Using a choice experiment approach to assess production tradeoffs for developing the croton value chain in Kenya

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Abstract

Trees that produce oilseeds have the potential to improve rural livelihoods through the production of vegetable oil for energy and other purposes, as well as valuable co-products, such as animal feed and organic fertilizers. In Kenya, *Croton megalocarpus* (Croton) is a prolific and widely distributed tree with such potential being currently underutilized. In support of scaling up the promising Croton value chain in Kenya, a choice experiment was designed and conducted as part of a survey with 200 rural households in four counties in the Central region of the country. The objective was to assess household preferences in planting and cultivating Croton trees for collection and selling of seeds to a growing market. Attributes for the choice model production system included seedling cost, oilseed yield, tree maturation period, labour for seed collection, and seed selling price. Results show that almost all households have Croton trees on their land and are willing to produce Croton seeds, although clear tradeoffs among the attributes exist. Seed price is the most dominant single attribute cutting across all socio-demographic characteristics. Time and labour constraints were significant for some households: farmers are more averse to longer maturation periods than non-farmers, while those already collecting seeds for the nascent industry are less concerned about the opportunity costs of time and labour than non-collectors. The results provide guidance for the development of a Croton value chain which can have positive impacts on rural livelihoods in East Africa.

1. Introduction

Smallholder farmers and rural households in many African countries produce and consume their own food for subsistence and search for on-farm or off-farm income to improve livelihoods (Ellis 1998, Haggblade et al. 2010). In 2015, the World Agroforestry Centre (ICRAF) started examining the sustainability of the infant *Croton megalocarpus* (Croton) tree value chain in Kenya, in addition to identifying and addressing existing gaps to support its upscaling, while maximizing positive impacts on the rural poor. Initial studies indicate the business model holds significant potential for generating additional income and improving local livelihoods, without jeopardizing the environment (ICRAF 2017). However, to ensure economic sustainability in the long term, it will be crucial not only to address some of the operational bottlenecks identified to improve the efficiency of the value chain, but also to scale it up, securing a consistent, reliable, and economical supply of seeds. This study provides insight to Croton value chains and optimal production systems for industry, policymakers, and other stakeholders interested in supporting this enterprise. The objective of this paper is to identify household preferences in production of Croton trees on their land and sale of Croton seed to processors.

Although classified as a middle income country, almost half the Kenyan population are in absolute poverty (46%) and it is ranked 146 out of 188 countries on the UNDP Human Development Index (<http://hdr.undp.org/>). In an FAO report comparing nine developing countries, Kenya ranked low in many categories related to agriculture, including crop yields per hectare and income per person per day (Rapsomanikis 2015). The report notes that the majority of the farming households are smallholders that generate gross income of about \$2,527 per year (which equates to about \$1.40 per day per person for a family of five). Agriculture provides livelihoods (employment, income, and food security needs) for more than 80% of the Kenyan population.

Croton is an indigenous tree found in most East African countries, usually in areas with a bimodal rainfall pattern of about 800-1,900 mm per annum, average annual temperatures ranging from 11 to 26°C, and altitudes between 1,200 and 2,450 m (ICRAF 2009). It is a fast-growing pioneer species that can survive in harsh climatic conditions and has the advantage that it is not a preferred browser by animals. Croton develops a deep taproot, which makes it quite drought tolerant and allows food crops to be grown underneath.

In Kenya, Croton is an abundant species across the Central and Western regions. Although no formal tree population census has been conducted for the species, anecdotal evidence suggests millions of Croton trees growing in the wild and on farms throughout the country (GTZ 2009). In the Mount Kenya area, for instance, Croton has been found on 40% of the farms at an average density of 15

trees per farm (PROTA 2014). Croton is considered an “undomesticated” plant, as little work has been done on its agronomic, commercial, or ecological value (GTZ 2009, Ndegwa et al. 2011). The tree is traditionally maintained and/or cultivated to provide shade, fuelwood, and live fences (Maundu et al. 2005). The wood is also used for fencing posts and poles, as it is termite-resistant. While not scientifically proven, the bark is used to treat coughs, stomach ailments, wound clotting, and pneumonia. The leaves are used for mulch due to their high phosphorous content. Flowering starts after three to four years, usually by end April-early May, producing seeds in October-December in Central and Northern Kenya, and around January-February in Western Kenya. The tree reaches full maturity between seven and 11 years (ICRAF 2009, Maundu et al. 2005).

