Genebank Impacts

Working Paper No. 17 | September 2021

An experimental approach to farmer valuation of African rice genetic resource conservation

Nicholas Tyack
Graduate Institute of International and Development Studies
nicholas.tyack@graduateinstitute.ch

Aminou Arouna
AfricaRice
A.Arouna@cgiar.org

Rachidi Aboudou
AfricaRice
R.Aboudou@cgiar.org

Marie-Noelle Ndjiondjop
AfricaRice
M.Ndjiondjop@cgiar.org

Abstract

Genebanks serve as both providers of valuable traits to breeding programs as well as repositories of diverse crop genetic material representing society's agricultural heritage. Using a lab-in-the-field experiment, we investigate how smallholder rice farmers in Côte d'Ivoire value having access to both new, advanced rice varieties containing genebank materials as well as landraces or farmers' varieties of African rice (*Oryza glaberrima*) maintained in the genebank of the Rice Biodiversity Center for Africa. We use a Becker-Degroot-Marschak (BDM) mechanism to elicit farmer willingness-to-pay for small amounts of seed of advanced rice varieties developed by AfricaRice as well as African rice landraces conserved in the AfricaRice genebank. In addition, we investigate whether farmers appreciate option and bequest values provided by the conservation of rice genetic diversity. We find that farmers generally value having access to African rice landraces at roughly the same level as for advanced rice varieties, and that most farmers are willing to pay something to maintain future option and bequest values associated with the conservation of rice varietal diversity. These findings demonstrate the value provided by the conservation of African rice landrace varieties in terms of safeguarding the ability of farmers to cultivate them in the future, and not just through the provision of inputs to the breeding process.

Acknowledgements

We thank Nelissa Jamora and Melinda Smale, whose assistance, facilitation and invaluable feedback made this study possible. In addition, thanks are also due to Jean-Louis Arcand and Timo Goeschl for their useful advice regarding the design of the study.

We express many thanks to the AfricaRice genebank and its staff for their enormous support, particularly to Fatimata Bachabi and Bienvenu Kpeki. In addition, we thank the enumerators who skillfully implemented our data collection; Wilfried Yergo, who provided some research support and assisted with the training of the enumerators; and Dule Zhao, who provided valuable inputs into the choice of ARICA varieties used in the study.

The funding for this research provided by the CGIAR Genebank Platform, AfricaRice, and the Crop Trust through the 2020 Genebank Impacts Fellowship is gratefully acknowledged.

Table of Contents

Suggested citation

Tyack, N.; Arouna, A; Aboudou, R.; Ndjiondjop, M. 2021. An experimental approach to farmer valuation of African rice genetic resources. Genebank Impacts Working paper No. 17. CGIAR Genebank Platform, Africa Rice Center (AfricaRice), and the Crop Trust.

1. Introduction

Genebanks are collections of genetic resources consisting of selections from the great diversity of extant crop varieties present in farmers' fields across time, and consist of conserved sets of accessions, which are previously collected samples of genetic material from farmers' fields in the past. They can be seen as collections of old genetic materials at risk of being lost that are maintained for future use as inputs into the research and development processes that drive the development of new varieties – in the context of agriculture, old resources containing valuable genetic diversity that are used in the plant breeding process to develop new varieties that are more productive and resilient. In addition, these old crop varieties may have value in and of themselves apart from their use in the breeding process (Poudel and Johnsen 2009; Rocchi et al. 2016). Genebanks thus serve as both providers of valuable traits to breeding programs as well as repositories of diverse crop genetic material representing society's agricultural heritage.

A primary value of the genetic resources of crop varieties is their use to breed new crop varieties that are more productive and resilient. The Green Revolution is a prime example of diverse genetic materials being used to breed more productive crop varieties (Hedden 2003), leading to substantial increases in crop yield and production, reduction of child malnourishment, and reduced crop prices in developing countries (Evenson and Gollin 2003). Many past studies have thus focused on demonstrating "impacts" of genetic diversity across a large scale. Others have attempted to demonstrate the value of genetic resources for research and development by using models in which individual firms engage in optimal search in pursuit of profits (Craft and Simpson 2001; Rausser and Small 2000; Simpson, Sedjo and Reid 1996), with some extensions, as in Zohrabian et al. (2003), who utilize a maximum entropy approach to value the expansion of the U.S. soybean collection based on search for a single pest resistance trait. However, it is likely that these approaches underestimate the social values of genetic resources. For example, Drucker and Caracciolo (2014) argue that the commercial value of plant genetic resources is likely to only represent a small proportion of its total economic value to society, while Goeschl and Swanson (2002) highlight several externalities that are likely to bias the private valuation of genetic resources below their true social value.

The process of innovation involves not only the creation of new technologies through research and development but also investments in diffusion and the innovations of users who must learn how a technology fits into their own personal setting. In the context of agriculture, farmers pursue innovation through a process of experimentation with new technologies to identify how they may contribute to higher yields or more valuable or resilient production in the local conditions of their farm and community. Thus, the connection between genebanks and farmer experimentation with novel crop varieties supported by genebank activities is essential in terms of better understanding the economic values provided by genebank collections.

In this experiment, we explore this connection directly by investigating how smallholder rice farmers in Côte d'Ivoire value both new, advanced rice varieties containing genebank materials as well as landraces[1] or farmers' varieties of African rice (*Oryza glaberrima*) that are conserved *ex situ*. We elicit these values through the implementation of a lab-in-the-field experiment utilizing the Becker-DeGroot-Marschak mechanism. These rice varieties are maintained by the AfricaRice genebank – the Rice Biodiversity Center for Africa (RBCA) – among which the improved rice varieties are products of breeding efforts with contributions from the Africa Rice Center (AfricaRice).[2] This study is thus designed to provide insights into how farmers themselves value genebank services and the products of their activities. The experiment also more broadly explores whether facilitating farmer experimentation with diverse crop genetic material can help to promote the diffusion of both newly developed and landrace rice varieties, contributing to farm-level yield growth and stability as well as on-farm conservation of African rice landraces.

In addition, we use a simplified version of the open selective trials methodology proposed by Chassang et al. (2012) to assign some farmers to experiment with cultivating either landrace or Advanced Rice Varieties for Africa (ARICA) seed in the off season based upon their elicited farmer willingness-to-pay for advanced rice seed and willingness-to-accept to cultivate small quantities of African rice landraces. The open selective trials approach is designed for situations where outcomes are influenced substantially by unobserved individual beliefs and efforts (as is the case for technology adoption in agriculture, particularly in the smallholder context). This component of the experiment is included to determine whether farmers who had an opportunity to experiment with these novel rice varieties were willing to pay more in the final willingness-to-pay elicitation carried out using the Becker-DeGroot-Marschak mechanism.

We build upon past studies by focusing on the newer generation of rice varieties promoted by AfricaRice, such as the ARICA varieties. The experiment thus provides direct evidence for how farmers in Vallée du Bandama in Côte d'Ivoire value having access to these new varieties. In addition, we also investigated how farmers value landrace accessions (conserved samples of rice varieties) of African rice (*Oryza glaberrima*) maintained by the AfricaRice genebank through a program in which we first paid farmers to cultivate small quantities of landrace seed, and then

[1] Local farmer varieties improved through traditional methods.

[2] AfricaRice is a CGIAR Research Center founded in 1971 as the West African Rice Development Association (WARDA), and as a pan-African intergovernmental association counts 28 African nations among its member states.

assessed farmer demand for more seed of such farmers' varieties of African rice (*O. glaberrima*). This latter focus of the study contributes to the literature on genetic resources and genebank economics by shifting the focus from values provided through crop breeding to a more participatory, farmer-based valuation of African rice varieties that relied on the activities of the RBCA (including its work to conserve crop diversity and its distribution of genebank resources to breeding programs), a genebank that conserves a diverse collection of landraces representing millennia of rice farming in Africa.

2. Our contribution

Our experiment contributes to a limited past literature on genetic resource valuation (see reviews by Smale, Jamora and Guarino 2021, Drucker and Caracciolo 2014) by focusing on a less explored area of the literature: how smallholder farmers themselves value having access to both improved varieties bred using genebank materials, and traditional, landrace varieties conserved as genebank accessions. We thus build upon an existing body of literature investigating how farmers value and decide to cultivate landraces and varying levels of agrobiodiversity on farm, including Meng et al. (1998); Smale, Aguirre and Bellon (2001); Gauchan et al. (2006) Van Dusen, Gauchan and Smale (2006); Birol et al. (2006) and Birol et al. (2008); Bellon et al. (2015), as well as more recent literature on the re-matriation / re-patriation of farmer varieties from genebanks such as Ocampo-Giraldo et al. 2020 and Luettringhaus et al. 2021.

Compared to much of the earlier work on the value of genetic resources, we take a more participatory, farmer-based approach to investigating the value provided by conserved diversity. While most past work in this area has focused on how diverse genetic material can be valuable for the research and development activities of private firms, we analyze here how farmers value the services provided by genebanks – not only in terms of providing inputs to improved varieties but also through their conservation of heritage crop varieties – in our case, African rice landraces.

Farmers may value having access to genebank materials for direct use – that is, they may value being able to access and cultivate rice varieties that were grown by previous generations but that have since disappeared from farmers' fields. In addition, we investigate the extent to which smallholder farmers in Côte d'Ivoire may care about option and bequest values supported by the conservation of African rice diversity at the RBCA. These questions are important, because if farmers are found to value having access to ancestral landrace varieties, as well as the provision of other types of value such as option and bequest value, this would indicate additional (and potentially important) sources of value provided by genebanks that are typically not taken into account, in addition to the more commonly addressed value in the literature provided by the use of collections of conserved genetic diversity in crop breeding efforts.

3. Context

3.1 Background

AfricaRice manages one of the largest collections of African rice (*Oryza glaberrima*) in the world, as well as traditional African landraces of *Oryza sativa* (introduced in the 1500s). Domesticated in West Africa about 3,000 years ago and indigenous to the continent, the cultivation of African rice has declined and been replaced in farmers' fields in many cases by the higher-yielding Asian rice (*Oryza sativa*). However, African rice genetic resources are of interest due to numerous valuable traits in the genepool such as resistance to diseases endemic to Africa like Rice Yellow Mottle Virus (RYMV) (Ndjiondjop et al 1999; Thiemele et al. 2010), tolerance to iron and aluminum toxicity, drought, and soil acidity, as well as other qualitative traits related to consumption preferences, such as taste, aroma, and cooking qualities (Wang et al. 2014).

