Farmers Preferences for Attributes of Seed Rice in Sierra Leone: A Best-Worst Scaling Approach

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Abstract:

An adoptive measure of improved rice is relevant for increasing food production and minimizing downside effects of rapid population growth. This study seeks to provide an empirical insight on farmers' improved rice adoption decision processes and implicitly on farmers' preference for 13 seed rice attributes, using a best-worst experiment and conditional logistic model (to explains the possible effects of the experiment on final choices of the best - worst attributes). The results showed that "potential yield, maturity; seed viability, tolerance to pest and disease" are respectively the first four important attributes for farmers' choice for seed rice varieties. Additionally, we derived important policy implications for seed rice development, breeding priority setting and adoption in Sierra Leone, centred on the inclusion of farmers' needs and participation in future seed rice related research to ensure continuous and appropriate adoption for achieving sustainable output in obviously poor and challenging farming conditions. Finally, we suggested that prerequisites for enabling improved rice to increase rice production in Sierra Leone should include farmers having improved access to seed rice and information as well as favourable policies supporting the development of agricultural sector.

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Key words

Seed, rice, attributes preferences, farmers, best-worst, Sierra Leone

1 Introduction

The perceived constraints to food production and food security for a rapid growing global population have been debated for a long period[1] (See Ehrlich 2008; Alexandratos and Bruinsma 2012). In the context of agricultural production in Sub Saharan Africa, the issue of rapid population growth becomes more crucial (Zehadul Karim 2013; Waldman et al., 1999; Nazziwa-Nviiri et al., 2017; Josephson et al. 2014; Mellor 2014), since the united nation's projection of rising population growth is expected to reach 9.7 billion in 2050. This expected growth is likely to be more evident in developing countries (FAO 2009; Alexandratos and Bruinsma 2012), and particularly in Sub Saharan Africa (FAO 2009). The implication is that rapid population growth will continue to drive-up global agricultural production and food demand will be expected to increase at the rate 98% by 2050 (Valin et al., 2014). This means, the agricultural production needs to increase by an estimated 70 percent globally and 100 percent in developing countries (Valin et al., 2014).

In the Sub Saharan Africa, where the majority of the population depends on agriculture for livelihoods (Feder et al. 1985; Staatz & Dembele, 2007; Pingali 2012) an estimated 51% of the poorest 20% of the rural population can be found on low potential degraded lands (Marenya et al., 2012). The declined in agricultural production has been exacerbated by declining soil fertility (Sanchez 2002; Muzari et al., 2012). For instance, the traditional agricultural system (e.g. fallow periods) that would possibly allow soil fertility restoration have been largely replaced by the system of continuous cropping and cultivable land expansions (Adesina 1996). This often leads to soil nutrients deficiency and declining crop yield (literally a recipe for food insecurity) (Mendola 2006; Sanchez and Swaminathan 2005; Meijer et al., 2015). As a result, per capita food output in Sub Saharan Africa has declined and the region has the highest proportion of undernourished people in the world, estimated to be 30% of the total population or 239 million people in 2010 (FAO 2010 as cited in Meijer et al., 2015).

In response, to the need for sustainable agricultural growth, many recent studies show that promoting investment in agricultural technology that include the use of promising, simple and efficacious inputs such as high yielding seeds (e.g. improved rice) and other recommended agricultural practices (e.g. integrated pest and crop management) (Feder et al., 1984; Feder et al., 1990; Foster and Rosenzweig 1995; Ghimire et al., 2015; Waldman et al.,

[1] The debate on rapid population growth gathered momentum in the late eighteenth century, following Malthus, and more recently with Paul Ehrlich's Population Bomb (See Paul R. Ehrlich 2008: The population bomb Current Biology Vol 18 No 13 for more)

2017; Kamel Louhichi and Sergio Gomez y Paloma, 2014; Nazziwa-Nviiri et al., 2017) will play an increasingly important role in upholding agricultural productivity and the long term goal towards the attainment of food security.

