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Prospects of Technology Adoption in Small Pump Schemes in the River Nile State, Sudan

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Abstract: Linear programming was used to simulate the farming systems of small pump schemes in Shendi area, River Nile State, Sudan, to assess the prospects for technology use in cool-season food legumes and wheat. Different production activities, with respect to target crops, were identified to reflect different technology levels. The model constraints were the pump capacity, the scheme size and family labour. Alternative versions of the model were developed to examine possible production options that exist and to examine the effects of alternative resource levels and policy options, which are likely to affect adoption. The model results revealed that while farmers' traditional practices were not economically feasible options, tendency is for adoption of medium rather than the recommended high technology levels. This reflects actual farmers' behaviour, particularly for irrigation water, and indicates that water is the main resource constraint. The results also showed that the technology is not well supported by the traditional institutions of production relations, which create conflicting perception between resource owners towards technology use.

Key words: Pump schemes; linear programming; food legumes; wheat; adoption

INTRODUCTION

The River Nile and the Northern states of Sudan are characterized by a relatively unique cool winter compared to the rest of the country, which makes them the most suitable for production of winter crops, e.g. wheat, cool-season food legumes (faba bean, chickpea and lentil), spices, potatoes and onion. These crops constitute important food categories, particularly cool-season food legumes which are consumed by all income

groups all over the country. The crops are produced under farming systems of small private pump schemes (farms) along the sides of the Nile river. These farming systems are characterized by a crop-sharing system based on resource participation. The main parties involved are the pump owner, known also as the scheme owner, and the farmer or tenant. The pump owner is responsible for the provision of water, while the farmer provides his labour for field operations. Other purchased inputs and services are shared. At the end, and in returns for water, the pump owner receives half the produce and the share-cropper gets the other half in return to his/her labour and management.

Research efforts on winter crops, particularly those of wheat and food legumes, in the two states have been ongoing since the early sixties. The main focus of research has been to improve productivity and quality through plant breeding and crop husbandry programmes. However, a system-research approach, which was started in faba bean in 1979 through the Agricultural Research Corporation (ARC)/ICARDA/IFAD Nile Valley Project (NVP), and has continued in the ARC/ICARDA/The Netherlands Nile Valley Regional Program (NVRP), covered all food legumes and wheat. After several seasons' testing, packages of improved production practices were developed and recommended for farmers' use in the two states. The packages include improved varieties, optimum sowing time, irrigation regimes, crop nutrition and pests and weed control.

On-farm trials under the NVRP have been carried out in various locations in the study area. Their objective was to verify the validity and adaptability of improved production technologies developed by the project. They are also used as media to demonstrate to farmers those improved management practices. They cover wheat, faba bean and lentil. Practices have been proposed in packages that differ according to the crop and location. The improved technology showed agronomic superiority and economic feasibility over farmers' traditional practices across the three crops, reflected in considerable yield advantage and high marginal rates of returns (Salih *et al*. 1996). Adoption studies carried out, mainly for faba bean, have shown different implementation levels of such factors by farmers (Ahmed 1991, 1992, 1993, 1995). However, those studies have

exposed the effect of factors related to farmers' specific conditions and to the technology itself. System constraints, such as the competition of all crops for scarce resources and policy related constraints, which affect technology use in all crops, are also crucial for technology adoption. These issues can only be, and have been, addressed with whole farm modeling (Faki and Ahmed 1992, 1993, 1994).

The objective of this study was to use linear programming to predict farmers' adoption behaviour, given the socio-economic characteristics of the small pump scheme as one production unit.

MATERIALS AND METHODS

Linear programming (LP) was used to simulate the farming system of the small pump schemes in the study area.. The model basically follows the standard form of linear programming which maximizes an objective function subject to a set of resource constraints, and based upon the work by Agrwal and Heady (1972) and Hazel and Norton (1986). The objective function together with the constraints form what is called the programming model.