While much applied economics research has focused on the impact of the interspecific NERICA varieties bred by AfricaRice, very little work has investigated the value of the newer generation of ARICA varieties or attempted to investigate how farmers value traditional African rice (*Oryza glaberrima*) landraces. Past studies have focused on the adoption and impact of NERICA rice varieties (Arouna et al. 2017), a previous generation of improved interspecific rice varieties bred by the AfricaRice Center. Agboh-Noameshie et al. (2007) find that NERICA adoption led to a positive and significant increase in yield and farmer income, with greater benefits being enjoyed by women than men farmers, while Kijima et al. (2008) found that NERICA adoption helped to decrease poverty (increasing income by USD 250 per hectare) without worsening the income distribution. However, others have found that barriers to adoption remain a serious problem. Yokouchi and Saito (2016) found that many farmers in Benin reported that they had limited access to NERICA seed, hindering adoption. Kijima et al. (2010) reports that in Uganda, more than 50% of NERICA adopters subsequently abandoned the variety, which they suggest was caused by weak dissemination of the necessary information for seed production. Diagne (2006) identifies a 23% "adoption gap" between the actual and potential adoption rates in Côte d'Ivoire, suggesting that a successful NERICA dissemination project could have a large potential adoption impact in the country.

The significance of this study is thus its combined investigation of how farmers value both newer improved rice varieties bred through AfricaRice's programs as well as landrace varieties of African rice conserved by the AfricaRice genebank. In addition, the study's employment of an innovative randomized controlled trial and open selective trials methodology (Chassang et al. 2012) is of interest given the insights it provides into farmer heterogeneity in terms of preferences regarding the valuation of rice genetic diversity (including both advanced and landrace varieties) in the West African context.

3.2 Institutional setting of the experiment

The experiment was carried out in the Vallée du Bandama region in collaboration with AfricaRice. AfricaRice is involved in both conserving and distributing tens of thousands of rice accessions as well as contributing to the development of new rice varieties in collaboration with the Africa-wide Rice Breeding Taskforce, which includes both AfricaRice breeders as well as national rice breeders. The newest generation of improved rice varieties developed by AfricaRice are called "ARICA" varieties,[3] short for "Advanced Rice Varieties for Africa," and are designed to be well adapted to local environments, have superior grain quality, and often be more resilient in the face of biotic and abiotic stresses (such as drought or pests and disease). These varieties are meant to first be nominated by one of the thirty African countries participating in the Africa-wide Rice Breeding Task Force. AfricaRice and their National Agricultural Research System (NARS) partners (such as CNRA in Côte d'Ivoire) produce breeder seed, the NARS organization produces foundation seed, and the private sector (including seed producer farmers and private NGOs) are meant to produce certified seed. ARICA seed is also meant to be distributed and diffused through different projects and field demonstrations with farmers.

AfricaRice's genebank, the RBCA, maintains the largest collection of African rice landraces in the world and is the largest collection of rice accessions in Africa with a total of almost 22,000 accessions. The collection represents a strategic resource for breeding new, advanced rice varieties that are well-adapted to growing conditions across Africa. The genebank also distributes samples widely, with a total of 113,083 samples having been distributed over the past 25 years to a total of 164 institutions across 57 countries. The majority of these samples were distributed to NARS institutions (~44.3%), other institutions within the CGIAR (43%), and to a lesser extent universities (10%). Only a single sample was provided to a farmer organization over this period (MN Ndjiondjop pers. communication).

4. Experimental design

4.1 Research questions and hypotheses

This study approaches genebank valuation by focusing on two mechanisms through which genebanks provide value: first, by providing useful genetic variation to research programs with plant breeding activities, and second, by maintaining farmer varieties of crops for future use, that may possess diverse cultural, culinary, agronomic and nutritional values. In addition, we also investigate the extent

[3] Other advanced varieties are also promoted by AfricaRice however, in addition to ARICA varieties, such as the aromatic variety "ORYLUX."

to which option and bequest values provided by genetic resource conservation are important to smallholder farmers in Côte d'Ivoire.

Thus, the primary research objective of this study is to investigate these two questions in the case of the Rice Biodiversity Center for Africa, namely:

1. To what extent do smallholder rice farmers in Vallée du Bandama (Côte d'Ivoire) value having access to traditional, African rice (*Oryza glaberrima*) landraces, in relation to how they value having seed of advanced rice varieties bred by AfricaRice (e.g., ARICA varieties)?
2. Are smallholder rice farmers willing to pay to maintain option and bequest values associated with the conservation of rice diversity (i.e., option and bequest values)? That is, is there a "social" value provided to rice farmers in Côte d'Ivoire by the AfricaRice genebank's conservation activities in addition to the value of maintaining the collection for breeding purposes?

The two primary hypotheses associated with these research questions can be expressed as follows:

Hypothesis 1: Farmers will value having access to conserved African rice landraces.

Hypothesis 2: At least some farmers will have a positive willingness-to-pay for option and bequest values associated with rice varietal conservation.

4.2 Data collection and sample selection

A recently published "e-registration" of about 8,000 rice farmers in Côte d'Ivoire was used to plan the sampling strategy, with a split between more connected villages located closer to Bouake and roads, as well as more isolated villages (Arouna and Aboudou 2020). In addition, villages with a higher ratio of female to male farmers were targeted, as well as villages reflecting different types of growing ecology (upland, irrigated lowland, and rainfed lowland). Table A1 provides details for each village, while Figure A1 illustrates the villages' locations on a map. The dataset includes a total of 569 farmers across the twelve villages (six in Hambol, six in Gbeke), with the number of rice farmers per village ranging from 13 rice farmers in Ouanan to 90 rice farmers in Nassoulo. We aimed to survey as many farmers as possible given budgetary constraints, and also to cover a diverse set of farmers through our sample selection.

An ethics approval was obtained at the Graduate Institute of International and Development Studies following internal regulations, and respecting the measures taken by AfricaRice. Safety precautions including social distancing measures were taken during surveying activities, which were conducted using electronic tablets in outside locations. Masks and disinfectant were purchased for enumerators.

Travel occurred strictly within the Vallée du Bandama area around Bouaké with local staff in small groups. Farmers were asked for their consent before being surveyed, with none being forced to participate against their will. During the two periods of data collection, the epidemiological situation was stable and at a low-risk level (around 0.1 cases per 100,000 per day) with active cases clustered in the greater Abidjan area.

Before beginning data collection, we published a pre-registration (AEARCTR-0006448) of the experiment on the AEA RCT Registry.[4] Survey enumerators were first trained in Bouaké, and then through a pilot conducted before the implementation of the main wave in a village nearby Bouaké.

4.3 Treatment assignment

We designed an experiment to understand how farmer experimentation with either of the types of rice seed would affect how they value having access to rice genetic resources. The first treatment arm is the assignment of farmers to cultivate 2 kgs of advanced rice seed released by the Africa-wide Rice Breeding Task Force, including both ARICA varieties and ORYLUX, an aromatic variety (see Figure A3 for an image of the 1 kilogram bags of improved rice seed provided). However, these varieties are not yet widely adopted in Côte d'Ivoire. The goal of this treatment arm is to determine whether farmers would prefer these varieties over what they are currently growing if the frictions to diffusion were relaxed by bringing seed directly to the farmer.

The second treatment arm involved the assignment of farmers to cultivate 70 grams of farmer landrace varieties of rice (*Oryza glaberrima*) from the AfricaRice genebank (see Figure A4 for an image of the 35-gram bags of landrace seed provided). The objective of this treatment arm is to determine whether farmers would be willing to pay for additional seed of landrace varieties that may possess potentially valuable traits including drought tolerance and good taste.

After the initial baseline survey was implemented, the team decided to include only lowland rice farmers in the experiment given the climatic conditions during the off-season. Taking only lowland farmers as the complete sample, 30% of farmers in each village were randomized to the ARICA treatment, 30% were randomized to control, and 10% were randomized to the landrace treatment. For the remaining 30%, 10% were randomized to ARICA selective trials (in which the farmers willing to pay the most for ARICA seed were assigned to the ARICA treatment) and 20% were randomized to the landrace selective trials (in which farmers willing to accept the least to grow the landrace seed were assigned to the landrace treatment). Figure A2 illustrates the overall experimental design.

---

[4] The pre-registration is accessible at http://www.socialscienceregistry.org/trials/6448.

Farmers in the selective trials were assigned to treatment based on their stated WTP and WTA values. Histograms of these values are shown in Figures A5 and A6 in the appendix, with Figure A7 plotting farmers' WTA and WTP values on the x and y axis, respectively.

4.4 The game – Becker-DeGroot-Marschak elicitation of use value

The experimental BDM elicitation of use value took place after several introductory sections of the survey questionnaire. Farmers were randomly assigned to start with either a bag of African rice landrace seed or a bag of ARICA seed. First, farmers were prompted to think about how much they would be willing to pay for the 35-gram bag of seed through a ladder elicitation method. A random value was pulled and they were asked, "Would you rather have ___ FCFA or the seed?" If they answered that they would rather have the seed, then the enumerators were instructed to ask the same question but add 25 FCFA to the amount of money. If they answered that they would rather have the money, they were instructed to ask the same question but subtract 25 FCFA to the amount of money. This exercise ended once the farmer switched their answer (from seed to money if they originally favored the seed and from money to seed if they originally preferred the money). At the end of this exercise, they were asked how much they would be willing to pay for the seed (not restricted by the increments of 25 FCFA or the maximum value of 550 FCFA).

After this, the BDM-elicitation dice game was explained to the farmer. The farmer was asked to pick a value they were willing to pay for the bag of landrace or ARICA seed, associated with a roll of the dice (2-12, a potential value resulting from the sum of the two dice rolled), and the enumerator explained that if the dice roll was greater than the roll associated with the value they had selected, they would not receive the seed, but rather the full sum of 550 FCFA (approximately $1). If the dice roll was equal to or less than the value they selected, they would receive the seed and the 550 FCFA minus the value associated with the roll of the dice (and not their WTP value). To further help the farmers understand the game, a hypothetical first round was played for a 1-kilogram bag of fertilizer (though no money or fertilizer changed hands as a result of this practice round). After this practice round, the dice game was played and the farmer received the combination of money and/or seed resulting from the game, before moving to the next seed type (ARICA or landrace).

