Executive summary

Global agricultural production has nearly tripled over the last 50 years and is likely to increase another 50 percent or more in the first half of the 21st century as global population edges past 9 billion and rising incomes drive up per capita consumption.1 Two-thirds of the growth in overall food demand is expected to come from Sub-Saharan Africa and South Asia. Production of vegetable oils and animal products—products with a high GHG intensity are expected to grow the most. Total demand for livestock products is likely to increase over 70 percent globally between 2005 and 2050. Increasing demand for biofuels and animal feed will also drive rapid growth in maize and sugarcane production.

Climate has obvious and direct effects on agricultural production. Greenhouse gas (GHG) implications of agriculture are also obvious and large. The Intergovernmental Panel on Climate Change (IPCC) has reported that agriculture is responsible for over a quarter of total global greenhouse gas emissions.

Given that agriculture's share in global gross domestic product (GDP) is about 4 percent; these figures suggest that agriculture is highly GHG intensive. This paper describes the potential role innovative agricultural practices and technologies can play in climate change mitigation and adaptation and aims to address the question: what policy and institutional changes are needed to encourage the innovation and diffusion of these practices and technologies to developing countries? We focus on developing countries in general with some specific references to Africa.
Concerns about mitigating and adapting to climate change are renewing the impetus for investments in agricultural research and are emerging as additional innovation priorities. In the coming decades, the development and effective diffusion of new agricultural practices and technologies will largely shape how and how well farmers mitigate and adapt to climate change. This adaptation and mitigation potential is nowhere more pronounced than in developing countries where agricultural productivity remains low; poverty, vulnerability and food insecurity remain high; and the direct effects of climate change are expected to be especially harsh. Most new technologies change the use of farm inputs, often in ways that alter the impact of weather on production and of production on carbon emissions.

Describe some technologies that seem particularly promising in mitigating or adapting to climate change and use these as a platform for exploring the policies and institutions necessary to support the development and diffusion of current technologies – and to provide incentives for technological breakthroughs in the future. While new traits, varieties and crops will play an important role, the range of relevant practice and technologies is much broader than this, including water management, production practices, post-harvest technologies, information and forecasting, and insurance.

Agriculture Technology for Climate Change Mitigation & Adaptation

The core challenge of climate change adaptation and mitigation in agriculture is to produce **(i)** more food, **(ii)** more efficiently, **(iii)** under more volatile production conditions, and **(iv)** with net reductions in GHG emissions from food production and marketing. As long as climate change and policy responses it induces do not interrupt long-term income growth or alter the long-term decline in relative food prices so much that the path towards improved diets is reversed, aggregate food

demand will continue to grow along with population and income growth. As climate change affects input availability, especially water in many places, input use efficiency must increase with these productivity demands. Carbon emission polices may simultaneously encourage or force producers to recognize GHG emissions as an important and costly "input" in production processes and open new opportunities and incentives for on farm GHG mitigation. Producers will grapple with these growing demands and shifting incentives amidst more volatile production conditions. Agricultural technologies will play a central role in enabling producers to meet these core challenges.

The agriculture sector in Sudan

Agriculture is the dominant sector of the Sudanese economy. The background information given should clearly show that the social and economic growth of Sudan depends to a great extent on the performance of the agricultural sector. In addition to generating directly about two-fifths of GDP, agriculture also drives activity in the industry and service sectors such as transportation, agro-industries, and commerce, which account for a large part of the rest of the economy. Even more importantly, 80 percent of the labor force is employed in agricultural and related activities, and the performance of agriculture is the main determinant of year-to-year changes in poverty levels and the food security of the population. Finally, agriculture is the source of virtually all of the Sudan's exports (before oil extraction in1999) and therefore, it is a key determinant of balance of payments developments.

The agricultural resource base covers several agro-economic zones that include forests, farmland, arable cropland and grazing land for livestock as well as fisheries in the Nile basin and in the Red Sea. The currently cropped area is about 41 million feddan2 (17 million hectares) which account to about 20 percent of the potential arable land. The arable land within the isohyets 400-800 mm (the rain-fed zone) is estimated at 59 million feddans (25 million hectares), of which 35 million feddans (15 million hectares) are currently utilized either traditionally (21million feddans) or mechanized (14 million feddans). The relatively light infertile soils and the limited availability of water are, however, serious constraints to agricultural production in most areas. Rainfall varies from near zero in the extreme northwest to 1,600 mm per year in the temperate and rich forest zones in the south. About half of Sudan is susceptible to periodic severe droughts that often span two years.

The Structure of the Sudanese Agriculture

The economy of the Sudan is highly dependent on agriculture, which occupies an estimated 43 percent of its labor force (ILO estimates of 2019) and accounts for about 30 percent of its GDP (World Bank). Its crop portfolio is quite diversified, including cereals (such as sorghum, millet, wheat, rice and maize), oilseeds (sesame, groundnuts and sunflowers), industrial crops (cotton and sugarcane), fodder crops (alfalfa, fodder sorghum and Rhodes grass), pulses (broad beans and pigeon peas) and horticultural crops (okra, onions, tomatoes, citrus, mango, etc.).

Moreover, land in the Sudan is suitable for animal husbandry, with an estimated total livestock population in 2019 of about 119 million heads of cattle, sheep, goats, camels and others. Crop production in the Sudan is practiced under three main patterns:

1. Irrigated agriculture, which includes:
   - Large national irrigation schemes *(Gezira, Suki, New Halfa and Rahad*) using river flow from the Nile and its tributaries.
   - Large spate irrigation schemes (*Gash and Tokar*) using seasonal floods.
   - Small-scale irrigation along the banks of the Nile and its tributaries.
2. Semi mechanized rain fed agriculture
3. Traditional rain fed agriculture.

Irrigated agriculture

The area under irrigation in the Sudan is estimated at about 1.68 million hectares (4 million feddans). Large scale mechanized federal schemes account for about 1.26 million hectares (3 million feddans), including the Gezira Scheme which, at approximately 1 million hectares (2.38 million feddans), and is one of the largest irrigation schemes in the world. As yield expectations are more reliable, the irrigated sector is the principal user of imported agricultural inputs. Crop yields in the Federal Irrigated schemes remain low by world standards, largely due to the poor maintenance and silting up of canals, the shortage of efficient modern pumps and the adoption of traditional agricultural practices that do not allow to make the most efficient use of the constant water resource and exploit the full potential of more intensive farming. Irrigation water is mainly obtained from the River Nile and its tributaries by means of gravity or pumps, or from spate flow from seasonal rivers at *Gash and Tokar* deltas. The principal crops of the irrigated sector include sugar cane, cotton, sorghum, groundnuts, wheat, vegetables, fruits and green fodders. According to the season, the sector also takes advantage of rains, especially during the establishment of summer crops. For example, rain is estimated to provide about 40 percent of the water requirements of crops on the *Suki* Irrigation Scheme. Rain is especially important for reducing production costs on privately-owned irrigated smallholdings along the banks of the Nile and its tributaries that depend on diesel-powered pumps. In recent years, several large private enterprises have emerged, producing fodder crops such as alfalfa and Rhodes grass for export, mainly to the Gulf countries. These enterprises are usually highly mechanized, use efficient irrigation systems such as centre pivots and other forms of sprinkler irrigation and generally achieve high yields of good quality fodder.

Semi-mechanized rain fed agriculture

Semi mechanized rain fed agriculture is so called because mechanization is usually limited to land preparation and seeding. Other field operations, including harvesting, are usually carried out manually, although combined harvesting is becoming less rare. Semi mechanized rain fed agriculture is practiced in a broad belt of 6.7 million hectares and receives, on average, more than 500 mm of rainfall annually. It runs through *Kassala, Gadarif, Blue Nile, Sennar, White Nile* and *South Kordofan* states. This belt is effectively the granary of the country, with sorghum accounting for about 80 percent of the cultivated land and usually producing about 45 percent of the country's requirements. Other crops include sesame, sunflowers, millet and cotton. Farms in the semi-mechanized sector are frequently very large, even above 50 000 hectares. Given the erratic nature of rainfall and, therefore, the possibility that yields could be very low, the system may be considered as opportunistic and operations are carried out as economically as possible. Standard crop varieties are sown using wide disc seeders with up to 30 discs and no fertilizer is applied. If the rains are

favorable, yields of up to 1 tone/hectare can be achieved, otherwise crops may be sold off as a standing crop to pastoralists for grazing.

