EVALUATION OF RICE PRODUCTION IN AWEIL RICE IRRIGATION SCHEME OF NORTHERN BAHR-EL-GHAZAL STATE IN SOUTH SUDAN

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Abstract

A 4 weeks' data collection was carried on Aweil Rice Irrigation Scheme (ARIS) and the rice farmers from the surrounding community including some governmental institutions such as State Ministry of Agriculture and Environment and the State Ministry of Cooperatives and Rural Development under Northern Bahr -el-Gazal State Government. The purpose of the study was to evaluate the economic viability of rice farming and production, existing infrastructures, water infrastructure, as well as other information related to capacity gaps in ARIS and the smallholders rice farmers in Aweil Town. Semi–structured interviews comprising of both qualitative and quantitative were used during the study to gather information on rice farming in Aweil. ARIS was established in 1944 by the British Colonial Administration in the then Sudan and the scheme covers an area of approximately 11,000 feddans with 9 basins which used to produce about 3 tons of rice per hector. However, the scheme remained inactive due to the long-standing civil wars in the former Sudan before South Sudan's independence and its administration is currently placed under the National Ministry of Agriculture and Food Security, Republic of South Sudan in Juba. There is very high demand for rice grains in the domestic and regional markets. The major challenges facing the scheme were: floods from the Lol River through the canal during the peak rainy season, zero germination rate of seeds received from partners, lack of seed multiplication technology and skills to preserve indigenous and adoptive rice seeds, limited mechanized tools, lack of credits from the formal financial providers to boost the rice farmers' earnings. The Government and partners should establish National Rice Projects in uplands/lowlands and encourage the private sector to implement the local banking policies with a focus on the rice scheme and the farmers' access to credits for resilience and sustainability in Aweil and the whole country. South Sudan is encouraged to obtain membership in the coalition for African Rice Development. Future studies into the Aweil Rice Irrigation Scheme is recommended.

Keywords: *Aweil Rice Irrigation Scheme, rice production, infrastructures, employment and opportunity*

1. INTRODUCTION

Rice is measured as a key food crop and is one of the main staple crops for 54% of the world population which provides 21% of the total human caloric requirements. Rice is not a new crop in South Sudan, and the modern rice farming began in the forties of the last 19 centuries. Rice consumption rate is high in South Sudan but are majorly imported. The rice industry in the country is in its early stages. Rice and its stalks are considered as an important source of forage for livestock and poultry. In addition to oil that could be extracted from its seed, rice can also be used in starch and glucose industries in many countries (NERICA, 2014).

Food Security trends in South Sudan indicate an alarming rise in food insecurity over the past five years. According to the latest IPC analysis in December 2020, an unprecedented sixty (60 %) percent of the population in South Sudan is projected to face severe food insecurity in the upcoming lean season from April to June 2021. The food insecurity situation will be widespread among rural households and many poor urban households will be unable to meet their daily food needs (FEWSNET, 2020).

In comparable vein per capita consumption of rice has shown the tendency of gradual increase starting from 1999 and it was 1.98 kg/capita/year in 2007. Since then, there has not been any significant increase, in the per capita consumption of rice which was only 2.00kg in 2019., However, it is projected that the per capita consumption will increase by 125% to 4.5kg by 2030. This is due to the fact that a large number of Sudanese people migrated to the Gulf countries since 1960s where the staple food is rice which has affected their food culture upon return to the Sudan (FMAF/FAO,2009). For the last three years, South Sudan imported most of its rice from Egypt (80~90%). Rice from Egypt is considered as short grain rice hence, most of it is consumed rice in the country. The locally cultivated rice is considered to be short grain type. Following Egypt, Thailand came with the share of 13.6% in 2008 though shares of imported rice from Thailand in 2006 and 2007 were very small. India and Pakistan had constant shares for the three years, totaling 6-7 percent. Some of the rice from India and Pakistan are considered Basmati which is aromatic rice with higher price (FAO/MAFS 2020).

South Sudan is a landlocked country with an area of around 640,000 sq. km and an estimated population of 12.5 million, placing it among the less densely populated countries in Africa (Tizikara and Lugor, 2009) with population density of about 19.53 persons per square kilometres. It has three levels of government, namely national, state and local. The local government is further subdivided into the County, Payam and Boma administrations, with the Payam and Boma corresponding roughly to the district and village levels, respectively. About 80% of the total population in the country are based in rural areas while only 20% live in urban areas. More than 90% of the total area is arable, with 50% considered as good and prime agricultural land. Of the total prime agricultural land, only about 5% is currently being utilised and 12-15% is covered by ASALs. Over the years, the severity and frequency of floods and droughts have increased drastically and their effects are exacerbated by the increasing phenomena of torrential or erratic rainfalls, land degradation, global warming and climate change. Most of the people (76%) in South Sudan derive their livelihood from crop farming and animal husbandry (South Sudan IDDRSI Feasibility Report, 2022).