Being inedible, the Croton seed remains a largely wasted renewable natural resource across most of East Africa. It can be, nonetheless, a valuable feedstock for several energy and industrial applications. Croton seeds contain approximately 30-32% oil by weight and have a high protein content of 50% (Aliyu et al. 2010, Mbarawa and Kafuku 2010, Kibazohi and Sangwan 2011, Wagutu 2009). This oil can be extracted mechanically (by pressing) or through solvent/chemical methods. The straight vegetable oil (SVO) can directly replace diesel in stationary engines, such as generators and irrigation pumps, or can be processed into biodiesel. It can also be used for leather tanning, as well as for the production of paint, soap, and cosmetics—this versatility is particularly welcome at a moment of low fossil fuel prices. A few studies have shown that Croton seedcake—the seed residue after oil pressing—is very suitable for poultry feed (Thijssen 1996). The husks (hulls or shells) can be composted and used as organic fertilizers (or as one of their components), since they have relatively high nitrogen content—although having lower potassium and phosphate when compared to typical composts and manures. They can also be used for briquettes made from agro-waste. Croton briquettes have been tested and perform well as a bioenergy feedstock, especially when mixed with sawdust (Cohen and Marega 2013).

It was only more recently, though, that all this potential from Croton seeds started to attract international interest, private capital, and professional management towards the development of a proper value chain. In Kenya, this effort has been spearheaded since 2012 by Eco Fuels Kenya (EFK) Group Ltd. The company sources Croton seeds from rural communities in the Central Highlands of Kenya through a growing network of over 5,000 collectors and agents (middlemen), most of whom are smallholder farmers or local businessmen. The seeds are harvested primarily from pre-existing Croton trees on farms, but also in forests and on other communal land. They then undergo a no-waste manufacturing process at the company’s factory in Nanyuki, Laikipia County. The extracted oil is sold to local industries, which use it for many purposes, including both biofuel applications (e.g., SVO to run off-grid generators, water pumps, and other agricultural machinery), as well as others,

such as painting, leather tanning, and cosmetics. The husks are processed into certified organic fertilizers and biochar, as well as used for the production of wood vinegar (Pyroligneous acid), a valuable biopesticide. The seedcake is sold to commercial and other poultry producers to be incorporated as a rich source of raw protein for animal feed. A key factor in Croton production is ensuring maximum value added not only for the oil but also for its several co-products.

Despite steady growth in the last years, to date EFK's scale of operations remains relatively small. In 2016, the company purchased 900 tons of Croton seeds and increased its processing capacity to 100 tons/month (ICRAF 2017). To achieve sustainable profitability, it estimates as necessary a minimum annual volume of 2,000 tons of seeds purchased and processed. Furthermore, the business' future will also require reducing logistical costs, especially for transportation of the seeds to the factory.

A successful scaling up will depend, in the short term, on identifying and reaching out to new areas with large concentrations of mature Croton trees, such as by tapping into geographic information systems. In the medium to long term, however, it will be crucial to increase the availability and supply of productive trees. This can only be achieved (while benefitting local communities) if a good combination of incentives is in place to encourage farmers to plant and cultivate more Croton trees, for instance, through agroforestry systems that do not jeopardize their key crop production systems.

As previously noted, Croton seeds are harvested mainly from existing trees on farms or from trees around a village, with few collectors venturing into forests for this. While monetary costs for collection are minimal, the amount of labour and time spent on this activity might be significant. In many cases, for instance, households opt to have their children collect the seeds in their spare time. The reduction of logistical costs for the company, due to improved availability of seeds close to the factory, would also create room for better prices to be paid to collectors. Currently, collectors receive approximately KES 5-10¹ per Kg of Croton seeds, depending on how far from the factory the seeds are harvested and whether intermediate agents are involved.

In an effort to support the scaling up of the Croton value chain in Kenya, ensuring it contributes to sustained rural development, this paper assesses whether Croton can contribute to the current livelihood portfolio of households and communities by examining household preferences in planting and cultivating new Croton trees for collection and selling of seeds to the market. To ascertain households' preferences to types of Croton production systems, a choice experiment (CE) was conducted. The CE allowed an analysis of trade-offs in monetary value of the factors that comprise Croton production on farms in Central Kenya. Participants indicated their preferences for each

¹ 1 USD equals KES 103.2 (2017)

choice set presented, comparing different options of costs and returns to planting Croton and collecting the seeds.

2. Methods

2.1. CE methodology

A choice experiment (CE) is a survey-based stated preference valuation technique allowing valuation of both existing and non-existing product and services. CEs have been applied in many areas, including environmental valuation of forests (Upton et al. 2012, Christie et al. 2007), recreation demand (Juutinen et al. 2011, Hanley et al. 2002), biodiversity (Hoyos 2010, Shoyama et al. 2013), and agribusiness (Balcombe et al. 2011, Alfnes et al. 2006). CEs have also been extensively applied in health and transport economics (de Bekker-Grob et al. 2010, Hensher and Rose 2007). While choice experiments in these domains are often consumer-oriented, within agricultural economics it is very common to use choice experiments for assessing producer preferences. Choice experiments have been used to investigate farmers' preferences for technological innovation (e.g., Lambrecht et al. 2015, Ortega et al. 2016), environmental values (e.g., Ruto and Garrod 2009), biodiversity conservation (e.g., Zander et al. 2013), and value chain organization (e.g., Schipmann and Qaim 2011). More specifically, choice experiments have been used to study farmers' adoption of agroforestry-based systems as well (e.g., Cranford and Mourato 2014, Kaczan et al. 2013, Mercer and Snook 2004, Torres et al. 2013).

