indigenous vegetables production systems

AIV growing was generally done by smallholder farmers, in two cropping cycles in a year. The main cropping season is from September to December, while the minor season is from March to June. A small proportion of farmers with adequate capital base to hire labour and purchase inputs allocated 1-2 acres for AIV production, and produced vegetables at least 3-4 times a year. This category of farmers also utilised both upland and swampy areas for AIV production, which were alternated depending on the season. Swampy areas were mainly used during the dry season, while upland areas used during the normal rainy season. Availability of water in swamps enabled farmers to produce AIVs even during dry season benefiting from high market prices during offseason. Similarly, the short growth duration (3 weeks to 3 months) of AIVs facilitated sequential cropping where the same or different vegetable crops were planted sequentially on the same piece of land within the season.

Farmers allocated on average 0.8 acres of land for various AIVs (Table 5). Land allocation varied across study locations and type of vegetable grown. Farmers in Wakiso generally allocated more land to AIV production (average 2 acres) and Mpigi allocated the least of the four production districts studied. Wakiso has closer proximity to Kampala the capital of Uganda and was generally the largest supplier of AIVs in the city markets. Their proximity to better markets could have motivated more engagement in AIV production. In terms of individual crops, farmers allocated more land for amaranths, eggplant and cowpea compared to other AIVs. However, given the observed high rate of AIV intercropping, it's difficult to associate land allocation to vegetable importance. Farmers intercropped up to three AIVs in the same plot. The most commonly observed intercrops were of *S. aethiopicum, A. lividus*, and *Cleome.* Farmers' rationale for mixing these vegetables was mainly economical but also due to the dynamic nature of AIV production cycles. *A. lividus* and *Cleome* are fast maturing (3 weeks and 5 weeks respectively), while *S. aethiopicum* takes up to 3 months to mature. Farmers were able to use proceeds from the sale of the first two crops to buy inputs (usually inorganic fertiliser) for the remaining crop.

The most commonly used fertility enhancing inputs were organic manure (79%), followed by inorganic fertiliser (22%). Farmers also indicated that they often used both organic and inorganic fertilisers in combination. Farmers adopted varying application rates, timing, frequency and combinations of fertilisers depending on their resources and availability of the inputs. Organic manure was often applied in the whole garden at planting time, while inorganic fertilisers were applied midway through the season. Chicken manure was the most commonly used and this was mixed with the seed and applied at planting time. The inorganic fertilisers commonly applied were NPK (nitrogen, phosphate, potassium) and CAN (calcium ammonium nitrate), often applied in combination in the same field. Inorganic fertiliser use intensity was on average 13 kg per year.

Table 5. Production of African indigenous vegetables and allocation of inputs by farmers.

Variable	Mean	St. dev
Output (kg per year)		
Aggregate production	4,509	20,457
Land allocation (acres per season)		
Buikwe	0.61	0.53
Masaka	0.43	0.47
Mpigi	0.38	0.40
Wakiso	2.02	3.16
Average land allocation (total sample)	0.80	1.68
Inputs used (kg per year)		
Purchased seed	1.08	5.69
Aggregated seed	3.08	21.42
Fertiliser	12.67	38.73

On average, farming households used 3.08 kg of seed per year. Average AIV production per farm household was 4,506 kg per year, aggregated for all AIVs. Volumes for *S. gilo, A. lividus,* and *S. aethiopicum* were relatively higher than other AIVs in that order of importance. Cleome and cowpea leaves were produced in relatively small quantities compared to other vegetables. The probable explanation for the low production of cowpea leaves could be because they are also consumed as grain, so farmers may keep a part of their production for grain. For cleome, the low production could be related to low demand.