Despite these robust studies focusing on the potential of agricultural technologies, barriers to adoption which include uncertainties, costs and other constraints (Doss 2006; Mendola 2006; Wollni et al., 2010; Kassie et al., 2014; Mwangi and Kariuki 2015; Tesfaye et al. 2016) also deserve attention. Some studies discussed the relevance and prospects of implementing these technologies (Akpokoje et al. 2003; Meinzen-Dick et al., 2004; Horna et al., 2005; FAO 2009; Markelova et al., 2009). Farmers' perception, willingness and adoption behaviour have also been studied (Adesina and Zinnah, 1993; Batz et al., 1999; Irz et al., 2001; Hossain et al., 2006; Awotide et al., 2016). As most studies conclude, factors such as: socio-economic (Feder et al., 1985; Ghadim et al., 2005; Barreto and Kemp 2008); farm households' wealth or income (Sall et al., 2000) etc. have been revealed as some factors influencing the adoption of improved technologies. Furthermore, studies have revealed that technology adoption has varied indicators (such as risk attitude, information and investment speculation), which remain conceptually debatable, but key in adoption of technology including improved rice (Griliches 1957; Just 2003; Barham et al., 2004; Greiner et al., 2009; Aldana et al., 2011). Horna et al., 2005 argue that for rice farmers' incentive to adopt improved rice seed is higher when the costs of production are low. However, even if these factors may provide explanation of farmers' improved technology adoption, a more constructive study is required to examine technology attributes. Plausible reasons could be reflected on the consistency of farmers' adoption rational-decision with preferences for the appropriate seed attributes (e.g. Adesina and Zinnah 1993; Mafuru et al., 2011; Asante et al., 2014; Etwire1 et al., 2016). According to Asrat et al., (2010), improved technologies (e.g. improved seed rice) might be high yielding, yet not attractive to farmers, unless they possess other attributes that farmers consider important and appealing. Therefore, expanding adoption studies to measure different technology attributes, ex-post adoption studies could address the need for directing appropriate technology development strategies. In this context, we provide an empirical insight on farmers' improved rice adoption decision processes, explicitly, on farmers' preference for rice attributes.

The main objective of the study is to elicit farmers' preferences for seed rice attributes using best-worst scaling approach. We provide a micro-perspective about farmers, their different realities', beliefs, aspirations and behaviours towards adoption of improved technology. This study uses framework of an agrarian system in Sierra Leone, characterised by high population

densities (Mellor 2014); recurrent food shortages and poverty that affect millions of households (Ghimire et al., 2015); missing high-input, intensive, market based production (Dingkuhn et al., 2006; Markelova et al., 2009; Waldman et al., 2017) and predominantly small scale subsistence farming (Conteh et al., 2012).

The later sections of paper are organised as follows: in Section 2, we provide a detail description of the methodology (including study design and implementation). In Section 3, an empirical model is constructed (including design of the choice modelling protocol and the elicitation of the individual preferences). Discussions of empirical results, conclusions and recommendations are presented in Sections 4 and 5.

2 Methodology

In this section, we provided description of the methodology and model specified. We utilised stated preference approach namely the Best Worst Scaling and a random utility theory (as a construct for basic premise and theoretical foundation of Best Worst Scaling) to evaluate farmers' preferences for various attributes of various seed rice. Best-worst is an innovative discrete choice experiment based on the inherited comparative judgments when individuals face numerous choices. The approach has its origin from Jordan Louviere in 1987 (Finn and Louviere 1992; Flynn and Marley, 2012) and an extension of Thurstone's (1927) method of paired comparison (Fabbris et al., 2016; Glenk et al., 2014). Comparisons made by various studies (Campbell and Erdem 2014) between best-worst scaling and other conventional rating scales that are more cognitive sensitive and susceptible to a range of behaviour anomalies showed strong relationships between the best-worst measures and real choices. The approach is considered "scale-free" and prevents a scale-use bias (Baumgartner and Steenkamp 2001; Campbell and Erdem 2014). Therefore, based on decision-making theories from cognitive science, best-worst scaling is an efficient approach to understanding farmers' preferences which avoids many of the problems associated with other methods.

The study was based on cross sectional data obtained from farm households within 13 administrative Districts of Sierra Leone between the months of April and September 2017. The selection of farmers was through a simple multi-stage sampling technique that involves a random selection of 2 chiefdoms from each of the 13 districts and a selection of at least 4 agricultural towns or villages from each chiefdom making a total of 26 and 87 sample chiefdoms and towns/villages respectively. An overall sample of 624 farm households including equal sub-samples of 48 farm households from each District were targeted in the study. See Table 1. Lists of rice cultivating communities (apparently dominated improved

rice cultivating communities) were generated in consultation with the pertinent authorities in the ministry of agricultural, forestry and food security of Sierra Leone.

