Chapter 2
Agriculture and farming systems

THE AGRICULTURE SECTOR

The Sudanese economy is predominantly agricultural (including crop and livestock production, forestry, wildlife and fisheries) with an overall average contribution of about 45 percent to the country's gross domestic product (GDP) (Table 4).

TABLE 4
GDP shares of the agriculture subsectors, 1992–2004

Subsector	Average 1992–94	Average 2002–04
	(%)	
Agriculture	40.3	45.4
Irrigated crops	10.9	12.3
Rainfed semi-mechanized crops	3.2	2.1
Rainfed traditional crops	4.9	7.5
Forestry & others	2.9	3.0
Livestock	18.4	20.5

Source: Bank of Sudan, annual reports.

In 2003, the agricultural share of the GDP increased by 5.2 percent compared with the previous year, in 2004 by 4.5 percent, marked by a recovery in the rainfed mechanized sector in these two years. The agriculture sector provides for some three-quarters of the population, accounts for about two-thirds of the employment and supplies about 60 percent of the raw materials needed by the manufacturing sector. Agriculture provides more than 90 percent of the non-oil export earnings. Cotton is the main export commodity, followed by oilseeds and livestock. The Sudan is the world's largest producer of gum arabic, whose exports range between 20 000 and 40 000 tonnes and earn some US$50–80 million.

LAND TENURE

The Permanent Constitution of 1973 established the rights to own, bequeath and inherit property. However, these rights were suspended in 1985.

The Sudan has long had a system of land registration through which an individual, an enterprise or the government could establish title to a piece of land. Such registration was used extensively in northern Sudan, especially in Al Khartoum, Al Awsat and Ash Shamali provinces. Before 1970, all other land (unregistered) belonged to the State, which held ownership in trust for the people who had customary rights to it. In 1970, the Unregistered Land Act declared that all wasteland, forest and unregistered lands were government land. Before the passage of this act, the Government had avoided interfering with individual customary rights to unregistered land, and in the late 1980s it again adhered to this policy.

The Government owned most of the land used by the modern agriculture sector and leased it to tenants (e.g. in the Gezira scheme) or to private entrepreneurs, such as most operators of large-scale mechanized rainfed farming. However, in the late 1980s, the large area of land used for pasture and for subsistence cultivation was communally owned under customary land laws that followed a broadly similar pattern. In agricultural communities, the right to cultivate an area of unused land became vested in the individual who cleared it for use. The rights to such land could be passed on to heirs but normally the land could not be sold or otherwise disposed of. The right also applied to land left fallow although there were communities in Bahr al Ghazal, Aali an Nil and Al Istiwai where another individual could claim such land by clearing it.

Among the northern communities practising transhumance, the rights to cultivated land were much the same, but the dominant position of livestock in community activities had introduced certain other communal rights, e.g. common rights to grazing land, and right-of-way to water and grazing land.

In the western savannahs, private ownership of stands of *hashab* trees could be registered, an exception to the usual government ownership of the forests. However, dead wood for domestic fuel and the underlying grass were common property. Water, a matter of greatest importance to stock raisers, was open to all if free standing, but wells that had been dug and the associated drinking troughs were private property and were retained by the person who dug them season after season.

In northern Sudan, especially in the western savannah where increasing population and animal numbers have put pressure on the land, violations of customary laws and conflicts between ethnic groups over land rights have been increasing. Local government agencies have attempted to resolve these problems, but only on a case-by-case basis.

LAND USE

As at 1991, only partial surveys of the land resources of the Sudan had been made, and estimates of the areas included in different land-use categories varied considerably. Figures for potentially arable land ranged from an estimate of 35.9 million ha made in the mid-1960s to one of 84 million ha published by the Ministry of Agriculture and Natural Resources in 1974. Estimates of the amount of land actually under cultivation ranged from 7.5 million ha, including about 10–11 percent in fallow, to 12.6 million ha.

Substantial variations also exist in land classified as actually used or potentially usable for livestock grazing. The Ministry of Agriculture and Natural Resources and FAO have classified about 24 million ha as pastureland. The 1965 estimate of land use classified 101.4 million ha as grazing land. In 1975, an interagency mission of the International Labour Organization (ILO) and the United Nations Development Programme (UNDP) to the Sudan estimated the total potential grazing land at between 120 million and 150 million ha.

However, in the late 1980s, the consensus was that the Sudan still had a substantial amount of land suitable for future cropping. The 1975 ILO–UNDP mission believed that two-thirds of the potential area for livestock grazing was already in use.

In addition to land suitable for cultivation and livestock grazing, the Sudan also has about 76–86 million ha of desert. In addition, swamps and inland waters cover an area of about 2.9 million ha, and urban settlements and other features created by human activity cover about 0.3 million ha.

FARMING SYSTEMS

Farming systems in the Sudan are functions of the AEZs and socio-economic conditions. There are three main farming systems for crop production: irrigated, semi-mechanized and traditional. Other farming systems are: livestock, fishery and forestry.

Historically, large-scale Nile-based irrigation schemes have been a pillar of the Sudan's strategy for agricultural development. There are 1.7–2.1 million ha of irrigated land within the Nile River basin in

TABLE 5
Government irrigation schemes in the Sudan

Scheme	Equipped irrigation area ('000 ha)
Gezira and Managil	871
White Nile pump schemes	192
New Halfa	152
Rahad	122
Blue Nile pump schemes	113
Gash Delta (spate irrigation)	101
Northern pump scheme	42
Suki	35
Tokar Delta (spate irrigation)	31
Guneid Sugar	16
Assalaya Sugar	14
Sennar Sugar	13
Khashm El Girba	18
Other areas	143
Total	1 863

Source: FAO AQUASTAT.

