

Estimating Demand When Turning a Public Bad into an Impure Public Good*

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Abstract

We conduct experimental generalized second price auctions in northern Senegal to estimate willingness to pay for not-yet marketed compost and animal feed produced from removed aquatic vegetation. Removing aquatic vegetation significantly reduces schistosomiasis infection rates. We find that households who were randomly informed of the potential health benefits of aquatic vegetation removal had higher individual demand for compost and animal feed by about \$3 USD and \$1 USD respectively. We find that informing individuals of both the private and public benefits of compost and animal feed from aquatic vegetation removal increases overall welfare compared to when participants are only informed of the private benefits and most of these welfare gains go to consumers. These results suggest that there is potential for a local market for compost and animal feed which could increase agricultural productivity and reduce schistosomiasis infection risk.

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1 Introduction

Schistosomiasis is a parasitic, neglected tropical disease that infects more than 200 million people worldwide (Gryseels et al. (2006); Steinmann et al. (2006); Hotez et al. (2014); Verjee (2019)). Schistosomiasis disproportionately affects children and causes loss of tissue function, stunted growth, and learning deficits among other ailments (King et al. (2005); Kjetland et al. (2006); Mohammed et al. (2007); Verjee (2019)). Deworming of schistosomiasis and other helminth parasitic infections significantly increases human capital, generates gains in earnings and economic productivity when dewormed children reach adulthood (Miguel and Kremer (2004); Baird et al. (2016); Hamory et al. (2021)), and has productive spillovers to siblings of dewormed children (Ozier (2018)). Deworming does not address the structural source of schistosomiasis infection, however. Dewormed children who reenter infected water sources quickly get reinfected¹ (Rohr et al. (2023)). Thus, additional work is necessary to find innovative solutions that target other parts of the schistosomiasis infection cycle to reduce worm burdens.

Aquatic vegetation that grows in freshwater access points provides habitat to aquatic snails, the intermediate vector of the parasite. Aquatic vegetation removal targets the infection cycle of schistosomiasis and offers a strategy for long-term infection control (Grimes et al. (2015); Hoover et al. (2018); Liang et al. (2018); Rohr et al. (2023)). Initial trials in our study area in northern Senegal confirm that aquatic vegetation removal significantly reduces schistosomiasis reinfection rates (Rohr et al. (2023)). However, aquatic vegetation removal requires regular activity for an indefinite period to maintain clear water access points, raising a key question around how to induce and sustain aquatic vegetation removal.

Toward that end, Rohr et al. (2023) experimentally study potential uses for removed aquatic vegetation. Crop trials reveal that compost produced from removed aquatic vegetation significantly increases pepper and onion yields profitability, even under conservative assumptions about the cost of labor used to clear vegetation and make and apply compost. Additional experimental trials found that using removed and dried aquatic vegetation is significantly cheaper than existing purchased feed to supplement sheep diets during periods of low forage availability.² These potential remunerative uses of biomass harvested through aquatic vegetation removal raises the prospect that aquatic vegetation can be turned from a public bad - a common property resource that causes harmful infectious disease - into an

¹Reinfection rates are as high as 99% one year later for treated children in Rohr et al. (2023).

²Most livestock in this system graze extensively. During the dry season, however, forage often grows scarce. While Rohr et al. (2023) demonstrate that animal feed produced from removed aquatic vegetation is not unconditionally profitable, it is far less expensive than other forms of feed. So, when insufficient forage is available, aquatic vegetation offers a low-cost supplement livestock feed.

impure public good that combines a private good (compost fertilizer or livestock feed) with the public good of infectious disease control if significant local demand exists to support aquatic vegetation removal. Additionally, might significant local demand exist to create a market for these products and do the public benefits boost that demand?

Using the same partner organization (Station d’Innovation Aquacole, SIA) and procedures as [Rohr et al. \(2023\)](#), we produced similar compost and animal feed from aquatic vegetation removal. We then conducted generalized second price auctions to elicit villagers’ willingness to pay for compost and animal feed produced from aquatic vegetation removal (AVR) ([Vickrey \(1961\)](#)).³ We randomly varied the information given to auction participants to assess how providing information about the public good nature of compost and animal feed produced using removed aquatic vegetation affects demand for these agricultural inputs.⁴ We then combine the information elicited in the second price auctions with estimates of the production cost of compost to estimate the welfare of these new of compost and animal feed products. We use the experimental variation in the provision of information on the public health benefits of these products to determine how much additional welfare information about the public good nature of aquatic vegetation removal generates. Finally, we compare our results to reported prices of close substitutes, primarily other forms of compost or animal feed and fertilizer, to assess the potential for creating a market for these not-yet marketed goods.

To assess demand for compost and animal feed, we calculate total individual demand. Total individual demand multiplies a participants per unit bid by the number of units they requested and provides a more comprehensive estimate of actual demand for these products in a potential market. We find that there is a strong, statistically significant positive effect of the public health benefits information treatment on total individual demand for compost or animal feed. The increase in total individual demand is quite meaningful. For compost, the increase is over 1,800 FCFA or \$3 USD. This is similar in size to the average daily agricultural wage in the region and suggests that the value of community benefits from aquatic vegetation removal are high enough to potentially sustain aquatic vegetation removal by members of the community. The estimate for animal feed is smaller as total individual demand increase by just under 600 FCFA or \$1 USD when participants were informed of the public health benefits of AVR. As expected, we find that willingness to pay for animal feed is higher when

³While it is common to use a Becker-DeGroot-Marshack (BDM) mechanisms to elicit willingness to pay in these settings, we were limited in production and transportation capacity of compost. Therefore, we used second price auctions that are incentive compatible ways to elicit willingness to pay while also reducing the compost and animal feed production requirements.

⁴All auction participants received both sets of information. We experimentally vary the information given prior to the auction.

households own livestock. Households that previously experienced schistosomiasis infection have higher willingness to pay for compost.

When we look only at willingness to pay for a single unit of compost or animal feed, we find that information about the public health benefits reduces willingness to pay for the product by about 300 FCFA or \$0.50. On average, individuals requested more units when informed of the public health benefits and thus they have a lower per-unit willingness to pay but want more. Thus, the negative result is akin to a bulk discount.

Demand for compost or animal feed is farther to the right when participants are provided with information on the public health benefits associated with the products. We then combine our elicited demand curves with estimates of the marginal cost to produce both compost and animal feed to then calculate the additional welfare from informing people of the public health benefits associated with aquatic vegetation removal. We find that the public health benefits information with compost generates an estimated \$12.18 USD per auction participant in extra welfare across all villages in the auction exchanges while it the information with animal feed generates an extra \$1.23 USD per auction participant relative to auction exchanges with only private productivity information. In a limited experiment, this added benefit suggests that there is a clear opportunity for a market for compost and animal feed that generates both agricultural and public health returns.

This study broadly contributes to the literature on impure public goods and the private provision of public goods. Theoretical models of impure public goods were perhaps first introduced by [Kotchen \(2006\)](#) and [Kotchen \(2009\)](#). [Chan and Kotchen \(2014\)](#) and [Wichman \(2016\)](#) develop further extensions of the model. In these settings, consumers have preferences over characteristics of goods. We take ideas developed around preferences for impure public goods and integrate them into an agricultural household model ([Singh et al. \(1986\)](#)). We also build on literature on the private provision of public goods ([Ajayi et al. \(2012\)](#); [Polasky et al. \(2014\)](#); [Li et al. \(2016\)](#); [Liu and Swallow \(2019\)](#)) where auction mechanisms incentivize the provision of public goods.

We also contribute to the literature on private provision of public goods like deworming ([Miguel and Kremer \(2004\)](#); [Kremer and Miguel \(2007\)](#); [Baird et al. \(2016\)](#); [Ozier \(2018\)](#); [Hamory et al. \(2021\)](#)) malaria control through insecticide treated nets (ITNs) ([Hoffmann et al. \(2009\)](#); [Cohen and Dupas \(2010\)](#); [Cohen et al. \(2015\)](#)), water quality improvements ([Kremer et al. \(2011\)](#); [Berry et al. \(2020\)](#)), and air quality improvements ([Berkouwer and Dean \(2022\)](#)). Mass deworming significantly improves schooling and economic productivity ([Miguel and Kremer \(2004\)](#); [Baird et al. \(2016\)](#); [Ozier \(2018\)](#); [Hamory et al. \(2021\)](#)). However, take up of deworming dropped dramatically to insufficient levels to maintain infection control ([Kremer and Miguel \(2007\)](#)). Similarly, low rates of take-up for ITNs at any non-zero

prices limits malaria control (Hoffmann et al. (2009); Cohen and Dupas (2010); Cohen et al. (2015)). Additional work on water and air quality improvements in sub-Saharan Africa reports very low private valuation for water filtration or improved cookstoves (Kremer et al. (2011); Berry et al. (2020); Berkouwer and Dean (2022)).

In all these cases, either deworming, using ITNs, treating malaria, or improving water quality the act is an impure public good as the individual taking the medication or using the ITN receives a benefit of better health while the community receives the public good of reduced infection risk. However, in all settings the private incentive of better health is not sufficient to fully reduce community infection risk, so there are insufficient private incentives to provide the public good.

Here, we study a new innovation with perhaps stronger private incentives as households receive private agricultural economic benefits in addition to the private and public health benefits. We evaluate the viability of a market for the impure public good. Most closely related to our setting is Huth et al. (2018) who evaluate the potential private market for lionfish fillets. Lionfish are an invasive species in the Caribbean and developing local markets could provide food for consumers (the private benefits) while also reducing the lionfish population (the public benefits). Similar to our setting, this would turn a public bad into an impure public good. However, the context and product differ greatly.

The rest of the paper is organized as follows. Section 2 introduces the study design while section 3 presents the empirical framework. Results are found in section 4 and we discuss and conclude in section 5.

2 Study Design

Our empirical analysis uses data from randomized, experimental generalized second price auctions in agricultural villages in the Saint Louis and Louga regions in Senegal in June 2023. We designed these auctions to assess demand for not-yet-marketed compost and animal feed from aquatic vegetation removal as described in Rohr et al. (2023). We partnered with the same organization to produce the compost and animal feed (Station d’Innovation Aquacole, SIA). We collected data in one or two visits to each village. During the morning or at the first visit, we enrolled households in the survey and informed them of their ability to purchase compost and animal feed at the arranged auction time. In the afternoon or at the second visit, we simultaneously conducted four auctions in each village, two auctions in each treatment arm, using the process described below. In each auction group, we conducted three auctions. The first auction of a sickle was a practice auction to help explain the auction procedure. Then, we auctioned off a 5 kg bag of compost and a 4 kg bag of animal feed.

2.1 Sample Selection and Randomized Information Treatments

Eligibility for the study was determined in two stages. First, we selected 20 villages in the Saint Louis and Louga regions. We selected 16 villages previously included in the [Rohr et al. \(2023\)](#) study and then selected four additional villages using the following criteria: 1) the village has between 500 and 5,000 residents; 2) the village is within 10 km of a freshwater source with known schistosomiasis transmission; and 3) the village has at least one water access point with submerged vegetation. Within each selected village, we randomly selected 40 households to participate and enrolled the household head or another adult in these selected households.⁵ We enrolled a total of 801 households in the study. Following the short enrollment survey, households were randomly assigned to one of four auctions within their village. We stratified household randomization based on household the amount of land cultivated and the number of children in the household.

To disentangle the two sources of value for compost and animal feed produced from removed aquatic vegetation, we assigned each participant to one of two information treatment arms: a private productivity gains information treatment arm (the control) and a public health information treatment arm.

Because we were auctioning inputs, all participants received information about the private benefits of using compost and animal feed made from aquatic vegetation removal so they understood the product up for sale. Material was based on estimates from [Rohr et al. \(2023\)](#) and developed with the team directly involved in the production of compost and animal feed for [Rohr et al. \(2023\)](#). The same team, SIA, produced compost and animal feed using the procedure developed in [Rohr et al. \(2023\)](#) to match the characteristics of the compost and animal feed as best as possible. All information treatments were reviewed by local partners and presented in a culturally appropriate way using posters and verbal descriptions from the enumerators (Appendix Figures C.2 - C.3). In the second, public health impacts information treatment arm, participants received information about the public health benefits of aquatic vegetation removal in reducing schistosomiasis exposure, explaining that the compost and feed are co-products along with infectious disease control. After the end of the private productivity gains auctions, participants in the first arm were informed about the public health benefits of aquatic vegetation removal such that all participants received potentially beneficial information.

