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Executive Manager and Editor in Chief
Hans Hemann, Steinstraße 19, D 37213 Witzenhausen, Fon: ++49 (0)5542 - 981216,
Fax: ++49 (0)5542 - 981313, Email: tropen@wiz.uni-kassel.de

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Gender and Rural Poverty in Myanmar: A Micro Level Study in the Dry Zone

D. Kyaw *[1] and **J. K. Routray** [2]

Abstract
The study investigates the poverty incidence, access to resources, and the factors influencing income of both male and female-headed households in the dry zone of Myanmar. A household survey was conducted in six villages with a sample of 220 households in 2003. The Cost of Basic Needs (CBN) method was applied in constructing the absolute poverty line. By applying the absolute poverty line of 252 Kyats[3] per person per day, the female-headed households are more likely to be poor than the male-headed households with or without household size adjustment. Results of the regression analysis revealed that average per capita income of rural households is significantly influenced by 8 independent variables. They are: gender of household head, household size, land holding size, degraded land size, cattle heads, labour force, sources of income, and irrigation water. Moreover, the separate regression analyses were run for male and female-headed households. In addition to the some common significant variables (land, labour, cattle, degraded land, and household size), female-headed households' income is significantly influenced by training attendance and schooling years of household head. In male-headed households, age of household head, number of income sources and irrigation water are highly linked with the average per capita income. The gender focus rural development strategies should be adopted for promoting the welfare status of both male and female-headed households in the dry zone.

Keywords: rural poverty, livelihoods, male and female-headed households, dry zone, Myanmar

1 Introduction

Myanmar is essentially an agrarian economy with two-thirds of the total population engaged in subsistence agriculture. The rural poor households have suffered from low access to various services (education, health, water supply, etc.), and lack of assets such as land and livestock, which are strongly related to the rural poverty status (UNDESA,

* corresponding author

[1] Dolly Kyaw, Lecturer, Department of Agricultural Economics, Yezin Agriculture University, Myanmar. Email: Dolly.Kyaw@ait.ac.th

[2] Professor. Dr. Jayant K. Routray, Regional and Rural Development Planning, School of Environment, Resources, & Development, Asian Institute of Technology, P. O. Box 4, Pathumthani 12120 Bangkok, Thailand. Email: routray@ait.ac.th

[3] 1 Kyat ≘ 0.123 € (Nov. 2006)

1999). Although there is widespread poverty in Myanmar, the comprehensive study for preparing a strategy to reduce poverty including gender equality in Myanmar, is still lacking. The Central Statistical Organization (CSO) has conducted the household income expenditure survey, covering all States and Divisions with total 25,470 households in 1997. Based on relative poverty line of daily per capita expenditure of 53.69 Kyats (for minimum subsistence food plus non-food consumption), the poverty incidence for urban was 23.9 percent, for rural was 22.4 percent, and for the whole country was 22.9 percent in 1997 (CSO, 1997).

The Japanese economists (Kurosaki *et al.*, 2004) have applied the poverty line corresponding to the value of 400 kg rice per person per year to estimate the Headcount Index (HCI) of rural households. The research findings indicate that the highest poverty incidence of 68 and 54 percent were found in the two villages of the dry zone.

The World Bank (2001) argues that the country is trapped in abject poverty despite its rich resources base and the trend of poverty is increasing through times in the last ten years (Collier and Dollar, 2001). According to UNDP (2004), life expectancy rate, adult literacy rate, and GDP per capita in Myanmar are 57 years, 85 percent, and US$ 1,027 (PPP), respectively in 2002. About half of the population does not have access to affordable essential drugs, while 36 percent do not have access to sanitation, and 28 percent do not have access to safe drinking water in 2000.

The feminization of poverty has been linked to a perceived increase in the proportion of female-headed households, and Myanmar is not an exception in this respect. In the study of UNDESA (1999), the 'worse-off women' of Myanmar were characterized as lack of income and assets, old age, sickness, heavy work burden, insufficient food, poor clothing, and low quality housing in the sample six villages in different regions (hilly, dry zone, delta, and coastal regions). Generally, female household heads are older and more economically active but less literate and own significantly less cultivated land than the male household heads.

The paper will investigate the female and male-headed households' poverty incidence, the factors influencing income, and their access to productive resources (land, cattle, and irrigation water, etc.), their human capital (labour, literacy, and head's schooling years), financial capital (capital investment, and received credit), and social capital (participation in various self-help groups, and trainings). The research findings will contribute to give recommendations for raising living standard of rural households in the dry zone.

2 Methodology

2.1 Livelihoods Framework

The application of a sustainable livelihood framework in the reduction of rural poverty is increasingly centered for the preparation of Poverty Reduction Strategy Paper (PRSP) and the rural development programme in the poor countries (Scoones, 1998; Ellis *et al.*, 2003). The current understanding of poverty gives considerable emphasis on ownership or access to livelihood resources that can be put to productive use as the building blocks by which the poor can construct their own routes out of poverty (World Bank, 2000). The utilization of a livelihood framework to understand rural poverty in this agrarian country, with focus on access to resources, could be the most appropriate.

In the vulnerability context, the rural people in the dry zone face frequent droughts, seasonal unemployment, and increasing land degradation. Their resources and capabilities such as land, livestock, labour, capital, educational level, health status, and income are not only interrelated with various vulnerabilities, but also with the government's policies, performance of rural institutions, and formation of self-help groups (social capital). Key questions, concerning with the following issues were developed from the framework in the study: (i) Who are the rural poor? (ii) What assets do they have? (iii) How do they make a living? (iv) What are the institutions helping for their rural livelihood activities in the dry zone?

2.2 Study Area

The UNDP has launched the Human Development Initiative Programme since 1993 in the most fragile and resource poor dry zone townships of Chaung U, Kyaukpadaung, and Magway. The Kyaukpadaung Township has the common characteristics of dry zone such as low rainfall, frequent drought, inadequate safe drinking water, low land productivity, and high land degradation. The sample six villages, in which same UN and NGOs' activities were implemented, were purposively selected to study.

The Kyaukpadaung Township suffers from drought twice in every three-year cycle due to low rainfall associated with crop failure. The average monthly temperature ranges from a minimum of 9°C (in December) to a maximum of 42°C (in March). The climate is influenced by the southwest monsoon, leading to a bimodal rainfall pattern with the average annual rainfall of less than 750 mm. The average land holding size of a rural household is decreased from 2.3 ha (or 5.8 acres) in 1999 to 1.4 ha (or 3.6 acres) in 2003. About one fifth to one third of the rural households is landless depending on the demographic and socio-economic characteristics of a village. Among the sample six villages, three sample villages are received irrigation water from a dam to grow rice.

2.3 Field Survey

The household income and expenditure survey was conducted in the sample six villages from August to November 2003, covering 160 male-headed households (MHs) and 60 female-headed households (FHs). The female-headed household is about 9 percent of total households in the sample villages. Primarily, the female-headed households are widows (95 percent), and the rest are divorcee and single women. On the other hand, nuclear household structure was dominant in the MHs. In the field survey, household's demographic, socio-economic data, and access to public services data were collected through a structured questionnaire. The sample households include 1,176 persons, implying that the average household size is 5.4 persons.

3 Research Findings

3.1 Poverty Line of the Study Area

The poverty line, used to identify poor against non-poor, was constructed based on the absolute poverty concept that refers to living below the subsistence minimum daily calorie requirement of 2100 kcal per person, and other essential goods (FOSTER *et al.*, 1984; RAVALLION, 1998). It is noted that other Asian countries of Lao PDR, Cambodia, Vietnam, and China have adopted 2100 calorie per person per day as benchmark indicator in their poverty analysis. The Cost of Basic Needs method (CBN) was applied in constructing the food poverty line as the dry zone rural households have a similar food consumption pattern. The second lowest quartile's food consumption basket was used as a reference for food consumption in order to avoid underestimation of poverty. Using the FAO calorie conversion table of 1985, each food quantity was converted and then scaled up by 1.13 to reach the recommended intake of 2100 kcal per person per day. The food poverty line was estimated as 215 Kyats per person per day by multiplying the food quantities[4] with average food prices (see Table 1).

Table 1: Food Composition and Respective Food Poverty Line in the Study Area

Items	*Food Quantities of Ref. Household × 1.13 (gm/person/day)*	*Received Average Calorie (kcal/person/day)*	*Average Food Expenditure (Kyat/person/day)*	*Calorie Contribution (%)*	
				From Survey	*FAO Recommended*
Rice	482	1701	68	81.0	45.0
Cooking oil	40	3	36	0.1	10.0
Meat & fish	35	120	28	5.7	20.0
Eggs	0.05	3	2	0.1	
Pulses	69	74	28	3.6	5.0
Vegetable	185	50	20	2.4	5.0
Spices	59	32	28	1.5	
Sugar	25	86	2	4.1	
Beverage	4.32	12	3	0.6	
Other foods	17	19	6	0.9	15.0
Total		2100	**215**	100	100

Source: Field survey, 2003

It is needed to check on not only the minimum requirement of calories for a person but also the percentage contributions of the food items to total calories in order to obtain a good balance food basket. The rural people rely on rice to get the recommended daily energy intake because the percentage contribution of rice to total energy is 81 percent, which is greater than the FAO recommendation of 45 percent. They take less in other food items (especially meat and fish) than the recommended level due to higher prices.

[4] Among the total food consumption, rice consumption contributes about 80 percent of total calories of the household. The paper set the food poverty line at average per capita consumption of rice is 174 kg per year plus other foods in 2003, and KUROSAKI *et al.* (2004) set the rice/food poverty line at 200 kg per year in 2001.

They more prefer to take pulses, which are produced and readily available in the study area.

After estimation of the food poverty line, the food share regression model (Ravallion and Bidani, 1994) was used to estimate minimum non-food expenditure of the households with income just reaching the food poverty line. The estimated food demand function is shown in Table (2).

Table 2: Estimated Food Demand Function

Name of coefficient	*Estimated coefficient*	*Standard error*	
Constant (α)	0.830***	0.008	R squared = 0.163
Coefficient (β)	-0.404***	0.056	

***: Significant at $p < 0.01$
Source: Field Survey, 2003.

The non-food poverty line can be estimated as follows:

$$\text{Poverty Line} = \text{Food Poverty Line } (2 - \alpha) \text{ or :}$$
$$\text{Non} - \text{food Poverty Line} = \text{Food Poverty Line } (1 - \alpha), \text{ thus :}$$
$$\text{Non} - \text{food Poverty Line} = 215 \text{ Kyats } (1 - 0.830) = 36.5 \text{ Kyats} \approx 37 \text{ Kyats}$$

Hence the absolute poverty line of 252 Kyats (215 Kyats + 37 Kyats) per person per day at the current price was finally derived and applied. If the absolute poverty line of 252 Kyats per day is converted into US$, it is equal to about US$ 0.3 at the market exchange rate of 850 Kyats/US$ prevailing during the study period in 2003. The World Bank's studies present that the national poverty lines at the market exchange rate of Cambodia is about $ 0.45 in 2004, Lao is about $ 0.26 in 2002-03, and Vietnam is about $ 0.35 in 1998.

3.2 Measuring Poverty Incidences of Male and Female-headed Households

The most commonly used income/consumption poverty indicator is simply the proportion of population whose income/expenditure falls below the poverty line, which is called the '*headcount index*'. In this research, poverty statistics are calculated using the standard FGT poverty measures (Foster *et al.*, 1984).

The sample population for male-headed household was 891, and for female-headed household were 285. Overall, about 43 percent of the total population was living below the poverty line of 252 Kyats/person/day. The Headcount Index (HCI) of male and female-headed households is about 39 percent and 58 percent, respectively assuming all members in the household enjoy equal food share. It can be summarized that the FHs are more likely to poor than the MHs without household size adjustment (see Table 3).

Table 3: Poverty Incidence of Male and Female-headed Households

Category of Household & population	*Without Household Size Adjustment* [1]					*With Household Size Adjustment* [2]				
	P_0	P_1	P_2	*Share of Poverty*		P_0	P_1	P_2	*Share of Poverty*	
				f	*%*				*f*	*%*
Female (285)	0.58	0.04	0.018	165	32	0.47	0.068	0.015	133	41
Male (891)	0.39	0.028	0.09	347	68	0.22	0.018	0.04	195	59
Total (1176)	0.43	0.034	0.011	512	100	0.28	0.031	0.07	328	100

Source: Field survey, 2003.
[1] all members in the household enjoy equal food share,
[2] children food consumption is 0.65 of the adult calorie consumption,
P_0 is the headcount index, P_1 is the poverty gap index, P_2 is the squared poverty gap index

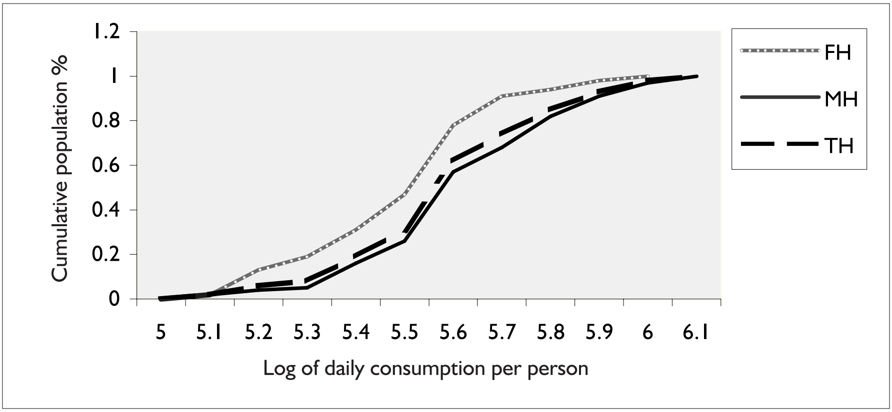
The household size adjustment and the scale of economy should be taken into account as ignoring household size will overestimate poverty of the families with children, and underestimate it for couples without children (White and Masset, 2003). By applying the common adult equivalent scale of 0.65, the HCI of FHs (47 percent) is higher than the MHs (22 percent). The female-headed households' share of poverty is increased from 32 percent to 41 percent when household size adjustment was made. It is obvious that the female-headed households are more likely to be poor than the male-headed households with or without household size adjustment. The evidence reveals that there is a gender dimension to poverty in the study area.

3.3 Cumulative Distribution Function of Daily Per Capita Consumption

It is important to test whether the group ranking is robust to the choice of the poverty line. The simplest way for the robustness of poverty comparisons based on the headcount index of poverty is to plot the cumulative distribution of consumption for two household groups at a defined poverty line. It is needed to observe whether the curves intersect or not. If they do not intersect, then the group with the highest curve is poorer than the other group (Quisumbing *et al.*, 2001).

In Figure (1), the horizontal axis shows monetary values (Kyats/day) in log while the vertical axis shows cumulative percent of the population. The absolute poverty line of 252 Kyats per person day is at the scale '5.53' and it is noted that about 60 percent of the total sample population have a sufficient consumption to get the minimum daily calorie allowance. However, the distribution of daily per capita consumption of female-headed household shows that about 40 percent of the population of female-headed households is above the poverty line. It can be concluded that male-headed household's poverty incidence is lower than the female-headed household as the cumulative distribution curve of male-headed households is lower.

Figure 1: Distribution of Expenditure in Rural Households



3.4 Characteristics of Poor by Gender of Household Heads

Poverty analysis in the rural dry zone indicates the following predominant characteristics of the poor by gender of household heads:

(a) Poor tend to live in larger households with younger household head in both male and female-headed households. Although the female-households have smaller household size, their lesser resources (land, cattle, and capital investment) lead to poorer than the male-headed households (see Table 5).

(b) Literacy and schooling are important indicators of the quality of life, as well as the determinants of the poor ability to take advantage of income earning opportunities. Poor heads are more likely to be less educated than non-poor. There is no illiterate male head but about 8 percent of female heads are illiterates.

(c) Poor especially female-headed households have more number of children school drop out at the primary education level than the poor male-headed households.

3.5 Employment, and Income of Male and Female-headed Households

Employment, and Income of Male and Female-headed Households The majority of male heads are engaged as farmers (81 percent), 3 percent in livestock farming, 3.8 percent as agricultural laborers, 4.4 percent as non-agricultural laborers, 2 percent as street vendors, and 2.5 percent as home-based workers and 2.5 percent as jaggery workers. About 63 percent of female heads are engaged as farmers, 7 percent in livestock farming, 3 percent as jaggery workers, 13 percent as agricultural laborers, 3 percent as non-agricultural laborers, and 5 percent as both street vendors and home-based workers. Because of provision of loan from Pact Myanmar women saving group, the rural women have an opportunity to engage primarily in livestock farming activity and street vendors for income earning. The FHs earn lower average daily per capita income than the MHs in all types of employment except non-agricultural labour.

Table 4: Average Per Capita Income of Male and Female-headed Households Category

	Average Daily Per Capita Income (Kyats)		*Average Daily Per Capita Income by Employment (Kyats)*							
			Farmers		*Agri Laborer*		*Non-agri Laborer*		*Self-employed*	
Categrory	*N*	*Mean*	*N*	*Mean*	*N*	*Mean*	*N*	*Mean*	*N*	*Mean*
MHs	160	248 (114)	136	258 (113)	6	187 (110)	7	130 (62)	11	229 (103)
FHs	60	197 (102)	42	224 (100)	8	126 (80)	2	155 (139)	8	142 (73)
THs	220	234 (113)	178	250 (112)	14	152 (96)	9	135 (74)	19	192 (99)

Field Survey, 2003.
Standard error in parenthesis.
MHs = male-headed households, FHs = female-headed households, THs = total households. Farmers = work as farmer & livestock farmer, Agri laborer = agricultural laborer, Non-agril laborer = non-agricultural laborer, Self-employment = petty trader, street vendor, & home-based worker

3.6 Livelihood Resources, and Rural Institutions

The majority of the sample rural household relies on the agricultural activities for their livelihoods in the dry zone. About 20 percent of sample FHs and 6 percent of MHs are landless. The FHs own significantly smaller land size than MHs. The FHs households have less number of cattle heads and have received less irrigation water for crop production. Moreover, the FHs have low capital investment and less number of cultivated crops than the MHs.

There are two sources of credit in the rural areas: (1) Myanmar Agricultural Development Bank (MADB), and (2) Group Fund of various Self-help Groups (SHGs). The MHs have received a large amount of credit from MADB than FHs. The farmers group, livestock group, women's income generation group, and soil conservation group have been formed in the UN poverty alleviation programme since 1997. Both FHs and MHs have received the nearly same amount of credit.

The households in rural areas have commonly more than one source of income as they usually work both in agriculture and non-agriculture sectors. Because of the sample MHs own a larger land size, their source of income primarily comes from rice, oil seeds, and pulses production. On the other hand, the FHs have received the average annual per capita income mainly from wage laborer, and oil seeds crop production.

3.7 Factors Influencing Per Capita Income

Household income or consumption measures a household's ability to obtain goods and services. Generally, household consumption typically fluctuates less than income. However, poor households may smooth income instead of consumption (Morduch, 1994) due to few opportunities for consumption smoothing. Therefore, poor households with no assets will consume all their current income (Fafchamps, 1999, p.19). This study has chosen the average per capita income as dependent variable in the regression model.

First, a multivariate correlation analysis was done to know the collinearity of the independent variables. The number of under 5 years old children deaths and frequency

Table 5: Livelihoods Resources of Male and Female-headed Households

Category	*MHs* (N=*160*)	*FHs* (N=*60*)	*THs* (N=*220*)	*t and* χ^2 *tests*
Landless (%)	6	20	10	p = 0.000***, df = 1
Land (acres)	4.4	2.6	3.9	p = 0.000***, df = 218
Degraded land (acres)	0.49	0.29	0.44	p = 0.023**, df = 218
Labour (No.)	2.5	2.4	2.5	p = 0.131ns, df = 218
Cattle heads (No.)	2.5	1.9	2.3	p = 0.077ns, df = 218
Capital (Kyats/year)	34,437	24,884	31,832	p = 0.000***, df = 218
Sources of income (No.)	2.2	2.0	2.1	p = 0.062ns, df = 218
Credit (Kyats/year)	25,669	25,075	25,507	p = 0.910ns, df = 218
Frequency of training attendance	1.3	0.9	1.2	p = 0.099ns, df = 218
No. of crops grown/year	2.8	2.1	2.6	p = 0.000***, df = 218
Received irrigation (%)	32	28	31	p = 0.732 ns, df = 1

Source: Field survey, 2003.
Significant at ** $p < 0.05$, *** $p < 0.01$, ns = not significant

of visiting the doctor variables are correlated weakly with the dependent variable. The capital investment per year, number of crops grown, land tenure status is highly related with the average land holding size. Hence these variables are excluded in the model.

The correlation result shows that land holding size and degraded land is correlated weakly ($r < 0.5$). Most of the small and marginal farmers own more degraded land. Although family size and number of labour is correlated, the correlation result is less than 0.5. The labour force means the labour who is able to work and at age of 16. These variables are included in the model. Finally, thirteen variables with high degree of correlation with the dependent variable and low degree of correlation with each other are included in the regression model.

$$I_j = \beta_0 + \beta_1 X_{1j} + \beta_2 X_{2j} + \beta_3 X_{3j} + \beta_4 X_{4j} + \beta_5 X_{5j} + \beta_6 X_{6j} + \cdots + \beta_{13} X_{13j} + \mu_j \quad (1)$$

where: I_j = average daily per capita income of household 'j', β_0 = constant, β_1 to β_{13} = coefficients to be estimated, X_1 = age of household head (years), X_2 = age squared of household heads, X_3 = household head's schooling years, X_4 = household size (number), X_5 = land holding size (acres), X_6 = degraded land size (acres), X_7 = cattle heads (number), X_8 = household labour force involved in agriculture and non-agriculture sector (number), X_9 = household loan amount from the rural bank and self-help groups in survey year 2003 (Kyats/year), X_{10} = training attendance for skill enhancing of household heads, X_{11} = household sources of income (number), X_{12} = dummy variable of receiving irrigation water for crop production, X_{13} = dummy variable of gender of household heads, and μ is the error term.

Results of the regression analysis reveal that the average per capita income of rural households is significantly influenced by 8 independent variables. They are: gender of household head, household size, land holding size, degraded land size, cattle heads, labour force, sources of income, and received irrigation water. The household size, and degraded land size variables are negatively and significantly associated with the average per capita income (Table 6). Among the significant variables, the effect of degraded land size on the average income is the largest: if degraded land size increases by one unit, then the average per capita income would be decreased by about 42 Kyats. The land holding size, cattle heads, and labour numbers have significantly and positively influenced on the average per capita income. Moreover, number of sources of income is an important strategy to improve the rural livelihoods of the dry zone. If a household has an additional source of income, then average per capita income would be significantly increased by 23 Kyats. Moreover, the irrigation water is also important for crop production and food security especially in the dry zone.

The gender of the household's head variable indicates that if a household head were male, then the rural income would be significantly increased. Keeping other things the same, FHs would receive a daily average per capita income of 30.4 Kyats less than MHs. Overall, the model is significant and can explain the variation in the rural household's daily per capita income by 52 percent. The F ratio of explanatory variables in the model for total household is statistically significant at $p < 0.01$ level.

The separate regression models were run for male and female-headed households. In addition to the some common significant variables such as land, labour, cattle, etc., household heads' age, sources of income, and irrigation water for crop production variables are positively and significantly influenced on the average income of male-headed households. Because of the majority of male heads are engaged in farming sector, receiving irrigation water would significantly enhance their crops production and income.

The additional determinants of average income in the female-headed households are household heads' schooling years and frequency of training attendance. It is obvious that human development programme (literacy, trainings, health, etc.) is important for increasing income of the FHs. Because of the adjusted R squares of male and female-headed households are 45 and 42 percent, respectively, the regression models with 12 independent variables, have moderate and high level of explanation on variations in the average income earning. The F ratio for both male and female-headed households' model is statistically significant at 0.01 level.