3.3 Farmer sources for African indigenous vegetables seed

The relative importance of AIV seed sources for farmers was assessed. The largest proportion of farmers (79%) obtained their seed from informal sources, dominated by own saved seed and seed from neighbours (Figure 1). A small proportion of farmers (8%) obtained seed from seed producing groups (or farmer-led seed enterprises) within their communities or agro-dealers (8%). Only 3% and 2% of farmers received AIV seed from government extension and NGO respectively. The largest proportion of farmer seed was own saved (41%) followed by neighbours and local market. Agro-dealers and seed producing groups contributed 12% and 5% of farmer seed respectively. Taken together, market sources contributed 37% of AIV seed used by farmers, and the balance was contributed by non-market sources. Government and NGO contributed about 1% of farmers' seed requirement.

According to 60% of the farmers, the reasons for using own seed lie on their perception that own saved seed is of better quality, and is readily available at the time of planting, compared to seed from the market. Farmers, who procured seed from other sources other than their own, did so when they lacked seed either due to a poor harvest or due to pests and diseases infestation. Seed sourcing from agro-dealers or formal seed system was done when farmers perceived the quality of their own seed to have gone down (seed replacement), or if they wanted to try out new varieties. However, this study revealed that 54% of the farmers never renewed their seed for planting, implying that they have continued to rely on traditional mechanisms of acquiring seed with no deliberate steps to replace seed on their farms. At least 33 and 13% indicated that they renewed their seed annually and bi-annually (after 4 seasons) respectively.

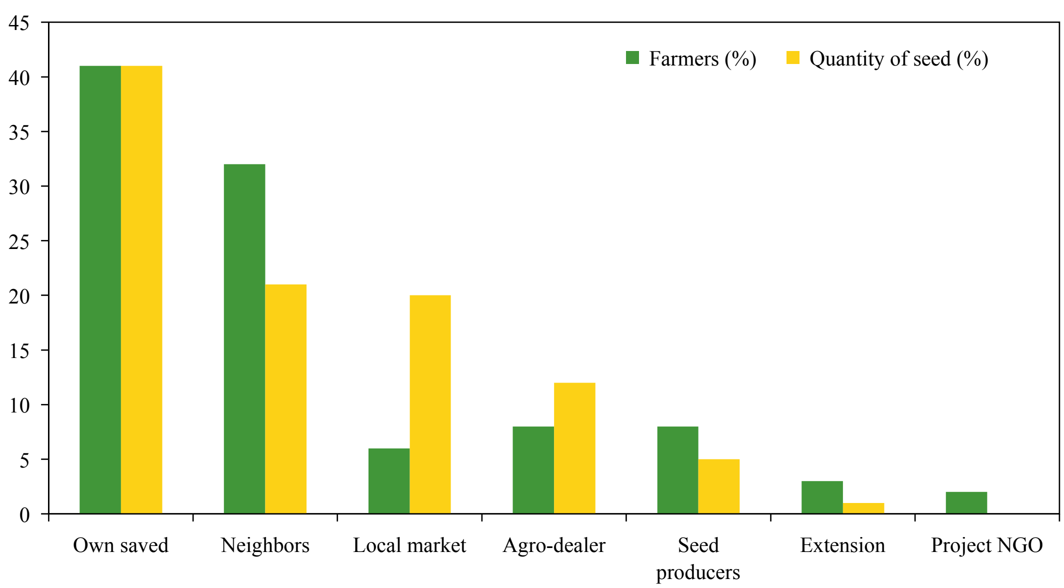

Figure 1. Proportion of farmer seed and sources (% of seed used). NGO = Non-governmental organisation.

3.4 African indigenous vegetables seed requirement and supply

In order to understand seed demand, we first computed seed requirement for farming households. The estimated aggregate seed requirement for AIVs was 168 tons (Table 6). The estimated seed requirement for *A. lividus* was the highest at 55 tons, followed by *S. gilo* at 44 tons and *S. aethiopicum* at 40 tons. If we computed seed requirement based on current farmer seed rates, the seed requirement would more than double for all AIVs. We noticed that farmers generally applied rates way above the recommended. This was because the normal practice for AIV growing was broadcasting and as such farmers could not easily achieve uniform rates. Farmers also intercropped most of the AIVs, which affected the rates applied. Considering a seed renewal rate of 2 years, the estimated seed demand per year was approximately 88 tons (for the most popular AIVs) (Table 6). Of this, at least 63% was supplied by farmers themselves and other non-market sources e.g. government extension. This implies that farmers would utilise seed from market sources of approximately 32 tons per year (of the total seed requirement), the estimated seed gap.

