RECONCILING THE TRADE-OFFS BETWEEN DOMESTIC DEMAND ANDEXPORT MARKET: THE CASE OF SUDAN DRY-LAND AGRICULTURE

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ABSTRACT

The primary objective of this research study is an attempt to examine the impact of public agricultural resource allocation policies on the agricultural sector focusing on food security. This focus is central to farmers in the dry-land agriculture. The study critically reviewed and evaluated the evolution of agricultural and other economic policies that have shaped the agricultural sector in Kordofan region, western Sudan. It proceeded to assess the impact of these policies, putting emphasis on public resource allocation, on the production of food and export crops and farm income.

Three reconciliation scenarios between domestic demand (food crops) and export market (cash crops) were investigated using a mathematical programming model for Kordofan agricultural sector, the area of study. These scenarios are the full consumption, the government export support and the mix scenarios.

The findings of this research study call for fair reallocation of public resources, in particular the credit market, favoring the dry land agriculture by the policy makers. In addition, the study also has emphasized more specialization of the agricultural commodity supply based on comparative advantage by the various zones in the dry-land agriculture of the Sudan.

Introduction

Dry-land agriculture, across a vast semi-arid region, is the largest economic sector in Sudan. It represents 85 percent by area of annual cultivation and supports over 70 percent of the population. It also espouses the two largest agricultural markets and contributes significantly to the export crop portfolio netting nearly 60 percent of the country's foreign exchange earnings (Bank of Sudan, 1998), before extraction of Oil.

Surprisingly, contrary to this substantial contribution to the nation's income, the dry-land farming sector, which was once sufficient in food grain, is now dependent on food aid and subsidies in most of its parts, largely from international donors. Sometimes, grain isdirectly imported by the local government and sold at subsidized prices to rural families.

This research intends to help resolve this policy paradox for the government of Sudan, in response to the recurrent gloomy economic scenario, and to initiate some suggested policies and reforms to resuscitate the dry-land agricultural system to its prime position.

Three highly interrelated factors have major influence in shaping the socioeconomic activity of the dry-land agricultural sector in Sudan. These are the recurrent drought, the agricultural policy, and the food grain markets.

Despite the potential of increasing food production, Sudan has been experiencing grain shortages since the early 1980s which have become severe enough to put the country onthe list of food crisis countries (Elamin, 1987). this means that contrary to the Sudan's stated goal of food self sufficiency, and apart from drought, credit and other agricultural and population policies have not been successful in closing the widening food gap. Further, the food-grain markets also have failed to transfer grains between surplus and deficit areas, giving room to the smuggling of grain abroad.

Generally, (Bates, 1982), agricultural policies in Africa are characterized by setting prices in markets in a way that is harmful to the interests of most farmers. Examining the position of cash crops producers for export in Africa, he pointed out that these have pricing policies that frequently reduce the prices they receive to levels well below world market prices.

In Sudan, agriculture is the main occupation, and the traditional dry-land sub-sector is the largest covering about 57 percent of the total cultivated land, an average computed for period 1995 –1999 based on public statistics (Department of Statistics, MOA, 2000). The other two divisions of agriculture in Sudan are the irrigated (9 percent) and the mechanized rain-fed (34 percent) sub-sectors. Like many low-income countries, Sudan is a poorly articulated agrarian economy, characterized by technical dualism. This dualism is depicted by the existence of government supported modern enclaves of irrigated farms and large-scale mechanized dry-land farms within the agriculture industry. This technical dualism, however, is functional in that the traditional sector, the largest non-mechanized dry-land farming, provides the modernized agriculture with labor, the vital factor of production. Traditional small-holder farmers, who have been gradually transformed into agriculture laborers, are paid subsistence wages when working for the modern sector. Accordingly, the encroachment of the large tracts of mechanized farms has the effect of driving the rural peasants to become marginal, maintaining a pool of cheap labor.

The Problem

Western Sudan is a typical dry-land agriculture sector reflecting the consequences of the agricultural policy followed by the government of Sudan for several years back.

The statistics of the sector reveal food deficits that range from 56 percent to 91 percent between 1984 and 1994. Although in 1995 there was a surplus of grain, the estimated food grain deficits in 1996 and 1997 were more than 75 percent and 50 percent of the people's needs, respectively (Elamin, 1998). In the agricultural season 2000/2001, the food gap went out of proportion as it rose to over 80 percent in most Western Sudan states (as estimated by NGOs and announced by regional governments). Besides becoming the recipient of donations of food, the sector also is experiencing a dramatically declining environment and economic condition,causing people to migrate in search for wage employment.

Surprisingly, and contrary to this gloomy situation, the agricultural sector of Western Sudan usually contributes significantly to the export crop portfolio, netting more than one-third of the country's foreign exchange agricultural earnings. Furthermore, it espouses the second largest agricultural market in the Sudan in El-Obeid, the capital city in the western part of the country.

A chronological survey of the farming system and conditions of the region better portrays the vulnerable economic situation of food shortages and declining productivity of all crops in West Sudan. The agricultural policies followed in the dry-land of western Sudan since the mid 1960s favor the expansion of cash crops, in particular the oil seeds which are mainly grown in this part of the country. These policies also favor the large-scale mechanized farms (> 400 ha per unit) in terms of capital allocation, where the large farmers' access to institutional credit is significantly higher than that of the small farmers, even when small farmers are organized in cooperatives or trust groups.

Prior to the mid 1960s, the small-holder dry-land farmers in Western Sudan grew mainly food crops (millet and sorghum) and produced limited amounts of cash crops for the market. Therefore, and in spite of the recurrent droughts, the small-holder farmers were able to secure sufficient food for their families and for the growing urban neighborhoods. This is because during the years of good rainfall the farmer could store part of the ample grain production in order to use during bad years. Consequently, the rural people of this region did not experience food gaps of the present magnitudes up to mid 1970s. That was the case, even though there was a drought year on averageevery three years, when the amount of rainfall dropped below the long term average (Meriod, 1989). Even in the bad rainfall years, the dry-land farmers could still harvest some grain by cultivating larger tracts of land and/or performing risk management practices (e.g. mix and inter-cropping) to hedge against the low rains.

Beginning in the second half of the 1960s a sudden transformation of the production pattern of the dry-land of Western Sudan from subsistence to commercial cropping producing increasing amounts of cash crops. When the small farmers were not obligated to reduce their normal cultivation of food crops, they were encouraged to increase cultivation of cash crops. This government-activated policy was mainly motivated by the high export value of these cash crops. Further, foreign capital was needed to meet the continuously increasing government expenditures; another reason for the increased transformation of traditional agriculture.

The policy favoring cash cropping has been pursued in different forms. One form is exhibited in the loan conditions of the Agricultural Bank of Sudan (ABS), the major agency lending the dry-land agriculture in Sudan. The ABS has conditioned its loans to individual small farmers sothat at least 80 percent of the 21 hectares, maximum permitted area for credit finance, must be grown with cash crops. Millet and/or other food crops could be cultivated on the remainder 20 percent of the financed area. But, given the labor limitations of the household, family labor is then stretched over a large cultivation with an inevitable decline of productivity for all crops. This is because the expansion in cultivation is not coupled with the introduction of intermediate machinery (e.g. oxen weeding tools and planters) to even out labor demand.

In addition, the fear of being indebted to the bank has compelled the farmers to divert efforts even more from food to cash crop production. The Ministry of Agriculture (MOA) also has followed a similar policy parallel to that of the bank as it is extensively engaged in providing improved seeds of cash crops, especially groundnut, on a credit basis. Moreover, the commercial banks have also played a major role in promoting unbalanced production of field crops by adopting a marketing rather than production-led strategy of agricultural finance. They extend loans to up-country cash crop traders (dealers) only during the time of harvest to finance market transactions and exports.

On the market side, the government pricing policy has not been fair to dry-land farmers; and hence indirectly affects their economic status. The pricing policy of cash crops is either declared late or is set at prices far below those of the international market. In either case, the ultimate losers are the farmers. Grain prices are always set at low levels even when the ABS and/or the government make purchases.

One logical conclusion to this survey is that small farmers are caught in a double threat: constrained grain and constrained income, where grain production has been low and unstable and farm income from cash crops declining in real terms.

In terms of income, the increased cash crop production does not seem to offset the loss in income resulting from contraction of food production. This situation is borne out of heavy taxation of export production by government price manipulations. A recent study has shown a nominal protection coefficient below 50 percent for most of the farm commodities in Sudan (Elamin et. al, 2000).

Farmers in the region also regularly experience food shortages and sometimes famines. This had not been the case prior to the government policy of promoting cash cropping. Government policy bias is observed in credit and input distribution and other provisions of agricultural services. Accordingly, the central theme to be addressed by the present research study is that of public resources allocation between food crop production and export crop production. This question, however, falls into a broader policy issue relating to sectoral allocation of public resources, and what should be the role of government in getting various economic sectors and sub-sectors into the process of development.

The Region

The Western Sudan region has a population of about ten million, the majority of whom are rural farming families. This region is well endowed with cultivable land, about one-third of the 85 million hectares estimated for the country. The annual cropped area in the region is estimated at 42 percent of the twelve million hectares cropped by the whole country during early 1990s (Hashim, 1994). Currently, the country cultivated area is about 16.3 million hectares. Administratively, the region of Western Sudan constitutes six large states, three in Darfur and three in Kordofan sub-region and collectively constitutes about one-third of the country by area. Therefore, western Sudan is often said to be one-third the country by area, by population and by contribution to agricultural export.