4 Conclusions and Recommendations

The female-headed households are more likely to be poorer than male-headed households. It is observed that the gender inequality in the distribution of income in the rural dry zone is substantial. The MHs receive higher average per capita income than FHs because FHs have poor livelihood resources (land, cattle, and capital) and they rely on low wage agricultural laborer as a major source of income. Therefore raising per capita income of the low-income rural households (especially FHs) demands the promotion of employment-generating activities. Furthermore, the promotion of human

Table 6: Factors Influencing Per Capita Income of the Rural Households

Variables	*Total Households* (β_j *and Std. Error*)	*MHs* (β_j *and Std. Error*)	*FHs* (β_j *and Std. Error*)
Intercept	7.50 (83.95)	16.53 (93.43)	188.81 (186.92)
- Age of head	4.75 (3.10)	6.68* (3.62)	-5.30 (6.70)
- Age squared	-0.036 (0.028)	0.054 (0.033)	0.0603 (0.06)
- Head's schooling years	3.98 (2.58)	2.48 (3.14)	9.95** (4.39)
- Household size	- 28.39*** (3.59)	- 30.01*** (4.54)	- 19.25*** (5.21)
- Land holding size	17.55*** (2.97)	16.95*** (3.45)	22.26*** (6.41)
- Degraded land size	- 41.90*** (13.43)	- 40.65*** (15.50)	- 82.52** (31.09)
- Cattle heads	8.68*** (2.47)	8.82*** (3.16)	8.05** (3.37)
- Labour force	27.64*** (8.71)	20.39* (10.81)	42.45*** (13.13)
- Loan money amount	- 0.00019 (000)	- 0.00012 (000)	- 0.0003 (000)
- Training attendance of head	5.02 (4.26)	2.38 (5.02)	22.82** (9.54)
- Sources of income	23.35*** (7.89)	27.34*** (9.90)	6.91 (11.63)
- Received irrigation water (Received =1, otherwise = 0)	23.15* (12.15)	29.48* (15.45)	18.83 (17.78)
- Gender of head (Male = 1, Female = 0)	30.41** (14.24)		
- R^2	0.55	0.49	0.48
- Adjusted R^2	0.52	0.45	0.42
- N	220	160	60
	$F_{13,206}$ 19.47***	$F_{12,147}$ 11.86***	$F_{12,59}$ 11.81***

Source: Field Survey, 2003.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

development programmes (literacy campaign, access to universal primary education, and skill-enhanced trainings) is needed to uplift the female-headed households' living standard. In order to increase the average income of male-headed households, the provision of loan (for increasing income diversification) and irrigation water are essential. Hence the gender focus development strategies should be adopted for promoting the welfare status of both rural women and men. Because of gender equality is an essential concept for the analysis and eradication of poverty, the gendered poverty analysis should be carried out especially where percentage of female-headed households is considerable high. Further research on why individual female are more disadvantaged than male should be done to understand intra household poverty, which has received less attention.

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Factors Affecting Farmers' Decision to Enter Agricultural Cooperatives Using Random Utility Model in the South Eastern Anatolian Region of Turkey

B. Karlı [1], **A. Bilgiç** [*2] and **Y. Çelik** [3]

Abstract

Farmers' decision and perceptions to be a member of agricultural cooperatives in the South Eastern Anatolian Region were investigated. Factors affecting the probability of joining the agricultural cooperatives were determined using binary logit model. The model released that most of variables such as education, high communication, log of gross income, farm size, medium and high technology variables play important roles in determining the probability of entrance. Small farmers are likely expected to join the agricultural cooperatives than the wealthier farmers are. Small farmers may wish to benefit cash at hand, input subsidies, and services provided by the agricultural cooperatives since the risks associated with intensive high-returning crops are high. Some important factors playing pole role in abstention of farmers towards agricultural cooperatives are gross income and some social status variables. In addition, conservative or orthodox farmers are less likely to join agricultural cooperatives than moderate farmers are. We also found that the direct government farm credit programs mainly should be objected to providing farmers to better access to capital markets and creating the opportunity to use with allocation of capital inputs via using modern technology.

Keywords: cooperatives, participation, random utility, logit

1 Introduction

In Turkey, the history of cooperatives goes back to the late 19th century. Of these, agricultural cooperatives perform a prominent role both historically and in terms of co-ordination between its agencies and members (ARCAS-LARIO and HERNANDEZ-ESPALLARDO, 2003; CHIEOCHAN *et al.*, 2000). There are estimated to be 11,427 agricultural cooperatives, with over 4.5 million members within Turkey (KARLI and ÇELIK, 2003). These cooperatives unfortunately process and commercialize a lower per cent of agricultural products as compared to the European Union (COGECA, 2000).

[1] Bahri Karlı, Harran Üniversitesi, Ziraat Fakültesi, Tarım Ekonomisi Bölümü

[*] corresponding author

[2] Abdulbaki Bilgiç, Harran Üniversitesi, Ziraat Fakültesi, Tarım Ekonomisi Bölümü, Eyyübiye Kampusu, 63040 Şanliurfa, Turkey; Phone: +90 414 247 0384; Fax: +90 414 247 4480; E-mail: abilgic@harran.edu.tr or tebrik@yahoo.com

[3] Yusuf Çelik, Selçuk Üniversitesi, Ziraat Fakültesi, Tarım Ekonomisi Bölümü

Institutional and financial barriers, not sufficient market coordination mechanisms, which will better transmit inputs and information from the market to its farmer members, and a high government intervention, permit them not to explore its power in the market. Consequently, new forms or merging have been the route chosen by agricultural cooperatives (KARLI and ÇELIK, 2003). Contrary to the current situation in the country, the agricultural cooperatives should have a large impact on the agricultural sector since a relatively higher gross national product (e.g., 14%) comes from agriculture and 40 per cent of active populations are currently employed in agriculture as compared to other sectors.

Turkey recently constructed a large dam in the Southern Anatolia Region (SAR) and irrigated agricultural lands increase rapidly. Despite the proliferation of irrigation system built in the region, a low number of agricultural cooperatives performed are present. The estimated number of agricultural cooperatives performed in the region is about 287 compared to the total number of agricultural cooperatives in the nation. Most of these cooperatives are held by agricultural union, credit, commercial, and irrigation cooperatives.

The lack of coordination and efficient distribution of resources to members and less membership willingness of farmers towards a cooperative, perhaps due to a lower educational attainment, can be reasons for low number of cooperatives operated in the region. Another reason could be that agricultural cooperatives are still supply oriented that is selling what has been produced by its farmer members and thus hardly find them selves in competing with private firms. Yet another possibly invisible reason is that the direct government support programs such as credit, input supplied to farmers might negatively affect the rate of participation to agricultural cooperatives (ABDULAI and DELGADO, 1999; ARCAS-LARIO and HERNANDEZ-ESPALLARDO, 2003; CHIEOCHAN *et al.*, 2000; HANSEN *et al.*, 2002; HUDSON and HERNDON, 2002).

Despite the crucial role played by agricultural cooperatives in the region, there are no empirical studies using micro level data to explore the behavioral perceptions of farmers towards an agricultural cooperative. The objective of this study is to explore the farmers' characteristics affecting the decision to join agricultural cooperatives by using a binary probabilistic model (e.g., logit) in the context of random utility framework.

The remainder of this paper is organized as follows. First, we outline the random utility and draw binary logit model. Next, the data collected is described. Section 4 discuses the estimated results and findings are more explored. The final section draws conclusions and suggestions for policy implications.

2 Methodology

2.1 Model

Assuming farmer i maximizes his profit subject to a subset of given input costs. Farmers' decision whether or not to join a agricultural cooperative is modeled in a random utility framework (COOPER, 1997; HANEMANN, 1984). The farmers face two choices or alternatives that the utility with a membership of the agricultural cooperative is at least as great as without it. This can be done as:

$$U(1, m_1 + P; x) \geq U(0, m_0; x) \tag{1}$$

where 1 indicates the membership to an agricultural cooperative and 0 without it, m_1 and m_0 are expected net income (profit) from agricultural product sale with and without an agricultural cooperative membership, respectively, and x is a vector of household, farm, and contextual characteristics that may affect the farmers' perception on the agricultural cooperatives and willingness to participate in the activity. P is an incentive payment usually measured as monetary value received by farmers from the agricultural cooperatives. The utility function is only partially observable to the researcher, that is $U(i, m_i; x) = V(i, m_i; x) + \varepsilon$ where $V(i, m_i; x)$ is the deterministic proportion of the utility and ε is the random proportion of the utility function (HUBBELL *et al.*, 2000; QAIM and JANVRY, 2003). The partially observable then can be written as

$$U(1, m_1 + P; x) + \varepsilon_1 \geq U(0, m_0; x) + \varepsilon_0 \tag{2}$$

As is common in literatures to assume the deterministic proportion of the utility as

$$V = x\beta^i + \alpha m_i \tag{3}$$

where $i = 0, 1$ and α is the marginal propensity of the income. The final outcome is written as

$$(x'\beta^1 - x'\beta^0) + \alpha(m_1 - m_0 + P) \geq \varepsilon_0 - \varepsilon_1 \tag{4}$$

Parameter estimates of the above equation can be obtained by assuming a $\varepsilon = \varepsilon_0 - \varepsilon_1$ with using maximum likelihood procedure.
If we let $x'\beta = (x'\beta^1 - x'\beta^0)$, $m = m_1 + P - m_0$ and $\varepsilon = \varepsilon_0 - \varepsilon_1$ equation (4) can be written as:

$$x'\beta + \alpha m_i \geq \varepsilon \tag{5}$$

The log linear in income can be modified by $\ln(m_i) = \log((m_1 + P)/m_0)$.
The invisible amount of the incentives, P, can be in terms of inputs, financing credit, services provided, and transaction facilities stemming from selling farmers' product. Farmers who are the member of the agricultural cooperatives will enjoy such incentives relative to non-union members. Since we do not observe the amount of P received by farmers, we can implicitly include m_i or log income, $\ln(m_i)$, variables in vector x. We assume that the P was as if presented to farmers or at least farmers know the amount of P for some time. The random utility model could be better framed by contingent valuation methods explicitly stating the amount of incentives received by those who are the members to the agricultural cooperatives and the randomly chosen amounts of incentives in monetary value presented to those who are non members of the agricultural cooperatives and estimate the mean value of willingness to accept which presents the amount of money that makes the farmer indifferent between with and without an agricultural cooperative scenario.

Assuming ε that is independently and identically distributed with the type I extreme value distribution, and then the resulting probability to join the agricultural cooperatives can be represented by the logit model as (Greene, 2003):

$$P(y_i = 1|x) = \frac{e^{x'\beta}}{1 + e^{x'\beta}} = \Lambda(x'\beta), \tag{6}$$

where $\Lambda()$ is the logistic cumulative distribution function.
The corresponding log likelihood function for the probability is

$$\ln L = \sum_{j=1}^{N} I_j \ln\left[\Lambda(x'\beta)\right] + (1 - I_j) \ln\left[1 - \Lambda(x'\beta)\right], \tag{7}$$

where I_j is a dummy indicator equal to 1, if the farmer is the member of any agricultural cooperative, 0 otherwise. The consistent maximum likelihood parameter estimates are obtained by maximizing the above log likelihood function.

2.2 Data

An interview-based survey of 110 farmers was carried out in 2001. 20 observations were excluded due to missing information. The survey comprised five provinces in SAR, namely Adiyaman, Diyarbakir, Gaziantep, Mardin and Sanliurfa Provinces. The SAR population is around six million and of which 83% live in these provinces. The numbers of agricultural cooperatives operated in SAR are 287 which are negligible in size as compared to the numbers operated in the nation. Five most agricultural cooperatives operated in the region are given in Table 1. The agricultural development cooperatives is the most operating in the region followed by credit supplied agricultural cooperatives. The less operated cooperatives is the fishery products cooperatives which could be sensible to some extend that the region is lack of access to see and the area is covered by only two major rivers, Tigris and Euphrates. Most of these five cooperatives are located in Diyarbakır, Gaziantep and Şanlıurfa provinces, respectively. It is worth noting that most of the agricultural land irrigation cooperatives are located in Gaziantep province despite the fact that the major irrigation takes place in Harran Plain located in Şanlıurfa city limit. This might be attributed due in large part to the fact that Gaziantep city is the most extensively industrialized province in SAR.

Table 1 shows descriptive statistics for agricultural cooperatives operated in SAR. The most common cooperative is an agricultural credit cooperative which aims to help and improve its members' economic condition by providing good production facilities, utilizing agricultural products and in turn increase gross marginal revenues. Despite the fact that the agricultural credit cooperatives found many agri-business or agricultural based industrial factories, it provides its members agricultural inputs and loans. Agricultural product sale cooperatives buy specified agricultural products from farmers, process and pack them for domestic and international trade. They also provide agricultural inputs to its farmers and they make also domestic and foreign product purchase in the name of the government if the government allows. Agricultural development cooperatives on the other hand participate in many agricultural activities such as provide agricultural

Table 1: Descriptive Statistics for Agricultural Cooperatives Operated in the Southern Anatolian Region

Provinces	*Agricultural Credit Cooperatives*		*Agricultural Product Sale Cooperatives*		*Agricultural Development Cooperatives*		*Agricultural Irrigation Cooperatives*		*Fishery Product Cooperatives*		*Total*	
	#	%	#	%	#	%	#	%	#	%	#	%
Adıyaman	14	0.159	2	0.091	19	0.139	5	0.185	8	0.615	48	0.167
Batman	3	0.034	1	0.045	2	0.015	0	0.000	0	0.000	6	0.021
Diyarbakır	7	0.080	3	0.137	61	0.445	4	0.148	2	0.154	77	0.268
Gaziantep	25	0.284	5	0.227	32	0.234	12	0.445	1	0.077	75	0.261
Kilis	8	0.091	1	0.045	2	0.015	1	0.037	0	0.000	12	0.042
Mardin	7	0.080	3	0.137	5	0.036	0	0.000	0	0.000	15	0.052
Siirt	2	0.022	1	0.045	7	0.051	0	0.000	0	0.000	10	0.035
Şanlıurfa	22	0.250	6	0.273	8	0.058	5	0.185	2	0.154	43	0.150
Şırnak	0	0.000	0	0.000	1	0.007	0	0.000	0	0.000	1	0.003
Total	88	1.000	22	1.000	137	1.000	27	1.000	13	1.000	287	1.000
SAR (%)	0.307		0.077		0.477		0.094		0.045		1.000	

inputs, market agricultural products, organize development activities, develop hand and households' arts.

Agricultural irrigation cooperatives develop project for how water can efficiently be supplied to agricultural lands, build irrigation channels at land entrance point, and build irrigation and drainage installations at agricultural lands. Agricultural fishery cooperatives in SAR provide and arrange aqua-culture species in Ataturk dam and in other artificial docks. It in turn utilizes aqua-culture species and markets these products. There are currently thirteen cooperatives of agricultural fishery cooperatives operated in the region.

The descriptive statistics for farmers' characteristic variables are given in Table 2. The data were, unfortunately, limited to information on farmer characteristics only. Information on farmer characteristics were farm size, gross product income, age, household size, education, communications with agricultural cooperatives, and technology levels used at farms. Approximately, 20% of farm sizes are less than 6 hectares and 70% of farmers have less than 20 hectares. The farm sizes in this region are usually above the country mean farm sizes, which are approximately 6 hectares per farm. Large farm sizes comprise 30% of the sample.

Factors that are specific to farmers include education proxy as attainment of the secondary and above schooling, total number of years worked at farm, age, and, household size. The level of education may indicate potential human capital stock on farm. An improvement in the level of educational attainment may increase the probability of entering agricultural cooperatives in leading better relationships with agricultural cooperatives.

The level of communication with agricultural cooperatives may play a key determining factor for entrance. The higher interaction with personnel or managers of cooperatives, the better understanding of the agricultural cooperatives operated in the region. An

Table 2: Descriptive Statistics of Variables

Variable	*Unit*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
Age	1 if the farmer is 40 and above years old	0.288	0.456	0.000	1.000
Experience	Years	13.000	8.100	5.000	25.000
Household size	#	6.667	2.884	3.000	13.000
Education	1 if the farmer had completed secondary and above any school	0.278	0.450	0.000	1.000
Low Communication	1 if the farmer has met at least ones or a few times any personnel of the agricultural cooperatives in his lifetime	0.456	0.501	0.000	1.000
Medium Communication	1 if the farmer has met more than few times, but not as frequently as he would like, to the agricultural cooperatives' personnel	0.389	0.490	0.000	1.000
High Communication	1 if the farmer has a good communication with agricultural cooperatives	0.156	0.364	0.000	1.000
Gross product income per hectare [1]	Turkish Lira in million	1668.046	258.347	500.000	2250.000
Farm Size	Hectare	37.364	49.619	3.000	250.000
Low technology used	1 if the farmer has a traditional farming tools and equipments	0.367	0.485	0.000	1.000
Medium technology used	1 if the farmer has at least a tractor and some other farming tools and equipments	0.533	0.502	0.000	1.000
High technology used	1 if the farmer has identified himself using all necessary machinery tools and equipments	0.100	0.302	0.000	1.000
N	90				

[1] $1 was approximately equal to 1,600,000 Turkish Lira during survey period.

important implication is that the farm neighborhoods are strong because houses built in a small villages are close to each other and a relatively strong kinship among farmers can be observed. An agricultural cooperative personnel working in one's farm, perhaps because of spraying with a chemical substance against insects or controlling weed, can be quickly observed or better informed by other neighboring farmers. Thus, observing the agricultural cooperative personnel in one's farm may increase the probability of some other farmers' entrances to the agricultural cooperatives. The non-members may be further affected by the agricultural cooperatives having a slide shows once a year to its member in the village.

3 Results and Discussions

The estimated parameter results are given in Table 3. Most signs on the all estimates make intuitive sense. The probability of a membership declines with increases in the age, household size, gross income, farm size-squared, and higher technology used variables. The membership probability increases with increases in the experience, education, high communication level with cooperatives, farm size and medium technological level variables. Age variable is statistically significant at 10% level. Younger farmers are more likely to enter agricultural cooperatives than elderly farmers. The education variable shows the expected sign and is statistically significant. The increased probabilities of the decision to enter agricultural cooperatives with higher educational attainment is presumably due in large part to foreseeing the diversification and make the use of available opportunities provided by the cooperatives. The higher the communication with the cooperatives, the more will be the farmer's attachment to the agricultural cooperatives. It is worth to note here that the better educated farmers have a larger human capital stock and exchange the information with the cooperatives and thus more attachment to cooperatives will results. Farmer's gross income variable is also statistically significant and negatively related to the decision to join an agricultural cooperative. A plausible explanation might be that the monetary value of gross income is quickly visible to the farmers as cash favoring a short term relaxation with an easy-going confidence. The farm size (hectares) variable has a positive impact on the probability level. We also compute the non- linear relationship of the farm size variable on the probability level. This non linearity relationship shows as farm size measured as hectares increases, thus gross income, producers show less willingness to be a member of agricultural cooperatives. The sign of the non-linearity variable is in line with the gross income variable indicating at a higher farm size, the probability of the membership decreases with increases in the farm size.

Table 3: Original Parameter and Marginal Effect Estimates of Binary Logit Model

Variables	*Binary Logit Model*			
	Initial Parameter Estimates		*Marginal Effects*	
	Coefficient	*t-value*	*Coefficient*	*t-value*
Constant	8.239	1.027	0.325	18.288
Age	-1.877[b]	-1.848	-0.216[a]	-4.562
Experience	0.027	0.501	0.001	0.054
Household Size	-0.009	-0.076	$-0.360 * 10^{-3}$	-0.018
Education	2.625[a]	2.649	0.165[a]	7.922
High Communication	3.181[b]	1.767	0.122[a]	13.277
Log of Gross Income	-1.203	-1.363	-0.047[a]	-2.122
Farm Size	0.093[b]	1.772	0.004	0.194
Farm Size-Squared	$-0.302 * 10^{-3}$ [a]	-1.645	$-0.119 * 10^{-4}$	-0.001
Medium Technology Used	2.221[a]	2.870	0.010[a]	5.108
Higher Technology Used	-1.310	-0.697	-0.152	-3.052
Log-Likelihood		-36.219		

Note: [a], [b] indicate significant levels at 5% and 10%, respectively.

Medium technology used at farms compared to the conventional (low) technology variable used as base variable is statistically significant. Farmers who are members of the agricultural cooperatives may be supplied with the new innovations as viewed services provided by the agencies. High technology used at farms is negatively related to the probability of entering agricultural cooperatives relative to the low and medium technological levels. Wealthier farms may operate such technology levels compared to the small farms usually growing larger proportion of intensive high-return crops and may thus seek to get cash credits or inputs/services supplied by the agricultural cooperatives.

The effects of schooling, high communication and medium technology used in farms on the probability decision are negligible in magnitudes. However, the true effect of each variable on the probability decision can be assessed deriving from marginal effect formulation.

The marginal impact of each variable on the probability level at the sample data mean is computed as:

$$\frac{\partial E(y_i = 1|x)}{\partial x_k} = \frac{\partial \Phi(y_i = 1|x)}{\partial x_k} = \Lambda(x'\beta) \left[1 - \Lambda(x'\beta)\right] \beta_k \ , \tag{8}$$

where $\Lambda(x'\beta) = \frac{e^{x'\beta}}{1+e^{x'\beta}}$

Marginal effects for indicator variables, say q, is the difference between two derivatives evaluated at the dummy indicator value 1 and 0, respectively:

$$\frac{\partial E(y_i = 1|x)}{\partial x_k} = \left[\Lambda(x'\beta) \left[(1 - \Lambda(x'\beta)\right] \beta_k\right]_{q=1} - \left[\Lambda(x'\beta) \left[(1 - \Lambda(x'\beta)\right] \beta_k\right]_{q=0} \tag{9}$$

If we let $C = \Lambda(x'\beta) \left[(1 - \Lambda(x'\beta)\right]$, then $\frac{\partial E(y_i=1)}{\partial x_k}$ has a logistic distribution with mean $C\beta$ and variance $C\Sigma C'$ where Σ is the variance-covariance matrix of initial parameters, β (Greene, 2003).

The signs of marginal effect variables are in line with the signs obtained from parameter estimates, however, larger t-values attributed to the significant variables. We will drive only intentions on the significant variables. The marginal impacts of dummy variables, surprisingly statistically significant variables, on probability of entering the agricultural cooperatives have fewer impacts in magnitude than that of the original parameter estimated impacts. One unit change in education, better to say one year increase in schooling, high communication and using medium technology variables will in turn increase the probability of participation by 0.165, 0.122, and 0.010 units, respectively. A unit change in using higher technology will in turn reduce the probability of entering the agricultural cooperatives by 0.152 units relative to the base variable. Noticeably, the impacts of these variables in magnitude are negligible when compared to each other on the probability decision model. As gross income increases by one unit, the probability of entrance decreases by 0.047 units and the variable is statistically significant. Although the age variable was statistically significant at 10% level in the probability model, the statistical significance of its marginal effect gains more. The impacts of the marginal effect estimates for continuous variables on the probability decision are higher in absolute values than the original parameter estimates. Farm size variable losses its significance as compared to the initial model.