The programming model is expressed mathematically as

$$\text{Maximize} \quad Z = \sum_{j=1}^{n} C_j X_j$$

$$\text{Subject to} \quad \sum_{j=1}^{m} a_{ij} X_j \leq b_i \quad \text{and} \quad X_j \geq 0$$

where Z = the value of the objective function,
C = a raw vector of costs and returns,
X = a column vector of products and resource allocations (decision variables),
A = a matrix of technical coefficients relating inputs to outputs, and
b = a column vector of resource endowments or restrictions.

The objective function maximizes net returns to crop production subject to land (the scheme area), the pump capacity and family labour. The model activities were set to reflect the major crop activities, with more emphasis on faba bean, lentil and wheat. Various scenarios of the model were developed in order to simulate alternative options with respect to cultivable area, inputs levels, production relations, cost and prices.

Different technology levels were identified for the target crops to reflect the state of technology under average farmers' practices and the proposed improved ones. Faba bean was assigned three technology levels denoted as low, medium and high. They, respectively, represent traditional practices, application of 7 irrigations plus one insecticidal spray and 9 irrigations plus two sprays. Two technology levels (low and high) were identified for lentil and wheat, representing, respectively, traditional and improved technology levels. Other non target crops were represented in the model at the average farmer's technology levels. The model constraints were land (scheme area = 15 to 20 feddans[1]). Irrigation water (pump capacity, 150 irrigations) and family labour (416 man-days), which all were obtained from the field survey data. It was observed from the field survey that labour hiring and formal credit use were not common; therefore, no activities of direct labour hiring and credit were included in the model. This is justified by the fact that in the resource-based institutional setup of a typical small pump scheme, the scheme/pump owner serves as a source of finance, and the sharecroppers are the source of labour.

The basic model was developed to reflect the prevailing production system with all crops other than the target ones represented. Different scenarios were developed in order to examine possible production options that exist in the area and to examine the effects of alternative resource levels and policy options which are likely to affect adoption of target crops. These scenarios reflect alternative scheme sizes, higher crop prices and production relations.

[1]One feddan = 0.42 hectare

The data and information on production aspects of the small pump schemes were obtained via a field survey conducted in the study area in season 1998/99. The collected data covered crop mix, management practices, production cost, crop prices and production constraints. Data on different technology levels and related yields were obtained from NVRP on-farm research data.

RESULTS AND DISCUSSION

The basic model scenario

The results of the free cropping scenario, with respect to cropping activities, were dominated by potatoes, onion, fenugreek and coriander. This reflects the high returns associated with the production of these non target crops. However, this option does not reflect the existing situation in the area. These crops are usually grown on limited areas because of the need for diversification and aversion of natural and market related risks. The data obtained from the field survey provided information on the maximum areas usually allocated to these crops, and these limits were used in the model as constraints. Accordingly, areas of the non target crops were restricted to 4 feddans, 2.5 feddans, 2 feddans and 2 feddans for onion, potatoes, coriander and fenugreek, respectively.

Table 1 shows the model results with respect to the crop mix (technology use) and resource use. With a 15-feddan scheme area, the crop mix was dominated by high technology faba bean. It was grown on 4.5 feddans. Lentil and wheat were not chosen at any level of technology. Other crops were as restricted.

Increasing the scheme area to 20 feddans, the same crop mix was adopted but medium technology level of faba bean was used instead of the high technology level. With respect to faba bean technology, this scenario reflects the current situation where irrigation water represents the major constraint. The shift to medium technology faba bean justifies farmers' behaviour. The reason was that marginal returns (termed as shadow price in the Table) for land were higher than those for water. It was, therefore, more rewarding to allocate more area to medium technology than to use

higher technology levels in smaller area, a situation actually prevailing in the study area. This outcome has inspired breeders to breed for varieties that would perform better under water stress (less irrigation).