The study area, however, is confined to the three states of Kordofan; an agricultural sector which usually contributes some 25 percent to the country's earnings from agricultural exports. A main reason of the limited study focus is the security problem in the Darfur sub-region, which delayed the collection of data. The contribution of Darfur to both domestic and export markets has never exceeds 10 percent for each market, but, in 1998 and 1999 the contribution of the Kordofan agricultural sector to the country's foreign exchange earnings was 27.77 and 34.15 percent, respectively.

The traditional agriculture of the region, in the recent past, is often described as subsistence rain-fed agriculture combined with a limited amount of cash cropping. At present the practice of cash cropping is considerable in amount and increasing in importance. Bare fallow cultivation, which primarily involves the use of hand tools and in which long fallow rotation is used to aid the soil regaining fertility, is commonly practiced. The principal production alternatives in this system include millet and sorghum, the staple food crops, and gum-arabic, groundnut, and sesame as the most important cash crops. Other food crops include cowpea and okra, while minor cash crops are watermelon seed and karkadeh (hibiscus). Livestock, though of secondary importance to cropping, is also a principal production and an increasingly important export alternative in the region.

The region is, in general, climatically divided into three productive zones (see figure 1). Most of the cultivated land is located in the middle zone, which constitutes the largest portion of the gum-belt area in Sudan, with long term average annual rainfall of 350 mm. The northern zone is dry, with less than 200 mm rainfall, whilst the southern zone is most favorable in terms of rainfall with an annual average of more than 600 mm. Therefore, the production patterns vary from pastorals in the north to sedentary traditional small farms in the middle gum-belt to the large mechanized farms in the south. However, the co-existence of the three production patterns in one zone is not uncommon, in particular in the southern zone. In this paper the word zone and state is used interchangeably.

Data and Aggregation

In the transition from farm-level to sector-level analysis, aggregation bias arises because all farms are not alike. To minimize this aggregation bias, farms in each zone are grouped into classes according to 1) similar proportions in resource endowments, 2) similar yields, and 3) similar technologies. These three rules satisfy Day's first requirement of aggregation, the "technological homogeneity" (Day, 1963). This is the most important rule, which requires that each farm in a class have the same production possibilities, the same type of resources and constraints, the same levels of technology, and the same level of managerial ability. This aggregation requirement is also the most relevant to this research study as it explicitly considers technological dualism as part of reality. The other two Day's requirements of aggregation concerning the proportionality of expectations from activity returns and resource constraints between individual farms and the aggregate one are handled through regression techniques when the data permits.

The representative farm (RF) is used to estimate the input/output coefficients of the aggregate (state) for each class of farms. The mean statistic is used to estimate the average farm size of the RF to generate its input/output coefficients per activity.

Both secondary and primary data are used in this research study at the sector or state level. Secondary sectoral data on past work on agricultural policies of credit, land reforms and marketing strategies, population and state incomes and domestic demands are obtained from records and relevant literature. Household surveys are carried out; one in each state, to collect primary data on resource uses and costs, cultural practices, yields and commodity prices associated with crop production alternatives undertaken by farmers. These surveys also quantified the farmers' resource base to determine the farmers' resource availability, historical enterprise patterns, staple food consumption, other domestic demands and crop exports at the level of the state and Kordofan agricultural sector, during the two agricultural seasons of the survey, 1998/99-2000/2001.

Empirical Investigation

The primary objective of this research study is an attempt to examine the impact of public agricultural resource allocation policies on the agricultural sector focusing on food security. This focus is central to farmers in the dry-land agriculture, characterized by production risk associated with low rains and droughts. To achieve this overall objective, the study critically reviewed and evaluated the evolution of agricultural and other economic policies that have shaped the agricultural sector in the region. Then it proceeded to assess the impact of these policies, putting emphasis on public resource allocation, on the production of food and export crops and farm income. With this scope, the study specific objectives are threefold as follows:

To construct a model which attempts to reconcile the trade-offs between the macro level (policy) decision and the micro level (farmer) decision. The model shall be positive simulating the sector's response to possible policy changes and simultaneously stimulating competitive partial market equilibrium.

To compute domestic resource cost indexes reflecting both micro and macro parameters (comparative advantage, exchange rates, border prices farm income .etc.) and use them in designing marketing strategies and export crop portfolio.

To determine cropping patterns which enable dry-land farmers to restore a balance between producing for home and the market?

To achieve these research objectives a number of seemingly conflicting policy goals are specified. The policy goals include 1) achieving greater export or foreign exchange earnings, 2) restoring the sector-wide self-sufficiency in food-grain, 3) increasing farm real income, 4) stabilizing the price of food-grain and 5) removal of food-grain imports and donations. The fulfillment of these policy goals requires the use of one or more policy instrument variables for each policy objective or goal.

For instance, maximizing earnings from export could be achieved through a number of policy variables. Such as export tax reduction, export comparative advantage using domestic resource cost ratios, changing the exchange rate, introducing intermediate machinery and new technologies, and paying farmers a considerable share of the export prices as production incentives.

Use of grain buffers as well as stabilization of food grain at its marginal unit costs of production can achieve the food security (policy) goal through increasing food retention, by farmers.

Empirical Model

The objective function of the empirical model specified below is originally non-linear sectoral model. However, it is linearized not only for purpose of easy computation but also for easy interpretation of results (see the previous progress report).

$$\text{Max} \quad Z = \Sigma j\Sigma s\ ?jsDjs + \Sigma j\Sigma zPxjzEjz - \Sigma j\Sigma zPimMjz$$

$$-\Sigma j\Sigma z\Sigma tCjztXjzt - \Sigma j\Sigma zCjzTjz - \Delta jzRjz - \Sigma z\Sigma t\ Phlhlab + \Sigma z\Sigma t\ Pflflab$$

$$- \Sigma z\Sigma t\ Pifinscred - \Sigma z\Sigma t\ Pff\ infcred + \Sigma z\Sigma t\ cta \qquad (1)$$

Such that

Sectoral (national) commodity balances

$-\Sigma zy^*Tjz + Ss?jsDjs + \Sigma zEj = 0$, all j [$\pi$j] (2)

Zonal (state) commodity balances

$-\Sigma tyjztXjzt + Tjz = 0$, all j, z [$\pi$jz] (3)

Capital inputs zonal balances

$-\Sigma tfmjztXjzt + Mjz = 0$, all j, z [$\pi$tjz] (4)

Resource restrictions

$\Sigma j\Sigma takjztXjzt = bkz\ (- \Sigma z\Sigma thlab + \Sigma z\Sigma tflab - \Sigma z\Sigma tinscred$

$- \Sigma z\Sigma t\ infcred + \Sigma z\Sigma t\ cta)$, all k, z [$\lambda$kj] (5)

Convex combination constraints

$\Sigma sDjs = 1$, all j [µj] (6)

Export limits for exportable j commodities

$\Sigma j \quad Ej \quad = \quad ej$ (7)

Home retention of j grain

$\Sigma tyjztXjzt + Rjz \geq Gjz$, [g] (8)

Dealer traders' income accounting rows

$\Sigma j\Sigma s?jsDjs + \Sigma z\ PxjEj - \Sigma j\Sigma zCjzTjz - Y = 0$ (9)

Farm-income accounting rows

$\Sigma j \Sigma s ?jsDjs + \Sigma z\ PxjEj - \Sigma j \Sigma z \Sigma t CjztXjzt - \Sigma j \Sigma z CjzTjz - \Delta jzGjz - F = 0$ (10)

and

$Djs, Xjzt, Tjz \geq 0$, all j,s,z,t

Where:

Ejz = the amount exported of product j from zone z;

Pxjz = export price (% of border) of product j, zone z;

Mjz = the amount of capital (import) input j by zone z;

Pijz = the purchased price of capital input j in zone z;

Cjzt = per unit cost of conventional farming inputs (seeds, labor..etc)

fm = capital (imported/improved) agricultural input used in the production of crop/animal j in zone z;

Tjz = the amount transferred of product j from zone z to domestic market;

Cjz = unit cost of transporting and processing of product j, produced in zone z and shipped to domestic market;

Gjz = the amount of annual requirement of grain j for zone z;

Δjz = the difference between the price the farm families pay for purchases of subsistence grain and the price they receive for its sale at harvest.

Cta = is a capital transfer activity of unused funds from previous to next period

Phl = price of hired labor (hlab in gams model)

Pfl = price of family labor (flab…)

Pif = price of institutional credit (crd …)

Pff = price of informal credit (crd …)

Terms between brackets are added for clarification

?j denotes the value of the area under the demand curve at point s on the demand curve of product j. The symbol ?js denotes the associated quantities. The variables Djs may not exceed unity in value. They are the choice variables regarding position on the demand function.

The convex combination constraint forces the model's solution to be located on or below the demand function. But it is inefficient to lie below the demand function. For with the same quantity sold being on the demand function can attain a greater value of Z. Hence constraint (6) effectively dictates the model's optimal solution to lie on the demand function, provided that it is feasible. ?js is the dealer traders' revenues and Y is their net income. Likewise, F represents the net farm income accrued by farmers', after costs deduction of production, marketing and purchased/retained grain activities.

TJz represents the marketing and transporting activity for product j in zone z, which transfers the product from state (rural) to the sector market through the zonal commodity balances.