We might be interested in the probabilities as a function of farm size or log of gross income keeping all other variables constant, *ceteris paribus*. Keeping all other variables at their means (e.g., dummy variables scaled at 1 indicating the presence of all dummy variables), the probability of the decision to enter an agricultural cooperative as a function of land size and log of gross income variables each as:

$$P_{1FS}(y_1 = 1) = \Lambda(-0.323 + 0.093 * Farm\,Size)\ , \tag{10-a}$$

$$P_{1LnGI}(y_1 = 1) = \Lambda(15.696 - 1.203 * Log\,of\,Gross\,Income) \tag{10-b}$$

The constant value, -0.323 comprises of all variables at mean (e.g., age, education, high communication, medium technology variables are scaled at 1) except the land variable and 15.696 captures all effects at mean values except the log of gross income variable. The probability as a function land size without present of education, high communication and medium and high technology variables, respectively, is as

$$P_{2FL}(y_1 = 1) = \Lambda(-2.984 + 0.093 * Farm\,Size)\ , \tag{11-a}$$

$$P_{3FL}(y_1 = 1) = \Lambda(-3.504 + 0.093 * Farm\,Size)\ , \tag{11-b}$$

$$P_{4FL}(y_1 = 1) = \Lambda(-2.544 + 0.093 * Farm\,Size)\ , \tag{11-c}$$

$$P_{5FL}(y_1 = 1) = \Lambda(-0.987 + 0.093 * Farm\,Size) \tag{11-d}$$

The probability of entering the agricultural cooperatives as a function of log of gross income with absence of education, high communication, medium and high technology variables, respectively, is as

$$P_{2LnGI}(y_1 = 1) = \Lambda(13.071 - 1.203 * Log\,of\,Gross\,Income)\ , \tag{12-a}$$

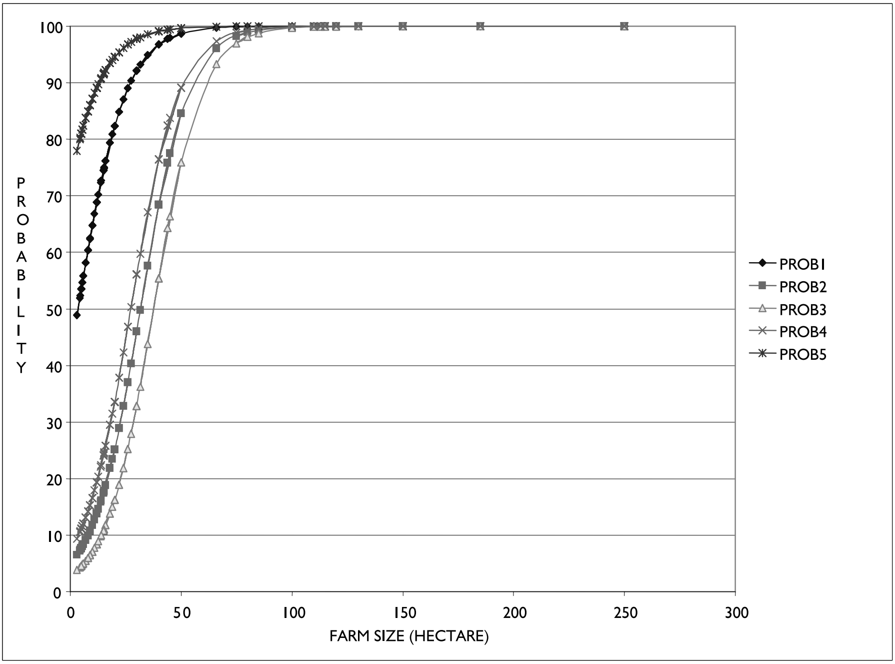
$$P_{3LnGI}(y_1 = 1) = \Lambda(12.515 - 1.203 * Log\,of\,Gross\,Income)\ , \tag{12-b}$$

$$P_{4LnGI}(y_1 = 1) = \Lambda(13.475 - 1.203 * Log\,of\,Gross\,Income)\ , \tag{12-c}$$

$$P_{5LnGI}(y_1 = 1) = \Lambda(17.006 - 1.203 * Log\,of\,Gross\,Income) \tag{12-d}$$

The calculated probabilities against farm size and log of income variables are depicted in Figure 1 and 2, respectively. The P_{1FS} represents the cumulative distribution function of logit model as a function of land size assuming all other variables scaled at their means, *ceteris paribus*. P_{1FS}, P_{2FS}, P_{3FS}, P_{4FS} and P_{5FS} account individually for when schooling, higher communication, medium and higher technologies used at farms are not present, respectively. For example, the P_{2FS} shows the cumulative distribution of the logit model as a function of farm size with the absence of the secondary or above educated farmers keeping all other variables constant at mean values, *ceteris paribus*. Other probabilities as well as the cumulative distribution function of the logit model as a function of log of gross income variable are constructed likewise.

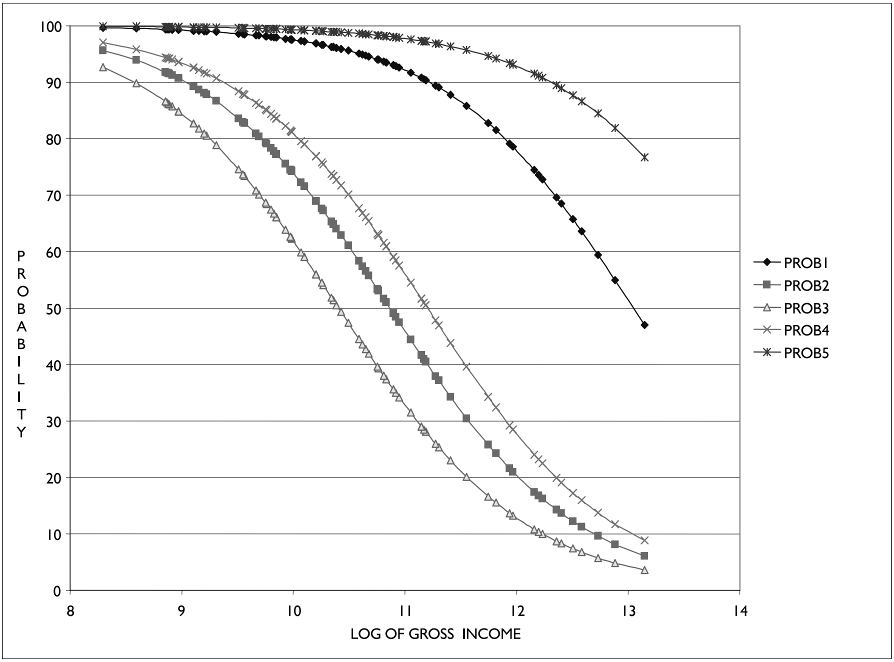
Figure 1: Estimated percentage of farmers participation probabilities at different farm size for different levels of farmer characteristics



It is worth noting when the farm size is scaled at the mean value (e.g., 37.5 hectares), the secondary school and above educated farmers using a high communication with an agricultural cooperative and having medium and higher technologies at farm are more likely expected to be a member to an agricultural cooperative than illiterate or elementary school educated farmers who use less communication with an agricultural cooperative and traditional conservative machinery-equipment used at farms. Farmers who do not use medium technology at farms are more likely expected to participate to the agricultural cooperative than those farmers not having secondary and above schooling. These farmers show also more willingness towards an agricultural cooperative than those who do not have a good communication with the cooperatives. We can say that the effects of these three factors on the probability level are negligible.

An interesting point can be said here that farmers who do not use higher technology at farms are highly expected to be a member to the agricultural cooperatives than those using such technology at farms. This can be related in some extent that the wealthier farmers using high technology levels always have more enthusiasms towards innovations and thus benefiting from incomes at hands. Noticeably, farmers using high technology level at farms are presumably wealthier farmers and thus the impact of this variable with

Figure 2: Estimated percentage of farmers participation probabilities at different log of gross income for different levels of farmer characteristics



the gross income effect move together. As land sizes rise, the probability of participation becomes constant neglecting the effects of all significant variables used in the model.

4 Conclusions

We present factors affecting the probability of joining the agricultural cooperatives using binary logit model. Most of variables such as education, high communication, log of gross income, farm size, medium and high technology variables play important roles in determining the probability of entrance. Small farmers are more likely expected to enter the agricultural cooperatives than the wealthier farmers are. Small farmers may wish to benefit cash, input subsidies, and services provided by the agricultural cooperatives since the risks associated with intensive high-return crops are high. Some important factors playing a pole role in abstention of farmers towards agricultural cooperatives are gross income and some social status variables. Although gross income and farm size variables move opposite direction on the joining decision process, the quick cash realization factor from gross income might give a temporary relief to the land owner and thus restrain the participation process towards agricultural cooperatives as compared to the role of farm size factor. In addition, as the gross income rises farmers become financially better off and they might think that all desired economic goals are achieved. Moreover, small farms are risk averse in nature relative to large farms. We, thus, expect small farms to join the agricultural cooperatives more frequently as the degree of risk increases. With anticipation to agricultural cooperatives, small farms may find more confidence if natural disasters happened because expenses incurred to the farms might be compensated by the agricultural cooperatives.

Religious factors may be a key determinant against an agricultural credit cooperative since the cooperative imposes an interest rate as paying back delayed by farmers. Thus, conservative or orthodox farmers are less likely to join agricultural cooperatives than moderate farmers are.

The direct government farm credit programs mainly is objected to provide farmers better access to capital markets and create the opportunity to use and allocate capital inputs with modern technology. The government credit programs may sometimes take the form of direct finance cash. This intervention, in turn, has a negative impact on the membership of the agricultural cooperatives especially on those farmers who seek to obtain the credit from agricultural cooperatives.

The effect of net income gain is lacked in this study. One way to elicit the effect of this factor is to use the contingent valuation (CV) method in dealing with the perceptions about the agricultural cooperatives. Eliciting CV method may further aid to policy makers for implication in emerging agricultural cooperatives. The development of the agricultural cooperatives in order for better access in market as well as the coordination between its members and managers should be objected by the policy makers.

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Farmers' Choice of the Modern Rice Varieties in the Rainfed Ecosystem of Nepal

G. Joshi *[1] and **S. Bauer**[2]

Abstract

In an effort to increase the productivity of rice in Nepal, several modern varieties have been released. Farmers have adopted these varieties to varying degrees depending upon the types of production environment and the considerations for attributes. This paper attempts to identify factors that condition the adoption of selected modern varieties of rice using a multinomial logit model including both production and consumption attributes valued by the farmers and farm and farmer related variables. The results show that both categories of variables are significant in determining the demand for a specific variety. The results of this paper have implications for crop improvement and the modern variety adoption. Research approaches that incorporate farmers' preferences for various attributes of rice in breeding programs and extension strategies have to be adopted. Various types of methods such as demonstration and farmer- participatory trials could be effective vehicles in this regard. Also the research system should develop a range of varieties in order to meet the multiple concerns of the farmers as a single variety may not be able to fulfill all of their concerns.

Keywords: attributes, demand, farmer, Nepal, rainfed, rice, variety

1 Introduction

Rice is the staple food crop of Nepal. It occupies about 50 percent of the total area under food crops of 3.2 million hectares and its contribution to the total food supply is more than 50 percent. This crop alone contributes to about 40 percent of the total calorie intake. In Nepal, the area under modern varieties (MVs) has increased from about 40 percent in 1993/94 to about 83 percent in 2003/04 (Ministry of Agriculture and Cooperatives, 2004). Compared to other ecological regions, this proportion is higher in *Terai* region where irrigation, roads and market infrastructures are well developed.

Nepal's experience with rice research and technology development illustrates the need to put this important sector on a high productivity path beyond what is currently attained. The rice sector in Nepal has experienced some developments especially in the spheres of

* corresponding author

[1] Ganesh Joshi, Director, Department of Agriculture, Ministry of Agriculture and Cooperatives, HMG Nepal, email: grjoshi20@yahoo.com

[2] Siegfried Bauer, Professor, Department of Project and Regional Planning, JLU, Giessen, Germany, email: siegfried.bauer@agrar.uni-giessen.de

varietal development. Over four dozens MVs have been released since 1960s. However, there has not been much progress in the productivity. The growth trend in yield of rice in Nepal during the last 30 years is about 1.5 percent per annum whereas this has been slightly higher (1.90%) for *Terai* region, which is considered the granary of the country.

The adoption of rice varieties may differ depending upon the concerns of the farmers, which are defined by the attributes. Farmers can view some attributes as positive and others as negative. The choice of one variety technology over others is greatly influenced by the balance between these two attributes. Depending on the preferences, resources, and constraints that individual farmers face, a beneficial attribute for one farmer may be a negative one for other, or the balance between positive and negative traits may be acceptable for one farmer but not for another (BELLON, 2001).

Farmers may assess a new technology such as crop variety, in terms of a range of attributes, such as grain quality, straw yield, and input requirements, in addition to grain yield (TRAXLER and BYERLEE, 1993). Crop improvement could potentially benefit from farmers' assessments of the relative performance of different varieties under farmer management. Information on the attributes desired by farmers and their knowledge of the production system could be invaluable in setting the goals of breeding program, delineating the target environment, identifying the parents for breeding and defining the management treatment for breeding work (SPERLING *et al.*, 1993; EYZAGUIRRE and IWANGA, 1996).

It is an established fact that farmers' are also capable of commenting on the design of particular technologies and suggesting changes that would make such technologies and innovations more appropriate for their needs. Taking farmers' input on technology design seriously would accelerate the ultimate adoption of new technologies (PINGALI *et al.*, 2001).Most of the experimental work in crop improvement evaluate the rice varieties often using yield as the sole criterion. Most often these varieties have either not been adopted or adopted for a shorter period. Understanding farmers' variety preference serves as an input to future variety development and diffusion. Thus, for a successful intervention, policy has to be informed on: 'who prefers what kinds of variety most?'

The varieties released in Nepal have been recommended for different agro-ecological zones and ecosystems. JOSHI (2003) reported that out of 48 varieties released, 13 for main season and 10 for spring season have been recommended for cultivation under irrigated condition of Terai region. Only about 5 varieties have been developed for rainfed lowland of Tarai. So far only 2 varieties have been released for upland ecosystem. There are 14 varieties recommended for mid-hills and 4 for high hills. Most of them do best under irrigated conditions.

The main objective of this paper is to identify the factors affecting the demand of modern varieties of rice using a discrete choice model. The paper is organized as follows. The research methodology and analytical techniques are presented in Section 2 while results and discussions are presented in section 3. The paper ends in section 4 with conclusions and recommendations.

2 Methodology and Analytical Techniques

2.1 Sampling and Data Collection

The data for this study were collected from Banke and Nawalparasi districts in the western *Terai*[1] region of Nepal. The farmers were selected from 3 Village Development Committees (VDCs) of each district using stratified random sampling. The VDCs where survey was carried out are Manikapur, Bethani and Bageswori from Banke district and Kushma, Deurali and Ramnagar villages from Nawalparasi district. A total of 222 rice growing farmers were randomly selected from these 6 VDCs of two districts.

The survey included collection of data on number and types of rice varieties grown, area under different varieties, seed sources, farmers' preference for variety characteristics, farm and farmer characteristics and associated socio-economic characteristics. The relevant data for the cropping year 2001/02 were collected by using structured questionnaires.

The farmers' preference/demand for varieties was determined following the two steps procedure. In the first step, most dominant variety (in terms of area) grown by the households in the study area were identified. Hence, five types of varieties were selected. In the second step, the selected varieties were offered to farmers and were requested to make a choice among them.

2.2 Empirical Model

Although the farmers in the study area cultivate about two dozen MVs, few varieties are prominent as exhibited by their area share. Based on the this, only 5 categories of the varieties are selected for this analysis. They are Radha 4, Janaki, Masuli, Sarju 52 and others. The multinomial logit (MNL) model was used to analyze the factors affecting the choice of these varieties. The MNL is based on the random utility model. The utility U to an adopter form choosing a particular alternative is specified as a linear function of the farm and farmer characteristics (β) and the attributes of that alternative (X) as well as a stochastic error component (e):

$$U = \beta X + e \tag{1}$$

Suppose the observed outcome (dependent variable) is choice j. This implicates for a given adopter: $U_{alternative\,j} > U_{alternative\,k}\ \forall\ k \neq j$, or

$$\beta X_j + e_j > \beta X_k + e_k\ \forall\ k \neq j \tag{2}$$

The probability of choosing an alternative is equal to the probability that the utility of that particular alternative is greater than or equal to the utilities of all other alternatives in the choice set.

Let the probability that the i^{th} farmer chooses the j^{th} variety be P_{ij} and denote the choice of the i^{th} farmer by $Y_i' = (Y_{i1}, Y_{i2}, \cdots, Y_{iJ})$ where $Y_{ij} = 1$ if the j^{th} variety is

[1] The *Terai* is a sub-tropical plain region located in the South of Nepal which borders with India.

selected and all other elements of Y_i' are zero. If each farmer is observed only a single time, the likelihood function of the sample of values $Y_{i1}, \cdots, Y_{iJ}$ is:

$$L = \prod_{i=1}^{T} P_{i1}^{Y_{i1}} P_{i2}^{Y_{i2}} \cdots P_{iJ}^{Y_{iJ}} \tag{3}$$

Assuming that the errors across the variety (e_{ij}) are independent and identically distributed leads us to the following multinomial logit (MNL) model.

$$P\{y_i = t\} = \frac{\exp\left(X_{it}'\,\beta\right)}{1 + \exp\left(X_{i2}\,\beta_2\right) + \cdots + \exp\left(X_{iJ}\,\beta_J\right)} = \frac{\exp\{X_{it}'\,\beta\}}{1 + \sum_{j=2}^{J} \exp\{X_{ij}\,\beta_j\}} \tag{4}$$

The multinomial logit model is used to predict the probability that a farmer demands a certain variety and how that demand is conditioned by different farm and farmer characteristics and attributes of the variety valued by the farmers.
By differentiating equation (3) with respect to the covariates we can find the marginal effects of the individual characteristics on the probabilities as

$$\frac{\partial P_j}{\partial X_j} = P_j \left[\beta_j - \sum_{k=0}^{j} P_k \beta_k\right] = P\left[\beta_j - \bar{\beta}\right] \tag{5}$$

The MNL model is general enough to be useful as a tool for studying different circumstances faced by farmers and different problems encountered in the context of choice among multiple varieties. The marginal rate of substitution (MRS) between two varieties is shown to be a weighted sum of the marginal contribution of each variety to the total amount of each attributes demanded (supplied). Households might simultaneously plant multiple varieties if certain attributes are unique to a particular variety. For this reason, we consider a multitude of production and consumption attributes preference of farmers as explanatory variables. The production characteristics considered are duration of maturity (MATURE), irrigation requirement (IRRIG), and threshability (THRESH) where as the consumption characteristics considered are the preference for taste (TASTE), and suitability of the grains for preparing special products (OTHUSE) that are valued by the farmers. Similarly, other farm and farmer's characteristics considered as explanatory variables are education of the household head (EDN), experience of the farmer in rice farming (EXPERI) and the source(s) of seed (SEEDSOU). The definition of the variables and their measurement is presented in Table 1.

3 Results and Discussion

3.1 General Features of the Production System

The basic features of the production systems in the two sampled districts are presented in Table 2. The average farm size is much larger in Banke than in Nawalparasi. While rice is the dominant crop in both the locations, the share of MV was higher in Banke than in Nawalparasi. The cropping intensity and the proportion of irrigated area are higher in Nawalparasi than in Banke.

Table 1: Definition of the variables used for variety demand analysis

Variable	*Definition*	*Measurement*	*Mean*
Attribute	Dependent variable used in multinomial logit	0 = Radha-4 1 = Janaki 2 = Masuli 3 = Sarju-52	-
EDU	Educational attainment of the household head	No. of years of schooling	3.90
EXPERI	Experience of the household head in rice farming	Number	26.3
SEEDSOU	Sources of seed	Binary; 1= if received from formal sources, 0 = otherwise	0.27
THRESH	Farmers' preference for easy threshability of the grains	Binary; 1= if a farmer considers easy threshing as an important attribute, 0 = otherwise	0.73
MATURE	Farmers' preference for early maturity of the variety	Binary; 1= if a farmer considers early maturity as an important attribute, 0 = otherwise	0.62
IRRIG	Farmers' preference for less irrigation requirement	Binary; 1= if a farmer considers less irrigation requirement as an important attribute, 0 = otherwise	0.36
TASTE	Farmers' preference for taste attribute	Binary; 1= if a farmer considers taste attribute as an important attribute, 0 = otherwise	0.88
OTHUSE	Farmers' preference for preparing other speciality products such as *murahi* and *chiura*	Binary; 1= if a farmers considers preparing speciality product(s) is an important attribute, 0 = otherwise	0.63

Table 2: General feaures of the production systems in the study area.

Description	*Districts*	
	Banke	*Nawalparasi*
Average size of land holding per household (ha)	2.3	1.1
Cropping Intensity (%)	151	185
Area under rice (% of total cropped area)	53	52
Area under MV of Rice (%)	81	73
Average Yield of MV (t/ha)	3	3
Percentage Area Irrigated (including seasonal)	35	72

3.2 Description of the Modern Varieties (MVs) Grown

Farmers in the study area grew about two dozens MVs. The most popular MVs and thir area share is presented in Table 3. Among them, Radha 4 ranked number one followed by Janaki, Masuli and Sarju 52 in terms of area coverage. The Radha 4, and Masuli were popular in both the districts whereas Janaki was popular among the farmers in the Banke district. Farmers have also cultivated Indian varieties such as Sarju 52 which was popular in Nawalparasi district. Based on the quality of the grains, the varieties such as Radha 4 and Janaki are considered as coarse rice and Masuli is considered as fine rice.

The discussions with District Agricultural Development Office, Banke revealed that the area under Janaki is decreasing in this district. This is mainly because of the difficulty in pulling of seedlings for transplantation and threshing of the grains manually. This variety is being replaced by Radha 4 in the recent years.

Table 3: Area share (%) of popular modern varieties in the study area

S.No.	*Variety*	*No. of households*	*Percentage share*
1	Radha 4	122	45.0
2	Janaki	59	19.3
3	Masuli	36	8.8
4	Sarju-52	34	6.1
5	Other Radha types[1]	46	6.5
6	Others[2]	-	14.3

[1] includes Radha 17, Radha 9, Radha 32, and Radha 9.

[2] includes Indian varieties such as Indrashan, Sona Masuli, Orissa (OR) and Nepalese varieties such as IR- 22, Sabitri, hybrids etc.

The maturity days and years of cultivation of some of the popular MVs is presented in Table 4. The varieties such as Radha 4, and Radha 17 are early maturing , Sabitri, Sarju 52 and Janaki are medium maturing and Masuli is a late maturing . The Masuli is grown as high as for 30 years since its release in 1973. Sabitri is being cultivated for 23 years since it was released in 1979. Janaki and Sarju-52 were released respectively by NARS of Nepal and India during 1979. These varieties are being cultivated for about 20 years. Radha-4 released during 1995 and recommended for western/mid-western Terai is also being cultivated for about 7 years.

3.3 Analysis of the Variety Demand

The descriptive statistics show that the response for five varieties was 35.7%, and 16.3% respectively for Radha 4 and Janaki, 10.9% each for Masuli and Sarju 52 and 26.2% for other category.

Table 4: Maturity days and years of cultivation of some of the important MVs.

Variety Name	Maturity days based on: Research system*	Maturity days based on: Farmers' response †	Years cultivated †
	Characteristics		
Radha 4	125-130	110-134	1-7
Janaki	135	125-150	1-18
Masuli	145-165	140-155	1-30
Sarju 52	NA	125-145	1-17
Radha 17	NA	115-140	1-4
Radha 9	135-140	125-145	2-5
Sabitri	140	115-140	2-23

Source: * NARC(1997); † Field survey.

The factors that could affect farmers' demand for specific variety using the multinomial logit model (MNL) is presented in Table 5. Taking the most preferred variety in MNL model should not imply that farmers are exclusively looking for a single variety. Of course, farmers are looking for multiple varieties with different intensity of preferences. The results show that estimated MNL model is significant in explaining farmers' preferences for variety. The Pseudo R^2 was 0.37 and the log-likelihood ratio was also highly significant.

The key and significant variables affecting demand for rice variety are attributes such as easy threshability, usage of grains for preparing special products (such as *murahi*-fried rice and *chiura*-beaten rice), early maturity, and less irrigation requirement. The variables related to farm and farmer characteristics affecting demand for variety are the sources of seed, education level and the experience of the farmers.

The contrasting results appear for Radha 4 and Janaki varieties. Farmers who are educated, having more experience in farming, preference for early maturity of the variety and easy threshability significantly increase the probability of demanding Radha 4 over Janaki. This is because Janaki is a variety with longer duration for maturity and difficult to thresh manually. The farmers who have to cultivate succeeding winter crops prefer early maturing variety. In Nepalese *Terai*, winter crops such as wheat and lentil are cultivated after rice. Due to the rainfed condition of the study area, farmers prefer early maturing varieties so as to cultivate winter crops when there is enough moisture in the soil. As a result the farmers are less interested to cultivate Janaki and Masuli varieties because of their long duration for maturity. Instead farmers prefer to cultivate Sarju 52 and Radha 4 because of their short duration. The negative and significant coefficient of IRRIG indicates that the probability of farmers' demand for Masuli and

Janaki decreases with their preference for less irrigation requirement increases, as these two varieties require high amount of water to grow and are mostly suitable to lowland areas.