Northern, Khartoum, Gezira, Sennar, Blue Nile and White Nile States. The Government owns and manages the Gezira scheme (0.9 million ha) and the Rahad, Suki and New Halfa schemes (0.4 million ha) (Table 5).

A rainfed, commercial semi-mechanized farming system has been developed on generally alkaline clay soils and loams. It extends to about 5.9 million ha in the states of El Gadaref, Blue Nile, Upper Nile, White Nile, Sennar and Southern Kordofan.

The rainfed, traditional farming systems are the main subsistence systems prevalent almost everywhere in the Sudan, accounting for an area of 9.2 million ha, mostly in Kordofan, Darfur, White Nile and Blue Nile States.

Cattle, goats, sheep and camels (about 130 million head in total) constitute the bulk of the livestock sector. Livestock in the Sudan may be classified as extensive, semi-intensive and intensive systems depending on the types of animals reared and whether for subsistence, traction or market. The extensive system is entirely dependent on natural pasture and is physically, socially and economically fragile. The system concerns the vast majority of herders in the drylands of the country. Unlike the extensive system, the intensive system requires considerable skills, efficient management and a great deal of animal feed. It is common in the irrigated and urban areas. The semi-intensive system lies between these two systems. Seventy percent of the rural population are agropastoralists.

Despite the fact that the ratio of cultivable land per person is high (about 3 ha/person), the Sudan faces food deficit problems and a lack of other basic needs, especially in rural areas.

Traditional farming systems

The contribution of crops and livestock to GDP fluctuates considerably. The available evidence suggests that GDP growth in agriculture has stemmed mainly from increases in the cultivated area in rainfed farming regions. This increase has come at a cost to the environment, while yields have declined on a long-term basis (Figure 6). In essence, there has been an unsustainable increase in the area harvested (Figure 7) and a decline in productivity for more than two decades.

Comparing the average productivity (yields) of the main cultivated crops (sorghum, millet, sesame and groundnut) in the traditional rainfed sector for the period 1992/93–2002/03 with the period 1970/71–1980/81 and assuming constant prices, farmers would have had to increase their cultivated area by 75 percent in order to maintain the same level of 1970/71 income.

If the trend of expansion in the area of sorghum continues, it is likely to have serious consequences on the sustainability of crop yields in the traditional farming systems and for farm incomes. It is particularly alarming for the poor because even in years of high output from crops and

FIGURE 6

Trends in yields of rainfed sorghum in semi-mechanized and traditional areas

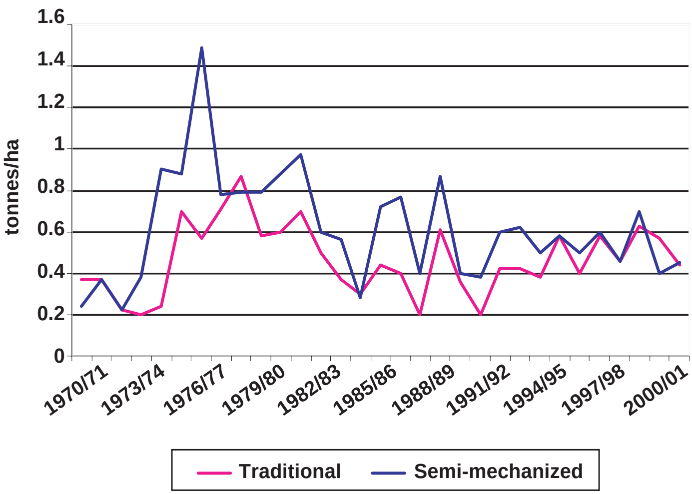
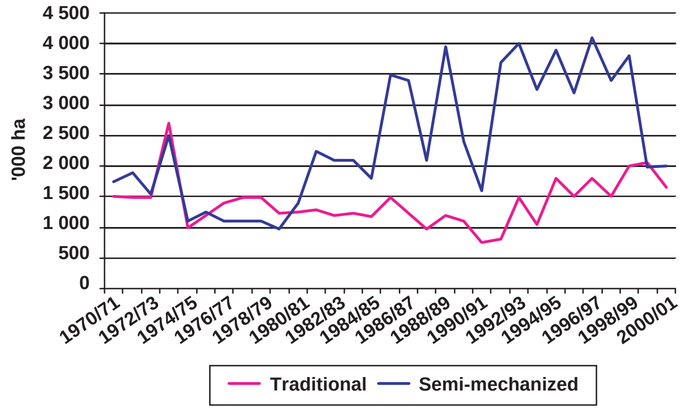


FIGURE 7

Trends in harvested area of rainfed sorghum in semi-mechanized and traditional areas



livestock the traditional farming areas produce a proportion of rural GDP that is lower than the proportion of the rural population that lives there.

Families living in the traditional farming areas find employment as casual labour for short periods outside the region. However, these opportunities have declined in the last 10–15 years. The traditional rainfed sector obtained only 1–5 percent of all formal agricultural credit in 2001 and received few other support services, such as research and extension. Public investment in the basic infrastructure for rural and agricultural development is also negligible. It is not surprising that yields are low and declining or stagnating for most crops. The pastoralists and small farmers in the traditional sector are those most vulnerable to poverty. Therefore, improved productivity in the traditional farming areas is of crucial importance if the large number of people who are to some extent dependent on this farming system are to improve their incomes.

Semi-mechanized farming systems

The GDP from semi-mechanized farming has been declining, although a partial recovery occurred in 2003 and 2004. In the 1980s, 1–2 million labourers moved to the semi-mechanized farming areas where they could find three to four months work at weeding and harvest time. This number has fallen by at least half as a result of the decline in the semi-mechanized farming areas, together with the substantial reduction in the irrigated cotton areas. This has serious negative implications for many families in the traditional rainfed farming areas that depended on the employment in the semi-mechanized subsector.

