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Dissemination of food crops with nutritional benefits: Adoption and disadoption of soybeans in Togo and Benin

Kelly J. Wendland and Erin O. Sills

Abstract

To combat high rates of malnutrition in sub-Saharan Africa, the UN Millennium Project has called for increased emphasis on technologies that explicitly link agricultural and nutritional components. While there is a large literature on the factors that influence household decisions to adopt new agricultural technologies with economic or environmental benefits, less is known about the factors that determine the uptake and continued use of agricultural technologies promoted exclusively for their health benefits. Using data from a 2004 survey in the Tamberma region of Togo and Benin, we identify factors that influence the adoption and disadoption of soybeans — a crop being promoted throughout West Africa for its high protein content. Similar to the literature on adoption of other sustainable agriculture technologies, we find that household preferences, resource endowments, and risk and uncertainty affect household decisions about soybeans. However, by analyzing decisions about initial uptake and continued cultivation separately, we uncover the importance of intrahousehold dynamics and experience with the soybean crop. To successfully address malnutrition through new agricultural technologies, researchers and rural extension agents should take a disaggregated view of technology adoption, seeking to identify and tailor their outreach to the different factors important at different stages of the dissemination process.

Keywords: Benin; Nutrition; Soybeans; Technology adoption; Technology disadoption; Togo.

1. Introduction

According to the UN Millennium Project's Task Force on Hunger (2005), 852 million people across the globe suffer from chronic or acute malnourishment.[1] Sub-Saharan Africa accounts for about a quarter of the malnourished, and is the only region in the world where rates are still increasing (UN Millennium Project, 2005). In addition to the morbidity and mortality associated with the disease, malnutrition can result in negative physical outcomes such as inadequate growth, stunting, and wasting, as well as negative impacts on mental development. Malnutrition is also often the underlying cause of death from routine infections and parasites (Unicef, 1998; FAO, 2004; UN Millennium Project, 2005). With the establishment of the Millennium Development Goals (2000), new efforts have been launched to reduce malnutrition, with the ultimate goal of halving hunger by 2015. In the action plan for this target, the UN Millennium Project (2005) recommends an interdisciplinary approach that links agricultural and nutritional interventions, including the promotion of more nutrient- and protein-rich food crops.

To implement this recommendation, policymakers need to understand the factors that encourage uptake and sustained cultivation of nutrient- and protein-rich food crops, since this fundamentally affects the possibility and cost of adding these to rural diets.[2] While there is an extensive literature on the factors that influence the adoption of agricultural and agroforestry technologies promoted for increased productivity or environmental benefits (Feder *et al.*, 1985; Pattanayak *et al.*, 2003; Lee, 2005; Doss, 2006), fewer studies have examined the determinants of growing agricultural technologies promoted exclusively for

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[1] Malnourishment, or malnutrition, refers to deficiencies, excesses or imbalances in energy, protein and other nutrients (FAO, 2003).

[2] We also recognize that it is important to study the consumption of these improved food crops and their impact on nutrition — especially of target populations such as children; however, this study focuses exclusively on understanding the determinants of cultivating these new crops.

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nutritional benefits or considered the reasons for abandonment of such technologies after uptake (Feder and Umali, 1993; Doss, 2006). To help address these research gaps, this article examines the determinants of initial uptake ("adoption") of an agricultural technology promoted for its health benefits and the factors that lead to its continued cultivation or abandonment ("disadoption").

Data for this analysis come from a 2004 cross-sectional household survey on the cultivation and consumption of soybeans in Togo and Benin. Fifteen percent of the population in Benin and 26% of the population in Togo suffers from malnutrition[3] (FAO, 2004). One strategy for addressing protein-energy malnutrition in these countries and throughout West Africa is dissemination of soybeans for household consumption. There is evidence from Nigeria that cultivation and consumption of soybeans contributes positively to child nutrition and household welfare (Owolabi *et al.*, 1996; Sanginga *et al.*, 1999). To date, dissemination efforts in Benin and Togo have focused on education about the health benefits of soybeans and how to process them for human consumption, as opposed to cultivation techniques and associated benefits for soil fertility (IITA, website).

The rest of this paper proceeds as follows. In Section 2 the literature on technology adoption is reviewed and a conceptual framework for the adoption and disadoption of a food crop promoted for its nutritional benefits is developed. Section 3 introduces the study areas and discusses the dissemination process and use of soybeans in the study region. In Section 4 the survey instrument, data and empirical methods are discussed. Section 5 presents the estimation results of the adoption and disadoption models. In Section 6 the paper concludes with a discussion of lessons learned from this analysis and the policy implications of its findings.

2. Background

2.1. Determinants of technology adoption

Understanding the factors that lead to adoption of new agricultural technologies — including new cultivation techniques and new crops such as soybeans — is necessary for targeting technologies appropriately, for designing dissemination strategies and ultimately, for ensuring they have the intended impact (Feder *et al.*, 1985). The large literature on adoption of agricultural technologies has been reviewed by Feder *et al.* (1985), Pattanayak *et al.* (2003), Mercer and Pattanayak (2003), Lee (2005), and Doss (2006). In this section, we: (1) describe the determinants of adoption found in this literature using the categories proposed by Pattanayak *et al.* (2003); (2) highlight key findings from the literature on dissemination and uptake of health technologies including food crops; and (3) review the recent literature on the disadoption process.

A 2003 meta-analysis by Pattanayak *et al.* reviews 120 studies of adoption of agricultural and forestry technologies and draws on household production theory to propose a framework for categorizing adoption determinants. The five broad categories of determinants are household preferences (H), resource endowments (R), market incentives (M), risk and uncertainty (U) and biophysical characteristics (B). H includes variables that measure household specific characteristics such as risk tolerance, innovativeness and household homogeneity. Since many of these factors cannot be measured directly, proxies such as age, gender and education are typically used. R reflects income and wealth. Labour, livestock, savings and asset holdings are commonly used measures. M refers to the market factors that influence the adoption of a new technology, such as prices. These factors are often difficult to measure and vary little in typical cross-sectional surveys, and as a result they are not included in many studies. U includes both short-term risks (rainfall) and long-term risks (tenure insecurity) associated with a new technology, as well as the uncertainty that surrounds an unfamiliar technology. Finally, B are the properties of farm land that impact the production costs and returns of a new technology. Many of these same factors are discussed in the reviews by Feder *et al.* (1985), Mercer and Pattanayak (2003), Lee (2005), and Doss (2006).