Examination of the formal seed sector, on the other hand, showed that the average seed quantity handled by agro-dealers is 50 kg per AIV crop per season, with large companies selling up to 600 kg per season for individual AIVs. Aggregate seed sales for the entire sample were approximately 4.4 tons of seed per season. However, this seed was generally distributed by 2 of the seed companies interviewed. Turnover per Seed Company was estimated at 1.2 tons of seed per season, with *A. dubius* having the largest amount handled at a time. The amount of seed sold by agro-dealers depended on how much they could obtain from their suppliers, and not necessarily how much was demanded. As such, most of the interviewed agro-dealers indicated that they have not been able to satisfy their customers' demand for seed.

3.5 African indigenous vegetables seed demand analysis

Analysis of the production function showed that as the production of AIVs increases, demand for inputs – seed and fertiliser increases (Table 7). This increase in input demand was reflected for all inputs but is only significant for aggregate seed and fertiliser. Output elasticities with respect to purchased seed and fertiliser do not explain much of the variation in AIV production except aggregate seed that has an elasticity of 0.18. This implies that a 1% change in the quantity of aggregate seed input used has a 0.18% change in the quantity of AIV produced, while a 1% change in the quantity of purchased seed used has minimal effect on the quantity of AIV produced.

Table 6. Seed requirement for the most common African indigenous vegetables (AIVs) grown in central Uganda.

	A. lividus	***A. dubius***	***Cleome***	***S. aethiopicum***	***S. gilo***
	(green amaranth)	**(red amaranth)**	**(spider plant)**	**(scarlet eggplant)**	**(African eggplant)**
Average area planted (acres)	0.3	0.4	0.2	0.3	0.4
Household growing AIV in sample districts[1]	369,792	147,917	170,104	680,416	221,875
Total area planted (acres) (A)	110,938	59,167	34,021	204,125	88,750
Seed rate (kg/acre) (B)	0.5	0.5	0.2	0.2	0.5
Total seed requirements (kg) (A×B)	55,469	29,583	6,804	40,825	44,375
Area needing new seed (acres/year)(C)[2]	55,469	29,583	17,010	102,062	44,375
Total seed demand (C×B) (kg/year)	27,734	14,792	3,402	20,412	22,188
Less seed demand met by farmers (62%)	17,195	9,171	2,109	12,656	13,756
Remaining seed demand	10,539	5,621	1,293	7,757	8,431
Seed requirement (%)	35	16	5	21	23

[1] Estimated household growing AIV in the sample districts as a proportion of the total population (UBOS, 2014) in the sample districts (excluding Kampala).

[2] Obtained by dividing total area planted by seed renewal rate (years). Seed renewal was taken at 2 years, based on results from this study.

Table 7. Trans-log production function with one output and three inputs.[1]

Variable name	Parameter estimate	Coefficient	Std. err.
Intercept	α_0	4.856***	0.300
Purchased seed (ln PS)	α_{PS}	1.258	1.380
Aggregate seed (ln AS)	α_{AS}	1.942***	0.577
Fertiliser (ln F)	α_F	0.377*	0.422
1/2 ln PS^2	β_{PS}	-0.984	1.323
1/2 ln AS^2	β_{AS}	-0.340*	0.223
1/2 ln F2	β_F	0.100	0.099
ln PS × ln AS	$\gamma_{PS\times AS}$	0.685	0.900
ln PS × ln F	$\gamma_{PS\times F}$	-0.338	0.297
ln AS × ln F	$\gamma_{AS\times F}$	0.028	0.198
Output elasticity_PS	σ_{PS}	0.021	0.023
Output elasticity_AS	σ_{AS}	0.181***	0.052
Output elasticity_F	σ_F	0.028	0.031
No. of observations		193	
F (9; 183)		10.55	
Prob>F		0.000	
Adj R-squared		0.309	

[1] Parameter estimates significance levels of 1, 5 and 10% are denoted by ***, **, and *, respectively.