CEs are constructed from consumer choice theory (Lancaster 1966) and random utility theory (Holmes and Adamowicz 2003). A person's utility for a certain alternative is a function of its attributes and an unobserved stochastic component. The utility U_{sqi} from alternative s in choice set q for respondent i is given by:

$$U_{sqi} = \alpha_i A_{sq} + \varepsilon_{sqi} \quad (1)$$

where A_{sq} is the vector of the attribute levels of alternative s in choice set q , α_i is the individual-specific vector of marginal utilities of each attribute, and ε_{sqi} is an unobserved stochastic component.

This paper uses Random Parameter Logit (RPL) and Latent Class Logit (LCL) models, which allow preference heterogeneity among people, to analyze the stated choice data (McFadden and Train 2000, Green and Hensher 2003). An RPL models preference heterogeneity by assuming that some or all marginal utilities α_i are randomly distributed within the population, e.g., normal, lognormal, triangular, or uniform. The researcher determines which parameters of the utility function are treated as random and imposes the density function distribution accordingly.

In an attempt to model the source of preference heterogeneity, we also use an RPL model that includes interactions of individual-specific characteristics with the attributes in the utility function.

The LCL model is another commonly used model to characterize the unobserved preference heterogeneity. The LCL model uses discrete distributions to capture preference heterogeneity among individuals (Boxall and Adamowicz 2002, Greene and Hensher 2003). To this end, the model assumes that the population falls into a finite number of classes, with preferences being different between classes, while each class has homogenous preferences. In contrast to RPL, α_i varies across classes but not across individuals within the same class. The RPL (using 500 Halton draws) and LCL estimations in this paper are performed in NLogit 5.

After model estimation, we can use various measures to compare the relative importance of the attributes. The marginal rate of substitution (MRS) between two attributes a and b can be calculated as the ratio of their marginal utilities, i.e., α_a/α_b . When the marginal utility parameters are randomly distributed, the empirical distribution of the MRS can be estimated using bootstrap methods or simulation techniques such as the Krinsky-Robb methods (Hole, 2007).

An alternative procedure is proposed by Green and Wind (1975). First, the utility ranges (UR) of each attribute are identified by calculating the difference between the highest and lowest utility values which can be obtained given the attribute levels and the marginal utility estimated in the choice models. The relative importance (RI) of attribute i can then be calculated as:

$$RI_i = \frac{UR_i}{\sum_{j=1}^k UR_j} \quad (2)$$

where $\sum_{j=1}^k UR_j$ is the sum of the utility ranges of all attributes. This index compares the largest potential impacts of a change in each of the attributes on the utility function.

2.2. Experimental Design

Five attributes of the Croton value chain that influence the household decision to grow Croton seedlings were selected. These attributes are labour option, maturation period, yield, seedling price, and seed price. The descriptions and levels of each attribute are summarized in Table 1. Each of these attributes represents an important factor in the decision about a preferred Croton production system. The labour option refers to whether the members of the household collect the seeds themselves or whether the company contracts a collector. The labour option can be viewed as an opportunity cost of labour. The maturation period reflects the time it takes for the tree to bear fruit. The array of maturation times used in the CE is 3, 4, and 6 years. The maturation period can be viewed as a proxy for their preferences or risks related to time value of money, or cost of waiting.

The yield attribute reflects the total kilograms of seeds produced by each tree per year when the trees are producing at full production. Since full tree fruit maturity ranges between 7-11 years, 10 years is used as the start of full seed yield. Although not well documented, the potential yield of mature trees is about 25 kilograms per year, with some projections as high as 50 kilograms per year. In the CE, the yields are 15 kg, 25 kg, and 40 kg per tree annually after 10 years. In the survey, we assume the annual yield after the fruiting begins and before the time having full seed yield is 10 kg per tree. The seedling price is what it costs to buy and plant a seedling. In this model, each seedling is free (KES 0), KES 10, or KES 20. The seed price is a flat rate the company would pay for a kilogram of seeds, regardless of distance from the factory or whether middlemen were involved. At present, the rate paid by EFK is KES 10/kg for seeds delivered to the factory. The price levels in this model range from KES 3 per kg to KES 40 per kg. Note that attribute levels vary to present a range of choices above and below the assumed averages.