Pattanayak *et al.* (2003) go on to select 32 agroforestry studies to estimate the significance of each of these categories to the adoption process. They find that B is significant 80% of the time in these 32 studies, U is significant 72% of the time, R is significant 65% of the time, M is significant 58% of the time, and H is significant 48% of the time. However, these significance levels do not measure the magnitude of the impact of these factors on the adoption decision, and the individual variables significant in any one study are likely to depend on the specific nature of the technology being introduced (Mercer and Pattanayak, 2003).

Turning now to the uptake of food crops for their nutritional advantages, our literature search revealed that most empirical studies have considered crops that combine improvements in nutrition with improvements in farm productivity (e.g., quality protein maize, golden rice, hybrid wheat varieties). In these cases, it is difficult to separate out the effects of yield versus better health on the adoption decision. For example, an assessment of the uptake of modern varieties (MV) of maize in Ghana found that few households were aware of the nutritional advantages of MV's or sought them out when preparing food for children; however, the adoption of MV's was clearly associated with farm-level productivity and income gains (Morris *et al.*, 1999). One example of a crop introduced solely because of its nutritional advantages, not offering any improvements

[3] The average rate of malnutrition in sub-Saharan Africa is 33% and in West Africa, 16%.

in productivity, is orange-fleshed sweet potatoes, which has been promoted in many parts of Africa to increase intake of Vitamin A (Lowe *et al.*, 2001; van Jaarsveld *et al.*, 2001). Using participatory rural appraisal methods, Hagenimana *et al.* (1999) describe how gender and intrahousehold decision-making impact the uptake of this crop. Specifically, since men control land resources in the research area, they play an important role in deciding whether a household cultivates the new crop.

Studies of other types of health technologies (other than food crops) can also help inform models of household decisions to uptake technologies specifically for the prospect of better health. Other technologies that have been studied include improvements in weaning and dietary practices (Onofiok and Nnanyekugo, 1998), water quality and sanitation practices (Feather and Amacher, 1994; Fewtrell and Colford, 2004), and cooking practices (Muneer and Mukhtar Mohamed, 2003). These studies identify variables in R, such as labour and income, and variables in H, such as education and age, as important determinants of adoption (Fewtrell and Colford, 2004). Intrahousehold responsibilities and gender are also identified as critical factors in the uptake of health behaviours in several studies (Munner and Mukhtar Mohamed, 2003; Fewtrell and Colford, 2004). Specific to malnutrition, Lauderdale (2000) finds that female education is one of the largest determinants of malnutrition rates in a household.

Turning to soybeans, the authors are not aware of any previous studies on the determinants of adopting soybeans for their health benefits, but there have been studies on the factors that drive adoption when the crop is promoted for its economic benefits (Ogunsumi and Ewoula, 2005; Ogunsumi *et al.*, 2007), for animal feed (Manuel *et al.*, 2002), for soil improvement (Sanginga, 2003) and as a genetically-modified crop (Hategekimana and Trant, 2002). These studies largely confirm the findings of the meta-analysis by Pattanayak *et al.* (2003): labour and land (measures of R) play large roles in uptake, but education (a component of H) is also important.

Finally, while there has been far less attention to the disadoption process, a few recent studies have modelled the disadoption decision. The overall finding of this nascent literature is that disadoption is influenced by the characteristics of and experiences with the technology itself, in addition to the five categories of determinants described by Pattanayak *et al.* (2003). These studies estimate disadoption models conditional on adoption (Moser and Barrett, 2006; Marenya and Barrett, 2007) or as part of sample selection models (Neill and Lee, 2001), using recall (Neill and Lee, 2001; Moser and Barrett, 2006) or panel (Marenya and Barrett, 2007) data. For example, Neill and Lee (2001) examine the adoption and abandonment of maize-mucuna farming systems in Honduras. They find that limited market access encouraged disadoption and farmers that experienced problems with the noxious weed Rottboellia were also more likely to disadopt. On the other hand, farmers who used the maize-mucuna system for more years, who had employed best management practices such as annual reseeding, and who cultivated more hectares of maize and high-value crops were less likely to disadopt.

Moser and Barrett (2002, 2006) model the diffusion of a high-yielding, low-external input rice intensification system in Madagascar. Estimation results suggest that better-educated farmers (with better understanding of agronomic principles) and those with more access to labour (including less participation in off-farm labour) were more likely to continue with the new system. In addition, farmers who had planted a greater cumulative area under the system were more likely to continue using the new rice system. Marenya and Barrett (2007) model the determinants of adoption and disadoption of soil fertility management practices in Kenya. They find that several variables in the R category, such as farm size, labour and off-farm income, contribute to abandonment of these practices, as do educational attainment and gender of the household head (H variables).

2.2. *Conceptual framework of food crop adoption and disadoption*

While technology adoption is usually defined as a binary variable, there are in fact many gradations of adoption, resulting in different definitions of what constitutes an "adopter" across studies (Doss, 2006). Most studies, as reviewed in Feder *et al.* (1985), Pattanayak *et al.* (2003), and Lee (2005), rely on cross-sectional data and define adoption as whether or not a farmer was employing the technology in the survey year (see Keil *et al.*, 2005, for an exception). However, defining adoption as "use in the survey year" obscures the important distinction between farmers who have never trialled the new technology ("non-adopters") and farmers who trialled the technology and later abandoned it ("disadopters") (Feder and Umali, 1993; Doss, 2006). Thus, in order to consider both adoption and disadoption in this study, we define adoption as ever having implemented the technology and disadoption as having implemented the technology but later abandoned it. In our study, "implementing the technology" means cultivating soybeans, which is a key step on the most likely pathway towards incorporating them into the diet.

The literature review suggests several hypotheses about the determinants of adopting and disadopting food crops promoted for their nutritional benefits. Given that these crops compete for the same land and labour as any other crop, their adoption is expected to be affected by many of the same types of variables highlighted in the meta-analysis of household production models by Pattanayak *et al.* (2003), specifically U, B and R. M may play a smaller role than for agricultural innovations promoted as cash crops. On the other hand, H may be even more important because of the potential impact that gender roles and intrahousehold responsibilities have on family nutrition. This includes elements of H that can be disaggregated by gender, such as education. We write the vector of potential determinants as $z_A = \{H, R, M, U, B\}$, which allows us to test the hypothesis that M is not a significant factor for these technologies.