The results also indicate that the probability of demanding Masuli variety decreases while that for Sarju 52 increases when the farmers consider the attribute such as suitability for preparing speciality products from rice. This is because farmers in the study area prepare other products such as *murahi* and *chiura* in addition to boiled rice. The experienced farmers do cultivate Masuli as exhibited by its cultivation to date since its release in 1973 where as its cultivation goes on decreasing as the farmers' consider early maturity attribute important. Farmers may not be able to cultivate succeeding winter crops because of the long duration of Masuli.

Farmers' probability of cultivating all varieties except Sarju 52 increases with the availability of seed from formal sources (SEEDSOU). As the seeds of these varieties are multiplied and distributed to farmers from the existing extension and research system as well as from NGOs, farmers demand for cultivating these varieties increases.

Table 5: Factors affecting the farmers' demand for rice variety .

Variables	*Coefficients for different variety preferences*			
	Radha 4	*Janaki*	*Masuli*	*Sarju 52*
constant	-4.572***(1.12)	2.806***(1.07)	-1.640(1.26)	-4.526***(1.40)
EDN	0.167***(0.06)	-0.159*(0.08)	0.042(0.08)	0.140**(0.07)
EXPERI	0.059***(0.02)	-0.014(0.03)	0.053*(0.03)	0.022(0.03)
SEEDSOU	1.890***(0.57)	1.602*(0.90)	2.322***(0.76)	-0.575(0.91)
THRESH	1.479**(0.71)	-3.826***(0.91)	0.883(0.78)	0.576(0.88)
MATURE	1.588***(0.50)	-0.552(0.66)	-1.720***(0.70)	1.820***(0.72)
IRRIG	-0.296(0.43)	-1.988***(0.74)	-1.862***(0.71)	-0.047(0.54)
TASTE	-0.515(0.38)	-0.422(0.48)	0.042(0.51)	-0.333(0.49)
OTHUSE	0.492(0.52)	-0.704(0.73)	-1.949***(0.70)	1.487**(0.77)
Pseudo R^2		0.37		
Log likelihood function		-205.95		
Likelihood ratio		246.61***		

***, ** and * imply statistical significance at 1% , 5% and 10% levels, respectively.
Figures in the parentheses are the standard errors.
Dependent variable is Variety. Other varieties as the reference.

4 Conclusion and Recommendation

The farmers in the study area have cultivated many modern varieties (MVs) of rice and some of them are being cultivated as long as for 30 years. The farmers also have multiple concerns and these are reflected in the selection of the variety(ies). In this paper, we have investigated the factors contributing the adoption of selected MVs of rice. We have considered the multitude of production and consumption attributes that are valued by the farmers, as well as farm and farmer specific variables. The key and significant variables affecting farmers' demand for variety are both production and consumption attributes valued by the households and farm and farmer characteristics. They are easy threshability, usage of grains for preparing special products, early maturity of the variety, less irrigation requirement, sources of seed, education and the experience of the farmers.

The results of this paper have implications for crop improvement and the modern variety adoption. The preference for irrigation and early maturity is the reflection of the production environment that the farmers are facing. Also their perceptions of the labor requirement for threshing and preparation of the special products are other variables that are the reflection of management aspects and the usage. As the farmers are the eventual consumers of the product of the agricultural research such as variety, their knowledge of the production environment and preference for the variety attributes are critically important in influencing not only the decision to adopt but also the level of the adoption. Hence, farmers' involvement in participatory varietal improvement and development programs needs to be emphasized so as to address their concerns and preferences.

The results also show that although the farmers value many attributes important, but there is no single variety that can supply all the attributes valued by them. Hence, the breeding efforts should be oriented to supply a range of varieties that can address the concerns of the farmers.

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Identification of Factors that Influence Technical Efficiency of Food Crop Production in West Africa: Empirical Evidence from Borno State, Nigeria

P. S. Amaza *[1], **Y. Bila** [2] and **A. C. Iheanacho** [2]

Abstract
The objective of this study was to examine the determinants of food crop production and technical efficiency in the guinea savannas of Borno State, Nigeria. A stochastic frontier production function, using the maximum likelihood estimation (MLE) technique was applied in the analysis of data collected from 1086 sample farmers in 2004. The MLE results reveal that farm size; fertilizer and hired labour are the major factors that are associated with changes in the output of food crops. The effect of land area on output is positive and the coefficient found to be significant ($p = 0.01$). Fertilizer and hired labour have positive effects on output and their coefficients are significant ($p = 0.01$). Mean farmers' technical efficiency index was found to be 0.68. Farmer-specific efficiency factors, which comprise age, education, credit, extension and crop diversification, were found to be the significant factors that account for the observed variation in efficiency among the farmers. The implication of the study is that technical efficiency in food crop production could be increased by 32 percent through better use of available resources, given the current state of technology.

Keywords: stochastic frontier, productivity, technical efficiency, food crops, farmers

1 Introduction

The Guinea savanna zone of West and Central Africa covers a large area of sub-Saharan Africa. Most of the countries in the zone have low per capita income and are characterized by high incidence of poverty and food insecurity. The rapid increases in human population and exploitative use of non-renewable resources have exacerbated food supply. Hence, providing adequate food supplies is a major challenge.

It is estimated that the annual food supply in Nigeria would have to increase at an average annual rate of 5.9 per cent to meet food demand and reduce food importation significantly (Federal Ministry of Agriculture, 1993). Most studies show that aggregate food production in Nigeria has been growing at about 2.5 percent per annum in recent years. But the annual rate of population growth has been as high as 2.9 percent

* corresponding author
[1] International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, c/o L.W Lambourn & Co., Carolyn House, 26 Dingwall Road, Croydon CR93EE England, Email: p.amaza@cgiar.org
[2] Department of Agricultural Economics and Extension University of Maiduguri, Nigeria

(Olayemi, 1998). The reality is that Nigeria has not been able to attain self-sufficiency in food production, despite increasing land area put into food production annually. The constraint to the rapid growth of food production seems to mainly be that of low crop yields and resource productivity. This is revealed by the actual yields of major food crops, compared with their potential yields (Federal Ministry of Agriculture, 1993). The low yield of crops may also be attributed to a relative decline in rainfall in recent years. Studies by Jagtap (1995) showed that annual rainfall in Nigeria during 1981-90 declined from that in 1961-70. The greatest change occurred in the onset of the rainy season and the extent of early rainfall, which resulted in a reduction by nearly one month in the growing season. There were fewer wet days and higher rainfall intensities in most of the country. The rainfall series showed prolonged dry periods, especially since 1970. The rainfall decline is unprecedented in duration; spatial, temporal character and seasonal expression (Kamara *et al.*, 2006) Thus, drought is one of the major causes of yield loss in the guinea savannas. This has aggravated the food supply situation in the area resulting in low food security index (Federal Republic of Nigeria, 2002).

This paper examines the determinants of food crop production and technical efficiency in the Guinea savannas of Nigeria. A pre-requisite for enhanced efficiency is the identification of those factors which prevail at the farm-level and which affect efficiency of production. Thus, it will help in providing information for the formulation of appropriate policies.

2 Materials

The study used primary data obtained through a farm management survey of farm-families in Borno State of Nigeria. The State is demarcated in four ecological zones: southern and northern guinea savannah in the south, Sudan savannah in the south and central, and the sahel in the north.

Farming is the predominant occupation in the study area, where rain-fed food crop farming and livestock rearing characterize the major land-use pattern. The cropping system is largely determined by both the amount and the duration of the rainy season (Amaza and Gwary, 2000).

The main instruments for data collection were well-structured questionnaires administered on farm-families. Multi-stage, random sampling techniques were employed in the selection of a sample of 1086 food crop farmers by 30 trained enumerators. The range of data collected covered those on household's farm activities. These include material input (input purchase cost); family and hired labour supply and use, sources of credit, tenurial arrangement, farm size, quantities of farm outputs and their farm gate and market prices. In addition, data were collected on household socio-economic variables, such as age, level of education, household size, and so on.

3 Methods

The stochastic efficiency frontier model independently proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) was applied in the analysis of data. The approach has the advantage because it accounts for the presence of measurement error in the specification and estimation of the frontier production function. The stochastic frontier function differs from the traditional production function in that the former consists of two error terms. The first error term accounts for the existence of technical efficiency and the second accounts for factors such as measurement error in the output variable, weather and the combined effects of unobserved inputs on production.

In the literature, the econometric approach has generally been preferred in the empirical application of stochastic frontier production model in agriculture. This is probably due to a number of factors. First, the assumption that all deviations from the frontier arise from inefficiency, as assumed by data envelopment analysis (DEA) is difficult to accept, given the inherent variability of agricultural production due to uncontrollable factors such as weather, pests and diseases.

Second, because many farms are small, family-owned enterprises farm records are seldom kept. Consequently, available data on production are likely to be subject to measurement errors.

3.1 The Stochastic Frontier Production Model

The frontier production model is based on the stochastic efficiency model by Parikh and Shah (1994), which in turn, derives from the composed error model of Aigner *et al.* (1977), Meeusen and van den Broeck (1977) and Forsund *et al.* (1980).

The frontier production model begins by considering a stochastic production function with a multiplicative disturbance term of the form:

$$Y = f(X_a; \beta)\, \varepsilon(v, u) \tag{1}$$

Where:

Y	is the quantity of agricultural output;
X_a	is a vector of input quantities;
β	is a vector of parameters and
ε	is a stochastic disturbance term consisting of two independent elements u and v, where

The symmetric component, v, accounts for random variation in output due to factors outside the farmer's control, such as weather and diseases. It is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. u is a one-sided component, where $u \leq 0$ reflects technical inefficiency relative to the stochastic frontier, $f(X_a; \beta)e^{\varepsilon}$. Thus, $u = 0$ for a farm output which lies on the frontier and $u < 0$ for one whose output is below the frontier as $|N(0, \sigma_u^2)|$, i.e. the distribution of u is half-normal.
The variance of σ^2 is, therefore

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{2}$$

The ratio of two standard errors[1] is defined by

$$\lambda = \sigma_u + \sigma_v \tag{3}$$

[1] Battese and Corra (1977) define γ as the total variation in output from the frontier and which is attributable to technical efficiency i.e. $\gamma = \sigma_u^2/\sigma^2$ so that $0 \leq \gamma \leq 1$

Jondrow *et al.* (1982) have shown that measures of efficiency at the individual farm level can be obtained from the error terms $\varepsilon = u + v$. For each farm, the measure is the expected value of u conditional on ε, i.e.

$$E(u|\varepsilon) = \frac{\sigma_u \sigma_v}{\sigma} = \left[\frac{f(\varepsilon\lambda/\sigma)}{1 - F(\varepsilon\lambda/\sigma)} - \frac{\varepsilon\lambda}{\sigma}\right] \tag{4}$$

Where f and F are the standard normal density function and the standard normal distribution function evaluated at $\varepsilon\lambda/\sigma$. Estimated values for ε, λ and σ are used to evaluate the density and distribution functions. Measures of efficiency for each farm can be calculated as:

$$TE = exp\,[E(u|\varepsilon)] \tag{5}$$

A number of empirical works (Parikh and Shah, 1994; Llewelyn and Williams, 1996) and recently Amaza and Olayemi (2002) have investigated the determinants of technical efficiency among firms in an industry by regressing the predicted efficiencies, obtained from an estimated stochastic frontier on a vector of farmer-specific factors such as age of the farmer, educational level of the farmer, access to extension, and so on, in a second-stage regression. The identification of those factors, which influence the level of technical efficiencies, is a valuable exercise because the factors are significant for policy formulation.

It is assumed that the inefficiency factors are independently distributed and that u arises by the truncation (at zero) of the normal distribution with mean μ and variance σ^2, where u in equation (5) is defined as:

$$u = f(Z_b; \delta) \tag{6}$$

Where Z_b is a vector of farmer-specific factors, and
δ is a vector of parameters

The β- and δ- coefficients in equations (1) and (6) respectively are unknown parameters to be simultaneously estimated, together with the variance parameters which are expressed in terms of:

$$\sigma_s^2 = \sigma_v^2 + \sigma^2 \text{ and} \tag{7}$$

$$\gamma = \sigma^2/\sigma_s^2 \tag{8}$$

Where the γ- parameter has a value between zero and one. The parameters of the stochastic frontier function are estimated by the method of maximum likelihood, using the computer program FRONTIER version 4.1 (Coelli, 1994)

4 Results and Discussions

The estimated stochastic frontier production function is presented in Table 1. All the coefficients in the model have the expected *a priori* signs and are mostly significant.

The estimated coefficient for land is positive, which conform to *a priori* expectation, and significant at 1-percent level. The magnitude of the coefficient of land, which is 0.07, indicates that the output in food crop production is inelastic to changes in the

Table 1: Maximum likelihood estimates of the parameters of the stochastic frontier function.

Variable	*Parameter*	*Coefficient*	*Standard error*
Production factors			
Constant	β_0	8.282	0.159**
Farm size (X_1)	β_1	0.073	0.033 **
Fertiliser (X_2)	β_2	0.204	0.012**
Hired labour (X_3)	β_3	0.063	0.003**
Family labor (X_4)	β_4	0.001	0.014
Seeds (X_5)	β_5	0.0009	0.008
Inefficiency effects			
Constant	δ_0	-9.904	2.581**
Age (Z_1)	δ_1	-2.042	0.417**
Education (Z_2)	δ_3	-0.221	0.059**
Credit (D_1)	δ_4	-0.380	0.092**
Extension (D_2)	δ_5	-0.24	0.050**
Crop diversification (Z_3)	δ_6	0.076	0.041*
Diagnostic Statistics			
Likelihood ratio = 161.42			
Sigma-squared (σ^2)	7.059	1.022**	
Gamma (γ)	0.897	0.015**	

**,* significant at the 1% and 5% level respectively

level of cultivated land area. The 0.07 elasticity of land implies that a 1-percent increase in cultivated land area, *ceteris paribus*, would lead to an increase of 0.07 percent in the output of food crops, and vice versa. This suggests that land is a significant factor associated with changes in crop output.

The production elasticity with respect to inorganic or chemical fertilizer is positive as expected and statistically significant at 1-percent level. The significance of the fertilizer variable derives from the fact that fertilizer is a major land fertilizing input and improves the productivity of existing land by increasing crop yields per hectare.

The magnitude of the coefficient of hired labour, which is 0.06, indicates that output in crop production is highly inelastic to changes in the amount of hired labour used. Thus, a 1-percent increase in hired labour would induce an increase of only 0.06 per cent in the output of crops, and vice versa. Farmers who have the main objective of income maximisation in food crop production would tend to allocate resources more efficiently, including the allocation of hired labour (Amaza and Gwary, 2000). On the other hand, farmers whose main objective is household food security would be more concerned with maximising their output per unit of resource used, especially family labour; that is, they tend to emphasize technical efficiency.

The inefficiency parameters are specified as those relating to farmers' specific socio-economic characteristics. These include the age, educational levels, access to credit, access to extension advice and their degree of crop diversification. The coefficient of age variable is estimated to be negative and statistically significant at 1-percent level. This indicates that farmers who are older are relatively less efficient in food crop production and vice versa. Thus, because food crop production in the study area is relatively labour intensive, especially weeding and harvesting operations, younger farmers tend to be more productive. Also, the younger farmers are likely to be more progressive and, hence more willing to adapt new practices, thus leading to higher efficiencies in food crop production.

The coefficient of education variable is estimated to be negative as expected and statistically significant at the 1-percent level. This finding agrees with comparable findings by Battese *et al.* (1996), Coelli and Battese (1996) and Seyoum *et al.* (1998). The implication is that farmers with formal schooling tend to be more efficient in food crop production, presumably due to their enhanced ability to acquire technical knowledge, which makes them move close to the frontier output. It is very plausible that the farmers with education respond readily to the use of improved technology, such as the application of fertilizers, use of pesticides and so on, thus producing closer to the frontier.

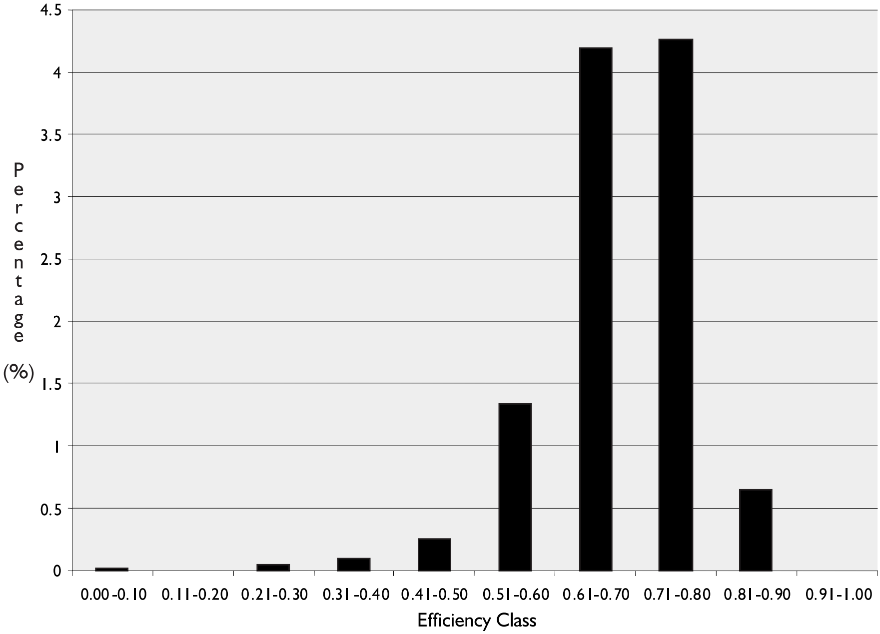
The coefficient of credit variable is estimated to be negative as expected and statistically significant at 1-percent level. This suggests that farmers who have greater access to credit tend to be more efficient in food crop production. Because food crop production is heavily labour-intensive, substantial part of the credit is used to hire labour, especially for weeding and harvesting operations. Also, the availability of credit helps to finance purchased inputs, especially fertilizer, which has positive effect on the productivity of farmers.

The coefficient of the extension variable is estimated to be negative and statistically significant at the 1-percent level. This indicates that increased extension services to farmers tend to increase technical efficiency in food crop production. The significance of extension in this study corroborates the findings of Seyoum *et al.* (1998) who reported positive influence of extension contact on efficiency in their study of technical efficiency and productivity of maize farmers in eastern Ethiopia.

The crop diversification variable in the model is negative and statistically significant at 5 percent level. As diversification decreases and fewer crops are grown, efficiency increases. The implication is that lesser diversification is associated with higher relative efficiency. The consideration for risk minimization is a major factor accounting for the practice of mixed-cropping (Norman, 1974; Just and Candler, 1985). A study by Abalu (1976) on crop mixtures in Northern Nigeria contends that crop mixtures are employed by farmers primarily as risk-minimizing precautions and that the immediate objective of farmers is not only one of profit maximization but also of stability of income.

A significant characteristic of the stochastic frontier production model is its ability to provide farm-specific measures of technical efficiencies. The distribution of farmers' technical efficiency indices derived from the analysis of the stochastic production function is provided in Figure 1.

Figure 1: Distribution of farmers' technical efficiency indices.



The technical efficiency of the sampled farmers is less than 1 (or 100 %), indicating that all the farmers are producing below the maximum efficiency frontier. A range of technical efficiency is observed across the sample farms where the spread is large. The best farm has a technical efficiency of 0.90 (90 %), while the worst farm has a technical efficiency of 0.02 (2 %). The mean technical efficiency is 0.68 (68%). This implies that, on the average, the respondents were able to obtain a little over 68 percent of optimal output from a given mix of production inputs.

The distribution of technical efficiency of the farmers reveals that only 7 farmers representing 0.64 percent had a technical efficiency of less than 30 percent, while 491 farmers, representing approximately 45.3 percent had a technical efficiency of above 70 per cent.

The picture that emerges from this analysis is one of generally average technical efficiency in food crop production in the study area. The magnitude of the mean technical efficiency of the farmers is a reflection of the fact that most of the sample farmers carry out food crop production under technical conditions, involving the use of inefficient tools, unimproved seed varieties and so on. The low production technology adopted by the majority of the farmers and their low levels of formal education are major factors that have influenced the level of their technical efficiency.

The distribution of the technical efficiency suggests that potential gain in technical efficiency among the sample farmers is large. The mean technical efficiency of approximately 68 per cent implies that, in the short-run, there is the scope for increasing technical efficiency in food crop production in the study area by 32 per cent. This can be achieved through improved farmer-specific efficiency factors, which include improved farmer education, access to credit, access to improved extension services and less crop diversification

5 Conclusion and Policy Implication

The study reveals that farm size; fertilizer and hired labour are the major factors that are associated with changes in the output of food crops. The effect of land area on output is positive and the coefficient found to be statistically significant ($p = 0.01$). Chemical fertilizer and Hired labour have positive effects on output and their coefficients are statistically significant ($p = 0.01$).

The model for the inefficiency effects in the frontier function includes age, education, access to credit, access to extension and crop diversification. All the farmer-specific variables were significant in accounting for the observed variation in efficiency among the farmers. The policy implication of the study is that technical efficiency in food crop production could be increased by 32 percent through improved use of available resources, given the current state of technology. This can be achieved through improved farmer-specific efficiency factors, which include improved farmer education, access to credit, access to improved extension services and less crop diversification.

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Population Levels of Indigenous *Bradyrhizobia* Nodulating Promiscuous Soybean in two Kenyan Soils of the Semi-arid and Semi-humid Agroecological Zones

J. M. Maingi *[1], **N. M. Gitonga**[2], **C. A. Shisanya**[3], **B. Hornetz**[4] and **G. M. Muluvi**[5]

Abstract

Soybeans grown in Africa have been selected to nodulate effectively with indigenous *Bradyrhizobium* spp. populations since *Bradyrhizobium japonicum* populations are considered absent or in very low numbers in African soils. The major objective of this study was to estimate total population of *Bradyrhizobia* specific to soybean in two agro-ecologically different study sites, Kiboko in Makueni District, Southeast Kenya (semi-arid to arid conditions) and Kaguru in Meru District, East Kenya (semi-humid climate) . The population of the indigenous rhizobia specific to soybeans was determined using the Most Probable Number (MPN) plant infection technique. In these experiments, the total *Bradyrhizobia* populations, the population sizes of taxonomically defined slow-growing *Bradyrhizobia* specific to soybean and the population sizes of *Bradyrhizobia* spp. specific to tropical *Glycine* Cross (TGx) varieties were determined for the two study sites. Cowpea, *Vigna unguiculata*, cultivar Ken Kunde I was used to estimate the total *Bradyrhizobia* spp. population. Clark soybean, *Glycine max*, was used to estimate the population sizes of taxonomically defined slow-growing *Bradyrhizobia* spp. specific to soybean while a TGx genotype, SB12-TGx1869-31E was used to determine the population sizes of *Bradyrhizobia* spp. specific to TGx varieties. The results of the MPN counts indicated that the total *Bradyrhizobia* population in Kiboko was between 2.59×10^4 and 1.89×10^5. The population size of taxonomically defined slow-growing *Bradyrhizobia* in Kiboko was between 2.59×10^2 and 1.89×10^3 cells per gram of soil sample while the approximate *Bradyrhizobia* population specific to TGx genotype was between 7.81×10^2 and 5.67×10^3 cells per gram of soil. In Kaguru, the approximate total *Bradyrhizobia* population was between 1.04×10^2 and 7.56×10^3 cells per gram of soil. The population size of taxonomically defined slow-growing *Bradyrhizobia* was be-

* corresponding author

[1] John M. Maingi, Department of Plant and Microbial Sciences, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya, E-mail: jmanguske@yahoo.com

[2] Nkanata M. Gitonga, see [1]

[3] Chris A. Shisanya, Department of Geography, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya

[4] Berthold Hornetz, Department of Geosciences, University of Trier, D-54286, Trier, Germany

[5] Geoffrey M. Muluvi, Department of Biochemistry and Biotechnology, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya

tween 1.33x10^2 and 9.72x10^2 cells per gram of soil while the approximate *Bradyrhizobia* population specific toTGx genotype was between 2.37x10^2 and 1.73x10^3 per gram of soil. These populations were adequate to give satisfactory results on nodulation and nitrogen fixation in the two study sites.