Aweil Rice Irrigation Scheme

Aweil Irrigation Rice Scheme (ARIS) is the oldest scheme in South Sudan having been initiated in 1945 as a Prison farm of 4 feddans. Since then, it has expanded to the present gross area of 22,000 feddans. The scheme‘s infrastructure was destroyed and abandoned during the civil unrest but was partially rehabilitated by GIZ IS through EU‘s 5 million Euros funding in the period 2008 – 2012. In October, 2012, GIZ IS handed over the Scheme formally to the Government (MAFCRD), together with 300 tenant farmers (both large and small-scale) and 92 staff members.

The Scheme is located just outside the town of Aweil in Northern Bahr El Ghazal State. Paddy production in AIRS was initiated in 1945 by the British Colonial Government District Commissioner as a prison farm with the size of four (4) feddans in the flood plains of river Lol (toich). By 1947 the rice production area was extended to 21 ha (50 feddans). In 1953, the scheme was taken over by the Sudanese Government Ministry of Agriculture and Forestry and expanded to cover an area of 210 ha (500 feddans). Flood protection dikes and a number of basins to enclose the irrigable area had been built since 1961 covering a total area of 11,000 feddan (4,600 ha).

In 1978, the European Economic Community (EEC) approved funding for the development of 4,600 ha (11,000 feddan). It is estimated that 1,100 ha (2,700 feddan) have been levelled and provided with water management structures before the war began in 1983 which in effect closed down the project. From 1983 to 2005 the Scheme was undeveloped.

After the Comprehensive Peace Agreement in 2005, under the Sudan Productive Capacity Recovery Programme funded by EU the Ministry of Agriculture and Forestry signed an agreement with GIZ to implement the Aweil Irrigation Rehabilitation Project (AIRP) from 2007 with provision of machineries and rehabilitation of three (3) basins totaling to 1,150 ha (2,700 feddans). The project was handed over to the Scheme management, which is under the Ministry of Agriculture, Forestry, Cooperative and Rural Development (MAFCRD) of the National Government in October 2012.

The Directorate of National Projects together with other senior staff of the National Ministry of Agriculture and Food Security and partners from FAO South Sudan and WFP South Sudan paid a visit to all the National Agricultural Projects in the country in 2021/2024. The main purpose of the visit was to assess the condition of Aweil Rice Irrigation Scheme and the other partners’ projects in the state. It was also meant to determine the level of farmers’ preparedness for this agricultural season.

History of the Irrigation Scheme

Generally, Irrigation schemes development in South Sudan started in the middle of the 20th Century during the British colonial area. The major irrigation schemes developed in this time are the Aweil Irrigation Rice Scheme (ARIS) and

Northern Upper Nile Irrigation Schemes (NUNIS). Also Mongalla-Gemmeiza sugar plantation was a planned large-scale irrigation scheme.

The operation and implementation of those irrigation schemes had been suspended during the civil unrest. To date, Mongalla-Gemmeiza sugar plantation has been abandoned and no concrete schedule yet for revitalization of its activities. Pump stations in the Northern Upper Nile have not been operated due to either incompletion of necessary rehabilitation or high operation cost; and farmers there are cultivating small-scale farmlands mainly by rain-fed.

Aweil Rice Irrigation Scheme (ARIS) was established in 1944 by the British Colonial Administration in the then Sudan and the scheme covers an area of exactly 11,000 feddans with 9 basins which used to produce about 3 tons of rice per hector but the scheme remained inactive due to the long-standing civil wars in the former Sudan before South Sudan's independence. ARIS administration is currently placed under the National Ministry of Agriculture and Food Security (MAFS), Republic of South Sudan in Juba. However, partners such as EU, GIZ and FAO provided financial support in its rehabilitation in 2007/8 and handed it over in 2012, though there are a lot of issues to fully operate the scheme in sustainable manner but remained low to meeting the required budget to fully scale up the operations. Currently, 400 feddans of rice are in operations supported by the MAFS with fuel and maintenance of the mechanized tractors meanwhile FAO office in South Sudan provides ARIS and the local farmers with rice seeds to strengthened rice farming in Aweil area (FAO/MAFS 2020).

Historically, flooded rice was first planted in Aweil Town of Northern Bahr-el-Gazal State in 1905 and then introduced to the Gezira scheme of the Republic of Sudan in 1976 – 1977, with total planted area of 4,200 hectares and achieved high productivity around 6 tons per hectare under irrigated low land cultivation. Studies carried out by Japan International Cooperation Agency (JICA) in between 1973- 1978 periods attested the feasibility of growing rice in the White Nile State of the Republic of Sudan as the average productivity for the experiments which reached 9.9 tons per hectare under irrigated low land cultivation. Flooded rice is being cultivated traditionally (local varieties) at the Kosti area of White Nile banks under 5000 - 8000 hectares with the average productivity of 3.5 tons per hectare.