While disadoption is likely to be impacted by many of the same factors as adoption, the literature review suggests that disadoption will also depend on experience with the crop or technology — including length or extent of experience, as well as management decisions and their interaction with biophysical factors that affect outcomes — which we label E. In general, we expect the same factors to influence the decision to continue planting soybeans in the same direction as in the adoption model. However, U may be less important, because the household has already invested in and learned about the crop and thus can predict utility with and without soybeans more accurately. Thus, for disadoption, we write the vector of potential determinants as $z_D = \{H, R, M, U, B, E\}$, recognizing that M and U may not be important for this decision.

We incorporate these factors into a two-stage random utility framework. In the first stage, we are interested in what drives initial uptake (including trialling and testing) of the new food crop. Farm households have some expected utility from the status-quo (not planting the food crop, Eu_0) and some expected utility from adoption (planting the food crop, Eu_1). If Eu_1 is greater than Eu_0 then the household adopts soybeans (Adopt = 1). However, we only observe the deterministic components of utility and not the stochastic element (e.g., due to missing and mis-measured variables and a random component of utility). Therefore, we model the probability of adoption as:

$$\Pr\{Adopt = 1\} = \Pr\{Eu_1(z_A, \varepsilon_1) > Eu_0(z_A, \varepsilon_0)\} \quad (1)$$

To transform this into an estimating equation, we assume that the expected utilities are additively separable in deterministic and stochastic preferences and that the deterministic part is linear in variables (cf. Mercer and Pattanayak, 2003; Caviglia-Harris, 2003). We can then re-write equation 1 as the difference in the deterministic portions of the expected utilities ($\alpha_A z_A$) and a single error term ($\varepsilon \equiv \varepsilon_0 - \varepsilon_1$):

$$\begin{aligned}\Pr\{Adopt = 1\} &= \Pr\{\alpha_A z_A - \varepsilon > 0\} \\ &= \Pr\{\alpha_A z_A > \varepsilon\} \\ &= F\{\alpha_A z_A\} \qquad (2)\end{aligned}$$

where F is the cumulative distribution function of ε. Conditional on the adoption decision, the probability of continuing to plant soybeans in subsequent years is:

$$\begin{aligned}\Pr\{Continue = 1\} &= \Pr\{\alpha_D z_D - \varepsilon > 0\} \\ &= \Pr\{\alpha_D z_D > \varepsilon\} \\ &= F\{\alpha_D z_D\} \qquad (3)\end{aligned}$$

The final requirement for empirical modelling is an assumption about the distribution of ε. This error is usually assumed to be independently and identically distributed with mean zero. Three common parametric distributions are normal, logistic and Gompertz. We test all three for both adoption and disadoption. Estimation results include the coefficients and marginal effects for each variable in z_A and z_D. These identify the characteristics of households (and their farms) who are most likely to adopt, and among those adopters, the characteristics of households who are most likely to continue planting and not abandon the crop. We expect this to be significantly more informative than the traditional approach of modelling adopters versus non-adopters, in which case the effects of equation 3 and specifically the factors in E cannot be tested.

3. Study area and soybean promotion and use

3.1. Study sites

This study was conducted in the villages of Koudogou, Benin and Warengo, Togo[4] (Figure 1), both located in the Tamberma region. In Warengo, there are approximately 2000 persons living in 213 households (Tanti, personal communication); in Koudogou there are approximately 800 persons living in 116 households (PNUD, 1993; Tanti, personal communication). In the 1990s, there were an estimated 70,000 persons living in the region (PNUD, 1993; AFVP, 1998), 90% of Tamberma ethnicity (also referred to as the Batammariba, Somba or Otammari [UNESCO]).

Geographically, the Tamberma region encompasses approximately 1,300 km^2 of undulating plateau with small hills not exceeding 200 m (PNUD, 1993; AFVP, 1998). Climatically, it is semi-arid and falls between the Guinean and Soudanian zones. There is only one rainy season (May to October), with a mean annual rainfall of 1,000–1,200 mm. The Harmattan season of high winds is December to February. The mean monthly temperature ranges between 29 and 32 degrees Celsius. The soils are classified as Alfisols under the US Soil Taxonomy System. In a 1996 Human-Induced Land Degradation status report by Brabant *et al.* (1996), the soils of the Tamberma region were assigned the worst ranking of "severe land degradation".

The dominant land use in the Tamberma region is for subsistence agriculture. Ninety-eight percent of the population is engaged in agricultural production. Principal food crops include sorghum (*Sorghum bicolor*), millet (*Pennisetum cereale*), maize (*Zea mays*), groundnuts (*Arachis hypogaea*), cowpea (*Vigna unguiculata*) and fonio (*Digitaria exelis*). The majority of fields are planted under a mixed cereal–legume cropping system, usually sorghum or millet and cowpea. In wetter areas, crops also include

[4] The first author served as a Peace Corps Volunteer in Warengo, Togo from 2002 to 2004.

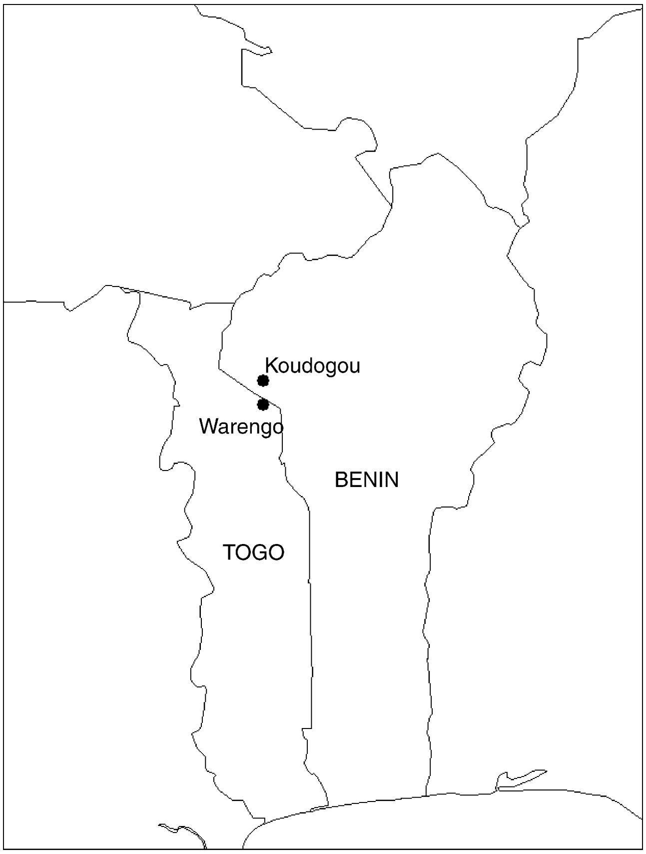

Figure 1. Study sites (indicated by black dots)

Figure 2. Woman planting soybeans in Warengo, Togo

rice (*Oryza sativa* L.), yams (*Dioscorea* spp.) and sweet potatoes (*Ipomoea batatas* (L.) Poir). Cash cropping, especially of cotton, has gained importance in the past two decades (*Gossypium spp.*) (PNUD, 1993; AFVP, 1998). There are distinct gender roles in agricultural production, with women typically farming non-cereal food crops and men farming cereal and cash crops (AFVP, 1998).