To check the relevance of the research questions about local conditions, farmers' expectations, and level of understanding, the survey was pre-tested on a number of 10 farm households. The pre-test results were discussed and necessary changes made to farmers' pre-responses.

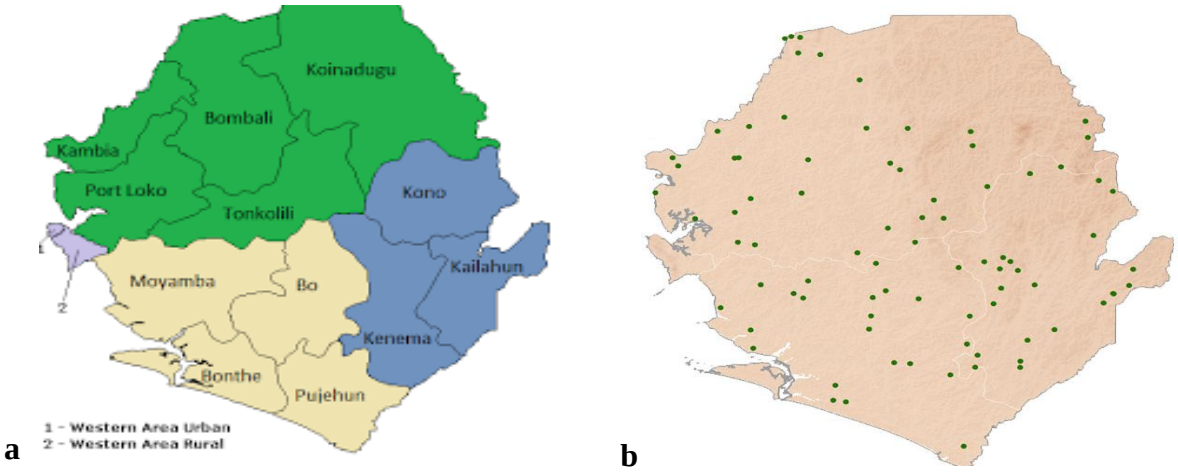

Figure 1: Maps of Sierra Leone indicating administrative divisions[a] and rice producing area[b]

Table 1: Distribution of sample regions and size

SN	Region	Districts	Chiefdoms	Sections	Towns/villages	No. of farmers
1	Eastern	Kailahun	2	6	8	48
2		Kenema	2	6	7	48
3		Kono	2	4	8	48
4	Northern	Bombali	2	8	8	48
5		Kambia	2	8	8	48
6		Koinadugu	2	4	4	48
7		Portloko	2	8	8	48
8		Tonkolili	2	4	4	48
9	Southern	Bo	2	4	4	48
10		Bonthe	2	4	8	48
11		Moyamba	2	4	8	48
12		Pujehun	2	6	7	48
13	Western Area	Western Rural	2	5	5	48
Total	4	13	26	71	87	624

Source: Authors' survey 2017

To elicit preferences for various attributes of rice seed, farmers were asked to choose rice seed attributes that could be best and least preferred in their improved rice adoption decision. In consultations with stakeholders and experts (e.g., farmers, agriculture officials from the ministry of agriculture, forestry and food security) with hands-on experience and practical knowledge about relevance of rice seed attributes, attributes such as: 'potential yield;

tolerance to pest and disease; maturity; ecology adaptability; taste (palatability); cooking quality; environment adaptability; seed price; seed viability; shattering; seed rate; fertilizer response and threshing' were identified as the important attributes. Each of these attributes varied across plausible levels encompassing the range of options that farmers would possibly consider in their efforts to adopt improve rice seed in Sierra Leone.

The best-worst utilizes an orthogonal design method based on a balanced incomplete block design to develop a design containing 13 choice sets with 4 attributes in each set. (See table 2 for an example of the 13 best-worst scaling design). Farmers were then asked to complete the 13 choice sets, simultaneously choosing the most important (Best) and least important (Worst) attributes respectively from the 4 attributes in each set. All attributes in the design had equal and independent occurrence so that farmers can judge all possible pairs of items within the displayed Best – Worst set and choose the pair that reflects their maximum difference in preference. The number of time attributes was chosen as best and Worst were respectively added across respondents to get the total number of Best – Worst for each attribute.