Accordingly, the cash-outlay costs are now broken into two categories: production costs per hectare (Cjz) and marketing costs per ton of product marketed (Cjz). Notice that model includes zonal (state) prices (πjz) and sectoral (national) prices (πj) for the same commodity j. That is because, a priori, it is expected that the marketing costs will enter into the determination of the inter-state (zonal) price differentials. According to the first-order conditions, the equation relevant to these price differentials between the state markets and the sector market is as follows:

$$\partial L/\partial Tjz = - Cjz - \pi j + \pi jz \leq 0$$

If marketing and transportation for product j take place from zone z, then the dual variables display the following relationship:

$$\pi j - Cjz = \pi jz$$

That is the zonal (state) price is lower than the sectoral (national) price by the amount of the marketing margin (Cjz). The greater the marketing margin costs, the greater the inter-zonal price differential, mainly due to market imperfections in the commodity concerned.

Interestingly, inter-state (regional) differences in production costs (Cjz) do not figure in the determination of the price differentials. Therefore, a state (zone) with higher production costs or lower yields will receive lower levels of income per unit of product harvested and marketed.

The linearized downward sloping demand functions in our empirical model are those for domestic market and the gum arabic export. They include groundnut oil, groundnut cake, sesame oil, sesame cake, sorghum, millet, and gum marketable commodities. The demand for other export crops, which include groundnut, sesame, watermelon, karkadeh and sheep, are assumed perfectly elastic within export limits, at this stage of analysis. Because, data to formulate demands for these export crops are limited. Also because the share of Sudan agricultural export in the international market is comparatively very weak, except for the gum-arabic commodity, with an absolute comparative advantage. Therefore, exogenous international prices are assigned to these export crops in the model specified.

Equation (1) states that the objective function maximizes the area under demand curves (domestic and gum-arabic demands) plus the value of exports less the costs of imports, input supply, marketing and transport, and farm family's purchases of subsistence grain in each zone. The domestic demands are meant to estimate the needs of local industry from oil seeds and consumption of grain inside the sector.

The maximand shown by Z objective function corresponds to the sum of consumers' and producers' surplus, with major forms of market imperfection, the dealers' problem and tendency toward production for home retention, added. This objective function is constrained by the market commodity balances, purchased input balances, transportation capacity and the availability of resources as well as exports and grain consumption limits. These constrained are expressed in equation (2) through (7) as follows:

Equation (2) states that the amount of product j supplied to the zonal market goes to export and domestic consumption i.e. there is no storage. y* is the yield coefficient for the marketing activities (Tj). For instance, y*jz is the output (in tons, say) of the joint marketing and processing activity, per ton of raw material input from the farm, for zone z. The variable Tjz is then the corresponding activity level, i.e., how many tons of raw farm products were marketed and processed. We call this equation national because it bears direct influences on the levels of macro (policy) variables investigated. y*jzTjz is a more expressed equivalent of the volume traded by dealer traders of product j produced in zone z.

The commodity balances in equation (3) refer to the movement of raw farm products from the farm gate to the marketing and processing centers. Therefore, equation (2) and (3) represent the supply - demand systems, the first at the national (macro) and the second at the regional (micro) or farm level. At the national level, those balances equate the supply of processed products to retail demand and international trade.

Equation (4) containing purchased capital input balances is introduced for each zone to ensure that derived demands for inputs in the production processes are consistent with the conditions of input supply and cost.

The remaining equations are limits on the use of resources and dispose off farm production. Equation (5) is the conventional resource restrictions by crop requirements and by zones. This set of equations imposes limitations on the use of resources unless augmented from equation (4). It may be more convenient to join equation (4) & (5) into one. Equation (7) sets the upper limits on the individual export crops and animals, while equation (8) defines the lower limits on annual grain consumption by zones. The last two equations are accounting rows for the trader-dealers' and farmers' net income, respectively. For example constraint (9) says that subtracting the costs of marketing and processing from total revenues gives the dealers net income (Y). Similarly constraint (10) collects all farmers' income by zone into variable F.

As a final note, the specification of international trade merits some comments. The specification of export allows export computation, using the bounds and associated shadow prices to impute DRC ratios for comparative advantage analysis. In addition, by parameterize the export bounds; it is possible to explore the consequences for the sector of achieving greater export volumes, a major policy objective in this study. This is because, during recent years, export sales have encountered observable market limitations, which make the use of bounds more relevant for such analysis. Since agricultural imports normally tend to respond rather quickly to shortages in domestic supply, no bounds are required on imports.

Comparative advantage at the export market can be achieved by imputation of the domestic resource cost (DRC), commonly used as a measure of the comparative advantage of earning or saving a unit of foreign exchange. Given marginal or average costs of production from input demand equations the DRC indexes can readily be calculated for individual export crops of the agriculture sector. Algebraically, the DRC is written, for a single export crop, as

$$DRC = (C - eCi)/(ePw - eCi)$$

where C is the cost of production

e is the exchange rate

Pw is the border price of cash crop

Ci is the cost of imported inputs

Comparative advantage indexes can then be used in designing marketing strategies and export crop portfolio as well as trade incentives.

Results and Discussion

The three states, North, West and South form Kordofan agricultural sector, and they closely represent the three agro-ecological zones shown in figure 1. Therefore, the word state and zone is used interchangeably.

The goal of any agricultural policy for a country is to pull together the often-divergent thrusts of achieving maximum food security, maximizing the value from an export portfolio, generating revenues for government spending, and accommodating environmental issues and traditional cultures. However, these objectives are always, seemingly, conflict each other and hence need reconciliation. This research paper addresses the reconciling mechanism.

The sectoral model developed and used in this research study is analyzed using GAMS (General Algebraic Modeling System) software and detailed in the Appendix of this text. Some of the results generated by the sectoral model are presented in tables (1) through (4). Basically three scenarios are attempted, investigated and compared as different paths to resolving the trade off between micro level decisions (the farmers) and macro level policies (the government). Put in simple words, minimizing the trade off between production to satisfy local (domestic) consumption and production for the market (export).

The first scenario, named consumption scenario, has assumed that the main concerns of the policy makers are to close the widening food deficits experienced recently by Kordofan region. In this scenario we imagine that the policy makers are attempting to satisfy full consumption from the agricultural sector own production of grain, by using this mathematical model. In addition, they also are refrained from discouraging any further deterioration in foreign exchange earnings from export. Accordingly, revenues from export is varied starting from its 1998 $100 million base, upwards by 10 percent, while keeping consumption at its full level annual requirement for the whole region, which is amounting to 600 thousand metric of grain.

As shown in table (1), the objective function has steadily increased from SD 42.54 through SD 42.95 to SD 43.34 billion when earnings from export are increased incrementally by $10 million. The objective function in this model specification is the sum of the consumer and producer surpluses. However, the substantial increases in the objective value have come mainly from the use of more capital inputs such as machinery, improved seed, pesticides and fuel. Most of these agricultural inputs are imported. For instance, for the combination run of $100 million and 600 thousand ton consumption the costs of capital inputs is SD 7.514 billion compared to the costs of conventional inputs (e.g. hand tools and labor) amounted to SD 5.513, in the same strategic policy plan.

The very high increase in purchased agricultural inputs is beyond the capacity of the majority traditional farmers, which in turns, must call for large reallocation of public capital in favor of these farmers, in form of credit. The government credit policy should target a minimum sum of as much as SD 4.615 to effect the full consumption scenario with $100 million export earnings of the 1998. And more credit for maximizing export earnings beyond 1998 level. The credit extended to traditional agriculture in Kordofan region during 1998 was SD 0.25 billion, only 6 percent of optimal requirement.

In the second scenario, the maintenance of export, the government is assumed to be less sensitive to the question of food in exchange for that of foreign earnings from export. The policy maker argument may be “anyhow, the production of food is the sole responsibility of the people concerned, the farmers, and they have maintained it for decades in the recent history”. Put it differently reinvesting in agriculture is of less priority for the government. Therefore, the macro (policy) decision has been to fix the export value while varying the level of annual consumption starting from as low as 50 percent of requirement and increased incrementally by 25 percent.

Looking at table (2) the government, to some extent, may be right. Increasing the level of consumption beyond 300 thousand metric ton should increase the objective value. But these increases of the objective value are offset by similar increases of capital (imported) inputs, which eventually decreases net export. Moreover, increasing food consumption beyond 75 percent of annual requirement is going to depress the nation’s objective of maximizing the overall sum of consumer and producer surpluses. Actually, this may be the thinking of a number of policy makers in the current governance of Sudan, which might explain the increased frequency of food shortage during the last one and half decade.

The results of the third scenario of varying both levels of annual consumption and total earnings from agricultural export are presented in table (3). Surprisingly, this scenario has revealed very promising results. The objective value has increased substantially in comparison with the first scenario and has not been offset by increased costs of imported capital inputs like the second scenario. This happens even though this scenario shows the highest costs of capital inputs and requires a largest total credit of SDD 5.158 billion. Moreover, this scenario must be more appealing to both farmers and policy makers as it is really reconciling their seemingly conflicting goals of utility (consumption) and profit (revenues) maximization.