Estimated own-price and cross-price elasticities for each factor of production are shown in Table 8. Demand for purchased seed and aggregate seed is inelastic with respect to own-price. Results show that a 100% change in the price of input seed will reduce the quantity demanded of purchased seed and aggregate seed by 2 and 37% respectively. While the demand for seed would go down as a result of an increase in its price, the change is considered insignificant in this case, implying that the price of seed is not the primary determining factor for quantity demanded. Own price elasticity for inorganic fertiliser, on the other hand, is positive implying that the output effect surpasses the substitution effect of seed for fertiliser.

Cross-price elasticities of demand for purchased seed show that it's considered a substitute for aggregate seed and a complement for fertiliser with cross-price elasticities of 0.21 and -0.09%. This means that a 100% increase in the price of purchased seed will increase the quantity of aggregate seed demanded by 21%. Farmers will normally apply fertiliser only to complement their production, but not necessarily as the primary production input. Therefore, an increase its price will have a negative effect on demand for complementary inputs such as purchased seed.

3.6 Profitability of farmer-seed enterprises in African indigenous vegetables

We assessed farmer-seed enterprises to better understand the potential for profitability for smallholder farmers. Profitability indicators were compared with those of groups producing vegetables only. Seed producers incurred added costs compared to vegetable producers such as pest management (since the crop stays longer

Table 8. Own-price and cross-price input elasticities.

Quantity	Price		
	Purchased seed	Aggregate seed	Fertiliser
Purchased seed	-0.021	0.209	-0.092
Aggregate seed	0.030	-0.371	0.499
Fertiliser	-0.067	0.864	0.390

in the garden), rouging, fertilisation and processing. Overall, positive gross margins were obtained for both leafy and seed production for two preferred AIVs – *A. aethiopicum* and *A. lividus* – although margins were higher for seed compared to leafy production (Table 9). Returns to labour day were also higher for seed production compared to vegetable production.

During FGDs, farmers indicated that seed production was more profitable than leafy vegetable production, especially the amaranths due to high productivity and higher seed prices compared to other AIVs. Farmers perceived production of leafy vegetable for *A. aethiopicum* to be more profitable compared to seed for the same vegetable, though gross margin analysis shows otherwise. The possible explanation could be due to the fact that production of leafy *A. aethiopicum* provides an added benefit of intercropping with other vegetables giving extra returns (which have not been computed in the current analysis).

The assessed seed producers had been linked to seed companies where they signed seed supply agreements. Supply agreements implied a consistent market for farmer-produced seed and quality assurance. Linkages to seed traders improve seed commercialisation and distribution to locations with higher seed demand. Seed sales to external markets were based on contractual obligations but may partly explain why farmers obtained a small proportion of their seed from seed producing groups in their communities, despite farmers indicating an increasing demand for quality seed locally. For sustainability, development of diverse markets for farmer-seed is key, including local seed markets.

An observed key challenge to current AIV seed production in the study areas was the existence of tedious and rudimentary seed processing mechanisms. Seed processing included threshing, pounding, soaking and sieving, all of which were local practices that contributed to seed losses and deterred potential seed producers especially men. In the promotion of local seed businesses, promotion of appropriate technologies and tools for seed processing and handling, as well as sensitising farmers on seed quality are important components to ensure continued production and supply of quality seed to farmers.