A design with 10 choice questions and two alternatives was generated for pre-test on a sample of 30 randomly selected households, using an orthogonal fractional factorial main effect design. The households for the pre-test were randomly selected from different villages in each of the counties where the survey was conducted.

An efficiency design was adopted to generate the choice questions for the main survey, which accounts for the panel setting of repeated choices and the property of random parameter. The priors of parameters are from the estimates of an RPL model with the pre-test data. An experimental design with three blocks and 10 choice questions in each block was generated using NGENE, resulting in a D-error of 0.2035.

Each respondent was randomly assigned a block of 10 questions to avoid any biases, and the order of the questions was random to minimize learning and fatigue effects. Each block was answered by the same number of respondents. Figure 1 shows an example choice set. It was translated in the local Kikuyu language. The goal of the choice experiment is to understand the key planting and collection designs that are preferred by the households, so an “opt out” option is not included. Also, there is no information available regarding the exact definition of “status quo.” The welfare can be biased when an opt out option is included but without correct definition (Domínguez-Torreiro and Soliño 2011).

Table 1. Attribute Description and Levels

Attribute	Definition	Level
Labour option (Labour)	Households collect the seeds themselves	<ul style="list-style-type: none"> • 1 = Yes (standard practice) • 0 = No
Maturation period (Mature)	Age at which tree starts bearing seeds. An annual production of 10 kg is assumed for the initial years (until 10 th year)	<ul style="list-style-type: none"> • 3 • 4 (standard age) • 6
Seedling Price (Seedling)	Cost of seedlings in KES	<ul style="list-style-type: none"> • 0 • 10 (standard price) • 20
Yield (Yield)	Average kg the tree produces from 10 years onwards	<ul style="list-style-type: none"> • 15 • 25 (standard yield) • 40
Seed price (Price)	Amount in KES farmer receives for 1kg of harvested seeds	<ul style="list-style-type: none"> • 3 • 5 • 10 (standard price) • 15 • 20 • 40

Given the above specifications, the utility generated from a given alternative s in choice set q (equation 1) can be rewritten as

$$U_{sqi} = \alpha_{1i}Labour_{sq} + \alpha_{2i}Mature_{sq} + \alpha_{3i}Seedling_{sq} + \alpha_{4i}Yield_{sq} + \alpha_{5i}Price_{sq} + \epsilon_{sqi} \quad (3)$$

While labour is a categorical variable, the other four attributes are treated as continuous. In particular, as we observed in the pre-test, we expect that the first three parameters (α_1 through α_3) will have negative signs, which indicate that respondents, on average, prefer not to collect by themselves, a shorter maturation period, and lower seedling price. The signs of α_4 and α_5 are expected to be positive as people prefer higher yield and seed price.

2.3. Questionnaire design and data collection

The questionnaire was divided into a number of sections in addition to the CE. Survey sections addressed household socio-demographic characteristics, agricultural production, tree cultivation, Croton seed collection, willingness to plant Croton trees, interest in processing Croton seeds, food security, and nutrition.

The data were collected through an in-person survey conducted in 20 villages in Embu, Kirinyaga, Laikipia, Murang'a, and Nyeri Counties in the Central Highlands of Kenya in June 2016. The Central Highlands is the most densely populated and intensely cultivated region in Kenya and home to one of the biggest and historically most influential tribes in Kenya, the Kikuyus. An increase in population over the years has put huge pressure on the natural resources, including diminishing water catchment areas and increased soil erosion. This has brought about changes in the poverty incidence, land use, livelihood, and income distribution in the regions surrounding Mount Kenya.

The values of the Human Development Index and other livelihood indicators for these counties are similar to the Kenyan national averages, but values for particular categories such as access to electricity and farm size are lower than average (Table 2). In the County Integrated Plans² the common major problems—in addition to poverty—can be categorized as poor infrastructure (e.g., roads, electricity, and water), limited employment opportunities and entrepreneurial skills (especially the youth), rising population densities, and concomitant land disputes.

Using a stratified sampling design, five villages were selected in each county and 10 households in each village. The criteria for selecting the villages included villages already involved with EFK Croton seed collection and villages not involved. The households within each village were selected based on whether they collected. Figure 2 shows the location and distribution of the 20 villages. A total of 200 households were surveyed, including both those who have already collected for EFK and non-collectors. For the purpose of this study, collectors were defined as households that have Croton trees and collect the seeds and/or households that, despite not having any Croton trees on their land, collect seeds from elsewhere. Non-collectors were defined as those households that did not collect the seeds.

² Data come from County Integrated Plans which are prepared by each county and are part of the reporting for Kenya Vision 2030 <http://www.vision2030.go.ke/>.

