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Economic Aspects and Agricultural Resources Use in Perennial Food Crops in Northern Sudan

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Authors' contributions

This work was carried out in collaboration between both authors. Author EAA designed the study, wrote the protocol. Author HHMF managed the final formatting of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Northern Sudan is considered as one of the main suppliers of perennials in the country. The production of perennial crops in the region faces numerous shortcomings regarding crop productivity, high cost of agricultural inputs and inefficiency in agricultural resource use. This paper illustrates the economics and potent for investing in perennial food crops in the region. Beside secondary data, primary data were collected using structured questionnaires for fifty randomly selected respondents' tenants. Partial budgets were constructed for perennial food crops. Linear Programming was used to model the optimal use of agricultural resources in perennial crops. The results showed that tenants would benefit and gain more profits from growing perennial crops among the predominant crop combination in the region. Therefore, they should be encouraged to invest in perennial food crops and to be guided on how to adopt the suitable crop combination that give more advantages, better returns and contribute significantly to farm sustainability in the region.

Keywords: Resources use; perennial food crops.

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1. INTRODUCTION

Sudan has a great opportunity to take the lead in the production of perennial food crops. Unfortunately, the country is still lagging behind even in comparison with the African countries. The country possesses tremendous resources to produce different types of fruit trees some of them are ancient in the country while others were introduced not long ago. The most well-known fruit trees in Sudan include palm, banana, guava, citrus fruits and mangoes. By nature, perennials aren't as inflicting erosion- a growing problem in the country – as seasonal crops. Moreover, perennials simply grow by themselves after harvest, thus avoiding the relatively expensive sowing operation. They are grown in different regions of the Sudan and the River Nile State of Northern Sudan is considered as one of main grower of perennial crops. In River Nile State of Northern Sudan perennial crops are regarded as essential food and cash crops within the prevailing cropping systems. They also play an important role in the sustainability of the farming systems through natural resources conservation and its good returns to investment with expanded cultivable area. In Northern Sudan public pump irrigated schemes are the important ones for perennial crops production due to their high acreage share and high number of tenants. The delivery of the irrigation water for the scheme depends on pump irrigation system from the River Nile (RN), and the effectiveness of irrigation is determined by the availability and supply of fuel for water pumping and the degree of siltation in canals in public schemes. Elketiab public irrigated scheme of the region, taken here as a case study, was established in 1917. The farming system of the RNS is characterized mainly as not full-mechanized system; the perennial crops are considered the main cash crops in the tenancies system beside cereal and legume crops, recently, the State enlarged animal production activities and oil crops. The last three decades witnessed critical problems regarding the production of perennial crops. Constraints contributing to the low level and instability of perennial crop yields include poor application of technical packages, stress inflicted by the changing environmental conditions, especially temperature, beside widespread of different diseases, insects, pests, weeds and inadequate irrigation water. Finally, this study looks into options to increase the productivity of perennial crops through increasing the efficiency of resources-use intensity in Northern Sudan public irrigated schemes. More specifically, the research addresses the issue of perennial farms to enhance more incomes attainable by producers and to improve the agricultural environment. Success will depend on designing and establishing farmer-friendly environmental system of management that utilizes the limited resources appropriately in the public schemes in the region. Investment in perennials farms of the State, at least in its public irrigated schemes, might be instrumental in saving the environment and improving household standard of living.

1.2 Objectives

This paper looks to the later options, specifically to promote investment in perennials production considering optimization of the available agricultural resources in Northern Sudan. Moreover, the research therefore seeks to address the issue of resources use efficiency to enhance more incomes that are reliable for producers hence to alleviate poverty Success will depend on designing and establishing farmer-friendly systems of management that utilize the limited resources appropriately to stretch perennial crops area. The study more specifically pursues to raise a more efficient use of expensive resources, through improvement of existing system in the region which might be able to save much the available resources.

1.2 Research Methods

The study was carried out in season 2005/2006 at River Nile State of Northern Sudan where perennial crops are commonly produced under pump irrigation mainly from the River Nile as well as by extracting underground water. The sample size was 50 tenants, selected randomly, forming about 3% of the total tenants in the scheme. The sample size was determined according to the desired level of precision and availability of resources in terms of cost, time and other relevant facilities, more over stratified random sampling proportional to size was used [1]. Numerous analytical techniques comprising descriptive statistics, partial budgeting and linear programming (LP) are used to illustrate and to assess the prevalent perennial crops combination in area of the study.