In the Tamberma region land tenure is based on ancestral affiliation and is considered the communal property of a clan. It is the responsibility of clan leaders to divide their land up among households, with access to land passing down through patriarchal lineages. Women are forbidden to own land and must ask their husband or some other male in the community for land to cultivate. Historically, land was never sold, but could be used by another clan with permission from the original clan (AFVP, 1998). Today, selling land for monetary profit has become more common.

In addition to the food crops listed above, the typical diet in the Tamberma region includes seasonal vegetables, fruits and local leafy greens. More prized food items include eggs, cheese, dried fish, chicken, guinea fowl, goat and sheep. Livestock is a large part of the Tamberma livelihood, with about 90% of the population engaged in animal husbandry (AFVP, 1998). However, livestock is typically consumed only by men on ceremonial occasions. While malnutrition rates specific to these two villages are not available, a recent report by UNICEF found that the northern regions of Togo (including the Tamberma region) have malnutrition rates significantly higher than the country average (IRIN, 2007). In particular, these northern areas are more likely to have malnutrition rates equivalent to Sahelian countries such as Mali and Niger. While the overall situation in Benin is better then in Togo (IRIN, 2007), one would still expect to find higher malnutrition in the Tamberma region of Benin given its distance from the capital and the biophysical conditions of this area.

3.2. Soybean promotion

Soybeans have been promoted in West Africa as a “miracle crop” because: 1) they are a relatively cheap source of protein compared to other sources in West Africa; 2) large areas of West Africa have soils and climate suitable for soybean cultivation; 3) incidence of pests and disease is low; and 4) the ability of soybeans to fix nitrogen can help address soil fertility problems. Despite these attributes, interest in soybeans by farmers in West Africa has been lower than expected[5] by agencies such as the International Institute for Tropical Agriculture (IITA), one of the primary organizations promoting the crop.

[5] This is not exclusive to the soybean technology, as adoption of most new agricultural technologies in developing countries has been lower than anticipated (Feder *et al*., 1985; Lee, 2005).

Low rates of soybean adoption have been attributed to the fact that there are few markets for soybeans and to lack of knowledge about how to prepare the product for home consumption (Shannon and Kalala, 1994). Outreach programs have been focusing primarily on the latter of these two problems by providing training on how to process soybeans and how to incorporate them into traditional and new food products (FAO, 1997; IITA website). Another possible factor limiting soybean adoption is low productivity due to agronomic constraints. Soybeans can be sensitive to low soil fertility, competition from weeds and inadequate water supply. Soybean growth can also be limited by a lack of micronutrients in the soil and missing rhizobium inoculators. Each of these factors can lead to low productivity of the soybean plant (IITA website), and IITA has developed several new soybean varieties with improved yields that are more tolerant to these abiotic constraints. However, these new varieties are not yet available in rural parts of Togo and Benin.

In the study sites, soybeans have been promoted by missionaries, volunteer organizations, government health centres and non-governmental organizations as a cheap and efficient source of protein. In Warengo, Togo the major promoters of soybeans have been a small French non-governmental organization, TILAPOLTI, and volunteers of the United States Peace Corps. Promotion of soybeans, including periodic education sessions at the community health centre, started in 1996. In Koudogou, Benin, soybeans have been promoted primarily by missionaries and the government health centre, located 5 km from the village. This extension started in the area around 1981.[6] In both sites, soybean promotion has been aimed predominately at women and training has focused on demonstrating how to prepare soybeans for home consumption. Specific food products include porridge, gruel, soy cheese and soy milk.

3.3. Soybean cultivation patterns and use in the study region

According to the survey, most (66%) households in the study region who had cultivated soybeans were intercropping them with other crops such as corn and sorghum. This is similar to the mixed cereal–legume system traditionally found in the area and suggests that soybeans are being planted in place of cowpeas in these fields. The majority of households in this study (68%) reported that women were in charge of growing soybeans. Less than 3% of households reported that men were in charge of cultivating the soybean crop, and about 29% reported that women with the help of men and/or children cultivated the crop.[7] This confirms that soybeans are predominately a “women’s crop” in the study region. We also asked questions about soybean use in the area. Most households (73%) reported using their harvested soybean for home consumption, while less than 5% of households reported selling their soybeans.[8] Of those that consume soybean, 90% use it for a popular fermented spice[9] traditionally added to sauces in the region; only 13% of households reported using soybeans to make other food products.

4. Data and methods

4.1. Household survey

In 2004, 135 of the 329 households in Koudogou, Benin and Warengo, Togo were surveyed. A sampling frame for each village was obtained from the local health centre; these lists of households had been established by the World Health Organization’s River Blindness Eradication Campaign and were updated annually. A random stratified sample of 96 households in Warengo and 39 households in Koudogou were selected, with a predetermined geographic rule of replacement used for households that could not be interviewed.[10]

The survey instrument was designed to elicit information on household[11] demographics and livelihoods, cultivation and use of soybeans, and the determinants of technology adoption as identified in Pattanayak *et al.* (2003), with the addition of variables characterizing the household’s experience with soybeans (E). This additional category was used to gather information on the soybean cultivation practices of adopters, such as area planted and cultivation problems. Based on experience in the region, it seems reasonable to assume that observable characteristics of the households and their land have not changed significantly and certainly not as a result of soybean cultivation. Thus, the survey elicits recall information on E, but current information on all other factors.

Face-to-face interviews were conducted by the primary author with the aid of a local-language translator from each village.[12] The preferred survey respondent was the female

[6] The missionaries in Boukoumbe had visited villages (including the study site Koudogou) around the area since 1981; however, they did not have a list of which villages were visited in each year.

[7] This result may be biased upward due to the fact that some of the surveys were conducted with men present or just with men.

[8] The rest of the sample reported not harvesting enough to consume or sell.

[9] It is interesting to note that in the soybean extension sessions women were not taught how to prepare this fermented spice; instead, women already know how to prepare this spice in the study area, as it is commonly prepared from the seeds of the tree species, *Parkia Biglobosa*.

