OPTIMUM WINTER CROPPING PATTERN IN THE NORTHERN STATE, SUDAN

By

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ABSTRACT

This research was conducted in the four localities of the Northern State, i.e., Halfa, Dongola, Al-Debba and Merawe. They differ in resource endowments and resource use. The main objective of the study was to determine the optimum cropping pattern and resource allocation for farms by using linear programming (LP) technique. The study depended mainly on primary data for 2003/2004 cropping season. The results of LP models revealed that the net farm incomes in the optimal models were more than the current situation by 77.30%, 73%, 49.40% and 121%, in the four localities, respectively. Many scenarios were tried to reflect a range of production options. According to the results of these scenarios, net farm income could greatly be improved with adoption of improved technology, efficient use of resources and application of the right market policy. The study conclude that, wheat could be produced on commercial scale in Dongola locality where its productivity could increase to 1.70 tons / feddan (1 feddan=0.42 hectare.).

KEYWORDS: Resource endowments; Linear programming; Optimal solution; Scenarios.

الملخص:

أجريت هذه الدراسة في محليات الولاية الشمالية (دنقلا والدبة وحلفا ومروى). تختلف هذه المحليات في الموارد المتاحة والموارد المستخدمة. الهدف الأساسي لهذه الدراسة هو تحديد التركيبة المحصولية المثلى والتوزيع الأمثل للموارد للمزارع في المحليات الأربعة باستخدام أسلوب البرمجة الخطية. اعتمدت الدراسة بصورة أساسية على المعلومات الأولية للموسم الزراعي 2004/2003 , ودلت النتائج

على أن صافى دخل المزرعة في النماذج المثلى أعلى من الوضع الحالي بحوالي 77.30% و 73% و49.40% و121% في المحليات الأربعة على التوالي. أجريت عدد من السيناريوهات, وبناءا على نتائج السيناريوهات يمكن تحسين صافي دخل المزرعة بدرجة كبيرة إذا تم تبني الحزم التقنية الموصى بها من البحوث الزراعية واستعملت الموارد بكفاءة مع تطبيق سياسة تسويقية صحيحة. كما يمكن أن ينتج القمح تجاريا في محلية دنقلا إذا زادت إنتاجيته إلى 1.70طن/فدان(1فدان=0.42 هكتار).

INTRODUCTION

The Northern State with an area of 83.20 million feddans is administratively divided into four localities; Halfa, Dongola, Al-Debba and Merawe, each with a number of administrative units. According 1993 census, the population of the State was 510 568 people.

The Northern State lies in the arid and semi-arid zone and is characterized by two distinct seasons; namely, summer and winter. Irrigated agriculture from the River Nile and/or underground water is the main economic activity. Irrigation is the most important constraint to agricultural production in northern Sudan [(1)]. The total currently cultivated area in the State is estimated at 476 091 feddans, 75% of which is cultivated in winter. wheat cultivated area is about 37% on the average of the total winter cultivated land in the Northern State, distributed as 59.80%, 20% 12.40% and 7.50% in Dongola, Halfa, Merawe and Al-Debba, respectively. Faba beans occupies around 25% of the total winter cultivated area on the average in the State distributed as 71.80%, 9.50%, 8% and 10.60% in the same respective localities. About 18 249 (88% of total) feddans in Dongola locality are grown by different types of spices (fennel, garlic and fenugreek). Vegetables area in the State on average is estimated at 19 508 feddans, 61.4% of which is cultivated in Dongola locality. Fodder crops in the State onaverage is estimated at 12277 feddans distributed as 51.2% 26.3% 10.3%, and 12.2% in Dongola, Halfa, Al-Debba and Merawe respectively (Northern State Ministry of Agriculture, Animal Wealth and Irrigation [(2).]

Agricultural production in the State is believed to be constrained by many factors; mainly high inputs cost especially fuel for irrigation water, unavailability of inputs at the right time, and land fragmentation. These constraints resulted in low yields, inefficient allocation of resources and low farmer's income ((3) and (4)).

The main objective of this study was to evaluate the performance of the existing farming system in the Northern State. Specifically, the study aimed at

i. identify the constraints facing agricultural production in the State.
ii. determine the optimum cropping pattern that enhances the efficiency of resource allocation and maximizes farmers' incomes.