Linear programming (LP) through the General Algebraic Modeling System (GAMS) was used to optimize the available agricultural resources and to conduct scenario analysis based on model solution to assess the optimally combining resources in prennial crops in the region through the change in value of the objective function (gross margin) and the allocation of the resources under study over the dominant crop combination this is an awkward sentence [2]. Reported that the model was specified with gross margins maximization as the objective function as:

$$\text{Max } Z = \sum_{j=1} Cj\,Xj \quad \text{..... (1)}$$

$$\textit{Such that: } \sum \alpha ij Xj \le bi, \text{all} = \overset{n}{1} \text{ to } m \quad \text{..... (2)}$$

$$\textit{And: } Xj \ge 0, \text{all } j = 1 \text{ to } n \quad \text{..... (3)}$$

Where:

- Z = Objective function value per year,
- Xj = Level of the jth the farm activity, such as the acreage of citruses grown. Let n denote the number of possible activities; the j=1 to n.
- Cj = Objective value, in this case the forecasted feddan -feddan= 0.42 Hectare-) gross margin of a unit of the jth activity (SDD per feddan,)
- Aij = Quantity of the ith resource available (i.e., days of labour or other required quantities of inputs) required to produce one unit of the jth activity
- m = Denote the number of resources; then i= 1 to m
- bi = Amount of the i^{th} resource available (e.g. cubic meter of water, feddan of land, days of labour or other required quantities of inputs).

The objective is to find the cropping system (defined as a set of activities levels X_j, j= 1 to n) that has the highest possible total gross margin, Z, but doesn't violate any of the fixed resource constraints or involve any negative activity levels.

Equation (1) is the objective function, which maximizes the gross margins from one feddan of prennial crops. Equation (2) shows the limits on the levels of the available resources (i.e., cubic meter of water, feddan of land, days of labour or other required quantities of inputs) that tenant can apply to produce the mentioned crops. Equation (3) which is a non-negativity

condition, states that all resources used in the production process and output must be equal to or greater than zero, meaning that negative use of resources and negative of production is impossible [2]. The coefficients represent the average requirement of the i^{th} activity (enterprise), calculated on per feddan basis. The calculation of the crop water requirements (CWR) of any crop requires estimation of its crop coefficient (Kc). Kc values could be used for estimation of CWR as a product of Kc * ETo in different regions of Sudan. Pen-man equation (1948) for calculating evapotranspiration from free water surfaces was used in the calculation of crop factors (CF) (crop factor by many scientists over the world. They were able to determine the crop factor of most filed and perennial crops in the world. Recently, Food and Agricultural Organization (FAO) Penman-Monteith (PM) method was developed to estimate ETo values from a hypothetical reference crop that were more consistent with the actual CWR and has been recommended by FAO as the standard method for CWR calculation. The reference crop evapotranspiration ETo was calculated from the daily whether data specifically the maximum and minimum temperature, relative humidity, wind speed at 2m height and sunshine duration by using Crop Wat4 windows program according to the recommended Penman- Monteith formula as shown in Equation (4).

$$ETo = C\ (WR_n + (1- W)\ f(u)\ (ea-ed) \quad (4)$$

Where:

C	=	error factor	W	=	weighting factors
R_n	=	net radiation	f(u)	=	function in wind speed
ea	=	saturation pressure	ed	=	perfumed water

The data used to calculate gross returns per feddan are output value (crop prices times' quantity of output, i.e. yield per feddan), while gross margin per feddan is obtained by subtracting the average total variable cost from the total returns. Gross margins reveals how much a firm (farm, company etc.) earns taking into consideration the costs that it incurs for producing its products and/or services and it could be expressed as a percentage. Gross margin is a good indicator of how profitable a firm is at the most fundamental level. Farms with higher gross margins will have more money left over to spend on other activities such as investment, improvement of production and marketing.

