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Status of Fertilization and Crop Nutrition in Irrigated Agriculture in Sudan 1: Fertilizer Use in Sudan

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Introduction

The Republic of the Sudan, approximately 250 million hectares, is the largest country in the African and Arabic region (see Map 1). Across this vast country, the climate is extremely varied, from the arid areas in the north to the more tropical southwest. Of the total land area, only about 16.3 million ha is cultivated (defined by FAOSTAT as "arable land and permanent crops"), whereas the potential for cultivation is much greater at around 85 million ha. Unfortunately, initiatives to exploit this potential have so far come to very little. Nevertheless, agriculture is the most important sector of the Sudanese economy, employing around 75 percent of the total population in a country with substantial surface water resources, especially the Blue and White Nile rivers.

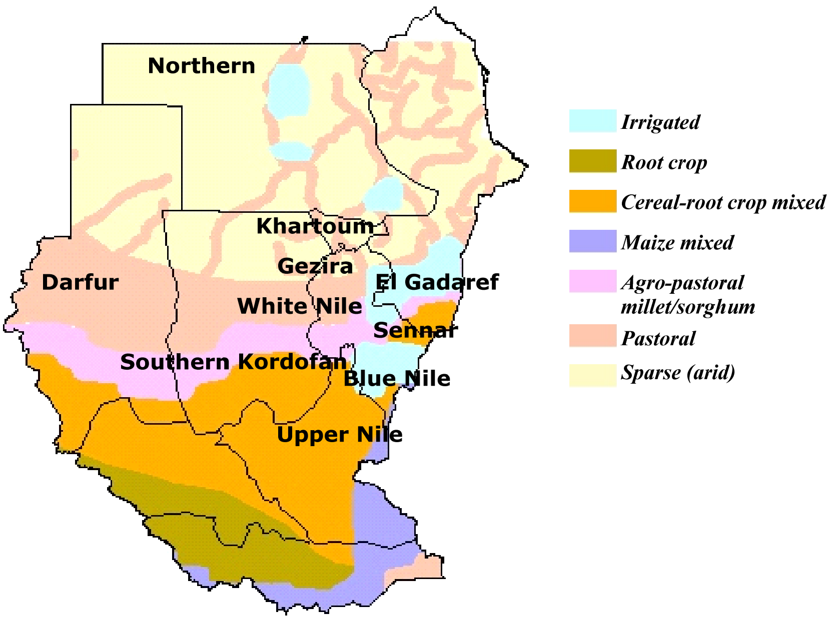
Three main farming systems for agricultural production are defined as shown in Map 2:

1. *Irrigated* (1.9 million ha; within the Nile River basin in Northern, Khartoum, Gezira, Sennar, Blue Nile and White Nile states; marked in blue in Map 2).
2. *Rainfed semi-mechanized* (5.2 million ha; within states of El Gadaref, Blue Nile, Upper Nile, White Nile, Sennar and Southern Kordofan states) using mechanization for some agricultural operations, such as sowing and harvesting.
3. *Rainfed traditional,* where no mechanization is used (9.2 million ha; prevalent almost everywhere in the Sudan, mostly in Kordofan, Darfur, White Nile and Blue Nile states).

This publication concerns the fertilizer status of irrigated areas. Most of the irrigation schemes (see Map 2) are located in Sudan's central clay plain, are of very poor quality and in need of replacement. The predominant soils of the irrigated areas are vertisols, or tropical black earths (Table 1). These soils are dominated by smectitic clay minerals, characterized by high clay content (54-65%) and are alkaline pH (8-8.4), containing $CaCO_3$ (2.5-3.0%). They expand when the 2:1 clay minerals absorb water, and major cracks are formed when the water dries out. These physical properties make them difficult to cultivate and, from a plant nutrient viewpoint, they are of moderate to poor fertility. The main constraints are the low content of organic matter (<1%), low nitrogen (N) (<0.1%) and low available phosphorus (P) (<10 mg kg^{-1} soil). Indications of potassium (K) deficiency have been detected in some