Two auctions in each village were assigned to each of the treatment arms. In total, 398 households were randomly assigned to the private productivity gains treatment arm

⁵In one village, there was only 35 households so all 35 household heads or adult representatives were enrolled. To reach our desired sample size, we enrolled 45 households from the next village. We also enrolled 41 households in one village to comply with requests from local authorities.

while 402 households were randomly assigned to the public health benefits treatment arm. Of the 801 individuals enrolled in the study, 712 completed the auctions with 355 auction participants in the private productivity gains treatment arm and 357 auction participants in the public health benefits treatment arm. Households were not informed which auction group they were assigned to until they showed up at the auction, so we do not expect there to be differences in the rate of auction completion across the two treatment arms. Appendix table D.1 presents summary statistics and balance tests for households that completed the auction and make up the analysis sample.

We find no statistically significant demographic, agricultural, or health characteristics across households assigned to the two different treatment arms. About half of our survey respondents are female, and slightly more than a third of household heads are able to read French. Average household size is quite large, consistent with other data from the region, just under 12 people including five children. Most of the sample owns livestock and grows crops. Fertilizer use is quite common; around 80% of the sample reporting that they use fertilizer. A smaller fraction of households report using any sort of compost, but compost use is still somewhat familiar to households. Households also report frequent use of health care as more than 60% report going to the health center in the last month. As expected, most households report having at least one member diagnosed with schistosomiasis in the past and most report that at least one member of the household used deworming drugs. Only about a quarter of households report that someone in the household currently has schistosomiasis or red urine which is commonly reported with *schistosoma haematobium* infection.

2.2 Generalized Second Price Auction Procedure

We used a generalized second price auction to elicit willingness to pay for compost and animal feed. We moved each of the four auction groups in each village to private location so that other auction groups could not see or hear what was going in the auction. The step-by-step procedure auction can be found in Appendix A.

Participants received 1500 FCFA (roughly USD 2.50) for participating at the beginning of the auction. This payment served two purposes. First, it is equivalent to roughly a day's wage as an agricultural day laborer, therefore compensating participants for their time in the study. Second, it helped to relax any liquidity constraints participants faced. While our study design did not allow for long periods of time to gather funds to participate in the auction, our auction items were relatively small and thus we did not expect them to be a large financial burden for participants. Additionally, it is common for vendors to come through these villages unannounced selling items, so households are accustomed to having to finance small- to medium-sized purchases without much advanced notice.

Once participants received their payments we explained the auction procedure, including the key features that they will be asked to bid on the items for sale and asked how many of the item they would like at the price they bid. We explained that the winner of the auction is the person who bid the highest price and that the winner will pay the second highest price bid for the item. We also informed participants that if they win they will purchase the item. This second price auction mechanism is incentive compatible, and a utility-maximizing participant should reveal their true maximum willingness to pay ([Vickrey \(1961\)](#)). Prior to starting the auction for the sickle, we asked each participant if they had any questions, if they understood the rules of the game, and asked them to explain who would win the auction and what price they would pay.

Generally, participants understood the auction procedure quite well. Prior to the practice auction, 98% of participants said they understood the rules of the auction, 85% of participants correctly identified how to win the auction, and 77% of participants correctly reported the price the winner pays. If participants had questions or incorrectly answered a question, the enumerator explained the rules again and/or answered their questions. We completed practice auctions after these comprehension questions and prior to the auctions for compost and animal feed. Thus, we are confident that participants understood the auction procedure.

Participants made their bids for the sickle, compost, and animal feed in a private area away from other auction participants. After all participants submitted their bids, all bids were read aloud to the group, the winner was announced, and a purchase was made. To limit the amount of outliers and to help with the elicitation of willingness to pay, we gave participants a price list, in 50 FCFA increments, that participants were allowed to bid for each of the items. The price list was determined based on current prices of urea and allowed for allowable bids well above and below prevailing urea prices in the region.⁶

2.3 Additional Data

To supplement data collected in the auctions experiment to estimate potential supply curves for compost and animal feed, we use detailed household survey data collected by [Barrett et al. \(2024\)](#) from 2,080 households within the Senegal River Valley. This household survey randomly selected 20 households from the village roster, stratified on relative wealth levels, in 104 villages. We use data on time use, agricultural production and inputs, household income and labor, and general household characteristics. Additional details on this data collection can be found in [Barrett et al. \(2024\)](#). While these data concerns an experiment,

⁶It is common to haggle for most items in this setting. It is common for participants not to want to report a bid prior to knowing a price or starting point. We used the price listing to give participants an idea of reasonable prices and to eliminate the need for enumerators to have to suggest a price to spur bidding.

we use data collected either prior to any evidence of changes within the targeted outcomes. Summary statistics for data used to estimate potential supply curves for compost and animal feed can be found in Table E.1.

3 Empirical Strategy

The auctions were designed to elicit consumer demand for compost and animal feed mad from aquatic vegetation removal and to identifier what, if any, demand boost the public health information generates. We run the following regression separately for compost and animal feed to test hypotheses about factors that influence total individual demand in a linear-in-parameters first order approximation of the shadow price functions derived in Appendix B:

$$TID_{piv} = \beta_0 + \beta_1 Public\ Benefits_{iv} + \beta_2 Land_{iv} + \beta_3 Crops_{iv} + \beta_4 Livestock_{iv} + \beta_5 Past\ Schistosomiasis_{iv} + \beta_6 Children_{iv} + \delta_v + \theta_s + \varepsilon_{piv} \quad (1)$$

where TID_{piv} is the individual's total individual demand for product p , compost or animal feed, elicited by a generalized second price auction for participant i in village v , $Public\ Benefits_{iv}$ is a binary indicator of whether the participant was randomly assigned to receive information on the public health benefits of compost and animal feed from aquatic vegetation removal in addition to the information on the private benefits that everyone received, $Land_{iv}$ is the land holdings of the participant's household in hectares, $Crops_{iv}$ indicates that the participant's household grows crops, $Livestock_{iv}$ indicates that the participant's household owns livestock, $Past\ Schistosomiasis_{iv}$ indicates that someone in the participant's household has been diagnosed with schistosomiasis⁷, $Children_{iv}$ is the number of children in the household, δ_v are village fixed effects, and θ_s control for stratification in the randomization process. We cluster our standard errors at the village auction level which is the level of treatment assignment. For our main results and the balance table, we also report standard errors clustered at the village level in Appendix Table ?? and Appendix Table ??; however, these standard errors suffer from not enough clusters and are likely biased downwards (Cameron and Miller (2015)).

Under randomization, the coefficient β_1 identified the impact of the additional public health information on willingness to pay for compost of animal feed. While some of the

⁷Based on pilot surveys in the summer of 2022, most households have at least one member who has been diagnosed with schistosomiasis. We can also measure exposure based on the use of deworming medication or reinfection.

villages have prior experience with vegetation removal in the [Rohr et al. \(2023\)](#) study, randomization is within villages and we use village fixed effects, so this should not pose a problem to our identification. Even so, the treatment effect can be seen as the effect of additional information about the public benefits of aquatic vegetation removal at the point of sale and thus the treatment effect is identified only off of randomization or exposure that happened within this study.

4 Results

4.1 Willingness to Pay (WTP)

4.1.1 Total Individual Demand

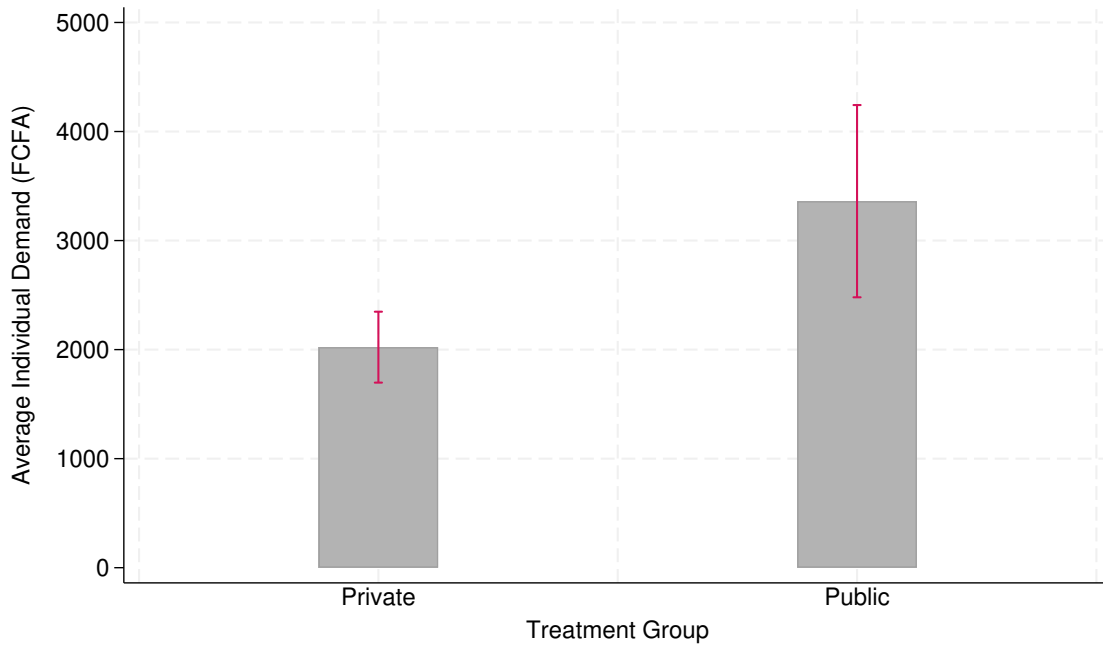
We first examine average total individual demand for compost and animal feed across treatment groups. We construct the total individual demand by multiplying the price each participant bid by the total amount they requested. This total individual demand measure combines the auction elicitation of both prices and quantities. [Figure 1](#) reports the average total individual demand for compost in Panel (a) and the average total individual demand for animal feed in Panel (b). In both cases, average total individual demand is higher in the public health benefits treatment arm.

We empirically test for differences in total individual demand using the regression equation specified in the previous section. Results from these regressions for compost and animal feed can be found in [Table 1](#). Consistent with the figures, we find that there is a strong, statistically significant positive effect of the public health benefits information treatment on mean total individual demand for compost or animal feed. The increase in total individual demand is quite meaningful. For compost, the increase is over 1,800 FCFA or \$3 USD per household. This is similar in size to the average daily agricultural wage in the region and suggests that the value of community benefits from aquatic vegetation removal are high enough to potentially sustain aquatic vegetation removal by members of the community.

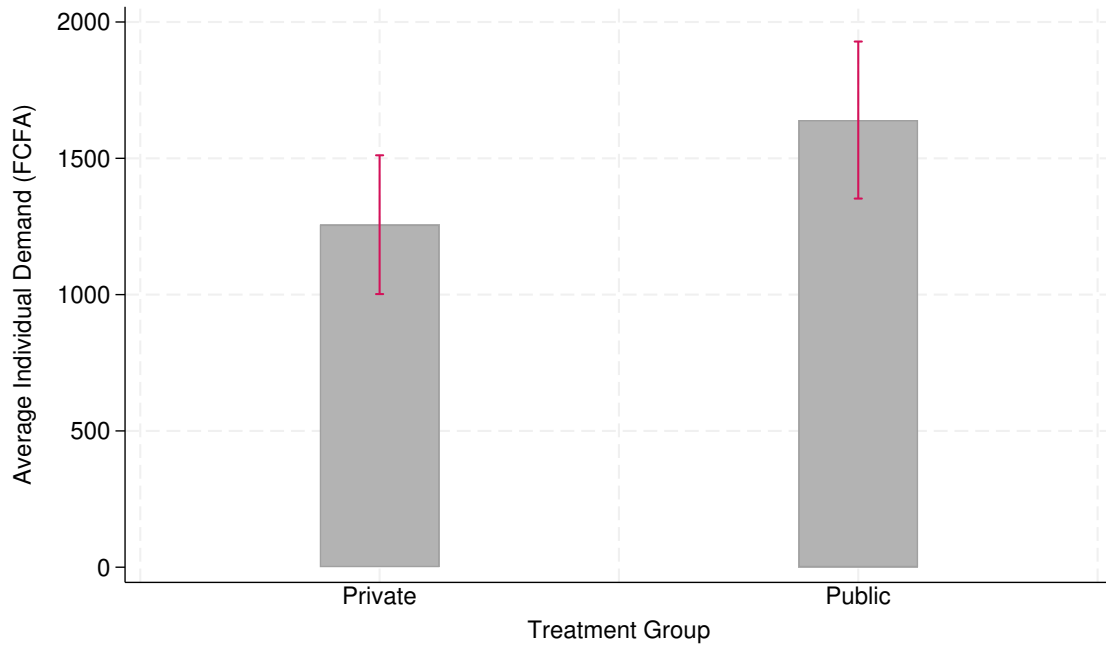
We find that households who have livestock are overall willing to pay more for animal feed. We explore this relationship further in [Table 2](#). We find that total individual demand for animal feed is higher for those who raise poultry, although the other estimates are positive but not statistically significant. We likely do not have enough power in our experiment to detect significant effect. We find no meaningful relationships between livestock ownership and total individual demand for compost. There are also no statistically interaction effects ([Tables D.2](#) and [D.3](#)).