4.5 Elicitation of option and bequest values

The willingness-to-pay of farmers for option and bequest values was elicited using open-ended questions that came after the Becker-DeGroot-Marschak component of the experiment, using a hypothetical scenario of a potential village seedbank. Farmers were asked how much they would be willing to contribute towards such a project on an annual basis if 1) they would be able to take out small amount of seed in the future (option value); or 2), only rice farmers currently under the age of

20 would be able to take out seed in the future (bequest value). Each farmer was asked how much they would be willing to contribute under these two scenarios and for seed banks focusing on either landrace varieties or new, improved rice varieties (for a total of four combinations). The first type of variety asked was alternated at random, while the option value scenario was always asked before the bequest value scenario.

5. Estimation strategy

This section describes the estimation strategy of the analysis. We run three sets of regressions. First, we run one set of regressions that take the BDM-elicited WTP for either ARICA or landrace seed as the dependent variable. Second, we run another set of regressions that takes as the dependent variable the farmer's preference for ARICA seed – that is, their WTP for ARICA seed minus their WTP for African rice landrace seed. Third, we run a set of regressions that take farmer WTP for option and bequest values associated with the conservation of as the dependent variable. These regressions are all run using ordinary least squares with robust standard errors.

The first set of regressions we run can be simply expressed as in equation (1). On the left-hand side, the dependent variable is defined as the farmer's BDM-elicited willingness-to-pay for either landrace or ARICA seed (in CFA francs).

$$WTP_{ive} = \alpha + \beta_i * x + \mu_v + \lambda_{\mathrm{e}} + \varepsilon \qquad (1)$$

Here, α is a constant, x is a vector of variables that may theoretically have a significant impact on WTP, μ_v is a set of village controls, λ_{e} is a set of enumerator controls (to control for any effect the individual enumerators may have had on WTP), and ε is the error term.

In equation (2), we run a similar set of regressions but instead take the farmer's preference for ARICA seed (over landrace) seed as the dependent variable – defined as the BDM-elicited WTP for ARICA seed minus the BDM-elicited WTP for landrace seed:

$$(WTP_{ARICA} - WTP_{Landrace}) = \alpha + \beta_i * x + \mu_v + \lambda_{\mathrm{e}} + \varepsilon \qquad (2)$$

The parameters here are defined as in equation (1).

Last, we run the following:

$$WTP_{non-market} = \alpha + \beta_i * x + \mu_v + \lambda_{\mathrm{e}} + \varepsilon \qquad (3)$$

Here, the dependent variable is the farmer's willingness to contribute towards the maintenance of a given option and bequest values for a given class of varieties (landrace or advanced), while the right-hand side of the equation are similar to those found in equations (1) and (2).

6. Results

6.1 Results of the Becker-DeGroot-Marschak elicitation of use values

In this section we summarize the results of the Becker-DeGroot-Marschak component of the experiment. We begin by first providing histograms of the elicited farmer WTP values for both landrace and ARICA seed, and then present a set of regression results investigating the different factors contributing to the farmers' demand for the two types of seed.

As an outcome of the experiment, approximately three-quarters of all farmers (430, or 76%) obtained at least one bag of landrace or ARICA seed, with 138 obtaining no seed bag. Seventy-five farmers (13% of the sample) received just the landrace variety, but not the improved rice seed, while 91 farmers (16% of the sample) received only the improved rice (ARICA) variety, but not the landrace variety. The remaining 264 farmers (46%) received both seed types.

Figure 1 provides histograms for farmer WTP for both landrace and ARICA seed.

On average, farmers in the sample were willing to pay 263 FCFA for the bag of ARICA seed (about \$0.50) and about 257 FCFA for the bag of landrace seed (about \$0.47). Fifty-two farmers (around 9% of the sample) were not willing to pay anything for either type of seed; around 5% of the sample were willing to either pay for landrace seed but not advanced rice (ARICA) seed or for ARICA seed (and not landrace seed). Sixteen farmers were willing to pay the maximum amount (550 FCFA) for both types of seed. These are striking results showing through an incentivized, revealed-preference experiment that farmers value having access to conserved African rice landraces roughly as much as advanced rice varieties, supporting our first hypothesis.

To better understand the factors driving farmer demand for either seed type, we run two sets of regressions: the first taking the BDM-elicited WTP for landrace seed as the dependent variable, and the second taking the BDM-elicited WTP for ARICA seed as the dependent variable. The results for the first set of regressions are shown in Table 3.

In the first regression (shown in column 1), we run a simple model incorporating just experimental variables: whether the farmers were assigned to either the landrace or ARICA treatment groups, whether the farmers actually grew the variety they were assigned in the off season, and the farmers' original WTA for landrace cultivation in the baseline survey (taking place in the fall of 2020). We include two additional variables associated with the dice game that may also influence WTP: whether the game was first played for the landrace seed, and whether the farmer had previously won the ARICA seed in the first round of the game.[5]

Most of these experimental variables are not found to be significant, with the exception of the original farmer WTA (which is significant and negative, indicating that farmers who had to be paid more originally to cultivate landraces were willing to pay less for landrace seed in the BDM experiment, as expected) and the variable for farmers assigned to the landrace group who had planted the African rice landrace seed they had been given, which is positive and significant (indicating that those farmers assigned to receive landrace seed who planted in the off-season had a higher WTP for seed of an additional landrace variety).

Next, we run two additional regressions with additional variables. The only difference between the second and third regression is the inclusion of an interaction variable in the third regression between the "female farmer" and "household head" variables (neither of which are found to be significant). We find that farmers who cultivate other crops (in addition to rice) and believe that the main rice variety they currently cultivate is better than average were willing to pay more for African rice landrace seed in the BDM dice game, while upland farmers, older farmers, and farmers who cultivate irrigated lowland rice plots were all willing to pay significantly less for landrace seed in the experiment.

We run a similar set of regressions for the BDM-elicited farmer WTP for ARICA seed. The results of these regressions are shown in Table 2. Here, we again find that those farmers who were assigned to the landrace treatment and who grew the landrace varieties they were provided in the off-season are willing to pay significantly more for ARICA seed (with the coefficient being almost half the mean farmer WTP for ARICA seed). In addition, we find that farmers speaking the Baoule language, who have a phone number, and who believe that the primary rice variety that they currently cultivate is better than average were willing to pay more for the bag of ARICA seed. Farmers with a larger household size were willing to pay less. Last, female farmers were found to be willing to pay less for the ARICA seed; however, when an interaction term between "female farmer" and "household head" is included, we find that female farmers who are household heads are in fact willing to pay more than the average male farmer for ARICA seed.

[5] These factors are potentially important because, for example, if the farmer had already won the ARICA seed in the first round of the game, this might bias their WTP for the landrace seed downwards. In addition, whether the farmer first played the game for the landrace seed, this may have the opposite effect – biasing the WTP for the landrace seed upwards.

6.2 Results – farmer preference for ARICA vs. landrace seed

In this section, we present a histogram and regression results illustrating the preference of individual farmers for either ARICA or landrace seed (that is, the difference between a farmer's WTP for ARICA vs. landrace seed). Approximately 36% (205 out of 569) of farmers had the same WTP for both seed types (with about 10% – 52 farmers – of this 36% having a WTP of zero for both the bags of ARICA and landrace seed). About 5% of the sample were willing to pay for ARICA seed, but not landrace seed; and a similar amount of farmers were willing to pay for African rice landrace seed, but not ARICA seed. Figure 2 presents the distribution of farmer preference for a given seed type, with a positive value indicating a preference for improved rice seed (ARICA), a negative value indicating preference for landrace seed (*O. glaberrima*), and a value of 0 indicating no preference for either seed type.

In Table 3, we present results of three regressions that take as their dependent variable farmer preferences for ARICA seed (over landrace seed), defined as the BDM-elicited WTP for ARICA seed minus the BDM-elicited WTP for landrace seed. We find that the willingness-to-accept for landrace cultivation is positive and significant (indicating that those who stated that they would have to be paid more to cultivate African rice landraces originally had a greater preference for ARICA over landrace seed in the BDM experiment), and those who were originally willing to pay more for improved rice seed also had a higher preference for ARICA seed.

We also found that speakers of Baoule as well as farmers possessing a phone number additionally exhibited a higher preference for ARICA seed than landrace seed. Otherwise, we do not find other significant variables, neither gender-related or experimental variables.

6.3 Results – elicitation of option and bequest values

In this section we describe the results of the value elicitation portion of the survey questionnaire. Figure 3 presents the willingness-to-pay results for both option and bequest values for *O. glaberrima* landrace varieties, while the same figure for improved rice varieties is shown in Figure A7 in the Appendix. The WTP estimates generated using the open-ended elicitation framework are much more dispersed than for the BDM dice game.

On average, farmers stated that they were willing to pay about \$4.34 and \$4.38 as an annual contribution towards a village seed bank that they themselves would be able to access (option value) for improved and landrace rice varieties, respectively, and \$3.94 and \$4.01 annually to a village seed bank if the varieties conserved would only be made available to the next generation of rice farmers (currently under 20 years of age).

However, the median WTP for all four value types is 1000 CFA francs, approximately $1.85, and the mean WTP estimates are strongly influenced by some farmers who are willing to contribute much more annually, reaching maximums of $47 per year for bequest values and $92 per year for option values.

Most farmers state that they are willing to pay at least something towards the construction and maintenance of a village seed bank, with 85% of farmers stating that they believed the construction of a village seed bank would be a good idea. Only twenty farmers (3.5% of the sample) stated that they would not be willing to contribute anything to such a project.

In Table 4, we present the results of four regressions, each taking a different combination of rice variety type and value type as the dependent variable. We find that the farmer's original WTA value for cultivating landraces is significant and has a negative impact on all four value types, indicating that those farmers who initially said they would be willing to cultivate landrace varieties for less are willing to contribute more towards a village seed bank under all described scenarios. Farmers who cultivated at least one irrigated lowland plot were willing to pay more for all four value types as well, while upland farmers were found to be willing to contribute more for a seed bank conserving landrace varieties.

Additionally, farmers who cultivate a landrace as their primary variety and who have larger household sizes were found to be willing to pay more for village seed banks that they themselves would be able to use, both for landraces and for improved rice varieties.

We also find that farmers willing to pay more for landrace seed in the BDM experiment were also willing to pay more for seed banks conserving both landrace and advanced rice varieties, conditional on their ability to access the conserved seed. Last, farmers who received landrace seed as a result of the BDM dice game were willing to pay more for the development of a seed bank conserving landrace varieties, while farmers who received ARICA seed as a result of the experiment were willing to pay more for the development of a seed bank conserving improved rice varieties.