Map 1. Sudan in the African continent.

parts of the Rahad Scheme. The relatively high cation exchange capacity (CEC) 60-75 cmol kg^{-1} soil, and high percentage base saturation of these soils indicate their great ability to retain added cationic nutrients. Irrigation schemes have been developed on a number of soil series showing similar vertisol properties to those described above and have been discussed in detail by various authors (Blokhuis, 1993; El Tom, 1972; El Sharif, 1992; Hamid,



Map 2. Farming systems of Sudan.

Adapted from: http://www.fao.org/countryprofiles/maps.asp?iso3=SDN&lang=en, and FAO, 2006.

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Table 1. Data and selected soil properties of the main irrigated schemes

Parameters	Locations			
	Rahad	Gezira	Sennar	New Halfa
Equipped irrigation area ('000 ha)	122	871	13	152
Classification	Typic Haplusterts, very fine, smect., isohy., shuheit soil series	Chromic Haplusterts, fine, smect., isohy., El Remeitab soil series, non sodic phase	Typic Haplusterts, very fine, smect., isohy., Dinder soil series	Sodic Haplusterts, very fine, smect., isohy., Khashm ElGirba soil series
Nature of parent material	Colluvium-alluvium	Blue Nile alluvium	Blue Nile alluvium	River Atbara alluvium
Current land suitability subclass	Moderately suitable land with vertisolic and chemical soil fertility limitations (S2vf)	Moderately suitable land with vertisolic and chemical soil fertility limitations (S2vf)	Moderately suitable land with vertisolic and chemical soil fertility limitations (S2vf)	Moderately suitable land with vertisolic and chemical soil fertility limitations (S2vf)
	Physical characteristics			
% clay	65	54	62	63
Air Dry Bulk Density (g/cm^3)	1.80	1.71	1.81	1.85
	Chemical Characteristics			
$CaCO_3$ (%)	2.5	3.7	2.0	3.2
EC_e (dS/m)				
0 – 30 cm	0.3	0.7	0.4	0.6
30 – 90 cm	0.4	3.7	0.7	2.6
ESP (%)				
0 – 30 cm	2	6	5	17
30 – 90 cm	3	12	10	25
pH (saturated paste)	7.8	8.1	8	8.6
Organic C (%)	0.74	0.36	0.52	0.440
N (%)	0.040	0.039	0.055	0.018
Available P (mg/kg soil)	3	2	4	1.5
Exchangeable K cmol(+)/kg soil	0.3	0.89	1.00	1.00
CEC cmol(+)/kg soil	77	54	64	60

Source: Blokhuis, 1993; El Tom, 1972; El Sharif, 1992; FAO, 2006; Hamid, 2001; Hamid and Saeed, 2001; Kevie and El Tom, 1987; SMSS-USDA/SSA, 1982; Soil Survey Staff, 1999.

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In terms of overall production in Sudan, irrigated farming accounts for 99 percent of cotton, 100 percent of wheat, 52 percent of groundnuts, 100 percent of sugarcane, 25 percent of sorghum, and 80 percent of fruits and vegetables. However, farmers` yields are generally low, which are attributable to various constraints and limitations and, in particular, to poor soil fertility and low rates of fertilizer application. For vegetables, for example, fertilizer consumption averages about 4 kg of total nutrient of NPK per cultivated ha (FAO, 2006).

Fertilizer use in Sudan

Results of early trials conducted under Gezira farm conditions (1918-1923) revealed the importance and benefit of allowing a fallow period compared to continuous cropping in the cultivation of cotton. Realizing the depressive effect of continuous cropping, an intensive fertilizer research program was started in 1925. This work investigated the effects of fertilizer type and required doses, as well as the method and time of application, and interactions with other cultural practices. Following the establishment of the out stations of the Agricultural Research Corporation, the research was extended to include other crops throughout the country.