We find that past household experience with schistosomiasis is associated with higher

Figure 1. Average Total Individual Demand by Treatment Arm



(a) Compost



(b) Animal Feed

Notes: Private represents auctions in the private productivity gains treatment arm. Public represents auctions in the public health benefits treatment arm. Bar height is the mean total individual demand and the error bar is the 95% confidence interval for the estimate of the mean.

Table 1. Total Individual Demand Regression Results

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Compost (FCFA)	(3) Total Individual Demand Animal Feed (FCFA)	(4) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	1812.848** (689.050)	1944.123*** (719.782)	570.993** (269.415)	586.120** (271.817)
Land Owned (Hectares)		-62.671 (53.929)		-6.738 (21.952)
Raise Livestock		92.155 (621.074)		471.848** (217.841)
Grow Crops		693.525 (681.197)		286.160 (243.823)
Past Schistosomiasis		1391.925*** (513.905)		119.389 (400.726)
Children		16.449 (56.164)		-35.769 (33.601)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	712	700	712	700
Adjusted R^2	0.029	0.029	0.054	0.052

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Raise Livestock and Grow Crops are indicator variables that takes the value of one if the participant's household raises livestock or grows crops, respectively. Past Schistosomiasis is an indicator variable that takes the value of one if at least on member of the participant's household was diagnosed with schistosomiasis. Children is the number of children within the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 2. Determinants of Total Individual Demand: Livestock Types

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	2036.192*** (726.342)	622.823** (257.216)
Cattle	556.384 (856.588)	175.316 (291.791)
Sheep	752.248 (647.125)	264.865 (291.658)
Goat	458.405 (642.982)	295.867 (276.866)
Poultry	502.366 (483.221)	383.363* (206.777)
Other Livestock	3.271 (650.875)	-64.364 (219.217)
Village FE	X	X
Stratification FE	X	X
Enumerator FE	X	X
Observations	634	634
Adjusted R^2	0.023	0.047

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Cattle, Sheep, Goat, Poultry and Other Livestock are indicator variables that takes the value of one if the participant's household raises cattle, sheep, goats, poultry or other types of livestock, respectively. The regressions also include controls for the amount of land a household owns, whether the household grows crops, the number of children in the household, and their experience with past schistosomiasis infections in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

overall willingness to pay for compost. This association is both statistically significant and economically meaningful in magnitude as it increases total individual demand for compost by over \$2 USD. In Appendix Table D.4 and Appendix Table D.5, we use different measures of schistosomiasis infection. We find some positive and statistically significant associations; however, these results should be corrected for multiple hypothesis testing so we interpret them with caution. We find that a household with a current schistosomiasis infection is associated with higher total individual demand for animal feed. We also report results for interaction effects with these different measures of schistosomiasis infection in Table D.6 and Table D.7. We see a negative interaction effect for reports of red urine and the public health benefits treatment; however, we once again interpret this with caution.

As prespecified in our pre-analysis plan (Doruska et al. (2023)), we also look at the interaction between our public health benefits information treatment and the number of children or experience with schistosomiasis within the households. We hypothesized since children are more vulnerable to schistosomiasis infection, households with more children may respond differently to the information about reducing potential schistosomiasis infections. Similarly, households with past schistosomiasis experience may be more informed about the risk and malaise associated with schistosomiasis infection and thus may respond differently to information about how to avoid future infections. We thus run separate regressions that interact the indicator for the public health information treatment arm with the number of the children or the household’s past experience with schistosomiasis. We look at the interaction between our public health benefits information treatment and the number of children or experience with schistosomiasis within the households. We report the results of the interaction with children in Table 3 and the interaction with past schistosomiasis infection in Table 4. We do not find that either interaction effect is statistically or economically significant.

Land ownership, which is a proxy for wealth, has no statistically or economically significant relationship with willingness to pay for either compost or animal feed. As land ownership increases, the public health benefits treatment results in lower total individual demand for compost (Table D.2). There is also no relationship between the number of children in the household (Table D.2). This interaction effect is not statistically significant for total animal feed willingness to pay (Table D.3). We find that households that have past experience with schistosomiasis infection in their household are overall willing to pay more for compost.

We do not find any statistically significant relationship between growing crops and total willing to pay for compost or not animal feed. When we consider the two main crops in these villages, rice and cassava, and peppers and onions which were used to test the compost, we

Table 3. Determinants of Total Individual Demand: Interaction with Children

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	2517.720*** (726.016)	870.541** (355.722)
Public Health $\times$ Children	-114.346 (107.666)	-58.292 (44.288)
Children	65.645 (64.466)	-9.402 (43.943)
Village FE	X	X
Stratification FE	X	X
Enumerator FE	X	X
Observations	700	700
Adjusted R^2	0.029	0.052

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Children is the number of children within the household. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, and their experience with past schistosomiasis infections in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 4. Determinants of Total Individual Demand: Interaction with Schistosomiasis Experience

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	1162.883 (777.048)	-275.567 (612.070)
Public Health $\times$ Past Schistosomiasis	942.993 (772.445)	1040.096 (660.069)
Past Schistosomiasis	906.571** (418.904)	-415.945 (673.564)
Village FE	X	X
Stratification FE	X	X
Enumerator FE	X	X
Observations	700	700
Adjusted R^2	0.028	0.057

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household was diagnosed with schistosomiasis. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops and the number of children in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 5. Determinants of Total Individual: Crop Types

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Compost (FCFA)	(3) Total Individual Demand Animal Feed (FCFA)	(4) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	2008.711*** (717.347)	2009.719*** (712.971)	676.592** (290.011)	680.200** (290.035)
Rice	119.675 (1153.764)	131.482 (1160.062)	-171.362 (371.098)	-211.892 (360.071)
Onion	-566.475 (621.658)		-329.494 (268.606)	
Pepper	-551.101 (583.298)		-30.038 (355.143)	
Cassava	2397.473* (1244.097)	2405.469* (1260.241)	288.779 (310.237)	273.861 (311.774)
Pepper or Onion		-696.117 (582.948)		-315.144 (273.493)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	616	616	616	616
Adjusted R^2	0.040	0.042	0.046	0.047

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Rice, Onion, Pepper and Cassava are indicator variables that takes the value of one if the participant's household grows rice, onion, peppers or cassava, respectively. Pepper or Onion is an indicator variable that takes the value of one if the household grows peppers or onions. The regressions also include controls for the amount of land a household owns, whether the household raises livestock, the number of children in the household, and their experience with past schistosomiasis infections in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

see that households who grow cassava have higher total individual demand for compost (Table 5). The relationship between growing cassava and higher total individual demand for compost may reflect that farmers grow cassava on poor soils and thus cassava plots may need additional soil remediation or nutrients from compost. As expected, there is no relationship between willingness to pay for animal feed and crop production of any crop types.

Finally, to build on previous work at [Rohr et al. \(2023\)](#), we explore how past experience with aquatic vegetation removal influences willingness to pay for both compost and animal feed. Because inclusion in the [Rohr et al. \(2023\)](#) was at the village level, we cannot use village fixed effects in this analysis as the variable of interest varies at the village level. We thus drop the village fixed effects and include an indicator variable for vegetation removal in the [Rohr et al. \(2023\)](#) study. Results from the regressions looking at past vegetation

Table 6. Determinants of Total Individual Demand: Past Vegetation Removal

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	1916.155** (826.085)	574.501* (295.334)
Past Removal	182.636 (566.763)	238.561 (279.740)
Village FE		
Stratification FE	X	X
Enumerator FE	X	X
Observations	700	700
Adjusted R^2	0.011	0.007

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Removal is an indicator variable that takes the value of one if the village had previous aquatic vegetation removal. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, the number of children in the household, and the household's past experience with schistosomiasis infection. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

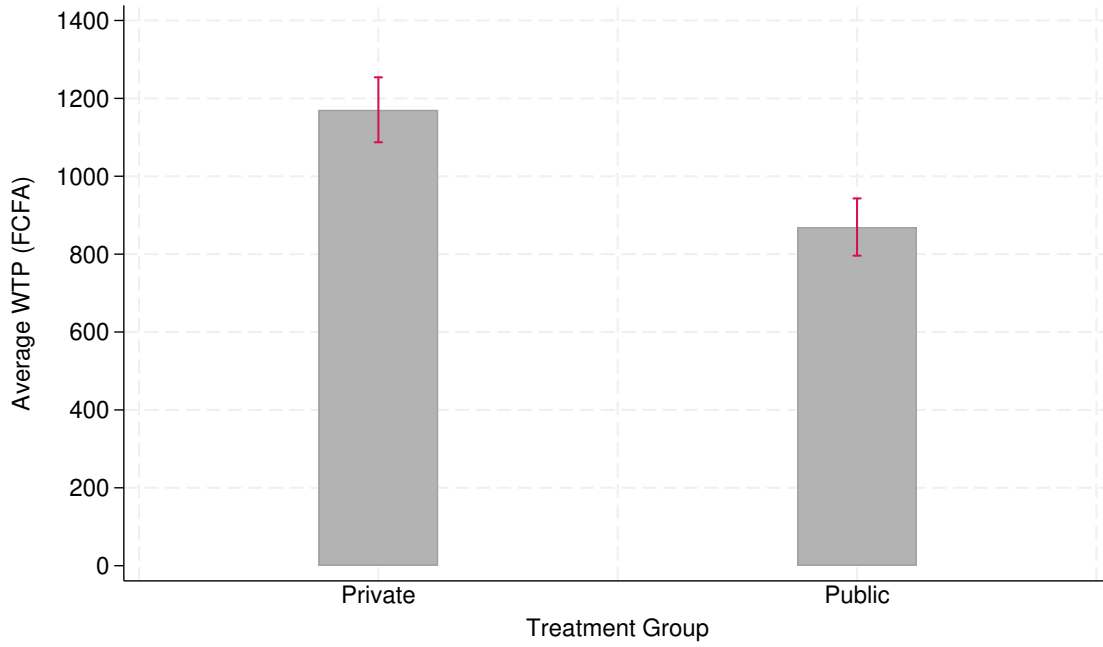
removal and total compost and animal feed willingness to pay are found in Table 6. We find that past removal is positively associated with willingness to pay, but this relationship is not statistically significant. The interaction effects, reported in Table D.8, suggest a positive interaction between past removal and the public health benefits information for total compost willingness to pay, but this effect is only weakly statistically significant.

4.1.2 Single Item WTP

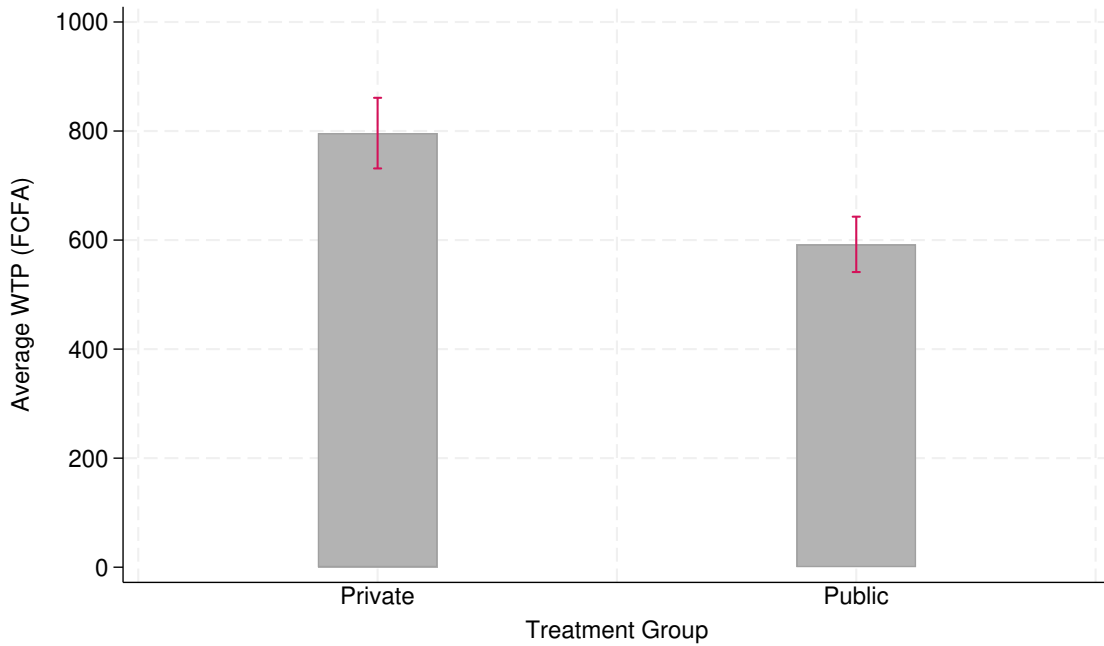
We next examine average willingness to pay for a single bag of compost and animal feed across treatment groups. Figure 2 reports the average willingness to pay for a bag of compost and a bag of animal feed. In both cases, average willingness to pay is lower in the public health benefits treatment arm.