Keywords: Bradyrhizobia, soybean, Glycine Cross, TGx, Glycine max, nodulation, Most Probable Number, soil, nitrogen fixation, Kenya

1 Introduction

Soybean has become famous as the plant that will help feed the world's present and future population and help to solve world protein deficiency. The soybean seed is the richest natural vegetable food. Soybean is an important aid to agriculture (Hill, 1978, pp. 340-341); it can help to enrich the soil with nitrogen through biological nitrogen fixation. Soybean as food is not as important in Africa as it is in developed countries or in Asia where it originated. The beans have a strong flavour, which is not liked by many local people. However, soybeans have a lot of uses in industry. Most soybeans grown in tropical Africa are for oil production and the protein-rich seed cake is fed to animals. Some soybean processors also produce soy flour, which has low carbohydrate content and is an excellent food for diabetics. The seeds can also be processed to give soymilk, which is an excellent source of protein for babies, especially those just weaned from breast-feeding. Cultivation of this crop in Sub-Saharan Africa has not been substantial but popularisation programmes by governments and non-governmental bodies have helped to create awareness to small scale farmers of the importance of soybean not only as a crop for improving their economic status but also as an important high protein food. Soybean is not an indigenous crop to Africa (Okogun and Sanginga, 2003) and it needs either inoculation with specific effective strains of *Bradyrhizobium japonicum* or addition of nitrogen fertilizer. Nitrogen is one of the major nutrients required by plants and is often the most limiting under cultivation. The small-scale farmers in Africa are resource poor and cannot afford the expensive nitrogen fertilizer inputs required to increase soybean yield. Many of the farmers in Africa cannot also afford the use of inoculants that provide an alternative and cheaper source of nitrogen for crop production than the N fertilizers (Kaleem, 2002). The technology for use of inoculants is also cumbersome and difficult to apply by the farmers (Hornetz *et al.*, 2000). They face problems in acquisition and storage of inoculants because cooling facilities are not readily available. Such requirements place constraints on the farmer's capacity to effectively use inoculants. As a result, soybean crops as are grown by farmers in Africa receive no inoculants and little or no commercial nitrogen fertilizer.

To avoid the need for inoculation, soybean breeders at the *International Institute of Tropical Agriculture* (IITA), Nigeria, developed new soybean genotypes for Africa. These genotypes, known as Tropical *Glycine* cross (TGx), nodulate with Bradyrhizobium sp. populations indigenous to African soils (Abaidoo *et al.*, 2000; Osunde *et al.*, 2003). These cultivars have been tested in a number of African countries (Mpepereki *et al.*, 2000; Javaheri, 1996). In Nigeria for example, the development of "promiscuous" soybean cultivars has led to the spread of the crop to large parts of Semi-humid Guinea savanna where it was not being grown before (Osunde *et al.*, 2003).

Much still needs to be done to ensure optimum productivity by the TGxs. One of the main areas that need attention is the quantification of the nitrogen fixed by the rhizobia, and in this way assess the symbiotic performance of the association of the TGxs and the indigenous rhizobia in the soil (Osunde *et al.*, 2003). The numbers of indigenous Bradyrhizobia as well as the soil available nitrogen have been cited as some of the main factors that have a significant effect on symbiotic relationships (Keyser and Li, 1992). The major objective of this study was to estimate the number of indigenous *Bradyrhizobia* in two ecologically different sites in Kenya, Kiboko in Makueni district, southeast Kenya and Kaguru in Meru district with the aim of assessing symbiotic relationship and performance of the indigenous Bradyrhizobia and promiscuous soybean varieties.

The experiments were carried out in the Greenhouse of the Department of Plant and Microbial Sciences, Kenyatta University Nairobi, using soil samples from the two sites in East and South East Kenya. The objectives of the study were: (1) to estimate the population sizes of taxonomically defined slow-growing soybean rhizobia (*Bradyrhizobium japonicum* and *Bradyrhizobium elkanii*, (2) to estimate the total *Bradyrhizobium* spp. populations and (3) to determine the population sizes of *Bradyrhizobium* spp. specific to TGx.

2 Materials and Methods

2.1 The Study Sites

The soil samples for this study were obtained from Kenya Agricultural Institute (KARI), Kiboko Sub-centre (AEZ: LM 5-6) in Makueni District, SE-Kenya and Kaguru Farmers Training Centre (FTC) (AEZ: UM 2-3) in Meru District, East Kenya respectively. KARI, Kiboko Sub-Centre (latitude 02° 12' S, longitude 3° 43' E), is located about 160 km south east of Nairobi, Kenya. The soils of the study area are well drained Fluvisols, Ferralsols and Luvisols. The soil pH is 6.9 (measured in 0.01ml^{-1} $CaCl_2$). Analysis of soil nitrogen and phosphorous by the method described by Forster (1995) indicates a deficiency of both nutrients. Rainfall is bimodally distributed, with median monthly maximum in April (126 mm) and November (138 mm). The mean annual rainfall is about 582 mm. The short rains (October- January) generally have more rainfall and are more reliable than the long rains (March-June) (Musembi and Griffiths, 1986). Mean monthly temperatures are highest in February and October, prior to the onset of the rains in March and November, respectively (KMD, 1984). Kaguru Farmers Training Centre (FTC) is located at latitude, 0° 05' S and longitude 37° 40' E. The soils are well drained, extremely deep, dark reddish brown, friable clay, with acid humid top soil (humid nitosols). The soil pH measured at the time of the study was 4.83. The rainfall is bimodal; the long rains normally start at the end of March while the short rains start normally in October. The short rains are normally more reliable and give higher yields (Jätzold and Schmidt, 1983).

2.2 Soil Sample Collection

Ten soil sub-samples were collected from each of the two study sites, Kiboko in Makueni district and Kaguru in Meru district. Surface debris were cleared from the area to be sampled. After clearance of debris from the surface, a soil core was removed from 15-20 cm depth with a soil auger (ABAIDOO *et al.*, 2002). Each soil sub-sample was cylindrical in shape, 3-5 cm in diameter. In the greenhouse, the soil sub-samples were thoroughly mixed together to obtain a homogenous composite sample.

2.3 Seed Procurement

The seeds which were used in this experiment were of *Vigna unguiculata*, cultivar Ken Kunde I (cowpea), *Glycine max*, cultivar Clark (Clark soybean) and a TGx soybean genotype, SB 12- TGx 1869-31 E. The cowpea seeds were purchased from Kenya Seed Company, Nairobi Kenya. Clark soybean seeds were obtained from United States Department of Agriculture-Agricultural Research Service (USDA-ARS) Soybean Germplasm Collection, Department of Crop Sciences University of Illinois, USA. The SB12-TGx 1869-31E seeds were obtained from International Institute of Tropical Agriculture (IITA), Ibadan Nigeria.

2.4 Leonard Jar Assemblies

The Leonard jar assemblies used were a modification of that described by VINCENT (1970). The assembly was composed of a plastic cup, 8 cm mouth (brim) diameter which tapered to a bottom diameter of 4 cm. The cup containing the rooting medium (vermiculite) was inserted into a larger plastic vessel containing the nutrient solution. Eight hundred mls of plant nutrient solution was added into the lower container of each Leonard jar assembly. A sponge connecting the upper and the lower units of the jar irrigated vermiculite with the nutrient solution. The whole set up was insulated with a khaki paper bag.

2.5 Rooting Medium

The rooting medium, which was used in this study, was vermiculite. This material was washed thoroughly for three successive days by changing the water three times per day and stirring frequently. The final rinse was with distilled water and the pH of the medium was adjusted to about pH 6.8. After attaining the correct pH, water was drained off and the vermiculite packed into the small plastic cups of the Leonard jar assemblies. To reduce contamination and entry of water, the top cups were covered with lids and the assemblies were then steamed for one hour, twice in an autoclave to get rid of microorganisms.

2.6 Plant Growth Medium

Plant nutrient solution was prepared as described by BECK *et al.* (1993). Five stock solutions were prepared (Table 1). For each litre of full-strength plant growth solution, 0.5ml were added from each of the five stock solutions. The pH of the solution was adjusted to 6.8 using $NaOH$ (1.0 M) or HCL (1.0 M). All solutions were sterilized by autoclaving at 121°C for 15 minutes.

Table 1: Nitrogen free nutrient solution (Source: BECK *et al.* (1993))

Stock	*Compound*	*Amount (g^{-l})*	*Final Solution Concentration*
1	$CaCl.\,2H_2O$	294.1	1.00mM
2	KH_2PO_4	136.1	0.50 mM
3	$MgSO_4.\,7H_2O$	123.3	0.25mM
	K_2SO_4	87.0	0.25mM
	$MnSO_4.\,H_2O$	0.338	1.00μM
4	H_3BO_3	0.247	0.30μM
	$ZnSO_4\,H_2O$	0.288	0.50μM
	$CuSO_4\,5H_2O$	0.1	0.20μM
	$NaMoO_2\,:H_2O$	0.048	0.01μM
	$CoSO_4\,7H_2O$	0.056	0.01μM
5	Fe Citrate+	5.4	10.00μM

For each litre of full strength solution, 0.5 ml was added from each of the five stock solutions.

2.7 Sterilization and Pregermination of Seeds

Cowpeas and soybean seeds of good viability (more than 80 %), undamaged and of uniform colour and size were selected MAINGI *et al.* (1999). The seeds were surface-sterilized by immersing them into a 3 % solution of sodium hypochlorite for 5-10 minutes (3 % sodium hypochlorite solution was prepared by adding 10 parts of commercial bleach [5.25 % sodium hypochlorite] to 7.5 parts of water). The seeds were rinsed with 8 changes of sterile distilled water after surface sterilization. They were then soaked in clean sterile distilled water and allowed to imbibe it for one hour. They were transferred aseptically to 2 % water agar plates with a spoon-shaped spatula. Twenty seeds were placed in each plate. The plates with the seeds were incubated upside down at 28°C to enable the radicles to grow away from the water agar. The incubation period was four days. Seedlings whose radicles attained a length of 1-2 cm after the incubation period were considered ready for transferring to Leonard jar assemblies.

2.8 Planting in Leonard Jar Assemblies

A pair of flame sterilized forceps was used to prepare one hole in the rooting medium in each Leonard jar. Seeds with radicle length of 1-2 cm were picked up with the sterile pair of forceps and placed one per hole, with the radicle facing downwards. The holes were deep enough to accommodate pre-germinated seeds 0.5 cm below the surface.

The seedlings were maintained for eight days in the Leonard jar assemblies before inoculation with serial dilutions of soil samples. For the preparation of the serial dilutions, one hundred grams of the composite soil sample were diluted in 900 ml of sterile distilled water. A four-fold dilution series was made from 4^{-1} to 4^{-10}. The Leonard jar assemblies with the seedlings were set in quadruplicates in the greenhouse and inoculated with 2 ml of the dilutions following the procedure of SOMASEGARAN and HOBEN (1994). After inoculation with the soil samples the plants were maintained in the greenhouse for 4 weeks after which they were harvested.

2.9 Harvesting of Plants

At harvest, the stems of the plants were cut at the level of the growth medium. Root and adhering rooting medium were removed and put into a coarse sieve. The rooting medium was washed from the roots using a gentle stream of water. nodulation was observed (+, for nodulation or - for no nodulation) and the number of nodulated (+) plants (units) was recorded beside each dilution.

2.10 Estimation of Bradyrhizobia Population

At harvest, the total number of nodulated units was obtained by summing up the nodulated units at each dilution level (Tables 2 and 3). Uninoculated controls were used to check for sterile conditions. The numbers of Bradyrhizobia in the soil were determined using the Most Probable Number (MPN) plant infection technique. The MPN was calculated from the most likely number (m) obtained from the MPN tables according to the formula:

$$MPN = \frac{m \times d}{v} \qquad (1)$$

where: m is the most likely number from MPN tables, d is the lowest dilution in the series and v is the aliquot used for inoculation (SOMASEGARAN and HOBEN, 1994). An estimated range for each of the population was obtained by multiplying and dividing the estimated population by a factor, 2.7 fiducial limit at 95% confidence level (BECK *et al.*, 1993).

3 Results and Discussion

The three soybean cultivars used in the study formed nodules when they were inoculated with serial dilutions of soils from the two study sites but there were great variations in the number of nodulated units per cultivar per study site. The estimated total *Bradyrhizobium* spp. population in Kiboko soil was between 2.59×10^4 and 1.89×10^5 cells per gram of soil sample while the population size of taxonomically defined slow-growing rhizobia (*Bradyrhizobium japonicum* and *Bradyrhizobium elkanii*) was between 2.59×10^2 and 1.89×10^3 cells per gram of soil sample. The population estimates from the TGx genotypes less the population estimates from soybean, cultivar Clark represented approximate population sizes of *Bradyrhizobium* spp. population specific to TGx genotype (ABAIDOO *et al.*, 2002). This was estimated to be between 7.81×10^2 and 5.67×10^3 cells per gram of Kiboko soil sample (Table 2). In Kaguru, the approximate total *Bradyrhizobium* spp. population was between 1.04×10^2 and 7.56×10^3 cells per gram of soil sample while the population size of taxonomically defined slow-growing rhizobia (*Bradyrhizobium japonicum* and *Bradyrhizobium elkanii*) was between 1.33×10^2 and 9.72×10^2 cells per gram of soil. Approximate *Bradyrhizobium* spp. population specific to TGx genotype in Kaguru soil was between 2.37×10^2 and 1.73×10^3.cells per gram of soil sample (Table 3).

Table 2: Nodulated units planted with Cowpea, Clark and SB 12 TGx-1869-31E in Kiboko soil.

Dilution	*Total number of nodulated units*		
	Cowpea	*Clark*	*SB 12 TGx-1869-31E*
4^{-1}	4	4	4
4^{-2}	4	4	4
4^{-3}	4	3	3
4^{-4}	4	2	3
4^{-5}	4	1	2
4^{-6}	4	0	1
4^{-7}	2	0	1
4^{-8}	1	0	0
4^{-9}	0	0	0
4^{-10}	0	0	0
Control	0	0	0
Total	27	14	18

Number of replications (n)= 4

Generally, population sizes of the different types of rhizobia were higher in Kikoko soil than in Kaguru soil. The total *Bradyrhizobium* spp. population was about 2.58×10^4 to 1.81×10^5 cells per gram higher in Kiboko soil than in Kaguru soil while the population of slow growing rhizobia was approximately 1.26×10^2 to 9.18×10^2 cells per gram higher in Kiboko soil than in Kaguru soil. The population size of taxonomically defined slow-growing rhizobia was approximately 5.44×10^2 to 3.94×10^3 cells per gram of soil higher in Kiboko than in Kaguru. The total *Bradyrhizobium* spp. population was higher in the two sites as compared to the population sizes of slow-growing rhizobia and also the rhizobia specific to TGxs. The population size of the taxonomically defined slow-growing rhizobia was the lowest in the two soils.

The plant infection count is commonly used to estimate numbers of rhizobia in soil or to determine the quality of inoculants produced in sterile conditions (Beck *et al.*, 1993; Somasegaran and Hoben, 1994). Empirical models describing the response

Table 3: Nodulated units planted with Cowpea, Clark and SB 12 TGx-1869-31E in Kaguru soil.

Dilution	*Total number of nodulated units*		
	Cowpea	*Clark*	*SB 12 TGx-1869-31E*
4^{-1}	4	4	4
4^{-2}	4	3	3
4^{-3}	4	2	3
4^{-4}	3	1	2
4^{-5}	2	1	2
4^{-6}	1	0	1
4^{-7}	0	0	0
4^{-8}	0	0	0
4^{-9}	0	0	0
4^{-10}	0	0	0
Control	0	0	0
Total	18	11	15

Number of replications (n)= 4

to inoculation of legumes (Thies *et al.*, 1991) indicated that density as estimated by the MPN- plant infection assay is one of the primary factors determining the magnitude of response to inoculation. This is one of the main reasons why the *Bradyrhizobia* populations were determined in the two field sites before inoculation of soybeans with commercial inoculum. The size of field populations of rhizobia may vary within short distances in a field. For this reason much care should be taken in sampling so that a truly representative sample of the field soil is obtained. This was put into consideration when samples were being collected from the two field sites. Sampling was done diagonally in the fields to ensure uniformity of the process. Lack of compatible rhizobia in the soil has been cited as one of the potential barriers to the introduction of soybean in most African regions (Mpepereki *et al.*, 2000). However the *Bradyrhizobia* populations observed in the two study sites are adequate to give satisfactory results on nodulation and nitrogen fixation. The results are in line with findings by Nambiar *et al.* (1983) that most cultivated tropical soils have a rhizobial population of more than 100 rhizobia cells per gram of soil capable of nodulating the legumes grown on such soils.

The Kiboko site had higher *Bradyrhizobia* populations in all the categories than the Kaguru site. Soil analysis indicated that the Kaguru soil was acidic. *Bradyrhizobia* strains normally fail to multiply in acid conditions (Cooper *et al.*, 1985). Therefore most legumes which depend on symbiotic nitrogen fixation require a neutral or slightly acidic soil for growth (Brockwell *et al.*, 1991). The low pH could be one of the possible reasons why the *Bradyrhizobia* population was low in Kaguru site compared to Kiboko. These variations in *Bradyrhizobia* populations have also been reported in other studies. Abaidoo *et al.* (2002) reported that the population sizes of indigenous promiscuous soybean *Bradyrhizobia* in soils from African countries were highly variable.

4 Conclusion

Strains of *Bradyrhizobium japonicum* and *Bradyrhizobium elkanii* were detected in the soils from the two study sites. However the numbers of these strains were far much lower than those of total *Bradyrhizobium* spp. (also referred to as cowpea miscellany) and *Bradyrhizobium* spp. populations that nodulate TGx soybean genotypes. Good infectivity was observed in *Bradyrhizobium* spp. (TGx) in this study. This implies that these rhizobia can be potential local source of strains for inoculum production and use in other soybean growing areas in Kenya where the *Bradyrhizobium* spp. populations are ineffective or inadequate. From this study, it can also be concluded that the TGx varieties are more restrictive in their *Bradyrhizobium* spp. requirements for effective nodulation than cowpea as evidenced by the fact that the population size of the cowpea miscellany was higher than that of *Bradyrhizobium* spp. (TGx) in the two study sites. This knowledge of the population characteristics of indigenous bradyrhizobia populations in East and South East Kenya will be very valuable for developing strategies to improve Biological Nitrogen Fixation (BNF) for increasing TGx soybean yields at low costs.

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Effects of Mineral N and P Fertilizers on Yield and Yield Components of Flooded Lowland Rice on Vertisols of Fogera Plain, Ethiopia

Heluf Gebrekidan *[1] and **Mulugeta Seyoum** [2]

Abstract

Despite its very recent history of cultivation in Ethiopia, rice is one of the potential grain crops that could contribute to the efforts for the realization of food security in the country. However, the scientific information available with regards to the response of flooded rice to N and P fertilizers for its optimum production on Vertisols of Fogera Plain is very limited. Therefore, a field experiment was conducted on Vertisols of Fogera plain, northern Ethiopia to study the yield and yield components response of rice and to establish the optimum N and P fertilizer levels required for improved grain yield of flooded rice. Six levels of N (0, 30, 60, 90, 120 and 150 kg ha^{-1}) and five levels of P (0, 13.2, 26.4, 39.6 and 52.8 kg ha^{-1}) laid down in a randomized complete block design with four replications were used as treatments. Nitrogen was applied in two equal splits (50% basal and 50% at maximum tillering) as urea and the entire dose of P was applied basal as triple super phosphate at sowing. The main effects of N and P fertilizer levels showed significant differences ($P \leq 0.01$) for all yield and yield components studied. The effects of N by P interaction were significant only for grain yield ($P \leq 0.05$), number of panicles per m^2 ($P \leq 0.01$), number of spikelets per panicle ($P \leq 0.05$) and plant height ($P \leq 0.01$) among the different yield and yield components studied. Application of N and P significantly ($P \leq 0.01$) increased grain yield of rice up to the levels of 60 kg N and 13.2 kg P ha^{-1}. However, maximum grain yield (4282 kg ha^{-1}) was obtained with the combined application of 60 kg N and 13.2 kg P ha^{-1}, and the yield advantage over the control was 38.49% (1190 kg ha^{-1}). Moreover, application of both N and P fertilizers have increased the magnitudes of the important yield attributes including number of panicles per m^2, number of spikelets per panicle, panicle length, dry matter accumulation, straw yield and plant height significantly ($P \leq 0.01$). Besides, grain yield was positively and significantly associated with number of panicles per m^2 ($r = 0.61{**}$), number of spikelets per panicle ($r = 0.49{**}$), panicle length ($r = 0.54{**}$), dry matter accumulation ($r = 0.46{*}$), thousand grain weight ($r = 0.41{*}$) and harvest index ($r = 0.39{*}$). These indicate that N and P application increased grain yield of rice by positively affecting the important yield components of the crop. Therefore, taking

* corresponding author

[1] Alemaya University, P.O. Box 4, Alemaya University, Ethiopia,
Email: helufgebrekidan@yahoo.com

[2] Amhara Region Agricultural Research Institute, Ethiopia

the findings of the present study into consideration, it may be tentatively concluded that the farmers at the Fogera plain may apply a combination of 60 kg N and 13.2 kg P ha^{-1} to improve the grain yield of flooded lowland rice cultivated on heavy black clay soils (Vertisols) under rain fed conditions.

Keywords: Flooded rice, dry matter, Fogera plain, grain yield, NP fertilizers, panicle, spikelet, yield components

1 Introduction

The cultivation of rice in Ethiopia is of more recent history than its utilization as a food crop. Some evidences indicate that cultivation of rice in Ethiopia was first started at the Fogera and Gambella plains in the early 1970s. Currently, the Fogera, Gambella, Metema, and Pawe plains located in the northern, northwestern, and western regions are developing in to major rice-producing areas in Ethiopia (MULUGETA SEYOUM, 1999, 2000). At the Fogera plain, rice plays an important role in relaxing the problem of food-insecurity of the farming community.

The rice crop offers variety of uses to the farming community. It is used in the preparation of local foods such *injera, dabbo, genffo, kinchie* and *shorba* in addition to the rice dish itself and local beverages like *tella* and *katikalla* either alone or mixed with other cereal grains such as teff, millet, wheat, barley, sorghum and maize. Moreover, rice could also be considered as one of the best and cheapest alternative technology available to farmers for efficient utilization of natural resources, such as land and water, under swampy and flooded environments (MULUGETA SEYOUM, 1999, 2000; MULUGETA SEYOUM and HELUF GEBREKIDAN, 2005).

Because of its wider adoption from farmers' social, economic, and environmental perspectives, rice production at the Fogera plain is expanding rapidly from year to year. As a result, between 1994 and 2000, the land cultivated with rice increased from 65 to 4,174 ha. However, the production and productivity of the crop under farmers' field conditions is low (about 2600 kg of rice grain ha^{-1} on the average) compared to its yield levels under farmers' conditions in other parts of the world. Yet, improvement of its production has not been possible due to a number of soil-plant-management related factors. Apparently, low soil fertility and inadequate nutrient management are among the major factors determining its yield level.

Results of several studies have indicated that application of N and P fertilizers increase grain yield of rice by increasing the magnitude of its yield attributes (THAKUR, 1993; CHANNABASAVANNA and SETTY, 1994; PANDA *et al.*, 1995). Increase in yield attributing characters is associated with better nutrition and increased nutrient uptake which result in better and healthy plant growth and development (KUMAR and RAO, 1992; THAKUR, 1993), leading to greater dry matter production and its translocation to the sink (DALAL and DIXIT, 1987). PANDA *et al.* (1995) reported increased dry matter production including grain yield of rice due to increased N and P uptake in response to external supply of both N and P fertilizers. Therefore, this field experiment was conducted to investigate the effects of applied N and P fertilizer doses on yield and yield components and to establish the optimum levels of N and P required for improved grain yield and production of flooded rice on Vertisols of Fogera Plain under farmers' field conditions.