7. Discussion

The strongest aspect of this analysis is its use of a realized preference approach to investigate how farmers value having access to two novel seed types (plant genetic resources) with which they have no previous experience – either new, advanced rice seed or heritage landrace varieties of African rice. Farmers are incentivized to be honest about their preferences because their stated willingness-to-pay will directly affect their probability of obtaining the bags of either landrace or ARICA seed as well as set a lower bound on their minimum potential financial reward from the experiment. We follow other recent papers utilizing this approach such as Berry et al. (2020) who use a BDM mechanism to estimate willingness to pay for clean water technology in a field experiment in Ghana, as well as other recent experiments investigating farmer WTP for different types of seed, such as Mastenbroek et al. (2021) and Gharib et al. (2021). In addition, we experimentally control for other factors that may affect the relative valuation of ARICA vs. landrace seed, including by alternating randomly which seed type appeared first in the experiment, and by including numerous variables in the regressions such as which seed type came first, whether the farmer had previously won a bag of seed, and others.

The open-ended elicitation framework used for the option and bequest valuation component of the experiment should not be considered as a robust method for identifying the true preferences of the farmers in the sample, as they are not incentive compatible. These results should thus not be interpreted as "true" estimates of farmer willingness to contribute to such a community seed bank project under different circumstances – but rather as an investigation and rough indication of farmers' relative valuation of the benefits provided by different proposals. The approach utilized was taken due to the absence of practical alternatives: whereas it was feasible to give some combination of a small amount of money as well as the bags of landrace and/or ARICA seed to farmers, revealed preference elicitation of option and bequest values associated with the conservation of rice varietal diversity within the villages would have required the actual collection of funds from farmers and construction of a community seed bank, a task outside the scope, time frame and resources available for this analysis. However, despite the use of a less rigorous methodology, we still find evidence that at least some farmers are likely willing to contribute to such a project – for both option and bequest values. These results can provide some important insights into the types of economic values (such as option and bequest value) provided by genebanks that are not often explored in the existing literature.

8. Conclusion

In this article, we have demonstrated using an incentivized, revealed preference experiment that smallholder rice farmers are willing to pay not only for seed of improved rice varieties developed by AfricaRice and its NARS partners through the Africa-wide Rice Breeding Task Force using diverse genetic resources maintained in genebanks, but also for heritage landrace varieties of African rice (*Oryza glaberrima*). In other words, while the payment-for-agrobiodiversity-conservation-services literature suggests that most farmers would have to be paid to grow landraces, most rice farmers in our sample were found to be willing to *sacrifice* financial gain to have access to the heritage rice varieties provided through the study – at around the same level as for improved rice variety seed. This is the most striking result of our experiment and suggests that the efforts of the Rice Biodiversity Center to conserve the agricultural heritage of African rice diversity provides economic value not only through the provision of inputs to the breeding process leading to the release of new, improved rice varieties such as NERICA and ARICA varieties, but also by maintaining the option to directly provide heirloom African rice varieties to farmers. Interestingly, we find that those farmers who were assigned to grow landraces during the off-season and followed through by planting were consistently willing to pay more for additional African rice landrace seed when compared to other farmers in the sample.

In addition, we provide some evidence that farmers at least state that they are also willing to pay to maintain option and bequest values. While the open-ended method used to elicit option and bequest values associated with genetic resource conservation is not as robust as the BDM mechanism used to elicit use values, the evidence we present here is at least suggestive that these values are not zero. Eighty-five percent of the farmers stated that they believed that the idea of constructing such a village seed bank would be a good idea, and just over half of the surveyed farmers thought that this would be most important for the next generation of rice farmers in the village. These results, providing some confirmation of both of our hypotheses, represent an important contribution to a literature on the value of genetic resources that has tended to reduce the importance of genetic diversity to its use for research and development, and neglected the role of farmer preferences and the cultural and historical values of agricultural biodiversity.

Finally, the experiment more broadly shows that while most farmers in the sample had not tried or experimented with new varieties in at least several years, almost all (around 90%) of the farmers exhibited some interest and willingness to experiment with the two types of rice seed provided as part of the experiment. This result suggests that low adoption of recently developed improved rice varieties is likely not a result of farmers being unwilling or uninterested in experimentation with new technologies, but rather other potential factors (such as the high cost of improved seed or an underdeveloped formal seed system).

9. References

Arouna, A.; Aboudou, R. 2020. Dataset of the survey on e-registration and geo-referenced of rice value chain actors for the diffusion of technologies: Case of Benin and Côte d'Ivoire. Data in Brief: 105642.

Arouna, A.; Lokossou, J.C.; Wopereis, M.C.S.; Bruce-Oliver, S.; Roy-Macauley, H. 2017. Contribution of improved rice varieties to poverty reduction and food security in sub-Saharan Africa. *Global Food Security* 14: 54-60.

Bellon, M.R.; Gotor, E.; and Caracciolo, F. 2015. Assessing the Effectiveness of Projects Supporting on-Farm Conservation of Native Crops: Evidence from the High Andes of South America. *World Development* 70: 162–76. https://doi.org/10.1016/j.worlddev.2015.01.014.

Berry, J.; Fischer, G.; Guiteras, R. 2020. Eliciting and utilizing willingness to pay: evidence from field trials in Northern Ghana. *Journal of Political Economy* 128(4):1436-1473.

Birol, E.; Smale, M.; Gyovai, A. 2006. Using a Choice Experiment to Estimate Farmers' Valuation of Agrobiodiversity on Hungarian Small Farms. *Environmental & Resource Economics* 34:439-469.

Birol, E., E.R. Villalba, and M. Smale. 2008. Farmer Preferences for Milpa Diversity and Genetically Modified Maize in Mexico: a Latent Class Approach. *Environment and Development Economics* 14: 521-540.

Brock, W.A., and Xepapadeas, A. 2003. Valuing biodiversity from an economic perspective: a unified economic, ecological, and genetic approach. *The American Economic Review* 93(5): 1597-1614.

Brown, G.M, Jr., and J. H. Goldstein. 1984. A model for valuing endangered species. *Journal of Environmental Economics and Management* 11: 303-9.

Brown, G. and J. Swierzbinski. 1988. "Optimal genetic resources in the context of asymmetric public goods," in V.K. Smith, ed., Environmental Resources and Applied Welfare Economics. Washington: RFF, pp. 293–312.

Brown, G.M, Jr. 1990. Valuation of genetic resources. In G.H. Orians, G.M. Brown, Jr., W.E. Kunin, and J.E. Swierbinski. *The Preservation and Valuation of Biological Resources*. University of Washington Press, Seattle.

Brush,, S.; Meng, E. 1998. Farmers' valuation and conservation of crop genetic resources. *Genetic Resources and Crop Evolution* 45: 139-150.

Chassang, S.; I Miquel, G.P.; Snowberg, E. (2012). Selective Trials: A Principal-Agent Approach to Randomized Controlled Experiments. *American Economic Review* 102(4): 1279-1309.

Craft, A. & Simpson, D. 2001. The Value of Biodiversity in Pharmaceutical Research with Differentiated Products. *Environmental and Resource Economics* 18: 1-17.

Diagne, A. (2006). Diffusion and adoption of NERICA rice varieties in Côte d'Ivoire. *The Developing Economies*, *44*(2), 208-231.

Di Falco, S. and J.-P. Chavas. 2009. On Crop Biodiversity, Risk Exposure, and Food Security in the Highlands of Ethiopia. *American Journal of Agricultural Economics* 91(3), pp. 599- 611.

Drucker, A.G.; Ramirez, M. 2020. Payments for agrobiodiversity conservation services: An overview of Latin American experiences, lessons learned and upscaling challenges. *Land Use Policy* 99:104810.

Drucker, A. & Caracciolo, F. 2014. "The Economic Value of Plant Genetic Resources for Food and Agriculture," In Moeller, Nina Isabella, and Clive Stannard, ed. 2014. *Identifying Benefit Flows: Studies on the Potential Monetary and Non-Monetary Benefits Arising from the International Treaty on Plant Genetic Resources for Food and Agriculture.* Rome, Italy: FAO.

Evenson, R.E., Gollin, D., 1997. Genetic resources, international organisations, and improvement in rice varieties. *Economic Development and Cultural Change* 45 (3), 471–500.

Evenson, R.E.; Gollin, D. 2003. Assessing the Impact of the Green Revolution, 1960 to 2000. Science 300: 758-762.

Gauchan, D., M. Smale, N. Maxted and M. Cole. 2006 Managing Rice Biodiversity on Farms: The Choices of Farmers and Breeders in Nepal. In Smale, M. (ed.). Valuing Crop Biodiversity: On-Farm Genetic Resources and Economic Change. CABI, Wallingford, UK.

Gharib, M. H., Palm-Forster, L. H., Lybbert, T. J., & Messer, K. D. (2021). Fear of fraud and willingness to pay for hybrid maize seed in Kenya. Food Policy, 102040.

Goeschl, T.; Swanson, T. 2002. The social value of biodiversity for R&D. *Environmental and Resource Economics*, 22: 477-504.

Gollin, D. and R.E. Evenson. 1998. An application of hedonic pricing methods to value rice genetic resources in India. In: Evenson, R. E. Gollin, D. and Santaniello, V. (ed.) *Agricultural values of plant genetic resources.* CAB International., Wallingford, U.K., pp. 139-150

Hedden, P. 2003. The genes of the Green Revolution. *Trends in Genetics* 19(1):5-9.

Hein, L. and H. Gatzweiler. 2006. The economic value of coffee genetic resources. *Ecological Economics* 60: 176-185.

Kassar, I.; Lasserre, P. 2004. Species preservation and biodiversity value: a real options approach. *Journal of Environmental Economics and Management* 48: 857-879.

Kijima, Y.; Otsuka, K.; Sserunkuuma, D. 2008. Assessing the impact of NERICA on income and poverty in central and western Uganda. *Agricultural Economics* 38:327-337.

Kijima, Y.; Otsuka, K.; Sserunkuuma, D. 2010. An Inquiry into Constraints on a Green Revolution in Sub-Saharan Africa: The Case of NERICA Rice in Uganda. *World Development* 39:77-86.

Krishna, V.V.; Drucker, A.G; Pascual, U.; Raghu, P.T.; King, E.D.I.O. 2013. Estimating compensation payments for on-farm conservation of agricultural biodiversity in developing countries. *Ecological Economics* 87: 110-123.

Krutilla, J. 1967. Conservation reconsidered. *The American Economic Review* 57: 777-786.