Table 2. Livelihood-related indicators for counties in the study area

County	Population Density (persons / km ²)	Human Development Index	Households with Electricity (%)	Average Farm Size (acres)	Agricultural Sector Contribution Income (%)	Absolute Poverty (%)
Laikipia	43	0.412	18	2.0	75	43
Kirinyaga	524	0.589	22	1.0	72	36
Embu	197	0.622	14	0.8	80	41
Murang'a	368	0.588	13	0.6	57	36
Nyeri	280	0.634	26	0.7	57	29
National	79	0.555	36	1.1	80	46

Sources: Reports as part of Kenya Vision 2030- Kirinyaga County First County Integrated Development Plan 2013 – 2017; Embu County Integrated Development Plan 2013 – 2017; Murang'a County Integrated Development Plan 2013 – 2017; Nyeri County Integrated Development Plan 2013 – 2017; Laikipia County First County Integrated Development Plan 2013 – 2017

	Cost of Seedlings	Maturation and Yield	Labor to Collect Seeds	Seed Price	Choice
Alternative 1	0 KES
Alternative 2	0 KES

Figure 1. Sample choice set card

Figure 2. Survey areas in Kenya

3. Results

3.1. Survey responses

All 200 questionnaires were completed. Table 3 describes the basic demographic and household characteristics. Most were male-headed households. Mean household size was four members, but ranged from one to eight members. In terms of occupation, most (68%) of the household heads were farmers. Other occupations included: service provision, trading, public service (civil servant, teaching), quarrying, and carpentry. Half of the household heads had at least primary school education, with 32% having secondary school education. Only 12% of the household heads had no formal education. It is difficult to estimate annual income, especially since most are subsistence farmers. Using food shortages as a proxy, about one-third worry that the household would not have enough food, would not be able to eat the kinds of foods preferred, or would have limited variety of foods because of a lack of resources. However, only about 5% go to sleep at night hungry because there is not enough food.

Almost all households had access to a parcel of land, with the number of parcels accessed per household averaging four (i.e., separate plots of land). When all the parcels of land owned/accessed by each household were combined, the mean and the median land size per household was 3.6 acres and 2 acres, respectively, ranging from 0.07 acres to 33 acres.

The main land use for most households was planting annual crops (58%) and perennial cash crops such as tea and coffee (25%), although most households carried out multiple land use activities. Almost every household has trees on their land. Eighty-four percent of the households said they had Croton trees on their land. Sixty-one percent of all the households had a household member collecting Croton seeds and/or had someone else come collect Croton seeds from their trees. Ninety-one percent of all the households would be willing to plant and maintain Croton trees if the seedlings were given for free. The majority of the households stated that they would be interested in adding value by processing seeds. They stated that creating a business at the household level (88%) and/or in groups or cooperatives (90%) would be a good opportunity, and they would be interested if adequate resources were provided. Most households would process the seeds for organic fertilizer and poultry feed to use at home and sell the surplus to generate additional income.

Table 3. Household demographic characteristics and attitudinal information collected from the sampled respondents (N=200)

Variable	Min	Max	Mean	SD
Demographics				
Age of the household head (years)	22	91	53	15.4
Household size (amount of members)	1	8	4	1.8
Male-headed households (%)	-	-	72	
Education of the household head				
No formal education (%)			12	
Primary school level (%)	-	-	50	
Secondary school level (%)	-	-	31	
Professional course (%)	-	-	7	
Occupation of the household head				
Farmers (%)	-	-	68	
Service providers (%)	-	-	15	
Traders (%)	-	-	9	
Civil servants (%)	-	-	2	
Other (%)	-	-	6	
Household land characteristics				
Land size (acres)	0	33	3.6	5.2
Own the land (%)	-	-	84	
Land Use				
Land mainly used for annual crops (%)			58	
Land mainly used for perennial crops (%)	-	-	25	
Land used for pasture (%)	-	-	7	
Land used for homestead, quarrying, etc. (%)	-		5	
Land used for tree cultivation (%)	-		3	
Land left fallow (%)	-		2	
Croton trees				
Have Croton trees on their land (%)	-	-	85	
Willing to plant and maintain Croton trees (%)	-		91	
Collect Croton seeds (%)	-	-	61	
Interested in processing Croton seeds at the household level (%)	-	-	88	
Interested in processing Croton seeds in groups and/or cooperatives (%)	-	-	90	

3.2. Base RPL model without socio-demographic interactions

Table 4 presents the results of the base RPL model without socio-demographic interactions. All five attributes are assumed to be normally distributed. The main effects in the base RPL model are all as expected. On average, our respondents prefer not to collect by themselves, shorter maturation periods, lower seedling prices, higher yields, and higher seed prices. The significant standard deviations of labour, maturation, and seed price indicate that there is significant preference heterogeneity among the respondents.