Equation (5) is the general mathematical form for the gross margin calculation per crop is as follow:

$$GM = GR – TVC \quad (5)$$

Where:

GM = Crop gross margin per fed in SDD,
GR = Crop gross revenue per fed in SDD and
GM = TVC: Crop total variable costs per fed in SDD.

2. RESULTS AND DISCUSSION

2.1 Production of Perennial Crops in Northern Sudan

In River Nile State of Northern Sudan, the cultivated areas consist of a narrow fringe of land along the Nile covering about 124,000 km^2 (29.5 million feddans) out of which about 3,201,300 fed are suitable for agricultural production. A high population density exists in the settled areas along the River Nile and Atbara River with a total population of about 720,000 forming 90% of the State's population [1]. Thus, most of the agricultural production depends

on irrigation in areas close to the rivers. The climate is extremely dry with very hot temperatures from April to September and relatively cool from October to March. Along with the alluvial fertile soils, the conditions furnish a comparative advantages situation over other parts of the country in producing relatively high-value perennials such as palm dates, citruses, mangoes, guava and alfalfa.

Although the last decade witnessed development of agricultural sector in the region, but it still suffers from some chronic constraints affecting farm productivity and incomes, such as high cost of production, inadequate finance, high marketing margins on agricultural produce and inadequate public investments in infrastructures and other facilities. This has resulted in annual variations in areas of crops production. Perennial crops are considered as strategic crops in the region occupying an estimated total area 120,000 feddan. The region implies numerous types of schemes such as, private, cooperative and public schemes with different production relation systems.

The production of these crops based on official relation between the scheme administration and the tenants and referred a water rate system. In Northern Sudan there are numerous factors qualified the scheme to take comparative advantages in producing perennial crops such as favorable climatic conditions, vast endowments (i.e. fertile land and irrigation water), and well skilled farmers. The option of irrigation is mandatory in the scheme from the River Nile by pumps, as well as ground water for supplementary irrigation.

The result of the study revealed that the perennial crops in the region occupied only about 16% of the total cultivated, while the prevalent perennial crop combination consist citruses, date palms, mangoes, guava and alfalfa (see Fig. 1). The research unveiled that the land devoted to perennial crops in the scheme was up to 53% occupied by citruses, followed by 15% for alfalfa, while date palms and guava were formed 13% and 11%, respectively. The lowest percentage (1%) was formed by mangoes as depicted in Fig. 1.

The paper also analyzed the land allocation at the tenancies level. It reflected that that citruses percentage share was 58% of respondent farmers' tenancies as the highest percentage over the perennial crop combination, while mangoes were formed the lowest one (see Table 1).

Table 1. Distribution of tenants according to area and production of crops

Crop	Area (fed*)	Production (kg)	Crop share of farm area (%)
Dates	1.23	3690	14
Citruses	5.01	17535	58
Mangoes	0.75	1219	8
Guava	1	1050	11
Alfalfa	1.43	8875	15

*Source: Field Survey 2006. *Feddan= 0.42 Hectare*

The perennial crop productivity that achieved by Elketiab surveyed tenants were generally low when compared to the research yields attained by the Agricultural Research Corporation (ARC) of the country that reported by [1], with minimum and maximum yield gap reaching 68% and 26% for mango and alfalfa, respectively, as shown in Fig. 2.