Mastenbroek, A., Sirutyte, I., & Sparrow, R. (2021). Information Barriers to Adoption of Agricultural Technologies: Willingness to Pay for Certified Seed of an Open Pollinated Maize Variety in Northern Uganda. *Journal of Agricultural Economics*, 72(1), 180-201.

Meng, E; Taylor, J.E.; and Brush, S.B. 1998. "Implications for the Conservation of Wheat Landraces in Turkey from a Household Model of Varietal Choice." In *Farmers, Gene Banks and Crop Breeding: Economic Analyses of Diversity in Wheat, Maize and Rice.* Vol. Edited by M. Smale. Boston, Dordrecht, London: Kluwer Academic Publishers, 1998.

Ndjiondjop M. N., Albar L., Fargette D., Fauquet C. and Ghesquière A. (1999) The Genetic Basis of High Resistance to Rice Yellow Mottle Virus (RYMV) in Cultivars of Two Cultivated Rice Species. Plant Disease 83 (10): 931-935.

Ocampo-Giraldo, V., Camacho-Villa, C., Costich, D.E., Martínez, V.A.V., Smale, M., and Jamora, N. 2020. Dynamic Conservation of Genetic Resources: Rematriation of the Maize Landrace Jala. *Food Security* 1–14. https://doi.org/10.1007/s12571-020-01054-7.

Polasky, S.; Solow, A.; Broadus, J. 1993. Searching for uncertain benefits and the conservation of biological diversity.

Poudel, D.; Johnsen, F.H. 2009. Valuation of crop genetic resources in Kaski, Nepal: Farmers' willingness to pay for rice landraces conservation. Journal of Environmental Management 90:483-491.

Rausser, G. & Small, A. 2000. Value Research Leads: Bioprospecting and the Conservation of Genetic Resources. *Journal of Political Economy* 108:173-206.

Rocchi, L.; Paolotti, L.; Cortina, C.; Boggia, A. 2016. Conservation of landrace: the key role of the value for agrobiodiversity conservation. An application on ancient tomatoes varieties. Agriculture and Agricultural Science Procedia 8:307-316.

Simpson, R.D., Sedjo, R.A., Reid, J.W. 1996. Valuing Biodiversity for Use in Pharmaceutical Research. *Journal of Political Economy* 104:163-185.

Smale, M., Bellon, M., and Gómez, J.A.A. 2001. Maize Diversity, Variety Attributes, and Farmers' Choices in Southeastern Guanajuato, Mexico. *Economic Development and Cultural Change* 50(1): 201–25. https://doi.org/10.1086/340010.

Solow, A. R., S. Polasky, and J. Broadus. 1993. On the measurement of biological diversity. *Journal of Environmental Economics and Management* 24 (1): 60-68.

Thiémélé, D., Boisnard, A., Ndjiondjop, M. N., Chéron, S., Séré, Y., Aké, S., ... & Albar, L. (2010). Identification of a second major resistance gene to Rice yellow mottle virus, RYMV2, in the African cultivated rice species, O. glaberrima. *Theoretical and Applied Genetics*, *121*(1), 169-179.

Tyack, N., Ščasný, M. 2018. Social Valuation of Genebank Activities: Assessing Public Demand for Genetic Resource Conservation in the Czech Republic. Sustainability 10, 3997; doi:10.3390/su10113997

Van Dusen, E.; Guachan, D. Smale, M. On-farm conservation of rice biodiversity in Nepal: a simultaneous estimation approach. *Journal of Agricultural Economics* 58(2): 242-259.

Wang et al. 2014. The genome sequence of African rice (*Oryza glaberrima*) and evidence for independent domestication. *Nature* 46(9): 982-991.

Weitzman, M. L. 1992. On diversity. *The Quarterly Journal of Economics* 107 (2): 363-405.

Weitzman, M.L. 1993. What to Preserve? An Application of Diversity Theory to Crane Conservation." *Quarterly Journal of Economics* 108(1):157–83.

Weitzman, M. (1998): The Noah's ark problem. *Econometrica* 66(6): 1279-1298.

Xepapadeas, A., P. Ralli, E. Kougea, S. Spyrou, N. Stavropoulos, V. Tsiaousi, A. Tsivelikas. 2014. Valuing insurance services emerging from a genebank: The case of the Greek Genebank. *Ecological Economics* 97: 140–149.

Zohrabian, Armineh, Greg Traxler, Steven Caudill, and Melinda Smale. 2003. "Valuing Pre-Commercial Genetic Resources: A Maximum Entropy Approach*." American Journal of Agricultural Economics* 85 (2): 429–36.

10. Figures

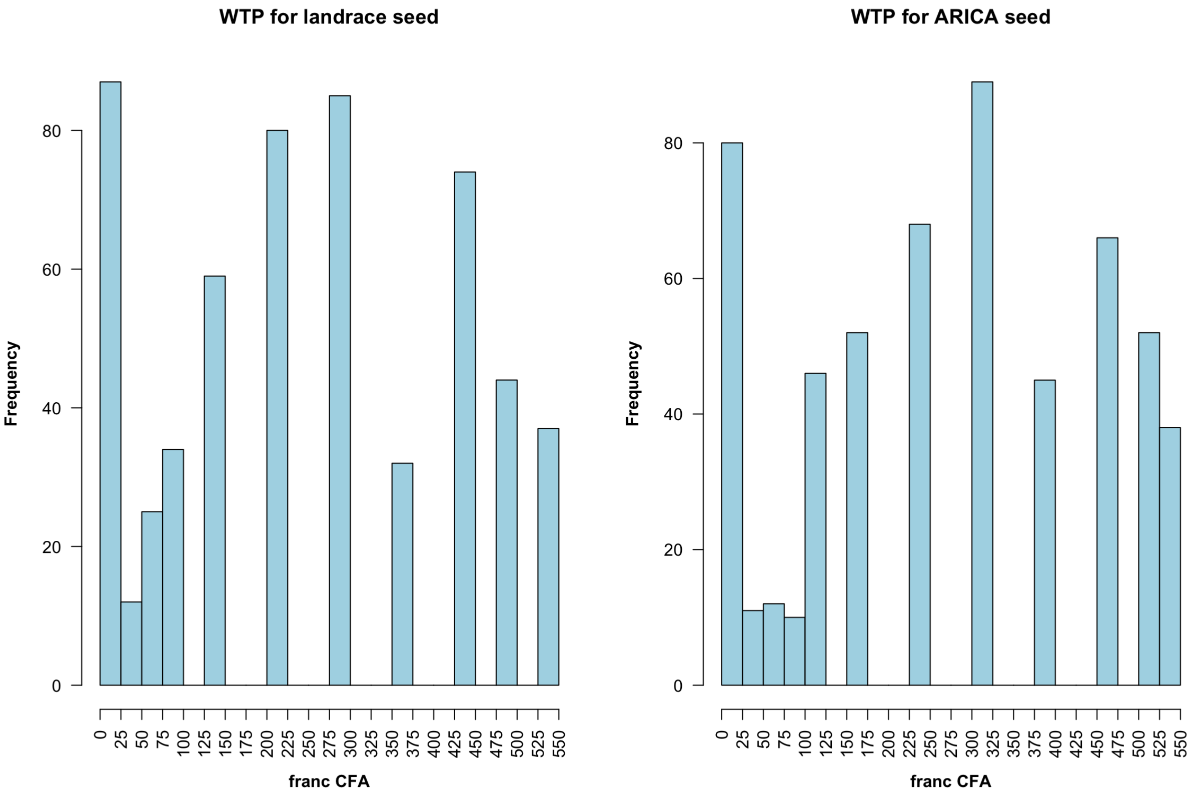
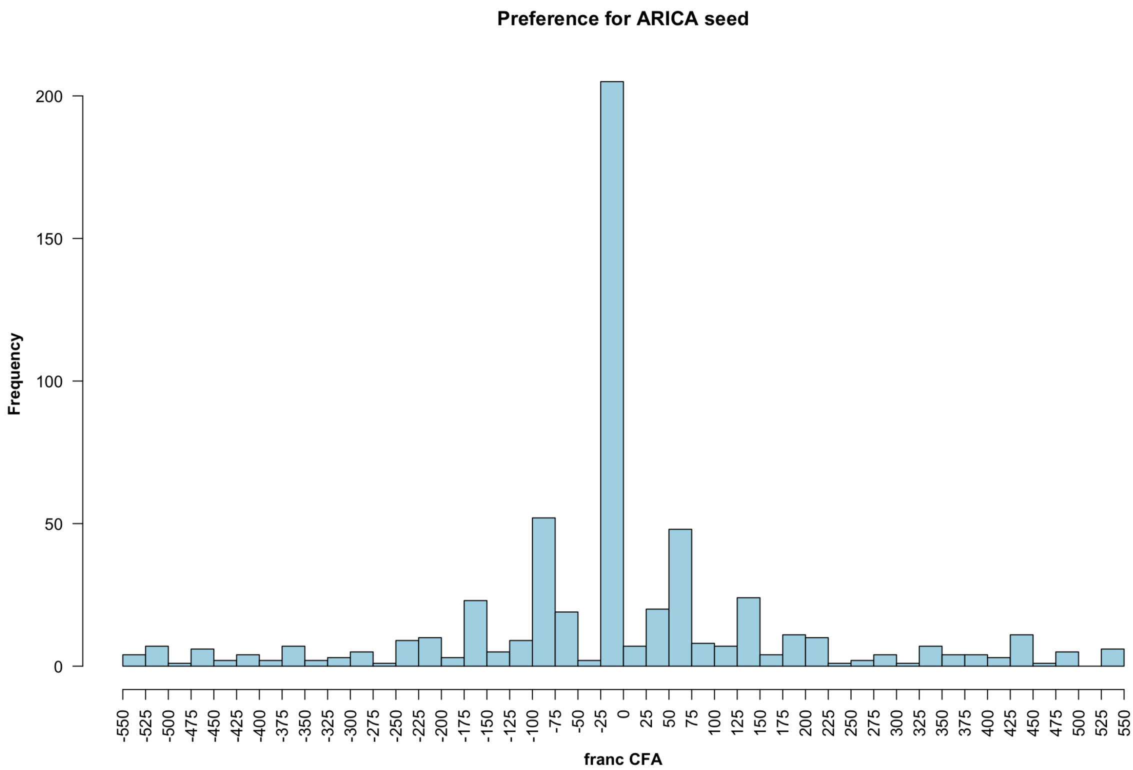


Figure 1. Histograms of farmer WTP for landrace and ARICA seed.



