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Determinants of Crop-Livestock Enterprise Combination Adoption and its Impact on Crop Productivity Among Resource-Poor Rural Farmers in Zamfara Grazing Reserve

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Abstract: This study evaluates the factors that affect the adoption of manure contract as soil management strategy as well as its impact on crop productivity in the study area. Data were collected from 228 respondents in Zamfara grazing reserve on the adoption of crop-livestock enterprise combination and the reasons for their decision to adopt this particular farm practice. A Probit analysis was used with Ordinary Least Square regression recursively to analyse factors that facilitate farmers adoption of crop-livestock enterprise combination and its impact on crop productivity. Results from the analysis have shown that farmers based their adoption decision on the following reasons; household size which is a measure of labour availability, traditional production method learnt from their forefathers, it guarantee more food for the family, as a means of saving asset, availability of manure for household farm production, availability of traction power for farm works and generation of more income for the family. The analysis has also shown that the adoption of crop-livestock production practice has contributed to yields improvement in the study area. The results have thus proved that resource-poor rural farmers are very innovative in solving their production resource problem with the use of available local alternative resources around them. Thus the analysis has helped to quantitatively confirm the validity of previous researches on evaluated factors as reasons for farmers adoption of crop-livestock integration. It can therefore be concluded that resource-poor rural farmers often have good reasons for farm production practices they engage in for the purpose of enhancing their productivity.

Key words: Crop-livestock, adoption, productivity, resource-poor rural farmers, Zamfara

INTRODUCTION

Crop-livestock interaction farming systems have been viewed as the poverty saving net for resource-poor rural farmers in the developing countries where the farmers are generally poor and unable to afford conventional fertilizers for soil fertility maintenance.

Apart from additional income derivable from the inclusion of livestock in the farming enterprise, other benefit is the increase in crop yields made possible through the availability of animal manure for soil fertility maintenance (Omolehin, 2005). According to Brouwer and Powell (1995), the application

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of manure to soil enhances the following 1). Improvement in soil physical and the provision of N, P, K and other mineral nutrients, 2). The application of livestock manure increases soil organic matter content and leads to improved water infiltration and water holding capacity as well as an increase cation exchange capacity, 3). Manure and urine raise the PH level and accelerate the decomposition of organic matter and termite activity and 4). If inorganic fertilizer, especially nitrogen, is combined with manure, the manure reduces soil acidification and improves the nutrient buffering capacity and the release of nutrients (Williams *et al*., 1995). The importance of crop-livestock enterprise combination and the factors driving the adoption of the practice have been widely recognised by various authors among them Abiassi (2001).

Factors influencing adoption of crop-livestock enterprise combination according to Abiassi are as following: size of the farmers' household, combining animals with cropping as part of tradition, animal keeping with cropping enhances more food, animal keeping with cropping as saving strategy, animal keeping provide manure for cropping on the farm, animal keeping provides traction power for cropping and lastly animal keeping enhances more income to the farm household. While all these factors as mentioned above have been cited as farmers reasons for adopting crop-livestock farming, quantitative evaluation of these factors and the impart of crop-livestock on crop productivity have not been examined quantitatively examined. This study is therefore aims at evaluating quantitatively these factors driving farmers adoption of crop-livestock enterprise combination and the impact of the adoption on crop productivity in the study area.

MATERIALS AND METHODS

Study Area and Data

Zamfara grazing Forest Reserve is located between 6° 30 and 7° 15' E and 12° 05 N in the North of Zamfara state and sharing a border with the Niger Republic to the north, Sokoto state to the West and Runka Reserve of Katsina state to the East. The annual rainfall within the reserve ranges from 500 mm in the north to about 850 mm in the south with considerable inter-annual variations. The vegetation of the reserve is of a northern Sahel savannah type.

The Zamfara reserve was established in 1918 and covers as of today an area of about 2300 km^2, including the four enclaves villages located within the reserve namely Shamushalle, Dumburum, Ajja and Tsabre. There are about 50 other villages lined up in the western fringes of the grazing reserve. About 130,000 people live within and around the reserve and are utilising its natural resources (Hoffmann, 1998). The reserve is very important for livestock grazing in the rainy season for the transhumance pastoralists as well as the herds being raised by the sedentary farmers living in the enclaves as well as the adjoining villages. After grain harvest, most of the livestock are fed on stubbles. At the heart of the dry season, most of the transhumance pastoral herders leave the region in search of greener pastures and water. However, about one third of the Fulani who have become sedentary stay in the region throughout the year (Schaefer *et al*., 1998).