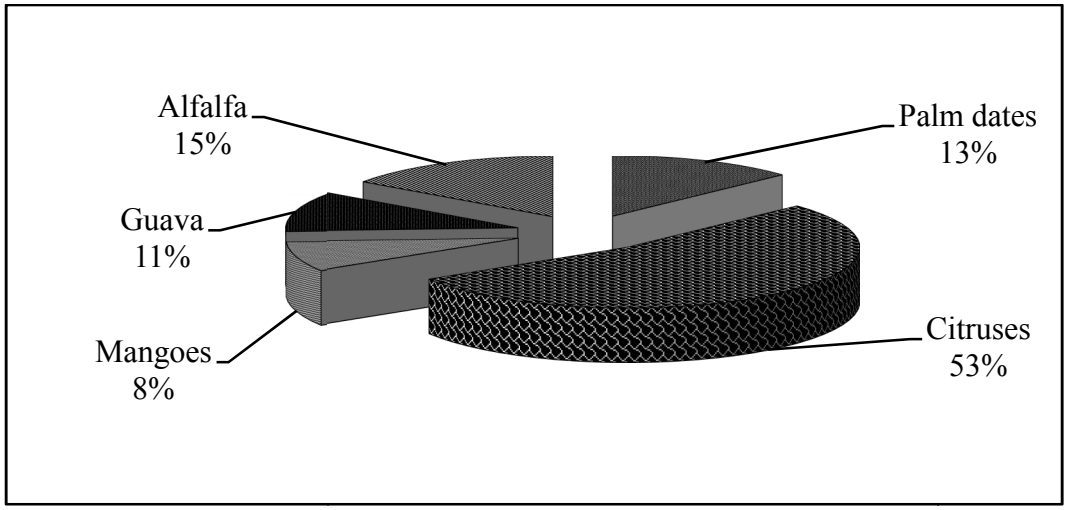

Fig. 1. Prevailing perennial crop combination in area of the study

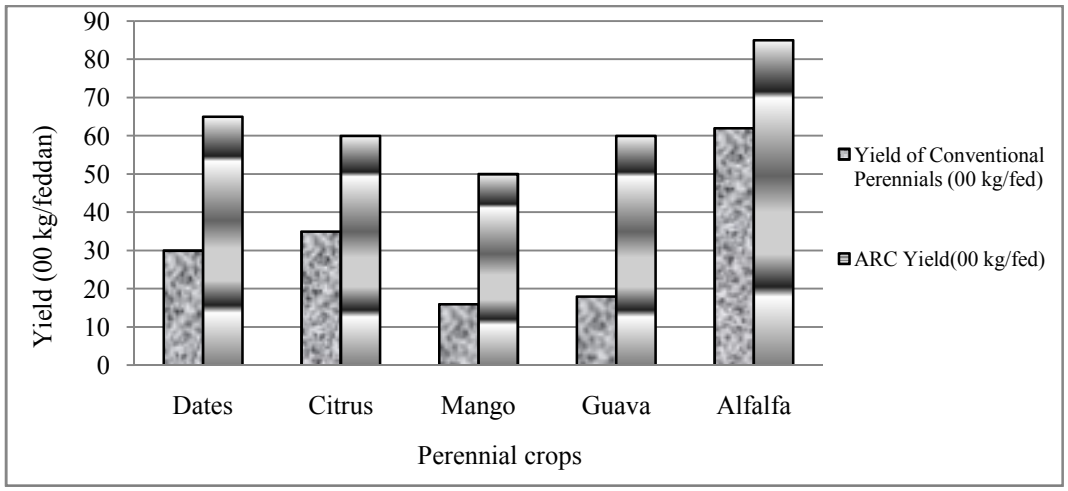

Fig. 2. Yield gaps of perennial crops compared to ARC ones

The results indicate that there is high potential to increase yields of all perennial crops under study. However, the average perennial crop yields are often lower than the average ARC yields. These differences might be due to different in farming practices and new technologies.

2.2 Cost of Production of Perennial Crops

Production economics play a unique role in farm management [3]. The dominant conception of production cost in the area of study is known as the cost of material inputs, labor, services, and the management used in producing a certain goods or/and crops. Generally, the high cost of production overall the region leads to low profit. The high cost of production is attributed to high cost of numerous production inputs. Northern Sudan farmers complain

from high cost of production, in addition they depend on their resources totally for finance their perennial crops by paying about 600 SDG/fed in absence of formal financial system. [4] mentioned that the formal financial system provides only small parts of agricultural credit to be used by farmers. Therefore, most of farmers seek other informal sources of finance to meet their farm expenses. Informal loans extended by friends and relatives, mostly without interest, constitute the non-commercial segment. In the commercial segment a range of people like traders, agricultural and professional money lenders operate. Fig. 3 reveals that about 12 main cost components constitute the cost of production for perennial crops.