The situation could worsen if the current trend toward a decline in the domestic and international demand for sorghum continues and there is no diversification into other crops. The absence of appropriate land tenure policies and environmental considerations are among the main constraints on this subsector.

Irrigated farming systems

The proportion of the irrigation sourced from surface waters, as opposed to groundwater (wells), was 96 percent in 1995. In 2000, 11 percent of the cultivated area was equipped for irrigation (Table 6). Between 1995 and 2000, the area with full or partial control fell at a rate of 0.9 percent/year.

Wheat, cotton, sorghum and groundnut are the most important crops in irrigated areas. While having a positive impact in some subsectors (e.g. livestock), liberalization had a negative impact on the irrigated subsector. The irrigated schemes were privatized without passing through a transitional stage, which could have paved the way for active private-sector involvement. When the schemes were privatized, the situation became one of a run-down irrigation infrastructure, withdrawal of basic agricultural services, and a lack of alternative source of credit. The poor performance of the irrigation schemes in the 1990s had a serious impact on the employment and welfare of farmers and of the many landless labourers living in the irrigation schemes.

Reductions in the areas of the traditional crops led to opportunities for other crops such as vegetables and a substantial increase in livestock production. This diversification was important

TABLE 6
Irrigated areas in the Sudan

Irrigation	Year	'000 ha
Full or partial control	2000	1 731
Spate	2000	132
Area equipped for irrigation	2000	1 863
Area salinized	1999	199

Source: FAO AQUASTAT.

but did not reduce the need for substantial reforms in the management of the large schemes such as the Gezira scheme.

Water users associations (WUAs) will in the future be responsible for water management of the irrigation system and collection of water fees will be established. Water fees, cost of inputs and services provided by the Government will be charged on the basis of full cost recovery.

Figure 8 shows that the area of irrigated wheat also fluctuated substantially between the mid-1980s and the end of the 1990s, and that the area planted to cotton declined steadily. This is partly a reflection of the poor management of cotton production in government-run irrigation schemes. As the area of irrigated cotton declined, it was offset by an increase in the area of irrigated sorghum until the early 1990s, but then this area fell again to about the same level as in the late 1980s. The main reasons were considerable pressure on the government-owned and government-run schemes to increase grain production. The Government requested that the irrigation schemes increase wheat and sorghum production as a contribution to its food security initiative, which it had

FIGURE 8
Trends in harvested areas of irrigated wheat and cotton

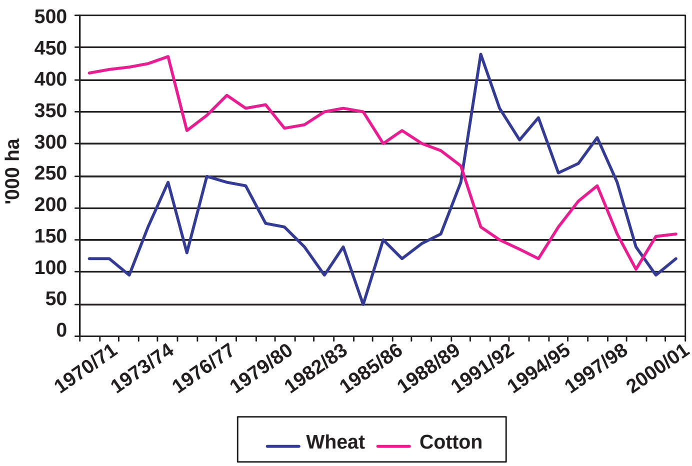
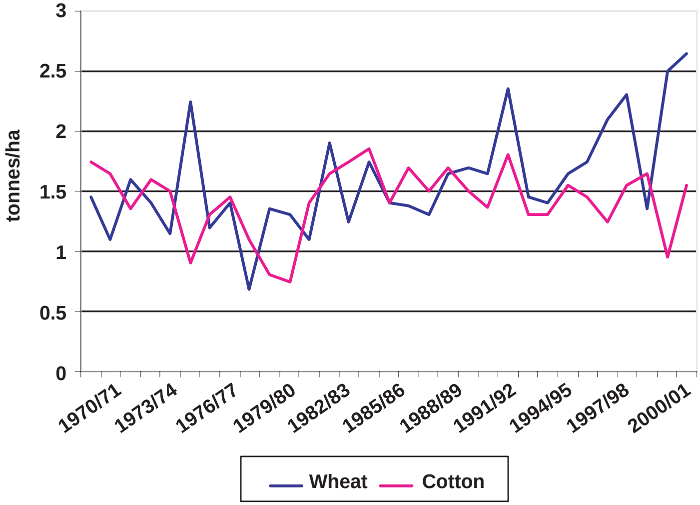


FIGURE 9
Trends in yields of irrigated wheat and cotton



introduced because of concerns about the impact of drought on rainfed sorghum production.

Farmers were strongly encouraged and assisted through credit programmes to produce wheat. With these inducements, the area under wheat increased sharply in 1990/91. The Government stimulated production using two main policies: (i) declaring an attractive price before planting at which the Government would purchase the production; and (ii) providing inputs for wheat production. Wheat production declined steadily after 1991/92 when the Government abandoned its efforts to stimulate an increase in grain production as part of its food security strategy. In subsequent years, reduced credit for wheat production has led to reductions in the area planted.

Figure 9 shows that wheat yields fluctuated considerably throughout the 1980s and 1990s and that production followed a similar trend, increasing on average at about 7 percent/year.

Table 7 shows the irrigated crops in full or partial irrigation schemes.