Table 1. Optimum crop organization with two scheme sizes

Item	15-feddan scheme		20-feddan scheme	
a. Net returns (SDD)	578511		739972	
b. Resource use	Level	Shadow price	Level	Shadow price
Land (feddan)	15	141240	17.75	-
Number of irrigations	147	-	150	18323
Labour (mandays)	416	2000	416	2000
c. Crop mix (feddan)				
Faba bean-medium	-		7.25	
Faba bean-high	4.5		-	
Onion	4.0		4.0	
Potato	2.5		2.5	
Coriander	2.0		2.0	
Fenugreek	2.0		2.0	

SDD is Sudanese dinnar – US$ 1 = SDD 252 (1999 rate);
1 feddan = 0.42 ha

The price support scenario

Another version of the previous scenario was developed by increasing wheat price by 10%. The increase in price was not very big, and the new price still falls within the range of prices in the area. The results of this run are shown in Table 2.

Under a 15-feddan scheme area, the model predicted a major change with respect to the crop mix. Wheat at high technology levels was introduced in 1.21 feddans. Faba bean was grown at high technology. Lentil was not competitive at all technology levels. It is evident that wheat production

was encouraged by the price increase which resulted in a change in the crop mix. This outcome reflects high competitiveness of the crops in the area, and farmers' responsiveness to market forces and policy changes. This situation has been observed few years ago in response to government policies of lentil and wheat promotion. Field observation indicated that wheat had been expanded at the expense of other crops. The point to be emphasized is that input subsidies and price support are important policy options to manipulate production decisions and technology use as predicted by the model.

Again, farmers' traditional practices (low technology levels) were not competitive for all target crops (Table 2), when the scheme size was increased to 20 feddans and other restrictions were as before. High technology wheat was substantially increased, while high technology faba bean was not chosen. Increasing the scheme size to 20 feddans increased the land-water ratio, and in view of the fact that marginal returns to land were greater than those of water, there were no chance for high technology (high number of irrigations) faba bean, hence medium technology rather than high technology faba been was adopted. On the other hand, the 10% higher wheat price increased returns to wheat production and attracted adoption of more high technology wheat. This indicates that price policy would be an effective tool in production decisions.
Another version of this scenario was developed in which lentil price, rather than wheat price, was increased by 25% (Table 3). A similar result to that of the previous scenario was obtained, and high technology lentil was introduced.

The production relations' scenario
Another scenario was developed to simulate the production relations, which are based on resource participation. In such relation, the pump owner is responsible for provision of water, and bears all its cost, while the farmer or share-cropper provides his family labour. Costs of purchased inputs, other than water, are shared. The results revealed a conflicting perception towards technology use. The model was modified to reflect each party's situation. It predicted that while the pump owner would adopt

the medium technology faba bean, the share-cropper would have liked to adopt the high technology with higher levels of irrigation (Table 4). However, the share-cropper has no control over water pumping and should follow the watering schedule dictated by the ump owner. The conflicting perception is a result of the traditional production relation, which needs to be amended so that equitable returns to resource owners are guaranteed.

Table 2. Optimum crop organization with two scheme sizes and 10% wheat price increase

Item	15-feddan scheme		20-feddan scheme	
a. Net returns (SDD)	594393		817479	
b. Resource use	Level	Shadow price	Level	Shadow price
Land (feddan)	15	170810	16.6	-
Number of irrigations	145	-	150	22672
Labour (mandays)	416	905	416	956
c. Crop mix (feddan)				
Faba bean-medium	-		1.5	
Faba bean-high	3.29		-	
Onion	4.0		4.0	
Potato	2.5		2.5	
Coriander	2.0		2.0	
Fenugreek	2.0		2.0	
Wheat-High	1.21		4.6	

SDD is Sudanese dinnar: US$ 1 = SDD 252 (1999 rate);
1 feddan = 0.42 ha

Table 3. Optimum crop organization with two scheme sizes and 25% lentil price increase

Item	15-feddans scheme		20-feddans scheme	
a. Net returns (SDD)	594864		766955	
b. Resource use	Level	Shadow price	Level	Shadow price
Land (feddan)	15	171690	16.24	-
Number of irrigations	145	-	150	19837
Labor (Man days)	416	872	416	1637
c. Crop mix (feddan)				
Faba bean-medium	-		1.19	
Faba bean-high	3.05		-	
Onion	4.0		4.0	
Potato	2.5		2.5	
Coriander	2.0		2.0	
Fenugreek	2.0		2.0	
Lentil-High	1.45		4.55	