Table 2: Examples of Best Worst (B-W) choice Situation

The most important item (select one attribute indicating "√"	Which attributes are the most and least important to you …	The least important item (select one attribute indicating "√"
	Potential Yield	
	pest & disease Tolerant	
	Maturity	
	Ecology adaptability	

Source: Authors' survey 2017

Thus the difference between the number of times the attribute was considered "best" ("most important") and the number of times it was considered "worst" ("least important"), was divided by the product of the number of respondents and the frequency of appearance of each attribute in the design to get the standard best-worst score as follow:

$$\text{Standard score} = \frac{n(b)-n(w)}{n \text{ X } r} \qquad (1)$$

Where: 'n(b)' is the total number of times an attribute was most important; 'n(w)' the total number of times an attribute was least important; 'n' is the number of respondents (624 in our study) and 'r' the frequency of appearance of each attribute in the design (which is 4 in our design).

3 The econometric approach

In providing descriptive results in explaining the importance of each attribute among the responsive farmers, we applied an econometric random utility theory model (Manski, 1977;

Thurstone, 1927; Campbell and Erdem 2014). In this model, the utility a respondent (farmer) n derives from choosing an attribute i of improved rice with j = (1, 2, …, J) number of attributes can be decomposed into an deterministic or observed component, V_{nit} and an unobserved random error component, ε_{nit}. Where the ε_{nit} terms are identically and independently distributed (iid) and follow a Type I (or Gumbel) distribution (See Glenk et al., 2014).

$$U_{nit} = V_{nit} + \varepsilon_{nit} \quad (2)$$

We defined the deterministic component V_{nit} by the difference in utility between the best and worst items describing farmer's (n) chosen pair (i) in Best Worst Scaling task (t):

$$U_{nit} = \underbrace{(\beta x_{b_{nit}})}_{Best} - \underbrace{(\beta x_{w_{nit}})}_{Worst} + \varepsilon_{nit} \quad (3)$$

Where the utility was assumed to be function of the choice attributes, with the utility parameter row vector β (subject to $\sum_{k=1}^{k} \beta_k = 0$) related to the best and worst items, x (indexed by b and w respectively chosen as best and worst with respect to the farmer's n preference of attribute i) and error term ε_{nit}.

Under these assumptions, the likelihood that farmer n chooses rice attribute i from choice set of improved rice with j = (1, 2, …, J) number of attributes was described by a conditional logistic model with the following expression (See Loureiro and Arcos 2012; Tong et al., 2017):

$$L_n(y_n|x_n) = \frac{\exp\left((\beta x_{b_{nit}}) - (\beta x_{w_{nit}})\right)}{\sum_{j=1}^{J} \exp\left((\beta x_{b_{nit}}) - (\beta x_{w_{nit}})\right)} \quad (4)$$

Equation 4 can jointly model the sequence of best – worst choices $y_n|x_n$ for farmer n. The sequential conditional logistic model can specify a product of logit probabilities ($Pr(y_n|x_n)$, integral with each factor of the best–worst choice as follows:

$$Pr(y_n|x_n) = \prod_{t=1}^{T_n} \frac{\exp\left((\beta x_{b_{nit}}) - (\beta x_{w_{nit}})\right)}{\sum_{j=1}^{J} \exp\left((\beta x_{b_{nit}}) - (\beta x_{w_{nit}})\right)} \quad (5)$$

4 Results and discussions

4.1 Ranking of preferred rice attributes

Table 3 reports the best-worst scaling results. The rankings of rice attributes based on the best-worst scaling Standard Score are shown in Ranking. The four most important attributes were "potential yield, maturity, seed viability, pest and disease tolerance" in that order, while "threshing, fertilizer response, cooking quality and shattering" were the three least important attributes in that order of sequence. Although Standard Score demonstrated a ranking of the

most to least attributes, there is a lack of knowledge with regards to the relative important information, i.e., how important the ranked attributes were relative to each other. To investigate the correlativity, we adopted a new index, which was calculated from taking the square root for best/worst score (Sqrt B-W). This value was scaled so that the most important with the highest index was assigned an interval scale of 100 (Yagi et al., 1997). The resulting coefficients in "relative importance" measured the choice probability compared to the most important attribute (Cohen 2009).