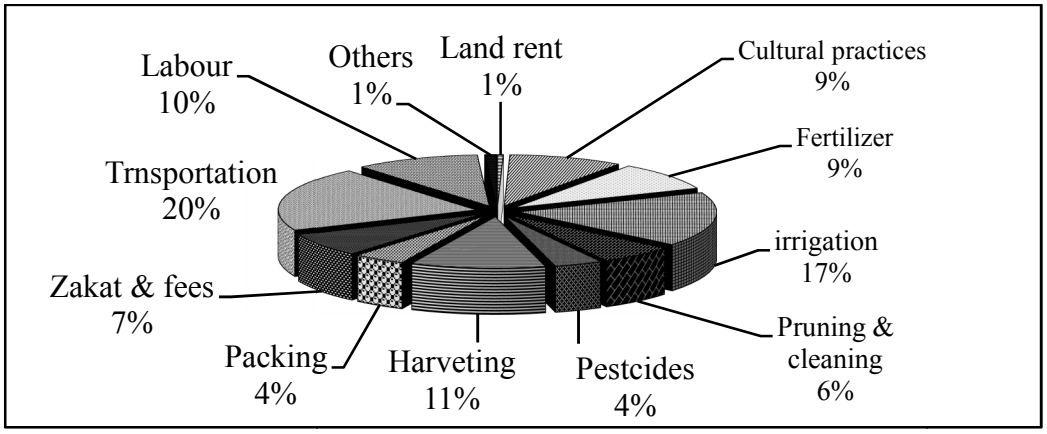

Fig. 3. Percentage share of operation cost components for Elketiab perennials

Fig. 3 shows that transportation cost component is absolutely considered as the most agricultural hindrance facing perennial crops production, having the highest cost item at 20% of total production cost. This might refer to the inadequate investments in infrastructure. This is followed by the irrigation water cost component, which is also considered as one of the most chronic constraints that causes by the high cost of water pumping; and justifies the need for strict allocation among the different crops grown. The perennials growers in Elketiab scheme pay the cost of this item as a fixed rate for the scheme administration at the end of the year.

2.3 Revenue of Perennials and Income Sources of Tenants in the Region

Most of farm studies confirmed that diversifying income sources opportunities might enhance farm sustainability. The most common sources of tenants' income are the sale of produced crops, livestock, and other products raised or bought for resale. Off-farm income is still one of the principal options for Elketiab tenants to meet their farm and household expenditures. The main off-farm sources in the region are mainly remittances, contributions of the family members, formal employment, trade, and other off-farm private activities as portrayed byTable 2.

The results of Table 2 reveal that 68% of Elketiab tenants earned off-farm income beside their farm income, while 32% of the total surveyed tenants relied only on farm returns from their main sources of activities as depicted in Fig. 4.

Table 2. Farm and off-farm income sources of tenants

Source of income	Value	Farm income	Income of total	Tenants
	(SDD*)	(%)	(%)	(%)
Perennial crops returns	1870280	78	-	-
Seasonal crops returns	396533	17	-	-
Livestock returns	107059	05	-	-
Total average of in-farm income	2373872	100	82	32
Total average of off-farm income	522700	-	18	68
Total average income of tenants	2896572	-	100	100