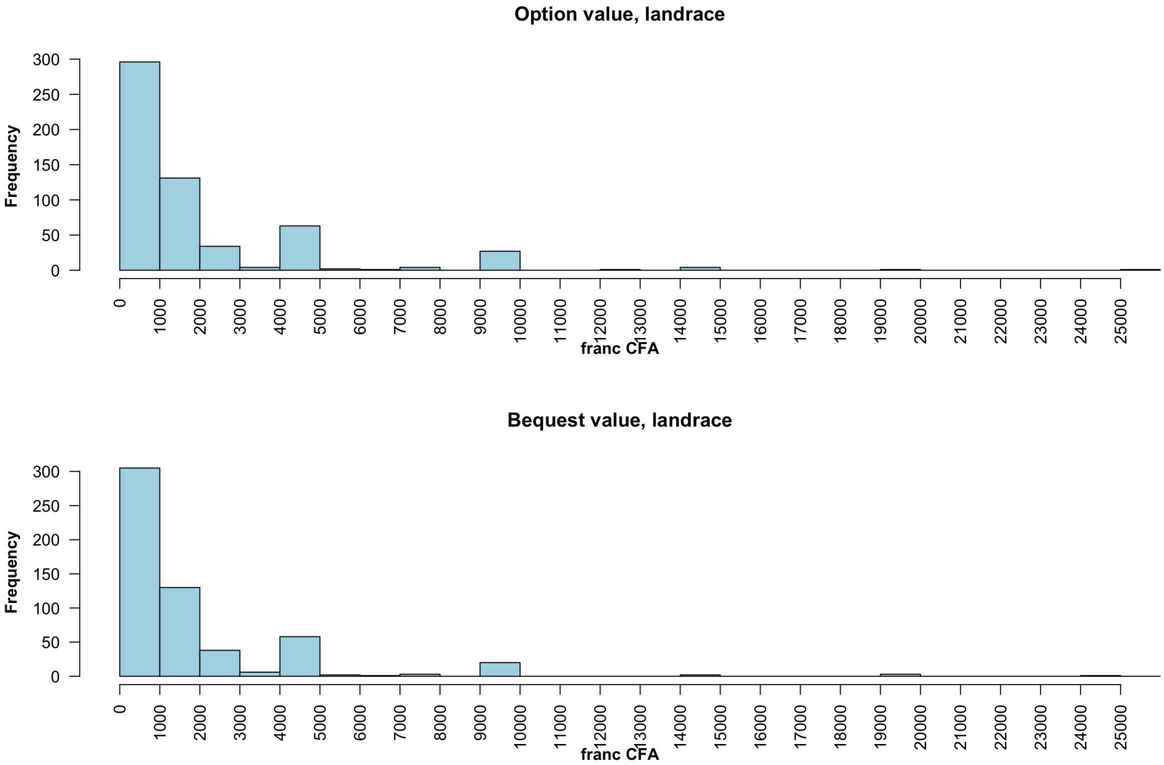


Figure 3. Farmer WTP for option/bequest values associated with village landrace conservation

11. Tables

Table 1. Determinants of WTP for African rice landrace seed

EXPLANATORY VARIABLES	(1)	(2)	(3)
Original WTA, landrace cultivation	-0.00133***	-0.00137***	-0.00136***
	(0.000358)	(0.000354)	(0.000355)
Landrace seed first (in game)	-0.301	4.891	4.431
	(14.87)	(14.44)	(14.44)
ARICA received first (in game)	16.34	13.44	13.40
	(16.49)	(16.10)	(16.11)
ARICA treatment	-12.98	-20.29	-20.26
	(23.12)	(24.17)	(24.21)
ARICA treatment, grew variety	44.82	37.14	36.59
	(28.88)	(29.26)	(29.27)
Landrace treatment	-25.92	-34.91	-34.33
	(31.11)	(32.37)	(32.49)
Landrace treatment, grew variety	83.04**	73.58*	73.55*
	(39.07)	(39.45)	(39.51)
Female		17.56	10.25
		(26.18)	(28.41)
Female Household Head			37.05
			(64.36)
Household Head		27.52	22.65
		(23.03)	(24.24)
Speaks Baoule		-25.26	-26.39
		(54.44)	(54.07)
Age		-1.828**	-1.782**
		(0.750)	(0.753)
Cultivates landrace		-20.54	-22.35
		(27.38)	(27.41)
Believes variety better than average		67.32***	66.85***
		(17.23)	(17.27)
Household size		-1.515	-1.532
		(1.401)	(1.408)
Has phone number		8.382	8.348
		(20.97)	(21.04)
Member of farmer association		30.88	30.87
		(27.00)	(27.04)
Cultivates other crops		60.77**	60.47**
		(28.58)	(28.58)
Income, last month		2.11e-06	1.87e-06
		(2.94e-05)	(2.93e-05)
Discount rate, two-year period		9.512	9.383
		(16.68)	(16.75)
Cultivates irrigated lowland plot		-48.90**	-48.54*
		(24.67)	(24.82)
Upland farmer		-79.36***	-78.23***
		(28.01)	(28.11)
Enumerator controls	Yes	Yes	Yes
Village controls	Yes	Yes	Yes
Observations	569	569	569
R-squared	0.117	0.179	0.179

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 2. Determinants of WTP for ARICA seed

EXPLANATORY VARIABLES	**(1)**	**(2)**	**(3)**
Original WTP, advanced rice seed	0.00129	-0.00133	6.09e-05
	(0.0113)	(0.0117)	(0.0114)
ARICA seed first (in game)	17.71	15.54	17.32
	(14.66)	(14.67)	(14.73)
Landrace received first (in game)	-6.003	-5.956	-7.767
	(16.35)	(15.94)	(15.91)
ARICA treatment	3.180	8.500	8.637
	(23.91)	(25.18)	(25.29)
ARICA treatment, grew variety	37.31	36.59	34.40
	(31.24)	(31.99)	(31.97)
Landrace treatment	-46.57	-39.31	-37.02
	(30.03)	(29.31)	(29.30)
Landrace treatment, grew variety	**115.7*** **	**124.5*** **	**123.7*** **
	(36.58)	(36.63)	(36.50)
Female		**-46.92***	**-74.67*** **
		(26.45)	(28.87)
Female Household Head			**140.6*** **
			(53.48)
Household Head		-7.886	-26.39
		(22.61)	(24.20)
Speaks Baoule		**129.2****	**124.5****
		(60.29)	(58.70)
Age		0.149	0.321
		(0.764)	(0.765)
Cultivates improved variety		5.167	11.81
		(28.82)	(28.30)
Believes variety better than average		**38.55****	**36.87****
		(17.32)	(17.44)
Household size		**-3.388*** **	**-3.449*** **
		(1.201)	(1.201)
Has phone number		**54.58*** **	**54.36*** **
		(20.99)	(20.98)
Member of farmer association		32.18	31.97
		(25.08)	(25.08)
Cultivates other crops		6.190	4.983
		(27.25)	(27.42)
Income, last month		-1.82e-05	-1.95e-05
		(2.18e-05)	(2.15e-05)
Discount rate, two-year period		1.153	0.759
		(16.32)	(16.25)
Irrigated lowland ecology		-23.18	-22.20
		(24.89)	(24.77)
Upland ecology		-8.472	-4.298
		(27.69)	(27.49)
Enumerator controls	Yes	Yes	Yes
Village controls	Yes	Yes	Yes
Observations	569	569	569
R-squared	0.117	0.179	0.179

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 3. Determinants of preference for ARICA seed (in relation to landrace seed)

EXPLANATORY VARIABLES	**(1)**	**(2)**	**(3)**
ARICA seed first (in game)	20.05	16.49	18.84
	(16.46)	(16.38)	(16.32)
Landrace seed won first (in game)	-7.033	-11.89	-10.60
	(18.72)	(18.87)	(18.96)
ARICA treatment	11.17	31.66	33.60
	(25.26)	(26.26)	(26.45)
ARICA treatment, grew variety	-6.139	-0.293	-5.618
	(32.45)	(33.30)	(33.45)
Landrace treatment	-25.97	-7.683	1.015
	(38.41)	(38.19)	(38.61)
Landrace treatment, grew variety	29.56	32.93	26.80
	(46.43)	(47.19)	(47.64)
Original WTA, landrace cultivation		0.00100*	0.00101**
		(0.000535)	(0.000514)
Original WTP, improved rice seed		0.0218*	0.0216*
		(0.0116)	(0.0112)
Female		-30.19	-40.52
		(25.38)	(48.12)
Household Head		-8.308	-15.40
		(20.84)	(21.90)
Female Household Head			88.22
			(68.27)
Female, speaks Baoule			-6.874
			(48.84)
Speaks Baoule			150.0**
			(58.45)
Cultivates other crops		-51.94	-49.04
		(36.77)	(36.48)
Manages rice income		10.23	11.47
		(23.55)	(23.39)
Household income, past six months		-6.85e-06	-7.37e-06
		(1.72e-05)	(1.76e-05)
Remembers lost varieties		-7.880	-7.178
		(18.91)	(19.02)
Contacted by extension agent		7.354	9.833
		(22.81)	(22.78)
Has phone		45.88*	46.76*
		(26.81)	(26.85)
Grows improved variety		-20.00	-13.38
		(29.77)	(28.71)
Plot controls	Yes	Yes	Yes
Enumerator controls	Yes	Yes	Yes
Village controls	Yes	Yes	Yes
OBSERVATIONS	**569**	**569**	**569**
R-sQUARED	**0.058**	**0.101**	**0.116**