TABLE 7
Irrigated crops

Crop	Year	'000 ha
Cotton	2000	167
Fodder	2000	142
Groundnuts	1989	91
Maize	2000	68
Other roots and tubers	2000	16
Potatoes	2000	16
Rice	2000	4
Sorghum	1989	355
Sugar cane	2000	70
Sunflower	2000	21
Vegetables	2000	97
Wheat	2000	103

Source: FAO AQUASTAT.

TABLE 8
Average yields of irrigated crops

Crop	Average yield	Potential yield
	(tonnes/ha)	
Millet	0.6	3.6
Sorghum	1.5	3.8–5.7
Wheat	1.6	3.3–4.1

Source: Agricultural Statistic Department, MOAF.

In terms of overall production, irrigated farming accounts for 99 percent of cotton, 100 percent of wheat, 52 percent of groundnut, 100 percent of sugar cane, 25 percent of sorghum, and 80 percent of fruits and vegetables.

Average yields in the irrigated areas are far higher than in the rainfed areas but are still below their potential, especially compared with yields obtained at research stations and by productive farmers. This is attributable to a variety of constraints and limitations.

Table 8 compares average crop yields with the potential yield with improved cereal varieties in the irrigated sector.

The cotton yield under irrigated systems is generally low, at about 5.5 kantar per feddan (1 kantar equals 143 kg of seed cotton, which gives about 45 kg of lint). Heat stress, pests and diseases are major causal factors. A few improved varieties have been released for the irrigated sector, and research is in progress to produce high-yielding and disease-free varieties.

The yields of oil crops (groundnut and sunflower) in the irrigated sector are very low: 2 000 kg/ha for groundnut and 793 kg/ha for sunflower. Improved varieties of groundnut (*kriz*, *medani* and *sudan*) have been released.

Table 9 provides a comparison of actual with potential yields in the Rahad irrigation scheme.

TABLE 9
Potential and actual crop yields in the Rahad irrigation scheme

Crop	Potential yield	Minimum actual yield		Maximum actual yield	
	(kg/ha)	(kg/ha)	(% of potential)	(kg/ha)	(% of potential)
Groundnut	760	160	21	340	45
Sorghum	400	120	30	284	71
Wheat	600	100	17	380	63
	(kantar/ha)	(kantar/ha)	(% of potential)	(kantar/ha)	(% of potential)
Cotton	3.6	1.2	32	2.9	80

Source: FAO AQUASTAT.

Large-scale irrigation schemes have not been financially sustainable. Therefore, they have needed subsidies from the federal budget as well as government guarantees for obtaining credit from commercial banks. Efforts to control production practices, including the choice of crop by the farmer, have resulted in farmers producing crops that are less susceptible to control by these measures. Performance problems in irrigation schemes include: inefficient water management; non-collection of water charges and land-use fees; low productivity; and large debt burdens. Government support to these large-scale subsidized schemes has deprived other agriculture subsectors of funds needed for the development of basic infrastructure and support services.

The Gezira scheme

The primary objective of the Gezira scheme was to produce cotton. The land is farmed by 114 000 tenants on an average holding of 20 feddan (about 8 ha). The scheme consists of 18 large units called “groups”, which range in size from 60 000 to 190 000 feddans. Each group consists of smaller units called “blocks”. These blocks consist of “numbers”, each of 90 feddans. Each tenant has to plant according to the approved rotation so that, for example, all the cotton grows at the same time. Initially, the tenants practised a six-course rotation. However, because of many failures, this was changed in the early 1980s to an eight-course rotation (cotton, fallow, fallow, cotton, fallow, sorghum, cowpea and fallow), with a nominal cropping intensity of 50 percent. This kept the demand for water within the capacity of the irrigation system. Since then, there has been further diversification and intensification.

Until recently, the main Gezira scheme had a nominal cropping intensity of 75 percent in a five-course rotation of cotton, wheat, groundnuts and sorghum with one fallow, while the Managil scheme had a 100-percent cropping intensity with no fallow. However, fallow has now also been introduced in the Managil scheme in order to give a target cropping intensity of 75 percent throughout, although various problems have kept the actual intensity below that figure in recent years.

AGRICULTURAL RESEARCH

Until 2001, several research institutes under different ministries administered various aspects of the national agricultural research programme. Under administrative reforms approved in 2001, the Government put all the research institutes, except the Animal Resources Research Corporation (ARRC), under the responsibility of the newly established Ministry of Higher Education and Scientific Research. The ARRC deals with livestock, while the Agricultural Research Corporation (ARC) is responsible for crops, forestry and pastures. A number of public universities (also under government control) contribute to agricultural research. The National Research Centre for Genetic Engineering is responsible for applied genetic research. The Industrial Research Centre is responsible for food science and medicinal plants; and the Atomic Energy Research Centre is responsible for mutation breeding, food preservation and sanitation.

Agricultural research has long been underfunded. Currently, the annual budget allocated to the ARC, ARRC and universities is only about 0.03 percent of GDP. The limited budget has resulted in a decline in staff numbers, reduced resources for funding research activities in the field, and a deterioration in the research facilities because of a lack of maintenance. Despite these difficulties, the ARC still has a staff of 250 researchers and in the last year it has generated some 60 innovations. However, few of the technologies developed have undergone testing in the field. An important challenge is to make them available in regions where they are relevant. There has been virtually no economic evaluation of technologies.

Another challenge facing agricultural research is the need to focus on small-scale farmers. Most agricultural research programmes tend not to be based on integrated land-use management or farmers' needs. The focus is often on high-input technologies for industrial crops, which may benefit large-scale farmers or those in irrigation schemes. Innovative, low-input technologies and farming systems, which could benefit small-scale farmers in rainfed areas, have often been neglected.