Accidentally, the federal Ministry of Economic Planning and Finance being over-whelmed by the tragic food situation in the dry-land agricultural sector, launched a credit programme aiming to allocate SD14 billion of production credit over 2001/2002 season. It did that so as to boost cereal production to eminently close the reoccurring food gaps. The share of Kordofan agricultural sector is anticipated to be at least equivalent to its share in the national agricultural exports (>20%) and amounts to about SD 3 billion. Whether this money was actually released, for this purpose, or not, nobody knows! The government also announced that it would increase the area under cultivation by at least 45 percent over the last season, across the country agriculture.

While the government policy of increasing credit sounds very logical, increasing cultivation horizontally is not. The results of the sectoral model have shown the opposite. Increasing production credit has substantially increased both food security and earnings from export but it also substantially decreased the area under cultivation by almost half the amount of 1998 base year. Increased production and export always come from vertical expansion of cultivation as a result of increased use of technology, both improved crop varieties and capital inputs, rather than expansion by area.

Table (4) may sum up the forgoing discussion by presenting the three reconciliation mechanisms investigated in this research. Going across the third row is the consumption scenario, going down the firs column gives the export retention mechanism and going diagonally on the table both consumption and export are varied.

Tables (5) through (7) present detailed allocation of cropped land by states for the third scenario of increasing both consumption and export simultaneously. They emphasize specialization of production and investment on the dry land agriculture of Kordofan agricultural sector. North Kordofan in gum arabic, karkadeh and sheep production, West Kordofan in groundnut, watermelon and sheep production and South Kordofan in sorghum and sesame production.

Table (8) indicates the comparative advantages of the whole agricultural sector where the sector has a high potential to exporting all crops, except millet and gum arabic, conditioned on the cultivation of improved varieties. The very high DRC for gum arabic is not expected as this region usually exports almost 60 percent of this commodity. However, a reasonable explanation for this odd finding is that the analysis is undertaken from both macro (policy) and micro (farmers' decisions) levels, with farmers having little confidence on the prevailing government pricing policy for this crop. Marketing of gum arabic is monopolized by the Gum Arabic Company where farmers' are highly taxed compared to international prices. Actually, a high proportion is usually smuggled to bordering countries and re-exported from there.

In all model runs the major export are groundnut and sheep. The groundnut comes mainly from Western Kordofan state (zone) while the sheep from North and West Kordofan. By contrast almost all the grain is produced in South Kordofan state. These important results emphasize the need for specialization in agricultural production and investment across the dry-land farming itself.

It is noteworthy to mention that a number of new crop technologies are tried in the specification of the empirical sectoral model employed in this study. These technologies included Aros elrimal, Yourwasha, Gadum elahamam, and Wad Ahmed improved sorghum varieties and Sodari groundnut and El Obeid-1 sesame oilseed improved varieties.

The exclusion of Aros elrimal and El Obeid-1 by our empirical model merits some comments. Aros elrimal and El Obeid-1are sorghum and sesame improved varieties developed by El Obeid Research Station as drought tolerant farm technologies. However, these two varieties failed to compete with similar varieties developed at Gezira Research Station, central Sudan, despite the less favorable conditions (dry land) for the latter.

Our explanation to these unanticipated results is as follows: Aros elrimal and El Obied-1 are developed to produce under worst drought conditions and hence when the rainy season is good or even normal they could not out-yield the local crop varieties. In contrast, the improved crop varieties developed by Gezira Research Station are researched to adapt to the conditions of dry-land agriculture in Sudan, but not tailored for drought conditions. Because the empirical model for this study used data from the agricultural seasons 1997 to 2000, during which the rainy season is more favorable, Aros elrimal and El Obeid-1 failed to enter the solution basis. This might lead to the wisdom that these two improved crop varieties should be distributed to the farmers only when the probability of a long-drawn-out drought is predicted to be high.

Conclusion

Policy-making is not a goal by itself, but merely a means to an end, namely to help a given community-often a nation- to achieve an objective or satisfy a need by sketching out the steps required. From the foregoing discussion, the direction of the agricultural policy for the dry land farming in Sudan is clear. It is high time for the Sudan's government to have a fair look in terms of reallocation of public resources, in particular the credit market, to the dry land agriculture. Moreover, the research paper calls for specialization of the agricultural commodity supply based on comparative advantages by the various zones in the dry-land agriculture.

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Table (1) Consumption Scenario: 600,000mt Grain with $100, $110 or $120 million Exports

	Foreign exchange earnings from export		
Policy plan	$100 mil.	$110 mil.	$120 mil.
Objective value [1]	42.545	42.950	43.344
Exports market portfolio			
Groundnut	108.879	123.351	137.376
Sheep	348.500	348.500	348.500
Gum arabica	2.821	2.821	2.821
Hibiscus	2.063	1.697	1.697
Watermelon	1.843	1.843	1.843
Domestic market portfolio			
Sorghum	479.705	479.705	479.705
Millet	12.505	12.505	12.505
Groundnut	4.388	4.388	4.389
Sesame	2.463	2.463	2.463
Value of capital (import) inputs	7.514	7.523	7.523
Machinery hours	232.818	233.183	233.183
Improved seed tonnage	2.390	2.390	2.390
esticide	.003164		
Production costs	5.513	5.715	5.916
Marketing costs (margin)	7.204	7.447	7.679
Institutional credit	4.615	4.841	5.158
North Kordofan state			
West Kordofan state		0.182	0.499
South Kordofan state	4.614	4.659	4.659
Dealers' income	211.768	212.430	213.102
Farmers' income	205.449	205.909	206.379
Sectoral prices at domestic market			
Sorghum	0.027	0.027	0.027
Millet	0.038	0.041	0.041
Groundnut	0.033	0.036	0.036
Sesame	0.071	0.071	0.071
Gum Arabic	0.070	0.070	0.070
Cropping Pattern (000' hectares)			
Traditional farming system			
Sorghum			
Improved sorghum	219.800	219.800	219.800
Millet	39.079	39.079	39.079
Groundnut	237.521	267.927	297.395
Sesame			
Watermelon	4.500	4.500	4.500
Karkadeh	20.300	20.300	20.300
Gum arabic	33.000	33.000	33.000
Mechanized farming system			
Sorghum			
Improved sorghum	178.583	178.583	178.583
Sesame	4.960	6.938	6.938
Pesticide treated sesame	1.582		

1 Values are in SDD billion and quantities of commodities and inputs in thousand tons, heads, hours and hectares for crops, sheep, machinery and land, respectively.

Table (2) Export Scenario: US$ 100 Million Export with 50%, 75% or 100% Grain Consumption*

Policy plan	Consumption in thousand tons of food grain 50% (300)	75% (450)	100% (600)
Objective value1)	41.016	42.652	42.545
Exports market portfolio			
Groundnut	109.326	108.879	108.879
Sheep	348.500	348.500	348.500
Gum arabic	2.821	2.821	2.821
Karkadeh	1.697	2.063	2.063
Watermelon	1.843	1.843	1.843
Domestic market portfolio			
Sorghum	479.706	479.706	479.705
Millet	12.505	12.505	12.505
Groundnut	4.388	4.388	4.388
Sesame	2.463	2.463	2.463
Value of capital (import) inputs	5.861	7.514	7.514
Machinery hours	4.513	232.818	232.818
Improved seed tonnage	1.348	2.390	2.390
Pesticide		.003164	.003164
Production costs	7.741	5.513	5.513
Marketing costs (margin)	7.159	7.204	7.204
Institutional credit	4.160	4.615	4.615
North Kordofan state			
West Kordofan state	1.437		
South Kor dofan state	2.723	4.615	4.614
Dealers' income	211.810	211.768	211.768
Farmers' income	203.480	205.555	205.449
Sectoral prices at domestic market			
Sorghum	0.027	0.027	0.027
Millet	0.025	0.038	0.038
Groundnut	0.036	0.033	0.033
Sesame	0.071	0.071	0.071
Gum Arabic	0.070	0.070	0.070
Cropping Pattern (000' hectares)			
Traditional farming system			
Sorghum			
Improved sorghum	522.710	219.800	219.800
Millet	39.079	39.079	39.079
Groundnut	238.459	237.521	237.521
Sesame			
Watermelon	4.500	4.500	4.500
Karkadeh	20.300	20.300	20.300
Gum Arabic	33.000	33.000	33.000
Mechanized farming system			
Sorghum			
Improved sorghum	116.208	178.583	178.583
Sesame	6.938	4.960	4.960
Pesticide treated sesame		1.582	1.582

*Values are in SDD billion and quantities of commodities and inputs in thousand tons, heads, hours and hectares for crops, sheep, machinery and land, respectively.