METHODOLOGY

Data collection: Two hundred farmers were interviewed, 80 in Dongola and fourty in each of the other three localities. Data on yields, costs of production, prices etc… were collected at the end of the 2003/2004 winter season, using a multi-stage stratified random sampling technique, which is characterized by time and cost saving. In addition, secondary data pertinent to the problem investigated were secured from relevant sources and resource persons.

Methods of analysis: Linear programming (LP) technique with the general maximization function ((5) and (6)) was applied to the data of the private schemes since they were represented by the majority of sampled farmers. The mathematical form of the model used to satisfy the objectives of this study was as follows:

Max $Z = \sum_{i=1} Cj\ Xj$ subject to

$\sum_{i=1}^{n} aij\ xj <= bi$ and $xj >= 0$,

all j = 1 to n

Where,

Z = objective function value (SDG)

Cj = gross margin per feddan of the jth farm activity, i.e., input-output coefficients (SDG)

Xj = the level of the jth farm activity including major winter crops which are wheat, faba bean, onion, tomatoes, potatoes, garlic, fennel and watermelon

n = no. of activities in the model (6)

aij = the quantity of ith resource required to produce one unit of the jth activity, i.e.,

input-output coefficients

bi = vector of resource availability (land, labour, capital and irrigation water)

The above structure was then formulated into a matrix that gave the model's technical input-output coefficients and resource endowments, where,

Land: The amount of the available area per farm in feddans.

Labour: Total mandays provided by family in each month plus possible hired and *Nafir* mandays in the respective month.

Irrigation: Number of waterings per month.).

Operating capital and credit constraint: The average amount of cash available at the beginning of the season plus credit provided by the Agricultural Bank of Sudan (ABS) to each farmer per year in Sudanese Dinar (SD).

The agricultural production resource constraints are summarized in Table 1

Table 1. Agricultural production resources Constraints in the four localities of the Northern State

Resource	Dongola	Al- Debba	Halfa	Merawe
Land (feddan*)	12	9.67	10.40	11.30
Labour (manday) (monthly average)	55	52	45.8	59.6
Capital Farmer (SDG**) Credit (SDG)	 1292.83 285.21	 1197.36 271.15	 1900.00 221.18	 2357.14 569.40
Irrigation water (av. no. of watering/month)	23.40	26.70	28.50	28. 50

*1 feddan=0.42 hectare

**SDG=Sudanese Ginieh (pound) = 0.5 US$

RESULTS AND DISCUSSION

The basic solution

Cropping pattern and resource use: Table 2 shows that in Dongola locality, fennel crop came first in area allocated (6.10 feddans); followed by garlic (3.40 feddans), onion (2.10 feddan), and faba bean (0.40 feddan). In the observed situation faba bean occupied the largest area (2.67 feddans) followed by wheat (2.16 feddans), fennel (1.92 feddans), garlic (0.90 feddan), and onion (0.52 feddan). Labour was the limiting constraint during January and April, while water totally consumed during January and March.

In AI- Debba locality, the basic solution shows the area under onion, faba bean and wheat was 7.70, 1.70 and 0.61 feddans respectively. Wheat productivity was relatively high in this locality. Potato entered the plan by 0.40 feddan. Because of the low yield of tomato, did not enter the plan. In the observed situation, wheat and faba bean occupied equal areas of 2.70 feddans. Tomato occupied 1.35 feddans, while onion and potato occupied only 0.80 feddan . The limiting constraints in the LP model solution were labour in May and irrigation water in February and March.

The basic solution shows that most of the land in Halfa locality was allocated to onion (6.40 feddans), followed by faba bean (2.00 feddans) and wheat (0.80 feddan), while watermelon did not enter the plan. In the observed situation faba bean occupied the largest area (3.50 feddans) followed by wheat (3.37 feddans), water melon (0.76 feddan) and onion (0.15 feddan). The limiting constraints were labour in May and irrigation water in January and February.