In 2009, the rice scheme was rehabilitated through the Aweil Irrigation Rehabilitation Project supported by GIZ under the Sudan Productive Capacity Recovery Program (SPCRP), funded by the EU. During the project period, demining, dike and canal maintenance were carried out and agricultural machinery (e.g., large scale rice mill and heavy equipment) and technical assistance were provided. However, after completion, the scheme has not operated effectively due to limited funds for operating costs and limited human resources. The Nile Basin Initiative recommended 3,000 ha expansion from existing land. The land around the scheme is inhabited by both the community and technical workers. The land, according to the government is basically in the hands of community leaders. The national government selected land for irrigation in which some parts of the land is not yet irrigated (NBI, 2012).

ARIS has the potential of supplying food needs of South Sudan and even for exports. During its best days, rice used to be exported to Europe from the irrigation scheme. The immediate beneficiaries are the inhabitants of the metropolitan town of Aweil municipality who would enjoy low-cost rice and members of the three chiefdoms of Ajuet, Sheimel and Aweil Centre. Once in operation, considering the current allocation of 2 feddans per household, it`s estimated that over 1,500 households would directly benefit from the project (IDDRSI, 2022).

According to the study, ARIS Administration has given out 100 feddans of their farm to 100 local farmers in the area supported by FAO pilot project for Resilience under special arrangements (Shares 40% to the administration 60% to the farmer). The water sources in ARIS and the surrounding areas include: Lol River through the constructed canal into the Rice farms, seasonal streams, the wells (ground waters) and the rainfalls (IDDRSI, 2022).

Global Rice Sector

Rice has been one of the world's most important food crops for ages and the total area under rice cultivation is estimated to be 150 million ha with annual production averaging to 465 million metric tons (milled rice) in 2010, with two percent harvest in 2009. Rice is a tropical crop that have been cultivated in moderate regions and achieved high productivity that reached 8 tons per hectare in Australia, 6 tons per hectare in China and Japan. Rice world trade in 2010 stands at 31.0 million tons, 6 percent above the previous year. FAO forecast of global rice trade in 2011 points to two percent contraction to 30.5 million tons (milled basis). However, rice world stocks have risen by five percent to 136.2 million tons, the highest since 2002 (FAOSTAT 2010).

Africa Rice Sector

Rice is a staple food for a rapidly growing population in the Sub-Saharan Africa (SSA) and is the fourth most important cereal crop in SSA in terms of production after sorghum, maize and millet. Rice occupies 10% of total land under cereal production and produces 155% of total cereal production in SSA. Approximately, 20 million farmers in SSA grow rice and about100 million people depend on it for their livelihood. Between 1960 and 2003, consumption of rice in SSA increased annually by 4.4%. Among the major cereals cultivated in SSA, rice is the most speedily growing food source and the annual increase in production is about 4%. New Rice for Africa (NERICA) is popular among farmers and has the potential for high impact on their livelihood (NERICA,2014).

In 2010, rice paddy production in Africa is projected at 24.6 million tons, one percent more than in 2009. Consumption of rice in Africa is within the range of 16.0 million metric tons while production is at 14.0 million metric tons, creating a deficit of 2.0 million metric tons. The increasing dissemination of imported rice in SSA does not only result from constraints that hampered the development of local production, it also reflects imported rice distribution channels advantages in terms of product handling and packaging. But as rice is becoming a core component of the diet in many

countries, consumers will be more sensitive to quality and taste attributes which might benefit local rice industry if handling is upgraded (Assessment mission report 2009/10).

South Sudan Rice Subsector

To strengthen the role of the agricultural sector in achieving resilience objectives such as food security, poverty alleviation and export promotion of rice produce, the government through the MAFS has adopted expansion of agribusiness enterprises with focus on both upper and low lands rice commercial farming as the planned approach to tackle food insecurity and jobs in the country. Rice is a secondary cereal crop that ranks the fourth after sorghum, wheat and millet. Its cultivation was limited between Latitudes 4 and 13.5 North, where the climatic conditions are suitable for its growth (FAO/MAFS 2020).

Status of Rice Subsector in the National Agricultural Policies of South Sudan

The Ministry of Agriculture and Food Security together with other partners have developed a comprehensive agricultural master plan in 2013 and an investment plan 2015 to foster commercial rice and other crops farming in the country. This program targets export development of agricultural products, poverty reduction, and food security as the overall goal of improving agriculture productivity and competitiveness of agricultural products. South Sudan Agricultural policies and the comprehensive master plans call that; agriculture sector is the engine of the country's economic growth and for that reason encourage the private sector to execute all the agricultural production, services, inputs and marketing activities. It calls to reduce taxes on agriculture, support extension services, avail finance and promote export of agricultural commodities. South Sudan placed rice as one of the strategic crops in the agricultural policy even though monitoring and evaluation of policies are insufficient, it is said that rice self-sufficiency was estimated at around 21% in 2007 (CAMP,2013/15).