Table 3. Results for farmer WTP for option and bequest values

DEP. VARIABLE: EXPLANATORY VARIABLES	LANDRACE: OPTION VALUE	LANDRACE: BEQUEST VALUE	ADVANCED: OPTION VALUE	ADVANCED: BEQUEST VALUE
Original WTA, landrace cultivation	**-0.0128****	**-0.0147*****	**-0.0108***	**-0.0112****
	(0.00597)	(0.00517)	(0.00570)	(0.00484)
Original WTP, improved rice seed	-0.0188	-0.0180	0.00436	0.0359
	(0.138)	(0.138)	(0.123)	(0.127)
Questions asked for landrace first	-275.4	-197.4	-270.6	-261.6
	(294.0)	(214.9)	(294.5)	(216.4)
BDM-elicited WTP for landrace seed	**1.561****	1.028	**1.448****	0.955
	(0.712)	(0.670)	(0.709)	(0.651)
BDM-elicited WTP for ARICA seed	-0.414	-0.245	-0.522	-0.426
	(0.642)	(0.650)	(0.612)	(0.597)
Relevant seed type received[1]	**524.6****	**361.1***	**495.7****	**521.5*****
	(212.0)	(203.8)	(199.7)	(191.4)
Remembers lost varieties	543.1	328.7	497.8	294.6
	(450.6)	(277.1)	(458.7)	(275.8)
Cultivates other crops	33.79	127.9	-25.19	63.72
	(362.3)	(401.7)	(363.5)	(399.5)
Female	-280.7	-656.9	-450.2	-541.9
	(737.5)	(523.4)	(748.8)	(531.2)
Female household head	38.88	71.45	848.5	430.9
	(1,188)	(1,149)	(1,455)	(1,347)
Household head	-203.6	-218.7	-300.8	6.002
	(536.6)	(422.8)	(529.8)	(419.4)
Wants children to grow rice	16.34	-250.2	21.74	-241.8
	(356.4)	(327.9)	(359.3)	(324.6)
Female*Wants children to grow rice	-329.8	28.53	-150.3	162.7
	(587.5)	(507.7)	(618.9)	(530.2)
Age	-15.19	-1.624	-7.962	1.307
	(10.98)	(11.88)	(10.22)	(11.80)
Cultivates landrace	**996.3****	522.8	**960.5****	488.5
	(443.9)	(385.7)	(445.0)	(384.6)
Believes variety better than average	18.24	148.0	-6.924	82.08
	(322.5)	(259.9)	(320.0)	(245.5)
Household size	**47.22****	29.76	**54.64****	29.39
	(22.67)	(20.35)	(24.51)	(19.70)
Has phone number	17.74	97.26	17.31	11.87
	(286.9)	(246.0)	(288.8)	(241.0)
Member of farmer association	334.4	299.5	59.90	326.6
	(396.2)	(393.1)	(293.7)	(395.3)
Personal income, past month	0.000930	**0.000716***	0.000938	**0.000726***
	(0.000607)	(0.000427)	(0.000621)	(0.000436)
Cultivates irrigated lowland plot	**1,002*****	**815.4****	**868.7****	**787.2****
	(366.4)	(371.7)	(380.6)	(384.2)
Upland farmer	**620.5****	344.7	488.9	240.1
	(294.2)	(379.6)	(302.5)	(384.2)
Enumerator controls	Yes	Yes	Yes	Yes
Village controls	Yes	Yes	Yes	Yes
Observations	569	569	569	569
R-squared	0.324	0.325	0.319	0.324

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. [1]Relevant seed type received indicates whether the farmer received landrace seed (for the first two columns) or ARICA seed (for the last two columns).

12. Supplementary Appendix

12.1 Tables

Table A1. List of study villages.

VILLAGE NAME	REGION	DRIVING DISTANCE TO BOUAKE (IN MINS)	NUMBER OF FARMERS	FEMALE FARMERS	% FEMALE	LATITUDE	LONGITUDE
GBÊKÊ region (n=302)							
Dieribanouan	GBÊKÊ	58	44	15	14.42	7.801118	-5.39288
Djekro	GBÊKÊ	51	47	8	7.69	7.883299	-5.14877
N'gatakoffikro	GBÊKÊ	51	52	21	20.19	7.884134	-5.14699
Samoikro	GBÊKÊ	62	25	5	4.81	7.816984	-5.40232
Tikakro	GBÊKÊ	42	59	13	12.50	7.840565	-5.17001
Youmien-Kouadiokro	GBÊKÊ	95	75	13	12.50	7.830607	-5.14736
Hambol region (n=267)							
Fendene	Hambol	139	84	19	18.27	8.516518	-4.672
Kaniéne	Hambol	109	31	3	2.88	8.516458	-4.67203
Nadiokaha	Hambol	166	32	0	0	9.216402	-5.23447
Nassoulo	Hambol	108	90	7	6.73	8.516502	-4.67202
Ouanan	Hambol	120	13	0	0	8.388819	-4.37754
Tenenakaha	Hambol	165	17	0	0	9.182076	-5.23745

Table A2. Sample Descriptive Statistics

Variables	Mean	Std. Dev	Min	Max
Farmer characteristics				
Age	42.47	11.47	19	78
=1 if male farmers	0.83	0.38	0	1
=1 if female farmers	0.17	0.38	0	1
=1 if None	0.71	0.45	0	1
=1 if primary education only	0.23	0.42	0	1
= 1 if higher than primary education	0.06	0.24	0	1
=1 if Muslim	0.60	0.49	0	1
=1 if Christian	0.19	0.39	0	1
=1 if Animist	0.21	0.41	0	1
=1 if language is Baoulé	0.52	0.50	0	1
=1 if living in Gbêkê region	0.53	0.50	0	1
=1 if living in Hambol region	0.47	0.50	0	1
=1 if have a phone (%)	0.81	0.39	0	1
Household characteristics				
Household size	12.59	6.17	3	65
Children	5.05	3.32	0	39
Adults	6.82	3.24	1	27
Older than 65	0.71	1.00	0	8
=1 if Skipped meal sometimes/often	0.11	0.31	0	1
=1 if Reduce food during the day sometimes/often	0.12	0.32	0	1
Institutional characteristics				
=1 if belong to farmer association (%)	0.15	0.35	0	1
=1 if contact with extension agents last six months (%)	0.52	0.50	0	1
=1 if access to credit (%)	0.08	0.27	0	1
Plot characteristics				
Total Area cultivated (ha)	5.82	6.25	0	40
Rice area (ha)	0.83	0.59	0.2	6
=1 if Lowland, irrigated	0.28	0.45	0	1
=1 if Lowland, rainfed	0.41	0.49	0	1
=1 if Upland, irrigated	0.11	0.31	0	1
=1 if Upland	0.17	0.38	0	1
=1 if Inherited	0.73	0.44	0	1
=1 if Marriage	0.04	0.19	0	1
=1 if Donation	0.16	0.37	0	1
=1 if Purchased	0.01	0.09	0	1
=1 if Rented	0.01	0.11	0	1
=1 if Sharecropped	0.05	0.21	0	1

12.2 Figures

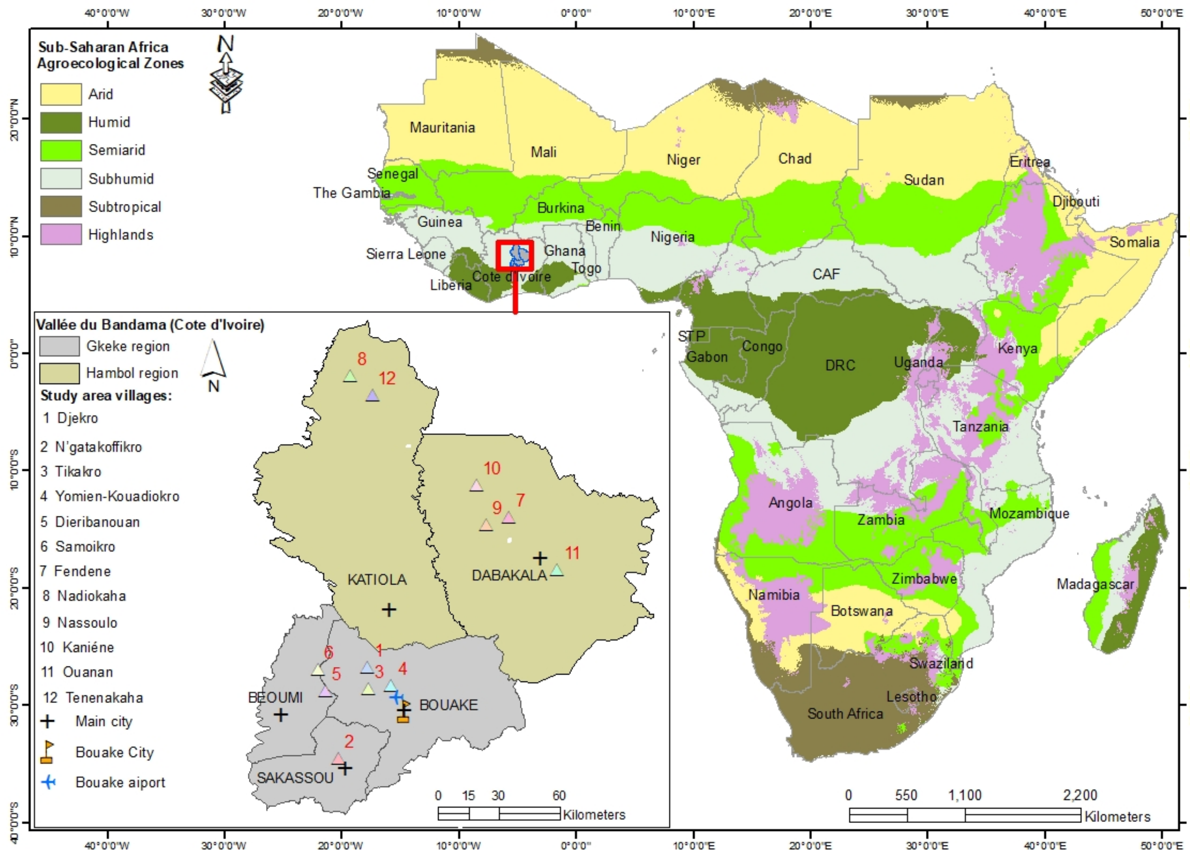


Figure A1. Map of the study villages.

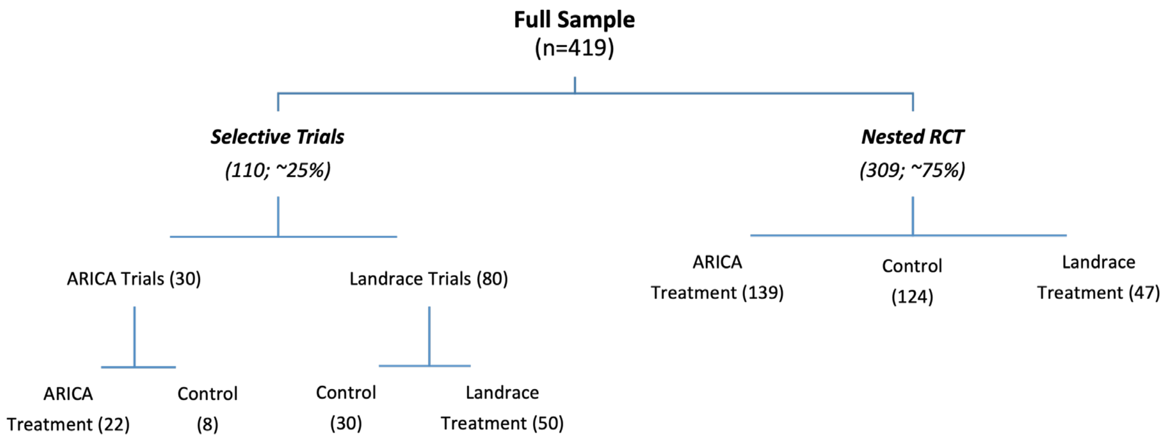


Figure A2. Experimental design diagram.