The largest area in Merawe model farm was occupied by faba bean (5.29 feddans) followed by tomato (3.87 feddans) and wheat (0.51 feddan). Onion was not included in the solution in spite of its high productivity due to its high cost of production and low crop price. In the observed situation wheat occupied 2.80 feddans, followed by faba bean (2.24 feddans), tomato (0.85 feddan) and onion (0.73 feddan). The limiting constraints were labour in March, available water consumed in December**,** accompanied by a problem of cash from October to February in all localities.

Table 2. Optimum solutions of the basic models of Dongola, Al-Debba, Halfa and Merawe in comparison with the observed situations

	Dongola	Al-Debba	Halfa	Merawe

Area (Feddan)	Observed	Optimum	Observed	Optimum	Observed	Optimum	Observed	Optimum
Total	8.17	12.00	8.22	10.40	7.81	9.30	6.35	9.67
Wheat	2.16	0.00	2.70	0.61	3.50	0.82	2.80	0.51
Faba bean	2.67	0.42	2.70	1.67	3.37	2.05	2.24	5.29
Onion	0.52	2.10	0.70	7.72	0.15	6.43	0.73	0.00
Fennel	1.92	6.10						
Garlic	0.90	3.38						
Potato			0.77	0.40				
Water melon					0.76	0.00		
Tomato			1.35	0.00			0.85	3.87
Labor use (% of available)	93.60	100.00	87.20	74.70	89.50	90.60	84.00	87.50
Water use (% of available)	39.36	73.80	29.53	47.94	25.26	35.57	30.97	58.10

Net farm income The LP basic solution showed that, the net farm income obtained from the observed situation can be improved by 77.30%, 72.90%, 49.40% and 121% in Dongola, Al-Debba, Halfa and Merawe localities respectively (Table 3).

Table 3. Net farm incomes of the basic LP models of Dongola, Al-Debba, Halfa and Merawe in comparison with the observed situation.

(a) Locality	(b) Observed income (SDG)	(c) Optimum solution income (SDG)	(d) =(c)-(b) Increases of optimum over observed (SDG)	(e) =(d)/(b)*100% % increases of optimum over observed
Dongola	4679.93	8293.93	3615.99	77.30
Al-Debba	2555.47	4418.17	1862.70	72.90
Halfa	3129.67	4676.32	1546.64	49.40
Merawe	1752.55	3878.48	2125.92	121.30

Sensitivity analysis

Agricultural production in the Northern State is characterized by deep changes in crops and inputs prices which in some seasons exceeded 25% [(2).] The stability of the optimum solution was subjected to different tests in order to see the extent to which the parameters arrived at would change if the basic crop production data, namely area, productivity level, output prices, costs of production and technology were changed.

The impact of improved crop productivities

Increase of wheat productivity by 25% in Dongola model did not change the basic solution. In the model of Merawe, the crop mix was approximately the

same as the basic solution, but the net farm income increased by 3.80%. In Halfa model, wheat area increased from 0.82 to 1.20 feddans, and the net farm income increased by 4.30%. In Al-Debba model, the net farm income increased by 4.10% and wheat occupied the largest area (5.90 feddans) (Table4)

Table 4. Changes in net farm income (in SD) and crop mix (in feddan) when wheat productivity is increased by 25% in the four localities

	Dongola	Al-Debba	Halfa	Merawe
Total area	12.00	10.40	9.30	9.67
Wheat area	0.00	5.90	1.20	0.50
Faba bean area	0.40	1.40	1.60	1.40
Onion area	2.10	3.00	6.50	3.00
Fennel area	6.10			
Garlic area	3.40			
Potato area				
Tomato area		0.00		3.90
Water melon area			0.00	
Net farm income	829593.80	460151.00	487831.20	402645.50

Increase of tomato productivity in Al-Debba model by 50%, tomato entered the plan by 3.10 feddan. Potato disappeared from the plan, wheat, faba bean and onion occupied 0.61, 2.90 and 3.80 feddans, respectively. The net farm income increased by 8.60%.

In Halfa model, increase of water melon productivity by 50%, lead to increase the net farm income by 4.90%. Water melon occupied the largest area with 5.50 feddan, followed by faba bean (3.30 feddan) and onion (0.51 feddan). Wheat did not enter the plan.

When faba bean productivity was increased by 25%in Dongola model**,** faba bean occupied the largest area (9.70 feddan) while garlic and fennel occupied equal areas of approximately 1.00 feddan. Wheat and onion did not enter the plan and the net farm income increased by 9.40%.