In spite of the low average population density of about 80 persons per km^2, pressure on cropland is very high. The estimate of the actual land area available per household of about 8 persons (Eckert, 1998) are between 1.6 and 1.8 ha for Dumburum, Ajja and Shamashalle, but about 5.4 ha for Tsabre (Hoffmann, 1998). Plot size among farmers in Zamfara reserve ranges from 0.2 to 4 h with an average of 1.1 ha. As arable land is increasingly becoming limited due to population growth, shifting cultivation and fallow are no longer practised and therefore the cultivated fields are under permanent use for the past 40 years, thus making the fertility maintenance of the cultivated field a very important requirement for sustainable production. The maintenance of the area already designated for cultivation in this forest reserve has the potential of reducing further deforestation and therefore essential for the sustainability of the forest reserve in itself. This is so in view of the unilateral bush clearing activities often embarked upon by farmers to enlarge their farms or to acquire fresh land due to loss of fertility of the old ones they have abandoned (Hoffmann, 1998). The position stated above have made the fertilization of the cropping area to be more compelling and underscores the importance of crop-livestock enterprise combination adoption as soil fertility management strategy in solving the fertility maintenance problems among the farmers in the Zamfara grazing reserve.

Data were collected with the use of structured questionnaires from 228 respondents in Zamfara grazing reserve comprising croppers involved in crop-livestock enterprise combination under same management as soil fertility maintenance and those that were not involved in 2002. Data for this research work commenced in December 2001 and lasted for ten months, bringing the survey to an end in September 2002. The respondents were selected by stratified random techniques to enhance fair representative of the sampled population of about 1190 households residing in the reserve. Information was collected on farmers' socio-economic and demographical attributes. Other important information was on whether farmer adopt cop-livestock enterprise combination for fertility maintenance or not and the factors driving the adoption, the expenses on crop production, labour expended in man-hour were equally collected. Finally, output from farms and the prices of produce were equally collected in the study area to enable the quantification of the value of outputs by the farmers for the year in question.

General Theoretical Considerations for the Modelling of Adoption Behaviour

Since the early work on adoption by Rogers (1962), efforts that have been made to explain the determinants of adoption have received a boost. There are two major groups of paradigms for explaining adoption found in literature: The innovation-diffusion and the economic constraint paradigms.

The innovation-diffusion model, following the work of Roger, contended that access to information about an innovation is the key factor determining adoption decisions (Agrarwal, 1983). The appropriateness of the innovation is taken as given and the problem of technology is reduced to communicating information on technologies to potential end users. By emphasising the use of extension, media and local opinion leaders, or by the use of experimental station visits and on-farm trials, sceptic non-adopters can be shown that it is rational to adopt (Adesina and Zinnah, 1993).

In contrast, the economic constraint model (Aikens *et al*., 1975) contends that economic constraints, reflected in asymmetrical distribution patterns of resource endowments, are the major determinants of the observed adoption behaviour. A lack of access to capital (Havens and Flinn, 1976) or land (Yap and Mayfield, 1978) is seen as factor significantly constraining adoption decisions. While attempts have been made to assert the superiority of the economic constraint model over the innovation model (Hooks *et al*., 1983), such conclusions have been challenged (Nowak, 1987).

A number of other studies have investigated the influence of various socio-economic factors on the willingness of decision makers to use new technologies (Nerlove and Press, 1973; 1983; Shakya and Flinn, 1985). From most of these studies of adoption behaviour, the dependent variables are constrained to lie between 0 and 1 and the models used are exponential functions. One common feature of these models is that Univariate and Multivariate Logit and Probit models and their modifications have been used extensively to study adoption behaviour of farmers and consumers (Nerlove and Press, 1973; Schmidt and Strauss, 1975; Garcia *et al*., 1983; Akinola, 1987; Akinola and Young, 1985; Adesina and Zinnah, 1993). Maddala (1983) and Shakya and Flinn (1985) have recommended Probit models for the functional forms with limited dependent variables that are continuous between 0 and 1 and Logit model for discrete dependent variables.

Many studies have simultaneously evaluated the determinants of adoption as well as the impact of the adoption on productivity and profitability. In the determination of reasons for farmers adoption, yields and profitability, for instance of recombinant bovine somatotropin rbST in America (Stefanides and Tauer, 1999; Foltz and Chang, 2002), the Heckman approach was used. What is known as the Heckman approach is determined by using a Probit model to determine adoption whereby an inverse mill, which is the probability prediction of the adoption, is now used as a variable in the right hand to run an OLS model to determine the impact or effect of the adoption on productivity and profitability. Khanna (2001) used a similar approach to evaluate the adoption of soil maintenance technology and the impact of the adoption on nitrogen production. We have used this same approach to analyzed adoption and impact of adoption for this study.