Trade-offs between the attributes are particularly interesting, and can be explored through the marginal rate of substitution (Table 5). Normalizing the estimates to the seed yield parameter shows how much the annual yield needs to increase on average to compensate for extending maturation by one year (5.0 kg), for an increase of 1 KES in seedling price (0.4 kg) or decrease of 1 KES in seed price (4.0 kg), and in order for the respondents to collect by themselves (8.8 kg). When combining these orders of magnitude with the practical feasibility of changing each attribute by one unit, one can easily see that a substantial utility effect can be most readily achieved by changing the seed price. Indeed, when comparing the relative importance (RI) of the attributes (Table 5), seed price proves to be distinctly the dominant attribute, followed by yield and maturation. Although these RI-values are heavily depending on the level ranges defined (Table 1), which might not entirely reflect reality, this information will be useful for stakeholders along the value chain, as well as policymakers, to consider optimal production options, given the technological and logistical constraints.

Table 4. Random Parameter Logit base model

Attributes and Characteristics	Attribute Main Effects (Standard Errors)	Standard Deviations (Standard Errors)
Labour Option	-0.695*** (0.231)	1.056*** (0.314)
Maturation	-0.392*** (0.077)	0.437*** (0.105)
Seedlings Price	-0.030** (0.014)	0.042 (0.027)
Yield	0.079*** (0.010)	0.017 (0.025)
Seed Price	0.320*** (0.038)	0.185*** (0.028)
# of choice questions	2000	
Log-Likelihood	-592.98	
Pseudo R ²	0.572	
# of Parameters [†]	10	

Note: ***, **, * significant at the 1%, 5%, and 10% level

†: 10 parameters are 5 parameters for means and 5 for standard deviations

Table 5. Marginal rates of substitution (using Krinsky-Robb procedure with 1,000 draws and the yield attribute as the common denominator) and relative importance of attribute

Attributes	Marginal Rates of Substitution (MRS)			Relative Importance
	MRS	Standard Errors	95% Confidence Intervals	
Labour	-8.794	2.772	[-14.226, -3.361]	0.043
Maturation	-4.958	0.953	[-6.825, -3.090]	0.072
Seedlings Price	-0.376	0.188	[-0.744, -0.080]	0.037
Yield	1.000	n.a.	n.a.	0.121
Seed Price	4.046	0.448	[3.168, 4.924]	0.727

3.3. RPL with interactions

In order to further investigate the sources of preference heterogeneity, the RPL model allows one to assess whether choice set alternatives are affected by household and farm factors. Interactions with socio-demographic variables were tested. Variables included gender, age, and education of the household head, land use and land size, occupation (farmer or not), and village type (whether they lived in an EFK collection village or not). Only occupation and village type show any significant interactions with the choice set variables.³

The estimation results of the RPL with interactions are reported in Table 5. The first column reports the main effects of each attribute for respondents who do not live in the EFK collection villages and are not farmers. The coefficients of all five attributes are significant at the 5% level and of expected signs. Those respondents prefer not to collect by themselves, shorter maturation periods, lower seedlings prices, higher yields, and higher seed prices. The second column shows the interactions between attributes and two household characteristics: EFK collection village and farmer. Although farmers and non-farmers do not have different preferences toward labour option and seed yield, farmers significantly devalue longer maturation periods (at 5% level). It is likely that farmers want shorter maturation periods since they depend on the land more for immediate benefits. Non-farmers could have off-farm income sources, making them less land-dependent and, therefore, less concerned about maturation period. Further, one can assume that farmers cannot set aside a large area of land for long-term payouts. However, they can and often do find small niches for trees, so it is not that they are averse to long-term investment, but less so on their own land than non-farmers with land.

Comparing respondents who do not live in EFK collection villages, those in EFK villages do have distinct preferences toward labour option, maturation period, and yield. While the respondents in EFK villages still place negative value on self-collecting, the magnitude is much lower than those who do not have experience working with EFK. The marginal utility of EFK villagers on self-collecting is only -0.488 ($= -1.814 + 1.326$), which is indeed not significant. It is not surprising that EFK collecting villages are less averse to self-collection than non-EFK collecting villages. Households that are already collecting know the hurdles and activities involved. Other studies show that getting started in a new and innovative enterprise such as Croton production is a barrier (Pattanayak et al. 2003).

³ The two demographic variables are interacted with labour option, maturation period, and yield. We also tested the specification with the two variables interacting with all five attributes, and the results show that the interaction terms with seedling and seed prices are largely insignificant. Note that the likelihood ratio test suggests that the inclusion of the six additional parameters significantly improves the model fit, while including four more interactions with seedling and seed prices does not.

Therefore, those in non-EFK villages would likely be less willing to collect than those already involved.