Research has developed packages for the sustained production of most crops grown under irrigation. These packages are available to the extension service, production schemes and private sector. Types, quantities, rates and/or times of application of inputs are usually specified for each crop. These packages have been developed and approved by the ARC after a long period of research. The variables include:

- high-yielding varieties of better quality that are tolerant to water or heat stress;
- land preparation;
- nutrient requirements;
- adequate water requirements;
- economic pest control;
- weed control;
- harvesting.

TECHNOLOGY TRANSFER AND EXTENSION

Extension is the responsibility of the individual states. The new national strategy for agriculture, launched in 2001, and the recognition that extension is a critical factor in improving agricultural production and food security, led to the Extension Department becoming the Technology Transfer and Extension Administration (TTE). The TTE plans to establish a network with administrations in the state ministries responsible for agriculture and working with the states, the ARC and universities. Plans are in place to have ten technology transfer and farmer training centres by 2006 and to have 2 000 demonstration farms. There is also a plan to merge the extension services for rainfed and irrigated crops.

The TTE has four main thematic programmes: improving crop productivity: promotion of improved seeds; integrated mechanization; and development for rural women. Only about 10 percent of farmers use certified seeds. Until recently, central government handled seed production and certification through the Seed Unit of the Extension Department in the Ministry of Agriculture and Forestry (MOAF). However, the seeds were not of good quality and they were also expensive. National seed production was limited to field crops, while seeds for horticultural crops were usually imported. The Seed Multiplication Department in the MOAF was semi-privatized in 2000 and entrusted to a new joint ownership company (public–private). The Government donated physical assets to the newly formed Arab Sudanese Seed Company, taking a 42 percent share of the company's capital. The Arab Authority for Agricultural Investment and Development (AAAID), Al Aktan Company and the Farmers' Bank provided the remaining financing. The TTE retained responsibility for seed certification and control.

AGRICULTURAL CREDIT

In total, formal lending to agriculture in 2001 was about SD44 000 million (US$183 million). About 58 percent of this credit was extended to irrigated agriculture, mainly for cotton production. Semi-mechanized rainfed agriculture and some large livestock enterprises received about 40 percent, while traditional small-scale farmers received only 1–2 percent.

The main sources of finance for irrigated agriculture are the Ministry of Finance and National Economy (MOFNE), the government-owned Agriculture Bank of Sudan (ABS) and commercial banks. A consortium of commercial banks has agreed to contribute to the financing of the agriculture sector. The MOFNE has considerable contingency liabilities through its guarantee of loans extended by commercial banks via the consortium. Other sources include the Sudan Cotton Company (SCC), and the Sudan Gezira Board provides fertilizer on credit to farmers.

In spite of the high contribution of the agriculture sector to GDP, the ratio of formal agricultural credit to the GDP in Sudan is very low compared with certain other Arab and Asian countries (Table 10).

Informal credit is an important source of finance for agriculture, but information on its extent is not available.

Lending to the agriculture sector commenced with the formation of the ABS in 1957. The ABS now has 91 branches and its loans provide about 20 percent of farmers' total credit requirements. On average, two-thirds of the credit disbursed by the ABS in the period 2000–02 was for the irrigated sector compared with only 9 percent for the traditional rainfed sector (Table 11).

TABLE 10
Ratio of agricultural credit to GDP in selected countries

Country	Credit as % of GDP
Bangladesh	14.1
Egypt	4.7
India	8.4
Jordan	2.5
Morocco	4.7
Oman	0.3
Pakistan	4.3
Philippines	17
Republic of Korea	24
Sudan	0.3
Syrian Arab Republic	8
Thailand	15
Tunisia	2.5

Source: MOAF, Committee Report, Decree No. 3/2003.

The prospects for improving the availability of credit to small-scale farmers are poor without government guarantees or collateral provided for loans. The ABS has attempted group lending but this has proved unsuccessful and costly.

Traditional farmers are a poor credit risk because of their uncertain environment, low yields (even in good years), remote location and inadequate infrastructure for marketing and support services.

The important policy changes needed for the irrigated sector are mainly structural. The most important are changes in the Land Act to allow conversion of tenants' current rights into tradable long-term leases. This arrangement coupled with the introduction of a sustainable savings and crop insurance system in the major irrigation schemes, through the creation of farmer-owned savings associations, will facilitate access to credit. Crop insurance will also provide more security to lending institutions.

TABLE 11
Annual disbursements by the ABS by farming system

Farming system	2000	2001	2002	Average	Percent of total
	(SD thousand million)				(%)
Traditional rainfed	0.54	0.33	0.55	0.47	8.9
Semi-mechanized rainfed	0.82	1.61	1.37	1.27	36.4
Irrigated	1.72	3.27	5.47	3.49	66.7
Total	2.28	5.21	7.39	5.23	100

Source: ABS.

AGRICULTURAL MARKETS: INPUTS AND OUTPUTS

Until 1992, the Government largely controlled the marketing of agricultural inputs and outputs. However, as part of the economic reforms in the 1990s, it removed most of the controls in favour of private traders. Private bodies now undertake the marketing of most agricultural commodities, including livestock. The remaining government interventions relate to cotton and sugar, and the pricing systems for both commodities are tied to international prices. The SCC sets farmgate prices for seed cotton, and the MOAF continues to announce a minimum price for gum arabic.

Since 1990, private traders have been playing an increasing role in input procurement and distribution systems. Private-sector specialist organizations are becoming increasingly important suppliers of seeds for the main field crops and vegetables. The ginneries select and distribute cotton seed. There is a proposal to privatize cotton-ginning activities. The National Seed Propagation Administration has been privatized and is now the Sudanese Arab Seed Company (SASC). Private companies, specialized banks and public schemes import crop protection chemicals and farm machinery.