Following Rahm and Huffman (1984), farmer adoption decisions are reasoned to be based upon utility maximization. If for example we define a varietals of soil maintenance technology by j, where j = 1 for the farm practice evolving for the acquisition of manure through crop-livestock integration to facilitate manure availability for soil fertility maintenance and j = 0 for the old management practice of not applying anything to the soil for the purpose of maintaining the soil fertility. The non-observable underlying utility function that ranks the preference of the ith farm household is given by U $(M_{ji}; A_{ji})$. From this, the utility derivable from the soil fertility maintenance practices depends on M which is a vector of farm and farm household-specific attributes of the adopter and A which is a vector of the attributes associated with that particular maintenance practices or technology in question. Though the utility function is unobservable, the relation between the utility derivable from a jth management practices is postulated to be a function of the vector of observed farm, farm household specific characteristics (e.g., farm size, age, family size education etc) and the practices or technology characteristics (e.g., enhance availability of manure, meet food needs, guarantee more income etc.) and a disturbance term having zero mean:

$$\mu_{ji} = \alpha_j F(\mathbf{M}_i, \mathbf{A}_i) + \varepsilon_{ji} \; j = 1, 0, I = 1 \ldots\ldots\ldots n \tag{1}$$

The Eq. 1 does not restrict the function in F to be linear. Since utilities U_{ji} are random, the ith farm household will select the alternative j = 1 if $U_{1i} > U_{0i}$ or the non-observable (latent) random variable $Y^* = U_{1i} - U_{0i} > 0$. The probability that Y_i equal one (i.e.,) that the farm household adopts a soil maintenance practices is a function of the independent variables.

$$\begin{aligned} P_i &= P_r(Y_i = 1) = P_r(U_{1i} > U_{0i}) \\ &= P_r[\alpha_1 F_i(M_i, A_i) + e_{1i} > \alpha_0 F_i(M_i, A_i) + e_{0i}] \\ &= P_r[e_{1i} - e_{0i} > F_i(M_i, A_i)(\alpha_0 - \alpha_1)] \\ &= P_r(\mu_i > - F_i(M_i, A_i)\beta) \\ &= F_i(\mathbf{X}_i\beta) \end{aligned} \tag{2}$$

Where X is the n × k matrix of the explanatory variables and β is the k × 1 vector of parameters to be estimated, P_r (0) is a probability function, μ_I is a random error term and F $(X_i\beta)$ is the cumulative distribution function for μ_I evaluated at $X_i\beta$. The probability that a farm household will adopt participation in a particular soil maintenance practice like crop-livestock enterprise combination is a function of the vector of explanatory variables and the unknown parameters and an error term.

Statistical Considerations for the Modelling of Adoption of Crop-livestock Combination and its Impact on Crop Productivity in Zamfara Grazing Reserve

The first step is to first estimate the determinants of farmers participation in the adoption of crop-livestock enterprise combination as soil maintenance strategies to facilitate improved crop productivity, while the second is the estimation of the impact of the adoption of this soil maintenance strategy on crop productivity. As a first step, it is assumed that the adoptions of soil maintenance strategies by different classes of farmers are a linear function of farm household characteristics and the attributes inherent in these soil maintenances practises. However, the decision as to whether a farmer adopts or not is based on self-selection rather than random assignment. Thus adoption A_i should be endogenised using an index function model (Heckman, 1976; Maddala, 1983; Greene, 1997). This index to estimate farm household adoption of manure contract is:

$$A_i^* = Z_i'\gamma + \mu_i \tag{3}$$

Where, A* is an unobservable index variable denoting the difference between the utility of adopting these maintenance practices (U_{1i}) and the utility of not adopting them (U_{0i}). If $A_i^* = U_{1i} - U_{0i} > 0$, then the individual household$_I$ will adopt a chosen soil maintenance strategy. The term $Z'\gamma$ provides an estimate of U_i1-U_i0, using farm household characteristics and the attributes of the soil maintenance practices, Z_i, an explanatory variables, while U_i is an error term unobserved by the researcher and assumed to be normally distributed $U_i \sim N(0,1)$. This model is estimated with a standard Probit log-likelihood function. The decision to use Probit was arrived at after we have fitted the data to both Probit and Logit and discovered that results from Probit were better than that obtained from Logit. It should also be noted that following Maddala (1983) and Shakya and Flinn (1985) recommendation, the dependent variable for this model is continuous and lies between 0 and 1 and therefore the use of Probit was quite in order and justifiable.

