Enhancing livelihoods of local communities in North Kordofan through integration of innovative agricultural technologies

Edited by

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Introduction

Sudan - with a population of 38 million - is one of the countries with the lowest human development indexes. High poverty rate (ca. 47%), illiteracy, lack of access to basic services, conflicts, unequal distribution and access to resources are some of the contributing factors to the development barriers of the country. Geophysical and climatic conditions further increase the livelihoods' fragility. Dominated by arid and semi-arid systems with increases in temperature, and low and erratic rainfall, Sudan is highly exposed to the negative effects of climate change. Such vulnerable conditions jeopardize the already precarious national food security. Drought is a big threat to the rainfall-dependent agro-pastoral areas, where main farming and livestock activities are concentrated.

The pastoral and agro-pastoral systems are the mainstay of the country's economy. Livestock is mainly raised by agro-pastoralists who are also engaged in cropping activities, predominantly millet and sorghum. Most of the animal feed comes from rangelands (53%) and the rest from crop residues and grain contributions. Overgrazing together with conflict over rangelands, scarcity of crop residues and water resources negatively impact the livestock productivity. Additional constraints are represented by precarious animal health services and land tenure issues, with pastoralists being required to pay for access to water and grazing to lease-holding tenants. While certain rangeland areas present a serious degradation, there are other significant ones underutilized because of lack of water points; this as a result of inefficient management practices and conflict between users.

The integrated rangeland-crop-livestock project is part of the bilateral collaborative activities between ARC-Sudan and ICARDA within the framework of Sudan's contribution to the CGIAR. ARC and ICARDA after their long presence in the irrigated sector have made a historic landmark shift, the first of its kind, by addressing research and development issues of the rain fed sector in Sudan. North Kordofan State was selected as the target area with activities focussing on improving crop-rangeland-livestock system productivity in an integrated management approach. The area of the state covers 20 million ha of which rangelands occupy 14.5 million ha. More than 4 million ha are annually cultivated and employ 70% of the population. The district comprises a population of 2.9 million, 8 localities, 46 administrative units and 3124 villages and communities.

This report describes four best-bet integrated crop-range-livestock technical interventions tested in semi-arid North Kordofan of Sudan.

Project area

The project is implemented in north Kordofan which is dominated by mainly Fares, Um Ushosh, Um Shogeira, Shigela and Khalda villages as the target sites for implementing project activities (Figure 1). During the first year of the project (2016), most activities were concentrated in Fares village to build a model which was then reproduced in other neighbouring villages. Currently, the

target area of the intervention extends to more than 250 km^2 in the semi-arid zone of North Kordofan, around the villages mentioned above and where a large number of communities live. By 2019, the project aims to reach at least 500 resource-poor men and women farmers. Part of the project expansion is the demand from Um Shogeira village to start business-oriented milk processing activities. The main livestock species in the village is goat and there is a highly active and enthusiastic women association involved in goat husbandry. In 2018, ARC and ICARDA established the first women-goat community-based breeding program (CBBP). The initial number of goats enrolled in the CBBP is around 900.