Traditional rain fed agriculture

The traditional rain fed sector covers about 9 million hectares and occupies the largest number of farmers. The sector is made up of small family units farming from 2 to 50 hectares for both income and subsistence. On the larger units, there may be a modicum of mechanization in the form of land preparation, but most operations are carried out manually. The traditional sector predominates in the west of the country, in Darfur and in much of Kordofan State, where the main cereal crops are millet and sorghum. Input levels are low and yields are especially vulnerable to unfavorable rainfall. Other important crops in this sector include groundnuts, sesame, hibiscus (*karkadé*), watermelon and Gum Arabic.

The traditional farming system features

1- Small size of holding (5 – 20) feddans.
2- Farming operation are entirely manual family labor using traditional hand tools.
3- Little or no external inputs are used.
4- Farming has limited resources and poor access to market, credit and improved production technologies.
5- Farming is cured out under risky environmental conditions.
6 – Low agriculture inputs.

Agriculture and Climate Change in National Policies and Action Plan in the Sudan
Main characteristics of Sudanese agriculture

Agriculture in the Sudan is practiced under two major farming systems, rain fed, both mechanized and traditional, which occupies more than 90 percent of the cultivated land, and irrigated, which makes up the remainder. Additionally, the sector is divided into three major subsectors, cropping, livestock, and forestry/fisheries, contributing 39, 60, and 1 percent, respectively, to agricultural GDP in 2015/16 (CBoS 2016). This highlights the importance of livestock, which has become even more important in contributing to foreign exchange earnings, especially with the shrinking contribution of oil exports. Agriculture provides a livelihood to 65 percent of the population, especially in rural areas and for poorer households. With respect to household income, 61 percent of households in the poorest income quintile rely on agriculture as their main livelihood compared to only 20 percent of households in the wealthiest quintile (World Bank 2015; CBS 2009). Thus, the agricultural sector is central to any poverty reduction policies and programs. Moreover, agriculture is the main employer in the country. It employed 47 percent of the labor force in 2011, including 41 percent of male and 63 percent of female workers. These shares are even more prominent in rural areas. Agriculture ovides 65 percent of total rural employment percent of male and 82 percent of female workers.

The land cover atlas of the Sudan (FAO 2012) classifies the total land area of the country (188 million hectares) into 83 different classes that are aggregated into seven major classes. Agriculture is mainly practiced on land in the 'agriculture in terrestrial and aquatic/regularly flooded land' category, which makes up 23.7 million hectares and represents 12.6 percent of the country's land area. A brief look at the distribution of this land cover class across states shows that the majority is found within the predominantly rain fed states

of northern Kordofan (19.3 percent), El Gadaref (14.6 percent), southern Darfur (9 percent), White Nile (8.7), and southern Kordofan (8.3 percent). The agricultural sector in the Sudan operates below its productive potential. That is not only because arable land is far from being fully cultivated, but also and importantly, because it operates far below its productivity potential (MAF 2017; World Bank 2015). This can be observed in the main crops, namely sorghum, cotton, groundnut, sesame, millet, and wheat. Other agricultural subsectors, such as sugar cane, gum Arabic, livestock (particularly live sheep and camels), and hides and skins are closer to their potential. Sorghum production during the last decade (only the last two seasons are shown in Figure 2) in the major farming systems of the country shows low productivity in the rain fed sectors, which represents more than 95 percent of the total sorghum-cultivated land compared to the irrigated sector. Productivity in the rain fed sectors is less than one-third of that of the irrigated sector (Figure 2).

In addition, harvested area and yields of crops fluctuate due to dependence on unpredictable rains, recurrent occurrences of droughts, pest infestation, and low application of fertilizer and other inputs (World Bank 2015).Millet, which is a main staple food in Western Sudan and produced in the traditional rain fed sector of Darfur and Kordofan, is low yielding with an average productivity of less than 240kg/hectare per year. The low productivity is mainly due to low input use usually, no purchased inputs, such as fertilizers, are used on millet. Besides, the amount and stability of rainfall affects and eventually determines production. Sorghum, sesame, millet, and pasture species are primarily grown in the traditional rain fed sector that is generally characterized by low crop productivity, associated with low usage rates of inorganic fertilizers and improved seed.

In general, average fertilizer usage in the Sudan is half that of Ethiopia in which the peasant community is much poorer than in the Sudan. A comparison of the fertilizer usage in 155 countries in 2009 ranks the Sudan 129th with average fertilizer application of 7.3 kg/ha compared to 17 kg / hain Ethiopia (ranked 115th) (World Bank 2015). This, however, is different than it was in the Sudan in the mid-1970s when 80 kg/ha were used and during the 1980s when 70 kg/ha were applied on average. While this partially explains the declining trends in the production of different crops in the Sudan, it also shows the need for stimulating fertilizer usage, as well as ensuring that agricultural policies conducive to increased input use in agriculture are in place. The traditional rain-fed sector receives few credit, research, and extension services, while public investments in basic infrastructure for rural and agricultural development are generally negligible. For wheat, government encourages domestic production despite no comparative advantage for its production in the Sudan. The average wheat yield in the Sudan is half that of Chad, one quarter that of Ethiopia, and only 7 percent that of Egypt (World Bank 2015). Wheat yields in the Sudan are among the lowest in the world. Similar developments and characteristics are observed in groundnut and sesame production in the Sudan. Next to rainfall variability and the low usage of inputs, distortive centralized marketing and distribution arrangements have also contributed to eroding producer incentives. Good news on the removal of these distortions are coming from the experiences of gum Arabic and cotton, which may pave the way for further policy reforms, including for other crops.

Environmental challenges to Sudanese agriculture

The increase in global temperature will affect all the Sudan. Vulnerable sectors to rises in temperature are particularly rain fed agriculture, aquaculture, natural ecology systems and biodiversity, water resources, and energy (production and consumption). This ultimately increases the vulnerability of certain communities,

such as poor farmers, pastoralists and generally communities that rely on rain fed agriculture (Figure 2). But the Sudan will not only experience changes in mean temperature, which are projected to increase by up to 3°C by 2050, and precipitation, which is projected to increase by 4 percent per decade, but also increasing rainfall variability with increased frequency of both droughts and floods (USAID 2016). Floods, flashfloods, and possibly landslides affect the southern and southeastern parts of the country as well as the mountainous areas in the northeast, while droughts affect more the northern parts and areas in the middle and Middle West of the country. Communities that are most vulnerable to droughts and floods are pastoralists, poor farmers, and generally poor families with senior members, children, and women (Sayed and Abdala 2013). Figure 2. summarizes the potential effects of climate stressors, including drought, rainfall variability, floods, temperature increases, seawater temperature increases, and sea level rise, on different sectors, areas, and communities in the Sudan. It is important to note that climate impacts summarized in Figure 2. point to the connection between climate change in the Sudan and agricultural productivity. It shows that four climate stressors – temperature increase, rainfall variability, droughts, and floods – affect the agricultural sector and ultimately reduce its productivity. This predominantly affects poor farmers, poor people, senior citizens, children, and women particularly in the northern, middle, and middle-western parts of the country.

The direct effect of climate impacts in agriculture sector in Sudan

Drought impacts on agriculture

1- Reduction in the length growing season and period of crop growth.
2- Reduced agricultural productivity.
3- Changes in distribution and incidence of insects, diseases and weeds.
4- Accelerated land degradation (declined soil fertility and soil erosion).
5- Increased livelihood of crop failure and increase in the diseases mortality of livestock.