While there are no longer restrictions on the importation of fertilizers, the fertilizer supply system still reflects the previous emphasis on cotton, and the SCC still largely coordinates their procurement and distribution. However, traders are increasingly contracting with farmers at the beginning of the season and they sometimes provide production inputs or land preparation services. The remaining state intervention hinders private traders from playing a more active role in the procurement and distribution of crop production inputs.

Chapter 3
Fertilizer use in the Sudan

CONSUMPTION OF MINERAL FERTILIZERS

Rainfed farming, whether mechanized or traditional, rarely uses any fertilizer, although responses of durum wheat and cotton to N and P are reported in high-rainfall areas. Fertilizer is used in the irrigated sector to varying degrees (Table 12).

TABLE 12
Mean fertilizer nutrient consumption in the irrigated sector, 2000–02

Fertilizer	N	P_2O_5	K_2O
	('000 tonnes nutrient)		
Urea	54.3		
Triple superphosphate		11.1	
Potassium chloride			3.8

Source: FAOSTAT.

Some NPK fertilizers are imported, mainly for use on vegetables. On the basis of a cultivated area of 16.6 million ha, this amounts to only 4 kg of plant nutrients per hectare. Table 13 lists estimates of the proportions of fertilizers used on the major crops.

PRICES OF IMPORTED FERTILIZERS

Table 14 evidences the rising prices of imported urea and triple phosphate (TSP) since 1995.

TABLE 13
Approximate proportions of fertilizers applied by crop

Crop	Urea	TSP	NPK
		(%)	
Cotton (2N–3N)	about 35	0	0
Wheat (2N–1P)	20–30	60	0
Sorghum (1N)	15–20	0	0
Sugar cane (4N–5N)	20	20	0
Vegetables (2N) NPK	10	5	90
Other crops	0	15	10

Note: 1N = basic dose of N × 1, 2N = basic dose of N × 2, 1P = basic dose of P × 1, etc. The basic doses are: 1N = 40 kg N fertilizer/feddan, 1P = 40 kg P fertilizer/feddan, and 1K = 40 kg K fertilizer/feddan.
Source: Approximations from figures of MOAF, Arab Organization for Agricultural Development and FAOSTAT.

TABLE 14
Fertilizer import prices, 1995–2005

Year	Urea		TSP	
	(SD/tonne)	(US$/tonne)	(SD/tonne)	(US$/tonne)
1995	19 142	73.63	1 445	54.02
1996	25 075	96.45	38 056	146.37
1997	40 896	157.29	44 380	170.69
1998	29 048	111.72	41 536	159.86
1999	30 346	116.72	46 634	179.36
2000	38 653	150.99	44 390	173.40
2001	22 769	87.58	45 397	174.61
2002	36 263	139.47	42 144	162.09
2003	39 658	152.53	44 422	170.86
2004	56 040	215.54	59 609	229.27
2005	54 519	209.69	67 684	260.32

Source: MOAF; Agricultural Statistics Department, August 2005.

TABLE 15
Recommendations for N (as ASN) application

Crop	Application rate (kg ASN/ha)
Banana	285–475 kg N*/ha/year, split in 6 applications (every 2–months), including 285 kg ASN/ha, the rest coming from other N sources
Citrus	190–380 kg/ha, basal at the beginning of vegetation phase, 95–190 kg/ha after harvest
Cotton	140–240 kg/ha basal and 95–190 kg/ha between square formation and peak lowering
Cucumber	240 kg/ha as basal dressing, 1–2 additional dressings with the same quantity
Date-palm	0.2–0.4 kg per tree and application (3 per year)
Eggplant	285 kg/ha basal 1–2 top-dressings with 140 kg/ha
Groundnut/alfalfa	50–70 kg/ha as starter application owing to later N fixation by symbiosis
Maize	190–285 kg/ha basal and 95–190 kg/ha at 4 leaf-stage
Mango	190–380 kg/ha basal at beginning of vegetation phase, 95–190 kg/ha after harvest
Melons	285 kg/ha basal 1–2 top-dressings with 140 kg/ha
Onions	190 kg/ha basal and 2 top-dressings with 140 kg/ha each
Sesame	140–190 kg/ha in one basal application
Sorghum	140 kg/ha basal and 95 kg/ha at 2–4 leaf-stage
Sugar cane	190–240 kg/ha basal and 190–240 kg/ha three months later
Tomato	140–285 kg/ha at sowing/transplanting, second application with 95–240 kg/ha 3–4 weeks later
Wheat/durum	190 kg/ha basal and 95–140 kg/ha at shooting

* In N, not ASN.

RECOMMENDED RATES OF FERTILIZER APPLICATION

Table 15 shows the recommended application rates for ammonium sulphate nitrate, while Table 16 lists those for urea and TSP.

TABLE 16
Recommended rates of fertilizer application

Crop	Urea	TSP
	(kg/ha)	
Cotton	190	-
Sorghum	190	-
Sugar cane	475	95
Wheat	190	95

Source: MOAF; Agricultural Statistics Department, 2005.

FERTILIZER RESEARCH

The Sudan has a tradition of research on the use of mineral fertilizers, probably associated with the development of irrigated agriculture.

Early investigations (Burhan, 1969, 1971; Burhan and Jackson, 1973; Burhan and Taha, 1974) examined crop response to single-nutrient fertilizers in long-term trials on cotton, over 18 seasons, in a 3–4 course rotation. The soils were typical Vertisols, low in organic matter, poor in organic N, low in available P but with a good reserve of K, characterized by a high pH (7.5–8.5). The results were as follows:

- The response to 190 kg/ha of urea was consistent and significant in all 18 seasons.
- There was a positive response to P as TSP in about 30 percent of the seasons.
- Responses to K were rarely reported.

The response to P was attributed to variations in soil moisture before the planting season. In wet seasons, there was generally a positive response. This may also be related to the yield of cotton. Responses to the rate of urea application over four seasons revealed a curvilinear relationship for all four seasons.