Table 3: Best-Worst Scaling Results

Attributes	Best		Worst		B-W Score	Average B-W Score	Sqrt (B/W)	Relative importance (%)	Share of preference	Rank
	Freq	%	Freq	%						
Potential yield	1459	17.99	288	3.52	1171	0.469	2.251	100.00	0.238	1
Pest and disease tolerance	658	8.11	481	5.87	177	0.071	1.170	51.96	0.081	4
Maturity	871	10.74	382	4.66	489	0.196	1.510	67.09	0.109	2
Ecology adaptability	730	9.00	699	8.54	31	0.012	1.022	45.40	0.071	5
Taste (palatability)	513	6.32	660	8.06	-147	-0.059	0.882	39.17	0.057	9
Cooking quality	319	3.93	824	10.06	-505	-0.202	0.622	27.64	0.042	12
Env. adaptability	670	8.26	819	10.00	-149	-0.060	0.904	40.19	0.064	7
Seed price	585	7.21	734	8.96	-149	-0.060	0.893	39.66	0.057	8
Seed viability	595	7.33	433	5.29	162	0.065	1.172	52.08	0.081	3
Shattering	342	4.22	1007	12.30	-665	-0.266	0.583	25.89	0.034	13
Seed rate	507	6.25	558	6.81	-51	-0.020	0.953	42.35	0.065	6
Fertilizer response	445	5.49	732	8.94	-287	-0.115	0.780	34.64	0.048	11
Threshing	418	5.15	572	6.98	-154	-0.062	0.855	37.98	0.053	10

Source: Survey 2017

"Relative importance and Ranking" in Table 3 refined the ranking using the standardized scale. "Potential yield" emerged as the most important attribute, after taking the interval scale of 100. All other standardized scales were computed relative to this value. For instance, "shattering" estimated to at 25.89% was 0.2589 times as important as "potential yield". Similarly, the relative importance of "Pest and disease tolerance" and "seed viability" were both about 52%, indicating that "Potential yield'' is about twice more important as ''Pest and disease tolerance'' and "seed viability". The second highest ranked attribute "maturity" had a standardized square root interval score of 67.1 relative to the score of 100 for the top ranked attribute. This essentially means that "potential yield" is considerably more important than all other rice attributes. The first four highest ranked attributes (including potential yield, maturity, seed viability and tolerance to pest and disease) were considered to be most suitable

for consideration in improved seed rice choice from farmers' perspectives according to the study.

4.2 Farm household's preference for rice attributes

Table 4, reports the results of the conditional logistic regression analysis. It explains the possible effects of the experiment on final choices of the Best - Worst attributes We reported the parameters of the decision-attributes with the correlation coefficients of the main regression and exponential coefficients or odds-ratios (which may be interpreted as the estimated odds of change in farmers' decision as a result of a unit change in the independent variable (Gould et al., 1989). Our analysis focused on parameters, as those measuring the quantity of key interest and preference strength. We assumed the other variables, such as those that are farm and farmers' related would have fixed effects across attributes and choice sets. Hence, we assumed these variables cannot convey information about the differences between attributes and levels of attributes so we do not consider them. According to the result, the p-value for the overall significance of regression was (0.000) indicating that the regression is highly significant and the logistic specification fits the data. Also, the pseudo R^2 measuring goodness of fit for the overall regression was estimated to be low at 0.0405, implying that about 4 percent of the variation in the dichotomous dependent variable was explain jointly by the predictors (rice attributes). The value of the log-likelihood in relative terms (-0.304) confirms the presence of substantial unobserved heterogeneity in the probability of choosing an attribute as also confirmed by the magnitudes and statistical significance of the standard deviations of the random parameter distributions.

