Using range and forage species to improve the system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Annual report (2017-2018)

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PROMOTING AGROFORESTRY PRACTICES

Introduction

Retaining and managing trees/shrubs in seasonally dry climates and degraded rangelands improves their productivity and sustainability, through increased nutrient cycling and improvement of soil structure, the provision of dry season livestock fodder and the provision of shade for livestock, which may reduce heat stress and increase feed intake (Cajas-Giron and Sinclair, 2001; Le Houérou, 1996). In particular, silvopastoral systems that integrate trees in pasture production systems are likely to enhance soil carbon (C) storage in lower soil layers due to the presence of deep tree roots, thus enhancing soil processes, supply of forage for livestock and provision of a habitat for flora and fauna (Haile et al 2010). These production systems also provide extra productive and environmental benefits, in addition to those provided by grass-based systems alone (Dagang and Nair, 2003).

When an agroforestry system is established by integrating trees/shrubs such as cactus into pasture systems, above and belowground productivity, rooting depth and distribution, and the quantity and quality of organic matter inputs to soil will change (Howlett et al. 2011). Tree/shrub-based land-use systems are expected to have better soil C sequestration potential than most row crop agricultural systems based on the premise that the tree components in agroforestry systems can be significant sinks of atmospheric C due to their high and long-term biomass stock and extensive root systems (Montagnini and Nair, 2004). From an environmental and productive point of view, one of the main advantages of silvopastoral systems is to fulfil multipurpose land use objective through the increase of resource use efficiency at spatial and temporal scales, the reduction of hazards and risks, the enhancement of system stability (multiple species) and the promotion of the social and recreational use of rural land (Howlett et al. 2011).

However, soil carbon (C) dynamics and storage in tree-grass continuum systems in general and silvopastoral systems in particular are poorly understood (Jackson et al 2000). There is both a need and an opportunity to improve the utilization of these systems in degraded ecosystems and resource challenged areas. This is because successful establishment and management of silvopastoral systems will yield sustainable production of multiple outputs (meat, milk and timber) alongside the generation of environmental services such as increased ecological diversity and carbon sequestration (Howlett et al. 2011). The aim of the work in North Kordofan

were to integrate agroforestry practices in the restoration of degraded ecosystems, with the objectives to maximize land productivity and reduce the feed gap during dry and barren seasons using shrubs such as the cactus pear.

THE PLAN OF WORK BUDGET (POWB) FOR 2018

Research Activities	Staff Involved	No of days allocated	Deliverables
A 1. Evaluate introduced cactus accessions performance and planting methods (density and season) under Kordofan conditions	1. Mounir Louhaichi	3	* Report on cactus performance * Dissemination of well adapted accession to selected farmers * Conduct one field day at ARC Obaid station to raise the awareness about spineless cactus
	2. Sawsan Hassan	6	
	3. Moyo, Hloniphani Peter	5	
A 2. Promote best practices to reduce feed gaps and reverse degradation (focus on silvopastoral activity)	1. Mounir Louhaichi	3	* Dissemination of silvopastoral activity to Om Ashouch * Characterization of key native species (factsheets) * Conduct one field at one village of Fares to highlight the importance of agroforestry using multipurpose fodder trees/shrubs
	2. Moyo, Hloniphani Peter	6	
	3. Sawsan Hassan	5	

Multipurpose fodder trees and shrubs of North Kordofan State

Agroforestry is defined as any land-use system that integrates the retention, introduction or mixture of trees with agricultural crops, pastures and/or livestock to exploit the ecological and economic interactions of the different components for improving human livelihoods (Albrecht and Kandji, 2003; Nair et al. 2009). Agroforestry has been widely practiced through the ages as a means of achieving agricultural sustainability and slowing the negative effects of agriculture such as soil degradation and desertification (Montagnini and Nair, 2004; Nair et al. 2010).

It is important as a carbon sequestration strategy because of the carbon storage potential in its multiple plant species and soil, as well as its applicability in agricultural lands and in rehabilitation of degraded ecosystems (Dixon, 1995). Through planting trees/shrubs, restoration of degraded lands and improving silvicultural techniques to increase tree/shrub growth rates, the implementation of agroforestry practices on agricultural lands has the potential to increase the amount of carbon stored in lands devoted to agriculture, while still allowing for the growing of food crops (Kürsten, 2000).

Methodology

Activities started in April 2016 with the selection of localities and sites for seed collection of multi-purpose fodder trees/shrubs. Seven were identified for seed collection. Activities carried out included the following:

1. seed collection
2. seed testing and characterization
3. nursery sowing and establishment
4. distribution of seedlings to the communities
5. community training in seedlings planting and tending

In April 2016 the seeds of seven multipurpose fodder trees/shrubs (*Acacia Senegal, Acacia tortillis, Faedherbia albida, Moringa olifera, Grewia tenax, Acacia mellifera* and *Ziziphus spinachristi)* were collected from eleven sites and five localities in Northern Kordofan State including: (Sheikan, Bara, Elrahad, Umkreidem and Eldebeibat).

The seven species were selected based on their ability to adapt to growth conditions which are characterized by high summer temperatures that coincide with shortage of water, as well as their ability to cope with the high aridity and low nutrient availability characteristic of semi-arid environments. These species are also multipurpose trees, such as nitrogen-fixing (e.g. *A. tortilis*), carbon sequestration and the ability to form habitats for a diverse array of plant and animal species. These species were also selected because they are economically important for fuel, fodder, timber and for soil stabilization and reducing sand dune movement.