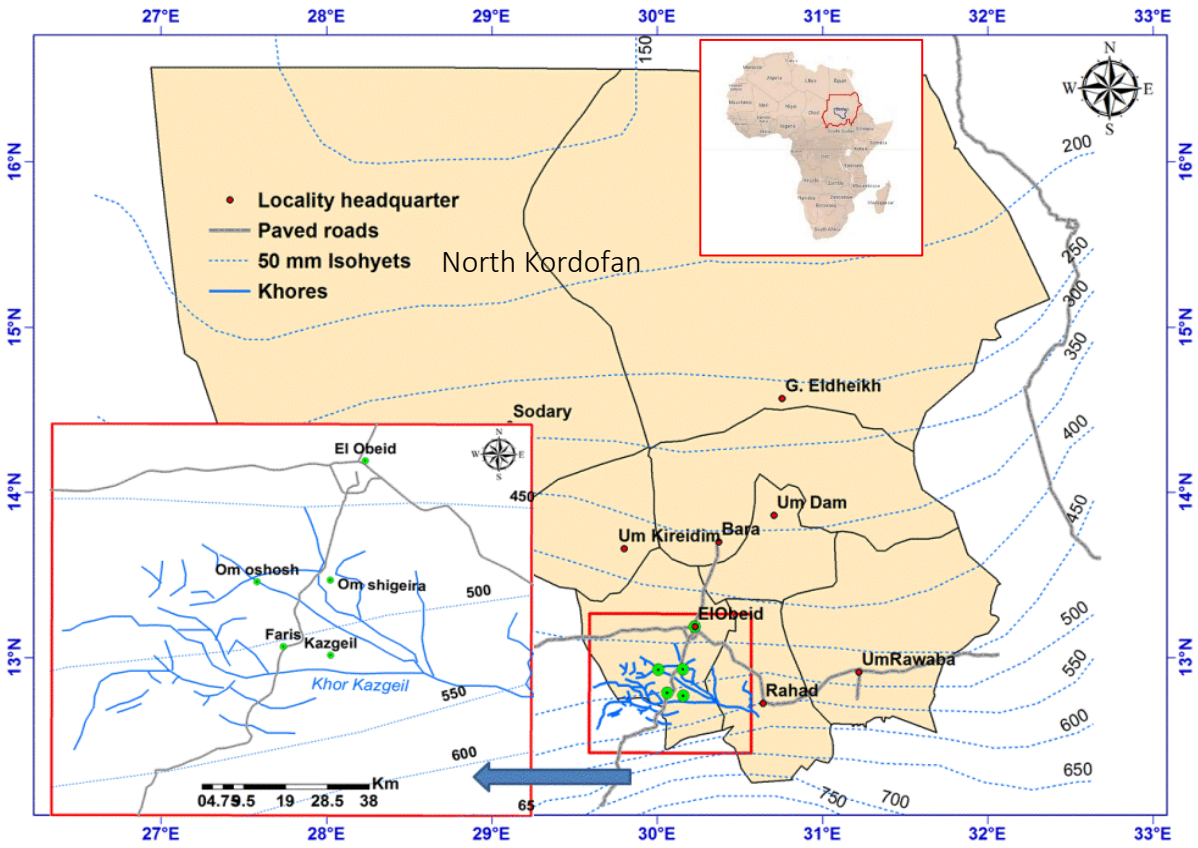

Figure 1. State of North Kordofan with project target areas and sites

Farm pond water harvesting: bridging intra-seasonal dry spells and extending the cropping season through supplemental irrigation.

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Key messages

- Farm ponds can capture a share of the water drained from the agricultural watersheds and store it in approximately 50–2000 m^3 large simple earth dug reservoirs
- The stored water can be used for supplemental irrigation of field crops through dry spells or to prolong the cropping season

Justification

The short and pronounced rainy season characteristics of Sudan have a huge impact on agriculture and the natural resources. Limited water availability in time and space lead to a reduced agricultural production. Simultaneously, the long period of bare soil conditions during the dry season decrease the soil's resistance to fertility depletion and erosion. Concretely, surface crusting and deep soil cracking affect the agricultural watersheds' hydrology and foster the losses of water through either deep percolation (soil cracking) or considerable surface runoff (surface crusting). This further limits the availability of rainwater in the soils for crop production.

Water harvesting is a popular method to collect and store surface runoff at various scales. Farm ponds have the proper scale-specification to serve the smallholder farmers' agricultural activities related with supplemental irrigation. This enables the farmers to either enhance their common field crops' quality or to prolong the cropping season suitable for the introduction of new crop varieties. Moreover, farm ponds are easy to construct; typically, the depth of a machine dug farm pond corresponds with the soil depths or the maximum excavation depths of common machinery.