Table 1: Climate stressors and their potential impact on sectors, areas, and communities in the Sudan

Drought	Rain fall variability	Floods	Temperature increase	Sea water temperature	Sea water level rise

Agriculture	Water Resources	Castel Zone	Energy
Loss of productivity land pasture and water due to extend of desertification	Increase evaporation from water storage facilities, reducing water supply.	Intensification of storm surges cyclones damaging existing infrastructure.	*Increased of evaporation and water storage area and reducing river flow, resulting in reducing water availability for hydropower and generation. *Increase energy consumption.
Shorten growing season and reduce yield and or crop failure	Decrease river flow from the Nile, leading to reduce availability of water supply for irrigation, drink and sanitation.	*Increase of seawater temperature damage coral reef systems through bleaching. *Increase in seawater temperature damage mangrove systems. *Increase in seawater surface temperature damage sea gross and salt marsh ecosystem.	**Legend:** *Stressor. *Sector. *Impact. *Affected communities and areas
*Conflict between pastoralist and farmers over resources. *Rural to urban migration due to strain rural livelihood.	Conflicts over the rights and access to water to the local, national and regional levels.		
Demand of crops, agriculture land and infrastructure.			
Communities: poor farmer, poor papal senior citizen children and women. Areas: northern, middle and middle western parts.	Communities: poor farmers, pastoralist communities relying to rain fed agriculture. Areas: all the country especially areas with temperature rise 2.5 C.	Communities: pastoralist communities in flood area, poor farmers. Areas: south. mountains areas in northern east and southern east.	Communities in the castle area of the red sea state. Areas: Red sea state with the direct impact and all the country with indirectly.

Source: Ministry of Agriculture

Methods of Adaptation and Mitigation in agriculture sector direct intervention

1- Indigenous Knowledge and research techniques.
2- Major Government Project National Program Integrated Solution for Agriculture Sector (NPISAS).
3- International Organization Governments Projects.

First Indigenous Knowledge research techniques

Research interaction throw produce some crop varieties resist the shortage of rainy season and water scarcity. Many simple techniques with other traditional knowledge's take place to adapted or mitigated climate change effects.

Indigenous crop varieties adapted with the local conditions, water harvesting crops in both micro and macro level in order to suitable water conservation and using. In addition, intercropping and promising technology as a seed priming and adding a micro dose of fertilizer in planting, beside the indigenous knowledge's in (the rate and distant between the seeds, crop structure caring , crop regeneration.

local cultivated methods like seeding special crops before the rainy season (*Remmal)**[1], cultivated crops in low lands in order to conservation water in the rainy season *((Sheerak)** [2] *make a trap to the rainy water*)), or making plant fence around cultivated area utilize brows dry plants to stop desert creeping towards cultivated lands.

In Northern state, farmers cultivate palm trees in desert land after dig a hole and fix sand into clay soil. In high rain fed areas, change of sowing date to cultivate certain Sorghum breed or applied new practices to mitigate crops failure due to floods or shortage of rain fall.

Adaptation & Mitigation

A -Research Technique

1 - Water harvesting crops in both micro and macro level in order to suitable water conservation by using green disk. (Appendix plate 1).

2- Intercropping

- Agro forestry: Combining Acacia Senegal with filed crop mainly sesame crop.
- To growing two types of crop in the same area utilize deferens levels of soil and air vegetation e.g. (legume with sorghums). (Appendix plate 2).

3 - Promising Technology

- Seed Priming

Seeds should be priming for a period about 8 hours, a little drying and treated against pests before seeding. Priming in water accelerates the germination giving a strong plant. But, priming in water for a long time resulting lose the plant. (Appendix plate 3).

- Adding a micro dose of Fertilizer Nitrogen Phosphorus Potassium (NPK)

Adding a micro dose of fertilizer focusing the Phosphor element (less than one gram) in with the seeds in planting lead to increase in the productivity. Methods & quantity of adding fertilizer very simple low cost without hazard and raised the resistance of the plant against environments stress.

B - Indigenous Knowledge

1- **Crop and Local Variety Selection**

Choice of local varieties is important. Varieties which have proven excellent in irrigated or high rainfall areas are generally unsuited for dry land conditions. Many attempts at dry land farming have failed, largely due to lack of recognition of the requirements for the variety selection. Variety requirements for dry farming: • Short-stemmed varieties with limited leaf surface minimize transpiration. • Deep, prolific root systems enhance moisture utilization. Quick-maturing varieties are important in order that the crop may develop prior to the hottest and driest part of the year and mature before moisture supplies are completely exhausted. (Appendix plate 4).

Local variety requirements for dry farming

• Short-stemmed varieties with limited leaf surface minimize transpiration.
• Deep, prolific root systems enhance moisture utilization.
• Quick-maturing varieties are important in order that the crop may develop prior to the hottest and driest part of the year and mature before moisture supplies are completely exhausted.

1- **Trapping rain fall sites (*Sheerak*)**

It means cultivated specific area where farmers predicts rain fall water summated, in other word it is a type of natural micro water harvest techniques which soil conserve rainfall water raise moisture for planting seasonal crops, this technique mainly use in west and central west of Sudan in traditional rainfed sector. (Appendix plate 5).

2- **Seeding before the rainy season (*Remmal):***

This type of indigenes techniques take place also in central west of the country, in a wide level of the traditional rain fed sector where the land structure was sand / sand loamy soil, and mainly applied (till now) in specific crop Millet, by putting the seeds in depth about 5cm under soil surface in (late April – May) before the start of rainy season (June - July). The strong coat of the Millet seed can resist the environment changes, on the other hand it the best utilization of the first water rainfall to seed germination which can avoid the shortage of the rainy season.

3- **Cultivated Palm Trees**

In Northern state the local farmers dig a hole in the surface sand soil in order to cultivate palm trees into the clay soil, the tree reach the surface after 6 – 12 months, this period well established the root system for strong plant. (Appendix plate 6).

4- **Dry plant fence**

Marginal areas in traditional rain fed sector mainly in *Bara* – North Kordofan state – farmers whom cultivated in a small scales (300 – 500 m / family) facing desert creep into their lands, they utilize brows dry plants as a fence around in order to protect cultivated area (Appendix plate 7).

5- **Change of the Sorghum sowing date**

As the old research recommendation the sorghum sowing date ranged between 21 June to the first of July, currently the change of rain fall period, quantity and distribution, local farmers change their methods of cultivation mainly in Sorghum crop into two local practices:

a- Change type of variety Sorghum breed to quick short growing type (*Geshish, Arfaa Gadamk*) to avoid the shortage of rain and unsuitable distribution of rain fall.

b- Change the sowing date till 20th of September in order to avoid the speared of pests and insects period.

6- **New practices in rain fed area to mitigate the situation impacts of crops failure due to floods or shortage rain fall**

Mainly in certain high rain fed areas in Sudan with clay soil (Gadarif. Sinnar, Blue Nile, White Nile and Gezera states) beside other similar sites, the famers lose their crops due to different climatic elements mainly the floods with the heavy rain in the rainy season last seasons. Sesame crop which cultivate early season very sensitive to high rain or moisture or the loss of Sorghum crop or Cotton .Sun flower of groundnut by sinking agricultural crops.

Farmer facing the loss agriculture season by cultivated Water melon seeds utilized the moisture in clay soil and the short time of grown (40 days) using family lobar or machinery for wide areas . The crop has a high demand in the market for export crops.

The high income of this crop mitigate the loss of the main target crops in the rainy season, now it fixed as additional cycle in rain fed sector.

Second: Major Government Program

National Program Integrated Solution for Agriculture Sector NIPSAS

(Technical packages for integrated solutions for developing the rain sector)

The Ministry of Agriculture and Irrigation launched the launch platforms program as a basic approach to crystallize an integrated project to increase production and raise productivity in the traditional and automated rain fed sector, accompanied by licensed agricultural technologies, especially guiding land and water resources, and with an integrated system to raise capabilities, organize producers, production inputs, financing and marketing policies, and added value. Since this program is consistent with the five-year economic reform program for the period 2015-2019, which aims to increase production for export and improve the standard of living after the stabilization of the triple program, the Ministry of Finance and National Economy, and with the effort of the Minister of Agriculture and Irrigation, funded the primary year,

provided that it expand in the following years with local or other funding External, if available, especially the Islamic Development Bank. Based on this funding, implementation plans have been drawn up for 15 states located within the rain sector and it has been fully implemented, provided that it will continue for a period of 5 years 2014 / 2015- 2019/2020. This year 2015-2016, the program targets 7.2 million feddans in the rain sector and 2.8 million feddans for the irrigated sector with modern technologies (10 million feddans), out of the ministry's overall indicative plan of 41.9 million feddans, of which 38.3 million feddans are rainy and 3.6 million feddans are irrigated and increase annually until It covers all the space.