[10] Only one household refused to respond to the survey; 11 had to be replaced due to prolonged absence.

[11] A farm household was defined as those who ‘eat out of the same pot,’ since those who eat together are also the same people who raise the food, or farm, together in this society.

[12] Time per interview ranged from 15 to 50 minutes, with an average time of 26 minutes.

head of household since soybean extension efforts are aimed predominately at women. However, if both female and male heads of household were present, for cultural reasons, both participated in the survey process, and for a small portion of the surveys only men were present.[13]

4.2. Model specification

The household survey provides a rich database from which to select explanatory variables representing the factors in equations 2 and 3 of the conceptual framework. Table 1 defines the variables selected, and provides means, and standard deviations for the overall sample. The components of z_A and z_D are as follows:

H = FEMALE EDUCATION, MALE EDUCATION
R = LABOUR, COTTON, BIKE, RADIO, CREDIT, LAND, HEALTH
M = PRICE BELIEFS
U = COMMUNITY, EXTENSION, MEMBER
B = SLOPE
E = EXTENT, NUMBER OF YEARS, SOIL TYPE, SOY PROBLEMS

These specific variables were chosen based on previous empirical studies, item response rates, and personal experience in the study area. The expected effects of these variables on adoption and continued cultivation, i.e., the expected signs of their coefficients, are given in Table 2.

4.3. Econometric analyses

As a first step, we calculate descriptive statistics and test for differences in means across adopters versus non-adopters and continued adopters versus disadopters. We next estimate multivariate models. For dependent variables that are binary choices, the most common parametric models are logit and probit, based on the assumptions of logistic and normal distributions of the difference in errors (ε) in equations 2 and 3. Both of these distributions are symmetric around zero, and for small samples, the estimation results should be essentially the same (Maddala, 1983; Ayuk, 1997). Other distributions, such as the Gompertz, are also possible for binary response models (i.e., the gompit model) (Johnson *et al.*, 1995). In this paper, estimation results for probit models are presented. The marginal effects for the logit and gompit are similar and are therefore not reported.

Since soybean extension could be endogenous to the adoption decision, we tested for selection bias using a "treatment effects" model (Ettner, 2004). We were able to reject the null hypothesis that soybean extension was endogenous using this model,[14] and we therefore present results from the standard probit model. In the disadoption model, clearly the E variables could be endogenous, but we were not able to directly test or control for this endogeneity because that dataset does not contain any potential instruments. Thus, we present the results from the full probit model and a reduced model excluding the E variables and compare results.

In the probit model, the magnitudes of the significant coefficients have little interpretive value. However, the signs on the coefficient indicate whether a particular variable has a negative or positive influence on the household decision. Marginal effects indicate how much the probability of the household decision (initial or continued adoption) would change if that particular variable underwent a one-unit change — an interpretation dependent on the unit of measurement. For the continuous variables, these marginal effects are the coefficients multiplied by a scale factor calculated at the means of z_A or $z_D(\phi(\alpha z))$. We report the coefficients, probability values and marginal effects below, taking probability values of 10% or less to indicate statistical significance.

5. Empirical results

5.1. Differences in means

The third and fourth columns in Table 3 identify statistical similarities and differences between adopters and non-adopters of the soybean technology based on the two tailed t-test. Adopters ($N = 73$ households[15]) are those households who had ever cultivated soybeans prior to the 2004 survey — not just in the survey year — and non-adopters ($N = 62$) are those households that never attempted to grow the crop. Household size (labour) and education levels of male and female heads of household are statistically identical. Adopters own more assets, farm more land, are more likely to farm cotton and are more likely to participate in credit groups than non-adopters. Hospital treatment (a proxy for poor health) is higher for adopters. Adopters and non-adopters have similar price beliefs about soybeans. Under the category of risk and uncertainty, adopters are more likely to be involved in an organization and to have

[13] Because men may know less about soybean dissemination and cultivation, we estimated the models presented in section 5 with the full sample and after dropping the "men-only" interviews. Results were robust to inclusion of men-only interviews, so we report results from the full sample.

[14] To test for endogeneity of the soybean extension variable we used a biprobit model. In the testing model we regressed soybean extension on distance to the local health centre, female education, male education, labour, cotton, bike, radio, credit, land, health, price beliefs, community, member, and soil quality. We were not able to reject the null hypothesis that soybean extension was exogenous to soybean adoption.

[15] This adoption rate is high relative to many previous studies that have defined adoption as use in the study year. It is important to remember that our study measures adoption as ever having cultivated the crop, and that we label use in the study year as "continued cultivation".

Table 1. Description of study variables

Category	Variable	Definition	Mean (S.D.)
	SOYBEANS	The dependent variable in the adoption model: 1 if household had cultivated soybeans at some time prior to the survey date, 0 otherwise.	0.541 (0.500)
	CONTINUE	The dependent variable in the disadoption model: 1 if household was cultivating soybeans as of the survey date, 0 otherwise.	0.712[a] (0.456)
H	FEMALE EDUCATION	Dummy variable for education of female heads of household: 1 if any education, 0 otherwise.	0.419 (0.487)
H	MALE EDUCATION	Dummy variable for education of male head of household: 1 if any education, 0 otherwise.	0.526 (0.482)
R	LABOUR	Total number of household members.	6.252 (2.509)
R	COTTON	Dummy variable for cotton farmer: 1 if household farmed cotton in previous year, 0 otherwise.	0.607 (0.490)
R	BIKE	Dummy variable for bicycle: 1 if household owns at least one bike, 0 otherwise.	0.600 (0.492)
R	RADIO	Dummy variable for radio: 1 if household owns at least one radio, 0 otherwise.	0.452 (0.450)
R	CREDIT	Dummy variable for participating in a formal or informal credit system: 1 if participate, 0 otherwise.	0.141 (0.349)
R	LAND	Number of parcels a household farmed in the previous year.	4.985 (1.583)
R	HEALTH	Dummy variable for having been treated at a hospital (not just the local health centre) in past year: 1 if had been treated, 0 otherwise.	0.504 (0.502)
M	PRICE BELIEF	Stated price for a bowl of soybeans in local market (USD).	1.156 (0.500)
U	COMMUNITY	Dummy variable for village: 1 represents the village of Warengo, Togo, 0 the village of Koudogou, Benin.	0.711 (0.455)
U	MEMBER	Dummy variable for membership in an organization: 1 if involved in an organization,[16] 0 otherwise.	0.289 (0.455)
U	EXTENSION	Dummy variable for having received soy education: 1 if received, 0 otherwise.	0.289 (0.455)
B	SLOPE	Average reported slope for a household's agricultural land, ranging from 0 if all fields are flat to 1 if all fields are hilly.	0.132 (0.147)
E	EXTENT	Dummy variable for area of soybeans cultivated: 1 if greater than mean of 1.25 ha, 0 if less.	0.521[a] (0.503)
E	YEARS SOY	Dummy variable for number of years soybeans were cultivated: 1 if greater than 1 year, 0 if just one year.[17]	0.479[a] (0.503)
E	SOIL TYPE	Dummy variable for type of soil where soybeans were grown: 1 if clayey soil, 0 otherwise.[18]	0.151[a] (0.360)
E	SOY PROBLEMS	Discrete variable for whether household experienced soybean problem: 0 if no, 1 if experienced one type of problem, 2 if experienced two or more problems.[19]	0.452[a] (0.578)