Research into crop productivity began on a commercial scale in the 1950s when ammonium sulfate was used as a source of N which, by the 1960s, was replaced by urea. By the 1980s, triple superphosphate (TSP) was being used as a source of P which was followed later, in the mid 90s, by the use of complex or compound fertilizers, applied in solid or liquid form.

As rates of application of fertilizers are low and usually based on crop yield and economic return, much of the more recent research has concentrated on testing for responses in crop growth to urea and compound fertilizers. The research has been carried in most of the irrigated area for different crops such as cotton, wheat, sorghum, sugarcane and

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vegetables. The results revealed that yield of the tested crops increased. As might be expected, complex fertilizers - providing more than one nutrient - were more effective in this respect than urea, supplying only nitrogen.

Nitrogen fertilizers

The need for nitrogen fertilization in most crops in Sudan, such as cotton, wheat and sorghum, has been appreciated for many years from the work conducted in the Gezira Scheme, as mentioned above. From these reports, research concentrated on testing the effect of different nitrogen forms, starting with ammonium sulfate as the N source. This fertilizer contains 21 percent N in the form of NH_4^+ and sulfur in the form of SO_4^{-2}. As well as supplying nitrogen to the crop, NH_4 -N exerts a beneficial influence by depressing the high pH of the soil. This is achieved in two ways: firstly the uptake and assimilation of NH_4^+ by plant roots is associated with the release of H^+ at the soil root interface; and secondly the process of nitrification in the soil - with oxidation of ammonium to nitrate - also releases H^+ ions into the soil. The effect of these contributing forms of acidity in depressing the high pH of the soil can greatly increase the availability of other nutrients, such as P and Zn, to benefit crop growth. Urea which contains 46 percent N $[CO(NH_2)_2]$ is hydrolyzed in the soil to ammonium carbonate to produce ammonia which can then be lost to the atmosphere, adsorbed to soil colloids, or oxidized to nitrate (Tisdale and Nelson, 1975). Soil surface applications or unfavorable soil conditions, such as low organic matter and high clay content, may result in N loss as ammonia ranging from 30-70 percent of the total N applied.

Phosphorus fertilizers

For wheat, phosphorus is supplied as the highly water soluble triple superphosphate $Ca(H_2PO_4)_2$ and is broadcast at sowing. Plants absorb P in the form of $H_2PO_4^-$ and its uptake is favored in the presence of NH_4 -N. Fixation of applied P is common in the form of calcium phosphate, because of the high content of free calcium in most irrigated scheme soils.

Farmers and Rural Women School. Photo by Ahmed Hassan, 2002.

Multinutrient or compound fertilizers

The application of one nutrient affects both the uptake and concentration of another nutrient in the plant tissues. Complex and compound fertilizers have proved to be more effective in increasing yield than fertilizers supplying only one nutrient. A possible explanation for this is that they contain more than one plant nutrient, and that the N present is in a more readily available form. Much of the current research is being conducted in the irrigated agriculture zone to test urea against other compound fertilizers for different crops, including cotton, wheat, sorghum, sugarcane and vegetables. The compound fertilizers tested are either solid or foliar. These are:

- Solid fertilizers: Ammonium sulfate (AS), potassium sulfate (K_2SO_4), NP "Super Star" (23:23:0), NPK "Super Star" (17:17:17), ammonium sulfate nitrate (ASN), potassium sulfate nitrate (KSN), diammonium phosphate (DAP), NPK "Nitrophoska" (18:18:5), NPK "Asdcofert" (20:20:20), NPK "Asdcofert" (10:10:10), NPK "Asdcofert" (10:10:35), NPK "Asdcofert" (10:44:10).
- Foliar fertilizer: Wuxal poly micro, Bayfolan, Greenzit, Elnada Elakhder.

All these fertilizers are approved for distribution in Sudan and are sold in many retail shops around the country.

