FACTORS AFFECTING THE ADOPTION OF IMPROVED SORGHUM VARIETIES AMONG FARM HOUSEHOLDS IN NORTHWEST GHANA: A PROBIT ANALYSIS

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ABSTRACT

In an attempt to boost sorghum production, the Savannah Agricultural Research Institute in Ghana, over the years, has released a number of improved sorghum varieties to farmers in northern Ghana. The purpose of this study was to estimate the level of adoption, and to identify the factors that influenced the adoption of the improved sorghum varieties, using a probit model. It was found that age, available family labour, non-farm income, farmers' perception about the varieties, farm size and farm type positively influenced adoption while frequency of extension visits, the length of the fallow period and distance to the nearest purchase point of improved seed affected adoption negatively. Farmers' choice of variety to plant depended on yield, maturity period, market value, taste and suitability for local dishes. Although the estimated level of adoption was 40% of the sample, the estimated area under the improved sorghum varieties was only 0.1% of sorghum area. For increased adoption of improved Sorghum varieties, the study recommends the following measures: (i) strengthening of research-extension-farmer linkages, (ii) intensified farmer education about the varieties, (iii) improvement in infrastructure and input distribution networks, (iv) active involvement of farmers in acquisition of inputs, (v) more sensitivity of research to farmer resource levels, (vi) empowering farmers to engage in non-farm income generating activities and (vii) a more concerted effort at technology transfer.

Keywords: Probit model; Sorghum varieties; Adoption; Northwest Ghana

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INTRODUCTION

Sorghum (*Sorghum bicolor (L) Moench*) commonly called 'guinea corn' in West Africa is an important food crop with multiple uses in the Savannah Zone of the region. In Ghana, sorghum is an important and widely cultivated cereal crop in the Guinea Savannah Zone. It is also grown, to a limited extent, in the Forest-Savannah Transition Zone and the Coastal Savannah Zone. Traditionally, sorghum is grown as a rain-fed crop in mixtures with other cereals and legumes but pure strands of the crop are common. Its production means almost everything to the mainly rural resource-poor farmers, who use little or no external input such as improved seed and chemical fertilizers. As a source of food, the grain is used, mainly, in preparing *koko* [13], *tuo zaafi* [14] (TZ) and *maasa* [15]. The crop has a potential use in the brewery industry in Ghana. For now, it is processed into malt for brewing a local beer called *pito* [16], which is widely consumed in Northern Ghana. The leaves provide fodder for farm animals while the stalks are used in fencing and roofing, as fuel wood and for weaving baskets and mats. In addition, the ash from burnt sorghum stalks provides potash for soap making, a cottage industry for some rural women (Songsore and Denkabe, 1995). It is clear from the above that this crop has a potential of contributing to livelihood improvement in the production areas.

However, the sorghum crop yields tend to be unacceptably low. Depending on the year, average yields range between from 0.6 Mt/ha to 1.4 Mt/ha in the Upper West Region; these yields are rather low as compared to the achievable yield of 2 Mt/Ha (Abatania 1998), in farmer-managed on-farm trials. Specific factors responsible for the above situation include declining soil fertility, lack of improved varieties, and infestation by *striga hermonthica* (Terbobri

[13] *Porridge prepared from dough or fine flour.*
[14] *Prepared by stirring and adding flour to porridge until it is cooked and viscous; served with vegetable soup.*
[15] *Cake prepared from fermented dough.*
[16] *An opaque local alcoholic beer.*

et al., 1998). These constraints triggered the inception of the sorghum (and millet) improvement programme at the Nyankpala Agricultural Experiment Station (NAES), now the Savannah Agricultural Research Institute (SARI), in the mid-1960s.

Through SARI's Sorghum Improvement Programme, a number of improved varieties have been released to farmers after being tested on-farm. Notable among such varieties are Naga White, Framida, Kaapaala, Kadaga and Dorado (Terbobri et al, 1998), which were found to be superior to the local varieties in terms of yield, striga tolerance and early maturity. However, the picture on the ground, in terms of adoption, has not assessed, scientifically. The purpose of this study, therefore, was to estimate the level of adoption of improved sorghum varieties and to identify the factors that influence their adoption.