On the other hand, to model the impact of the soil maintenance practices adoption on crop productivity, we assumed that crop yields Y_i is a linear function of a vector of explanatory variables (X_i) and (A_i*) Trauer and Knoblauch (1997). The linear equation can be written as

$$Y_i = X_i\beta + \delta A_i^* + e_i \tag{4}$$

Where, e_i is a normal random disturbance and A_i* is a 0 or 1 dummy variable for the adoption and non-adoption of soil maintenance practices. The vector X_i represents inputs such as labour and inputs expenses expended on crop production. Using Eq. 3 and 4 the expected crop yields Y_i can be obtained by:

$$\begin{aligned} E[Y_i] &= E[Y_i/A_i{=}1]^*\ Prob(A_i{=}1) + E[Y_i/{=}0]^*Prob(A_i{=}\ 0) \\ &= X_i\beta+\delta+E[\mu/A{=}1])\ ^*Prob(A = 1) \\ &\quad +(X_i'\beta+E[\mu_i/A_i{=}0])^*\ Prob(A_i = 0) \\ &= X_i'\beta+\delta Prob(Z_i'\gamma+\mu_i>0) \\ &= X_i'\beta+\delta\Phi(Z_i'\gamma) \end{aligned} \tag{5}$$

Where Φ is the normal cumulative density function for μ_i. Thus, $\Phi(Z_I'\gamma)$, the probability of soil maintenance practices adoption by farm household I, serve as the instrumental variable for A_i* = Adoption probability in the Eq. 4 helps to avoid biasing the estimators.

The two models to be estimated are therefore:

$$A_i^* = Z_i'\gamma+\mu_i \tag{6}$$

i.e., Probit for adoption determinants.
However, the Probit parameters was estimated using maximum likelihood methods

$$Y_i = X_i'\beta+\delta A_i^*+ e_i \tag{7}$$

for impact of adoption on productivity.

These two models (6 and 7) were used to achieve the objectives of determining the factors that facilitated the adoption of crop-livestock enterprise combination for soil fertility maintenance in the study area and the impact of these practices on farm productivity.

Variables in the Participation of Crop-livestock Enterprise Combination Adoption

The evaluation is based on the estimation of models 6 and 7. A total of 228 households comprising those that are involved in crop-livestock enterprise combination as means of generating manure for soil fertility maintenance and those not involved in this practice were collected in 2002. As earlier explained, there were four enclaves in the Zamfara reserve where the data were collected. These are Dumburum, Shamushalle, Ajja and Tsabre. The area covered is a very wide expanse. The four enclaves covered were further divided into two regions namely Shamushalle-Dumburum and Ajja-Tsabre. The population structures and the nearness of these communities as well as the similarity in their locations with respect to the major roads informed the decision for this grouping. Dumburum and Shamushalle have larger population and are closer to the major motor road in the area while Ajja and Tsabre are smaller and a little far of the motor road.

Data for the adoption of farmers participation in crop-livestock enterprise combination was grouped into Dumburum-shamushalle with 109 respondents and Ajja-Tsabre with 119 respondents while the total respondents of 228 were equally considered to show the overall significance of the determinants of adoption participation in the whole of the study area.

The participation of farmer in crop-livestock enterprise under same management is the dependent variable and farmers that combine these two enterprises together were scored one while those not involved were scored zero. There were seven explanatory variables that serve as influencing the decision of farmers to participate in adopting crop-livestock enterprise combination as soil maintenance practice. They are family size, traditional practise of the people, food security driven, as a form of savings, to ensure availability of manure, to ensure availability of traction power and for more income generation. The impact of the adoption of the mixed enterprise on crop productivity was equally investigated and for that the yields of crops measured in grain equivalent in kg ha^{-1} as proxy for productivity was used as the dependent variable whiles the indicator variables were labour, inputs expenses and the mixed enterprise combination probability prediction from the adoption model.

According to Kebede *et al*. (1990), family size FAMLSIZE has been recognised to play vital role in the adoption of any particular farm practices or technologies. In African context, family are known to play dual and opposing roles in determining what occurs on the farm (Akinola, 1987). On the one hand, it provides the human factor in farming through labour and management inputs. It also has certain demands, which may motivate the adoption of new practices, or technologies that would increase the farmers income as a means to meeting these demand. Furthermore, the strength of family ties has the effect of encouraging the farmer to improve his earning power because many family workers tolerate, for a time, extremely bad conditions of employment or very poor wages, either in kind or cash, as a result of their family loyalty. This therefore puts the farm operator in a financially advantageous position to spend more money on adoption of new practices especially when the practices in question demanded more expenses. Conversely, family demands may compete with the farm enterprises for scarce financial resources of farmer. Dependency of relatives on farm operator may weaken his motivation to work harder since he knows that his financial success might result in more claims from the poorer members of his family. Hence, the actual relationship between the size of family dependant and adoption of crop-livestock enterprise combination will depend on the balance of these effects.

The other variables discussed bellows have been recognised in literature qualitatively to be crucial in guiding the decision of crop farmers to combine animal enterprise with their cropping activities (Abiassi, 2001; Ndubuisi, 1999).