Consumption of mineral fertilizers

Consumption of mineral fertilizers is meager and the data on total nutrient consumption is relatively sketchy. The total N, P_2O_5 and K_2O consumption for Sudan is only approximately 50,000, 3,000 and 1,000 mt, using mainly urea, SSP and KCl, respectively. This indicates a very low level of application per unit area, in the order of a few kg N ha^{-1} only.

Use of fertilizers in rainfed farming, whether mechanized or traditional, is rare. A recommendation for sorghum of 43 kg N ha^{-1} was recently approved, but only for very localized areas. During 2000-2002, the irrigated sector consumed 54.3, 11.1 and 3.8 tonnes x 10^3 of N, P_2O_5 and K_2O in the form of

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urea, TSP and KCl, respectively (FAO, 2006). From 2002-2006, the annual consumption of the main nutrient sources, expressed in tonnes x 10^3, ranged as follows: N (39.7-74.6), P_2O_5 (2.9-10.3) and K_2O (0-0.15), (FAOSTAT, 2009); the use of potash being particularly low. Fertilizers are normally imported on the basis of cultivated area. For example, horticultural crops are provided with an average annual consumption of NPK fertilizer of only 4 kg ha^{-1}. This rate of fertilizer consumption is really very low, especially when compared with that of other Arabian countries, or with global usage. Improving the use of fertilizers is now in progress, forming part of the Executive Program for Agricultural Development initiated by the Sudan Government for 2008-2011. In this program, areas under crop cultivation are being expanded for most major crops, such as sorghum, cotton and wheat. In particular, the program should result in a significant increase in the production of vegetables. This development necessitates an increase in fertilizer usage to around 300,000 mt of urea and 50,000 mt of TSP for the irrigated sector in 2009/2010 for all crops, including sunflower, sugarcane and rice, besides the ones mentioned above. Future consumption of fertilizers may increase up to 1,000,000 mt per year if all the planned irrigable areas are put under cultivation.

Foliar fertilization

Foliar fertilization, by spraying crops, has recently been adopted for some crops such as wheat, cotton, tomato, and onion, with the aim of providing balanced nutrition including macro- and micronutrients.

Constraints in increasing fertilizer use

There are many constraints which restrict the increased use of fertilizers in Sudan. These can be grouped into three categories: financial, administrative and technical. The main points relating to each are given below:

Financial constraints

(a) Fertilizer imports are controlled by the government.

(b) Lack of funds for small-scale farmers.

Administrative constraints

(a) Taxes, methods of transportation, and lack of storage facilities.

(b) Delay in time of fertilizer availability in markets.

(c) Marketing policy.

Technical constraint

(a) Institutional constraints or research problems, such as adopting new concepts of fertilizer application e.g. fertigation which increases the efficiency of fertilizers, use of plastic hose, and technical problems in laboratory equipment or lack of skills in plant analysis.

(b) Lack of extension system capabilities.

(c) Lack of technical knowledge and its transfer to farmers.

(d) Relatively low level of education and knowledge of farmers.

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The paper "Status of Fertilization and Crop Nutrition in Irrigated Agriculture in Sudan 1: Fertilizer Use in Sudan" is also available at:

Regional Activities/WANA

The top produced commodities (by area) are presented in the table. Sorghum is by far the most important cereal crop in Sudan: in 2007 it was grown on 6.5 million ha (only 4 million in 2000), with yields increasing from 600 kg ha^{-1} in 2000 to more than 750 kg ha^{-1} in 2007. However, productivity of all crops remains very low; well below their potential.

Crop	Area
	ha
Sorghum	6,522,920
Millet	2,322,500
Sesame seed	1,113,333
Groundnuts	597,917
Vegetables	341,240
Fruit	135,464
Wheat	284,167
Roots and tubers	79,358
Sugar cane	68,000

Main crops grown in Sudan. Source: FAOSTAT, 3-2010.