Benefits

- Storing surface water in the agricultural areas
- Providing a local access to water during water shortages (e.g. dry spells)
- Enabling the diversification of the cropping pattern

Evidence

The technique was tested in various areas throughout the dry areas including Sudan. However, the proper positioning and design of a farm pond is critical for the successful collection and storage of water avoiding the e.g. rapid siltation. In both Kordofan and Gedaref Governorate various farm ponds have been successfully implemented for the support of the local smallholder farmers. These farm ponds enable the supplemental irrigation of farm-trees in Kordofan and the introduction of new cash crop (e.g. Jute mallow) managed by a women farm group in Gedaref.

Suitability

Farm ponds are suitable in areas with distinct rainfall seasonality (wet and dry periods) and deep soils with a low permeability. However, farm ponds can be also constructed on soils with a higher permeability (e.g. larger sand content) as long as the pond-excavation is stable and the pond can be lined with a non-permeable foil. Farm ponds can be also constructed as a concrete structure but planning and development costs are accordingly higher - commonly leading to a lower suitability for smallholder farmers. The farm ponds' water is usually suitable for robust irrigation devices after the settling of sediments e.g. through a siltation reservoir prior to the surface water inlet to the pond.

Resource requirements (scale of 5)

Land	**3** III
Water	**0** (as it contributes to water availability)
Labour	**2** II
Cash	**3** III
Access to inputs	**2** II
Knowledge and skills	**3** III

Impact areas (scale of 5)

Food security	**3** III

Human nutrition	**2** II
Employments and livelihoods	**0**
Natural resource base	**1** I
Gender empowerment	**1** I
Market linkages	**4** IIII

Value chain focus

Input & Services; Production

Promoting agroforestry practices for ecological and nutritional security

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Key messages and solutions

- Agroforestry involves the integrated cultivation of woody perennials, crops, and animals
- Is a means of conserving human energy by making full use of the limited space
- it is an inexpensive means of combating erosion and leaching, and of maintaining soil fertility
- Thus, it ensures protection and enhancement of the soil condition over time

Justification

Unsustainable use of land resulting from shifting cultivation, energy requirements and population growth have increased the pressure to provide more land to produce more resources to meet these demands. Sustainable food security has been a major human goal. Therefore, enduring sustainable food and nutrition should be built on the foundation of ecological security, i.e. the security of the basic life-support systems of the soil, water, animals and the plants. This implies that increases in sustainable food production must come from increases in productivity of currently tilled soils, rather than increases in cultivated area. Because some land is being taken out of production and diverted to uses such as roads, housing and industry, better use of soil and water will have to be implemented.

Benefits

- symbiotic economic and ecological interaction
- sustain and diversify the total land output
- maintain and improve soil health
- decrease farmer's exposure to seasonal environmental variations
- a lower level of investment in supporting infrastructure

Evidence

- The practice is currently being tested in North Kordofan, Sudan with a variety of species (*Acacia senegal, Acacia tortilis, Faedhebia albida, Moringa ollifera, Grewia tenax, Acacia mellifera* and *Ziziphus spinachisti*).
- Seedlings have been raised in a nursery and distributed to farmers for transplanting

Suitability

- Ideal for not only the humid lowlands but also the sub-humid to semi-arid zones
- Ideal for intercropping medium shrubs and short annual crops to produce a variety of foods and green manure besides reducing soil erosion.

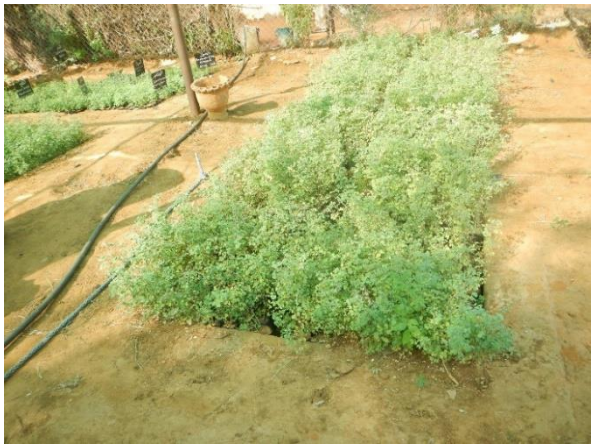
- Pruned foliage is allowed to decompose in the alleys and the nutrients released increase grain yields of interplanted crops
- The foliage is also used to feed livestock, while the shrubs provide other by-products such as fuelwood and stems for staking building material.