2 Materials and Methods

2.1 Description of the Study Area

A field experiment was conducted under rain fed conditions during the main rainy season (June to October) of 1999 to investigate the effects of N and P fertilizers on grain yield and yield components of flooded lowland rice under farmer's fields on Vertisols of the Fogera plain. The site is located near Woretta town at 13° 19' north latitude and 37° 03' E longitude at an average elevation of 1815 m amsl. The Woretta area receives an average annual rainfall of 1300 mm of which 1127 mm were received between June and October during the 1999 cropping season. The average yearly minimum and maximum temperatures are 11.7 and 27.5 °C, respectively (North Western Zone Meteorological Service, unpublished data).

According to Mulugeta Seyoum (2000), the soil on which the field experiment was conducted is classified as Pellic Vertisol. Analysis of composite surface soil samples collected from the experimental field indicated that the soil is moderately acidic (pH in 1:1 soil:water ratio of 5.6) and clayey (71.3% clay). The surface soil was high in total N (0.28%), organic carbon (3.0%), percent base saturation (79.4%), cation exchange capacity (52.9 cmolc kg^{-1}) and in Olsen extractable available P (36.2 mg l^{-1}), and medium (265.2 mg l^{-1}) in available K contents (Mulugeta Seyoum, 2000).

The land used for undertaking the field experiment had not been fertilized for the last over 10 years either with organic or mineral fertilisers. The area is usually flooded for most of the time during the cropping season. During the season the experiment was conducted, the depth of water above the surface of the soil at the site between July and October ranged from 5-10 cm. Based on the classification by IRRI (1993), the ecology and type of rice cultivation practiced at the Fogera plain is possibly categorized as rain fed lowland rice culture.

2.2 Experimental Treatments, Design, and Procedures

The fertilizer treatments considered in the study consisted of six levels of N (0, 30, 60, 90, 120 and 150 kg N ha^{-1}) and five levels of P (0, 13.2, 26.4, 39.6 and 52.8 kg P ha^{-1}) and their complete factorial combinations. The experiment was then conducted using a factorial experiment laid out in a randomized complete block design with four replications consisting of a total of 30 treatments. The field was oxen plowed four times before laying the experimental plots on the field. A 3m $\times$ 3m (9m^2) plot size was used as an experimental unit. The blocks were separated by a 2 m wide open space whereas the plots within a block were separated by a 1 m wide space. Soil bunds were constructed around each plot and around the entire experimental field to minimize nutrient and water movement from plot to plot.

A local well-adapted farmers' rice variety, known as *X-Jigna*, was used as planting material. Planting was made on 25 June 1999 by hand drilling the seeds at a rate of 80 kg ha^{-1} in rows spaced 25 cm apart. Nitrogen was applied in two equal splits, wherein 50% of the N rate was applied basal at planting and the remaining half was top dressed at the maximum tillering stage which occurred 32 days after germination, as urea (46% N). The field was drained off before top dressing the second half of N, and urea was hand drilled to the side of plant rows at 5-10 cm depth of the soil. Unlike N, the total dose of P was applied basal as triple super phosphate (20% P) during sowing. Due to the frequent prevalence of vigorous growth and high infestation of weeds, the field was hand weeded four times at 20, 40, 60, and 90 days after sowing.

2.3 Yield and Agronomic Data Collection and Analysis

Number of panicles per m^2 was counted before physiological maturity using 1m $\times$ 1m quadrant whereas panicle length was measured from the neck node to the tip of panicle on 20 random plants just before physiological maturity from 20 sample plants. Total number of spikelets (florets) and unfilled spikelets per panicle were determined at harvest by taking twenty random plants (tillers) from each plot. Number of filled spikelets per panicle was then obtained from the difference between the total number of spikelets per panicle and the number of unfilled spikelets per panicle. Plant height was determined by measuring the lengths of 20 random sample plants from the ground level to the top of the panicle just before physiological maturity.

At physiological maturity, the plants were harvested close to the ground level by hand using sickles, and the dry matter of the above ground plant parts was determined from 20 random pants collected at harvest. The sample plants were subsequently oven dried to constant weight and weighed using a sensitive balance. Grain yield was measured by threshing the plants harvested from the middle 6 rows (1.5m $\times$ 2m = 3.0m^2) of each plot to avoid border effects. The moisture content of the rice seeds was determined using a hygrometer at the time of the measurement of the grain yield. Grain yield was then recorded on 14% seed moisture content basis. Straw yield was determined as the difference between the total above ground biomass (straw plus grain) recorded after air drying at harvest and the grain yield of the respective treatments. Thousand-grain weight was determined by counting the number of seeds in 250 g of seed samples randomly taken from each plot and recorded on 14% moisture basis. Harvest index was obtained from the ratio of grain yield to the grain plus straw yield of each plot expressed as percentage.

Analysis of variance and simple correlation coefficients were carried out for the yield and yield components studied following statistical procedures appropriate for the experimental design using MSTATC computer software. Whenever treatment effects were significant, the means were separated using the least significant difference (LSD) and Duncan's Multiple Range Test (DMRT) procedures.

3 Results and Discussion

3.1 Grain Yield of Rice

Analysis of variance for two factors randomized complete block design (Table 1) revealed significant difference ($P \leq 0.01$) due to the main effects of the levels of N and P application for the means of all of the yield and agronomic parameters studied. However, the magnitude of the mean squares for the effect of N for each crop parameter far exceeded that of the corresponding mean squares of P. The mean squares due to N×P interactions were significant only for number of panicles per m^2 ($P \leq 0.01$), plant height ($P \leq 0.01$), grain yield ($P \leq 0.05$) and number of spikelets per panicle ($P \leq 0.05$).

Table 1: Analysis of variance for yield and yield components of rice on Vertisols of Fogera plain.

Parameters studied	*Mean squares for source of variation*			
	N *(5)*	P *(4)*	N×P *(20)*	*Error (87)*
Grain yield (kg ha^{-1})	198.807**	110.039**	4.058*	2.030
Number of panicles m^{-2}	2931.548**	356.792**	17.457**	0.644
Number of spikelets $panicle^{-1}$	315.776**	45.112**	2.188*	0.962
Filled spikelets $panicle^{-1}$	642.329**	165.745**	1.890ns	4.042
Thousand grain weight (g)	58.945**	18.343**	0.569ns	0.399
Panicle length (cm)	12.580**	2.468**	0.086ns	0.098
Plant height (cm)	197.316**	15.241**	0.524**	0.248
Dry matter (g)	1.109**	0.322**	0.005ns	0.008
Straw yield (kg ha^{-1})	775.337**	81.726**	1.152ns	1.480
Harvest index (%)	170.581**	54.891**	1.176ns	1.254

Figures in parentheses ≘ Degrees of freedom; * ≘ Significant at $P = 0.05$; ** ≘ Significant at $P = 0.01$; ns ≘ Non-significant.

Nitrogen had a marked effect on grain yield of rice. Grain yield significantly increased ($P \leq 0.01$) from 3240 to 3962 kg ha^{-1} with an increase in the level of N from the control (no N) to 60 kg N ha^{-1} and decreased with further increase of applied N fertilizer (Table 2). This could mainly be attributed to the increase in the number of panicles per m^2 and total number of spikelets per panicle. On the other hand, increasing panicle length and plant height might have increased grain yield of rice indirectly by increasing the number of spikelets per panicle and panicle length, respectively. Kumar and Rao (1992); Thakur (1993); Channabasavanna and Setty (1994); Behera (1998) also reported findings indicating improvements in grain yields attributed to increments in yield components. Increases in yield components are associated with better nutrition, plant growth and increased nutrient uptake (Kumar and Rao, 1992; Thakur, 1993).

The magnitude of increase in grain yield over the control due to application of 30 and 60 kg of N ha^{-1} were 13.5% (436 kg ha^{-1}) and 22.3% (722 kg ha^{-1}), respectively.

Reduction of grain yield with further increment in applied N level beyond 60 kg ha^{-1} (Table 2) was mainly caused by successive reductions in the number of filled spikelets per panicle and thousand-grain weight. SINGH *et al.* (1995) have also reported a decrease in grain yield of rice with application of high doses of N fertilizer. REINKE *et al.* (1994) noted that where the grain yield response is negative, yield reduction is primarily caused by a reduction in the proportion of the number of filled spikelets per panicle. Moreover, the higher organic carbon (3.0%) and higher native total N (0.28%) contents observed on the surface soil of the experimental field (MULUGETA SEYOUM, 2000) have also negatively affected crop response and increment in rice grain yield at higher application doses of mineral N ($>$ 60 kg N ha^{-1}) fertilizer.

Table 2: Effects of N fertilizer levels on yield (paddy kg ha^{-1}) and yield components of rice on Fogera Vertisols.

Applied N	*Yield and yield components*									
(kg ha^{-1}*)*	*GY*	*NP*m^{-2}	*NSP*$^{-1}$	*NFSP*$^{-1}$	*TGW*	*PL*	*PH*	*DM*	*SY*	*HI*
0	3240^{c}	165.96^{f}	94.01^{e}	75.21^{a}	20.84^{a}	19.55^{d}	87.98^{f}	4.17^{e}	3971^{e}	44.93^{a}
30	3676^{b}	176.54^{e}	97.34^{d}	73.87^{a}	21.36^{a}	20.28^{c}	89.80^{e}	4.36d	4591^{d}	44.47^{a}
60	3962^{a}	188.38^{d}	100.08^{c}	71.48^{b}	21.15^{a}	20.74^{b}	92.02^{d}	4.57^{c}	4990^{c}	44.20^{a}
90	3957^{a}	194.42^{b}	102.85^{b}	66.93^{c}	19.79^{b}	21.44^{a}	93.82^{c}	4.67^{b}	5296^{b}	42.69^{b}
120	3847^{a}	197.12^{a}	104.20^{a}	63.91^{d}	18.84^{c}	21.57^{a}	95.36^{b}	4.73^{ab}	5507^{a}	41.05^{c}
150	3334^{c}	192.46^{c}	103.26^{b}	61.11^{e}	16.89^{d}	21.37^{a}	95.88^{a}	4.78^{a}	5606^{a}	37.22^{d}
LSD (0.01)	118.7	0.668	0.817	1.674	0.526	0.261	0.415	0.074	101.3	0.933
CV (%)	3.88	0.43	0.98	2.92	3.19	1.50	0.54	1.93	2.44	2.64

Means within a column followed by the same letter(s) are not significantly different at $P = 0.01$. GY = Grain yield (kg ha^{-1}); NPm^{-2} = Number of panicles per square meter; NSP^{-1} = Number of spikelets per panicle; NFSP^{-1} = Number of filled spikelets per panicle; TGW = Thousand grains weight (g); PL = Panicle length (cm); PH = Plant height (cm); DM = Dry matter (g); SY = Straw yield (kg ha^{-1}); HI = Harvest index

Application of phosphorus fertilizer had also significantly ($P \leq 0.01$) increased the grain yield of rice up to the applied level of 26.4 kg P ha^{-1} (Table 3). However, the response of grain yield obtained at 26.4 kg P did not show significant differences compared with application of 13.2 kg ha^{-1} of P. The magnitudes of increase in rice grain yield over the control due to application of 13.2 kg and 26.4 kg P ha^{-1} were 10.5% (366 kg ha^{-1}) and 11.2% (390 kg ha^{-1}). In line with applied N, application of P increased rice grain yield through its effects on major yield attributes such as number of panicles per m^2 and spikelets per panicle. ZAMAN *et al.* (1995) also reported similar response in rice yield and yield components to increasing rates of applied P fertilizer. Increase in the magnitude of yield attributes is associated with better root growth and increased uptake of nutrients favoring better growth of the crop (KUMAR and RAO, 1992; PANDA *et al.*, 1995). Phosphorus application has also improved 1000-grain weight, panicle length and plant height thereby indirectly contributing to increment in grain yield.

Successive increase in the levels of P beyond 13.2 and 24.6 kg P ha^{-1} application showed reduction of grain yield (Table 3). ZAMAN *et al.* (1995) also reported similar trends in rice with higher doses of P fertilization. At higher doses of P, reduction of grain yield was caused mainly by the successive reduction in the number of filled spikelets per panicle and 1000-grain weight of rice. Thus, the results of this investigation substantiated the works of NI-WUZHONG *et al.* (1997) who reported that at higher levels of applied P , grain yield increased marginally or decreased due to the reduction in the number of filled spikelet and 1000 grain weight, particularly in soils with high soil test values of available P.

Moreover, the response of rice grain yield above 13.2 and 24.6 kg P ha^{-1} was possibly affected by the higher amount of inherent Olsen extractable available P (36.2 mg l^{-1}) of the experimental field soils. The availabilities of both native and applied P have also been reported to increase on soils under flooded rice production (ZIA *et al.*, 1992). The flooded condition that prevailed at the experimental site might have therefore increased the availability of P to the extent the rice crop benefits from it. As a result, significant grain yield response of the crop was obtained only at lower level (13.2 kg ha^{-1}) of P fertilization (Table 3). Similarly, DE DATTA and GOMEZ (1982) stated that due to the increase in the availability of P, yield responses to P fertilization are not as significant in flooded rice as in upland crops.

Table 3: Effects of P fertilizer levels on yield (paddy kg ha^{-1}) and yield components of rice on Fogera Vertisols.

Applied P	*Yield and yield components*									
(kg ha^{-1}*)*	*GY*	*NP*m^{-2}	*NSP*$^{-1}$	*NFSP*$^{-1}$	*TGW*	*PL*	*PH*	*DM*	*SY*	*HI*
0	3485^{c}	180.18^{e}	98.09^{c}	71.82^{a}	19.87^{b}	20.32^{c}	91.30^{d}	4.36^{c}	4705^{d}	42.68^{bc}
13.2	3851^{a}	186.28^{c}	100.23^{b}	70.35^{ab}	20.81^{a}	20.90^{ab}	92.15^{c}	4.54^{b}	4923^{c}	43.93^{a}
26.4	3875^{a}	188.97^{b}	101.22^{a}	69.16^{b}	20.37^{a}	21.08^{a}	92.92^{b}	4.62^{a}	5059^{b}	43.42^{ab}
39.6	3730^{b}	189.62^{a}	101.61^{a}	67.35^{c}	19.43^{b}	21.10^{a}	93.39^{a}	4.66^{a}	5153^{a}	42.06^{c}
52.8	3404^{c}	184.02^{d}	100.31^{b}	65.08^{d}	18.55^{c}	20.73^{b}	92.63^{b}	4.54^{b}	5128^{ab}	40.04^{d}
LSD (0.01)	108.3	0.610	0.746	1.528	0.480	0.238	0.379	0.068	92.5	0.851
CV (%)	3.88	0.43	0.98	2.92	3.19	1.50	0.54	1.93	2.44	2.64

Means within a column followed by the same letter(s) are not significantly different at $P = 0.01$. GY = Grain yield (kg ha^{-1}); NPm^{-2} = Number of panicles per square meter; NSP^{-1} = Number of spikelets per panicle; NFSP^{-1} = Number of filled spikelets per panicle; TGW = Thousand grains weight (g); PL = Panicle length (cm); PH = Plant height (cm); DM = Dry matter (g); SY = Straw yield (kg ha^{-1}); HI = Harvest index

The interaction effect of applied N and P levels on grain yield (Table 1) was significant ($P \leq 0.05$). The highest mean yield (4282 kg ha^{-1}) was obtained with the applications of 60 kg N and 13.2 kg P ha^{-1}, representing an increase of 38.5% (1190 kg ha^{-1}) over the control treatment followed by 4214 kg ha^{-1} with the applications of 60 kg N and 26.4 kg P ha^{-1} (Table 4). These findings were in agreement with the results obtained from mineral fertilizer studies by KUMAR and RAO (1992) on upland rice and RAJU and REDDY (1993) on winter rice. Without P application, the grain yield increased from 3092 kg ha^{-1} to 3716 kg ha^{-1} when the level of applied N increased from zero (control) to 120 kg N, while it increased from 3092 kg ha^{-1} to 3413 kg ha^{-1} when the level of applied P increased from zero to 26.4 kg P ha^{-1} under no applied N (Table 4).

Table 4: Interaction effect of N and P fertilizers on grain yield (paddy kg ha^{-1}) of rice

P *levels* (*kg* ha^{-1})	N *levels* (*kg* ha^{-1})*						*Mean*
	0	*30*	*60*	*90*	*120*	*150*	
0	3092^{q}	3445^{lm}	3617^{k}	3714^{ij}	3716^{ij}	3328^{nop}	3485
13.2	3326^{nop}	3865^{h}	4282^{a}	4149^{bc}	4024^{def}	3461^{l}	3851
26.4	3413^{lmn}	3972^{fg}	4214^{ab}	4196^{abc}	4014^{ef}	3442^{lm}	3875
39.6	3253^{p}	3740^{i}	4115^{cd}	4102^{cde}	3896^{gh}	3277^{op}	3731
52.8	3114^{q}	3360^{mno}	3580^{k}	3626^{jk}	3583^{k}	3162^{q}	3404
Mean	3240	3676	3962	3957	3847	3334	

* Means across all rows and columns followed by the same letter(s) are not significantly different at $P = 0.05$; LSD (0.05) = 0.8955; CV (%) = 3.88

3.2 Yield Components of Rice

3.2.1 Panicles per square meter

Application of N up to 120 kg ha^{-1} increased the number of panicles per m^2 significantly ($P \leq 0.01$) apparently by increasing the number of productive tillers (Table 2). This finding was in agreement with the results reported by BEHERA (1998). On the other hand, reduction in the number of panicles per m^2 observed at the highest doses of N application was due to reduction in the number of productive tillers which was caused by excessive vegetative growth of the rice crop. Phosphorus fertilization also increased the number of panicles per m^2 significantly ($P \leq 0.01$) up to 39.6 kg P ha^{-1} (Table 3) by increasing the number of productive tillers of the crop. ZAMAN *et al.* (1995) also observed increments in the number of panicles per m^2 of rice plant due to applied P by enhancing the production of effective tillers.

The interaction effect of applied N and P levels on panicles per m^2 (Table 1) was also significant ($P \leq 0.01$). Applied N levels exhibited significant positive effect up to 26.4 kg P ha^{-1} with the exceptions of 90 and 120 kg N ha^{-1} which significantly increased the number of panicles per m^2 up to 39.6 kg P ha^{-1} (Table 5). Similarly, all the P levels significantly increased panicle number up to 120 kg N ha^{-1} with the exceptions of 26.4 and 39.6 kg P ha^{-1} which significantly increased the number of panicles per m^2 up to 90 kg N ha^{-1}. The highest mean number of panicles per m^2 (201.8 m^{-2}) was obtained with the applications of 120 kg N and 39.6 kg P ha^{-1} (Table 5), representing an increase of 25.3% (40.8 panicles per m^2) over the control treatment. Among the yield attributes of rice, panicle number was associated positively ($r = 0.61 **$) with grain yield (Table 6). In conformity with the findings of the present study, THAKUR (1993) noted that panicle number is the most important factor that causes variation in the grain yield of rice.

Table 5: Interaction effect of N and P fertilizers on number of panicles per m^2 of rice.

P *levels* (*kg* ha^{-1})	N *levels (kg* ha^{-1}*)**						*Mean*
	0	*30*	*60*	*90*	*120*	*150*	
0	161.0^{q}	169.0^{o}	179.3^{l}	187.3^{k}	193.0^{fg}	191.5^{hi}	180.18
13.2	166.0^{p}	177.3^{m}	189.8^{j}	194.8^{e}	197.3^{d}	192.5^{gh}	186.28
26.4	168.0^{o}	180.3^{l}	192.5^{gh}	199.0^{c}	200.0^{bc}	194.0^{ef}	188.97
39.6	168.3^{o}	180.3^{l}	193.8^{efg}	200.5^{ab}	201.8^{a}	193.0^{fg}	189.62
52.8	166.5^{p}	175.8^{n}	186.5^{k}	190.5^{ij}	193.5^{efg}	191.3^{hi}	184.02
Mean	165.96	176.54	188.38	194.42	197.12	192.46	

* Means across all rows and columns followed by the same letter(s) are not significantly different at $P = 0.01$; LSD (0.01) = 1.494; CV (%) = 0.43

3.2.2 Total and filled spikelets per panicle

In agreement with the findings reported by THAKUR (1993), the present study indicated that increasing the levels of applied N resulted in higher number of total spikelets per panicle. Nitrogen fertilization significantly increased ($P \leq 0.01$) number of spikelets per panicle up to the applied level of 120 kg ha^{-1} (Table 2) mainly due to an increase in panicle length and panicle number. Application of more than 120 kg ha^{-1} of N reduced the number of spikelets per panicle, which may be caused by an increase in competition for metabolic supply among tillers thereby decreasing the production of spikelets (WU *et al.*, 1998) or possibly due to vigorous vegetative growth causing heavy drain on soluble carbohydrate resulting in its reduced availability for spikelet formation (HASEGAWA *et al.*, 1994).

Increasing the levels of P up to 26.4 kg ha^{-1} also significantly increased ($P \leq 0.01$) the number of spikelets per panicle (Table 3). CHANNABASAVANNA and SETTY (1994) and RAJU and REDDY (1993) also reported that application of P increases the total number of spikelets per panicle in rice thereby contributing to increment in grain yield. Increased number of spikelets with P application is mainly attributed to an increase in the number of panicles per m^2 and panicle length. Number of spikelets was the second important yield-forming attribute of rice. It was associated positively and highly significantly with grain yield and panicle length (Table 6). The results of the study confirmed similar findings reported by THAKUR (1993) and RATHI and SHARMA (1996). Number of spikelets per panicle was also correlated positively and highly significantly with the number of panicles per m^2 and panicle length (Table 6) indicating that N and P fertilization increases the number of spikelets of rice crop by increasing number of panicles per m^2 and panicle length.

The interaction effect of applied N and P levels on number of spikelets per panicle (Table 1) was also significant ($P \leq 0.05$). The responses of 30 and 60 kg N ha^{-1} levels showed significant positive effect up to 26.4 kg ha^{-1} of P application (Table 7). However, the levels of N at 90 and 120 kg N ha^{-1} significantly increased number of spikelets per panicle up to 13.2 kg ha^{-1} of P fertilization. Similarly, at 0 and 13.2 kg ha^{-1} of P application, the response was positive and significant up to 120 kg ha^{-1} of N application. The highest mean number of spikelets per panicle (105.1) was obtained with the applications of 120 kg N and 26.4 kg P ha^{-1} and 120 kg N and 39.6 kg P ha^{-1} (Table 7), representing an increase of 14.0% (12.98 spikelets per panicle) over the control treatment where the lowest (92.2) on number of spikelets per panicle was recorded.

Table 6: Simple correlation coefficients (r) among yield and yield attributes of rice.

Parameter	*GY*	*NP*m^{-2}	*NSP*$^{-1}$	*NFSP*$^{-1}$	*TGW*	*PL*	*PH*	*DM*	*SY*	*HI*
GY	-									
NPm^{-2}	0.61**	-								
NSP^{-1}	0.49**	0.98**	-							
NFSP^{-1}	0.02	-0.76**	-0.84**	-						
TGW	0.41*	-0.47**	-0.59**	0.88**	-					
PL	0.54**	0.97**	0.99**	-0.80**	-0.52**	-				
PH	0.29	0.93**	0.96**	-0.92**	-0.73**	0.94**	-			
DM	0.46*	0.96**	0.97**	-0.85**	-0.58**	0.96**	0.96**	-		
SY	0.35	0.94**	0.97**	-0.91**	-0.68**	0.95**	0.98**	0.96**	-	
HI	0.39*	-0.48**	-0.60**	0.90**	0.97**	-0.53**	-0.75**	-0.61**	-0.73**	-

* ≙ Significant at $P = 0.05$; ** ≙ Significant at $P = 0.01$; GY = Grain yield (kg ha^{-1}); NPm^{-2} = Number of panicles per meter square; NSP^{-1} = Number of spikelets per panicle; NFSP^{-1} = Number of filled spikelets per panicle; TGW = Thousand grains weight (g); PL = Panicle length (cm); PH = Plant height (cm); DM = Dry matter (g); SY = Straw yield (kg ha^{-1}); HI = Harvest index

Nitrogen application significantly reduced ($P \leq 0.01$) the number of filled spikelets per panicle up to 150 kg ha^{-1} (Table 2). Likewise, increasing the level of P significantly reduced ($P \leq 0.01$) the number of filled spikelets per panicle up to 52.8 kg ha^{-1} (Table 3). Application of both N and P fertilizers reduced the number of filled spikelets per panicle by increasing the proportion of unfilled spikelets per panicle. Increasing the levels of N and P fertilizers favored vigorous growth of the rice crop, which resulted in competition for metabolic supply among spikelets thereby affecting the production of fertile spikelets. HASEGAWA *et al.* (1994) and WU *et al.* (1998) also reported similar results in that with increasing levels of soil fertility, the number of filled spikelets per panicle decreased with corresponding increase in unfilled spikelets.