Strategic goals:

• Increasing exports and contributing to import substitution,

• Increase farmers' income, Rehabilitation of existing agricultural projects,

• Expanding strategic partnerships related to production integration and adding value, Diversifying agricultural production by encouraging export-oriented production and expanding horticultural crops that is promising,

• Optimizing the use of available agricultural areas in the states to take advantage of geographical diversity and comparative advantages. Raise the institutional and human capacities to raise production efficiency.

In order to achieve the above general objectives, the following methods are used:

• Creating an environment conducive to agricultural production and its sustainable development by pursuing organized macro and sectoral policies that encourage the advancement of agricultural potentials.

• Raising the capabilities of producers and restructuring their institutions to bring about the qualitative transformation of producers and raise their production efficiency

• Addressing issues related to agricultural lands Upgrading support services, especially developing scientific research, transferring technology and extension, developing agricultural education, establishing and developing markets, enhancing the capabilities of the informational sector and means of preventing risks, and expanding agricultural insurance services.

• Development and modernization of agricultural systems.

• Protection and development of natural resources.

• Establishing autonomous capabilities for the sector to manufacture production inputs and provide products for the national agricultural manufacturing industries.

Specific goals:

1. Expanding technologies for water harvesting and conservation agriculture in the rainy sector with the aim of improving agricultural production in order to bring about a qualitative. Transformation in the sector from a traditional subsistence sector that produces at subsistence rates to a modern and renewable economic sector to achieve sustainable and competitive production.
2. Providing agricultural services at the level of technology and extension centers, village or production groups.
3. Raise the capabilities of mentors and producers.
4. Integration of efforts for all stakeholders interested in agricultural development.

Program components:

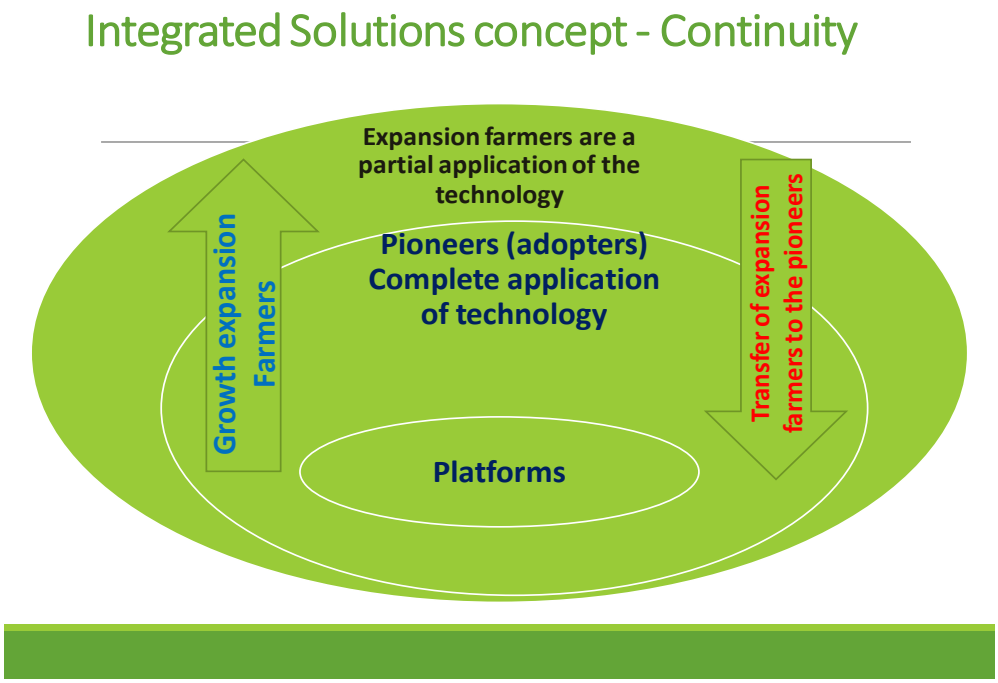
The program consists of six main components, two of which are concerned with increasing water supply and preserving humidity, and four supporting components concerned with crop management, providing

institutional and technical support, capacity building, financing, monitoring and evaluation. Project implementation mechanism: Simplified administrative and institutional levels for the program have been set up between the ministry and the states with specific responsibilities supported by service provider partners from funding to technical inputs and support from agricultural research.

Implementation Methodology

1. Parallel work in establishing launch platforms in the clarification stage for new communities with the support of the project to develop technology transfer centers to promote technologies and expand farmers at bearing the cost.
2. Formation, registration and training of production groups.
3. Providing extension services, training and easy access to producers at the village and association level.
4. Helping to provide financing to producers from various financing agencies.
5. Attention to concentrating efforts by implementing complete production packages in specific areas instead of horizontal expansion with few inputs to prevent resource degradation, reduce costs and increase productivity.
6. Appropriateness and suitability of the technologies and productive alternatives proposed for the environmental, economic and social aspects of the rainy agricultural areas in the central, eastern and western mud plains.
7. Integration of organizations ’efforts with the project and coordination in terms of the state’s priorities and strategy in directing resources towards production.
8. Considering the value chain as a basic complement to achieving the greatest return on the product and marketing.

Figure 1. The Mechanism of Interventions



Program outcomes and outputs:

A / The basic institutional structure:

The formation of productive groups For the purpose of the sustainability of the project, the program was able to form producer groups, in the form of associations or struggles working with the new system and its settlement, and to facilitate the process of financing, making mechanisms and technical support for this type of collective adoption, as it was able to form 153 new production groups in 11 states in 26 localities with 2212 members. 104 officially registered and 49 unregistered spread across 102 villages. In addition to the new groups, some states have expanded the implementation of platforms with existing associations. This activity included working with 117 groups formed in 115 villages in 20 localities with a capacity of 15523 members, of which 102 were registered and 15 were unregistered.

B / Output input Agricultural machinery:

In order to enable the productive groups to access the agricultural services associated with these technologies, the Ministry provided production inputs, including machinery and agricultural inputs, at cost, in coordination and cooperation with the Ministry of Finance and National Economy, the Agricultural Bank and some commercial banks. A total of 110 machines were distributed to the states, which included 14 tractors, 12 and 6 small and large crops, 25 gears, 6 and 12 pesticide sprayers with a capacity of 400 and 600 liters, 17 cruisers and 18 terraces. As the share of each state from these units ranged from 5 to 8 machines. We recommend supplementing and increasing these units to be a nucleus for supplying technology transfer and extension centers with the required equipment that enables the provision of extension services and demonstration fields at the village and community levels, taking into account the relative

potentials of resources in the states of agricultural and production weight. In addition to what the Ministry provided from the above mechanism model, some states were able to obtain the machinery services from private and private sector sources for their target producers. In total, 114 tractors, 27 cultivators, 24 slewing plows, 32 cruisers, 16 machine guns and 14 other mechanisms (disc harrow, wide, plow) to serve the producers, which had an effective impact in covering the shortage of machinery in some states. (Appendix plate 8).

C / Funding:

The Ministry's contribution to financing the program's activities: In addition to the above mechanisms provided for the production groups at cost, the program has invested in increasing the capabilities of engineers and producers, managing and following up, setting up a workshop for the first launch platforms and paying the value of fertilizers and pesticides to the Agricultural Bank and the private sector in advance. The Ministry also assisted in facilitating the obtaining of gasoline for farmers in order to ensure the agricultural season at an early date.
Contribution of producers to self-financing In addition to the funding provided by the ministry, the producers have contributed to the quest to obtain financing for the agricultural season from several sources, including banks, the ministry, family and other sources. The lending from banks, the ministry, family and other sources represented about 3 million pounds. It is certain that the real funding value is more than that, but the lack of follow-up and lack of monitoring of funding data by many states misses this fact. That is why we bring to the attention of the states the constant follow-up of this issue from the beginning of the season to its end, to obtain real data and figures, especially from the financing portfolios for the season.