2.0 CONCEPTUAL MODELS

2.1 THE PROBIT MODEL

It is generally assumed that farmers' response to innovation adoption is individualistic, and the decision to adopt is dichotomous between two mutually exclusive alternatives. That is to say, the individual chooses either to adopt or not to adopt a given innovation. The probit model has been used in a number of empirical studies to capture the factors influencing farmers' adoption decision (Rahm and Huffman, 1984; Hailu, 1990; Kebede et al, 1990; Adesina, 1996). It is usually assumed in these models that farmers make adoption decisions based on utility maximisation as an objective. Let improved sorghum varieties be defined as 'f' where $f =1$ for adoption and $f=0$ for non-adoption. The underlying utility function which ranks the preference of the ith individual is assumed to be a function of farmer-specific characteristics, 'X' (examples of such characteristics include age, sex, household size among others) and a normally distributed error term (zero mean and constant variance):

$$U_{i1}(X) = \beta_1 X_i + \varepsilon_{i1} \qquad (1)$$

for adoption and

$$U_{i0}(X) = \beta_0 X_i + \varepsilon_{i0} \qquad (2)$$

for non-adoption.

Given that the utilities are random, the ith farmer would choose the alternative 'adoption' if and only if $U_{i1} > U_{i0}$. Therefore, for the ith farmer, the probability of adoption is given by:

$$\wp(1) = \wp(U_{i1} > U_{i0})$$

$$\wp(1) = \wp(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0}) \qquad (3)$$

$$\wp(1) = \wp(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i) \qquad (4)$$

$$\wp(1) = \wp(\varepsilon_i - \beta X_i) \qquad (5)$$

$$\wp(1) = \Phi(\beta X_i) \qquad (6)$$

where Φ is the cumulative distribution function for ε. The functional form of Φ depends on the assumptions made about the distribution of ε. A probit model arises from assuming the normal distribution for ε (Nkamleu and Adesina, 1999). Thus for the ith farmer, the probability of adoption of improved sorghum varieties is given by:

$$\Phi_f(\beta X_i) = \int_{-\infty}^{\beta X_i} \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-t^2}{2}\right) dt \qquad (7)$$

The last equation can then be estimated using the probit technique (see Goldberger, 1964; Dagenais, 1969; Judge et. al., 1985). Though this model assumes normal distribution of the sample, its use with large samples is justified even when the underlying distribution of the sample is not normal (Pindyck and Rubinfeld, 1991).

2.2 EMPIRICAL MODEL

In the choice of variables, the study was guided by a number of hypotheses based on the findings of similar studies in the past. Twelve factors were hypothesized to influence adoption. These factors are either farmer-specific, technology specific, or because of policy. These are age and education of the household head, farm size, available family labour, extension visits, credit, non-farm income, length of fallow period, use of complementary inputs (fertilizer), farm type, distance to nearest sales point as a proxy for market access to improved seed and farmer's perception of improved sorghum varieties.

It is often presumed that younger farmers, being more adventurous and with a longer planning horizon, are more inclined to accept innovations than older ones (Polson and Spencer, 1992). Hence, the age of the household head (AGE) is often hypothesized to have a negative influence on adoption. It has been argued that education enhances one's ability to receive, decode and understand information (Schultz, 1964) and hence the education of the household head (EDUC), is expected to have a positive influence on adoption.

Farm size (FSIZE) is often a good proxy for wealth (CIMMYT, 1993). It is assumed that households with larger farm sizes are more likely to adopt new technologies. FSIZE therefore has a positive influence on adoption. Similarly, availability of family labour may offer cheap farm labour. Households with a greater supply of family labour (FLABOUR) are more likely to adopt new technologies. This suggests a positive influence of FLABOUR on the adoption of improved sorghum varieties.

Similarly, people with non-farm income have the means to procure purchased inputs that the adoption of a new technology may require. Thus, access to non-farm income (NFINCOM) is also assumed to have a positive influence on the adoption of improved sorghum varieties.

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Shorter fallow periods are a sign of increasing pressure on farmland and hence an incentive for land-constrained farmers to adopt high yielding varieties. Longer fallow periods (FPERIOD) would therefore have a negative effect on the adoption of improved Sorghum varieties. To determine the effect of the use of complementary inputs by a farm-household on the adoption of improved sorghum, the use of chemical fertilisers (FERT) in the survey year has been entered as an explanatory variable. FERT is expected to exert a positive influence on the adoption of improved sorghum varieties, by reinforcing the high yielding potential of the improved varieties. Contact with sorghum extension activities (EXTN) is expected to have positive influence on a farmer's adoption decision. Also, access to credit (CREDIT) in the survey year is expected to influence adoption positively whereas the distance between the farmer's village and the nearest purchase point for agricultural inputs (DISTPP) (e.g., improved seed, chemical fertilisers etc.), is hypothesized to negatively influence adoption.