Table 4: Initial parameter and odd ration estimates of conditional logistic model

Variables (Attributes)	Conditional (fixed-effects) logistic model					
	Initial parameter estimates			Odd ration		
	Coef.	Std. Err.	z	Odd ratio	Std. Err.	z
Potential yield	1.083	0.038	28.40*	2.953	0.113	28.40*
Pest & disease tolerance	0.000	0.034	-0.00	1.000	0.034	-0.00
Maturity	0.297	0.035	8.54*	1.345	0.047	8.54*
Ecology adaptability	-0.124	0.035	-3.56*	0.884	0.031	-3.56*
Taste (palatability)	-0.355	0.034	-10.49*	0.701	0.024	-10.49*
Cooking quality	-0.660	0.035	-19.14*	0.517	0.018	-19.14*
Env. adaptability	-0.227	0.030	-7.47*	0.797	0.024	-7.47*
Seed price	-0.349	0.034	-10.11*	0.706	0.024	-10.11*
Seed viability	0.004	0.034	0.11	1.004	0.034	0.11
Shattering	-0.854	0.035	-24.38*	0.426	0.015	-24.38*
Seed rate	-0.216	0.034	-6.35*	0.806	0.027	-6.35*
Fertilizer response	-0.513	0.034	-14.88*	0.599	0.021	-14.88*
Threshing	-0.429	0.040	-10.71*	0.651	0.026	-10.71*

Note: * indicates significant levels at 1%

LR chi^2 (13) 2567.14

Prob > chi^2	0.000
Log likelihood	-30438.093
Pseudo R^2	0.0405

Source: Authors' survey 2017

The results for all interactive variables with the dummy variable (i.e., coefficient of parameters) capturing differences in farmers' preference for rice attributes were negative except for potential yield, maturity and seed viability, demonstrating that stated preferences are largely influenced by the three attributes (potential yield, maturity and seed viability) as specified in the Best – Worst scaling results. Also, the z values for the regression coefficients were highly significant at 1% level significance for all excepting for two estimates (pest and disease tolerance and seed viability). This means that pest and disease tolerance and seed viability could be removed by farmers without biasing preference data. Also, the statistical significance of most of the regressors suggests that the attributes considered in the study were generally what farmers assume to be among the most relevant in improved rice adoption decision. And that any of the significant attributes increases the likelihood that a seed rice attribute is chosen.

We found that the inclusion of odd ratios led to more precise estimates, corresponding to greater sensitivity in the measurement of farmers' preference strengths. For instance, results show constant effect at high levels (i.e., equal to or more than 100%) for potential yield, maturity, seed viability and pest and disease tolerance respectively. Potential yield has the largest odd ratio of 2.95, indicating its 295% more likelihood preference than all other attributes in the analysis. Maturity with 1.35 (second largest odd ratio) was 135% more likely to be preferred. Similarly, seed viability and pest and disease tolerance were respectively 100% more likely to be preferred than the other attributes below the threshold. Thus, the conditional logistic model-based analyses confirm direct convergent conclusions with the best-worst scores (see Table 3).

5 Conclusions and recommendations

This study employs a best-worst scaling to explore important seed rice attributes in farmers' preference for improved rice . Best-worst scaling method gives high levels of validity making it easy to ascertain farmers' preferences of improved seed rice. The results have revealed farmers' strong preferences for potential yield, maturity, seed viability, tolerance to pest and disease and farmers' weak preferences for threshing, fertilizer response, cooking quality and shattering. The conditional logistic model estimation also ultimately indicated the same conclusions with the best-worst scores.

The results have important implications for improved seed rice development, breeding priority setting and adoption in Sierra Leone. Considering the growing concern for food insecurity and the rapid growing population, adoptive measures of improve rice varieties becomes relevant for increasing food production and minimizing downside effects of rapid population growth. The low adoption of improved rice has been related to ineffective development and promotion scheme. This study therefore suggests the inclusion of farmers' needs and participation in future seed rice related research, which will ensure their continuous and appropriate adoption for achieving sustainable output in obviously poor and challenging farming conditions. Development and promotion of better quality seed rice to possess the most important and preferred attributes (slated in this study) would possibly offer opportunities to farmers to create better balance between rice production and demand.

Varieties which have all best preferred or important attributes can have a strong impact on the rice farming conditions in Sierra Leone. Therefore, prerequisites for enabling such improved seeds to increasefarm output in the country should include farmers having access to seeds and information as well as favourable policies supporting ahricultural development.

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