Note: [a] Indicates N = 73.

received soybean extension than non-adopters. Both groups report similar slopes on their agricultural fields.

The sixth and seventh columns in Table 3 present statistical similarities and differences between continued adopters (N = 52) — defined as those households that were still planting soybeans as of the survey year — and disadopters of the soybean technology (N = 21) based on two-tailed t-tests.[20] As expected, there are more statistical similarities between these two groups than between adopters and non-adopters. Education levels, household size, credit use, price beliefs and slope, among other variables, are all statistically similar for the two groups.

[16] This includes formal organizations such as the cotton cooperative or school board, as well as informal organizations, for example a women's soap-making group.

[17] This variable had a limited range, with most households having only cultivated the crop for 1, 2, or 3 years. We therefore chose to group respondents into households with just 1 year of experience and households with more than 1 year.

[18] The other category represents what we refer to as "sandy" soils. Experience in the region suggests that (1) most households have at least some clay and some sandy soils on their land, and (2) soybeans tend to grow better on "sandy" soils. Thus, planting soybeans on one versus the other is considered part of the farmer's "experience" with cultivating the new crop rather than a biophysical resource constraint.

[19] The survey asked about five specific problems (plant never sprouted, plant didn't produce any grain, plant produced low yield, livestock ate plant, rains were late) and also queried whether the households experienced any additional problems with soybeans.

[20] Only households that initially adopted soybeans (N = 73) are included in this sample.

Table 2. Expected signs

Category	Variable Name	Expected Sign Adoption Model[a]	Expected Sign Continued Use Model[b]
H	FEMALE EDUCATION	+	+
H	MALE EDUCATION	+	+
R	LABOUR	+	+
R	COTTON	–	–
R	BIKE	+	+
R	RADIO	+	+
R	CREDIT	+	+
R	LAND	+	+
R	HEALTH	–	–
M	PRICE BELIEFS	+	+
U	COMMUNITY	–	–
U	MEMBER	+	+
U	EXTENSION	+	+
B	SLOPE	–	–
E	EXTENT		+
E	YEARS SOY		+
E	SOIL TYPE		–
E	SOY PROBLEMS		–

Notes: [a] Where + means that variable is expected to be positively correlated with probability of adoption.
[b] Where + means that variable is expected to be positively correlated with probability of continued use (i.e., negatively associated with probability of disadoption).

The amount of land farmed is higher for continued adopters versus disadopters.

For the variables reflecting soybean experience (E), disadopters are more likely to report problems cultivating soybeans than continued adopters, but this difference is not statistically significant. Two of the most commonly reported soybean problems are that the soybean grain was eaten by livestock before harvesting and that the seed planted did not produce abundant grain. The extent of soybeans grown in the last year of cultivation is statistically different between continued adopters and disadopters, as is the number of years the household has been growing soybeans.

5.2. Adoption/non-adoption model

In Table 4 we present our results from the probit model. The estimated model fits the data reasonably well, with the adoption status of 79% of respondents predicted correctly.

From H, MALE EDUCATION is statistically significant at the 5% level. If the male head of household has at least some education the probability of adopting soybeans increases by 33%. The marginal effect of FEMALE EDUCATION is also positive, but is not statistically significant. These results are consistent with the literature on the role of education in the adoption of new technologies, which posits that education level influences a person's allocative and technical efficiency, thus positively influencing the adoption decision (Welch, 1979; Jamison and Lau, 1982).

Under R, LAND is significant and has the expected positive effect, increasing the likelihood of adoption by 10%. This finding is consistent with the literature on technology adoption that posits that resource constraints play an important role in whether a household uptakes a technology. We do not find that any of our measures of wealth or income (e.g., bike, radio, cotton, credit) have a significant influence on adoption; this may reflect the fact that soybeans require almost no upfront costs since seed is typically subsidized by the extension program and inputs such as inorganic fertilizer are not typically used on soybeans. Measures of labour and health have the expected signs, but are insignificant.

Table 3. Characteristics of adopters versus non-adopters and continued adopters versus disadopters

Category	Variable	Adopters (N = 73)	Non-Adopters (N = 62)	T-test[a]	Continued Adopters (N = 52)	Disadopters (N = 21)	T-test[a]
H	FEMALE EDUCATION	0.42	0.40	0.946	0.47	0.30	0.197
H	MALE EDUCATION	0.57	0.48	0.198	0.59	0.55	0.761
R	LABOUR	6.49	5.98	0.227	6.38	6.76	0.520
R	COTTON	0.52	0.71	0.025**	0.52	0.52	0.972
R	BIKE	71.2	46.8	0.004***	76.9	57.1	0.093*
R	RADIO	60.3	27.4	0.000***	61.5	57.1	0.730
R	CREDIT	0.19	0.08	0.065*	0.21	0.14	0.506
R	LAND	5.29	4.63	0.016**	5.56	4.62	0.006***
R	HEALTH	0.58	0.42	0.072*	0.60	0.52	0.578
M	PRICE BELIEFS	1.17	1.14	0.667	1.22	1.05	0.173
U	MEMBER	0.38	0.18	0.008***	0.40	0.34	0.581
U	EXTENSION	0.40	0.16	0.002***	0.39	0.43	0.731
B	SLOPE	0.127	0.137	0.696	0.136	0.106	0.434
E	EXTENT				0.60	0.34	0.043**
E	YEARS SOY				0.56	0.30	0.036**
E	SOIL TYPE				0.12	0.24	0.200
E	SOY PROBLEMS				0.40	0.57	0.265

Notes: [a] We report significance level here based on two-sided t-tests, where * indicates significance at the 10% level, ** at 5%, and *** at 1%.