A perception index (PINDEX) included in the model was computed from among eleven (11) technology specific factors. These include disease tolerance, drought tolerance, pest tolerance, maturity period, fertiliser requirement, varietal yield, storage or shelf life, taste quality, suitability for local dishes, weed suppression and marketability. Farmers were asked to compare (i.e. rank improved variety as 1 if better, 0 otherwise) the best-known improved variety with their best traditional variety in terms of these varietal characteristics. It is assumed that farmers give these characteristics equal weight on an eleven-point scale. The index is specified as a dummy and takes on a value of 1 if the cumulative score for the given characteristics is greater than 6, 0 otherwise. This index is expected to capture a farmer's perception of the risks associated with the adoption of improved sorghum as well as the compatibility of the improved varieties with the socio-cultural setting of the people in the study area. Hence, PINDEX is expected to have a positive relationship with adoption of improved sorghum. Finally, the type of farm (FTYPE) is assumed to influence adoption. Farmers are more inclined to

adopt the early maturing improved sorghum varieties on compound farms [17] than on bush farms[18] for ease of bird scarring. Thus, FTYPE is expected to influence adoption of improved sorghum varieties positively. FTYPE is a dummy 1 if sorghum farm is around the homestead (less than 1 km), 0 otherwise. The descriptive statistics of the variables used in the empirical model are given in Table 1.

An iterative maximum likelihood algorithm (Greene, 1992) was used to estimate the empirical model in order to obtain asymptotically efficient parameter estimates (Rahm and Huffman, 1984).

Table 1: Description, mean, standard deviation and percentages of the independent variables used in the model

Variables	Description	Continuous variable Mean S.D.		Categorical variables (Percentages)	
AGE	Age of household head, a dummy 1 if farmer between 31-50years, 0 if farmer is above 50years			1=71	0=29
EDUC	Education of household head, measured by a dummy 1=literate 0=illiterate			1=28	0=72
EXTN	Extension measured by number of extension visits to farmer	7.86	15.03		
NFINCOME	Nonfarm income measured by a dummy 1= has non-farm income 0 = has no off-farm income			1=38	0=62
FSIZE	Farm size measured by number of acres under sorghum	1.96	1.63		
FPERIOD	Number of years land is left to fallow	3.41	2.44		
FTYPE	Farm type measured by a dummy:				

[17]*Farms around homesteads often reserved for short duration crops which are harvested during the lean season.*
[18]*Farms away from home often reserved for late maturing full-season crops.*

	1 if sorghum farm is around homestead (less than 1km), 0 otherwise	1=48	0=52
CREDIT	Credit measured by a dummy: 1 = Additional cash 0 = Own cash	1=10	0=90
FERT	Use of complementary inputs by farmer measured by a dummy variable 1 if the farmer used chemical fertilizer in the survey year, 0 otherwise	1=59	0=41
FLABOUR	Available family labour for farm work on household farm measured in persons aged 16 years and above	8	4
DISTPP	Distance to nearest sales point as a proxy for market access to improved seed	14.28	8.41
PINDEX	Perception index measured by a dummy: 1 if the cumulative score for the given characteristics is greater than 6, 0 otherwise.	1=39	0=61

3.0 METHODOLOGY

In order to obtain the necessary information on the adoption of improved sorghum varieties in the Upper West Region, an exploratory survey was conducted in 1999 using rapid rural appraisal approaches. This survey provided information on the distribution and relative importance of sorghum in the region under consideration.

The exploratory survey was followed by a detailed structured sample survey conducted in all the five districts of the Upper West Region. A purposive sample of two villages from each district was first selected based on importance in terms of sorghum production as well as whether the communities benefited directly from dissemination of improved sorghum varieties. A simple random subsample of 20 farmers was then selected from the selected villages in each of the districts that benefited from the dissemination of the improved varieties, giving a total of 100 respondents. Trained enumerators interviewed the respondents using structured questionnaires.

4.0 RESULTS

Based on the likelihood ratio test (LRT), the probit model specified to examine the factors affecting the adoption of improved sorghum varieties is significant at the 1% significance level. This implies that the explanatory variables included in the model jointly influence a farmer's decision with respect to the adoption of improved sorghum varieties. In addition, the model predicted 83% of the cases (adopters and non-adopters) rightly and could therefore be used to test the validity of the hypotheses laid down earlier. The parameter estimates of the probit model are shown in Table 2 below.