We empirically test for differences in willingness to pay using our specified regression equation specified. Results from these regressions for compost and animal feed can be found in Table 7. Consistent with the figures, we find that there is a strong, statistically significant negative effect of the public health benefits information treatment on mean willingness to pay

Figure 2. Average Willingness to Pay (WTP) by Treatment Arm



(a) Compost



(b) Animal Feed

Notes: Private represents auctions in the private productivity gains treatment arm. Public represents auctions in the public health benefits treatment arm. Bar height is the mean willingness to pay and the error bar is the 95% confidence interval for the estimate of the mean.

for either a 5 kg bag of compost or a 4 kg bag of animal feed. The reduction in willingness to pay is meaningful in FCFA, but is about \$0.50. For a more standard size of 50 kg of compost, this would be about a 3000 FCFA or \$5. However, since we estimated willingness to pay with small bags of compost due to production constraints, this estimate is a very coarse back-of-the envelope calculation as we expect the price per kilogram to fall as the size of the bag of compost or animal feed increases consistent with common non-linear pricing schemes ([Attanasio and Pastorino \(2020\)](#)). Indeed, the increase in total individual demand from the public health information signals added demanded but at a lower per unit price.

The negative effect is on willingness to pay for a single bag of compost or animal feed is not inconsistent with the externalities described in the public health treatment information. While the overall intention of the public health benefits treatment arms was to inform individuals of the decrease in schistosomiasis infection risk from aquatic vegetation removal, we discouraged individual from entering the water source to remove aquatic vegetation themselves because entering the water can result in schistosomiasis infection. Therefore, we also informed individuals of additional personal cost associated with directly producing these items. Overall, our public health benefits information treatment arm suggests that the community as a whole benefits from aquatic vegetation removal, but individuals that remove aquatic vegetation and produce the compost and animal feed incur extra personal cost in the form of increased infection risk, personal protective equipment, or both. Combined with our results on total individual demand, the lower price per unit reflects that individuals are willing to contribute to public goods only at modest costs and individuals are only willing to pay a premium for direct benefits.

4.2 Estimated Demand

While looking at willingness to pay for a single item can be informative, we also collected data on the quantity of compost or animal feed participants requested at their bid. We then use the information about the joint bid price and amount to construct demand curves for both compost and animal feed by treatment group. The estimated demand curves are reported in Figure 3. We construct estimates of the error by bootstrapping the sample 1,000 times.

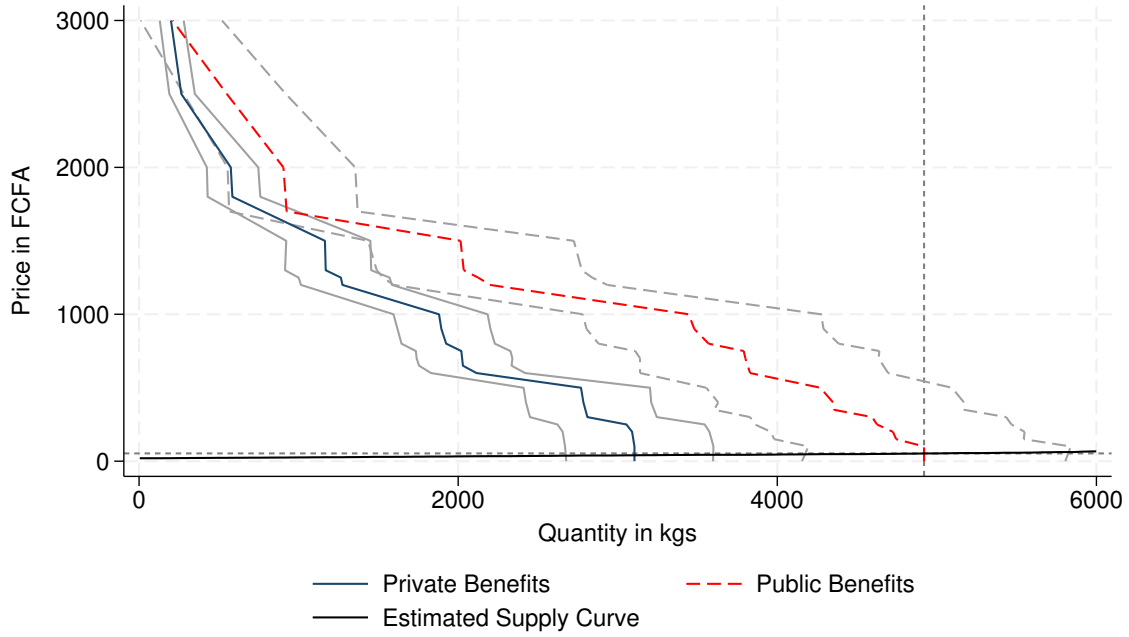
We see that the public health information treatment shifts the demand curve to the right and this difference is statistically significant. The shape of the demand curve is driven by a higher number of bids for more than one bag of compost or animal feed in the public health information treatment group. While we could not enforce incentive compatibility for bids greater than one due to limited production capacity, these higher number bids suggest that there could be additional consumer surplus and thus added welfare from information about

Table 7. Willingness to Pay (WTP) Regression Results

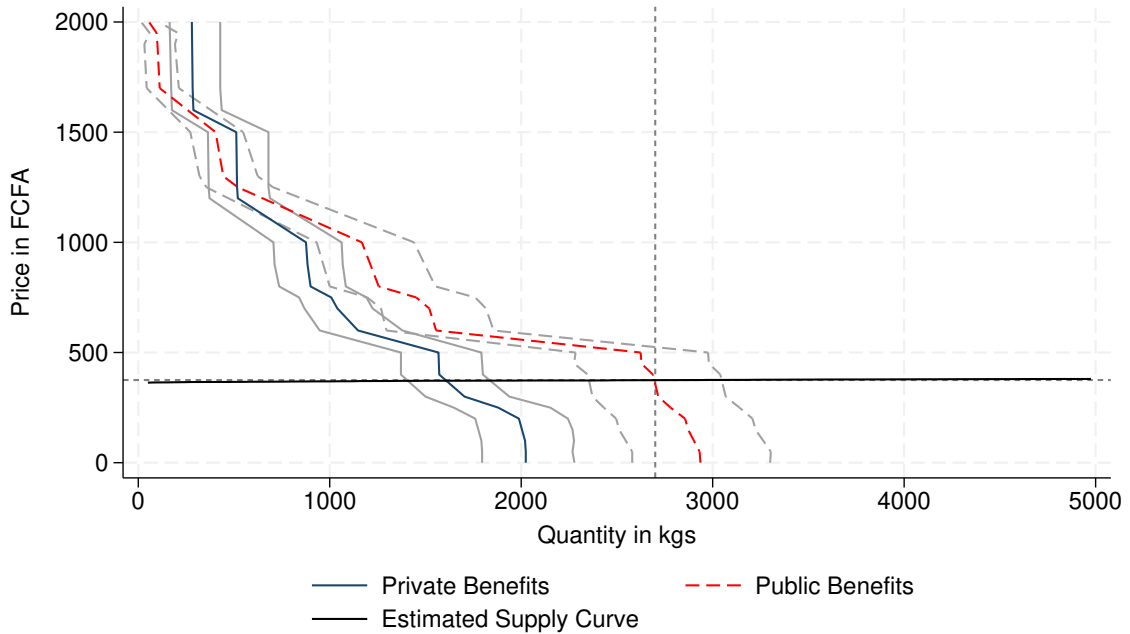
	(1) WTP Compost (FCFA)	(2) WTP Compost (FCFA)	(3) WTP Animal Feed (FCFA)	(4) WTP Animal Feed (FCFA)
Public Health Benefits	-283.978*** (98.167)	-274.072*** (97.047)	-325.384*** (69.506)	-323.664*** (67.495)
Land Owned (Hectares)		-3.566 (8.694)		6.748 (5.827)
Raise Livestock		-50.073 (95.786)		130.522* (73.237)
Grow Crops		241.598*** (78.143)		-6.672 (69.398)
Past Schistosomiasis		44.585 (68.300)		-32.772 (50.644)
Children		1.823 (10.744)		-10.340 (7.997)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	712	700	712	700
Adjusted R^2	0.185	0.179	0.178	0.173

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Raise Livestock and Grow Crops are indicator variables that takes the value of one if the participant's household raises livestock or grows crops, respectively. Past Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household was diagnosed with schistosomiasis. Children is the number of children within the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Figure 3. Demand Curves by Treatment Arm



(a) Compost



(b) Animal Feed

Notes: Private benefits represents auctions in the private productivity gains treatment arm. Public benefits represents auctions in the public health benefits treatment arm. The gray lines represent the 5th and 95th percentiles from 1,000 bootstrap replications. The black line is the estimate of the supply curve following the procedure in [Rohr et al. \(2023\)](#).

reduced schistosomiasis risk. These figures suggest that the relevant elasticities are different between the two treatment groups and thus point to possible increases in welfare resulting from fully capturing the public and private benefits of aquatic vegetation removal.

4.3 Estimated Supply

We estimate the supply curve for households producing either compost or animal feed from removed aquatic vegetation. The main input for households is labor spent removing aquatic vegetation and bags to store and package either product. Animal feed also requires purchased feeds, like peanut straw, to be mixed with removed aquatic vegetation. Compost productions also requires fixed costs to purchase a cart and rakes to aide in moving and turning the compost.

Because households in this setting likely face multiple market failures, we assume they solve a nonseparable agricultural household model. The shadow wage is the relevant value of labor in this model, so we estimate shadow wages following [Barrett et al. \(2008\)](#) in a larger dataset of agricultural households from the same region ([Barrett et al., 2024](#)).

We estimate a generalized Leontief production function with the following functional form:

$$y_{ivt} = \sum_i \sum_j \beta_{ij} X_i^{0.5} X_j^{0.5} + \alpha_1 Manure + \alpha_2 Compost + \alpha_3 HHWaste + \gamma_v + \delta_t + \varepsilon_{ivt} \quad (2)$$

where y_{ivt} is the total value of agricultural production for household i in village v at time t , X_i and X_j are vectors of inputs to production that include the hectares in production, household labor hours spent on agriculture, fertilizer use, the number of hired laborers, the livestock holdings of the household⁸, and the number of mechanical agricultural equipment the household owns, $Manure$, $Compost$, and $HHWaste$ are indicator variables if the household uses manure, compost, or household waste on one of its plots, γ_v are village fixed effects, and δ_t are survey wave fixed effects. We estimate this model as a random effects model. We impose that when $i = j$, $\beta_{ij} = \beta_{ji}$. We cluster the standard errors at the village level. Estimated factor elasticities for continuous inputs of the production function can be found in Table 8.

Using the estimation results, we then calculate the marginal product of household labor for each household. This calculation defines the relevant value of household labor for each

⁸We measure livestock holdings in TLU where cattle, horses, and draft animals are one TLU, goats and sheep are 0.1 TLU, donkeys are 0.5 TLU, pigs are 0.2 TLU and poultry are 0.01 TLU.

Table 8. Generalized Leontief Estimated Elasticities

	Land	HH Labor	Fertilizer	TLU	Hired Labor	Equipment
Estimated Elasticity	0.145	0.018	0.109	0.037	0.066	0.163

Notes. This table reports estimated factor elasticities for the estimated generalized Leontief production function for the continuous inputs in the production function.

household. Summary statistics showing the estimated marginal product of labor can be found in Table 9.

Table 9. Estimated Marginal Product of Labor

	Count	Mean	St. Dev.	Min	Max
Leontief, Random Effects	2088	710.718	1221.994	0	16638.62
Daily Wage for Paid Work	1165	2725.448	1938.665	0	6666.667

Notes. This table reports summary statistics of the estimated marginal product of labor for households who cultivate crops and have non-zero household labor hours and the daily wage for households reporting paid work. The specification reports the specification used to calculate the marginal product of labor.