In the 1960s and 1970s, a number of researchers examined the fertilization of sorghum and wheat. In this period, tissue analysis as an indicator of the fertilizer status of cotton was investigated.

Cooperative programmes

Some programmes have been carried out in cooperation with other agencies:

- FAO Fertilizer Programme 1977–1991;

- European Economic Community (EEC) Fertilizer Programme 1977–1987;
- ARC / International Center for Agricultural Research in the Dry Areas (ICARDA) / Organization of the Petroleum Exporting Countries (OPEC)/ Nile Valley Regional Programme (NVRP);
- Sasakawa Global 2000 (1980s);
- Gesellschaft für Technische Zusammenarbeit (GTZ – German development agency);
- International Atomic Energy Agency (IAEA);
- AAAID.

FAO Fertilizer Programme

The initial donor was Denmark, followed by the EEC, Belgium, the United Kingdom, the Netherlands, the International Fertilizer Industry Association and, later, Kuwait, Saudi Arabia, Morocco and the Arab Fertilizer Association. On-farm trials were carried out on cotton and wheat in Gezira. Demonstrations using N and P complemented the research findings. The programme also covered Khartoum, the Nile River and Gezira outside the scheme. Later, it included the White Nile River, the Blue Nile River, Kassala, Kordofan and Jabal Marrah. Trials were carried out on smallholder vegetable farms producing onions, tomatoes and potatoes. The programme procured fertilizers and other inputs and established rural stores. A good distribution system for inputs was established involving the ABS and implemented by the Extension Department of the MOAF. The programme involved about 1 000 demonstrations and trials, and 9 000 field days with 200 000 farmers participating.

ARC/ICARDA/NVRP

The programme ran from 1978 to 1994 and focused on cool-season legumes and wheat. Leguminous crops respond to small starter doses of N and P. The project addressed the needs for fertilizers on various soils (Gezira Vertisols, *Gerf*, upland terraces, and *Karu* soils). The programme involved both on-station and on-farm research. It established N and P recommendations for wheat in Gezira and the northern region, for different varieties on different soils (Ageeb and Abdalla, 1988; Gorashi, 1988; Ibrahim *et al*., 1991). The project was extended to New Halfa, where the response to phosphate was not significant. Foliar fertilization gave positive results, indicating a response to micronutrients and trace elements.

Global 2000

This programme started in the 1980s in association with Sasakawa Global 2000. Its aim was to promote wheat production and technology transfer to farmers. It covered most of the Gezira scheme and developed technological packages involving land preparation, food needs and balanced fertilization in both demonstrations and on-farm fields. The results achieved on wheat with the cooperation of the ARC and Gezira extension staff were very positive.

IAEA

This work involved trials with N^{15} and P^{32} and, in cooperation with GTZ, research on micronutrients.

AAAID

The AAAID was established in 1977 with the following objectives:

- development of agricultural resources and food production;
- exchange of agricultural products;
- promotion, financing and implementation of agricultural projects;
- research and studies;
- cooperation with relevant organizations.

The AAAID has carried out work on zero tillage in the context of a full technological package for all agricultural operations supported by an efficient management system. It has also conducted fertilizer trials on the effect of:

- Zn and boron (B) on grain filling of sunflower (5 ha);
- Zn and P on grain filling of sunflower (5 ha);
- P on the growth and yield of cotton (10 ha);
- P on the growth and yield of sorghum (5 ha);

- different sources of N (urea, ammonium nitrate) on the growth and yield of sorghum, cotton and sunflower (5 ha per crop).

The main findings were:

- The superiority of zero tillage was confirmed on the pilot farm.
- The local variety *wads ahmed* out-yielded local and imported sorghum varieties.
- The sunflower variety *hysun 33* out-yielded *damazin 1/3*, *panar 7353* and *panar 7393*.
- Application of B to sunflower resulted in an increase in grain filling.
- Application of P resulted in an increase in the yield of sunflower.

Cotton in irrigated schemes

A poor response of cotton to urea fertilization as well as N losses from urea have been reported, with a negative impact on yield. Comparisons showed that yields with NPK complex fertilizer, ASN and ammonium sulphate (AS) were higher than with urea. Possible explanations are that the N is present in a more readily available form for crop uptake and, therefore, losses are lower compared with urea. Moreover, the fertilizers tested contain more than one plant nutrient.

Sugar cane

An NPK fertilizer, ASN and AS were compared with urea on sugar cane on the Gunied and Kenana sugar estates. The rates were the equivalent of two, four and six times the basic dose of N compared with four times the basic dose of urea. NPK and ASN at the first two rates produced better yields and, in one trial, an equal yield compared with standard practice. These results need confirming on on-farm plots.

Sorghum in irrigated schemes

In recent years, sorghum yields in irrigated schemes have been falling. An NPK complex fertilizer, ASN and AS were compared with urea. A considerable yield increase was observed compared with standard fertilization practice using urea, possibly for the reasons mentioned for cotton.

Wheat

On-station and on-farm trials on wheat took place in 1999/00 and 2000/01 at Gezira, Rahad and New Halfa in order to test the effect of different sources and rates of N on the growth and yield of bread wheat. Both types of trials used different levels of NPK complex fertilizer, ASN and AS. Compared with the control (zero N), the application of the fertilizers resulted in a significant increase in grain yield at the three locations: 51–160 percent at Rahad, 39–162 percent at Wad Medani, and 13–45 percent at New Halfa. The N-use efficiency for all three sources was at its lowest level with the highest dose of N at all three locations. At Rahad, a single dose of ASN was more efficient under a low yield environment, as were two doses of N as NPK under a high yield environment. In Gezira, one dose of N as NPK or one dose of N as ASN seemed to be more efficient for the low-yield environment and two doses of N as NPK for the high-yield environment. At New Halfa, the response to the fertilizers and N-use efficiency for all three sources was relatively low; this warrants further research.