In this study, the highest number of filled spikelets per panicle was recorded at the control plot (no N and no P application). Compared with the number of filled spikelets obtained at the control treatment, reduction in the fertility of spikelets recorded at 150 kg ha^{-1} N and 52.8 kg ha^{-1} P application were 18.7% (14.10) and 9.4% (6.74), respectively (Tables 2 and 3). Thus, the results further revealed that N fertilization has more contribution over P to the reduction of the fertility of spikelets in rice. The cool daily minimum temperature (9.8-10.0 °C), which occurred during the flowering stage of the rice crop between September and October, might have also contributed to the reduction of the fertility of spikelets by increasing spikelet sterility. NISHIYAMA (1995) reported that the prevalence of cool air temperature at flowering of the stage increases sterility in rice crop by affecting pollination and fertilization.

Table 7: Interaction effect of N and P fertilizers on number of spikelets per panicle of rice.

P *levels* (*kg* ha^{-1})	N *levels* (*kg* ha^{-1})*						
	0	*30*	*60*	*90*	*120*	*150*	*Mean*
0	92.21^{n}	94.75^{l}	96.40^{jk}	99.97^{g}	102.60^{cde}	102.60^{cde}	98.09
13.2	93.35^{mn}	96.65^{ij}	100.10^{g}	103.10^{cd}	104.40^{ab}	103.80^{abc}	100.23
26.4	94.61^{lm}	98.53^{h}	101.50^{ef}	103.90^{abc}	105.00^{a}	103.80^{abc}	101.22
39.6	95.21^{kl}	98.92^{gh}	102.20^{de}	104.70^{ab}	105.10^{a}	103.50^{bcd}	101.61
52.8	94.68^{lm}	97.86^{hi}	100.20^{fg}	102.60^{cde}	103.90^{abc}	102.60^{cde}	100.31
Mean	94.01	97.34	100.08	102.85	104.20	103.26	

* Means across all rows and columns followed by the same letter(s) are not significantly different at P = 0.05; LSD (0.05) = 1.378; CV (%) = 0.98

On the other hand, reduction in the number of filled spikelets per panicle has contributed more to the negative yield response of rice under higher levels of N and P fertilizers in this study. In line with this, REINKE *et al.* (1994) concluded that where the yield response to fertilizer application is negative, yield reduction is primarily caused by a reduction in the proportion of unfilled spikelets. Moreover, the number of filled spikelets per panicle was highly and negatively associated with the total number of spikelets per panicle and plant height (Table 6).

3.2.3 Thousand grain weight

In this study, application of N fertilizer did not significantly ($P > 0.01$) improve 1000-grain weight of rice crop (Table 2) which was in agreement with the findings reported by THAKUR (1993). On the contrary, CHANNABASAVANNA and SETTY (1994) reported positive response of rice grain weight to N application. Similarly, only application of 13.2 kg ha^{-1} of P fertilization significantly increased ($P \leq 0.01$) 1000-grain weight of rice (Table 3). This was in agreement with the findings of CHANNABASAVANNA and SETTY (1994) and RAJU and REDDY (1993). Reduction in 1000-grain weight with increasing applied levels of N and P is probably the result of insufficient supply of carbohydrates to individual spikelets due to competition effect resulted by vigorous rice growth and the increased number of its spikelets. This effect further results in poor dry matter accumulation in the spikelets of rice. Similarly, HASEGAWA *et al.* (1994) also indicated that increased number of spikelets and vigorous growth of rice due to high rates of N fertilizer application induce competition for carbohydrate available for grain filling and spikelet formation. High doses of P are also believed to cause reduction in grain weight of rice in similar conditions explained for high rates of N fertilizer application.

3.2.4 Panicle length and plant height

Applications of N and P fertilizers increased panicle length significantly ($P \leq 0.01$) up to 90 and 13.2 kg N and P ha^{-1}, respectively (Tables 2 and 3). Since one of the most important functions of N is promotion of rapid growth, application of N fertilizer increased panicle length of rice crop more than P fertilizer. The increment in panicle length due to application of low levels of P observed in the present study was in agreement with KAVIMANI and KRISHNARAJAN (1991) and BEHERA (1998) who noted increases in panicle length of rice with increasing P fertilizer rates. The study further revealed that panicle length was correlated positively and significantly with number of panicles per m^2 ($r = 0.97**$), number of spikelets per panicle ($r = 0.99**$), dry matter yield ($r = 0.96**$), straw yield ($r = 0.95**$), plant height ($r = 0.94**$) and grain yield ($r = 0.54**$) of rice (Table 6). In accordance to the findings reported by BEHERA (1998), panicle length has contributed to increment of rice grain yield indirectly by increasing the number of panicles per m^2 and number of spikelets per panicle.

Plant height responded highly significantly and positively to the increasing application levels of both N and P fertilizers and their interaction effects (Table 1). Increasing the levels of N up to 150 kg ha^{-1} increased rice plant height significantly ($P \leq 0.01$) from 87.98 cm in the control treatment to 95.88 cm with the application of 150 kg N ha^{-1} (Table 2). Likewise, plant height increased significantly with increasing applied P levels up to 39.6 kg P ha^{-1} while further increase in P rates beyond 39.6 kg P ha^{-1} resulted in a negative effect on plant height (Table 3). With regards to the interaction between N and P fertilizers, the responses of all N levels were significant ($P \leq 0.01$) up to 26.4 kg ha^{-1} of P application except at no N (Table 8). With no N, P significantly increased plant height at the application rate of 13.2 kg ha^{-1} of P. On the other hand, all of the P levels significantly ($P \leq 0.01$) increased plant height up to 120 kg N ha^{-1}. Among all of the N and P treatment combinations, the maximum plant height of rice (96.59 cm) was attained at 150 kg N and 39.6 kg P ha^{-1} (Table 8).

Table 8: Interaction effect of N and P fertilizers on plant height (cm) of rice.

P *levels (kg* ha^{-1}*)*	N *levels (kg* ha^{-1}*)**						
	0	*30*	*60*	*90*	*120*	*150*	*Mean*
0	87.11^{l}	88.42^{k}	90.53^{h}	92.38^{g}	94.28^{ef}	95.10^{cde}	91.30
13.2	88.36^{k}	89.47^{j}	91.35^{h}	93.17^{g}	95.02^{def}	95.51^{bcd}	92.15
26.4	88.46^{k}	90.40^{hi}	92.58^{g}	94.15^{f}	95.75^{abcd}	96.18^{ab}	92.92
39.6	88.38^{k}	91.10^{h}	93.18^{g}	94.91^{def}	96.19^{ab}	96.59^{a}	93.39
52.8	87.60^{kl}	89.59^{ij}	92.48^{g}	94.50^{ef}	95.57^{bcd}	96.02^{abc}	92.63
Mean	87.98	89.80	92.02	93.82	95.36	95.88	

* Means across all rows and columns followed by the same letter(s) are not significantly different at P = 0.01; LSD (0.01) = 0.927; CV (%) = 0.54

The promotion of rice plant height in the present study due to applications of N and P fertilizers is apparent as N is essential for plant growth since it is a constituent of all proteins and nucleic acids whereas P is essential for the production and transfer of energy in plants. THAKUR (1993), HARI *et al.* (1997) and BEHERA (1998) have also observed enhanced rice plant height due to N fertilization. Similarly, RAJU and REDDY (1993) and ZAMAN *et al.* (1995) reported increases in rice plant height due to increasing P fertilizer application rates.

3.2.5 Dry matter accumulation and straw yield

The data in Table 2 indicate that increasing the levels of applied N increased dry matter accumulation and straw yield of rice significantly ($P \leq 0.01$) up to 90 and 120 kg N ha^{-1}, respectively, while further increment in N increased both dry matter accumulation and straw yield non-significantly. Generally, straw yield increased from 3971 kg ha-1 in the control (no N) treatment to 5606 kg ha^{-1} with application of 150 kg N ha^{-1} (Table 2).

Increasing the levels of applied P also increased dry matter accumulation of rice significantly ($P \leq 0.01$) up to 26.4 and 39.6 kg P ha^{-1}, respectively (Table 3). However, the response in dry matter obtained at 39.6 kg P ha^{-1} was at par ($P > 0.01$) with that at 26.4 kg P ha^{-1} while further increase in applied P levels resulted in reduction of dry matter accumulation of rice plant. The increase in dry matter application due to application of increasing rates of N fertilizer is apparently attributed to its effect in enhancing vigorous vegetative growth of the rice plant. In this study, dry matter accumulation was associated positively and significantly ($P \leq 0.01$) with plant height, panicle length, number of panicles per m^2, spikelets per panicle and straw yield (Table 6).

The results of the present study are in agreement with the findings of HARI *et al.* (1997) who observed increasing dry matter accumulations due to increasing rates of applied mineral N fertilizer. This is attributed to enhanced plant N uptake (DALAL and DIXIT, 1987) thereby promoting vigorous vegetative growth of the rice crop plants (KUMBHAR and SONAR, 1980; MULUGETA SEYOUM and HELUF GEBREKIDAN, 2005). Likewise, ZAMAN *et al.* (1995) also reported that increasing rates of P increased dry matter accumulation as a result of increased vegetative growth favored by enhanced nutrient uptake by rice plants.

3.2.6 Harvest index

Nitrogen showed a highly significant negative effect on harvest index of rice crop (Table 1). As indicated in Table 2, harvest index consistently declined with increasing levels of applied N up to the highest level (150 kg) of N ha^{-1}. On the other hand, application of 13.2 kg P ha^{-1} significantly ($P \leq 0.01$) increased harvest index of rice (Table 3). However, the harvest index recorded with the application of P fertilizer at the rate of 26.4 kg P ha^{-1} was at par ($P > 0.01$) with that at 13.2 kg P ha^{-1} while further increase in applied P beyond 26.4 kg P ha^{-1} resulted in highly significantly different reduction of harvest index.

Generally, increasing the levels of N fertilizer from 0 to 150 kg ha^{-1} decreased the harvest index of rice from 44.93 to 37.22% (Table 2). Results of a number of similar studies (KUMAR and RAO, 1992; PATRA *et al.*, 1992; HARI *et al.*, 1997) have also revealed decreasing trends of harvest index with increased rates of applied N fertilizer. They also stated that harvest index in rice is closely related to the percentage of productive tillers which generally decreases with increase of N fertilizer. Accordingly, harvest index of the rice crop was negatively and significantly ($P \leq 0.01$) correlated with plant height, panicle length, number of panicles per m^2, number of spikelets per panicle and straw yield (Table 6). This explains that vigorous vegetative growth of the rice plants promoted by higher rates of N application results in lower harvest index by favoring higher dry matter accumulation in the vegetative parts than in the grains of rice. The increase in harvest index at lower doses of P indicates that N enhances vegetative growth of rice more than P. In agreement with the results of this study, BUDHAR (1992), KUMAR and RAO (1992) and PANDA *et al.* (1995) showed that harvest index increased initially with increasing rates of applied P and decreased finally with further increase in application rates of P fertilizer.

4 Conclusions

The grain yield and yield components of the rice crop responded more to N than to P fertilization. However, the maximum grain yield and greater magnitude increase in yield and yield components were obtained with combined application of N and P fertilizers. In this study, number of panicles per m^2 and number of filled spikelets per panicle as well as panicle length were the most important yield forming attributes causing significant variation in grain yield of rice. Panicle length contributed to grain yield increment indirectly by increasing the number of spikelets per panicle. The results of the study indicate that farmers at the Fogera plain need to apply a combination of 60 kg N and 13.2 kg

P ha^{-1} in order to improve the grain yield and yield components of flooded lowland rice grown on black clay soils (Vertisols) under rain fed conditions. Moreover, fertilizer application under flooded rice production should consider soil-water-environment related factors that affect the availability and evaluation of nutrients in soils as integral parts of efforts to improve rice production and soil fertility. Thus, in the light of the significant response of rice to both N and P fertilizers, further studies aimed at promoting integrated soil fertility management and formulation of fertilizer recommendation on soil test basis over locations are desirable.

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Food for Work Program and its Implications on Food Security: A Critical Review with a Practical Example from the Amhara Region, Ethiopia

Ashenafi Gedamu *[1]

Abstract

A systematic evaluation of food-for-work (FFW) programs in Ethiopia is seriously lacking. Most of the few available reports indicate that these programs have reached very few achievements in terms of food security and reduction of poverty at large. As expressed by Holden *et al.* (2005), FFW programs are commonly aimed to produce or maintain potentially valuable public goods necessary to stimulate productivity and thus income growth. Natural resources management, like rural road construction, erosion control and afforestation of degraded lands can be mentioned as valuable measures which could stimulate productivity and agricultural growth. The poverty reduction and food security impact of food or cash for work activities are larger if they offer not only seasonal job opportunities to the rural community but also long term employment possibilities. This is more likely if the projects are regionally dispersed and combined with basic education. In the Ethiopian context, it was always questionable if the continuous boom in food aid (regardless of cash or food for work purposes) was the solution for the long standing food insecurity and poverty crises in the country. The study discusses the efficiency of FFW programs that aimed to reduce rural poverty and ensure food security on the one hand, and the impact of the food aid on resource and time allocation of the participating households for own food production on the other. The study is based on a field research conducted at a FFW program project, in the Amhara region, Ethiopia run by the German Agency for Technical Cooperation (GTZ) with the view of improving food security in the Amhara region, Ethiopia. A household theoretical model is used to analyze the sample data, whether FFW program may indeed reduce household food insecurity and/or has some crowding-out effects on labour allocation of participating households for own field production.

Keywords: Ethiopia, Amhara, GTZ, food for work program, poverty, food security, malnutrition

* corresponding author

[1] University of Kassel, International Agricultural Sciences, Development Economics and Agricultural Policy

1 Introduction

FFW programs have long been used to protect households against the decline in purchasing power that often accompanies seasonal unemployment, climate-induced famine, or other periodic disruptions by providing employment opportunities to the people (SUBBARAO, 2001). The FFW project, being undertaken by the German Technical Cooperation Agency (GTZ) was established in 1996 and provides funding for rural roads construction and some afforestation activities in the Amhara state. The funding was said to have been allotted almost entirely for the construction of rural roads, multiplication and distribution of multipurpose plant species like *Acacia* sp., Pigeon pea (*Cajanus cajan*) and Vetiver grass[1] (*Vetiveria zizanioides*). The vetiver grass is mainly used for the replacement of stone terraces as a hedge against water erosion. The varieties of multipurpose tree species are thought to provide animal forage, controlling soil erosion and at the same time improve soil fertility. Rural energy supply is another issue requiring attention. After large increases of funding in the second half of 1996, the program has diversified and includes investments in a much larger number of areas, including soil conservation, Triticale crop introduction and introduction of an improved ox-drawn cultivator to the Amhara farmers.

According to HOLDEN *et al.* (2005), food for work programs are essentially used both for short-term relief and long-term development purposes. From analysis based on data from FFW projects in early 1990s, it appears that villages with more favorable economic conditions with higher populations receive more FFW projects. Building a road or providing electricity in a remote and sparsely populated village, for example, would not be the most efficient use of poverty reduction funds. In the mid 1990s, more remote areas were said to be targeted for FFW projects, but results from these efforts have not yet been assessed.

AAS and MELLEMSTRAND (2002) stated that most of the FFW programs in Ethiopia had long-term development goals and were formally distinguished from the disaster relief FFW programs. Provision of public goods may be socially desirable because private investment in soil and water conservation and tree planting maybe well below socially optimal levels due to poverty and market imperfections (HOLDEN *et al.*, 1998; HOLDEN and BEKELE SHIFERAW, 2002). However, there is also a danger that FFW programs crowd out private investments (GEBREMEDHIN and SWINTON, 2000). It is therefore, appropriate to evaluate these programs based on their long-term goals and not only on the basis of short-term relief provisions. In a case study in Tigray state, Ethiopia, AAS and MELLEMSTRAND (2002) found out that the FFW recipients considered the long-term benefits of FFW more important than the short-term benefits of food provision. Keeping this in mind, this study examines whether or not the FFW programs show a significant long term contribution in terms of increasing food security, calorie intake and marketed surplus effects for the participating rural households in Northwest Ethiopia. And, the study raises the question whether or not the FFW programs also show crowding

[1] Vetiver is a little known tropical grass with strong and deep root system suites to hold back sediments and slows runoff.

out effects on resource and time allocation of the participating households for own crop production. The analysis draws mainly on the findings of a recent FFW program study at the Integrated Food Security Project (IFSP), sponsored by the German Technical Cooperation Agency (GTZ) in the Amhara region.

The project site characteristics
Ethiopia is one of the poorest countries in the world in almost all measures of poverty. For example in terms of food consumption, it does not fulfil the minimum nutrition requirement of 2,200 calories per adult person per day, including non food consumption requirements. The Amhara region is one of the poorest regions in Ethiopia. It is characterized by undependable rainfall, very high land degradation, rapid population growth, high rate of poverty and malnutrition. Food security is also threatened by frequent droughts which as a result makes the majority of the population food recipient.

The Ethiopian government has a policy of committing 80% of food aid resources to FFW programs (Sanford and Habtu, 2002). The FFW programs have been especially widespread in northern Ethiopia on government attempts to improve food security and promote sustainable rural development in this chronically poor and food insecure region (Holden *et al.*, 2005).

2 Materials and Methods

The survey data covering 200 households has been taken in 3 districts (*Weredas*) in south Gondar zone of the state. The samples were taken from farming communities participating in different FFW activities such as construction of hillside terraces, planting of fodder plant species and implementation of improved ox-drawn sub cultivator.

The first round sample survey took place during the *Belg* or short rainy season extending from February to April while farmers were in preparation of their land. Land preparation in the region is carried out by using ox-drawn plough as is commonly used by the vast majority of the Ethiopian farmers. The plough is light in weight, cheap and endurable and home made implement that has been in use for centuries in the country. The second sample survey was taken during the *Meher* or long cropping season between June and October at full maturity of the crops shortly before harvest. Both round surveys were carried out in 2003. Two hundred sample households in three districts were randomly selected for interview and videotaped individually in different occasions when the households were participating in FFW programs. Household questionnaire was also developed, which was filled by one of the project employee assigned to assist.

The agricultural household modelling approach was used to analyze the food security and marketed surplus outcomes of the new technologies. The agricultural household model providing a joint model of production and consumption decision is a natural phenomenon for the rural subsistence households. The section starts with the general theoretical framework for small farm households which can be adapted for the particular problem in the study. The equations specified in this part provide the theoretical support for the empirical specifications of the following equations to be estimated, these are: food consumption equations and calorie intake equations.

2.1 A simple basic model

The agricultural household model incorporating production and consumption in this section forms the basic structure of empirical equation estimated in this paper. Following BECKER (1965); SINGH *et al.* (1986) and BEHRMAN and DEOLALIKAR (1988), households obtain utility from the consumption of G-goods specified as:

$$U = U(G_1, G_2, G_3, \ldots, G_n) \tag{1}$$

where the Gs are consumable goods. Let us assume that there are two sets of goods: calories (G_1) and other n-1 consumable goods. The production functions for the G-goods are:

$$G_i = G_i(X_m, X_a, X_l, F, R)\ i = 1, 2, \ldots n \tag{2}$$

where X_m is market-purchased goods, X_a is agricultural staples produced by the households, X_l is leisure, F is family labour endowments and R, a non-choice vector of variables, represents individual and household characteristics, such as ages, years of education, household size, dependency ratio and other environmental variables. The household utility function can therefore be specified as:

$$U = U(G_1(X_m, X_a, X_s, F, R), G_2(X_m, X_a, X_s, F, R), \ldots, G_n(X_m, \ldots)) \tag{3}$$

The household picks the optimal consumption bundle, subject to its production technology:

$$Q_a = Q_a(A, L, V, K) \tag{4}$$

where Q_a is the household's production of staple food, A is land, L is total labour input, V is a vector of variable inputs (fertilizer etc.), K is a vector of capital (drought and other animals). Model details can be seen at the appendix.

3 Results and Discussion

3.1 The effect of food for work program for food security

In both round surveys 25% of households stated that they were participating in a FFW project aimed at rehabilitating the environment and controlling soil erosion caused by water. According to these participants, the FFW project enabled them to secure their daily food, to purchase additional food items to be kept in stock for harder times. These households have further stated that they were provided some vegetables seeds such as onions and cabbages to grow at their home gardens in order for them to diversify income and improve household nutrition. However, lack of fertilizer and insecticides combined with scarcity of irrigation water devastated their interest to grow these vegetables. Out of the participated households (hhs) 15% stated that due to the participation in FFW programs they had less time to focus on the cultivation of their own land, while 13% stated that they were not crowded out by the FFW participation at all. About 26 % of the households stated that their own food production need was reduced due to their enjoyment of FFW program, whereas 9% mentioned that their household situation has hardly changed by the FFW program in terms of food security and daily calorie intake.

As a result, the survey sample suggests that the FFW program has indeed negatively effected to time and resource allocations for own production. Because the household labour was spent more on FFW activities than on own field works. In Table 1 is indicated the various FFW activities in which the sample hhs participated during the field surveys.

Table 1: Various FFW activities in which the sample hhs participated during the field surveys

Type of FFW activity	*Participation of hhs in %*
Rural roads construction	30
Bio-physical soil and water conservation activities	25
Multiplication of multipurpose plants incl. vetiver grass	20
Gully erosion control	12
Check dam construction	8
Stone band and related metal works	5

Source: own data

As has been summarized in the table, much of the FFW program of the GTZ food security project in the Amhara region focused on road construction activities, multiplication of various plant species including vetiver grass that would be distributed back to the farmers themselves. Multiplication of various plant varieties were carried out on selected individual farmers' fields who have also participated in the FFW programs. Gully erosion control both by bio-physical i.e., by planting trees in the gullies and using stone bund control measures were carried out in different worst affected communal lands. These new implements were used by the GTZ food security program with the view of improving food security and rural poverty by increasing food production for the mainly drought affected, degraded areas of the Amhara state.

FFW programs were also carried out by the local administration in mass mobilization of the community. This takes place in different weredas throughout the country, especially in the highly degraded highlands. HOLDEN *et al.* (2005) also stated that an annual activity in Tigray state had been under implementation for many years. These authors further stated that in this region, each able bodied adult person had to contribute 20 days of work to the community without any direct payment. During the survey, hhs were asked what activities they consider most important in their communities if they offered to choose FFW funded activities to be carried out for their communities. As is summarized in Table 2, the majority (30%) of the participants consider irrigation development as most important, while 25% stated that health centre construction would be their first preference in their community. This was argued that especially the prevalence malaria

Table 2: Various FFW activities which sample hhs consider most important

Type of FFW activity	*HHS response in %*
Irrigation development	30
Building health centres	25
Vegetable seedlings or seeds supply	22
Roads construction	13
Culvert construction	10

Source: own data

was very high in the dry seasons infecting hundreds of people each year making many households unable to cultivate their fields on time and costing others their lives.

3.2 Calorie intake impacts of FFW program

Several studies have documented that technological change and commercialization of smallholder production improve the level of food consumption, hence the calorie intake of participating households (von Braun and Kennedy, 1994). Changes in food consumption are generally associated with more readily available cash income. Meanwhile, increased commercialization may result in greater self sufficiency via increased productivity of the land and labour inputs allocated to the commercial activity and changes in cropping patterns (von Braun, 1995). With a higher income a substitution of cheap calories for more expensive calories can take place and consequently, diets gain not only in quantity but also in quality and diversity. Consumption changes affected by technological change and commercialization have been attributed to increased income rather than to higher food availability (Alderman, 1987; Binswanger and von Braun, 1991).