For households that have individuals working on the farm and for a wage, we then calculate allocative inefficiency which is defined as the inverse hyperbolic sine of the ratio of the wage for paid work to the estimated marginal product of labor. We then plot allocative inefficiency across the land to labor ratio or the asset index of the household below, along with the fractional polynomial line of best fit. (Figure E.1). We then estimate factors that influence allocative inefficiency (Table E.3).

We use these estimates to estimate allocative inefficiency for households that only have agricultural labor. Using the estimated allocative inefficiency, we can then estimate the shadow wage for households only working on their farm as

$$sw = e^{AI} * MRP_L \quad (3)$$

where AI is the estimated allocative inefficiency and MRP_L is the estimated marginal revenue product of labor. Summary statistics for shadow wage estimation for households that only engage in agricultural labor can be found in Table 10. We see that the median shadow wage is below the daily wage for paid work outside of the home, consistent with Agness et al. (2025). There is a long right tail of the shadow wage distribution that pulls up the estimated shadow wage.

We then value household labor as either the estimated shadow wage for households that only work on the farm or their outside wage if a household member works for a wage.

Table 10. Estimated Shadow Wages

	Count	Mean	St. Dev.	Min	Median	Max
Shadow Wage	1430	2892.208	4461.797	0	1715.504	57848.91
Daily Wage for Paid Work (FCFA)	1165	2725.448	1938.665	0	2500	6666.667

Notes. This table reports summary statistics of the estimated shadow wage for households who only cultivate crops and the daily wage for households who work outside the farm.

We use labor inputs to produce compost or animal feed from [Rohr et al. \(2023\)](#). Bags to hold compost or animal feed cost 200 FCFA/bag and peanut straw to supplement aquatic vegetation in animal feed costs 375 FCFA/kg. We then calculate the amount of slack labor hours each household has for household members above 15 years old and assume they devote this slack labor to compost or animal feed production to determine how compost or animal feed households could produce. We use these estimates of household compost or animal feed production to trace out the supply curves for compost or animal feed in Figure 3. Estimated supply is quite flat in the relevant areas suggesting that there is sufficient slack labor to produce low-cost compost in these areas and that most of the gains from trade would go to consumers of compost or animal feed. Animal feed is more expensive to produce than compost given that it requires peanut straw to supplement aquatic vegetation.

4.4 Welfare Gains

The gains from trade will primarily go to consumers given the flat shape of the supply curve. We estimate that welfare gains from trade in the market for compost are \$18.54 USD per auction participant with just the private benefits information. These welfare gains grow to \$30.72 USD per auction participant when participants are also informed about the public health benefits of aquatic vegetation removal. In the market for animal feed, the welfare gains from trade are \$6.09 USD per auction participant with private benefit information and \$7.32 USD per auction participant with private benefit and public health benefit information. In both cases, there are significant welfare gains from informing individuals about the public health benefits of aquatic vegetation removal as public health information increases welfare by \$12.18 USD per auction participant for compost and \$1.23 USD per auction participant for animal feed.

5 Discussion and Conclusion

We ran generalized second price auctions in 20 villages in rural northern Senegal to elicit willingness to pay for not-yet marketed compost and animal feed produced from removed

aquatic vegetation. We experimentally varied whether households were informed that removing aquatic vegetation reduces schistosomiasis infection risk to test if turning the compost and animal feed from a purely private good to an impure public good with both private and public value changes household willingness to pay for the items. We find that informing households about the public value of this compost and animal feed increases their total individual demand resulting in higher welfare in a potential market for compost and animal feed primarily for compost consumers. These results suggest that there is sufficient local demand to justify a local market for these products.

More generally, aquatic vegetation removal is part of potential strategies to reduce schistosomiasis and potentially increase welfare for households in this region ([Doruska et al. \(2024\)](#); [Rohr et al. \(2023\)](#)). Given the wide economic benefits of other efforts to reduce parasitic infections ([Miguel and Kremer \(2004\)](#); [Baird et al. \(2016\)](#); [Ozier \(2018\)](#); [Hamory et al. \(2021\)](#)), evaluating the prospects of endogenous take-up and the sustainability of aquatic vegetation removal by local households. Whether or not households decide to produce compost and animal feed on their own depends not only on the potential benefits from these products, but also the prices and availability of substitutes in the local market. Household survey data reports that fertilizer prices are between 200 FCFA and 300 FCFA per kilogram for fertilizer. Our average willingness to pay for compost is around 200 per kilogram which is quite similar to the price of fertilizer. Thus, our estimated value of compost is competitive with fertilizer. For animal feed, standard animal feed is also around 200 FCFA and 300 FCFA per kilogram. Our average willingness to pay was about 140 FCFA per kilogram, suggesting that animal feed from aquatic vegetation removal may be cheaper than other options currently available on the market. Overall, the elicited prices suggest that households may find it profitable to switch to products produced from removed aquatic vegetation. Future work will build upon this work to determine how to best induce endogenous take-up of aquatic vegetation removal as a sustainable way of schistosomiasis infection control.

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A Instructions for the Generalized Second Price Auction

The generalized second price auction will be implemented using the following process:

1. At the agreed upon time, participants will be split into the assigned auction groups and taken into four areas in the village so that activities in the other auctions are not observable by other participants.
2. Once each group is off in their own area, the enumerator will explain the rules of the auction
 - (a) The auction is won by the household who offers the highest price per unit. The winning household pays the second highest price per unit offer for the good and buys the quantity listed in their offer.
 - (b) If the winning household cannot pay or their is additional product available after the first household buys all of the product they bid on, continue with the household who offered the second highest price per unit. This household pays the third highest price per unit for the good and purchases the quantity listed in their offer. If this household cannot pay or there is product remaining, continue down the list in this manner. This process continues until the supply is exhausted or demand is exhausted, whichever comes first. It is important to explain to households that their offers are important and if they win, you will visit to sell the product. We will develop procedure to minimize the instances of nonpayment by winning households.
3. The enumerator will explain the bid procedure (steps 6-8).
4. The enumerator will then complete the practice auction so participants can learn the auction procedure.
5. The enumerator will invite each household to write their “proposition” - the maximum price per unit at which you would buy the agricultural equipment (ex. sickle) and the number they want at that price - on the proposition paper that contains your name and your proposed price.
6. All households in the auction group will be invited to submit their proposals and put them in a jar.
7. Once all bids are submitted, the enumerator will open the jar and publicly read the propositions.

8. The household that wrote the highest proposition wins the auction and will buy the agricultural equipment at the second highest price per unit proposed in the jar. They will buy the quantity they put on their proposition. If there is remaining agricultural equipment, continue with the second highest price per unit bidder paying the third highest price per unit and follow this process until all fertilizer has been purchased.
9. Then, the enumerator will complete the auction using the following procedure.
 - (a) First, the enumerator informs all participants of the benefits found in [Rohr et al. \(2023\)](#) relating to private productivity gains (benefits to pepper and onion production, cheaper than traditional forms of animal feed). If the participant has been assigned to the public health impacts treatment arm, we will also inform them of reduced schistosomiasis infection risk from AVR. Then, the enumerator will allow households to inspect the products carefully prior to making their bids.
 - (b) The enumerator will then explain the bid procedure (steps 10c-10e).
 - (c) The enumerator will ask each household to write their “proposition” - the maximum price per unit at which you will would buy to compost or animal feed and the amount you will buy at that price - on the proposition paper that contains your name and your proposed price.
 - (d) All households in the auction group will be invited to submit their proposals and put them in a jar
 - (e) Once all bids are submitted, the enumerator will open the jar and publicly read the propositions.
 - (f) The household that wrote the highest proposition wins the auction and will buy the compost or animal feed at the second highest price per unit proposed in the jar. They will buy the quantity they put on their proposition. If there is remaining compost or animal, continue with the second highest price per unit bidder paying the third highest price per unit and follow this process until all compost or animal feed has been purchased or there are no bids remaining, whichever comes first.

B Theoretical Model

We develop a variant of the nonseparable agricultural household model to conceptualize household decision making and non-marketed valuation of the impure public good of aquatic vegetation removal within this context. In this nonseparable agricultural household model, consumption and production decisions become inextricably linked by multiple market failures (Singh et al. (1986)). The economic model begins with the household, which maximizes utility, defined over consumption of food, consumption of an aggregate household good⁹, leisure, and the health status of members of the household. We assume that utility is well-defined, increasing in all its arguments and concave. We model health status using a health production function that depends on the amount of vegetation in the water source - a proxy for schistosomiasis density - the household's nutrient intake via food consumption, the number of children in the household,¹⁰ and the household's knowledge about schistosomiasis. In this context, knowledge about schistosomiasis includes information like a household's past experience with schistosomiasis, whether or not a household is informed about aquatic vegetation removal and its benefits, and any past experience with aquatic vegetation removal. We assume that health status increases with food consumption, representing the value of more nutrition. Health status decreases as vegetation increases since more vegetation leads a larger population of snails - the helminth's vector - and therefore to more infection Rohr et al. (2023). Consistent with Rohr et al. (2023), we allow a household to clear the water source with only small fraction of its overall labor availability. Households with more children have lower health status since children are more susceptible to schistosomiasis. Knowledge about the link between vegetation and health increases health status through avoidance behaviors. There is no market for health in the model.

The household engages in agricultural production of both crops and livestock. The main decisions facing the household are how to allocate time and money. They can choose to allocate time between agricultural activities (cultivation and livestock husbandry), harvesting aquatic vegetation, selling labor on the labor market or leisure. Households can also buy labor on the labor market to use in agriculture crop production or aquatic vegetation harvest. Because aquatic vegetation is a common pool resource, there is no market for aquatic vegetation, either in the water or as harvested vegetation. Thus, the multiple market failures in health status and aquatic vegetation create nonseparability between the household's production and consumption decisions. We also assume that there is no land market because relatively few land rentals occur in this region. Harvested vegetation be-

⁹The aggregate household good represents all non-food goods and services a household can consume that are available on the market.

¹⁰Children are most adversely affected by schistosomiasis.

comes compost or animal feed, which increases agricultural productivity [Rohr et al. \(2023\)](#). Households produce crops using land, labor, fertilizer, and compost from harvested aquatic vegetation. Producing harvested vegetation only requires labor.¹¹ Livestock production only depends on the amount of food provided to the animal, which can either be produced from harvested vegetation or bought in the market.

Let i denote the different goods a household consumes, produces, or uses as an input. Let q_i denote the quantity of goods produced or used as inputs in the production process by the household. The household produces ($q_i \geq 0$) of crops ($i = f$) using land ($i = d$), labor ($i = lf$), fertilizer ($i = u$), and compost (δq_v). The household makes compost from harvested vegetation ($i = v$), and harvesting vegetation requires labor ($i = lv$). Households can also hire labor to produce food L_f^h or to harvest vegetation L_v^h . Let $L_f = q_{lf} + L_f^h$ be the total amount of labor used in the production of food and $L_v = q_{lv} + L_v^h$ be the total amount of labor used to harvest vegetation. The household's production technology for crops is then given by $F(L_f, q_d, q_u, q_v)$ and the production technology for vegetation is $G(L_v)$. The household produces ($q_i \geq 0$) of livestock $i = a$ using feed q_{af} and endowment of livestock e_a with the production technology $J(q_{af}, e_a)$. Vegetation becomes livestock feed with technology $K(L_v)$.

Let $\mathbf{c}$ denote the vector of all goods consumption, comprised of food ($i = f$), non-food household goods ($i = g$), and leisure ($i = l$). Let $H(V, c_f, n, I)$ denote the household's health status, where $V(L_v)$ is the amount of vegetation in the water source, n is the number of children in the household, I is the information set of the household, and c_f is food consumption. Household utility is denoted $U(\mathbf{c}, H)$.

Each household has endowments of labor e_l , land e_d , and livestock e_a . Each household member has one unit of labor; however, infection reduces the labor availability of an individual to τ where $0 \leq \tau \leq 1$. Infection reduces nutrient absorption from food and overall results in less labor productivity, effectively reducing the labor availability of infected individuals. The labor available to the household a_l is the sum of the labor availability of its individual members. A household generates income by growing crops and livestock and selling its labor in the local labor market, L^m . The household buys and sells labor at wage w . There are perfectly competitive markets for food, the aggregate household good, labor, fertilizer, livestock, and animal feed (the tradables set $T = \{f, h, l, u, a, af\}$), but there are not markets for vegetation, land, and health (the non-tradables set $NT = \{v, d, H\}$). Each household must fully self-provide non-tradable goods. Finally, let p_i denote the market price for good

¹¹While it requires a pit to convert vegetation into compost, consistent with conditions in our study region, we assume that there exists sufficient unused and free land within the village such that land is not a constraint to the production of compost and thus land does not enter into the production of vegetation or compost. Animal feed simply requires drying the vegetation, which can be done on available marginal land.

i.