Table 9. Costs and benefits of production of leafy vegetables and seed for African indigenous vegetables (AIVs) in central Uganda (computations based on 0.25-acre production area).

Parameter	**Leafy vegetable**		**AIV seed production**	
	***S. aethiopicum* (scarlet eggplant)**	***A. lividus* (red amaranth)**	***S. aethiopicum* (scarlet eggplant)**	***A. lividus* (red amaranth)**
Costs (UGX[1])				
Inputs	70,000	90,000	127,000	132,000
Labour	235,000	219,675	490,000	350,000
Total cost	305,000	309,675	617,000	482,000
Benefits				
Output	1,200	536	120	150
Units	Bundles	Bundles	kg	kg
Price per unit (UGX)	500	1000	15,000	30,000
Value of production (UGX)	600,000	536,000	1,800,000	4,500,000
Labour input				
Labour days (no.)	25	10	72	60
Profitability indicators				
Gross margin (UGX)	295,000	226,325	1,183,000	4,018,000
Benefit cost ratio	2	2	3	9
Returns to labour day (UGX/day)	21,200	44,600	23,236	72,800

[1] UGX = Uganda shillings. Exchange rate 1 USD = UGX 3,500; conversion calculated on the basis of the exchange rate on August 8, 2015.

4. Discussion

The results showed that potential annual demand for AIV input seed by far exceeds the current supply from formal sources. This gap is filled by informal sources, dominated by farmer-saved seed. Farmer seed – self-supplied or from other farmers, accounted for 62% of seed used by farmers. This implies that the informal seed sector will continue to play a big role in the supply of AIV seed given the large seed requirement that formal sector is unable to fully meet. Nonetheless, this study observed the occasional use of seed from formal sector largely to replace stock or introduce new varieties. This shows an emerging integration of both the formal and informal seed systems. Previous studies have recommended that an integrated seed system is the best approach to developing local seed systems (Louwaars and De Boef, 2012; Sperling and Mcguire, 2010). This requires linking formal and farmer's seed systems and improving the latter to improve national and local seed supply (Almekinders and Louwaars, 2002; Singh *et al.*, 2013).

The observation that farmers purchased a substantial part (37%) of their seed requirements from various sources implies that farmers would be willing to buy seed. The most important element is for the seed to meet their quality expectations and be available when required, the main reasons farmers gave for sticking to own-saved seed. Own-price elasticity of demand for purchased seed showed that seed demand is less sensitive to own price in the long run. Results also show that in case of price increase for purchased seed, farmers would naturally revert to alternative seed, often their own saved seed. This behaviour could be attributed to the trust farmers have in the various seed sources against their investment in that seed. Therefore farmers' insistence on quality of seed rather than price as the key factor for using own saved seed is not surprising. This shows prospects for continued utilisation of purchased seed meeting farmers' quality expectations. Daniel and Adetumbi (2006) report similar findings of farmers' willingness to buy seed of improved varieties if they are readily available. It's important however to note that farmers' seed demand can also change at planting time based on seed prices, availability and prices of other inputs (especially complementary ones) and financial constraints. Therefore, strategies that can ensure sustainable access to quality seed at the local level at the right time and price are important. Farmer-seed entrepreneurs provide opportunities for farmers to obtain good quality seed within their locations. This study shows a minimal contribution of farmer-seed enterprises to local level consumption mainly because seed production was contracted, but also because the concept of local seed businesses is still at the pilot in many areas in Africa, Uganda inclusive. The potential of local farmer seed enterprises is premised on their ability to produce and supply quality seed locally, addressing both affordability and availability issues. Empirical evidence shows that farmer-seed entrepreneurship achieves dual objectives; establishment of a regular source of clean seed of both local or modern varieties, and sustainable distribution and promotion of improved crop varieties (David, 2004). Coomes *et al.* (2015) further assert that such farmer seed and their networks can be favourable in terms of crop/seed choice, accessibility, cost, and non-economic utility (e.g. social values). It's also argued that the genetic quality of seed sourced locally is most often acceptable to farmers, as it is generally grown in nearby agro-ecological contexts that match their own needs (CIAT, 2014), further justifying local seed production and marketing.