National Rice Production Trends

In South Sudan, rice is ranked amongst the first four major staple cereals and is produced in two types of production systems, that is, uplands and lowlands or paddy rice production. However, the total rice area, productivity and production remain low due to lack of commercial rice farming practices coupled with the existing small scale rice farming activity in the country. Although the demand for rice cereals is potentially high in the domestic markets, the rice supplied into South Sudan were majorly through imports from the regional and international countries.

Rice Import and Self Sufficiency

Before the secession of South Sudan, rice self-sufficiency reached to almost 100% in the mid-70's, but it has dropped to less than 30% during the 80's and below 5% during the 90's. The amount of rice as food has shown an upward trend since 1961, and rice imports has increased drastically. As of 2007, the quantity of rice consumed as food was about 70,000 tons of milled rice while domestic production of milled rice was estimated at about 15,000 metric tons which gave a deficit of fifty-five thousand metric tons of milled rice which was imported; this showed a self-sufficiency of 21% (IDDRSI,2022).

Rice Marketing and Consumers' Preference

Rice is majorly imported into South Sudan by traders, it is distributed via wholesalers or packaging companies to retailers in the whole country. Traders import only milled rice, which is traded for all distribution channels. On the other hand, traditional rice produced in the swamp area in the White Nile state is consumed in the surrounding areas. In most of these areas the farmers consume all the rice they produce, with little or none for the market. Therefore, this supply channels end within the production area. In those areas, although local rice is preferred by local consumers, imported rice is also sold in the local shops. Elements of consumers' preference of rice can be divided into variety and quality. There could be three different groups based on varieties for imported rice. One is Basmati group. Basmati is normally imported from Pakistan and India and preferred by high income consumers with high price. The other two groups, namely other long grain group and short grain group, are for the general consumers. In the markets, other long grain seems to be imported from Thailand and Vietnam, and Egypt is a big exporter of short grain to South Sudan. As for quality, important traits are color and shape of grain of rice. For all three groups of imported rice, common traits are white and head rice (without broken particle). The quality of rice can meet these standards if the new released varieties and the proper production and processing technologies are adopted (MOAF,2018).

Rice Demand Projection in Sudan

Demand for rice in the Republic of Sudan was projected as shown in Table 1. Assumptions adopted for this projection are that i) rice demand per capita was assumed to increase from the current level and ii) population growth is assumed as linear using the past data (1993 to 2007 from FAOSTAT & National Rice Program- reports 2018) Target year was tentatively set as 2030 for this projection.

Descriptions	**2019**	**2024**	**2030**
Per capita consumption(kg/year)	2.00	3.13	4.50

Population (Million)	43	48	53
Domestic Rice Demand(MT)	86,000	150,240	239,000

Source: Sudan Agricultural Statistics Department MOAF, 2018.

Problem Statement

Aweil Rice Irrigation Scheme in Northern Bahr-el-Gazal State of South Sudan is potentially known for its huge rice production since 1940s, as well as in the Horn of African (HOA) region but the scheme was faced with the challenges of severe droughts and flooding directly from the Lol River caused by heavy torrential rains in Aweil area.

Aweil Rice Irrigation Scheme Water Gauge

2. Materials and Methods

2.1. Study Area,

Aweil Town is the administrative headquarter of Northern Bahr-el-Gazal Sate situated in the North of South Sudan with a population estimated at 147,579 people and a population density of 13.5 ppl/km^2 in 2013 by South Sudan National Bureau of Statistics as shown below in the map 1.

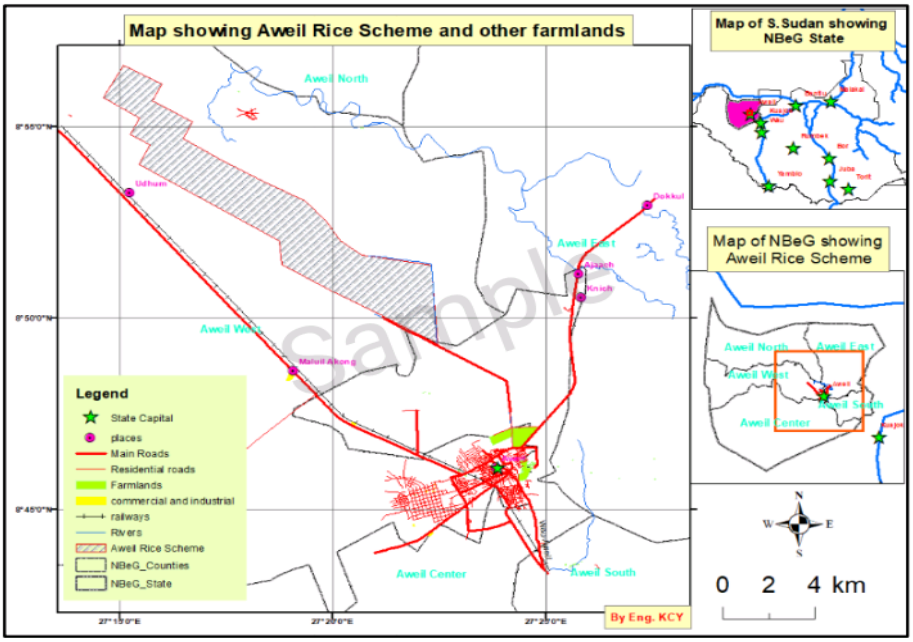

Figure 1: Shows the map of Aweil Rice Irrigation Scheme, Northern Bahr-el-Gazal State of South Sudan