Table (3) Consumption/Export Scenario: Increased Grain Consumption and Export Earnings

Policy plan	300000mt grain $100mil.	450000mt $110mil.	600000mt $ 120mil.
Objective value1)	41.016	43.056	43.344
Exports market portfolio			
Groundnut	109.326	123.351	137.376
Sheep	348.500	348.500	348.500
Gum arabic	2.821	1.697	2.821
Karkadeh	1.697	1.843	1.697
Watermelon	1.843		1.843
Domestic market portfolio			
Sorghum	479.706	479.705	479.705
Millet	12.505	12.505	12.505
Groundnut	4.388	4.388	4.389
Sesame	2.463	2.463	2.463
Value of capital (import) inputs	5.861	7.523	7.523
Machinery hours	4.513	233.183	233.183
Improved seed tonnage	1.348	2.390	2.390
Pesticide			
Production costs	7.741	5.715	5.916
Marketing costs (margin)	7.159	7.447	7.679
Institutional credit	4.160	4.841	5.158
North Kordofan state			
West Kordofan state	1.437	0.182	0.499
South Kordofan state	2.723	4.659	4.659
Dealers' income	211.810	212.430	213.102
Farmers' income	203.480	206.016	206.379
Sectoral prices at domestic market			
Sorghum	0.027	0.027	0.027 .
Millet	0.025	0.041	0.041
Groundnut	0.036	0.036	0.036
Sesame	0.071	0.071	0.071
Gum Arabic	0.070	0.070	0.070
Cropping Pattern (000' hectares)			
Traditional farming system			
Sorghum			
Improved sorghum	522.710	219.800	219.800
Millet	39.079	39.079	39.079
Groundnut	238.459	267.927	297.395
Sesame			
Watermelon	4.500	4.500	4.500
Karkadeh	20.300	20.300	20.300
Gum arabic	33.000	33.000	33.000
Mechanized farming system			
Sorghum			
Improved sorghum	116.208	178.583	178.583
Sesame	6.938	6.938	6.938
Pesticide treated sesame			

Values are in SDD billion and quantities of commodities and inputs in thousand tons, heads, hours and hectares for crops, sheep, machinery and land, respectively.

Table (4) The Trade-off Between Domestic Demand and Export Market for Kordofan Agricultural Sector

	Export in thousand US $ Dollars		
	100,000	110,000	120,000
Consumption (000' ton of grain)	Sum of consumer and producer surplus in billion Sudanese Dinars (SD)		
300 (50%)	41.016		
450 (75%)	42.652	43.056	
600 (100%)	42.545	42.950	43.344

Table (5) Policy Option I: $100 Million Export and 50% Consumption (300000 mt grain)

	Kordofan Agricultural Sector		
Cropping policy plan	North State	West State	South State
Cropping pattern (000' hectares)	53.000	590.848	340.046
Traditional farming system	53.000	584.948	219.800
Sorghum			
Improved sorghum		302.910	219.800
Millet		39.079	
Groundnut		238.459	
Sesame			
Watermelon		4.500	
Karkadeh	20.300		
Gum arabic	33.000		
Mechanized farming system		5.900	120.246
Sorghum			
Improved sorghum		5.900	113.308
Sesame			6.938
Pesticide treated sesame			
Sheep production (000' heads)	111.100	237.400	

Note: Improved sorghum is Yourwasha in West Kordofan State and Gadam elhamam in South Kordofan State. Improved groundnut is Sodari. Other improved crop varieties failed to enter the solution basis.

Table (6) Policy Option II: $110 Million Export and 75% Consumption (4500000 mt grain)

Cropping policy plan	Kordofan Agricultural Sector		
	North State	West State	South State
Cropping pattern (000' hectares)	53.300	311.506	405.321
Traditional farming system	53.300 0.000	311.506	219.800
Sorghum			
Improved sorghum			219.800
Millet		39.079	
Groundnut		267.927	
Sesame			
Watermelon		4.500	
Karkadeh	20.300		
Gum arabic	33.000		
Mechanized farming system			185.521
Sorghum			
Improved sorghum			178.583
Sesame			6.938
Pesticide treated sesame			
Sheep production (000' heads)	111.100	237.400	

Note: Improved sorghum is Yourwasha in West Kordofan State and Gadam elhamam in South Kordofan State. Improved groundnut is Sodari. Other improved crop varieties failed to enter the solution basis.

Table (7) Policy Option III: $120 Million Export and 100% Consumption (600000 mt grain)

Cropping policy plan	Kordofan Agricultural Sector		
	North State	West State	South State
Cropping pattern (000' hectares)	53.300	311.506	405.321
Traditional farming system	53.300 0.000	311.506	219.800
Sorghum			
Improved sorghum			219.800
Millet		39.079	
Groundnut		297.395	
Sesame			
Watermelon		4.500	
Karkadeh	20.300		
Gum arabic	33.000		
Mechanized farming system			185.521
Sorghum			
Improved sorghum			178.583
Sesame			6.938
Pesticide treated sesame			
Sheep production (000' heads)	111.100	237.400	

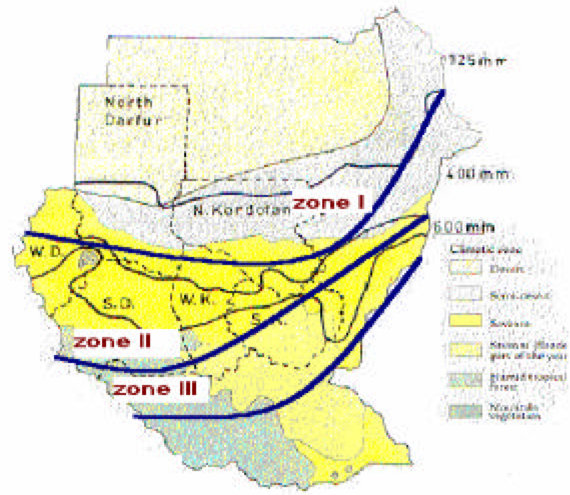
Note: Improved sorghum is Yourwasha in West Kordofan State and Ga dam elhamam in South Kordofan State. Improved groundnut is Sodari. Other improved crop varieties failed to enter the solution basis.

Table (8) Export Portfolio at an Exchange Rate of SD 257/ US$

Crop	DRC	Comparative Advantage
Sorghum	Ng	Very high
Millet	634	Very low
Groundnut	74	High
Sesame	Ng	Very high
Watermelon	137	Moderate
Karkadeh	187	Moderate
Gum arabic	437	Very low
Sheep	47	High

Ng: Negligible value

Figure1


North
Darfur
N. Kordofan
zone I
400 mm
600 mm
W.D.
S.D.
W.K.
zone II
zone III

```
$title A Sector Model of Kordofan Agricultural Region, western Sudan
$stitle set definitions

*  Reference: Eltighani M. Elamin of the Socioeconomic Research Programme, ARC
and
*           Hamid M. Mohamed of the Department of Computer Science, University of
Kordofan.
*           El Obeid, Sudan, 2000.

SETS    J       crops      /sorghum, millet, gnut, sesame, wmillon, karkadeh,
                            gumarabic, sheep/
        D       demand     /dem, oil, cake/
        A       crop activities     /pst, imp, pstimp, loc, impfert/
        f       finance credit      /inscred "institutional", infcred "informal"/
        cta     capital transfer    /ctr12, ctr23, ctr34, ctr4o/
        fhlab   fam and hired labor  /flab, hlab/
        S       Segments             /1*11/
        Z       States           /NKS, WKS, SKS/
        T       Technology           /trd "traditional" , mec "mechanized"/
        K       Resources            /land, capital, labor/
        P       Period for labor     /1*6/
        pc      period for capital   /1*4/
        km      technology characteristics /tractor, combine, sorgseed, sesmseed,
gnutseed, fertilizer, pesticide/

Table      w(j,d,S)       Domestic demand revenues (in SD billions)
                          1        2        3        4        5        6        7        8        9
10       11
sorghum.dem          27.63   29.07   30.36   31.51   32.49   33.33   24.01   34.55
34.93  35.15   35.23
millet.dem           11.83   12.43   12.98   13.46   13.87   14.23   14.51   14.74
14.89  14.99   15.03
gumarabic.dem        .7467   .8722   .9845   1.084   1.169   1.242   1.302   1.349
1.381  1.401   1.407
gnut.oil             1.731   2.423   3.043   3.590   4.064   4.464   4.793   5.048   5.230
5.340   5.376
sesame.oil           1.297   1.816   2.281   2.691   3.045   3.346   3.592   3.784
3.920  4.002   4.030
gnut.cake            .1910   .2200   .2460   .2690   .2887   .3055   .3193   .3300
.3376  .3422   .3437
sesame.cake          .1227   .1414   .1580   .1728   .1855   .1963   .2052   .2120
.2169  .2199   .2209;



Table      wd(j,d,S)       Domestic demand coefficients
                          1     2     3     4     5     6     7     8     9     10    11
sorghum.dem               1     1     1     1     1     1     1     1     1     1     1
```

```
millet.dem          1     1     1     1     1     1     1     1     1     1     1
gumarabic.dem        1     1     1     1     1     1     1     1     1     1     1
gnut.oil            1     1     1     1     1     1     1     1     1     1     1
sesame.oil           1     1     1     1     1     1     1     1     1     1     1
gnut.cake           1     1     1     1     1     1     1     1     1     1     1
sesame.cake          1     1     1     1     1     1     1     1     1     1     1

Table      Px(J,Z)   State export price coefficients (in SD billions per thousand tons)
              NKS      WKS      SKS
Gnut         .06447  .03981  .03981
sesame        .05321  .05001  .05210
wmillon     .03255  .03200  .03200
karkadeh     .07731  .06500  .07100
sheep        .00409  .00293  .00350 ;

Parameter      Pxd(J)   Export dollar price (in $000' per 1000 ton or sheep)
           /gnut          713
            sesame         682.7
            wmillon       253.1
            karkadeh      869.3
            gumarabic     831.7
            sheep         057.7/ ;

Table      Pi(km,z,t)  Import price coeficients (SD billion per ton or 1000 hrs for
tractor)
             NKS.trd       WKS.trd   WKS.mec   SKS.trd   SKS.mec
tractor                              .00466              .00466
combine                             .00867               .00867
sorgseed     .000054        .00007    .00007      .00007    .00007
sesmseed      .00045        .00045    .00045       .00045    .00045
gnutseed     .00016        .00016                .00016
fertilizer                                      .00280    .00280
pesticide    .00110        .00110                 .00110    .00110 ;

Table      tech(J,A,z,km,t) cropping technology requirements ( in tons or 1000 hrs per
1000 ha)
                              tractor.mec     combine.mec    sorgseed.mec
sesmseed.mec    fertilizer.mec    pesticide.mec
sorghum.loc.(nks,wks,sks)        .92               .35
sorghum.imp.(nks,wks,sks)        .92              .35               6.0
sorghum.impfert.sks              .92              .35               6.0
40
sesame.loc.(nks,wks,sks)         .92
sesame.imp.(nks,wks,sks)         .92                                                1.75
sesame.pst.(nks,wks,sks)         .92
2.0
sesame.pstimp.(nks,wks,sks)   .92                                                1.75
2.0
+
```

```
                                    sorgseed.trd   sesmseed.trd   gnutseed.trd
fertilizer.trd   pesticide.trd
sorghum.imp.(nks,wks,sks)     6.0
sorghum.impfert.sks                                                            40
sesame.imp.(nks,wks,sks)                       1.75
sesame.pst.(nks,wks,sks)
2.0
sesame.pstimp.(nks,wks,sks)                    1.75
2.0
gnut.imp.(nks,wks,sks)                                        59.50
millet.pst.(nks,wks,sks)
4.0 ;

Table     C(J,A,z,t)     Production cost coeficients (in SD billions per 1000 ha)
                    NKS.trd  WKS.trd  WKS.mec  SKS.trd  SKS.mec
sorghum.loc         .00263   .00999   .01307   .00176   .01307
sorghum.imp         .00605   .01020   .01452   .00220   .01452
sorghum.impfert                                .00397   .02000
millet.pst          .00606   .00461            .00461
millet.loc          .00606   .00461            .00461
gnut.loc            .00815   .00684            .00168
gnut.imp            .01277   .00700            .00210
sesame.pst          .00583   .00583   .00620   .00129   .00174
sesame.pstimp       .00700   .00700   .01822   .00155   .01822
sesame.loc          .00583   .00583   .00620   .00129   .00174
sesame.imp          .00700   .00700   .01822   .00155   .01822
wmillon.loc         .00384   .00384            .00384
karkadeh.loc        .00368   .00368            .00368
gumarabic.loc       .00840   .00840            .00840
sheep.loc           .00070   .00070            .00070
Table    hl(fhlab,p) price of hired labor (SD billions per 1000 MD)
        1        2        3        4        5        6
hlab  .00100   .00100   .00143   .00143   .00143   .00143

*Table    fl(fhlab,p) price of family labor (SD billions per 1000 MD)
*       1        2        3        4        5        6
*flab  .00095   .00095   .00231   .00231   .00136   .00136

Table     chat(J,Z) Marketg costs coefficients (in SD billions per 000' tons)
              NKS      WKS      SKS
sorghum      .0281    .00886   .00933
millet       .01378   .01921   .01575
gnut         .01148   .01573   .02666
sesame       .03042   .03744   .03544
wmillon      .02703   .02082   .02082
karkadeh     .05379   .04210   .04210
gumarabic    .02179   .02110   .02110
sheep        .00112   .00087   .00144

Table     Delta(J,Z)    Grain price coefficients (in 000' tons)
```