D/ Raising capacity

The platform and expansion plan included a training and extension program to build the capacity of engineers, extension workers, farmers and members of production groups on this new production system.

Training extension workers and agricultural engineers

The training program for instructors and engineers included intensive theoretical and practical courses on the application of technology, introduction to water harvesting systems, conservation agriculture, extension aspects, dedication and crop management, and the law of community formation. Accordingly, 5 training courses were held during the period from May to June 2014 in the state sectors, and 250 engineers and instructors from all the target states benefited from them, in addition to the departments of the Federal and State Ministries in Khartoum and the specialized marine extension. These trainees expanded the training in the states, in cooperation with agricultural research stations, in training more extension workers in various fields, from which extension workers and agricultural engineers benefited for a period of 164 days.

Training of productive groups and farmers (fields, farmer's schools, field days, exchange visits, workshops)

According to the knowledge obtained by the engineers and mentors through training, many training courses were implemented, including farmers' schools, field demonstrations, workshops and exchange visits, and field days in different states that took in about 10269 farmers, including 5783 participants and 4495 not participating in the program during 307 days. In addition to the Technology Transfer, Extension and Agricultural Research departments, IFAD projects, Islamic Relief (South Kordofan), Practical Action (North Darfur), and Gezira University (Al-Jazeera) participated in the training. Response and contribution of voluntary organizations and the University of Gezira to the training.

E / Participation of farmers in adopting water harvesting technologies

The program was able to spread and localize technologies for 1726 farmers, including 1,373 and 353 female farmers, in 100 villages covering 13 states. This achieved the coverage of a total treatment area of 7830 feddans out of a targeted 9725 feddans, of which 7676 feddans were planted and 6971 feddans were harvested.

F / Sorghum yield Water harvesting technology

The production data obtained showed that the water harvesting systems are more than two to three times higher than the current rain fed farming systems (automatic, semi-automatic and traditional). In terms of general production, most states achieved higher productivity of 6-9 sacks / acre compared to less than 3 bags / acre for the traditional, in addition to estimated quantities of fodder and good yield also for millet, peanuts and sesame. As an average for all states, Table 1 shows the overall averages of the models in the first year compared to the experimental water management project (White Nile - 2012) and the applied research of the White Research Station - 2011. The comparison shows the importance of using the full package in increasing productivity to bridge the gap, which was not used in this program. (For example, small doses of fertilizers and pesticides). In order to improve production conditions, it is necessary to create a policy and an investment climate that secures the provision of its requirements and the full implementation of the systems package, and working on the sustainability of its application through the introduction of systems concepts into research channels and their inclusion in the extension bodies and agricultural policies.

Figure 2. Crop Production (Ton / H) due the type irrigation

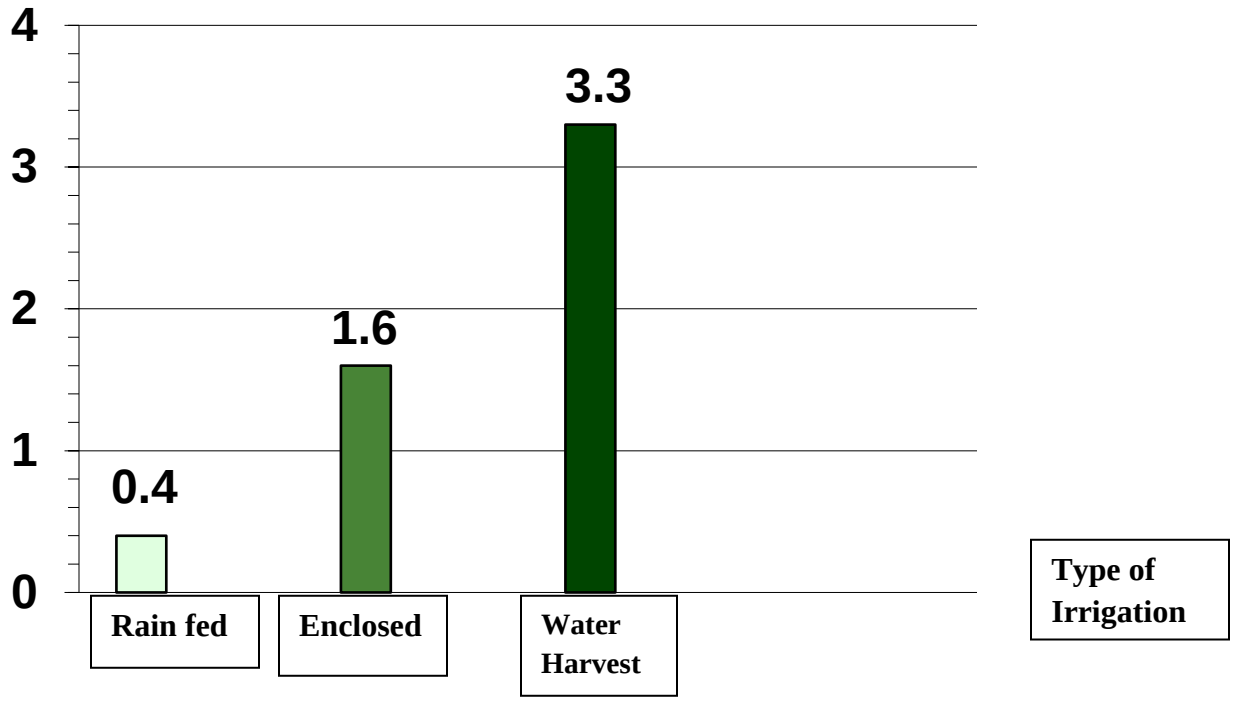


Table 2: Average yield sorghum crop by adopting three water harvesting systems compared to conventional (kg / Fadden) and previous results

System	Program 2014	Water management pilot project (White Nile 2012)	Applied Research (North Kordofan 2011)
The first model (external hometown, farm, input, agricultural parameters)	582	733	*1235
The second model (spatial conservation, inputs, agricultural transactions)	554	514	*1175
The third model - supplemental irrigation (inputs, agricultural transactions, complementary irrigation)	818	750	-
Traditional	219	270	329

Complete package with small doses of triple fertilizer By looking and comparing it at the African, regional and global levels and Sudan, we find that the program has increased production by a level exceeding that of Sudan in general, and Africa and the world except America (Figure 3) from its first year. We believe in the

continuation of this program, with emphasis and provision of its material, human and technical requirements and favorable and supportive policies. This program can achieve great leaps that put the country at the forefront of countries in production.