2.2 Approach

A 4 weeks' data collection on Aweil Rice Irrigation Scheme farming and production, infrastructure, water infrastructure, as well as other information related to capacity gaps related to rice farming in the scheme and the surrounding community in Aweil Town using a harmonized semi–structured interviews (SSI) comprising of both qualitative and quantitative methods. The study targeted Aweil Rice Irrigation Scheme Administration, community smallholder rice farmers, traders, associations and the cooperatives.

Key informants' interviews were held with ARIS staff, paramount chiefs, FAO Aweil Field Office and other governmental institutions such as State Ministry Agriculture, Forestry and Environment and the State Ministry of Cooperatives and

Rural Development to gather specific data towards rice production in Aweil and the trending demand both in the domestic and regional markets.

2.3 Data management and analysis

During the study process, all data quality control measures were adhered to which included; review of the study tools, regular supervision and cross-checking of the completed tools. The data collected was reviewed and analyzed through critical reading to ensure that, the fillings are in line with the study objective. During analysis, cross tabulations was conducted by comparing the evolving information with the secondary data to ensure correctness and consistency.

3. Results and Discussion

3.1 Participant's observations

Participant observations were considered in the study to providing direct access to the rice irrigation scheme fields and the interviews were administered in the interest of the respondents for easy collection of data. This involved watching, recording and taking on-spot photographs. In the observation process, some information was collected based on the rice farms, rice stores, rice traders and their farming environment including the markets. This has clearly indicated whether the participants feel isolated or no due to the government's current marketing policies (Barbara et al., 2005).

3.2 Water Management

Rice cultivation is being done mainly by using rainfall water and the flooding in the scheme and the other areas in South Sudan. Irrigation water is the most critical input factor in rice cultivation as well as other crops and the rice sowing date is mainly associated with rainfall and flooding time. The main constraints facing the Aweil rice irrigation scheme water resources management practices on rice cultivation may possibly be listed as follows:

- Inadequate cleaning of irrigation channels from sediments
- Ineffective irrigation pumps to distribute the water promptly
- Inadequate funds for operations and maintenance of irrigation pumps
- Old and damaged irrigation distribution structures which facilitate availability of irrigation
- Lack of appropriate and efficient irrigation techniques
- Frequent flooding from the Lol River through the canal constructed during the peak seasons

One of the adoptions is to increase rice productivity in the country so as to improve water distribution and management strategy which ensures that water is efficiently distributed. The water requirement level for upland rice is similar to wheat cultivation, although the total requirement of water is relatively small, water deficiency especially at some specific growth could cause serious damage to the production of upland rice. Government should embark on undertaking rehabilitation of the existing irrigation scheme in order to ease current situation. It is also important to tackle the rehabilitation and modernization of infrastructure of the existing schemes and traditional farming areas as well in order to increase high rice cultivation in the area.

3.1 Pests and Disease Control

The farmers employed both modern and traditional methods in control pests and diseases such as pesticides through spraying and the use of local ash sprayed on the rice regularly to avoid crop infection. According to the farmers, ash was found to be effective although it requires a lot of labor during its application process in the rice fields.

One of the major challenges to rice production was the issue of pests and diseases which the farmers would need to be trained on the effective use of chemicals and its environmental impacts. There is need for coordination on handling of agro-chemicals used to controlling the pests and diseases. Furthermore, the need for the public sector to facilitate access to credit facilities for agro-chemical trade and other inputs is required.

3.3 Weed Control

Weed control is an important and essential operation in cultivating rice for any kind of rice variety or any area and the failure to controlling weeds results into low yields in the country. According to the observations taken during the study, hand weeding was effective at the early stage of weeds, but is suitable for small area considering high labor cost. In comparison of upland rice to the low land rice production, weed control of upland rice is more important and critical in terms of its impact on yield, meanwhile weed percent in field of seed production for any crop is an important element for quality evaluation, since it should be free of noxious weeds. The standard for weed percentage in field of rice seeds should be only about 0.01 - 0.02%, therefore intensive rouging should be done for seed certification.

In the case of paddy fields, keeping water could prevent some kind of weeds from growing to a certain degree, whereas upland rice growth could be retarded by the growth of various weeds unless otherwise properly controlled. However, the efficient ways to controlling weeds in upland rice field needs to be established. In addition, specific herbicides for rice are not available in Sudan, so herbicide for other crops must be used for rice cultivation for the time-being. New herbicides should be examined in a small test trial base. The relation between water (including land leveling, irrigation and rainfall and herbicide application need to be studied further so as to find out effective way, amount and proper timing of herbicide application.