Thus, in each period, the household solves the problem:

$$\max_{(\mathbf{c}, \mathbf{q})} U(\mathbf{c}, H) \quad (4)$$

subject to the budget constraint for tradable goods,

$$p_f c_f + p_g c_g \leq p_f (F(L_f, q_d, q_u, q_v)) - w(L_f^h + L_v^h) - p_u q_u + p_a J(K(L_v), e_a) - p_{af} q_{af,b} + wL^m \quad (5)$$

the constraint for vegetation use,

$$q_v - c_v \geq 0 \quad (6)$$

the constraint on the household's labor endowment,

$$e_a \tau \equiv a_l \geq q_{lf} + q_{lv} + L^m + c_l \quad (7)$$

and the health production function.

$$H = H(V, c_f, n, I) \quad (8)$$

The household will optimally use all its land in food production and all of its harvested aquatic vegetation turns into compost, an agricultural input, or animal feed according to

$$q_v = G(q_{lv}, L_v^h) \quad (9)$$

and

$$q_{af,v} = K(q_{lv}, L_v^h) \quad (10)$$

where the total animal feed is the sum of the amount produced from vegetation and the amount bought on the market, $q_{af} = q_{af,v} + q_{af,b}$,

The labor constraint can be substituted into the budget constraint to create a full income constraint:

$$\begin{aligned} p_f c_f + p_g c_g + w(c_l + q_{lf} + q_{lv}) \leq \\ p_f (F(q_{lf}, L_f^h, q_d, q_u, q_v(q_{lv}, L_v^h))) - w(L_f^h + L_v^h) + p_a J(q_{af,v}, q_{lv}, L_v^h, q_{af,b}, e_a) - p_{af} q_{af,b} - p_u q_u + wL^m \end{aligned} \quad (11)$$

Assuming an interior solution, and a Lagrange multiplier λ on the household's full income

constraint, the first order conditions for the maximization problem are

$$\frac{\partial U}{\partial c_f} + \frac{\partial U}{\partial H} \frac{\partial H}{\partial c_f} = \lambda p_f \quad (12)$$

$$\frac{\partial U}{\partial c_g} = \lambda p_g \quad (13)$$

$$\frac{\partial U}{\partial c_l} = \lambda w \quad (14)$$

$$\lambda p_f \frac{\partial F}{\partial q_{l,f}} = \lambda w \quad (15)$$

$$\frac{\partial U}{\partial H} \frac{\partial H}{\partial V} \frac{\partial V}{\partial q_{lv}} + \lambda (p_f \frac{\partial F}{\partial q_v} \frac{\partial q_v}{\partial q_{lv}} + p_a \frac{\partial J}{\partial q_{af,v}} \frac{\partial q_{af,v}}{\partial q_{lv}}) = \lambda w \quad (16)$$

$$p_f \frac{\partial F}{\partial L_f^h} = w \quad (17)$$

$$\frac{\partial U}{\partial H} \frac{\partial H}{\partial V} \frac{\partial V}{\partial L_v^h} + \lambda (p_f \frac{\partial F}{\partial q_v} \frac{\partial q_v}{\partial L_v^h} + p_a \frac{\partial J}{\partial q_{af,v}} \frac{\partial q_{af,v}}{\partial L_v^h}) = \lambda w \quad (18)$$

$$p_f \frac{\partial F}{\partial q_u} = p_u \quad (19)$$

$$p_a \frac{\partial J}{\partial q_{af,b}} = p_{af,b} \quad (20)$$

Equations (10), (11), and (12) can be rearranged to show that the ratio of the marginal benefit of consuming food (which includes direct increases in utility and indirect utility increases through improved in health) to the marginal benefit of consuming the aggregate household good or leisure equals the price ratio. Equation (13) demonstrates that labor is used in crop production until the value of the marginal product equals the shadow wage and equation (15) states the same condition for the use of hired labor in food production, so the marginal product of labor equals the wage. Equations (14) and (16) indicate that the value of labor in vegetation removal has multiple benefits. First, there is the benefit that comes from more food and livestock production via the creation of compost and animal feed, which generally means that labor is used until the value of the marginal product of labor in aquatic vegetation removal equals the shadow wage for household labor or the market wage for hired labor. In this model, however, labor used in aquatic vegetation removal impacts utility indirectly via the health production function. Therefore, the optimal use of labor in aquatic vegetation removal depends on the household health status in addition to the wage and/or shadow wage. Finally, equations (17) and (18) say fertilizer is used and animal feed is bought until the value of the marginal product equals the marginal cost.

The key first order conditions governing the amount of vegetation harvest and thus the amount of compost and animal feed from aquatic vegetation removal produced are equations (14) and (16). From these first order conditions we can define the reduced form relationship between household and community characteristics and their price of compost p_v and animal feed $p_{af,v}$:

$$\left. \begin{matrix} p_v \\ p_{af,v} \end{matrix} \right\} = f(V, n, I, w, p_f, p_a, p_{af,b}, e_a, e_d, e_l, \lambda) \quad (21)$$

So, the households willingness to pay for compost or animal feed depends on their household-specific information I , the number of children they have n , and their land and livestock endowments e_d and e_q . Household willingness to pay also depends on community-level characteristics: vegetation in the water source V and market prices w , p_f , p_a , and $p_{af,b}$. With village fixed effects to control for these community-level characteristics, household willingness to pay for compost and animal feed depends on the household-specific information, number of children, and livestock and land endowments that can be estimated using the following equation:

$$WTP_{iv} = \beta_0 + \beta_1 Public\ Benefits_{iv} + \beta_2 Land_{iv} + \beta_3 Crops_{iv} + \beta_4 Livestock_{iv} + \beta_5 Past\ Schistosomiasis_{iv} + \beta_6 Children_{iv} + \delta_v + \varepsilon_{iv} \quad (22)$$

The household-specific information set is determined by whether or not the household receives information on the public benefits of aquatic vegetation removal and the household's past experience with schistosomiasis. The number of children, household land holdings and livestock holdings follow directly from the model. We include whether or not the household cultivates crops to model since compost only applies to crop and thus willingness to pay for compost should depend on the household's cultivation decisions.

C Appendix Figures

Figure C.1. Poster for the Private Productivity Information of Compost

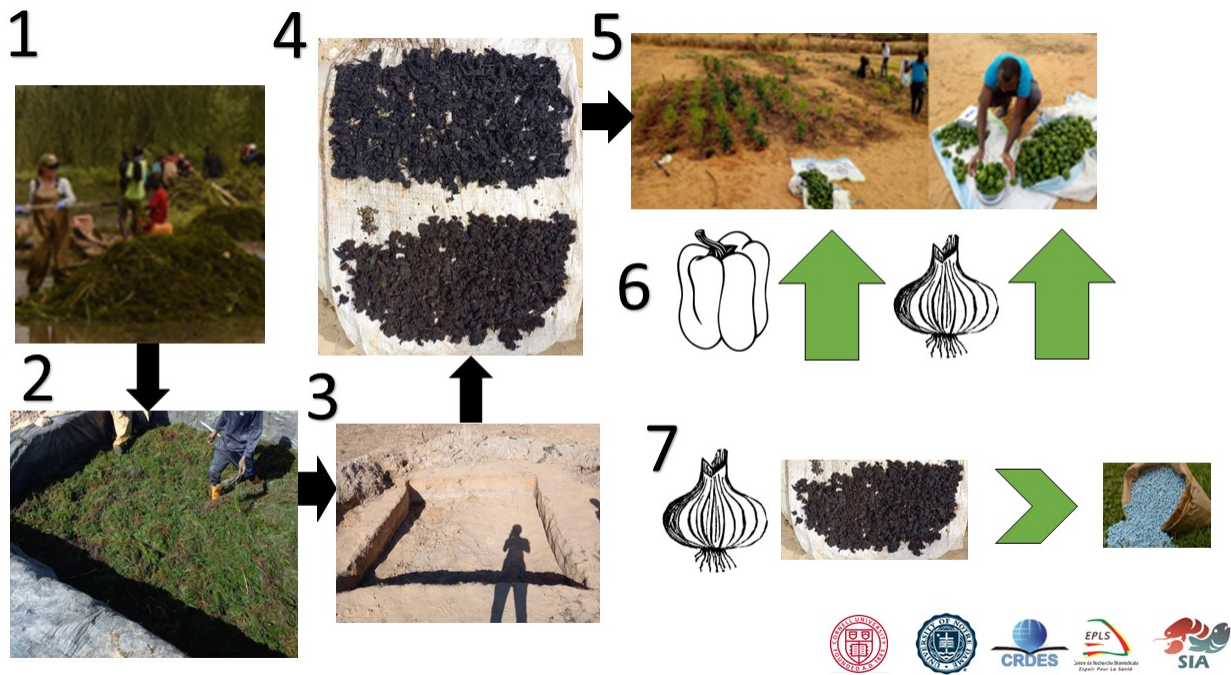


Figure C.2. Poster for the Private Productivity Information of Animal Feed

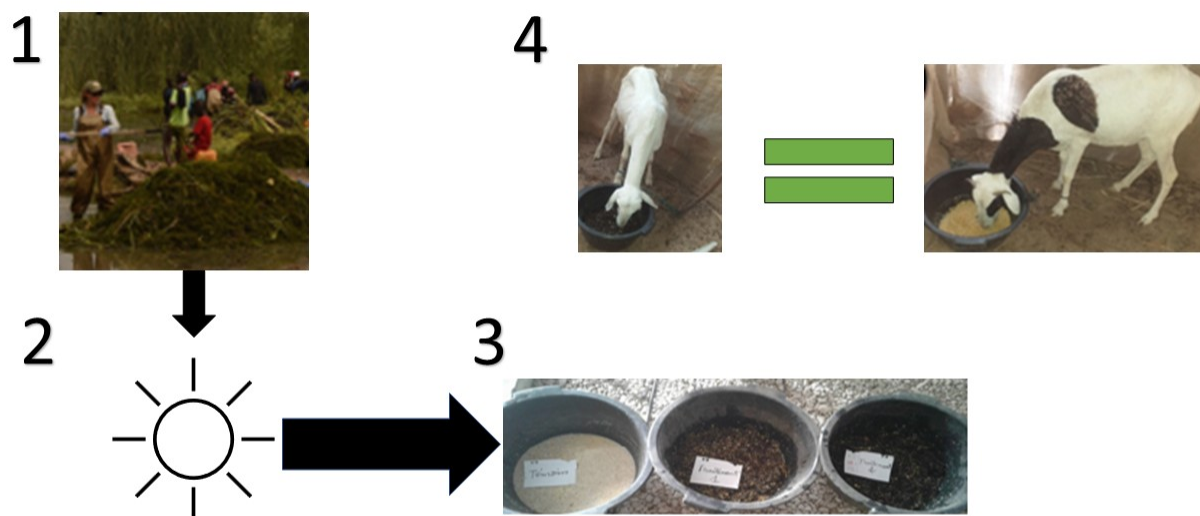
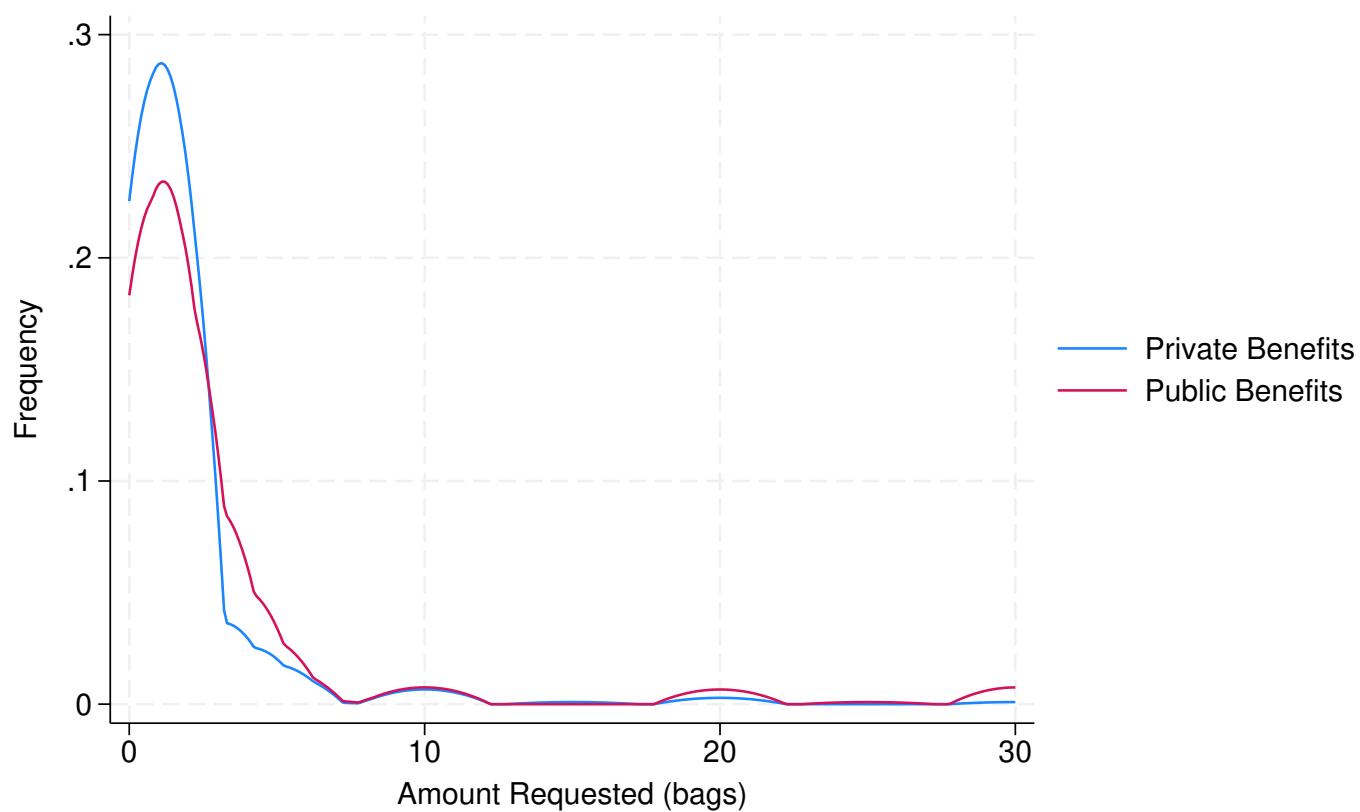