Achieved results and observations for water harvesting and conservation systems

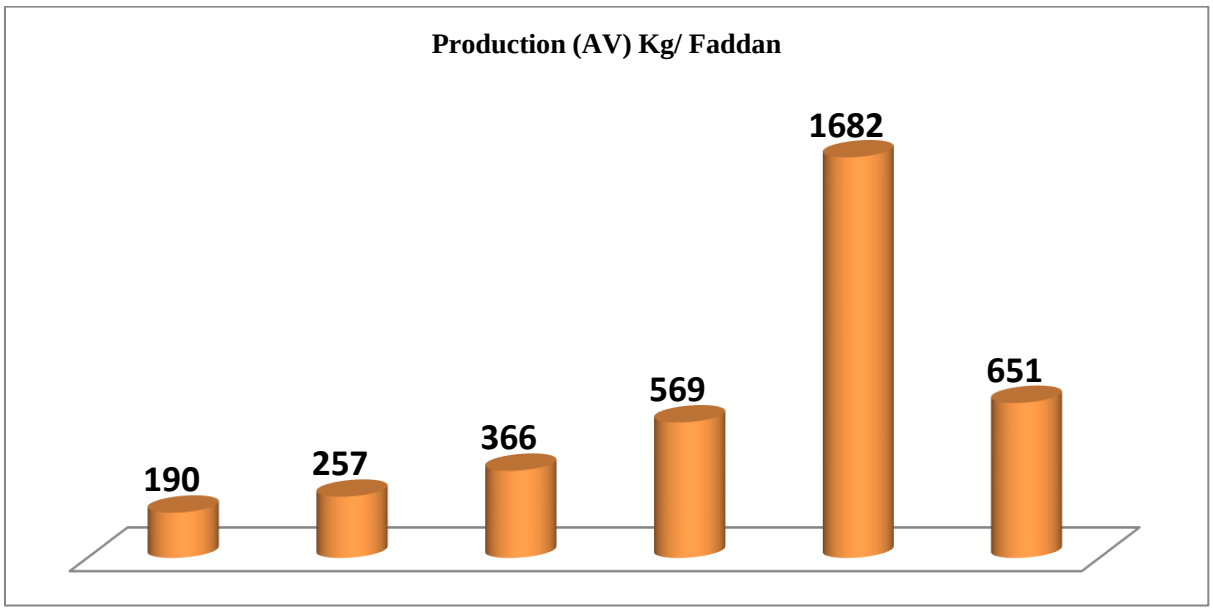
- Increased wetness depth and greater water absorption with sliding in the first model, speeded weed germination Early growth enabled weeds to be removed almost completely, mechanically or chemically first, and then early planting at the recommended times, which reduced the cost of not resorting to manual labor. Create better crops.

- Reducing the impact of seasonal droughts that may reach 21-30 days by large storage of water in the soil sector Preventing soil erosion and good distribution of water, which raises the efficiency of water use Achieving a much higher production compared to traditional systems.

- Productivity stability.

- Increased conviction by farmers of the importance and feasibility of water harvesting as an alternative to the prevailing traditional systems

Figure 3.Comparison of average corn production in the rain sector at the global and regional levels and Sudan



Traditional AV	Sudan AV	Africa AV	International AV	USA AV	NAPISAS AV

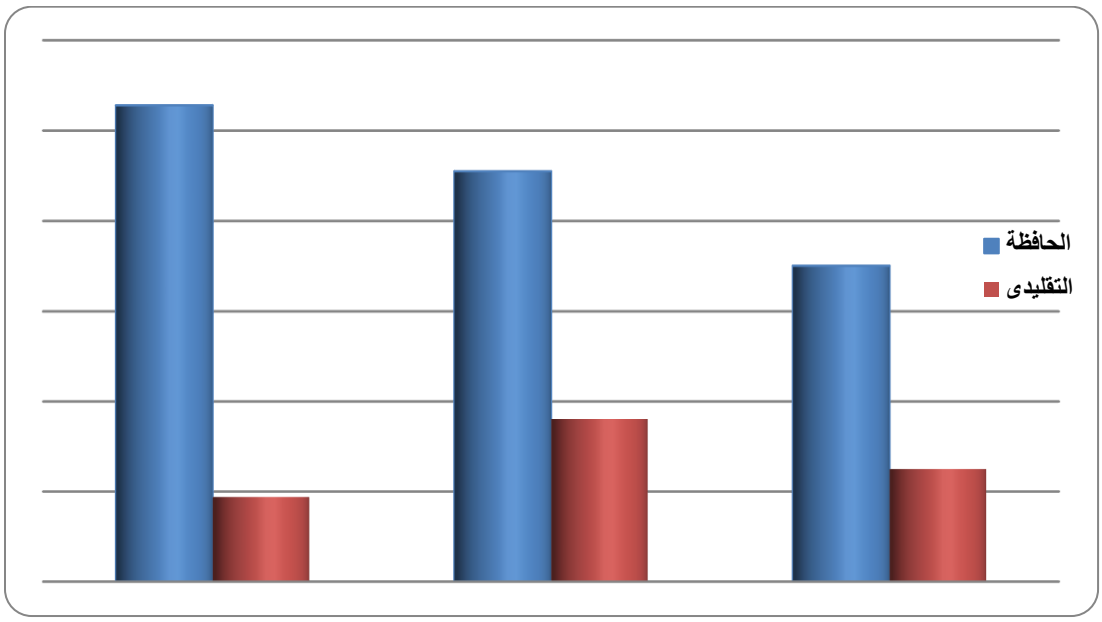
Conservative agriculture (CA)

After the success that accompanied the application of the cultivation system without plowing by the *Arab Authority* and the ACSAD project, this activity was implemented in the previous three states (Gadarif, Sennar and the Blue Nile), and the White Nile was added to the new system in preparation for its deployment to the rest of the rain sector farmers and the characteristics and capabilities available in it, the most important of which are the higher rainfall rates From 600 mm. 149 farmers, on an area of 2,230 feddans, benefited from it. This investment resulted in good results, as the productivity ranged between 513 - 1170 kg / Fadden (6 - 13 sacks) with an average of 700 kg / acre (8 sacks) compared to 250 kg / acre (3 sacks) for the traditional - Figure 3. In comparison with the results of the averages of the Arab Authority and the Auxiliaries, with the exception of the White Nile, which is equal to those of these bodies (13 sacks), the average of the program is less than 200-350 kg / Fadden, which may be attributed to the lack of full application of the terms of the system packages or to the lack of their inputs, especially crops and triple fertilizer. In order to achieve better performance, higher productivity, similar to the body, and ACSD, it is necessary to:

- That the program provides technical and material support, including the deployment plan, the appropriate mechanisms for conservation agriculture, and the inputs. An indicative program to build the capacity of farmers and members of production groups and cooperatives on a sustainable and competitive system.

- Spreading the system with demonstration fields for farmers with the support of research, including monitoring the performance of technologies in new and stalled expansion areas.

Figure 3: Comparison of average yield of Sorghum (kg / feddans) for conservation agriculture with the production of the Arab Authority and the ACSAD project and the traditional rain fed sector.



Achieved results and observations of the CA system

The system was superior to the traditional one in terms of germination speed, good growth and similar plant density The cultivated crops showed a greater tolerance to water stress compared to the traditional ones Implementation of agricultural operations in a shorter time, as they are fully mechanized Convinced farmers of the system - Concentrating technology in a specific area with a complete package is better than vertical expansion, as in the experience of one of the farmers from the south of the White Nile, who focused on guiding the program on 500 acres and produced 13 sacks per acre and equaled the production of 4 agricultural projects automated with the traditional semi-automatic agriculture (the wide disk), which does not exceed Its average productivity is 3 sacks / Fadden. – Affordability.

G / Production costs and investment returns for water harvesting technologies, conservation agriculture and traditional practices to ensure the economic viability of the applied technologies; the program conducted simplified calculations of the seasonal cost, outputs and returns. The economic return is what determines whether a system is effective or not.

Water harvesting WH

Table 2 summarizes the average cost, total revenue, and net profit per acre for the water harvesting canals of 10 states that were able to collect data for outlay and return. The numbers in the table refer briefly to the following: The average cost per acre for water harvesting systems ranged from 677 to 780 pounds, and 904 to 981 pounds, compared to 464 pounds and 236 pounds for the traditional one. • The rate of return on investment is equal to 1.3 for the first three systems, compared to 0.5 for the traditional one • Water harvesting systems outperformed the conventional by 4 times • The differences in costs in the states, as well as due to differences in service prices, inputs and selling prices at harvest, and of course the quantity of production.