Resource requirements (scale of 5)

Land	**2** IIIII
Water	**3** IIIII
Labour	**3** IIIII
Cash	**2** IIIII
Access to inputs	**1** IIIII
Knowledge and skills	**1** IIIII

Impact areas (scale of 5)

Food security	**5** IIIII
Human nutrition	**5** IIIII
Employment and livelihoods	**3** IIIII
Natural resource base	**5** IIIII
Gender empowerment	**2** IIIII
Market linkages	**2** IIIII



Components of an agroforestry system

- Alley cropping - rows of shrubs (either standard shrubs or coppice) in between alleys of crops or pasture
- shrubs in pasture
- Grazed wood/shrubland

Products

- Food, fuelwood
- Fodder, forage and fibre
- Gums and resins
- Thatching and hedging materials
- Medicinal products
- Ecological services

Expected impacts

- Agroforestry is a low-cost, sustainable agricultural technology
- increases the grain yield of agricultural crops and moisture availability in soil
- reduction of surface run-off and evaporation
- income generation and improved livelihood of farmers
- sustainable resource management and ecological and economic rehabilitation
- increasing food production in problem soil areas
- maintaining the long-term soil health of poor or average quality lowland soils

Agroforestry must be:

- **Intentional**- combining shrubs, crops and/or animals and managed as a whole unit, rather than as individual elements in close proximity but controlled separately.
- **Intensive**- intensively managing a system to maintain its productive and protective functions, with annual operations such as cultivation, fertilization and periodic irrigation.
- **Integrated**- it must actively manipulate the biological and physical interactions between the shrub, crop and animal components to enhance the production of

Challenges

- Pests and disease outbreaks are a constant threat
- the difficulty of establishing shrubs and their slow initial growth
- Some species need scarification of seeds for germination
- agroforestry is long-term and does not promise major returns in the short run
- farmers adapting to new farming practices due to lack of awareness
- soil scarification may be needed before transplanting/planting seeds

Value chain focus

Input & services

Service delivery for ultrasound-based pregnancy diagnosis in sheep and goats

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Key messages and solutions

- Ultrasound-based solutions fit into the broader concept of clean, green management of sheep and goat reproduction;
- Ultrasound-based solutions are accurate for diagnosis of early pregnancy and litter size which is a key factor for successful reproduction and flock management in sheep and goat farms;
- Early pregnancy detection, litter size determination and foetal age are key determinants to design feeding management and to prepare the lambing environment;
- The technology is the most accurate to identify non-pregnant animals at the end of the mating season and to reprogram their mating or to opt for their culling. In addition, the technology provides additional information on:
    - Repeat breeders
    - Females with reproductive pathologies (uterine abnormalities)
    - Pregnant females to be discarded from synchronization in artificial insemination programs
    - Preventing slaughter of pregnant females

Justification

In north Kordofan, the low inputs and extensive mode of production for Desert sheep delay the age at first lambing, reduce productive lifetime, are responsible for low conception and lambing rates as well as the high abortion rates and ewe and lamb mortality rates (El-Hag. Et al., 2007). High ambient temperatures and high prevalence of both enzootic and zoonotic diseases are further exacerbating the reproductive outputs from sheep and goat flocks. Ultrasound-based tools for monitoring of pregnancies and the reproductive function can provide farmers, veterinarians and extension staff with a real-time information on the reproductive status of the females for timely-appropriate corrective management actions. Ultrasound-based solutions are available as easy-use, high resolution, portable machines; prices are going down and they are more accessible to suit even the most extensive, low input systems.

Benefits

- Ultrasound-based solutions can be used as a cost-effective management tool to improve breeding program management, feeding management;
- Ultrasound-based solutions are an early, reliable, non-invasive, fast, repeatable and reproducible method for early diagnosis of pregnancy;
- Ultrasound-based solutions allow dry ewes to be sold (culled animals) or reprogrammed for mating, hence reducing the “unproductive time” of females in the flock;
- Ultrasound-based solutions allow single and multiple bearing ewes to be managed according to nutritional requirements and enable optimization of pasture/feed resources.