*Source: Field Survey 2006. *SDD = Sudanese Dinar = US$ 0.5*

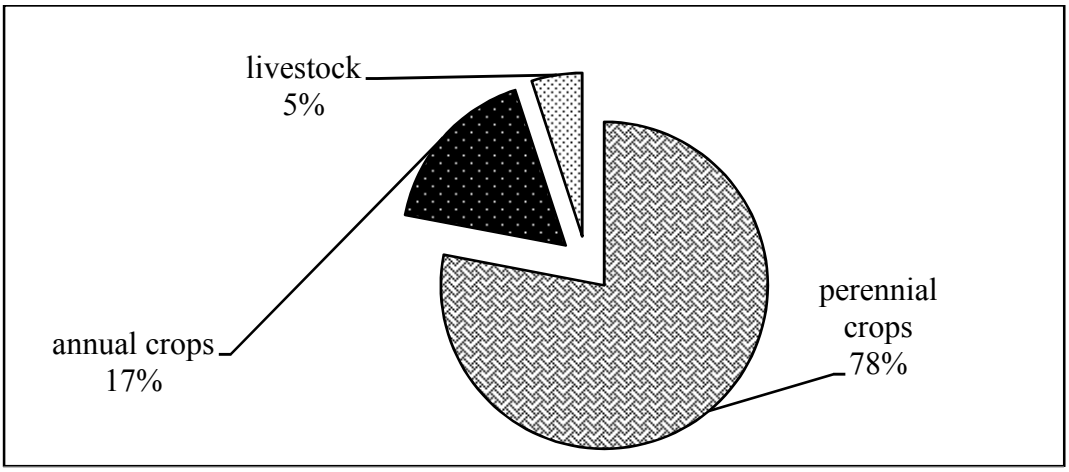

Fig. 4. Sources of farm income for Elketiab surveyed tenants

Fig. 4 also shows that farm income accrues mainly from three sources: perennial crops providing the highest farm returns (78%) followed by annual crops (17%), and 5% from livestock as the lowest one. This confirms the importance of perennials in shaping the tenants' income in area of the study. The farmers in Northern Sudan diversify their businesses by growing several crops at one time, often having both livestock and field crops, and sometimes value-adding enterprises as a dominant technique to manage and reduces economic risks. Moreover, enterprise diversification makes it easier for farms to be more self-sufficient in terms of nutrients, livestock feed, soil organic matter and energy.

2.4 Analysis of Perennials Returns

Perennial crops under study have lower costs of production with much less emphasis on purchased inputs and it is feasible in the agricultural sub-sector, the aim should be its dissemination in the country and maximization of perennials production. Farmers cultivating those food products will also get more income, which will be positively reflected on their standard of living. More national revenue means more money available for solving pertaining problems hindering Rural Development. Marketing such large amounts of perennial foods will make Sudan a prominent figure in the international market of these products. It will also attract global investors to agricultural production of such crops [5]. Partial budgeting methods continue to be the backbone of much of analysis on agricultural policy. In their simplest form,

budgets provide the evidence that policy makers use to make decisions about private profitability and hence the incentives that farmers have to grow particular commodities. The basic data used to calculate gross returns per feddan are output value (crop prices times' quantity of output, i.e. yield per feddan) from which average total variable cost are deducted to get gross margin per feddan.

2.5 Gross Margins

Gross margins reveal how much a firm (farm, company etc.) earns to pay for its fixed costs. Gross margin is a good indicator of how profitable a firm is at the most fundamental level. Farms with higher gross margins will have more money left over to spend on other activities such as investment, improvement of production and marketing (see Equation 5).

The last decade witnessed that the global demand for perennials products is annually increasing due to consumers' awareness of their nutritional value and other benefits. [5] reported that, Sudan exported 20 plant and livestock food products as conventionally cultivated foods valued at US$305.7 millions. The gross margins for perennial crops under study also were assessed individually per feddan and the results were expressed in Sudanese Dinar (SDD) as discerned in Table 3.

Table 3. Gross margin analysis for perennial crops (SDD/fed)

Components \ Crops	Date	Citruses	Mangoes	Guava	Alfalfa
Production cost (SDD/fed)	139224	251704	203120	158506	147549
Average yield (kg/fed)	3000	3500	1625	1800	6206
Average price (SDD/kg)	48	80	150	110	26
Gross returns (SDD/fed)	144000	280000	243750	198000	161356
Gross marginal (SDD/fed)	4776	28296	40630	39494	13807

Source: Field Survey 2006

The Tables illustrate that gross margins of perennial crops were positive. The high returns applicable to perennials by improving their yields and optimizing the available resources, that means still higher gross margins can be obtained. In general, expenses are lower and the income is greater and that might be to their high demand. The prices of perennials vary between crops and over time. Perennials production is changing rapidly, leading to price fluctuation. For example, a high price for one crop in a particular period can lead many tenants to grow that crop, which might increase its supply and hence depress its price. Thus tenants' awareness is needed about marketing issues within the promise offered by perennials farming.

The results also revealed that, the gross margins from mangoes was the highest one, followed by guava, citruses and alfalfa for as important perennials in the region, while the gross margin of date palms was the lowest (see Fig. 5).