	NKS	WKS	SKS
sorghum	.00840	.00238	.00264
millet	.01651	.01441	.01243

Table crd(f,Z) Credit finance (price in SD billions)

	NKS	WKS	SKS
inscred	.24	.24	.24
infcred	.54	.54	.54

Table crdreq (f,pc,z) Credit supply by zones (in SD billions)

	NKS	WKS	SKS
inscred.1	1	1	1
inscred.2	1	1	1
inscred.3	1	1	1
infcred.1	1	1	1
infcred.2	1	1	1
infcred.3	1	1	1

Table crdpi(f,pc,Z) Credit repayment (principle & interest in SD billions)

	NKS	WKS	SKS
inscred.1	1.24	1.24	1.24
inscred.2	1.24	1.24	1.24
inscred.3	1.24	1.24	1.24
infcred.1	1.54	1.54	1.54
infcred.2	1.54	1.54	1.54
infcred.3	1.54	1.54	1.54

Table ctareq (cta,pc,z) Capital transfer activities (in SD billions)

	NKS	WKS	SKS
ctr12.1	1	1	1
ctr12.2	-1	-1	-1
ctr23.2	1	1	1
ctr23.3	-1	-1	-1
ctr34.3	1	1	1
ctr34.4	-1	-1	-1
ctr4o.4	1	1	1

Table Y(J,Z) Yield proportions for sectoral commodity balances

	NKS	WKS	SKS
sorghum	.95	.95	.95
millet	.95	.95	.95
sesame	.95	.95	.95
wmillon	.95	.95	.95
karkadeh	.95	.95	.95
gumarabic	.95	.95	.95
sheep	1.0	1.0	1.0
gnut	.95	.95	.95

Table Seta(J,d,S) Associated quantities demanded (in 000' tons)

	1	2	3	4	5	6	7	8	9	10	11
sorghum.dem	317.85	345.42	373.00	400.57	428.15	455.72	483.3	510.87	538.45	566.02	593.59
millet.dem	89.01	96.63	104.25	11.88	119.50	127.12	134.74	142.36	149.99	157.61	165.23
gumarabic.dem	10.72	13.05	15.38	17.71	20.04	22.38	24.71	27.04	29.37	31.70	34.05
gnut.oil	4.169	6.113	8.057	10.001	11.945	13.889	15.834	17.777	19.721	21.665	23.609
sesame.oil	2.34	3.43	4.52	5.62	6.72	7.81	8.90	10.00	11.09	12.18	13.28
gnut.cake	8.33	10.00	11.67	13.33	15.00	16.66	18.33	19.99	21.66	23.32	24.99
sesame.cake	4.99	5.99	6.99	7.99	8.98	9.98	10.98	11.98	12.98	12.98	14.97

* improved sorghum varieties are Arows elremal in for nks and gadam elahmam for sks
* and Wadhamed and A. Gadanak in sks.mes
* improved sesame variety is ElObeid-1 and groundnut is Sodiri
* pesticided crop yield is 25 per cent more of normal

Table yx(J,A,Z,T) production yield (in 000' tons per 000' ha)

	NKS.trd	WKS.trd	WKS.mec	SKS.trd	SKS.mec
sorghum.loc	.131	.309	1.54	.562	1.54
sorghum.imp	.211	.371	.742	.72	1.80
sorghum.impfert				1.3	2.6
millet.pst	.207	.400		.202	
millet.loc	.166	.320		.162	
gnut.loc	.229	.501		.510	
gnut.imp	.410	.877		.892	
sesame.pst	.096	.186	.444	.386	.444
sesame.pstimp	.232	.232	.475	.404	.475
sesame.loc	.077	.149	.355	.309	.355
sesame.imp	.186	.186	.380	.323	.380
wmillon.loc	.431	.431		.431	
karkadeh.loc	.088	.107		.081	
gumarabic.loc	.090	.090		.090	
sheep.loc	1.0	1.0		1.0	

Table rr(j,d,S) dealer traders revenues (in SD billions)

	1	2	3	4	5	6	7	8	9	10	11

sorghum.dem	175.26	171.42	164.53	154.60	141.63	125.62	106.57	84.48	59.34	31.17	-0.05
millet.dem	74.70	72.99	70.01	65.75	60.21	53.39	45.29	35.92	25.27	13.33	0.26
gumarabic.dem	6.07	6.65	6.97	7.02	6.81	6.34	5.60	4.60	3.33	1.79	-0.00
gnut.oil	5.63	20.63	24.17	26.25	26.88	26.04	23.75	20.00	14.79	8.12	0.00
sesame.oil	11.71	15.46	18.12	19.68	20.14	19.52	17.80	15.00	11.08	6.08	-0.01
gnut.cake	1.53	1.65	1.71	1.71	1.65	1.53	1.35	1.10	0.8	0.43	0.00
sesame.cake	0.98	1.06	1.10	1.10	1.06	0.98	0.86	0.71	0.51	0.51	0.00

Table aln(k,j,a,z,t) input-output coefficients (land in thousand ha capital in SD bil labor in thousand MD)

	NKS.trd	WKS.trd	WKS.mec	SKS.trd	SKS.mec
land.sorghum.loc	1.0	1.0	1.0	1.0	1.0
land.sorghum.imp	1.0	1.0	1.0	1.0	1.0
land.sorghum.impfert				1.0	1.0
land.millet.pst	1.0	1.0		1.0	
land.millet.loc	1.0	1.0		1.0	
land.gnut.loc	1.0	1.0		1.0	
land.gnut.imp	1.0	1.0		1.0	
land.sesame.pst	1.0	1.0	1.0	1.0	1.0
land.sesame.pstimp	1.0	1.0	1.0	1.0	1.0
land.sesame.loc	1.0	1.0	1.0	1.0	1.0
land.sesame.imp	1.0	1.0	1.0	1.0	1.0
land.wmillon.loc	1.0	1.0		1.0	
land.karkadeh.loc	1.0	1.0		1.0	
land.gumarabic.loc	1.0	1.0		1.0	

Table acap(k,j,a,z,pc,t)