Groundnut in irrigated schemes

On-station and on-farm trials tested the response of groundnut to three sources of N fertilizer (NPK, ASN and AS) at two doses (0.5 N and 1 N) on the large irrigated schemes in the 2000/01 season. At New Halfa, Gezira and Sennar Research Station, the treatments gave a higher average yield than did the unfertilized control. At Rahad Research Station, a treatment of 1 N as AS and a treatment of 1 N as NPK gave the highest average yield compared with the control. At New Halfa, 1 N as NPK, 1 N as ASN and 0.5 N as NPK gave a higher yield than the control. The results for immature pods also followed this trend, apart from the treatment 0.5 N as NPK (which gave a lower number of pods than did the control). The result of the average number of pods per plant at Rahad Research Station shows that all the treatments gave lower numbers than did the control apart from a treatment of 1 N as AS and a treatment of 0.5 N as AS. However, the differences in all trials were not significant.

Sunflower

On-station trials and on-farm trials at Rahad and New Halfa for the seasons 1999/00 and 2000/01 evaluated the response of sunflower to different types of fertilizers. The fertilizers tested were NPK complex, ASN, AS and urea at varying application rates. Significantly higher yields were obtained in response to the application of fertilizers. The yield increases in the on-station trials were in the range of 43–81 percent and those in the on-farm trials were in the range of 27–100 percent.

Vegetables in irrigated clay soils

Field experiments carried out in the winter seasons of 1999/2000 and 2000/01 evaluated the effect of different sources of N on the yield performance of certain vegetables. The experiments were carried out at the Gezira and Rahad research farms using three levels of N (1 N, 2 N and 3 N). However, in the 2000/01 season, the 3-N treatment was discontinued at Wad Medani and a treatment of 1.5 N was added at the Rahad experiments. These treatments were compared with the standard treatments for tomato and onion (2 N as urea + 1 P) and control (zero N) in randomized complete block designs.

On tomato at the Gezira research farm in 1999/2000, 3 N as NPK and 2 N and 3 N as ASN produced the highest tomato yield and significantly out-yielded the standard treatment (2 N as urea). There were no significant differences in tomato yields between the standard treatment and 1 N in the case of all three fertilizers. At the Gezira research farm in 2000/01, treatments of 1 N and 2 N as NPK complex produced the highest yield of tomatoes. Significant yield differences between the sources and rates of N were obtained in both seasons. The highest tomato yield was obtained by applying NPK at the rate of 3 N, followed by NPK at the rate of 2 N.

In the case of onions, in the experiments at Gezira research farm in the 1999/2000 season, the overall average bulb yield was low but the treatment effects were significant. The treatment of 3 N as NPK produced the highest bulb yield, but differences in the case of the 1-N treatment, for each of the N fertilizers, were not evident. At Rahad, applying 2 N either as AS or as NPK resulted in significant variations in the onion yield. No significant yield differences were detected between the various N sources for broad bean, snake cucumber and pumpkin.

ECONOMIC EVALUATION OF FERTILIZERS

The economic evaluation of fertilizer applications was performed for the on-farm trials in the Gezira, Rahad, New Halfa, Guneid and Kenana schemes. This involved constructing partial budgets for each crop tested at each location and comparing and evaluating net benefits of the different fertilizer treatments.

For cotton, the treatments of 2N as ASN and 2N as NPK yielded higher net returns in the Gezira scheme. In the case of Rahad, the most promising treatments were: 1 N as ASN + 1 N as ASN, and 1 N as NPK; while in New Halfa the treatments of 1 N as ASN and as NPK were the most profitable.

For wheat, the treatment of 1 N as AS in Gezira and 1 N as NPK in New Halfa were the best options.

For sorghum, the treatment of 2 N as ASN yielded the highest net benefits in the Gezira Scheme, while treatment 1 N as AS proved best in the New Halfa scheme. In the case of Rahad, treatments of 1 N NPK and (1 N NPK + 1 N NPK) produced the highest net benefits.

For groundnut, the application of 1 N as NPK yielded the highest net return was achieved from, but with the marginal rate of return was low.

For sugar cane, the treatment of 2 N as ASN gave the highest net returns in Guneid, while a treatment of 4 N as ASN was the most profitable in Kenana.

Chapter 4
The 25-year plan

The Government has prepared a 25-year plan to promote rural development. Its objectives are: "to stir up and trigger rural development so as to give rise to rural communities in which all services are provided: fresh water, technical education, health care, electricity, fossil fuel and renewable sources of energy and other development projects with fair and just distribution between all regions, cultures and ethnic groups."

The plan addresses six constraints facing the sector in the medium term:

- low and declining yields,
- recurrent drought,
- inadequate infrastructure,
- trade constraints,
- weak institutional capacity,
- low private investment.

The plan proposes that the main policy for resolving these constraints should be through a broad framework for growth in the agriculture sector based on the following actions:

- a new land law that provides for, among other measures, long-term leases with land-use conditions, tradability of leases and a reduction in the number and size of very large farms in the semi-mechanized areas;
- more relevant and effective agricultural research and extension;
- improved financial services in rural areas;
- programmes to improve the marketing of agricultural and livestock products, such as wheat, oilseeds and milk;
- maintenance of a strategic reserve to enhance national food security;
- investments to improve domestic water supplies in rural areas;
- programmes to improve the welfare of families in the traditional rainfed farming areas;

- efficient use of water for irrigation;
- combating desertification by rehabilitating vegetation cover through upgrading of pastures, rehabilitation of forests, reforestation and the promotion of agroforestry.

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