Table 3: Average production costs and investment returns for water harvesting technologies and traditional practices (g / Feddans)

Models	Cost	Production value	Income	Income : Cost Percentage
First	780	1761	981	1.3
Second	693	1617	924	1.3
Third	677	1581	904	1.3
Traditional	464	700	236	0.5

Conservative agriculture CA

We believe that the cost-benefit calculation is of particular importance for conservation agriculture, as it is for the first time that these data appear documented despite the activity that the Arab Organization and ACSAD had previously performed. Table 22 numbers refer to the following: • There is a great variation in the cost of an acre from one state to another, as the highest amounted to nearly 1,200 pounds in Gadarif, the lowest in the Blue Nile 535 pounds, and a convergence between Sennar and the White Nile, with an average of 941 pounds • White Nile State recorded the highest net worth and came from its

production, which amounted to 13 sacks and the lowest return in the Blue Nile (577 pounds), with an average of 1201 pounds.
• As for the cost of traditional agriculture, it ranged between 350 and 560 pounds, with returns in the range of 51-170 pounds. The average is 472 pounds for the cost and 108 pounds for the return. In comparison with the water harvesting systems, the conservation agriculture was better, with an increase of 200-300 pounds • Conservation agriculture surpassed the conventional in yield by nearly ten times

Obstacles

The implementation faced several obstacles that require attention to them and a review of the mechanism and methodology of work to ensure that these dilemmas are overcome for effective sustainability and wider participation. And based on an inventory of the obstacles that 13 states undertook, the most important of them in order and importance are as follows:

1. Scarcity of mechanisms.
2. Poor funding.
3. Movement is questioned.
4. The scarcity of improved seeds.
5. The unavailability and high prices of fertilizers.
6. Insufficient extension.
7. Weak agricultural transactions.

Also, some states added that agriculture was delayed, due to the late arrival of the machinery that provided. The figure below indicates that out of 13 states, all of them mentioned the scarcity of machinery and the lack of funding, 11 referred to the problem of movement means and the scarcity of improved seeds, 9 acknowledged the scarcity of fertilizer, its high prices, and the lack of extension services, and 7 acknowledged the weakness of agricultural transactions.

Recommendations

The previous season was concluded by holding an evaluation workshop for it in Khartoum on 11-12 March 2015, in which representatives of the states including mentors, general managers, producers, ministers of agriculture, experts and specialists, and stakeholders from the Ministry of Finance and National Economy, the Ministry of Agriculture and Irrigation, Agricultural Research, Agricultural Bank, Microfinance, Sector Private, and development organizations organized by the Ministry of Agriculture and Irrigation and under the auspices of the Vice President of the Republic. The workshop resulted in the recommendations below:

• Continuing to support the formation and registration of producer associations and motivate them to apply technologies on a large scale.
• Agreement and coordination with financing banks to give priority in financing to productive groups and cooperative societies after providing them with a list of those who wish and the cost of the unit based on the economic feasibility of investments as a guarantee compared to traditional systems.
• Supporting the establishment of new technology and extension centers and strengthening the existing ones logistically, technically, and establishing a nucleus for establishing integrated models and providing agricultural and extension services in cooperation with research stations.

• Linking producers' associations, subsidies, and villages with technology transfer and extension centers, agricultural service companies, and financing outlets directing horses to manufacture small-sized (homemade) no-till crops and sprinklers to be accessible to small farmers.

• Reducing costs by training farmers to use technologies and application at the field level on their own.
• Attention to documentation and publication of brochures, applications, and guiding aspects to support the adoption process.
• Paying attention to field controls, collecting correct data in a timely manner, and intensifying the presence in the field.
• More cooperation and coordination with agricultural research stations in developing plans, applying technologies, contributing to training and participating effectively in data collection and field monitoring.
• Paying attention to implementing integrated packages and focusing on increasing productivity anchored to narrow the gap in research results.
• Logistical support for the states by providing means of movement.
• Separation of the operating budget for research from state ministries.
• Convincing farmers of the agricultural, economic and environmental benefits, especially the effect of the system on protecting the soil from erosion.
• Continuing to build the capabilities of technical personnel and producers, both internally and externally.
• Establishing favorable policies to support this type of motivated production and solve marketing problems.
• That the Ministry of Electricity and Water Resources (Water Harvest Department) support the program by investing in the implementation of large water harvesting facilities (water dispersal, torrential irrigation, surface and sand water tanks, water containers) for supplementary irrigation and capacity building.
• Coordination with this ministry in linking its program for water harvesting intended for agricultural purposes to this program.
• Coordination with development projects and voluntary organizations to help spread and expand the program's technologies.
• Creating a network of technology users and beneficiaries, organizations and the private sector to promote them.
• Continued flow of operating and management installments on a timely basis.
• That the budget of the program is not used or transferred for other purposes in the states.
• Good documentation and preservation of data for future use to calculate the program's internal rate of return.

Future directions for the program

• The introduction of conservation agriculture activity in the irrigated sector for the winter season in the Northern states and the Nile River.
• Working to maximize the benefit by adopting the value chain by improving animal nutrition from packages and processing of feed, mixtures of Sorghum and groundnut cake.
. • Spreading the value chain by supporting producers by providing sectors and packages of feed and small oil squeezers.
• Investment in the construction of water containers in large water basins (water dispersal, sand tanks).
• Work to obtain external funding for the program.

Third: The International Organization Activities

The adapt project aims to integrate environmental management, governance and climate-resilience best practices into a humanitarian and development program to help the people of Sudan cope with environmental stress and climate change. IWRM is "a process that promotes coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." The overall objective of the integrated water resources management (IWRM) theme in adapts is to enhance management, control and use of water resources in a sustainable manner.

National Adaptation Program for Action NAPA
Climate Change Adaptation Project.

This project aimed to build the community adaptive capacity to vulnerability due to climate change in four pilot areas. The areas covered different geographic and climatic zones. The project based its interventions on stakeholder participation, awareness-raising, training through demonstration farms, empowerment of women, coordination, establishment of revolving funds and increase of crop productivity through field water harvesting (construction of terraces) to increase soil moisture. The project received international, national and State support, which also contributed to its success. The project produced excellent results in the pilot areas, exemplified by increased productivity of crops by three folds (from 400 to 1200 kg/hectare), and forage by 50 per cent compared with the traditional rain-fed agricultural method. This project demonstrated a good IWRM practice, though its scale was a concern as the unit used is not a catchment unit.3. Butana Integrated Rural Development Project. This International Fund for Agricultural Development project in Gadarif State aimed to improve, in a sustainable manner, the livelihoods and resilience to drought of poor rural households. The project helped to establish a coherent and cost-effective governance framework that ensured regulated access to land and water resources. It also developed the capacity of community-based organizations (CBOs) to engage in environmentally sound, social and gender-equitable development initiatives in the Butana area. The project resulted in improved access to domestic water supplies, which is considered as a lever for communities (especially women) to actively participate in development activities. It also increased the involvement of communities in successfully combating botulism, which is a common livestock disease in the area. Organization and empowerment of communities, supported by local policy acts and orders, are proven to be effective. The project significantly contributed to protecting the community reserved rangelands and assuring a high level of follow-up and good productivity. There were also partnership among water committees (WCs), the Rural Water Corporation (RWC), localities and the project, thus allowing better participation leading to a higher probability of sustainability of services and innovative interventions in soil and water conservation. Generally, there was improved crop productivity, range-carrying capacity, and biodiversity and water availability. The project demonstrated IWRM good practices, especially in the empowerment of women, through the use of pilot areas for further up-scaling.

1 – Butana Integrated Rural Development Project

Background

Like most of Sudan, Butana area (East of Sudan) is characterized by erratic rainfalls, high temperatures and strong winds. Herds have traditionally grazed freely, and livestock production is the most important economic activity in the Butana region of Central Eastern Sudan. However, an increase in livestock population over recent years, the presence of nomadic pastoralists from Southern Sudan and fluctuating

rainfall patterns have all contributed to severe deterioration of grazing resources. This has led to the collapse of the existing economic system, which has particularly affected sedentary farmers, who lost many animals. To support these farmers, the local government fenced a large area of land close to the town of *As-Subagh* in 2006, trying to protect it from harmful dust and erosion. This was to serve as a demonstration plot to build awareness on environmental degradation and the need for natural resource protection, conservation and restoration. The fence also protected the area against unwanted grazing, allowing space for the cultivation of crops. However, no additional activities were carried out, and eventually large portions of the fence were looted or dismantled, leaving the land unused. The development goal of the project was to improve the livelihoods and resilience to drought of poor rural households in a sustainable manner. The specific objectives were to:

1. Establish a coherent and cost-effective governance framework that ensured regulated access to land and water resources of Butana.
2. Improve the access and bargaining position of women and men in the marketing of livestock.
3. Develop the capacity of CBOs to engage in environmentally sound, social and gender-equitable development initiatives.