On the traditional practise of the people TRADITN, the people of these communities are predominantly Muslims where animals such as cattle, sheep and goats are very important in the periodic Muslims festivals. The desire to have animals as part of farm business so as to prevent these farmers from buying at exorbitant prices during these many celebrations is very important in farmers decision to include animal's possession as part of their farm business. In fact, it was stated by some of the farmers during interview with them that keeping animals with cropping is seen generally as part of their normal life.

More so, food security driven FOOD, as a variable is very important since animals especially cows produce milk for family use and sales. The traditional food of the people in the northern region particularly the Hausas and the Fulani is millet usually made into porridge called Fura and taking with fresh milk called Nono. Therefore, the desire to have more food is very crucial in farmer decision to participate in crop-livestock enterprise combination practice as a way of production in the study area. As a form of savings SAVINGS, here, the farmers sell one or two livestock to raise money whenever the need arises and as such the keeping of animals is seen as a form of money savings since the animals can be converted to money when monies are needed. Savings is therefore seen as one of the motive driving the desires of the farm household to embark on crop-livestock enterprise combination to save parts of their assets in animals.

The other reason for combining animals with cropping is to ensure availability of manure MANURE. Due to poor soils structure and low nutritional values of these soils as well as the highly porous nature which tend to make the use of conventional chemical fertilizers less effective, manure is seen here as an important input in crop production, the availability of which heavily depends on livestock possession. The farmers here therefore will certainly based their decision to practise mixed enterprise combination mainly most of the time on the desire to have manure for the maintenance of the fertility of their soils so as to enhance sustainable crop production to meet family food needs as well as for sales (Powell, 1986). To ensure availability of traction power TRACTION is viewed as an important factor in farmers' decision to adopt crop-livestock enterprise combination. In this fragile region of the country where there are fewer trees couple with sandy soils that is very light, with lack of motorised tractors, the local alternative farm power available to these rural farmers is animal draught power and the possession of animals like Bulls are very important in this direction. Therefore draught animals are very serious in farmer decision consideration to get involve in crop-livestock enterprise combination. Farmers are known to always want to maximise their income and since having animals along with cropping will ensure income generation from multiple products like crops, milk and meat, the desire for more income is seen here as very crucial in farmer decision to combine cropping with animals and hence the variable MOREINCO. This is because farmers aspiring to enlarge their production are most likely to have the motive of higher income as their reason and since new practices when adopted are geared towards higher yields and income, it is believed that farmers will be much willing to adopt a practice that has the potential of increasing their income.

Determinants of Decision to Participate in Crop-Livestock Enterprise Combination in Dumburum-Shamushalle Zone

The models of decisions to participate in crop-livestock enterprise combination under same management as strategy for soil fertility maintenance identify characteristics that stimulate households' participation as opposed to those who do not. These models attempt to determine factors that encourage farm households' participation in crop-livestock enterprise combination. The model is specified as:

$$\Pr(\text{TLU}) = f(\text{FMLSIZE, TRADITN, FOOD, SAVINGS, MANURE, TRACTION, MOREINCO}) \tag{8}$$

That is the probability of participating in crop-livestock enterprise combination under same management as strategy for soil fertility maintenance depends on the set of explanatory factors as shown in the right hand side of the equation above for both probit models.

Table 1 presents the results of the probit estimations of factors significantly influencing the decision of farm households to participate in crop-livestock enterprise combination under same management as strategy for maintaining soil fertility in the study area. The Probit model correctly predicted about 65% of the observations, with significant chi-squared of 14.90. Five of the seven

Table 1: Probit model for the adoption of crop-livestock Enterprise combination participation in dumburum-shamushalle zone

	Probit model		
Variables	Coefficients	t-ratio	p-value
Size of the household	0.053**		
	(0.018)	2.93	0.003
Traditional way of life of the people	0.68*		
	(0.41)	1.65	0.098
Availability of more food	0.19		
	(0.44)	0.43	0.66
As means of savings capital	-0.27		
	(0.41)	-0.65	0.51
Availability of manure for crop	0.68*		
	(0.34)	2.01	0.45
Availability of traction power	0.59*		
	(0.41)	1.46	0.14
More income for the farmer	1.10**		
	(0.36)	3.02	0.003
% Correctly predicted = 65.14			
Model Chi-sq = 14.90*			
Log likelihood function = -67.99			
N = 109			

*, **, Significant at 10 and 5% levels, respectively, No. in parentheses is standard deviations

variables had coefficients that were significantly different from zero and were positively associated with the probability of adopting crop-livestock enterprise combination as strategy for soil fertility management.