3.4 Fertilizer and Soil Management

It is generally familiar that soil in South Sudan is rich in nutrient where rice is cultivated, however, soil fertility differs from one place to another depending on the nature of the soil. In over-all, field soil in ARIS and others States in the country have very heavy clay soil and is suitable for paddy rice cultivation from the view point of nutrient content. Organic fertilizers such as manures and mulch were spread all over the rice fields to boost the rice growth. In ARIS, fallowing was practiced throughout as a strategy to manage soil in terms of soil nutrients maintenances as a way to obtaining higher yields of rice in the rice fields. During the flooding, sediments rich in nutrients were flown into the fields by the flooded water which contribute directly into healthy growth of low land rice.

3.5 Agricultural Mechanization

In order to expand rice cultivation within the ARIS and other areas, rice specific machines such as tractors' friendly to our context not Belarus types, seed multiplication machines, combine harvester machines and husking/milling machines are necessary in the shorter course exactly designed for rice is needed. In the villages closer to the producing areas of swamp rice, it is vital to foster private millers in the area nearby the production areas. Once specifications of husk/milling machines are clarified, dealers/agents can import them by giving the specifications. The private sector companies provide agricultural machinery and equipment.

3.6 Target Yield of Rice Ecosystem

Yield of submerged rice is generally high when farming operation is properly managed. Target variety in submerged ecosystem could be any type of varieties if available but Basmati is the promising one because of this ecosystem it will be promoted primarily by private investors and Basmati is the highest value rice in South Sudan market.

3.8 Research

The government (national or states) should play role to producing seeds and distribute them to farmers but gradually, it would be recommended that such a role is played by the private sector. Production of high types of seed is the responsibility of private sector to multiplying the required amount of certified seeds for local farmers. The cooperatives or companies should provide farmers with certified seeds and be committed with the role of technical supervision and the farmers should adhere to all the cultural practices until the approval of the production by the seed authority is done.

3.8 Extension

The National and state ministries of Agriculture together with ARIS have a role to play to ensure adequate extension services. The mandate of the MAFS include i) training and strengthening of extension workers, ii) coordination, iii) technical backup, policy formulation, and iv) international relations, implementation of actual extension services is delegated to the state ministries hence, there is need to train more extension workers and establish extension centers nationwide.

3.9 Rehabilitation of Irrigation Facilities

The Ministry of Agriculture and Food Security together with partners need to rehabilitate Aweil rice irrigation infrastructures for full scale of rice productions in the country. South Sudan Agricultural Bank and other financial institutions should provide credit facilities for availing irrigation pumps and equipment needed for rice area expansion. Also the irrigation canals from the Lol River into the rice farm need to be regularly maintained in order to reduce wastage of irrigation water.

3.10 Post-Harvest Technique and Marketing

After the rice yields in the scheme, the farmers harvest the rice manually and gather them in one place for 1 – 3 weeks drying on the sun and clean off the rice stalks to getting the rice grains. The rice grains are transferred to the mill house for further cleaning and packaging using the sisal sacks and kept in the stores ready for distribution and marketing within the area and beyond. Rice processing and packaging processes should be improved to reduce heavy labor and the cost of production to improving the quality. On the other hand, the consumers in South Sudan are more attracted by the rice quality traits.

3.11 Post-Harvest Technique

It is recommended to use mechanical harvesting and modern milling machines to making smooth linkages between harvest and storage, harvest and milling. There is need to rehabilitate and set up the milling machinery and rice storage facilities and set renting system of harvest machinery such as combined-harvester or reaper by the local rice farmers in ARIS and the area. Milling machine of high capacity: 30 tons/ hour, in which hulling and milling with the same machine is in one passage together with cereal threshing machines are required for the large scale rice production in ARIS. Extra machines such as cleaning machines are required for rice produce. Private sector is encouraged to deliver such services in their ranges of process, large rice producers and service companies can also apply such machines. Programs to improving storage and warehouse facilities should focus on increasing the dimension of the storage facilities and make smooth linkages between the upper and downstream of rice value chain in the country.

3.12 Rice Market

The marketing strategy for Sudan agricultural exports will hinge on joint marketing, promotion of commodities being sold in niche markets e.g. basmati rice, monitoring the need for change in operating strategy as commodities enter into mainstream markets and the building of strategic alliances with market participants (producer/exporter/ importer alliances). Private sector is responsible for the bulk of grain marketing, although a significant share of farmer consumption is met by retentions from own production, a major share of urban needs of cereals, are provided by surpluses produced on farms and marketed by private sector merchants. In order to be more competitive, marketing services with strong private sector participation should be seen as the agencies best placed to provide market intelligence and information; export facilitation, and develop farmer's cooperatives in addition to private traders and exporters. Nevertheless, in direction to compete with imported rice cereals due to sensitivity of consumers to rice quality and taste attributes, marketing cooperatives should take care of post-harvest operations and be aware of standards and quality measures.