Evidence

- Ultrasound-based solutions for the management of reproduction and reproductive disorders in sheep and goats were tested and established in 5 villages of North Kordofan: Fariss, Om Shogira, Fargalla, Eldomokia and El Shigila;
- Total sheep and goat females reached out by the ultrasound-based service for pregnancy diagnosis is over 18,000 and sterility rate as determined by screening is high around 12%. Recommendations to cull these animals were given to the farmers;
- Farmers are provided with accurate information on animals that are pregnant with an estimate of litter size and stage of pregnancy and the corresponding needed changes in the nutritional management;
- Reliability of the diagnosis by trained veterinarians and livestock specialists beyond 40 days of pregnancy exceeds 95%;
- Evidence from Ethiopia, Jordan, Pakistan and Central Asia shows that ultrasound service provision is helping sheep and goat producers to check for the repeat breeders, to identify females with uterine reproductive disorders and to provide the farmers with a tool to take decisions related to the management of the females in the flocks.

Suitability

- Knowledge and skills are the main resource requirement. Well trained veterinarians and livestock technicians are able to handle a large number of animals (> 200 females in one single day). Initial cash investment to buy the machine is also needed;
- The technology is most suited for private veterinarians who can develop ultrasound service provision, in addition to other health services, for a small fee;
- Ultrasound-based solutions can be a very useful tool in managing reproduction of the existing sheep and goat genetic resources and in synchronizing reproductive outputs to market demand;
- A whole generation of easy-use, high resolution, portable machines is now available with a high reliability of diagnosis as early as 30 days of pregnancy.

Resource requirements (scale of 5)

Land	**1** I
Water	**1** I
Labour	**2** II
Cash	**4** IIII
Access to inputs	**4** IIII
Knowledge and skills	**5** IIIII

Impact areas (scale of 5)

Food security	**5** IIIII
Human nutrition	**1** I
Employments and livelihoods	**3** III
Natural resource base	**1** I
Gender empowerment	**3** III
Market linkages	**3** III

Value chain

Production

Improving dairy quality through innovation and precision technologies

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Key messages

- Milk for drinking must be boiled or at least pasteurized before consumption
- Pasteurization is the first step to produce safe and high-quality dairy products where raw milk is heated to 65°C for 20 min or 73°C for 15 seconds to kill pathogenic bacteria
- The thermometer is an essential instrument to ensure the proper thermal treatment and is used to control other processing steps like cooling process.
- Centrifugal milk fat separation increases the yield of butter and enhances the quality and enables higher returns through processing high value products from the obtained skimmed milk
- The separation of milk fat offers a solution to handle larger quantities of milk and increases the efficiencies of butter processing.
- Controlled acidity and temperature in butter processing will ensure high churning efficiency and thus high yield.
- The use of dairy culture are essential for the production and the quality of yogurt and concentrated yogurt and enables the rapid processing of Mudaffara cheese
- Using dairy cultures is a simple way to produce a day to day stable product with specific characteristics based that meets the consumer preferences.

Justification

- Raw milk can be a source of pathogens that cause illnesses and can lead to serious health problems like zoonotic diseases like brucellosis that can lead also to abortions in pregnant women. Pathogenic microorganisms such as Brucella, Staphylococcus, coliforms and E. coli are killed by pasteurization.
- White cheese is widely-consumed in Sudan. Producers were able to signal on quality problems that directly infringe in the marketability of these products. In some locations, cheese was observed to have blowing (eye formation) due to contamination with fecal bacteria like enterococcus coliforms and E. coli that will affect the health of producers and consumers. Pasteurization will reduce these problems and will improve cheese texture and make product safe.
- Butter is an important product sold by the farmers in the market. However, the processing procedure is labor-intensive for women. Butter is processed by continuously churning of yogurt for at least 1.5 hours. Fat separation technique is a method to reduce water consumption and also to reduce the work needed. Moreover, the skimmed milk that is produced can be used to produce reduced fat white cheese and low-fat yogurt and concentrated yogurt.