A similar pattern is observed for maturation time. The marginal utility of a year longer in maturation period is -0.112 ($= -0.483 + 0.371$) for those non-farmers who live in EFK villages, which is again insignificantly different from zero. The hurdles and concerns for getting involved in the enterprise make earlier returns, i.e., shorter maturation periods, more desirable. Those already collecting for EFK obviously have a supply, at least in the short term that they may believe will carry them through until new seedlings mature. Therefore, the waiting period for seedlings planted to mature is not as big a concern. Lastly, those respondents living in EFK villages place significantly less value on yield, with a marginal utility of 0.072 ($= 0.137 - 0.065$). This indicates that yield is less of a concern for those who have been working with EFK. Again, EFK villagers might consider planting Croton as a positive opportunity, so they do not require very high yield to compensate the perceived risks.

Table 6. Results: Random Parameter Logit with interactions

Attributes and Characteristics	Attribute Main Effects (Standard Errors)	Interaction Effects (Standard Errors)	Standard Deviations (Standard Errors)
Labour Option	-1.814*** (0.675)		1.074*** (0.324)
EFK Village		1.326** (0.611)	
Farmer		-0.137 (0.432)	
Maturation	-0.483** (0.193)		0.380*** (0.099)
EFK Village		0.371** (0.182)	
Farmer		-0.299** (0.138)	
Seedlings Price	-0.027** (0.014)		0.027 (0.030)
Yield	0.137*** (0.024)		0.006 (0.025)
EFK Village		-0.065*** (0.022)	
Farmer		-0.005 (0.014)	
Seed Price	0.313*** (0.032)		0.172*** (0.028)
# of choice questions	2000		
Log-Likelihood	-583.74		
Pseudo R ²	0.579		
# of Parameters [†]	16		

Note: ***, **, * significant at the 1%, 5%, and 10% level

[†]: 16 parameters are 5 parameters for means and 5 for standard deviations of the main effects and 6 parameters for means of the interactions.

3.4. Latent Class Logit (LCL)

While the assumption of homogenous preference within groups makes LCL less flexible compared to RPL, it is able to capture the preference heterogeneity when the marginal utility is discretely distributed. The LCL process involved an extensive search of model specifications. The two-class LCL model is the one that converges well and produces sensible interpretations. The results are presented in Table 6. The same two socio-demographic variables, occupation and village type, are included for predicting class probability. Fifty-nine percent of respondents fall into class one, where they mainly care about the attributes that are monetarily important, while the costs of time (maturation period) and their labour are less important. All three significant parameters have the expected signs. The preferences of the respondents in class two are distinguished from those in class one. Although class two respondents still prefer higher yield and seed price, which is very intuitive, the magnitudes of the two parameters are much smaller than those in class one. This can be observed when normalizing the coefficients to the labour attribute. In fact, class two respondents mainly care about labour option and maturation period. That is, they want seeds that mature sooner and prefer to have the EFK help them to collect, while the revenue (i.e., yield times seed price) is less of a concern. The two socio-demographic variables are not strong predictors of the class probability. The marginally significant estimate of farmer indicates that a farmer is less likely to be in class one, where respondents consider maturation time being less of a concern. This result is in line with that from the RPL models.

Table 6. Results: Latent Class Logit

Attributes and Characteristics	Class 1 Attribute Main Effects (Standard Errors)	Normalized Effects (to Seed Price)	Class 2 Attribute Main Effects (Standard Errors)	Normalized Effects (to Seed Price)
Labour Option	0.172 (0.553)	0.240	-0.407** (0.170)	-5.908
Maturation	-0.063 (0.115)	-0.088	-0.230*** (0.052)	-4.356
Seedling Price	-0.210*** (0.056)	0.293	-0.010 (0.011)	0.141
Yield	0.169*** (0.033)	0.235	0.049*** (0.007)	0.708
Seed Price	0.718*** (0.141)		0.069*** (0.009)	
Class Probability	59.2%		40.8%	
Marginal Effect on Class Probability				
Constant	0.510 (0.543)			
EFK	0.547 (0.518)			
Farmer	-0.809* (0.436)			
# of choice questions	2000			
Log-Likelihood	-575.06			
Pseudo R ²	0.7323			
# of Parameters [†]	13			

Note: ***, **, * significant at the 1%, 5%, and 10% level

[†]: 13 parameters are 5 parameters for means in each of the two classes and 3 parameters for the mean marginal effects on class probability.

The LCL results suggest that there are two classes of households: those for whom price of seeds is their key attribute and another where labour and time value of money are more important. This distinction is not unusual. Other studies find that households, especially in developing countries, are labour and time constrained (Barrett et al. 2001). However, we can't categorically determine which factors influence time and labour concerns more than price.