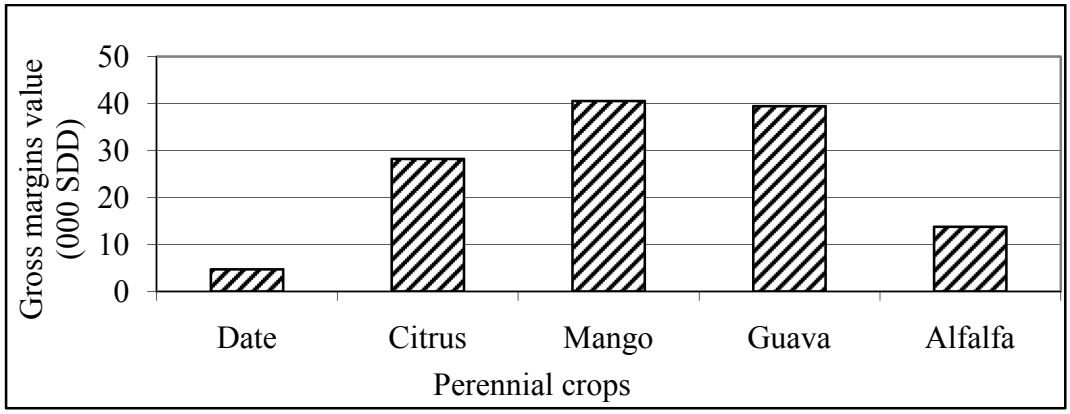

Fig. 5. Gross margins of perennial crops in Northern Sudan

2.6 Optimal Perennials Production Obtained By RNS of Northern Sudan Model

Secured land and water-use rights are more important preconditions for investments in perennials diversification and commercialization than for other forms of agriculture. Perennials background of RNS tenants for growing perennials, field crops and animal breeding offer a promising option for improving the farm system and livelihood of people both in rural and peri-urban areas. The competition for irrigation water and land increases resource management complexity. These inputs constitute the most important factors of agriculture in the River Nile State, due to their scarcity and importance raised from population pressure on land when compared to the rest of the country and from the high cost of irrigation by pumps. They became common problems are aggravated even more by the diminution of the canals capacities and lead to low productivity of crops. [6] summarized that the high cost of production coupled with low productivity and lack of a cheap source of power has made it difficult for farmers to realize the full potential of the State. Further, development is considered serious affected by the limitation of these two basic resources of land and water. This situation led to an important fact that optimizing of the available resources should improve agricultural production, thus, achieve food security, poverty alleviation and improve the livelihood of the farmers of the scheme. Yet, the potential of resources for raising both food production and living standards of the rural poor has since long been recognized. Generally, a third of the current crop production comes from one-sixth of the irrigated arable land. This necessitates improved reliability of crop production under greater intensity of land-use with removal of seasonal water supply constraints. Then the problem is how to balance demand and supply of resources under these conditions. The solution lies in resources use optimization.

The received information from the model run is the objective function value (returns), the optimal crop combination, and utilized resources accompanied by their respective marginal value productivities. The analysis also provided some other relevant results as shown in Table 4. The Table also presents the actual and optimal cultivated area for the different perennial crops and gives also the optimal allocation for the average area. The farmer's trend in RNS towards diverse crop combination is a dominant practice as means of increasing efficiency of resources. This behavior might be acquired by experience to avoid agricultural risks such as pests and unfavorable climatic conditions (i.e. high temperature, low moisture and others). The optimal solution reflects devoting land only for citruses,

mangoes and alfalfa as 4, 2, and 4 fed respectively, while the rest of the crops didn't appear in the optimal plan. The actual returns from crop production are SDD 134998, while the optimal returns are SDD 427050 which is more than the actual returns by 68%.

2.6 Resource Use and Constraints

The last decades witnessed increased interest to grow perennial crops overall the State, and that might be due to the higher prices or the low operation costs of those crops when compared to the annual crops according to their duration on land. Many studies mentioned that the higher prices for perennial crops have enhanced incentives to grow them. Moreover, growing of perennial crops allows intercropping with some crops, particularly alfalfa. According to the mentioned characteristics of the perennial crops, resources use and availability might be under competition. [7] stated that perennial plants are highly efficient and responsive micromanagers of soil, nutrients, and water. Annual crops are not; they require churning of the soil, precisely timed inputs and management, and favorable weather at just the right time. With shorter growing seasons and ephemeral, often small root systems, annual crops provide less protection against soil erosion, wasting water and nutrients, storing less carbon below ground, and are less tolerant to pests than are perennial plant communities (Table 4).