SDD is Sudanese dinnar – US$ 1 = SDD 252 (1999 rate);
1 feddan = 0.42 ha

Table 4. Optimum crop organization[1] for pump owners or tenant farmers, 20 feddans scheme size

Crop mix	Land allocation (feddan)	
	Pump owner	Farmer
Faba bean – high	0.00	2.20
Faba bean - medium	7.25	0.00
Wheat - high	0.00	3.13
Wheat – low	0.00	0.00

'Other crops were restricted as before and are not reported in the table.
1 feddan = 0.42 ha

CONCLUSIONS

The results of the study predicted by the LP model provided good reflection of the level of technology use by farmers of the small pump schemes in the study area. On the other hand, the results indicated that the adoption behaviour is influenced by the resource-based institutional setup of the small pump schemes. The main conclusions of the study are as follows:

(i) Farmers' traditional practices (low technology levels) are not feasible production options in all target crops. Their levels of yield and rates of returns are relatively low to compete with the recommended improved technology. This is a clear indication that research efforts are successful in development of improved technology for production of important crops in the farming systems of the small pump schemes in the study area.

(ii) High technology faba bean production (specifically high level of irrigation) is not feasible under the observed land-water ratios. Its production was confined to medium technology levels and was explained by the fact that marginal returns to land were greater than those to water. The on-going efforts to expand crop production in the River Nile State would, therefore, require serious consideration of the water supply issue.

(iii) Price support and input subsidies are effective policy tools to affect production decisions. With the adoption of privatization and free market policies, their use would seem remote. They could still be limited and targeted to meet national as well as farmers' objectives.

(iv) Production relations between resource owners (scheme/pump owners and sharecroppers or tenants) regulate access to resource inputs; therefore, they influence technology use. However, they result in a conflicting perception by resource owners towards technology use as revealed by the results. These traditional production relations were historically based on the primary resources, land, labour and irrigation water, and they need to be amended to respond to the new development in the production process so that equitable returns to alternative resources are guaranteed.

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احتمالات تبني تقانات الأنتاج في مشاريع الطلمبات الصغيرة بولاية نهر النيل، السودان

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المستخلص: هدفت هذه الدراسة لمعرفة مدي تبنى المزارعين لتقانات انتاج محاصيل البقوليات الشتوية والقمح بمشاريع الطلمبات الصغيرة بمنطقة شندي، ولاية نهر النيل، السودان. أستخدمت البرمجة الخطية لبناء أنموذج لتمثيل النظام الزراعي بمنطقة الدراسة والتي تعد من المناطق الرئيسية لمشاريع الطلمبات الصغيرة. تم تحديد خيارات أنشطة أنتاج المحاصيل المستهدفة بما يعكس مستويات تقانات الأنتاج المختلفة، تقليدية كانت أم محسنة. صمم الأنموذج لأخذ في الأعتبار محددات الإنتاج الرئيسية المتمثلة في حجم طلمبة المياه، ومساحة المشروع، والعمالة الأسرية. كما أعدت مشاهد معدلة (سيناريوهات) من الأنموذج لعكس خيارات ألإنتاج السائدة ولاستقصاء دور كل من الموارد والسياسات في تبني المنتجين لتقانات الأنتاج. أظهرت النتائج أن تقانات الأنتاج التقليدية تبدو ضعيفة الجدوي وأن خيارات تبنى المزارعين يغلب عليها استخدام مستوى وسطا بين الخيار التقليدي والخيار الموصى به من هيئة البجوث الزراعية. ويعكس هذا الخيار الواقع السائد خاصة بالنسبة لعدد الريات جيث يوضح أن مياه الري هي أهم محددات الإنتاج. كما أظهرت النتائج أن نظم الشراكة وعلاقات الإنتاج التقليدية، المؤسسة على الموارد الأساسية – الماء والأرض والعمالة – غير مشجعة لتبنى التقانات المحسنة والجديدة الموصى بها.