The project components were

1. Institutional support and project management.
2. Agricultural, range and water development.
3. Livestock and marketing development.
4. Community development. The Butana Development Agency (BDA) carried out coordination and backstopping functions for five State Coordination Units (SCUs) and their development teams. Direct/indirect beneficiaries were 40,000 households with total project costs of 29.8 million United States dollars. Keys to success

1. Capacity-building and institutional strengthening supported by local policy acts and orders.
2. Community involvement.
3. Innovative interventions in soil and water conservation for rangeland rehabilitation and development
.4. Organization and empowerment of communities.

Title Integrated rural development Situation

In the Butana area Domestic water supply is not easy, and women and children suffer a great deal in fetching and carrying water over long distances.

Drought recurrences are frequent; thus, improved crop varieties need to be promoted where a dual-purpose crop could reduce the risks in drought years. Feed rationing should be based on what is available and/or could be made available through strengthening range, pasture, forest and rain-fed crop development. There is a need for a coherent cost-effective governance framework that ensures regulated access to land and water resources of Butana so that community and open grazing areas can be protected, improved and supplemented with dual-purpose dry land crops, irrigated fodder, leguminous crops, left-over crops and agriculture by-products.

Problems

1. Communities have no easy access to domestic water (it takes 2-4 hours to carry water from the source to the home).

2. Spread of botulism.
3. Lack of governance framework
.4. Severe degradation in land and grazing resources causing low productivity of agriculture and livestock.

How the problems were overcome Involvement of communities has been a key factor in successfully combating the dreadful botulism. The solution was to start a process within communities to address the problem. This involved creating an understanding of the disease, namely the bacterium *Clostridium botulinum*, which flourishes in animals with deficiencies. Organization and empowerment of the community, supported by local policy acts and orders, before the introduction of soil and water conservation interventions for rangeland rehabilitation and development are proven to be effective. They significantly contribute to protecting the community reserve rangelands and assuring a high level of follow-up. Access to improved domestic water supply is a prerequisite for communities to actively participate in development activities, especially for women. In the interest of communities' access to potable water services, partnerships among WCs, RWC, localities and the project allowed increased participation, leading to a higher probability of sustainability of services. The innovative interventions in soil and water conservation improved the productivity. Wisdom of the keys to success the close coordination between the institutions at the State, locality and community levels along with BDA. The State line ministries' involvement in decision-making over planning and execution (SCUs) and coordination mechanisms at locality level, and CBOs showed a high degree of national ownership for the project. Community awareness, gender sensitization and community organizations provided significant input to the governance of natural resources, exemplified in protecting and rehabilitating range and forest areas. Communities showed their potential as champions and drivers for up scaling. Women and men played active roles in the protection, rehabilitation and utilization of these range and forest areas. This resulted in improvement of the range capacity, as manifested in the restricted movement of sheep flocks. Conditions and limitations in applying the keys to success

1. Difficulty in solicitation, involvement and coordination among the different relevant institutions.
2. Absence of proactive institutions coupled with policy acts and legal framework.
3. Ideas for enhancing applicability of the keys to success.
4. Build awareness and consensus.
5. Strength community-based decision-making.
6. Stakeholder participation at all stages.

Results

Areas for open-access ranges and community ranges were delimited. BDA was established and had a unique set-up, which is perceived as being powerful and important. The Board of Directors was active in guiding BDA. Generally; there was improved crop productivity, range-carrying capacity, and biodiversity and water availability. Enhanced terrace cultivation: the project helped in enhancing irrigated fruit and vegetable gardens and annual coverage of fire lines. The benefits of demonstration farms, wadi cultivation and water harvesting for rangeland improvement were evident. About 51,348 feddans of rain-fed areas were treated with terrace cultivation, benefiting 6,427 households. Farmers have already adopted tree boundary planting, while some have developed fodder (Clitoria, Philpesera and Guar) plantation in terraces. An approximate 540-900 kg/feddans increase in sorghum productivity was recorded compared to 180-270

kg/feddans under traditional cultivation. Considerable achievement was made in wadi cultivation and contour ploughing cultivation.

2- South Darfur

For agriculture and water harvesting, the project supported treatment and distribution of improved seeds (5,773 farmers), distribution of 300 improved animal-drawn ploughs on a revolving fund basis, preparation of 1,547 feddans (700 farmers) (including demonstration farms) using different water harvesting and tillage practices, cultivation of 14,210 feddans using traditional ploughing methods, and distribution of 130 kg of improved vegetable seeds (80 rain-fed and 50 irrigated) for the benefit of 824 farmers. The impact of improved production packages was that in 2015 (rainfall of 257.8 mm), the combination of water harvesting, and chisel ploughing resulted in increasing the crop productivity by 8.5 times its original productivity and dry matter productivity (animal feed) by 10 times compared to that of natural rangelands. Fodder production was 1.4 t/feddans using water harvesting and chiseling, 0.4 t/feddans with chiseling only and 0.1 t/feddans with traditional methods. In 2016 (rainfall of 419 mm) a combination of water harvesting, and chiseling resulted in crop production of 1,325 kg/feddans, chiseling only produced 841 kg/feddans and traditional ploughing produced 419 kg/feddans. For fodder in 2016, production was 1.5 t/feddans for chiseling and water harvesting, 1 tone /feddans for chiseling only and 0.17 t/feddans for traditional methods. For forestry and range improvement renewable energy, the project conducted a Training of Trainers (TOT) in intensive special package (ISP) for 40 participants and trained 750 women in ISP. And as result of this training productivity of clitoris and cowpea increased by four and five times, respectively. Use of improved stoves reduced firewood consumption by 50 per cent. Production and distribution of 35,000 forest and fruit tree seedlings was supported for 1,165 beneficiaries, and the survival rate was 65 per cent. For animal production, the project distribution of 21 improved breeding goat males (986 off springs). This resulted in increasing goat milk production from 0.7 kg/day to 1.6 kg/day and body weight gain at the age of 6 months (9-17 kg). The difference in price at age of 6 months was 100 per cent (50-100 SDG). Improved breeding cockerels were also introduced.

3-River Nile

For agriculture and forestry, there was distribution of 28 irrigation units, establishment of 55 shelterbelts, and distribution of 729 butane gas units (revolving fund) and 15 gas ovens. This resulted in reduction of policed cases in the violation of the Forestry Act by 40 per cent in the project area. A 5-feddan women's collective farm equipped with an irrigation unit was also established. A total of 34 demonstration farms led to tremendous improvement in the productivity: five bean production increased from 405 kg to 990 kg and broad bean production from 660 kg to 1,265 kg. For animal protection, 8,624 farm animals were treated and 1,811 were vaccinated, 30 wooden moulds for cheese production were distributed, 108 improved breeding goat males were introduced, and pesticide application pumps were distributed.

Conculsion

Climate change is expected to intensify existing problems and create new combinations of risks, particularly in Sudan. The situation is made worst due to factor such as widespread poverty, over dependence mainly in

traditional rain fed agriculture, inequitable land distribution, limited access to capital and technology, inadequate public infrastructure, such as roads, long term weather forecasts and inadequate research and extension. By lessening the severity of key damages to the agricultural sector, adaptation is the key defensive measure.

Adaptation to climate change involves changes in agricultural management practices in response to changes in climate conditions. This report reviews agricultural adaptation strategies employed by farmers in various parts Sudan in cushioning the effects of climate change. The common agricultural adaptation strategies used by farmers were the use of drought resistant varieties of crops, crop diversification, changes in cropping pattern and calendar of planting, conserving soil moisture through appropriate tillage methods, improving irrigation efficiency, and afforestation and agro-forestry. The report concluded that improving and strengthening and improve indigonous knowleageds and human capital through education, outreach programs, extension services at all levels will improve capacity to adapt to climate change impact.

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