	NKS.1.trd	NKS.2.trd	NKS.3.trd	WKS.1.trd	WKS.2.trd	WKS.3.trd	SKS.1.trd	SKS.2.trd	SKS.3.trd
capital.sorghum.loc	.00176	.00066	.00021	.00103	.00122	.00781	.00030	.00033	.00113
capital.sorghum.imp	.00185	.00066	.00025	.00108	.00122	.00937	.00032	.00033	.00136

```
capital.sorghum.impfert
.00036     .00037     .00245
capital.millet.pst          .00197     .00540     .00371     .00104       .00562
.00282       .00104      .00562     .00282
capital.millet.loc          .00197     .00100     .00309     .00104       .00122
.00235       .00104      .00122     .00235
capital.gnut.loc            .00244     .00105     .00466     .00286       .00143
.00255       .00097      .00027     .00044
capital.gnut.imp            .00256     .00105     .00559     .00300       .00143
.00306       .00102     .00027     .00053
capital.sesame.pst          .00232     .00272     .00370     .00143       .00363
.00355       .00023     .00266     .00082
capital.sesame.pstimp    .00244     .00272     .00370     .00150       .00363
.00426       .00024     .00258    .00098
capital.sesame.loc          .00232     .00043     .00308     .00143       .00143
.00296       .00023     .00038    .00068
capital.sesame.imp          .00244     .00043     .00370     .00150       .00143
.00355       .00024      .00038    .00082
capital.wmillon.loc         .00117     .00131     .00094     .00117       .00131
.00094       .00117      .00131    .00094
capital.karkadeh.loc       .00058     .00131     .00440     .00058       .00131
.00440       .00058      .00131    .00440
capital.gumarabic.loc      .00278                .00069     .00278
.00069       .00278                .00069
capital.sheep.loc           .00030     .00030     .00010     .00030       .00030
.00010       .00030      .00030    .00010

+                          WKS.1.mec  WKS.2.mec  WKS.3.mec  SKS.1.mec
SKS.2.mec  SKS.3.mec
capital.sorghum.loc       .00488        .00286       .00542        .00488
.00286       .00542
capital.sorghum.imp       .00512        .00286       .00678        .00512
.00286       .00678
capital.sorghum.impfert                                            .00514       .00286
.00970
capital.sesame.pst         .00524        .00506       .00810        .00524
.00506       .00810
capital.sesame.pstimp     .00550        .00726       .01012        .00550
.00726       .01012
capital.sesame.loc          .00524        .00286       .00810        .00524
.00286       .00810
capital.sesame.imp         .00550        .00286       .01012        .00550
.00286       .01012

Table alab(k,j,a,z,p,t)
                           NKS.1.trd   NKS.2.trd   NKS.3.trd   NKS.4.trd   NKS.5.trd
NKS.6.trd
labor.sorghum.loc        8.45          5.17          12.60         4.57          10.68
5.28
```

labor.sorghum.imp 8.45 5.17 12.60 4.57 12.82
6.34
labor.millet.pst 8.45 3.43 8.77 3.45 10.93
5.93
labor.millet.loc 8.45 3.43 8.77 3.45 9.11
4.95
labor.gnut.loc 8.45 6.86 12.75 15.93 14.60
8.76
labor.gnut.imp 8.45 6.86 12.75 15.9 17.54
10.51
labor.sesame.pst 8.45 9.52 14.95 8.69 15.66
2.92
labor.sesame.pstimp 8.45 9.52 14.95 8.69 18.79
3.50
labor.sesame.loc 8.45 9.52 14.95 8.69 13.05
2.43
labor.sesame.imp 8.45 9.52 14.95 8.69 15.66
2.92
labor.karkadeh.loc 8.45 12.17 13.52 .00 26.43
26.43
labor.gumarabic.loc 0.0 0.0 7.50 .00 5.00
7.50
labor.sheep.loc 10.0 10.0 10.0 10.0 10.0
10.0

\+ WKS.1.trd WKS.2.trd WKS.3.trd WKS.4.trd WKS.5.trd
WKS.6.trd WKS.1.mec WKS.2.mec WKS.3.mec WKS.4.mec WKS.5.mec
WKS.6.mec
labor.sorghum.loc 8.45 7.43 13.52 6.76 .0
21.98 3.04 3.04 8
labor.sorghum.imp 8.45 7.43 13.52 6.76 .0
26.38 3.8 3.8 10
labor.millet.pst 8.45 7.43 13.52 7.78 .0
33.60
labor.millet.loc 8.45 7.43 13.52 7.78 .0
28.07
labor.gnut.loc 8.45 20.33 20.33 11.50 59.50 .00
labor.gnut.imp 8.45 20.33 20.33 11.50 71.40 .00
labor.sesame.pst 8.45 5.07 10.81 7.78 70.20 .00
3.8 3.8 10 .8
labor.sesame.pstimp 8.45 5.07 10.81 7.78 84.24 .00
3.8 3.8 12 1
labor.sesame.loc 8.45 5.07 10.81 7.78 58.50 .00
3.04 3.04 8
labor.sesame.imp 8.45 5.07 10.81 7.78 70.20 .00
3.8 3.8 10
labor.wmillon.loc 8.45 6.76 19.62 .00 10.24
33.81

labor.karkadeh.loc 8.45 12.17 13.52 .00 26.43
26.43
labor.gumarabic.loc 0.0 0.0 7.50 0.0 5.00
7.50
labor.sheep.loc 10.0 10.0 10.0 10.0 10.0
10.0

+ SKS.1.trd SKS.2.trd SKS.3.trd SKS.4.trd SKS.5.trd SKS.6.trd
SKS.1.mec SKS.2.mec SKS.3.mec SKS.4.mec SKS.5.mec SKS.6.mec
labor.sorghum.loc 16.429 53.096 19.524 20.000 11.191 10.714
3.8 3.8 10
labor.sorghum.imp 16.429 53.096 19.524 20.000 13.430 12.850
3.8 3.8 12
labor.sorghum.impfert 16.429 53.096 19.524 20.000 24.248 23.201
5.5 5.5 17
labor.millet.pst 10.476 25.477 14.857 12.143 10.572 18.571
labor.millet.loc 10.476 25.477 12.381 12.143 08.810 15.476
labor.gnut.loc 25.715 41.429 22.143 37.144 19.286 11.905
labor.gnut.imp 25.715 41.429 22.143 37.144 28.929 17.857
labor.sesame.pst 8.095 60.954 22.143 18.334 15.428 10.572
3.8 3.8 10 1.0
labor.sesame.pstimp 8.095 60.954 22.286 18.334 18.520 12.680
3.8 3.8 10 1.0
labor.sesame.loc 8.095 60.954 18.572 18.334 12.857 08.810
3.8 3.8 10 1.0
labor.sesame.imp 8.095 60.954 18.572 18.334 15.430 10.570
3.8 3.8 10 1.0
labor.wmillon.loc 8.45 6.76 19.62 0.00 10.24 33.81
labor.karkadeh.loc 8.45 12.17 13.52 0.00 26.43 26.43
labor.gumarabic.loc 0.0 0.0 7.50 0.00 5.00 7.50
labor.sheep.loc 10.0 10.0 10.0 10.0 10.0 10.0

Table RG(j,z) Rcap coefficient

	nks	sks	wks
sorghum	1	1	1
millet	1	1	1

Table Bc(k,pc,z) Boundaries for resource restrictions (land 000 ha capital SD bil lab 000 MD)

	NKS	WKS	SKS
Capital.1	3.01	3.30	2.43
Capital.2	0	0	0
Capital.3	0	0	0

Table Blb(k,p,z) Boundaries for resource restrictions (land 000 ha capital SD bil lab 000 MD)