Table 2: Probit Model estimates of the Determinants of the adoption of improved Sorghum varieties (1999/2000, UWR, Ghana)

Variable	Estimated coefficient	Standard error	Asymptotic T-ratio	Elasticity of predicted probability
AGE	1.45610	0.54427	2.67530***	0.48764
EDUC	0.22157	0.41231	0.53738	0.02895
EXTN	-0.02487	0.01465	-1.69740*	-0.08473
CREDIT	0.62022	0.65814	0.94239	0.02533
NFINCOME	0.67108	0.40451	1.65900*	0.10725
FPERIOD	-0.31391	0.12340	-2.54390**	-0.47781
FERT	-0.45282	0.41076	-1.10240	-0.10160
FLABOUR	0.26043	0.07219	3.60780***	0.84712
DISTPP	-0.09015	0.02671	-3.37510***	-0.58011
PINDEX	1.24290	0.55290	2.24790**	0.15464
FTYPE	0.69223	0.40315	1.71700*	0.16177
FSIZE	0.38752	0.15964	2.42750**	0.32727
CONSTANT	-2.20780	0.86753	-2.54500	-0.94036

Likelihood -ratio statistic   65.1467***   Significance levels ***
= 1%; ** = 5%; * = 10%

According to the asymptotic t-values of the coefficients, two of the explanatory variables in the model were found not to be in conformity with *a priori* expectations. These were the use of chemical fer-

tilizer, and the extension contact variable, which however, was statistically significant at the 10% level. Educational status and the use of farm credit, though with the expected signs, were not statistically significant.

The rest of the factors proved to be significant determinants of the adoption of improved sorghum varieties. These were AGE, FSIZE, FLABOUR and NFINCOM, which tend to exert positive influence on farmers' adoption decisions. Also, FTYPE and FPERIOD were found to influence significantly the adoption behaviour of sorghum farmers. As expected, FPERIOD (indicating intensity of land use) showed a negative effect as opposed to FTYPE. The distance to the nearest purchase point for improved sorghum seed (DISTPP), a proxy for market access to improved sorghum seed was significant at 1%.

Last, but not the least, is the variable examining the effect of the characteristics of the technology itself, the perception index (PINDEX). This variable was found to be significant at the 5% level and to exert a positive influence on adoption. Sperling and Loevinsohn (1993) have noted that the salient factor in the adoption and spread of new varieties is the grower's appreciation of the variety. In an earlier study, Haugerud (1988) observed that the acceptability of new potato varieties depended, among other things, on taste preference, the starch content, cooking time, blight resistance, market acceptance and compatibility with the existing farming system. In addition, Yapi et al. (1998) reported that the most important reasons that were advanced for adopting S-35, an improved sorghum variety was its early maturity, high yield and good taste. These are some of the characteristics factored into the perception index and such findings should be of utmost interest to breeders.

6.0 CONCLUSION

The results above indicate that seven factors influence the adoption of improved sorghum varieties in the Upper West Region of Ghana.

It can therefore be concluded that in order to increase sorghum adoption in the study area, efforts must focus on farmer and technology-specific characteristics as well as policy issues. Concerning farmer-specific characteristics, efforts to increase adoption should be directed at younger farmers, farmers who have access to non-farm income or provide farmers access to financial resources to acquire the new varieties, farmers with shorter fallow periods and farmers with larger sorghum farm sizes. These characteristics connote a willingness to bear risk as being critical to adoption of the new sorghum varieties. The younger farmers are generally less risk averse than older ones, and access to non-farm income spreads the risks associated with farm income. Similarly, larger farmers tend to be wealthier and therefore less vulnerable to risks hence their tendency to adopt the new varieties. The other farmer specific factors are greater access to family labour and farming on compound fields.

Finally, the technology-specific factors would concern sorghum breeders and agronomists who, need to consider tolerance to disease, drought and pests, and maturity period, fertilizer requirement, varietal yield, storage or shelf life, taste quality, suitability for local dishes, weed suppression and marketability in the development of improved sorghum varieties.

7.0 RECOMMENDATIONS

The results show that farmers who are able to bear risk are more likely to adopt new sorghum varieties. The obvious recommendation is to target this category of farmers with new varieties, at least as pace setters. For others, provision of financial support, say through credit may be needed for initial testing of the new variety. On the other hand, breeder should be sensitive to the resource limitations of target farmers and develop varieties that are less dependent on purchased inputs such as chemical fertiliser.