The size of the farm household was found to be highly significant at 1% level of probability and this is very understanding given the fact that the combination of the two enterprises, crops and animals require a lot of labour for cropping activities as well as the tending of animals. Since family labour is a very important integral parts of farmers source of labour for farm operations in the whole of Nigerian rural communities in particular, therefore the larger the size of the family, the more the probability and the capacity of the household to adopt crop-livestock enterprise combination since large size family will provide the much needed labour to facilitate the adoption.

More so, as a traditional way of life of these farmers, they keep livestock so that they can have animals from their own farm for the Muslim's festival celebrations that occurred two to three times a year. The desire to have animals for festival celebration is therefore paramount in farm households decision to adopt both crop and livestock enterprise as production practises in the study area. Furthermore, the desire for animal traction to facilitate ease of farm operation is considered very important in farmer decision to adopt crop-livestock enterprise combination as production practice in the area. Farmers here are generally poor and cannot afford tractors and implements needed to engage in farm operations. Having work bulls have proved to be a good substitute for tractor in this area since the structure of their soils are loosed and can easily be worked by work bull in this environment that have little tress making work bull use for farm operation relatively easy. Therefore, the desire for draught power to work on the farm will encourage farmers to adopt the production practice of having crops and animals under same management since part of the farm animals can be used as work bull on the farm.

In the same vein, the desire for more income from both crops and animals is a strong motivating factor encouraging the farmers to adopt crop-livestock enterprise combination. Crop production is carried out under rain-fed and therefore seasonal. Since farmers require income throughout the year for family needs, the animal sales and sales of animal products like milk helps farmers to generate income at off-season to meet family social and financial needs. Hence the desire for more income will serve as a motivating factor for the adoption of crop-livestock production enterprise combination in the study area. It was equally found that manure availability was positively correlated and statistically significant in explaining farmers adoption of crop-livestock enterprise combination in the study area. This is because farmers belief that keeping animals along with cropping will guarantee their access to manure for cropping.

As shown from the Table 1, savings was negatively associated with adoption here and it is not surprising since the farmers here are closer to the main motor roads and participate very well in trading. They may not have savings therefore as a motive for adopting having animals with cropping since rather they will want to use available capital to boost their part-time trade at off-seasons. However, food motive even though not significant was positively associated with crop-livestock enterprise combination adoption and will therefore still encourage farmers to adopt since it will help them to have more food and equally shore up the family nutritional needs.

Determinants of Decision to Participate in Crop-Livestock Enterprise Combination in Ajja-Tsabre Zone

Table 2 presents the results of the probit estimations of factors significantly influencing the decision of farm households to adopt crop-livestock enterprise combination practice in Ajja-Tsabre area. The Probit model correctly predicted 60% of the observations, with significant chi-squared of 5.13. Four of the seven variables had coefficient that were significantly different from zero and were positively associated with the probability of farm households adopting crop-livestock enterprise combination practice under same management.

At Dumburum-Shamushalle zone, the size of the household family was very important in farmer decision to adopt crop-livestock practices because of high level of labour required to run the combined farm business. Labours are required for both crops and animals and since family labour forms the most important part of farm labour, the higher the size of family, the more labour that would be available for farm works from family and hence higher family size will encourage the farm household to adopt crop-livestock enterprise combination.

Also, the traditional production requirement of having animals in the household that could be used to celebrate Muslim festivals drives the desire to adopt crop-livestock enterprise combination farm practice in the area.

Table 2: Probit model for the adoption of crop-livestock enterprise combination in Ajja-Tsabre zone

	Probit model		
Variables	Coefficients	t-ratio	p-value
Size of the household	0.33*		
	(0.17)	1.94	0.052
Traditional way of life of the people	0.59*		
	(0.35)	1.66	0.098
Availability of more food	0.63*		
	(0.41)	1.58	0.115
As means of savings capital	-0.20		
	(0.38)	-0.53	0.60
Availability of manure for crop	0.38		
	(0.31)	1.200	0.230
Availability of traction power	0.70*		
	(0.36)	1.97	0.048
More income for the farmer	0.41		
	(0.30)	1.38	0.169
% Correctly predicted = 59.98			
Model X^2 = 5.13*			
Log likelihood function = -79.41			
N = 119			

* Significant at 10%, No. in parentheses are standard deviations

However, in contrast to Dumburum-Shamushalle zone, desire for more food plays an important role in the farm household decision to adopt crop-livestock enterprise combination practice in this zone. The traditional food of the people is millet usually prepared into porridge called Fura and eating with fresh mild called Nono. The inclusion of livestock in the farm business along with crops will enhance readily availability of milk needed for consumption of Fura and will also shore up the nutritional value of the farm household. Also, the fact that these people are far from any known market make the purchase of other sources of protein close to milk impossible as could be found in Dumburum-Shamusahalle and hence the importance of milk from own animals for the farmers household nutritional need in this zone. Hence the desire for more food for the family will encourage the decision of farm household to adopt crop-livestock enterprise combination in the farm business. As a means of savings capital was found to be not significant and negatively correlated with the desire to keep animals as part of farm business also in Ajja zone. The desire for more income is almost significant here and positively associated with crop-livestock enterprise combination practice, since keeping animals as part of farm business could provide these farmers with additional income from the sales of animals and animals' products like milk.