On the basis of the calorie content of the various food categories, the Ethiopian Nutrition Institute has set at a daily calorie intake of 1,518 per person. This is of course, well below the medically recommended minimum daily intake of 2,100 calories (72.3%) and almost 34% below the 2,300 calories/person/day representing staple food self-sufficiency (FAO/WFP, 1995). The current low calorie intake reflects the dramatic magnitude of malnutrition still existing in Ethiopia, particularly among the vulnerable groups.

The impact of the FFW programs in Amhara that aims to improve food security and alleviate poverty through food for work payments in kind, results a small increase in the calorie intake of the participating households. As can be learned from the responses of the sample households, FFW members indicated to have increased consumption up to about 30% of the daily requirements of 1,518 per person. Nevertheless, the households have often criticized the FFW program to have had undermining them to produce their own crop due to the fact that the FFW activities in which they participate, competes with the households' own field related activities especially at crucial times of cropping seasons. Highland Ethiopia, including the Amhara region has two main cropping seasons i.e., the Belg or short rainy season the Meher or long rainy season. Therefore, it needs to be mentioned that the FFW activities may effectively utilize households' labour if targeting the programs at off-farm seasons and in accordance to priority areas selected by the communities themselves. FFW may then be more effective to enhance food security, improve daily calorie intake and resource conservation, provided that the programs are compatible with local priorities. A policy combining promotion of tree planting and conservation of cropland may achieve win-win long term benefits in terms of increased household incomes as well as more sustainable land use (Holden *et al.*, 2005).

4 Conclusion and Recommendations

Following the liberalization process in Ethiopia, the number of non-governmental organizations (NGOs) involved in the country has increased substantially. However, whatever numbers of NGOs do exist in the country and whatever programs are carried out by them, there is no significant change of life for the overwhelming majority of the rural community at all. With the current state of affairs, it is also clear that food for work projects are by no means the best alternative solutions to the worsening living conditions of millions of Ethiopians.

Though the FFW provision contribution to food security is negligible when compared with the large scale of destitution and high food deficiency prevalent in the Amhara region, maintaining the program to supply basic needs of Ethiopia's most destitute population is indispensable. However, the choice of the programs need to be left to the local community, and must focus in long term rural development operations in order to shift the debate from whether poverty is dropping, and how best to improve the continued poverty and malnutrition in the Amhara region and Ethiopia at large.

The types of investment, for instance, soil and water conservation (SWC), road construction, land use management and other food security and related programs also implemented by the regional and district authorities, require better coordination efforts between the different stakeholders involved in the region. As over 80% of Ethiopia's population said to live in rural areas, it is essential to resettle the sparsely distributed households into small villages, which would enable both the government and non-governmental organizations (NGOs) to effectively utilize resources for execution of the FFW operations. Operations include providing safe drinking water, electricity, telecommunication facilities and facilitating access to rural roads for better marketing of agricultural produce. At this point, the resettlement program undertaken by the previous government or the failed Tanzanian Ujamaa movement may come in the minds of many, there is no doubt however, if the choice is provided to the households themselves and infrastructure such as road, health, water and electricity availability is ensured, the resettlement program can be successfully implemented.

The conclusion in accordance to this sample survey can be summarized into two reciprocating scenarios: a) In the first scenario, the empirical evidence from the Amhara region shows that the number of people in need of food aid and the number of undernourished children in the region have been increasing from time to time, which might have been attributed by the rising frequency of food aid being distributed in the area that in turn created the so called a *dependency syndrome* among the small scale producers. However, it should be stressed that the food aid had saved millions of lives in the region that resulted in due to drought or other crises. Given the number of undernourished people in Amhara and the increasingly complex risks to food security, local authorities together with partner NGOs need to put the FFW program at the top list of their agenda, not only as a relief provision in short terms but also with the view of reducing food aid dependency and increase food self sufficiency in longer terms. An improvement in the widespread under-nourishment due to FFW activity, was not conspicuously prevailed by the study, except the fact that a small increase in calorie intake was reported by sample households b) In the second scenario, it was also revealed that the FFW program has some crowding-out effects on own field productivity and resource management by participating households. Time and labour allocation by farmers for own field works, especially during field cultivation and weeding periods, was limited due to the permanent involvement of the farmers in FFW activities.

Generally, the way in which "aid" decisions are made should be with reference to those whom they utilize it most. Coincidence of food aid import or distribution with harvesting seasons needs to be avoided in order not to destabilise market prices of home grown agricultural produce. In this regard, payments can also be made in cash that would allow the beneficiaries to purchase the food of their choice at times they are in need. The recent shift of FFW into Cash for Work (CFW) programs by the GTZ-IFSP is a very good move towards the right direction, that other aid organisation could follow suit. The workers of aid organizations in general should be ones who listen to the opinions of the supposed beneficiaries of the process of development and have a degree of access to what one observer has called "the rich and the detailed system of knowledge of the poor".

In the opinion of the author, the overall food for work program could be improved by more explicit targeting of the poorest households, and by refocusing its work on the types of programs that bring the greatest benefits to the destitute in greater scale. The author strongly believes only direct investment (for e.g. in middle and big scale agricultural industries, investment in irrigated agriculture) both by national and international stakeholders is the best alternative to food aid, which we believe is a long lasting solution for Ethiopia's recurrent food insecurity and poverty crises. After all, there is no single country in the world that is considered to be 'developed' as a result of food aid. The author is by no means criticising the humanitarian assistance, which is meant to save lives effected by natural or manmade disasters.

Finally, there are ominous signs for the future especially amidst concerns in water scarcity, soil depletion, the lack of improved agricultural techniques, the continued threat of disease epidemics such as HIV/AIDS and malaria and family birth control pose a grave threat to the food security of the growing population in the region, which lacks the attention of many FFW program operators.

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Appendix

A simple basic model

The agricultural household model incorporating production and consumption in this section forms the basic structure of empirical equation estimated in this paper. Following G. (1965); Singh *et al.* (1986) and Behrman and Deolalikar (1988), households obtain utility from the consumption of G-goods specified as:

$$U = U(G_1, G_2, G_3, \ldots, G_n) \tag{1}$$

where the Gs are consumable goods. Let us assume that there are two sets of goods: calories (G_1) and other n-1 consumable goods. The production functions for the G-goods are:

$$G_i = G_i(X_m, X_a, X_l, F, R)\ i = 1, 2, \ldots n \tag{2}$$

where X_m is market-purchased goods, X_a is agricultural staples produced by the households, X_l is leisure, F is family labour endowments and R, a non-choice vector of variables, represents individual and household characteristics, such as ages, years of education, household size, dependency ratio and other environmental variables. The household utility function can therefore be specified as:

$$U = U(G_1(X_m, X_a, X_s, F, R), G_2(X_m, X_a, X_s, F, R), \ldots, G_n(X_m, \ldots)) \tag{3}$$

The household picks the optimal consumption bundle, subject to its production technology:

$$Q_a = Q_a(A, L, V, K) \tag{4}$$

where Q_a is the household's production of staple food, A is land, L is total labour input, V is a vector of variable inputs (fertilizer etc.), K is a vector of capital (drought and other animals).

The household also faces a budget constraint:

$$P_m X_m = P_a(Q_a - X_a) - w(L - F) + E \tag{5}$$

That is, given prices, P_m, the total market consumption, $P_m X_m$, cannot exceed the total income, that is the sum of non-labour income, E, labour earnings, $w(L-F)$, and the value of food marketed surpluses, $P_a(Q_a - X_a)$. F is the family labour supply, such that $(L - F)$ if positive it represents hired labour, and if negative it is off-farm labour supply. The household also faces a time constraint: that is the total time, T, available to the household cannot exceed the sum of time in leisure X_s and time working on-farm or off-farm, F. In this case:

$$T = F + X_s \tag{6}$$

Substituting the production constraint (4) for Qa and incorporating the time constraint (6) into the budget constraint (5) for F, yields the following constraint:

$$P_m X_m + P_a X_a + w X_s = W_T + \pi + E \tag{7}$$

where, $\pi = P_a Q_a(A, L, V, K) - wL$ measures farm profit. The left-hand side of (7) represents total household expenditures on purchases of market commodities $(P_m X_m)$, the household's purchases of its own output $(P_a X_a)$, and the household's purchase of its own leisure time (wX_s) The right-hand side represents the full income in which the value of the stock of time available to the household wT, profit π and non-labour income (E) are explicitly recorded.

From equations (3) and (7), the household can choose (i) the consumption levels for the Z-goods through the consumption of X_m, X_a and X_s and (ii) the total labour input into agricultural production. The first order conditions (FOC) for maximizing the choice variables are explored in TANGKA (2001). FOC for labour can be solved for L, as a function of prices (P_a and w), the technological parameter(s) of the production function and the fixed area of land (A)

$$L = L(w, P_a, K, A) \tag{8}$$

Since production is not influenced by consumption choices, this form of the model is recursive.

The value of the full income, when profits have been maximized through the appropriate choice of labour input, can be obtained by substituting L into the right-hand side of the full income constraint (7), which could then be re-written as:

$$P_m X_m + P_a X_a + wX_s = S \tag{9}$$

Since production is not influenced by consumption choices, this form of the model is recursive.

Various elements of the basic model will be modified in the following sub-sections to address pertinent issues specific to the problem to be analyzed. This includes the impact of intensified dairying and market-orientation of small farmers on food consumption, per capita calorie intake and food marketed surplus for the harvesting and planting seasons.

In this case if the household maximizes utility, where utility is a function of consumption (C) and leisure (X_l),

$$U = U(C, X_l) = P_q Q(L_a, L_q) + W_{FFW},\ L_{FFW}\ (T - L_a - L_{FFW}) \tag{10}$$

where P_q is the price of output produced, Q is a production function with the marginal returns to every input increasing, L_a is labour input in crop production, L_q is the land quality, W_{FFW} is the FFW participants' wage, L_{FFW} is the amount of labour performed by the participants and T is total time spent for FFW. The model has no factor markets for land instead a market FFW labour and crop value.

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Kurznachrichten – News in Brief

Professor Ploeger im Vorstand des Internationalen Arbeitskreises Kulturforschung des Essens

Kassel/Witzenhausen. Prof. Dr. Angelika Ploeger ist jetzt in den Vorstand des Internationalen Arbeitskreises Kulturforschung des Essens berufen worden (http://www.gesunde-ernaehrung.org/de/Arbeitskreis_Kulturforschung). Prof. Dr. Ploeger ist Ernährungswissenschaftlerin, und seit Oktober 2001 als Leiterin des Fachgebietes Ökologische Lebensmittelqualität und Ernährungskultur an der Universität Kassel in Witzenhausen tätig. Neben Forschungs- und Lehreaktivitäten an drei Universitäten in Deutschland verfügt sie über praktische Erfahrung mit Zertifizierung für Produkte des Ökologischen Landbaus. Sie ist Mitglied im wissenschaftlichen Beirat der Nationalen Verzehrsstudie (Bundesforschungsanstalt für Ernährung und Lebensmittel). Zudem ist sie seit 2002 Mitglied in zwei wissenschaftlichen Beiräten des Deutschen Ministeriums für Landwirtschaft, Ernährung und Verbraucherschutz (BMELV), Berlin.

UNIK-Tropengewächshaus ausgezeichnet: Offizielles UNESCO-Projekt „Nachhaltigkeit lernen“

Witzenhausen/Kassel. Eine hohe Auszeichnung hat jetzt die Bildungsarbeit des Tropengewächshauses der Universität Kassel in Witzenhausen erhalten. Ab sofort ist es als offizielles UNESCO-Projekt in die Liste der Veranstalter aufgenommen, die „Bildung für nachhaltige Entwicklung“ leisten. „Das hat mich riesig gefreut“, bekennt Marina Hethke, die das „Gewächshaus für tropische Nutzpflanzen“ - so der offizielle Name - als Kuratorin leitet. Zusammen mit ihren Witzenhäuser Partnern Deutsches Institut für Tropische und Subtropische Landwirtschaft, Arbeitskreis „Eine Welt Laden e.V.“ und dem Internationalen Bildungszentrum Witzenhausen hat die Diplomagraringenieurin die Vereinigung „Eine-Welt-Garten“ gegründet und bietet mit ihren freien Mitarbeitern rund um das Tropengewächshaus thematische Rundgänge, Projekttage und Seminare an, die die exotischen Atmosphäre und die außergewöhnliche Nutzpflanzensammlung des Gewächshauses als Einstieg in komplexe entwicklungspolitische, ökologische und ökonomische Zusammenhänge nutzen. Bananen, Kaffee, Kakao und Co. werden so nicht nur bestaunt, sondern mit Informationen zu Produktionsbedingungen, zu Handel und Weltmarkt sowie zu Interdependenzen zwischen Nord und Süd verknüpft. Dabei werden Verbindungen zum eigenen Alltag und zum eigenen Konsumverhalten hergestellt und individuelle Einfluss- bzw. Handlungsmöglichkeiten deutlich gemacht. „Tropen bei Nacht“ können die Besucher ebenso erleben wie „Einmal zum Äquator und zurück“. Schulklassen kommen zu Projekttagen unter dem Titel „Alles Banane“ und aktuell wer-

den Gruppen unter dem Motto „Lassen Sie sich Fair-Führen“ angesprochen.
Die Auszeichnung geht zurück auf einen Beschluss der Vollversammlung der Vereinten Nationen, die mit einer Weltdekade „Bildung für nachhaltige Entwicklung“ (Education for sustainable Development - ESD) die Prinzipien nachhaltiger Entwicklung weltweit in den nationalen Bildungssystemen verankern wollen. Darin heißt es: „Nachhaltig ist eine Entwicklung, die den Bedürfnissen der heutigen Generation entspricht, ohne die Möglichkeiten künftiger Generationen zu gefährden, ihre eigenen Bedürfnisse zu befriedigen und ihren Lebensstil zu wählen. In diesem Zusammenhang spielen ebenso emotionale wie auch handlungsbezogene Komponenten der Bildung eine entscheidende Rolle.“ (http://www.dekade.org). Das Tropengewächshaus der UNIK hat die Kriterien erfüllt und erhielt am 29. November in Bonn von der Deutschen UNESCO-Kommission die offizielle Urkunde. Den Titel „Offizielles Projekt der Weltdekade 2006/2007“ darf es jetzt schon führen. Das Gewächshaus für tropische Nutzpflanzen ist Anschauungs-, Studien- und Praxisort in der Ausbildung zukünftiger Agraringenieure am Witzenhäuser Fachbereich Ökologische Agrarwissenschaften. Auf einer Fläche von 1.200 Quadratmetern werden mehr als 500 Nutzpflanzenarten von Ananas bis Zimt gepflegt. Es ist für Einzelbesucher Mittwoch, Freitag, Samstag und Sonntag von 14 - 16 Uhr geöffnet.

UNIK: DFG-Graduiertenkolleg zu Humus- und Nährstoffhaushalt in der ökologischen Landwirtschaft eingerichtet

Kassel/Witzenhausen. Die „Steuerung von Humus- und Nährstoffhaushalt in der ökologischen Landwirtschaft“ ist Thema eines neuen, jetzt von der Deutschen Forschungsgemeinschaft (DFG) an der Universität Kassel eingerichteten Graduiertenkollegs. Sprecher ist Professor Dr. Bernard Ludwig, Universität Kassel, Fachgebiet Umweltchemie im Fachbereich Ökologische Agrarwissenschaften der Universität Kassel in Witzenhausen. Damit soll eine zentrale Fragestellung der ökologischen Landwirtschaft bearbeitet werden, da Humus- und Nährstoffhaushalt von entscheidender Bedeutung für die Fruchtbarkeit und dauerhafte Produktivität von Böden sind. Das Graduiertenkolleg begann am 1. Oktober 2006 mit sieben Stipendiaten, fünf weitere werden später folgen. Die Laufzeit ist zunächst auf viereinhalb Jahre festgelegt. Die Betreuung der Promovenden wird durch fünf Professoren, davon vier der Universität Kassel und einer der Universität Göttingen, erfolgen. „Mit dieser Zusage wird deutlich, dass sich unser agrarwissenschaftlicher Fachbereich in Witzenhausen inzwischen fest in der Scientific Community verankert hat“, so Prof. Dr. Jürgen Heß, Dekan des Fachbereichs. Es zeige darüber hinaus, dass die Themen der Ökologischen Agrarwissenschaften von ihrer Außenseiterposition in eine anerkannte Insider-Position in der Wissenschaft gerückt sind.
Wie die DFG mitteilt, will sie mit der Einrichtung von insgesamt 34 neuen Graduiertenkollegs die strukturierte Promotion in Deutschland weiter vorantreiben. Die Graduiertenkollegs bieten Doktorandinnen und Doktoranden die Möglichkeit, möglichst interdisziplinäre Expertise zu sammeln und frühzeitig wissenschaftlich selbstständig zu werden, siehe auch die Pressemitteilungen unter http://www.dfg.de .

Universitäten Kassel und Göttingen richten länderübergreifende Professur ein

Kassel/Witzenhausen/Göttingen. Erstmals wurde in Deutschland jetzt eine Professur über zwei Bundesländergrenzen hinweg besetzt. Prof. Dr. Eva Schlecht hat den neuen Lehrstuhl „Animal Husbandry in the Tropics and Subtropics“ am Fachbereich Ökologische Agrarwissenschaften der Universität Kassel und an der Fakultät für Agrarwissenschaften der Universität Göttingen übernommen. Ein Kooperationsvertrag zwischen den beiden Universitäten hat die bislang einmalige länderübergreifende Professur ermöglicht. Prof. Dr. Schlecht war zuvor wissenschaftliche Mitarbeiterin am Institut für Tierproduktion in den Tropen und Subtropen der Universität Hohenheim und hat sich dort habilitiert. In Witzenhausen und Göttingen wird sie das Fachgebiet in seiner ganzen Breite vertreten und an beiden Universitäten entsprechend forschen und lehren. Ihr Interesse gilt der verhaltensmäßigen und physiologischen Anpassung von Tierarten und -rassen an die Umwelt- und Haltungsbedingungen an tropischen und subtropischen Standorten. Ferner thematisiert Schlecht die Rolle von Tierhaltungssystemen in agrarökologischen und sozio-ökonomischen bzw. politischen Kontexten sowie ökologisch verträgliches und ökonomisch nachhaltiges Ressourcenmanagement durch Tiere in ländlichen und städtischen Agrarsystemen.
Sie lehrte bereits an der Universität Kassel in Witzenhausen im dortigen Bachelor- und Masterstudiengang „Ökologische Landwirtschaft“ im Bereich Tierernährung und Tierproduktionssysteme der Tropen und Subtropen. Für ihre herausragenden Arbeiten wurde die Wissenschaftlerin 2002 mit dem Preis des Stifterverbands für die deutsche Wissenschaft für besonders förderungswürdige Projekte und 2004 mit dem baden-württembergischen Landesforschungspreis für angewandte Forschung ausgezeichnet.

Privatdozent Dr. Gerold Rahmann zum Honorarprofessor ernannt

Kassel/Witzenhausen. Die Ernennung von Privatdozent Dr. Gerold Rahmann zum Honorarprofessor am UNIK-Fachbereich Ökologische Agrarwissenschaften erfolgte im Oktober 2006.
In seiner Begründung für die Verleihung der Auszeichnung verweist der Fachbereich auf die umfangreichen Leistungen in Wissenschaft und Praxis, die Rahmann als Leiter des Instituts für Ökologischen Landbau der Bundesforschungsanstalt für Landwirtschaft (FAL) in Trenthorst (Schleswig-Holstein) erbracht und initiiert hat. So hat er über den energieautarken Hof ebenso geforscht, wie über die Milchkuhhaltung mit und ohne Kraftfutterzusatz. Auch die Optimierung der Prozess- und Produktplatte Öko- Schweinefleisch hat er untersucht oder zum Herkunftsnachweis ökologisch und konventionell hergestellter Produkte gearbeitet. Rahmann kann auf eine umfangreiche Publikationsliste verweisen. Seine Forschungen macht er nicht nur der wissenschaftlichen Fachwelt, sondern auch der Praxis zugänglich. Rahmann wird am Fachbereich das Fachgebiet „Kleine Wiederkäuer“

übernehmen. In diesem Fachgebiet hat er habilitiert und umfangreiche Lehrererfahrungen gesammelt. In der Laudatio hat Dr. Urs Niggli, Direktor des Forschungsinstituts für biologischen Landbau (FiBL), Schweiz, die zukünftigen Aufgaben der Forschung im Ökolandbau beleuchtet und auf die Notwendigkeit hingewiesen, die Zusammenarbeit aller einschlägigen Forschungseinrichtungen zu vertiefen.

Challenges and Opportunities for Nutrient Efficient Agriculture in West African Cities ('UrbanFood')

an Integrated Research Network Project

Kassel/Witzenhausen. Urban agriculture (UA) increasingly supplies food and non-food values to the rapidly growing West African cities. However, with its typically heavy use of fertilizers, agrochemicals, municipal wastes and sewage as inputs to the production of crops, vegetables and livestock feeds, UA bears severe risks of environmental pollution and food contamination. This project therefore aims at quantifying nutrient inputs, transfers and potential problems of UA activities in the three West African cities of Sikasso (Mali), Bobo Dioulasso (Burkina Faso) and Kano (Nigeria), which differ in their population density and biophysical conditions. The project couples process-oriented biophysical research and the use of bio-economic models with a north-south transfer of knowledge in the quantification and modelling of nutrient fluxes and a south-south transfer of expertise on soil and product contamination with faecal pathogens, pesticides and heavy metals. The project thereby aims at (i) minimizing negative side effects of UA on food safety and environmental health and (ii) in cooperation with NGOs and local administrative bodies developing scientifically sound recommendations at the producers' level to enhance the resource use efficiency and productivity of the UA production systems.

The Time Frame is a three years (Phase I, 03/2007 - 02/2010) with possible extension by another three years (Phase II, 02/2010 - 01/2013).

More information under: **http://www.agrar.uni-kassel.de/UrbanFood**

Tropentag 2007

Exploiting diversity in landuse systems: sustainable and organic approaches to meet people's needs

Witzenhausen. The Tropentag 2007 is from 09. - 11. Oktober 2007 in cooperation with the University Göttingen, at the University Kassel in Witzenhausen.

The annual Conference on Tropical and Subtropical Agricultural and Natural Resource Management (TROPENTAG) is jointly organized by the universities of Göttingen, Hohenheim, Bonn and Kassel-Witzenhausen as well as by the Council for Tropical and Subtropical Research (ATSAF e.V) in cooperation with BEAF/ GTZ.

All students, Ph. D. students, scientists, extensionists, decision makers, politicians and practical farmers, interested and engaged in Agricultural Research and Rural Development in the Tropics and Subtropics are invited to participate and to contribute.

Further information under **http://www.tropentag.de/**

Notes to authors

The Journal of Agriculture in the Tropics and Subtropics publishes papers and short communications dealing with original research in the fields of rural economy and farm management, plant production, soil science, animal nutrition and animal husbandry, veterinary hygiene and protection against epidemics, forestry and forest economy.
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Manuscripts should be typed double-spaced with a wide margin, preferable on disk.
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Tables should not be prepared with blanks and should fit on a DIN A5 page
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All tables should have captions and should be numbered consecutively.

Figures should be black&white/greyscaled and suitable for reproduction (if possible, vector formats, postscript .ps .eps). Photos should be high-gloss prints of good contrast, maximum size 13 by 18 cm, line drawings with Chinese ink on white or transparent paper. All figures should be numbered consecutively. A separate list of captions for illustrations has to be added.

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References in the text should be made by the name of the author and the year.
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Journal of Agriculture and Rural Development in the Tropics and Subtropics, former
Der Tropenlandwirt/Beiträge zur tropischen Landwirtschaft und Veterinärmedizin
Editorial Board
Steinstrasse 19,D-37213 Witzenhausen
E-mail: tropen@wiz.uni-kassel.de , Fax (0) 5542 981313

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