Consumers of swamp rice are farmers producing swamp rice and their neighbors, if surplus is obtained; it has to be linked to the local market. In order to do so, post-harvest technique must be improved. For submerged sector, private investors can create new marketing channel to domestic market or even to international market by export to Arabic countries. For sustainable and spontaneous dissemination of rice, the most important ecosystem for marketing is aerobic (upland) rice system. Strategy of rice technology dissemination in this ecosystem is to introduce rice as one of the rotation crops. In this sense, creation of new marketing channel is indispensable. It could happen that the government continues to purchase whole increased paddy in order to stabilize the market in years of surplus.

Thus, it is recommended that increased domestic rice production should get into private marketing flow. Based on the current imported distribution channel of rice, the proposed strategy is to create new channel under the aerobic system. Producing milled rice with good quality is what is required to convince key stakeholders such as wholesalers, packaging company, and local shops. Once they are aware of availability of good domestic rice with reasonable price, they start to patronize the market gradually. The proposed activities by the government should be i) Conduct a campaign of domestic rice for consumers and wholesalers, ii) Conduct some workshops with rural entrepreneurs to foster rural millers and iii) Facilitate export of surplus rice production to neighboring countries.

Some challenges that need to be addressed include i) lack of producers' associations for rice farmers ii) lack of specialized agricultural machinery and equipment for rice post-harvest handling and iii) lack of knowledge of the private sector rice marketing system.

3.13 Inputs and Machineries Provision

In direction to promote commercialize agricultural operations, there is a need to change negative attitude to credit and a need for the credit institutions to devise financing schemes for small/medium commercial operators and agricultural cooperatives to develop rice production and marketing.

3.14 Financing Mechanism

The financial organizations such as South Sudan Agricultural Bank and financial services providers should give attention on the resource-poor farmers to enabling them purchase agricultural inputs**.** Farmers must be assured of equitable access to effectual financial services. Despite the high contribution of the agricultural sector to the national GDP, the ratio of the formal agricultural credit and finance to the GDP in South Sudan is inadequate compared to other developing nation state. Availability and accessibility of credit will be critical to achieving diversification and intensification of agricultural sector. Loaning environments should be satisfactorily extensive and plastic to permit for the thoughtful savings related to the farm growth mechanism.

To promote rice production in South Sudan, the existing loan systems of Agricultural Bank and other banks should be leveraged. It is basic to indicate that, the domestic demand for rice is high and could be sold within the local market. Once rice is sold to the market, farmers start to grow more rice, and demand for loan for rice production will increase. Loan provision in kind can be done except rice seed, however, repayment in kind by paddy or rice seems difficult at the initial stage. So repayment has to be made by cash at the beginning, and in-kind repayment is gradually accepted as transactions of rice in the markets are increased, and rice is confirmed as a salable crop.

3.15 Cooperative Societies.

A total of 10 Farmers' Cooperative were founded with each group consisting of 100 members who were given some portion of land inside the ARIS to farm rice and they received seeds from FAOSS to concentrate on farming practices. The farmers give 20% shares out of the rice produce to ARIS administration after successful harvest as part local arrangement made by both sides. The farmers will sale 60% of their rice produce leaving 20% of their produce for home consumption according to the farmers' groups members interviewed. However, Agricultural cooperatives facilitate provision of credit, processing, and other additional services such as education, extension, training and adoption of new technologies services. It provides member farmers with required production inputs and sell their crop to local whole-sellers and exporters within their locality.

3.16 Capacity building

The gaps identified in this study amongst others include: lack of skills in rice seeds multiplication, limited knowledge in controlling pests and diseases, lack of laboratory for seeds test, marketing, good agricultural management practices and lack of water harvest and preservation techniques for effective farming throughout the seasons. Programs such as trainings on rice pre-harvest and post-harvest, extension and dissemination of technologies and marketing practices of rice are well

thought-out essential. However, programs such as technical capacity building and upgrading of farmers' skills training should continue to provide additional knowledge and information concerning aerobic rice production and new ecosystems. Some specific areas for capacity building proposed include seed technology, rice seed production, field inspection, variety testing, variety characterization, seed processing, and laboratory seed testing (physical purity, germination. seed vigor, seed viability and seed diseases). Nevertheless, the training package should consider areas such as breeders, agronomists, entomologists, pathologists, plant nutrition, and extension services as well.

Conclusion

This study was the first to show the Evaluation of Rice Production in Aweil Rice Irrigation Scheme of Northern Bahr-el-Ghazal in South Sudan. Results of the study indicate that, the land is potential for rice production in the country and the region and could be integrated with fish farming for increased food, nutrition and incomes. The Ministry of Agriculture and Food Security together with Aweil Rice Irrigation Scheme Management should mobilize funds from government and partners to rehabilitate the rice scheme into its full-scale operations. The demand for rice food is very high both domestically and in the region which could generate more revenues to South Sudan government and the locals involved in rice farming practices in the country. Future studies into Aweil Rice Irrigation Scheme is recommended.