Finally, the desire for animal traction was found to be also significant in farmers decision to adopt crop-livestock enterprise combination as a practice of soil fertility maintenance, since these farmers are poor and cannot afford tractors and other advanced technologies. The soil being loosed enhances the use of animals' traction for effective farm operations.

Determinants of Decision to Participate in Crop-Livestock Enterprise Combination by All Farm Households in Zamfara Grazing Reserve

In attempting to fit models with limited dependent variables or the so-called dichotomous variable, the larger the number of observations, the better the results from the models (Greene, 1997). For this reason, the pooled data was estimated for all farmers in the study area to see whether there was overall better results. The Probit model showed estimations of factors that significantly influenced the decision of farm households to adopt crop-livestock enterprise combination in the study area for the observation collected in the two zones representing the whole observations collected in Table 3.

Table 3: Probit model for the adoption of crop-livestock enterprise combination participation by all farmers in the study area

	Probit model		
Variables	Coefficients	t-ratio	p-value
Size of the household	0.040***		
	(0.012)	3.41	0.0007
Traditional way of life of the people	0.50*		
	(0.27)	1.84	0.066
Availability of more food	0.50*		
	(0.24)	2.08	0.038
As means of savings capital	0.53*		
	(0.25)	2.137	0.033
Availability of manure for crop	0.54*		
	(0.26)	2.217	0.027
Availability of traction power	0.42*		
	(0.27)	1.55	0.121
More income for the farmer	0.61**		
	(0.24)	2.59	0.009
% Correctly predicted = 60.09			
Model Chi-sq = 13.33*			
Log likelihood function = -151.29			
N = 228			

* = Significant at 10% level, ** = Significant at 5% level and *** = Significant at 1% level, No. in parentheses is standard deviations

Table 4: Impact of crop-livestock enterprise combination on crop productivity

Dependent variable	Mean		SD
Yields of crops in grain equivalent	1916.4		1102.61
Explanatory variables	Coefficients	St. Error	t-statistic
Constant	0.73*	0.29	2.54
Inputs expenses	-0.02	0.033	-0.47
Probability of crop-livestock	1.08***	0.21	5.27
Labour used	1.09*	0.43	2.54
R-square = 0.22			
R-adjusted = 0.20			
F-statistic = 9.84***			
N = 109			

*, *** Significant at 10 and 1%, respectively

The Probit model correctly predicted 60% of the observations, with significance chi-squared of 13.33. For the Probit model, all the seven variables had coefficients that were significantly different from zero.

The implication was that pooling the whole observations together has significantly improved the results of the models. It also showed that all the variables taken together collectively were all important to the whole farmers in making of the decision to participate in the adoption of crop-livestock enterprise combination practice in the study area as strategy to increase soil fertility and sustain the productivity of their soils. It has been discovered that in the process of the farmers trying to improve the fertility of their soils, this practice have equally enable them to fulfilled other notable objectives such as traditional religious duty, meeting food needs, meeting manure needs, as a form of savings, meeting farm power needs and increasing the general level of their income.

Impact of the Adoption of Crop-Livestock Enterprise Combination on Crop Productivity in Dumburum-Shamushalle Zone

As shown from the Table 4, all the three variables in the estimate played very important role in crop yields and productivity. Two of the three variables, labour and the probability of the farmer participating in crop-livestock enterprise combination were positively associated with crop yields. It means these variables were instrumental to the increase in yields of crop among the agro-pastoralist group in the study area.

On the other hand, the variable expenses on inputs have a negative sign on its coefficient showing that the more of it the farmer use, then the decrease in crop yields and productivity. The negative sign for this variable may mean that certain inputs expenses have been pushed beyond optimal level of usage among the farmers in the zone.

However, the participation of the farm household in crop-livestock enterprise combination was significant at 1% level of probability showing the importance of this particular variable to increase and sustainable crop productivity in the area. This is because manure, one of the bye-products of animals in the area has become an essential input in soil fertility maintenance. Thus the presence of animal along side with crops has become the usual way of securing manure for crop production, as manure is an important means of soil fertility maintenance in the area.

The variable labour was also significant at 10% level of probability and reinforces the belief that the more labour the farmer invests in his farm business, the better the yields from his crops. Labour is a critical input in crop-livestock farming systems since there is competing needs for labour between crops and livestock enterprise. The availability of labour and how effectively it is managed will go a long way at enhancing good returns from farm business.