Figure C.3. Poster for the Public Health Benefits Information

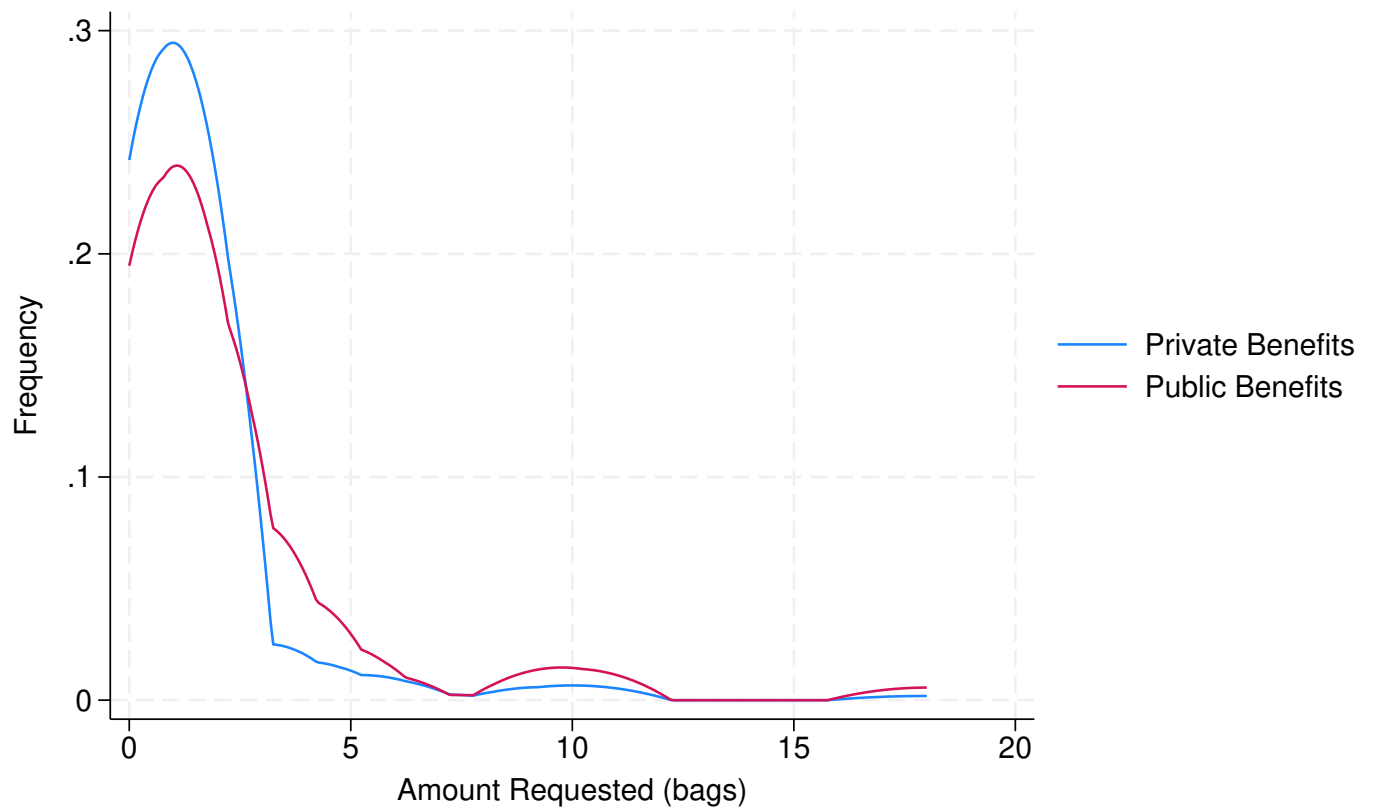


Figure C.4. Histogram of Bags of Compost Requested



Notes: Private represents auctions in the private productivity gains treatment arm. Public represents auctions in the public health benefits treatment arm.

Figure C.5. Histogram of Bags of Animal Feed Requested



Notes: Private represents auctions in the private productivity gains treatment arm. Public represents auctions in the public health benefits treatment arm.

D Appendix Tables

Table D.1. Balance Table

Variable	Private Benefits		Public Benefits		Difference (1)-(2)
	N/[Clusters]	Mean/SE	N/[Clusters]	Mean/SE	
Age	355 [40]	48.394 (0.947)	357 [40]	48.207 (1.041)	0.011
Female	355 [40]	0.527 (0.032)	357 [40]	0.493 (0.029)	0.067
Read French	355 [40]	0.386 (0.037)	357 [40]	0.409 (0.036)	-0.047
Household Size	355 [40]	11.797 (0.355)	357 [40]	11.765 (0.393)	0.005
Children	355 [40]	5.042 (0.195)	357 [40]	5.020 (0.208)	0.007
Raise Livestock	355 [40]	0.890 (0.019)	357 [40]	0.922 (0.018)	-0.108
Grow Crops	355 [40]	0.885 (0.026)	357 [40]	0.868 (0.028)	0.049
Land Owned (Hectares)	349 [40]	2.847 (0.253)	352 [40]	3.065 (0.309)	-0.055
Fertilizer	354 [40]	0.780 (0.038)	355 [40]	0.780 (0.040)	-0.001
Compost	353 [40]	0.300 (0.027)	354 [40]	0.305 (0.023)	-0.010
Health Center	354 [40]	0.653 (0.027)	355 [40]	0.606 (0.030)	0.097
Past Schistosomiasis	355 [40]	0.820 (0.030)	356 [40]	0.806 (0.026)	0.035
Past Deworming	353 [40]	0.887 (0.019)	356 [40]	0.874 (0.018)	0.040
Current Schistosomiasis	343 [40]	0.274 (0.035)	346 [40]	0.257 (0.033)	0.038
Red Urine	345 [40]	0.249 (0.034)	350 [40]	0.249 (0.026)	0.002
F-test of joint significance (F-stat)					0.696

Notes: The value displayed for t-tests are the differences in the means across the groups. The value displayed for the F-test is the F-statistic. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table D.2. Determinants of Total Compost Individual Demand: Other Interactions

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Compost (FCFA)	(3) Total Individual Demand Compost (FCFA)
Public Health Benefits	2521.290*** (819.767)	1185.524 (1011.671)	1200.007 (1143.747)
Land Owned (Hectares)	55.542 (60.105)	-62.598 (54.008)	-62.976 (53.995)
Public Health $\times$ Land Owned (Hectares)	-202.286** (88.765)		
Grow Crops	704.513 (683.187)	239.295 (519.513)	692.954 (682.655)
Raise Livestock	64.745 (615.523)	108.122 (617.110)	-264.440 (654.838)
Public Health $\times$ Grow Crops		862.350 (976.823)	
Public Health $\times$ Raise Livestock			840.206 (1032.221)
Village FE	X	X	X
Stratification FE	X	X	X
Enumerator FE	X	X	X
Observations	700	700	700
Adjusted R^2	0.031	0.028	0.028

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Raise Livestock and Grow Crops are indicator variables that takes the value of one if the participant's household raises livestock or grows crops, respectively. All regressions also include controls for the number of children in the household and their experience with past schistosomiasis infections in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table D.3. Determinants of Total Animal Feed Individual Demand: Other Interactions

	(1) Total Individual Demand Animal Feed (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)	(3) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	534.353 (324.086)	319.101 (282.662)	461.704 (429.471)
Land Owned (Hectares)	-17.341 (26.436)	-6.713 (21.964)	-6.789 (22.017)
Public Health $\times$ Land Owned (Hectares)	18.144 (39.246)		
Grow Crops	285.174 (243.310)	126.275 (291.866)	286.064 (243.523)
Raise Livestock	474.306** (215.908)	477.468** (217.706)	412.225* (224.804)
Public Health $\times$ Grow Crops		303.538 (278.821)	
Public Health $\times$ Raise Livestock			140.482 (393.420)
Village FE	X	X	X
Stratification FE	X	X	X
Enumerator FE	X	X	X
Observations	700	700	700
Adjusted R^2	0.051	0.051	0.051

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Raise Livestock and Grow Crops are indicator variables that takes the value of one if the participant's household raises livestock or grows crops, respectively. All regressions also include controls for the number of children in the household and their experience with past schistosomiasis infections in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table D.4. Determinants of Total Individual Demand: Other Schistosomiasis Measures with Compost

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Compost (FCFA)	(3) Total Individual Demand Compost (FCFA)	(4) Total Individual Demand Compost (FCFA)
Public Health Benefits	1944.123*** (719.782)	1850.182** (709.382)	1843.048** (718.739)	1929.880*** (702.408)
Past Schistosomiasis	1391.925*** (513.905)			
Past Deworming		511.277 (572.169)		
Current Schistosomiasis			295.101 (484.198)	
Red Urine				-485.085 (464.553)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	700	698	680	685
Adjusted R^2	0.029	0.023	0.023	0.026

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household was diagnosed with schistosomiasis. Past Deworming is an indicator variable that takes the value of one if at least one member of the participant's household has ever received deworming medication. Current Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household currently has schistosomiasis while Red Urine is an indicator variable that takes the value of one if at least one member of the participant's household currently has red urine. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, and the number of children in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table D.5. Determinants of Total Individual Demand: Other Schistosomiasis Measures with Animal Feed

	(1)	(2)	(3)	(4)
	Total Individual Demand Animal Feed (FCFA)	Total Individual Demand Animal Feed (FCFA)	Total Individual Demand Animal Feed (FCFA)	Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	586.120** (271.817)	584.448** (263.773)	539.624** (270.558)	575.087** (267.082)
Past Schistosomiasis	119.389 (400.726)			
Past Deworming		-348.931 (526.116)		
Current Schistosomiasis			793.641*** (284.871)	
Red Urine				67.059 (198.334)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	700	698	680	685
Adjusted R^2	0.052	0.054	0.065	0.053

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Schistosomiasis is an indicator variable that takes the value of one if at least on member of the participant's household was diagnosed with schistosomiasis. Past Deworming is an indicator variable that takes the value of one if at least one member of the participant's household has ever received deworming medication. Current Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household currently has schistosomiasis while Red Urine is an indicator variable that takes the value of one if at least one member of the participant's household currently has red urine. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, and the number of children in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table D.6. Determinants of Total Individual Demand: Other Schistosomiasis Measures with Compost with Interactions