Table 4. Probit regression of the probability of adoption

Category	Variable	Coefficient	P-value[a]	Marginal effects
H	FEMALE EDUCATION	0.431	0.152	0.169
H	MALE EDUCATION	0.835	0.012**	0.327
R	LABOUR	0.030	0.642	0.012
R	COTTON	−0.255	0.522	−0.099
R	BIKE	−0.157	0.617	−0.061
R	RADIO	0.490	0.106	0.189
R	CREDIT	0.157	0.727	0.061
R	LAND	0.262	0.032**	0.103
R	HEALTH	−0.478	0.134	−0.186
M	PRICE BELIEFS	0.002	0.994	0.001
U	COMMUNITY	−2.384	0.000***	−0.662
U	MEMBER	0.328	0.366	0.126
U	EXTENSION	0.734	0.023**	0.271
B	SLOPE	−1.263	0.230	−0.495
	Constant	−0.118	0.859	
	N	135		
	Log likelihood	−57.627		
	LR chi2	71.00		
	Prob>chi2	0.000		
	% Correctly Predicted	79		

Notes: [a] Where * indicates significance at the 10% level, ** at 5%, and *** at 1%.

Under U, COMMUNITY is strongly significant with a negative effect on adoption. This indicates that farmers who live in Togo are less likely to adopt soybeans than farmers who live in Benin — with an estimated marginal effect of –66%. This dummy variable captures unmeasured and unobservable differences between the two study sites.[21] Under U, we also find that the EXTENSION variable is significant and has a positive effect on the decision to adopt soybeans, with a marginal effect of 27%. Extension has been shown repeatedly to have a positive influence on adoption in prior studies (Jamison and Lau, 1982; Feder and Slade, 1984; Jamison and Moock, 1984; Rahm and Huffman, 1984; Baidu-Forson, 1999; Marra *et al.*, 2003; Pattanayak *et al.*, 2003), in part because information helps reduce uncertainty. The MEMBER variable is not significant.

The M variable, PRICE BELIEFS, and the B variable, SLOPE, are both insignificant in the adoption model.

5.3. *Continued use/disadoption model*

The continued use/disadoption model was constructed by adding variables measuring the household's experience with the soybean technology (E) to the adoption model. Given the potential multicollinearity problems between the four E variables (Section 4.2) we ran auxiliary regressions to test for this problem. We detected severe multicollinearity problems between SOY PROBLEMS and YEARS SOY. Therefore, the model reported below has the 14 variables from the original adoption model, to facilitate comparison with Table 4, plus EXTENT, YEARS SOY, and SOIL TYPE to test the significance of the E category to the disadoption decision.[22]

As shown in the full probit results in Table 5, there are some important differences in the variables that affect continued cultivation of soybeans, as compared to initial adoption. Under H, FEMALE EDUCATION has a significant and positive effect on the probability of continuing to cultivate soybeans. The variable has a marginal effect of 33%. Thus, education is a significant factor in both adoption and continued cultivation of soybeans, similar to Moser and Barrett's (2002, 2006) findings. However, while men's education affects the probability of adopting soybeans, only women's education significantly reduces the probability of disadoption.

Under resource endowments (R) the LAND variable is again highly significant, with a positive marginal effect of 22%. Similar to the adoption model, having more land resources is associated with the continued use of this technology. This is consistent with findings from other disadoption studies. RADIO, BIKE, COTTON, CREDIT and HEALTH continue to be insignificant to the disadoption

[21] Since these two villages were in different countries, they were subject to different political and institutional structures which could have affected access to the soybean technology. One example of how these (political and institutional) differences could have affected access is through the amount of development aid received by each country and how it was spent (Siegle *et al.*, 2004; Kosack, 2005).

[22] We chose to drop SOY PROBLEMS versus YEARS SOY because in all specifications, SOY PROBLEMS was highly insignificant (>0.8 p-value).

Table 5. Probit regression of the probability of continued use

Category	Variable	Full Probit Model			Probit Model Excluding E Variables		
		Coefficient	P-value[a]	Marginal Effect	Coefficient	P-value[a]	Marginal Effect
H	FEMALE EDUCATION	1.317	0.017**	0.324	0.836	0.057*	0.256
H	MALE EDUCATION	−0.649	0.327	−0.159	0.012	0.981	0.003
R	LABOUR	−0.069	0.513	−0.016	−0.040	0.639	−0.012
R	COTTON	−1.278	0.134	−0.306	−1.032	0.117	−0.305
R	BIKE	0.665	0.213	0.185	0.494	0.241	0.162
R	RADIO	−0.941	0.149	−0.210	−0.124	0.761	−0.037
R	CREDIT	0.470	0.478	0.099	0.444	0.426	0.122
R	LAND	0.898	0.006***	0.221	0.547	0.004***	0.167
R	HEALTH	−0.106	0.853	−0.026	−0.046	0.919	−0.014
M	PRICE BELIEFS	0.496	0.419	0.122	0.799	0.154	0.245
U	COMMUNITY	0.669	0.428	0.166	−0.023	0.969	−0.007
U	MEMBER	0.439	0.419	0.103	0.436	0.325	0.128
U	EXTENSION	−0.225	0.693	−0.057	−0.374	0.401	−0.117
B	SLOPE	−0.326	0.834	−0.080	−0.962	0.498	−0.295
E	EXTENT	1.052	0.040**	0.263			
E	YEARS SOY	1.347	0.020**	0.321			
E	SOIL TYPE	−1.128	0.111	−0.365			
	Constant	−4.758	0.008***		−2.934	0.015**	
	N	73			73		
	Log likelihood	−25.227			−33.221		
	LR chi2	37.15			21.16		
	Prob>chi2	0.003			0.096		
	% Correctly Predicted	79			79		

Note: [a] Where * indicates significance at the 10% level, ** at 5%, and *** at 1%.

model at the 10% level. None of the variables in M, U, or B are statistically significant to the disadoption model.

Under the category of soybean experience (E), EXTENT has a positive effect on continued cultivation of soybeans, with a marginal effect of 26%. Likewise, YEARS SOY is positive and statistically significant with the continued adoption decision. Cultivating soybeans for one additional year increases the probability of continuing to adopt by 32%. These two variables are likely to indicate households that have gained more experience and confidence in the technology, this is similar to what Neill and Lee (2001) and Moser and Barrett (2002, 2006) find in their disadoption analyses. The estimated coefficient on SOIL TYPE is negative, indicating that farmers who cultivate soybeans on sandy soil are more likely to continue planting soybeans, but this variable is not significant at conventional levels.