Impact of the Adoption of Crop-Livestock Enterprise Combination on Crop Productivity in Ajja-Tsabre Zone

The estimates from Ajja-Tsabre zone also showed that all the three variables in the regression played important role in farm households' crop yields and productivity. Whereas the estimated

Table 5: Impact of crop-livestock enterprise combination on crop productivity

Dependent variable	Mean		SD
Yields of crops in grain equivalent	1549		912.24
Explanatory variables	Coefficients	St. Error	t-statistic
Constant	1.08***	0.28	3.88
Inputs expenses	0.20***	0.038	5.14
Probability of crop-livestock	0.35*	0.18	1.99
Labour used	-0.25	0.47	-0.53
R-square = 0.21			
R-adjusted = 0.18			
F-statistic = 9.88***			
N = 119			

*, *** = Significant at 10% and 1, respectively

Table 6: showing impact of crop-livestock enterprise combination on crop productivity

Dependent variable	Mean		SD
Yields of crops in grain equivalent	1724.7		1022.18
Explanatory variables	Coefficients	St. Error	t-statistic
Constant	0.78	0.21***	3.74
Inputs expenses	0.06	0.03*	2.33
Probability of crop-livestock	0.74	0.14***	5.25
Labour used	0.83	0.33*	2.51
R-square = 0.13			
R-adjusted = 0.12			
F-statistic = 11.33***			
N = 228			

*, *** = Significant at 10 and 1%, respectively

coefficient for inputs expenses was negative at Dumburum-Shamushalle, it was positive for Ajja as shown in the table. It shows that productivity here is a linear function of inputs expenses and as you use more of expenditure here on inputs, the productivity all things being equal increases progressively (Table 5).

The probability of farm household participation in crop-livestock enterprise combination adoption practices was also positively associated with crop productivity and shows that participation of farm households in the practice increased soil fertility and hence crop yields. The coefficients of both inputs expenses and farm households' participation in crop-livestock enterprise combination were significant at 1 and 10% level of probability respectively showing that they are very crucial to production by farmers in the area.

However, labour was found in this zone in contrast to Dumburum-Shamushalle to have negative coefficient, which was also not significant. In this zone, motorways are very far away and the likelihood of labour migrating to bigger towns was remote. Labour is much in higher supply here than the other zone and may have been overused here. The fact that animals population per household here are smaller means that less labour were expended on animals leaving excess labour that were overused on crops.

Impact of the Adoption of Crop-Livestock Enterprise Combination on Crop Productivity among All Agro-Pastoralists in the Entire Study Area

The overall impact of farm households' participation in the adoption of crop-livestock enterprise combination on crop yields and productivity was estimated by pooling all the data for the two zones together. It was found that all the three variables played an extremely important role in farm households' crop yields and productivity. All the three variables of inputs expenses, adoption of crop-livestock enterprise combination and labour expended on crop production were positively associated with increase in crop yields and productivity (Table 6).

The positive signs on their coefficients showed that more use of these variables would lead to an increase in crop yields and productivity. While inputs expenses and labour coefficients were significant at 10% level of probability, it is very interesting to note that the probability of crop-livestock enterprise combination was highly significant at 1% level of probability. It showed that overall, crop-livestock enterprise combination have is an important means of generating manure for the purpose of soil fertility maintenance in Zamfara grazing.

CONCLUSIONS

This study has shown that there are factors affecting the decision of farmers to participate in the adoption of crop-livestock integration practice in the study area.

At Dumburum-Shamushalle zone, the size of the farmers' household, traditional way of production, availability of manure from the crop-livestock combination, availability of traction power from the combined enterprise and more income arising from the combination of the two enterprises were significant in farmers' decision to adopt this production practice.

On the other hand, in Ajja-Tsabre zone, the results shows that size of the farmers household, traditional way of production, availability of more food from crop-livestock combination for the farm household and availability of traction power from the animal component were the factors facilitating adoption of the practice.

However, it was found that all the investigated variables were all significant for the pooled results in farmers' adoption of crop-livestock enterprise combination. The results also have shown that adoption of crop-livestock enterprise combination has significant impact of crop productivity in the study area. The results have thus proved that resource-poor rural farmers are very innovative in solving their production resource problem with the use of locally available alternative resources around them. Thus the analysis has helped to quantitatively confirm the validity of previous researches on these evaluated factors as reasons for farmers' adoption of crop-livestock integration. It can therefore be concluded that resource-poor rural farmers often have good reasons for farm production practices they engage in for the purpose of enhancing their productivity. Some of these reasons as could be seen in this study is to maximize the use resources at their local environment as substitute for commercial alternatives they are unable to afford in order to ensure that their ability to produce on the farms are not impaired.

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