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Compost (FCFA)	(3) Total Individual Demand Compost (FCFA)	(4) Total Individual Demand Compost (FCFA)
Public Health Benefits	1162.883 (777.048)	1157.041 (1016.497)	1972.046** (830.678)	2381.031*** (793.097)
Public Health $\times$ Past Schistosomiasis	942.993 (772.445)			
Past Schistosomiasis	906.571** (418.904)			
Public Health $\times$ Past Deworming		781.108 (1020.879)		
Past Deworming		103.105 (724.766)		
Public Health $\times$ Current Schistosomiasis			-505.262 (976.767)	
Current Schistosomiasis			543.220 (402.049)	
Public Health $\times$ Red Urine				-1815.670** (780.650)
Red Urine				446.100 (377.855)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	700	698	680	685
Adjusted R^2	0.028	0.022	0.021	0.028

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household was diagnosed with schistosomiasis. Past Deworming is an indicator variable that takes the value of one if at least one member of the participant's household has ever received deworming medication. Current Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household currently has schistosomiasis while Red Urine is an indicator variable that takes the value of one if at least one member of the participant's household currently has red urine. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, and the number of children in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table D.7. Determinants of Total Individual Demand: Other Schistosomiasis Measures with Animal Feed with Interactions

	(1) Total Individual Demand Animal Feed (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)	(3) Total Individual Demand Animal Feed (FCFA)	(4) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	-275.567 (612.070)	-760.128 (896.752)	522.150* (304.646)	595.853** (283.794)
Public Health $\times$ Past Schistosomiasis	1040.096 (660.069)			
Past Schistosomiasis	-415.945 (673.564)			
Public Health $\times$ Past Deworming		1515.216 (951.805)		
Past Deworming		-1140.715 (957.507)		
Public Health $\times$ Current Schistosomiasis			68.441 (516.663)	
Current Schistosomiasis			760.032* (423.083)	
Public Health $\times$ Red Urine				-83.577 (373.002)
Red Urine				109.922 (225.644)
Village FE	X	X	X	X
Stratification FE	X	X	X	X
Enumerator FE	X	X	X	X
Observations	700	698	680	685
Adjusted R^2	0.057	0.061	0.064	0.051

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Schistosomiasis is an indicator variable that takes the value of one if at least on member of the participant's household was diagnosed with schistosomiasis. Past Deworming is an indicator variable that takes the value of one if at least one member of the participant's household has ever received deworming medication. Current Schistosomiasis is an indicator variable that takes the value of one if at least one member of the participant's household currently has schistosomiasis while Red Urine is an indicator variable that takes the value of one if at least one member of the participant's household currently has red urine. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, and the number of children in the household. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table D.8. Determinants of Total Individual Demand: Past Vegetation Removal Interaction

	(1) Total Individual Demand Compost (FCFA)	(2) Total Individual Demand Animal Feed (FCFA)
Public Health Benefits	1192.015 (1093.758)	415.677 (390.521)
Past Removal	-726.597 (460.792)	39.140 (405.482)
Public Health $\times$ Past Removal	1810.002* (1066.463)	396.985 (535.244)
Village FE		
Stratification FE	X	X
Enumerator FE	X	X
Observations	700	700
Adjusted R^2	0.014	0.007

Notes: Public Health Benefits is an indicator variable that takes the value of one if the participant received the public health benefits information prior to the auctions. Past Removal is an indicator variable that takes the value of one if the village had past aquatic vegetation removal. The regressions also include controls for the amount of land a household owns, whether the household raises livestock or grows crops, the number of children in the household, and the household's past experience with schistosomiasis infection. Standard errors are clustered at village auction level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

E Estimating Shadow Wages

We will estimate a household production function using a generalized Leontief production function where the outcome of interest is the total value of production. We use village level price data to value production of rice, maize, millet, sorghum, cowpea, tomatoes, onions, and peanuts. For cassava, sweet potatoes, yams, carrots, cucumbers, peppers, beans, peas, and lentils, we use the median price per kg reported by households. Inputs into production are the land, measured as the total hectares in production for crops reported in the total value of production, household labor, measured as the total household hours spent on agriculture aggregates the 7-day recall hours for the last 7-days, the planting season, the peak growing season, and the harvest season, the number of hired laborers, fertilizer use including urea, NPK, phosphates, and other chemical fertilizer, the number of pieces of mechanical equipment, livestock ownership measured in tropical livestock units (TLU) to proxy for the amount of manure used on the farm, and indicator variables of if the household uses manure, household waste, or compost on any of their plots. Summary statistics can be found in Table E.1.

We estimated two different functional forms of the production function for households that cultivate crops. Prior to estimation, we demean the data. We first estimate a generalized Leontief production function with the following functional form:

$$y_{ivt} = \sum_i \sum_j \beta_{ij} X_i^{0.5} X_j^{0.5} + \alpha_1 Manure + \alpha_2 Compost + \alpha_3 HHWaste + \gamma_v + \delta_t + \varepsilon_{ivt} \quad (23)$$

where y_{ivt} is the total value of agricultural production for household i in village v at time t , X_i and X_j are vectors of inputs to production that include the hectares in production, household labor hours spent on agriculture, fertilizer use, the number of hired laborers, the livestock holdings of the household, and the number of mechanical agricultural equipment the household owns, $Manure$, $Compost$, and $HHWaste$ are indicator variables if the household uses manure, compost, or household waste on one of its plots, γ_v are village fixed effects, and δ_t are survey wave fixed effects. We estimate this model as a random effects model or using household fixed effects. We impose that when $i = j$, $\beta_{ij} = \beta_{ji}$. We cluster the standard errors at the village level. Given that livestock holdings are not very well correlated with manure use, We estimate these production functions with and with including livestock holdings as a factor of production.

Table E.1. Summary Statistics for Supply Curve Estimation

	Count	Mean	St. Dev.	Min	Max
Cultivate Land (1 = Yes)	4147	0.585	0.493	0	1
Number of Plots	4147	0.801	0.913	0	11
Total Value of Crop Production (FCFA)	4160	1.01e+06	1.79e+06	0	1.04e+07
Hectares in Production	4160	1.893	6.232	0	50
Total Household Hours Spent on Agriculture	4160	144.969	182.286	0	892
Total Fertilizer Used (kgs)	4160	285.439	588.836	0	4000
Number of Plots Collectively Managed (1 = Yes)	2415	0.364	0.744	0	7
Household Grows Rice	2415	0.740	0.813	0	10
Number of Plots that Used Manure	2415	0.361	0.664	0	6
Number of Plots that Used Compost	2415	0.066	0.277	0	3
Number of Plots that Used Household Waste	2415	0.068	0.286	0	3
Has Hired Ag Labor (1 = Yes)	4160	0.124	0.336	0	2
Number of Hired Laborers	4150	0.494	1.955	0	25
Total Number of Pieces of Mechanical Ag Equipment	4160	0.555	1.212	0	25
Livestock Owned (TLU)	4160	2.199	4.738	0	32.3
Household Member Paid Work (1 = Yes)	4154	0.295	0.456	0	1
Daily Wage for Paid Work (FCFA)	1165	2725.448	1938.665	0	6666.667
Household Does Agriculture and Paid Work (1 = Yes)	4160	0.178	0.383	0	1
Household Head Age	4160	54.682	13.066	14	99
Household Head Female (1 = Yes)	4160	0.210	0.407	0	1
Household Head No Education (1 = Yes)	4160	0.782	0.413	0	1
Household Size	4160	8.117	3.682	1	55
Number of Children	4160	3.578	2.362	0	28
Household Grows Rice	2415	0.740	0.813	0	10
Number of Crops Grown	2415	1.379	0.800	1	11
Standardized Asset Index	4160	-0.000	1.000	-2.153	4.883

Notes. This table reports summary statistics for household level data used to estimate a potential supply curves for compost and animal feed.

We then also estimate a generalized quadratic production

$$y_{ivt} = \sum_i \beta_i X_i + \sum_i \sum_j \beta_{ij} X_i X_j + \alpha_1 Manure + \alpha_2 Compost + \alpha_3 HHWaste + \gamma_v + \delta_t + \varepsilon_{ivt} \quad (24)$$

where the variables are defined as before. We then calculate factor elasticities for continuous inputs which can be found in Table E.2. We selected the generalized Leontief production function with TLU and random effects as it produced the most sensible substitution patterns.

Table E.2. Estimated Elasticities

	Land	HH Labor	Fertilizer	TLU	Hired Labor	Equipment
Quadratic, Random Effects	-0.005	0.014	0.162	0.034	0.073	0.172
Leontief, Random Effects	0.145	0.018	0.109	0.037	0.066	0.163
Quadratic, Fixed Effects	-2.238	-0.536	-0.474	-0.854	-0.675	0.218
Leontief, Fixed Effects	0.120	-0.121	0.169	-0.780	5.012	-0.954
Quadratic, Random Effects, No TLU	-0.977	-0.133	-0.223		-0.055	0.006
Leontief, Random Effects, No TLU	0.047	0.027	0.031		-0.278	0.194
Quadratic, Fixed Effects, No TLU	0.237	0.151	0.644		0.014	-0.085
Leontief, Fixed Effects, No TLU	0.853	-0.170	0.525		0.142	0.077

Notes. This table reports estimated factor elasticities for estimated production functions. The specification reports the specification used to calculate the elasticities across the row. Each column represents a different continuous input in the production functions.

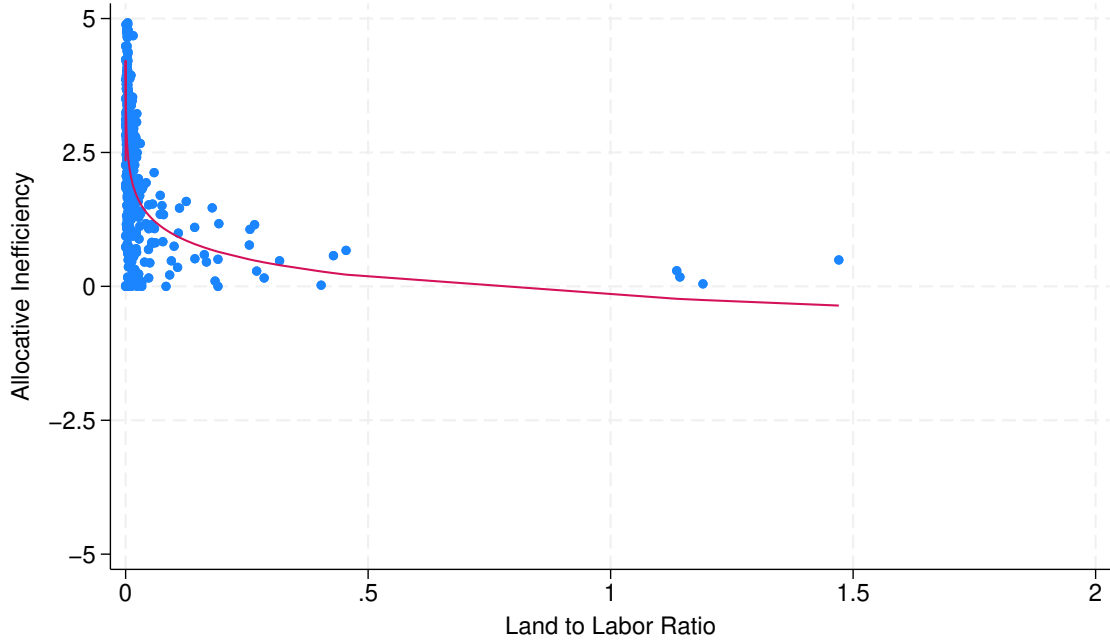


Figure E.1. Plot of the allocative inefficiency changes with the land to labor ratio using the generalized leontief random effects model with TLU as in input.

Table E.3. Factors that Influence Allocative Inefficiency

	(1)
Household Head No Education	-0.040 (0.140)
Household Head Female	0.209 (0.129)
Household Head Age	0.002 (0.030)
Household Head Age ²	-0.000 (0.000)
Household Size	0.048 (0.046)
Household Size ²	-0.000 (0.002)
Number of Children	-0.079 (0.070)
Number of Children ²	0.003 (0.006)
Household Grows Rice	0.086 (0.099)
Number of Crops Grown	-0.077 (0.139)
Number of Crops Grown ²	-0.009 (0.018)
Hectares in Production	-0.191*** (0.026)
Hectares in Production ²	0.003*** (0.001)
Livestock Owned (TLU)	-0.048 (0.036)
Livestock Owned (TLU) ²	0.002* (0.001)
N	473
R^2	0.135

Notes. This table presents the results of generalized quadratic production function estimates for households that cultivate crops. Standard errors clustered at the village level in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.