4. Discussion and Conclusions

Since almost every household surveyed is willing to participate in Croton production, the study tried to better understand key factors influencing preferences for Croton production systems. As expected, households wanted higher yielding trees and higher seed prices, while also preferring external collection, shorter maturation periods, and lower seedling price. It is no surprise that seed price is the most dominant single attribute influencing willingness to collect Croton seeds. The price factor cuts across all socio-demographic characteristics. Time and labour constraints also play a significant role, more so for some households than others. Other studies, including ones in biofuel systems (e.g., *Jatropha*) show the importance of labour opportunity costs (Van Eijck et al. 2014). In particular, the LCL model identifies two main classes of households: those for whom price of seeds is their key attribute (59% of respondents), and another one in which labour and time value of money (represented by the maturation time) are more important. However, from the data, there are no clear factors that distinguish which households have more labour and time constraints than others.

Choices made could not be ascertained through interaction effects with socioeconomic and land use characteristics. In relatively poor households with resource constraints, the risk, barriers, and hurdles of starting a new enterprise are difficult to overcome (Davis et al. 2010, Brown et al. 2006). In this survey, although income data was not collected, one-third of respondents stated that they are concerned about their household not having enough food. Overall in Kenya, almost half the population has a daily expenditure under the poverty line of \$1.25/day (USAID 2013). This is especially pertinent when returns take time due to long maturation periods. Respondents with non-farm occupations seem more willing to invest in Croton production, realizing they can afford the longer time payoffs. Farmers, who live off the land, are likely to be more concerned about the relatively long maturation periods and other risks involved in starting something new. This is in line with other studies which show that rural African farmers are very land constrained, risk averse, and need to maximize short-term farm production (Barrett et al. 2001). Also, as Kenya's population density increases (population growth of 2.6% per year), land becomes more scarce, which can result in lower farm productivity and household income (Muyanga and Jayne 2014). Farmers, especially

those relying on subsistence production and having little or no off-farm income, would expect returns on production sooner rather than later.

Relevant differences were also noted between respondents from villages already involved in the Croton business and others not yet reached by the industry. The latter are significantly more concerned than the former about labour requirements and maturation period, having strong preferences for external collection of seeds and early returns. This makes sense, especially since it is likely those already collecting for EFK can meet demand, at least in the short term, which they may believe will carry them through until new seedlings mature. Yield is also less of a concern for those who have been collecting Croton seeds. EFK collecting villages might consider planting Croton as a positive opportunity, so they do not require a relatively higher yield to compensate the perceived risks.

Such results mean that, to improve Croton supply from current collection areas by encouraging households to plant more trees, EFK and other potential industry players should focus mainly on increasing payment to primary collectors. This would mostly depend on achieving efficiency gains and cost reductions along the value chain. For instance, instead of Croton seedlings being provided to farmers for free, they could be sold at cost or even at a reasonable margin, since the study reveals that seedling prices are not a strong attribute affecting the decision to plant Croton. Studies of agroforestry adoption show more inclination to maintain and tend trees when the farmer paid for the seedlings (Pattanayak et al. 2003).

Nonetheless, to scale up the feedstock supply in new areas—those suitable for Croton, but with currently low concentration of adult trees—or to increase the engagement of the poorest farmers (especially those with lesser land availability), investments will be necessary in further research focused both on increasing yields and reducing the maturation time. The Central Highlands of Kenya still have major development and livelihood issues. High indices of poverty, lack of basic infrastructure, and limited employment opportunities suggest the need for new income opportunities which Croton can potentially offer and have an impact on development in Kenya. Most of these farmers rely on subsistence production and have little off-farm income. Inducements to engage farmers in Croton production and trade could be done by guaranteed contracts to buy their seed at maturity. For those already with trees, they can sell seed from existing trees while new trees are maturing. The introduction of innovative collection arrangements should also be considered for expansion of this value chain. As mentioned, respondents would be more willing to directly collect Croton only if the maturation time were about 1.77 years shorter, the annual yield increased by 8.79 kg, or if the seed price per kg were KES 2.17 higher.

The results of this study provide useful tools and guidance to industry, policymakers, and other stakeholders interested in supporting the development of the Croton value chain. A sustainable and consistent supply of seeds is critical for scaling up, since feedstock is the single largest variable operating cost across the value chain (Jacobson 2015). Increasing and scaling up production to meet demand for biofuel and other Croton products will require the engagement of new farmers. Fortunately, unlike other oil seed tree crop initiatives based on exotic and unfamiliar species such as *Jatropha*, most households in Kenya are acquainted with Croton (GTZ 2009). Given the range of Croton products and the potential for profits as seed collection and processing increase, developing the Croton value chain in Kenya could have a significant positive economic impact on rural livelihoods at the individual and community levels.

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