Results from the probit model that exclude the E variables are also reported in Table 5. These results show that FEMALE EDUCATION and LAND are robust to these different specifications. Both variables contribute significantly to whether or not a household continues to cultivate the soybean crop.

6. Discussion and conclusion

This analysis of adoption and disadoption determinants provides insight on the factors that influence the cultivation of food crops promoted for their nutritional benefits in West Africa. First, many of the categories of determinants found in the sustainable agriculture and agroforestry technology adoption literature (Feder *et al.*, 1985; Pattanayak *et al.*, 2003; Lee, 2005; Doss *et al.*, 2006) are also significant indicators of adoption and continued use of soybeans for nutritional reasons. The determinants of adoption include variables from three of the categories proposed by Pattanayak *et al.* (2003): H, R and U. In the decision to continue using the technology, H and R remain important, along with measures of E. We find that the signs of specific variables significant in these decisions — such as education, information and land resources — are consistent with the current literature on agricultural technology adoption. Of particular importance is the fact that land resources (LAND) is significant in the adoption and continued adoption decisions, highlighting that food crops promoted for nutritional benefits face the same resource constraints as other types of agricultural technologies.

Atypical of the literature on technology adoption, we do not find that M and B are significant in the adoption or disadoption decisions, and U is not significant in the decision to continue using the technology. There are several possible explanations. First, as in many adoption studies, the proxies that we use to represent market incentives and biophysical characteristics may not effectively capture the influence of these factors on soybean decisions — real market prices and biophysical measurements of slope, or additional information on other biophysical factors such as soil quality, would provide more objective and precise measures of the variables in this category. Unfortunately, these more precise estimates were not feasible in this case because there was no price variation in soybeans within the study region and we did not have the necessary resources to measure slope or to test soil samples. Second, as hypothesized, the category of market incentives may not be significant because there is not currently a significant market for soybeans in the study area. Thus, we expect the decision to grow soybeans to be based more on perceived health returns than on potential income. Risk and uncertainty (U) may not be a factor in the disadoption decision because, as hypothesized, the household has already invested in and learned about the technology.

The second conclusion of this analysis is that in addition to the categories proposed by the adoption literature there are other variables important for understanding disadoption. As seen in this analysis, the household's experience with soybean cultivation is important to this decision process. Specifically, we find that households that had been cultivating soybeans for more years (YEARS SOY) and on more land (EXTENT) are more likely to continue growing the crop. This is similar to the findings in Neill and Lee (2001) and Moser and Barrett (2002, 2006). These two variables can be considered proxies for knowledge about soybeans acquired by trialling the crop. Surprisingly, we do not find that problems cultivating the new crop[23] or soil type (SOILSOY), a proxy for yield since clay soils are less suitable for soybeans in the study area, influence the disadoption decision.

A third lesson is the importance of intrahousehold responsibilities and gender. Of particular interest is the fact that men's education is significant in the adoption but not the disadoption decision, whereas women's education is significant in the disadoption but not the adoption decision. This is consistent with the tenure system in the region, where men alone decide on agricultural land use and have responsibility for cultivation of cash crops, while women are responsible for cultivation of non-cereal food crops. Since men control access to land, their education level is important for the adoption decision. Higher levels of education may mean that they are more likely to understand the health benefits of new crops or more likely to experiment with new technologies. However, since it is the responsibility of women to grow the non-cereal food crops (and to feed the family), their education is critically important for learning how to cultivate and prepare new crops. Further, the women decide whether it is worthwhile to continue to grow new crops in their non-cereal mix in future years. This suggests that adoption of food crops promoted for health benefits depends on the compatibility of dissemination efforts with traditional intrahousehold responsibilities and dynamics.

There are at least three major implications of these results. First, our findings suggest that dissemination strategies should identify the decision-maker at different stages in the adoption cycle. It is widely recognized that women are important decision-makers for nutritional technologies (Onofiok and Nnanyelugo, 1998; Johnson-Welch, 1999). However, where men make decisions about land allocation, their understanding of a new technology can also be critical. This finding supports the qualitative results from Hagenimana *et al.* (1999) on uptake of orange-fleshed sweet potatoes in Africa. In that study, it was found that since men make decisions related to land allocation they wield significant influence over "women's crops" and their promotion. Thus, dissemination strategies for nutritional crops in areas where land is controlled by men should not focus exclusively on women or men, but educate them both about the nutritional advantages, as well as other potential advantages (e.g., soil fertility in the case of soybeans), of these new crops. Of course, where tenure arrangements differ from those in this study, different intrahousehold and gender dynamics may need to be considered. An additional concern for the dissemination of nutritional technologies where men decide land allocation is that when these food crops combine nutritional improvements with income generation opportunities, they are likely to run the risk of becoming "men's crops". This was experienced with sweet potatoes in Kenya (Hagenimana *et al.*, 1999) and could easily become an issue with a crop like soybean if markets expand into rural areas, which is the case in some other parts of West Africa (Ogunsumi and Ewoula, 2005; Ogunsumi *et al.*, 2007).

Second, this study highlights the importance of understanding the various stages of dissemination of a new technology, including both initial uptake and trialling (adoption) and the decision whether to continue cultivating or abandon a new crop (disadoption). Adoption and disadoption decisions can be affected by different factors, and technology dissemination and rural nutritional strategies need to consider all of these factors. To obtain lasting impacts from nutritional technologies or any type of new technology, we cannot focus exclusively on the factors that drive the adoption decision but must also consider what encourages households to stick with the new technology after the initial promotion effort. One difficulty in studying this phenomenon is that many of the measurements of farmers' experiences with a new technology (E) are predetermined but may still be endogenous to the disadoption decision, complicating econometric estimation. In this study, we did not have exclusion restrictions that would allow us to estimate a treatment effects model to account for the endogeneity of the E variables. Instead, we estimate the model with and without these E variables to evaluate the robustness of our results. Future research on this topic would benefit from larger sample sizes to estimate systems

[23] This is omitted from the model presented here due to multicollinearity, but when it is included as sole measure of E, it is not statistically significant.

of equations, and from panel data on adoption decisions across time.

Finally, we recognize that uptake of soybean cultivation is only one step towards addressing protein malnutrition in the region. While survey responses indicate that a significant proportion of households cultivating the soybean crop were preparing food products, we do not have information on the contribution of these prepared products to protein intake in the area, particularly for children. Determining who is actually consuming what quantities of soybean products is an important next step in evaluating the health benefit of soybeans in rural parts of West Africa.

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