	NKS	WKS	SKS
Labor.1	9134	12174	21704

```
Labor.2        9134     12174   17051
Labor.3        18268    24348   14669
Labor.4        18268    24348   11968
Labor.5        18268    24348   15068
Labor.6        9134     12174   10206

Table  Bl(k,t,z)      Boundaries for resource restrictions (land 000 ha capital SD bil lab
000 MD)

                NKS      WKS      SKS
land.trd       1570.8   2086.2   219.8
land.mec                5.9      750



Parameter     g(z)
           /nks    205.05
             wks    221.25
            sks    156.54 /;

Variables
       ccta(cta,pc,z)
       income                  Final profit
       Dx(j,d,S)        Demands
       E(J,Z)           Exported quantity
       M(j,Z,km,t)      Imported quantity
       X(J,A,Z,T)       Crop productions
       Tx(J,Z)                   Produce for market
       Rcap(J,Z)        Retained grain for home consumption
         Yinc(J,Z)            Accounting for dealers' income
         Finc(J,Z)            Accounting for farmers' income
         vinscred(f,pc,z)   Formal (institutional) credit by zone
         vinfcred(f,pc,z)   Informal  credit by zone
         SLx(fhlab,p)       Sell of family  Labor
         HLx(fhlab,p)       Hire outside Labor
         Gumall(j)          Total cultivated gam arabic
        Wtmall(j)           Total cultivated watermelon
         Krkall(j)          Total cultivated karkadeh

Positive Variables Dx,X,Tx,E, Rcap, yinc, finc, CCTA, M, vinfcred, vinscred, hlx,
slx,gumall,wtmall,krkall ;

parameters
     CTx(j,z)          Marketing costs
     CX(j,z)           Production costs
     cm(Z,km,t)        Costs of capital (imported/improved)
     EXPVALUE   Export limit
     grncnm            Grain consumption limit ;
```

```
* scalars
*       Expvalue     /120000/
*       grncnm       /582.84/
*       inscred      /6.0/
*       infcred      /2.0/

Equations
            Profit                    Define Objective Function
            ScommBal(J)               Sectoral Commodity Balance
            ZcommBal(J,Z)             Zonal Commodity Balance
            Reslnd(k,Z,T)             Land Resource Restriction
            Reslab(k,p,z)             Labor Resource Restriction
            Rescap(k,pc,Z)            Capital Resource Restriction
            ConvComb(J)               Convex Combination Constraints
            ExpLimit                  Export limit for Exportable J Commodities
            HomRet(Z)                 Home retention of J grain
            InAccRow                  Dealer traders' income accounting row
              TImportBl(j,z,t,km)     Technology Import/improved input Balance
            FarmInRow                 Farm income accounting row
              mlndsks                 Mechanized land limit for sks
              mlndwks                 Mechanized land limit for wks
              infcredlim              Informal credit limit
              inscredlim              Institutional credit limit
              MarkSes                 Marketed sesame
              MarkGnt                 Marketed Groundnut
              sheeplim                Sheep limit
             Cendy(z)                 End of year cash balance
             Fofm(z)                  Farm own fund maintenance
             Gumlnd                   Total tapped gum
             Wtmlnd                   Total watermelon cultivation
             Krklnd                   Total karkadeh cultivation ;


Profit ..               income =e= SUM((J,D,S),w(J,D,S)*Dx(J,D,S))
                        + SUM((J,Z),Px(J,Z)*E(J,Z))
                                - SUM(p,hl("hlab",p)*hlx("hlab",p))
                        - SUM((j,z,km,t),pi(km,z,t)*M(j,z,km,t))
                        - SUM((J,A,Z,T),C(J,A,Z,T)*X(J,A,Z,T))
                        - SUM((J,Z), chat(J,Z)*Tx(J,Z))
                        - SUM((J,Z),Delta(J,Z)*Rcap(J,Z))
                                - sum((f,pc,z),crd(f,z)*vinscred(f,pc,z))
                                - sum((f,pc,z),crd(f,z)*vinfcred(f,pc,z)) ;
*                              + SUM(p,fl("flab",p)*slx("flab",p))     ;

ScommBal(J)..                   SUM((D,S),Seta(J,D,S)*DX(J,D,S))
                        + SUM(Z,E(J,Z))
                        - SUM(Z,Y(J,Z)*TX(J,Z)) =L= 0       ;

MarkSes..             sum(z,y("sesame",z)*Tx("sesame",z)) =g= sum(z,e("sesame",z))
```

```
                              +
sum(s,0.6*Seta("sesame","cake",S)*DX("sesame","cake",S))
                              + sum(s,0.4*Seta("sesame","oil",S)*DX("sesame","oil",S)) ;

MarkGnt..                    sum(z,y("gnut",z)*Tx("gnut",z)) =g= sum(z,e("gnut",z))
                                  +
sum(s,0.6*Seta("gnut","cake",S)*DX("gnut","cake",S))
                                  + sum(s,0.4*Seta("gnut","oil",S)*DX("gnut","oil",S)) ;

ZcommBal(J,Z)..               y(J,Z)*TX(J,Z) - SUM((A,T),YX(J,A,Z,T)*X(J,A,Z,T)) =L=
0   ;

*ImportBlce(Z)..              sum((km,t),M(km,Z,t)) -
SUM((j,A,t),(sum(km,tech(J,A,z,km,t)))*X(J,A,Z,T)) =L= 0  ;

TImportBl(j,Z,t,km).. M(j,z,km,t) - SUM(A,tech(J,A,z,km,t)*X(J,A,Z,T)) =g= 0  ;

Reslnd("land",Z,T)..  SUM((J,A),Aln("land",J,A,Z,T)*X(J,A,Z,T)) =L= Bl("land",T,Z);

mlndwks..                     SUM((J,A),Aln("land",J,A,"wks","mec")*X(J,A,"wks","mec"))
=g= 0 ;

mlndsks..                      SUM((J,A),Aln("land",J,A,"sks","mec")*X(J,A,"sks","mec"))
=g= 0 ;

Reslab("labor",p,z).. SUM((J,A,T),Alab("labor",J,A,Z,P,T)*X(J,A,Z,T)) =L=
Blb("labor",P,Z)
                                                   -HLx("hlab",p);

Rescap("capital",pc,Z)..     SUM((J,A,T),Acap("capital",J,A,Z,pc,T)*X(J,A,Z,T))
                                     +sum(cta,ctareq (cta,pc,z)*ccta(cta,pc,z)) =L=
Bc("capital",pc,Z)
                                     +crdreq("inscred",pc,z)*vinscred("inscred",pc,z)
                                     +crdreq("infcred",pc,z)*vinfcred("infcred",pc,z)
                                     -SUM((km,t,j),pi(km,z,t)*M(j,z,km,t))- SUM(J,
chat(J,Z)*Tx(J,Z));

inscredlim..                   sum((pc,z),vinscred("inscred",pc,z)) =g= 0 ;

infcredlim..                  sum((pc,z),vinfcred("infcred",pc,z)) =g= 0 ;

ConvComb(J)..                    SUM((D,S),wd(j,d,s)*DX(J,D,S)) =l= 1  ;

ExpLimit ..                 SUM((J,Z),Pxd(J)*E(J,Z)) =e= EXPVALUE  ;

sheeplim..                     sum(z,Tx("sheep",z)) =g= 0 ;

HomRet(Z)..
SUM((J,A,T),Yx(J,A,Z,T)*X(J,A,Z,T))+SUM(J,rg(j,z)*Rcap(J,Z)) =G= G(Z);
```

```
InAccRow ..                SUM((j,d,S),rr(j,d,S)*Dx(j,d,S)) + SUM((J,Z),Px(J,Z)*E(J,Z))
                              - SUM((J,Z),chat(J,Z)*Tx(J,Z)) - sum((J,Z),Yinc(J,Z))  =E=
0   ;

FarmInRow ..                    SUM((j,d,S), rr(j,d,S)*Dx(j,d,S))+
SUM((J,Z),Px(J,Z)*E(J,Z))
                              - SUM((J,A,Z,T),C(J,A,Z,T)*X(J,A,Z,T)) -
SUM((J,Z),chat(J,Z)*Tx(J,Z))
                             - SUM((J,Z),Delta(J,Z)*Rcap(J,Z)) - sum((J,Z),Finc(J,Z))
=E= 0  ;

Cendy(z) ..                  -sum(j,Finc(j,z)) - ccta("ctr34","3",z) + ccta("ctr4o","4",z)
=e= 0 ;

Fofm(z) ..                   -SUM(pc,crdpi("inscred",pc,z)*vinscred("inscred",pc,z))
                             -SUM(pc,crdpi("infcred",pc,z)*vinfcred("infcred",pc,z))
                             +ccta("ctr4o","4",z) =g= bc("capital","1",z) ;

GumInd..                     Gumall("gumarabic")=e= SUM((A,z,T), Aln
("land","gumarabic",A,Z,T)*X("gumarabic",A,Z,T)) ;
WtmInd..                     Wtmall("wmillon")  =e= SUM((A,z,T), Aln
("land","wmillon",A,Z,T)*X("wmillon",A,Z,T)) ;
KrkInd..                     Krkall("karkadeh") =e= SUM((A,z,T), Aln
("land","karkadeh",A,Z,T)*X("karkadeh",A,Z,T)) ;

MODEL FARM1  /ALL/  ;
option limrow= 3 ;
$OFFLISTING ;
X.UP("sheep",A,"NKS",T) = 222.3 ;
X.LO("sheep",A,"NKS",T) = 111.1 ;
X.UP("sheep",A,"WKS",T) = 474.9 ;
X.LO("sheep",A,"WKS",T) = 237.4 ;
X.UP("sheep",A,"SKS",T) = 93.9  ;
X.LO("sheep",A,"SKS",T) = 0  ;
Gumall.UP("gumarabic")  = 210;
Gumall.LO("gumarabic")  = 33;
Wtmall.UP("wmillon")    = 31.1;
Wtmall.LO("wmillon")    = 4.5;
Krkall.UP("karkadeh")   = 174;
Krkall.LO("karkadeh")   = 20.3;
Dx.LO("gnut","oil","1") = 1.0 ;
Dx.LO("sesame","oil","1") = 1.0 ;
FOR (EXPVALUE = 90000 TO 120000 BY 10000,
FOR (GRNCNM = 400 TO 600 BY 100,
SOLVE FARM1 USING LP MAXIMIZING INCOME ;
CTx(j,z) = chat(J,Z)*Tx.l(J,Z) ;
CX(j,z)  = SUM((A,T),C(J,A,Z,T)*X.l(J,A,Z,T)) ;
CM(z,km,t) = SUM((j,A),pi(km,z,t)*M.l(j,z,km,t));
DISPLAY Dx.L, E.L, M.L, X.L, Tx.L, Rcap.L, vinfcred.l, vinscred.l,Finc.L,Yinc.L,
CTx,CX, ccta.l, CM, HLx.l, FOFM.l,
```

gumall.l,Wtmall.l,Krkall.l,Reslnd.m,Reslab.m,Rescap.m,ScommBal.m,ZcommBal.m,ConvComb.m,ExpLimit.l,HomRet.l,Profit.l)) ;

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