The findings of the study also emphasize the need for breeders to be guided by farmers' preferences for crop characteristics in their

breeding programmes. The only policy issue to consider is the location of sales outlets for farm inputs. Farmers should be supported to develop efficient farmer owned service centres (including seed sales) in local communities

REFERENCES

Abatania, L. N. (1998). Sustainability of Maize-Based Cropping Systems in Northern Ghana. A Master of Philosophy Degree Thesis submitted to the Department of Agricultural Economy and Farm Management, University of Ghana, Legon.

Adesina, A.A. (1996). Factors affecting the adoption of fertilisers by rice farmers in Cote d'Ivoire. Nutrient Cycling in Agroecosystems 46: 29-39.

CIMMYT Economics Program. (1993). The Adoption of Agricultural Technology: A Guide for Survey Design. Mexico, D.F.: CIMMYT.

Dagenais, M. G. (1969). A Threshold Regression Model. *Econometrica* 37: 193-203

Goldberger, A. S. (1964). Econometric Theory. John Wiley and Sons Inc., New York.

Greene, W. (1992). LIMDEP Version 6.0 User's Manual and Reference Guide. Econometric Software, New York.

Hailu Z. (1990). The Adoption of Modern Farm Practices in African Agriculture: Empirical Evidence about the Impacts of Household Characteristics and Input Supply Systems in the Northern Region of Ghana. Nyankpala Agricultural Research Report No.7

Haugerud, A. (1988) "Anthropology and Interdisciplinary Agricultural Research in Rwanda". In: Anthropology of Development and Change in East Africa. West View Press, 1988, p.137-160.

Judge, G. G.; W. E. Griffiths; R.C. Hill; T. C. Lee and H. Lutkepol. (1985). Introduction to the Theory and Practice of Econometrics. (2nd ed.) John Wiley & Sons, Inc. New York.

Kebede, Y., Gunjal, K., and Coffin, G. (1990). Adoption of New Technologies in Ethiopian Agriculture: The case of Tegulet-Bulga District, Shoa Province. Agricultural Economics 4 (1): 27 - 43. Elsevier Science Publishers B.V.

Nkamleu, G.B. and Adesina, A. (1999). Modelling Farmers Decisions on Integrated Soil Nutrient Management in Sub-Saharan Africa: A Multinomial Logit Analysis in Cameroon. Agricultural Economics (in review).

Pindyck R.S. and Rubinfeld D.L. (1991). Econometric Models and Economic Forecasts MaGraw-Hill, Inc. New York. 3rd ed.

Polson, R. S. and D. S. C. Spencer. (1992). The Technology Adoption Process in Subsistence Agriculture: The Case of Cassava in South-Western Nigeria. IITA Research No.5.

Rahm, M.R. and Huffman, W.E. (984). The Adoption of Reduced Tillage: The
Role of Human Capital and other Variables. American Journal of Agricultural Economics. 66: 405-413.

Schultz, T.W. (1964). Transforming Traditional Agriculture. New Haven, Connecticut, USA. Yale University Press.

Songsore, J. and A. Denkabe (1995). Challenging Rural Poverty in Northern Ghana: The Case of the Upper-West Region. The University of Trondheim, Centre for Environment and Development, UNIT-SMU.

Sperling, L. and M. E. Loevinsohn. (1993). The Dynamics of Adoption: Distribution and Research Impacts. Proceedings of an

International Workshop on Joint Impact Assessment of NARS-ICRISAT Technologies for the Semi-Arid Tropics, Patancheru, India, 2-4 Dec. 1996.

Terbobri P., L. Abatania., I. D. K. Atokple and R. A. Kanton. (1998). Evaluation of the Adoption of improved Sorghum Varieties in Ghana. A Research Proposal submitted to the West and Central Africa Sorghum Research Network.

Yapi, A., Kergna, A. O., Bebrah, S. k., Sidibe, A., Sanogo, O., Bantilan, M. C. S., and P.K., Joshi (1998). Impact of Sorghum and Millet Research in Mali. In: Assessing Joint Research Impacts. Proceedings of an International Workshop on Joint Impact Assessment of NARS-ICRISAT Technologies for the Semi-Arid Tropics, Patancheru, India, 2-4 Dec. 1996.