Table 4. Proposed scenario of cropping pattern plan perennial crops in RNS

Item	Actual	Optimal	Units
Resources use:			
Total land	10	5	Fed
Total irrigation water	65613.75	45120	Cubic meter (m^3)
Total labour	101	60	Man-day
Total capital	960108	737760	SD
Returns: objfn value (Z)	134998	255215	SD
Cropping pattern:			
Date	1.23	-	Fed
Citrus	5.01	-	Fed
Mango	0.75	-	Fed
Guava	1.29	-	Fed
Alfalfa	1.72	5	Fed

Source: Field Survey 2006

From Table 4 the optimal and actual water used are 45120 m^3 and 65613.75 m^3 respectively, while the optimal level of hired labours found to be at 60 forming 59.4% of the total available labours used. The optimal and actual quantities of the capital used for the different perennial crops under the study are SD 737760 and SD 960108, respectively. The research presents the monthly distribution of the resources used for Elketiab scheme. The optimal plan investigated that 4893.198 m^3 of the total water would be used, which is 89.47% of total available water, while the monthly distribution of labour in the optimal plan is that 5 man-day, forming 59.4% of total available labour. The optimal plan also shows the monthly distribution of actual available cash to finance the perennial crops at Elketiab as SD 61480 would be allocated annually over the months, forming to 77% of the total available capital.

3. CONCLUSIONS AND POLICY IMPLICATIONS

Our results show that there are promising opportunities for the production of perennial crops in River Nile State of North Sudan.

However, a major obstacle expanding and realizing the potential of perennial crops is the high cost of establishing new farm plantations and the recurrent cost of financing crops for four to five years before any significant production can be realized. Finance provision for these crops is absent in Northern region of Sudan. The study unveiled the low productivity of all perennials crops where yield gap reaching 68% and 26% for mango and alfalfa, respectively, that form promising strategic crops. The farmers of the region paying about 600 SDG/fed in absence of formal financial system, thus, encouraging policies imply reducing the cost of production or providing incentives to the perennials growers of the region by buying their products at reasonable prices. Diversifying income sources opportunities might enhance farm sustainability. The most common sources of tenants' income are the sale of produced crops, livestock, and other products raised or bought for resale. The study revealed that 68% of Elketiab tenants earned off-farm income beside their farm income. The research suggest that the optimal and actual water used are 45120 m^3 and 65613.75 m^3 respectively, while the optimal level of hired labours found to be at 60 forming 59.4% of the total available labours used. The optimal and actual quantities of the capital used for the different perennial crops under the study are SD 737760 and SD 960108, respectively. Based on these facts and the obtained results, the study concludes that:

- The potential for perennial farms production in the RNS of Northern Sudan is quite promising on account of the huge natural resources and the wide range of biodiversity available with high relative advantages.
- Establishment of organizing and specialized entities and development of national regulation for certified and standardized perennial crops production, handling, processing and marketing can be useful for implementation and sustainability of perennials farms in the region.
- Because basic services and low public investment are regarded as one of the chronic constraints facing agricultural production in area of the study, intervention is needed to establish the needed infrastructures (i.e., roads, stores, processing stations).
- Spreading perennial culture among producers, processors and exporters of the region is important, and here extension will be of fundamental importance to build agro-ecological knowledge. The fact that perennial farms emphasize multi-, rather than mono-cropping is also important in terms of food security, which can be jeopardized when farmers produce a single commodity and have no safety net to fall back on.
- Relevant stakeholders' interventions are needed to transfer improved and update technologies to increase farm productivity; in addition, Northern Sudan tenants also need to be encouraged to produce perennial crops as high value crops when designing crop combination.
- Improving finance institutions will enable the tenants of the region to improve their resources use and significantly increase their perennials farm returns.
- Resources use optimization of perennial crops system and appropriate plan combination of land, water, labour and capital resources for producing perennial crops combined with the other perennial crops in RNS is very important and should be well designed and applied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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