The potential to commercialise seed of AIVs is demonstrated by the unmet seed demand and farmers' willingness to invest in quality seed. Commercialisation allows profitability, provides incentives for seed production and enhances the sustainability of AIV seed sector. The increasing demand for AIVs particularly in urban areas as mentioned by farmers also provides an opportunity for scaling seed entrepreneurship and commercialisation. The high demand was attributed to increasing consumer awareness of nutritional benefits of AIVs, growing populations and rising incomes (Waibel, 2011). Demand-side patterns such as festive seasons also contribute to increased demand where consumers include AIVs in their diets. In Uganda, marketing of quality declared seed is legally permissible, which gives an opportunity to seed producers to continue to benefit from seed production and marketing. The government of Uganda through the Ministry of Agriculture, Animal Industry and Fisheries has developed a draft seed policy which recognises farmer-produced seed. Seed quality can be achieved through linking farmers with extension and the National Seed Certification Agency for technical training and seed inspections.

Finally, the potential and sustainability of AIV farmer-seed entrepreneurship lie in its ability to impact farmers engaged in seed production. In this analysis, seed producers exhibited higher gross margins and returns to labour day compared to vegetable producers. Returns to labour day represent the opportunity cost of labour. The normal agricultural labour day in the study location was UGX 10,000-15,000 ($ 2.8-4.3), which was significantly lower than values obtained on returns to labour day for both vegetable and seed production. This implies that farmers would easily allocate their labour to vegetable or seed production, compared to local wage employment because of higher returns of the former. In a related analysis in Tanzania, Kansiime *et al.* (2016) demonstrate higher returns for AIV seed producers compared to leafy vegetable or traditional staple crops e.g. maize. Seed profitability provides opportunities for smallholder farmers especially women and youth to diversify their income sources. This also helps improve important indicators of sustainability, including not just improvement in seed quality, but increased productivity of AIVs, better nutrition from those who consume the vegetables and resource use efficiency at the farm level. This indicates prospects for profitability and sustainability of development of farmer-seed enterprises. The added benefit of strengthening existing social system of community and informal seed exchange could be a starting point for viable seed enterprises for smallholder farmers.

5. Conclusions

AIV production in central Uganda is dominated by small-scale farmers, allocating about 0.8 acres of land. Farmers indicated multiple features of vegetables though the perceived contribution to household food and income were the main criteria for selecting the various AIVs they grew. Farmers noted an increasing trend in the number of households growing AIVs, attributed to increased demand for vegetables. In order to meet the growing demand, building farmer capacity in better production practices, and improving access to quality seed are justified. This will go a long way in enhancing the productivity of AIVs at the farm level, at the same time addressing food and income security of households, especially in areas with land constraints.

The estimated demand for AIV seed confirmed the existence of higher demand than can be met by current formal seed supply in the region. Though dominated by the informal system, farmers' source of AIV seed represented both formal and informal seed systems, highlighting an emerging integration of both systems. This can be enhanced through market linkages. Farmers were sensitive to seed quality and they responded to it by sticking to own saved seed or seed from sources they trust, mainly local sources. This implies that the availability of quality seed at the local level would elicit demand for AIV seed. Farmer seed entrepreneurship emerges as a strategy to fill the observed seed demand and seed quality gaps by providing farmers with a reliable supply of quality seed at the local level. Seed quality can be achieved through farmer training and strategic linkages with extension and the National Seed Certification Agency for seed inspections. Observed opportunities for enhanced sustainable farmer-seed entrepreneurship include; increasing demand for AIVs to meet nutrition and health benefits; existing legal frameworks in Uganda which support the diversification of seed production activities; existing seed demand gap, and enterprise profitability contributing to improved livelihoods of farmers engaged.

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