Restricting wheat area

Another scenario was to restrict wheat area to meet the estimated consumption requirements of the farmer's household in each locality, the net farm income

decreased by 3.10% and 1.00% in Dongola and Al-Debba respectively. Inr Halfa or Merawe localities there was no change in the net farm income from the basic solution.

The impact of changes in crop prices

In Dongola and Merawe models, increasing wheat price by 25% did not change the basic solution. In Al-Debba locality by 25% increase in wheat price, all the land was distributed between wheat (5.60 feddans) and onion (4.80 feddans) and the net farm income increased by 4.70%. In Halfa locality with 25% increase in wheat price, the net farm income increased by 21.20%, and onion occupied the largest area (6.50 feddans).

Increasing the price of potato by 20% increased the net farm income by 35.50% in Al-Debba as well as the potato area (8.84 feddans), wheat area was 0.61 feddan and faba bean area was 0.19 feddan. Onion and tomato did not enter the plan.

Onion did not enter the plan with 25% increase in its price in Merawe model, while with 50% increase; it occupied the largest area of 9.40 feddans, and the net farm income increased by 28.80%.

Changing the costs of production and increasing water supply

Lowering the production cost by 25% raised the net farm income by 17.10% 77.10%, 49.20% and 71.80% in Dongola, Al-Debba, Halfa and Merawe respectively. The crop mix did not change. On the other hand, water seems to be a more serious constraint in Dongola locality. In Dongola, with 25% increase in water supply, the net farm income increased by 14.50%. The area of garlic, fennel and onion increased to about 3.20, 3.10 and 3.10 feddans respectively**.**

The impact of improved technology of faba bean and wheat production

The parameters of faba bean and wheat activities were changed according to the agricultural production technical packages recommended by the Agricultural Research Station in Dongola and an LP model run was conducted under the prevailing farmers' conditions (Table 5).

In Dongola locality, with the improved technological package the net farm income increased by 74.50%, faba bean occupied the largest area of 11.00 fed.

and wheat occupied 0.44 fed. compared to 0.00 fed. and 0.42 fed. in the basic solution for the two crops respectively.

The effect of improved technologies increased the net farm income by 127.77% in Al-Debba locality. The areas of faba bean and wheat were 6.30 fed. and 0.40 fed., compared to1.67 fed. and 0.60 fed. in the basic solution for the two crops respectively.

In Halfa model, the effect of improved technology increased the net farm income by 80.40%. Faba bean occupied the largest area of 8.12 fed., compared to 2.00 fed. in the basic solution. While wheat area decreased from 0.82 fed. to 0.50 fed. with improved technology.

With improved technology, the net farm income increased by 12.65% in Merawe locality. Wheat occupied the largest area with 4.40 fed. and faba bean occupied 1.80 fed.

With improved technology land, labour, and capital were the constraining factors in Al-Debba, Merawe and Halfa, while the constraining factors in Dongola were land, labour, and water availability.

CONCLUSION

Increase of crop prices especially, the minor crops like spices, potato and onion, have a positive impact on farmer's income, therefore an appropriate marketing policy is essential to absorb the increased production of such crops domestically and abroad. Lowering the cost of production can be achieved by efficient use of resources, increases of crop productivity and adoption of improved technologies. To produce wheat commercially in Dongola locality, the yield needs to be raised to not less than 1.70 tons per feddan. Thus policies aiming at expanding wheat production in the State (National programme to produce wheat) need to consider the achievement of high productivity especially in Dongola locality.

Table 5. Changes in net farm income (in SDG) and crop mix (in feddans) due to improved technology in four localities

	Dongola	Al-Debba	Halfa	Merawe
Wheat				
Low technology	0.00	0.60	0.80	0.50

Improved technology	0.40	0.40	0.50	4.40
Faba bean				
Low technology	0.40	1.70	2.00	5.30
Improved technology	11.00	6.30	8.10	1.80
Onion	0.00	3.70	0.70	0.00
Fennel	0.40			
Garlic	0.00			
Potato		0.00		
Tomato		0.00		3.40
Water melon			0.00	
Net farm income	14474.61	10063.25	8437.71	4369.22

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