Figure A3. Image of 1 kg bags of advanced rice varieties

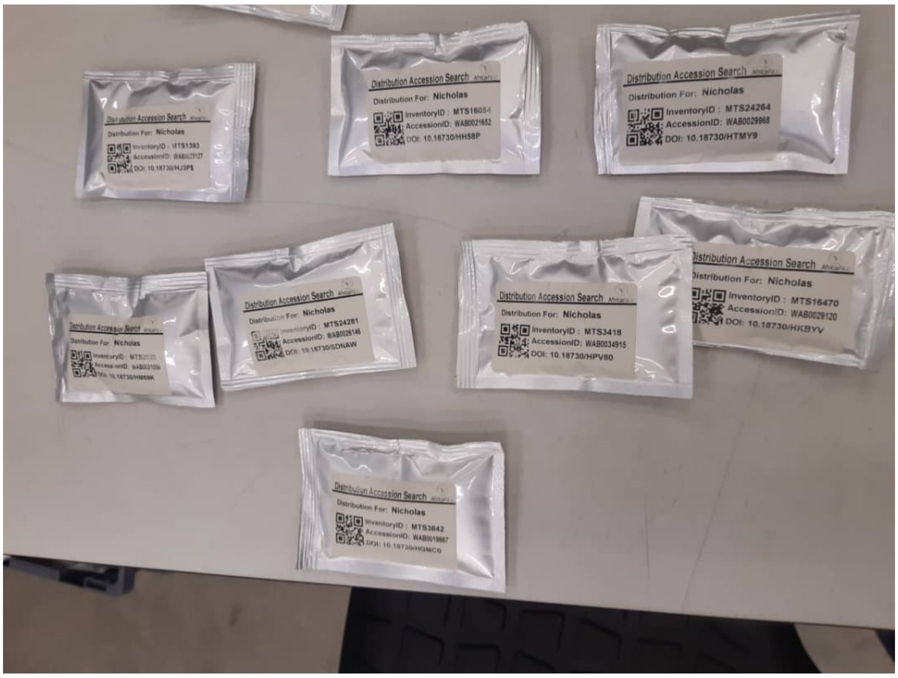


Figure A4. Image of 35g bags of African rice landrace varieties

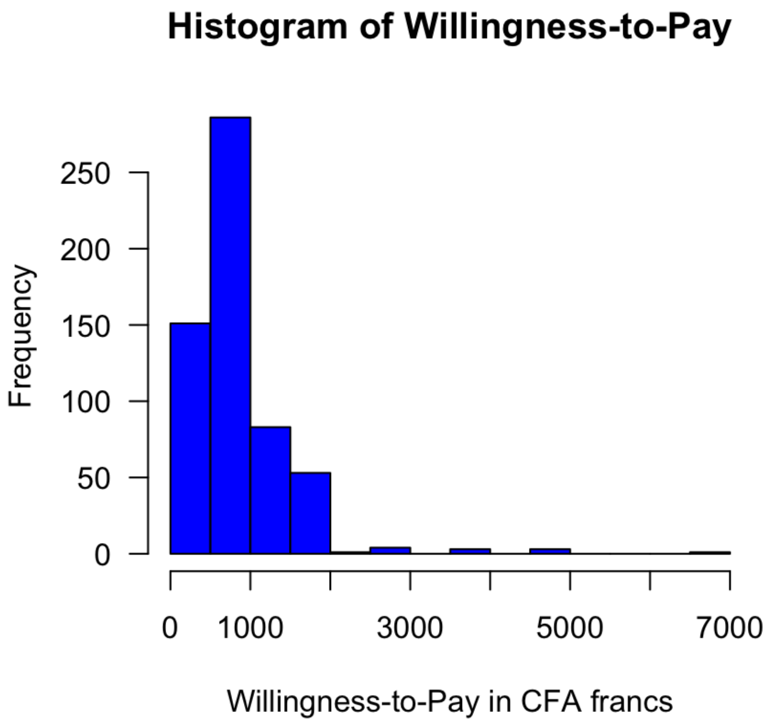


Figure A5. Histogram of willingness-to-pay values (for ARICA seed) in CFA francs

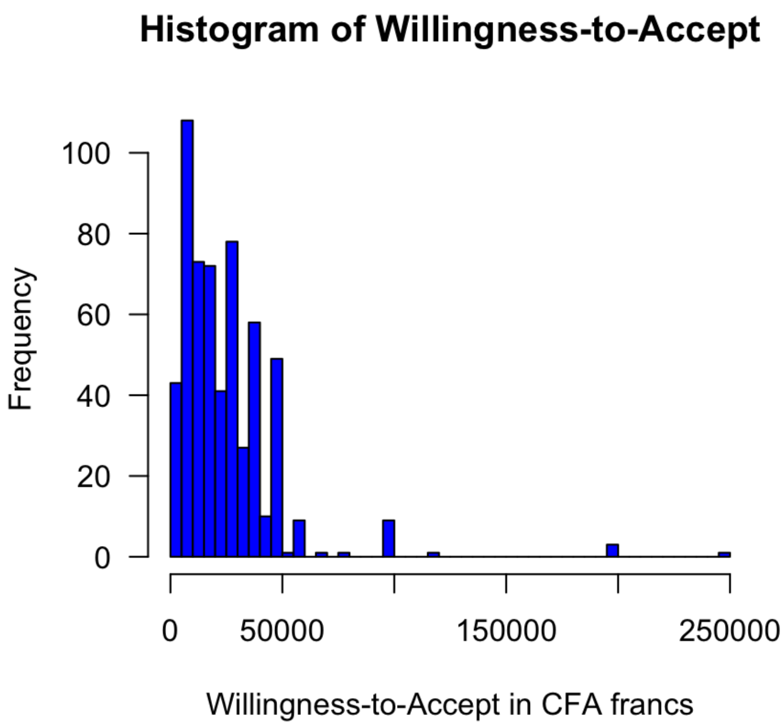


Figure A6. Histogram of willingness-to-accept values (for the cultivation of landrace seed) in CFA francs

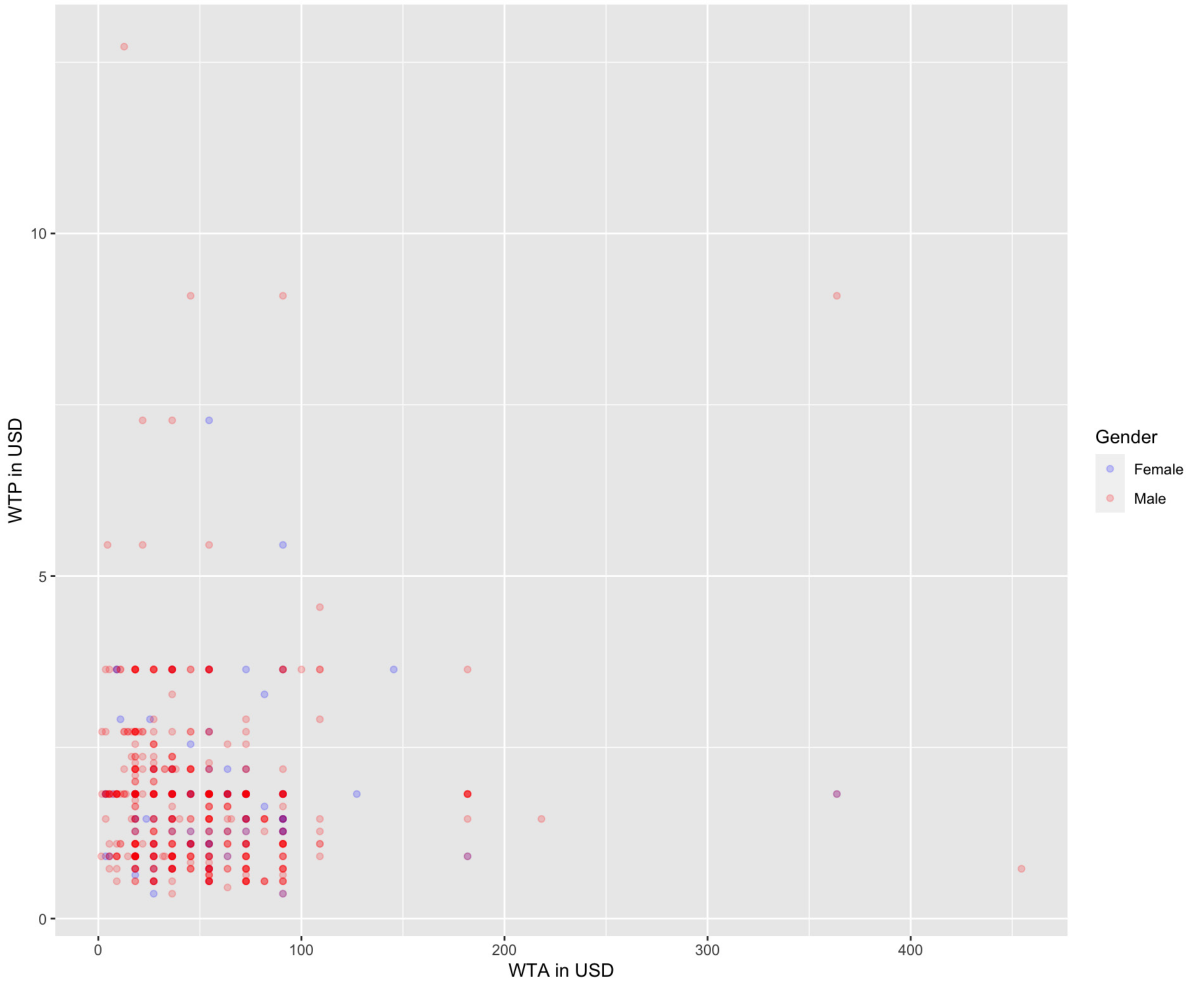


Figure A7. Histogram of willingness-to-accept values (for the cultivation of landrace seed) in CFA francs