Recommendations

- The locally produced rice seeds were adaptive to climate change, the rice irrigation scheme and the rice farmers should be encourage to preserve the seeds, store and be used for further production. The newly introduced rice seeds or hybrid rice seeds by the humanitarian and development partners in South Sudan should be planted in the designed demonstration plots of smaller scales for experimental purposes and confirmation to minimize the challenge of zero germination in the scheme and the surrounding rice farms in Aweil.
- According to the study, there is need to introduce and establish integrated Rice Fish Farming and fish basements to promote resilience, nutrition and food security to both the scheme and the locals in the surrounding area of Aweil Town to reduce the fishing practices in the scheme during the peak season by the community members in the surrounding area.
- The Ministry of Agriculture and Food Security together with Aweil Rice Irrigation Scheme Management should consider recruiting more technocrats such as agronomists, agricultural engineers, business experts, motor mechanics to maintain and repair the tractors, trailers, rice mill plant and an information technology officer to support in data collection, management, business and the storage using devices.
- The scheme and partners should provide trainings on preparations and preservation of local rice seeds friendly to the climate change in Aweil area.
- The Government should establish National Rice Projects and encourage the private sector to implement the local banking policies with a focus on the rice scheme and the farmers' access to credits for resilience and sustainability in Aweil and the whole country as well.
- ARIS administration should design earthen dam including hydrometric Stations installations and equipment and civil works at the point of the Canal of Lol River. one at Wedweil village and the other one at Peth village all on the Lol River for water hydrometric purpose.
- ARIS Engineers should design and construct Flood Protection, water reservoir and river abstraction point based on the topographic arrangements of the area.
- There is need to supply improved rice seeds including fish fingerlings and locally formulated fish feeds for integrated farming.
- There is need to supply spare parts for the dominant rice mill for different grades (One Spare parts, Switch separator)- Schule Germany made.
- Renovation of existing rice stores and scheme offices including Solar power energy installation for irrigation scheme headquarters and the fencing of the rice irrigation scheme using chain link wire mesh should be taken into consideration.
- There is need for continues capacity building programs of technicians to maintain the tractors and the irrigation structures and establish Research Centre for rice selection and varieties within ARIS.
- There is need for supply of fertilizers (Phosphate and Urea, herbicides, pesticides and fungicides) - urea 50Kg /feddan/season, TSP (50 kg/feddan/season).
- The National Government is to intervene on the issue of damaged main bridge to Aweil Rice Irrigation Scheme
- The Research Institution should come up with Program to address the issue of outdated varieties of Rice and the dominance of wild rice varieties.
- The Issue of availing enough funds to the Scheme should be perceived as the basis for any success of a Program.
- There is need for dialogue on the issue of some buildings of the scheme being occupied by the State Authorities in Aweil.

Conflicts of Interest

There is no conflict of interest; any individual or institution can use the information for their use of the publication.

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Reference

[1]. Ferreira, T. (2018). *Does education enhance productivity in smallholder agriculture ?* Causal evidence from Malawi Does Education Enhance Productivity in Smallholder Agriculture Causal Evidence from Malawi.
[2]. South Sudan Feasibility Study Report 2022, Igad Drought Disaster Resilience and Sustainable Initiative (IDDRSI) phase II in the Horn of African Countries for Food security and Nutrition
[3]. Sudan's National Rice Development Strategy 2019.
[4]. Assessment mission report 2009/10: Crop production and food security assessment for the northern states of the Sudan by the Federal Ministry of Agriculture and Forestry and the Sudan Food security information for action in collaboration with the emergency rehabilitation and coordination unit, Food and Agriculture Organization of the United Nations.
[5]. Maltinational: New Rice for Africa 2014, Dissemination Project, U.S Department of the Treasury MDB Awards.
[6]. CAMP. (2013). Comprehensive Agricultural Development Master Plan, situation Analysis.
[7]. National Bureau of Statistics. (2012). Government of the Republic of South Sudan. Juba-South Sudan.
[8]. Post – conflict development of Agriculture in South Sudan 2009: Perspective on approaches to capacity strengthening by Loro George leju Lugor and Clesensio Tizikara.
[9]. Nile Basin Initiative Report 2012, on the State of the River Nile Basin Provided general health and the framework on the state members.
[10]. Famine Early Warning Systems Network (FEWSNET). (2020). Food Security Outlook for October 2020 to January 2021 period.
[11]. Ferreira, T. (2018). *Does education enhance productivity in smallholder agriculture ?* Causal evidence from Malawi Does Education Enhance Productivity in Smallholder Agriculture Causal Evidence from Malawi.
[12]. FAO/MAFS 2020, crop and food security assessment mission (CFSAM) Report.