- Traditional processing of yogurt is based on uncontrolled fermentation and in the best cases on the use of a day before yogurt that is in many cases contaminated with bacteria that produces off flavors. Mudaffara cheese is also based on spontaneous fermentation of the curd that lead to quality problems and elongate the processing period. These problems will be solved using dairy cultures that control the fermentation process and produce the desired flavor and texture to dairy products. Moreover, it helps in product conservation and to extend product shelf life.
- Dairy cultures provide options to control acidification and diversify flavor profiles to meet consumer preferences.

Benefits

Using pasteurization for milk leads to:

- Safe cheese and other dairy products
- Closed texture cheese that is paid more in the market
- yogurt with improved texture
- Products with extended shelf life

The use of milk fat separator helps:

- Reduce labor needed for butter churning
- Handle bigger quantities and increase butter yield
- Improve the quality of butter
- Enables the processing of high economic products from the skimmed milk.

Dairy cultures help:

- Provide the required viscosity for yogurt
- Develop the desired flavor in yogurt
- Enhance the yogurt characteristics particularly for reduced fat yogurt
- Give the proper texture for cheese and yogurt
- Reduce time needed to process Mudafara cheese
- Prevent pathogenic bacteria from taking over

Evidence

The different techniques were tested in Faris, Um Shugaira and Shigilla. Pasteurization and the use of thermometer is easy and essential to use and apply. In Faris, the women group are using and practicing these interventions. The milk fat separator reduced the heavy load on women needed to churn the butter from 1.5 hours to almost 20 minutes and enables the increase in butter yield by at least 5%. Moreover, yogurt characteristics were developed by testing different dairy cultures to meet the regional consumer preferences which was evaluated by sensorial evaluation. Producers in Fares started to provide the market with yogurt processed using the new technique capturing the additional added value.

Suitability

- The interventions are appropriate for pastoral and agro-pastoral communities like in Cordovan where these communities produce dairy products.
- The needed equipment for pasteurization is a fire source, a suitable pot and a simple thermometer that is available to buy in Khartoum to control temperature particularly for cheese processing.
- The milk fat separator can serve a community as a shared action and the resources required are cash. There is a need to know how the device works and operates. The technique enables the reduction of the workload on women.
- The pasteurization and dairy culture technique contributes mainly to human nutrition as safer food, market linkages as better products and consumers preferences through enhanced product texture. Whereas, the fat separation technique contributes labor reduction and reduce losses during processing and increase yield
- Resources required are some cash and the knowledge to read.
- The interventions contribute especially to human nutrition as a safer food

Resource requirements (scale of 5)

Land **0** IIIII

Water	**0** IIIII
Labour	**2** **II**III
Cash	**3** **III**II
Access to inputs	**2** **II**III
Knowledge and skills	**3** **III**II

Impact areas (scale of 5)

Food security	**3** **III**II
Human nutrition	**4** **IIII**I
Employments and livelihoods	**4** **IIII**I
Natural resource base	**0** IIIII
Gender empowerment	**3** **III**II
Market linkages	**3** **III**II

Value chain

Production, processing and consumption

Conclusion

The technologies designed and fine-tuned for North Kordofan were tested with farmers in different communities. A series of activities have been implemented with the objective to minimize faced constraints and enhance opportunities. Generally, farmers receive the technologies with appreciation as they were able to touch the benefit particularly on the economical side. Moreover, the process of integration and packaging technologies enabled the improvement of productivity of crop-range-livestock systems.

In parallel to the implementation of the above four technologies, on-the-job training of the farmers in the different target villages and farmers' field days were organized for the different components of the project (supplemental irrigation, agro-forestry, forage production, harvesting and conservation, milk processing, management of reproduction…). These trainings were undertaken either by already trained ARC scientists or by joint teams between ARC and ICARDA scientists when the latter visited the project site.