Species description

i) *Acacia senegal*

Also known as the Gum arabic tree, *Acacia senegal* is a member of Acacieae within the subfamily Mimosoideae of the family Leguminosae (the Pea family), native to Western Sudan, Nigeria and the Arabian Peninsula. Gum arabic has many commercial uses: food (flavour fixative, emulsifier, stabilizer of dairy products), pharmaceutics (these two sectors representing 60-75% of the use of gum arabic), and industrial products (inks, pigments, polishes) (Al-Assaf et al. 2007). Gum arabic trees grow where annual rainfall is in the range between 380 and 2280 mm, and annual mean temperatures between 16.2°C and 27.8°C (Al-Assaf et al. 2007). Gum arabic is extensively used as an emulsifier/stabilizer in beverage emulsion for soft drinks (Tan, 2004).

ii) *Acacia tortillis*

Also known as the umbrella thorn, the timber is used for fenceposts, firewood, furniture, and wagonwheels (Mwalyosi, 1990). The prolific pods make good fodder for desert grazers and the foliage is also palatable, being one of the major dry season fodder trees for the Sahara-Sahelian belt, while its gum is edible and is used as a poor man's gum (Kennenni and Maarel, 1990). It is the tree most recommended for reclaiming dunes in India and Africa (Mwalyosi, 1990). A very drought resistant species, the umbrella thorn grows in areas with annual rainfall as low as 40 mm and as much as 1200 mm, with dry seasons of 1-12 months (Mwalyosi, 1990).

iii) *Acacia mellifera*

Also known as the black thorn, its leaves, pods and young shoots are nutritious and are reliable fodder for livestock and wild animals (Heuze and Tran, 2015). They are browsed by camels, goats. The black thorn is a drought-resistant species widely spread in arid and semi-arid areas of Africa and the Arabian Peninsula (Heuze and Tran, 2015). It grows better on sandy, clayey or stony-rocky soils, and it tolerates a wide range of soils, including black cotton soils (vertisols). The black thorn is found in regions with 400-800 mm annual rainfall ranges, although it can grow in areas with a minimum of 100 mm rainfall (Heuze and Tran, 2015).

iv) *Faedherbia albida*

Also known as the ana tree, *Faidherbia* is a leguminous nitrogen-fixing acacia-like species that is indigenous all over Africa (Coates Palgrave, 2002). Its leaves only grow during the dry season and provide nutritious livestock fodder during critical periods of drought. When used in agroforestry, *Faidherbia* has a unique compatibility with cropping systems due to its 'reverse leaf phenology', as it is dormant during the wet season and drops its leaves to fertilize associated crops (Coates Palgrave, 2002). The ana tree can also be used medicinally, used to treat diarrhoea, bleeding and inflamed eyes (Coates Palgrave, 2002).

v) *Moringa olifera*

Also known as drumstick tree, *Moringa oleifera* belongs to the family of Moringaceae. It is an effective remedy for malnutrition. *M. oleifera* can be grown in any tropical and subtropical regions of the world with a temperature around 25–35 °C. It requires sandy or loamy soil with a slightly acidic to slightly alkaline pH and a net rainfall of 250–3000 mm. The direct seeding method is followed as it has high germination rates (Gopalakrishnan et al. 2016).

vi) *Grewia tenax*

Also known as Phalsa cherry or Gangara, *G. tenax* is highly drought resistant and occurs in the driest savannas at desert margins and regions of higher rainfall, where it grows in thickets on termite mounds in otherwise seasonally flooded country (Orwa. et al. 2009). In the Sahel it grows in rocky places on hills and slopes, in regions with 100-600 mm of rain per annum. Its young leaves are consumed by livestock as they are slightly palatable at the end of dry seasons,

and have fairly good feed value. This tree has been used as a dune fixing plant in desert reclamation (Orwa. et al. 2009).

vii) *Ziziphus spinachristi*

Also known as the Christ's thorn jujube, it is found over the whole Sahelian region from Senegal to Sudan and across a large portion of North Africa, the Middle East, eastern Afghanistan, and northwestern India (Saied et al. 2008). It can tolerate high temperatures and grows in desert areas with annual rainfall of 50 to 300 mm. The fruits of Christ's Thorn Jujube are used as food especially by people in western and central Sudan and other Saharan regions, as well as in Oman (Saied et al 2008). Fruits are collected by women and children and sold in local markets, and it widely used for a range of purposes, including its reputed medicinal properties (Saied et al. 2008).

Seed collection

The selected trees and shrubs were found to be distributed within eleven sites in five localities in Northern Kordofan State which included Sheikan, Bara, Elrahad, Umkreidem and Eldebeibat in South Kordofan (Table 1). A total of 110 kg of high quality purified seeds were collected.

Table 1. Species and quantities of seeds collected within the state of Kordofan.

Species	**Local name**	**Locality**	**Quantity (kg)**
Acacia senegal	Hashab	Umkreidem	20
Acacia tortillis	Sayal	Greigkh	20
Faedherbia albida	Haraz	Debeibat	20
Moringa olifera	Rawag	Elobeid	10
Grewia tenax	Godeim	Abu haraz	5
Acacia mellifera	Kitir	Elsemeih	20
Ziziphus spinachristi	Sidir	Elhegeina	15
Total			**110**

Seed processing and seedling growth

Seeds were taken to the tree seed centre in Elobeid for testing and quality determination (Table 2) according to the testing protocol of the seed centre. Seeds from all species exhibited high viability and germination percentages (Table 2). In the third week of April (2016), seeds were sown directly in pots (10 cm diameter and 20 cm depth) filled with a mixture of 1/3 silt and 2/3 sand. A total of 5600 seedlings were established from the seven species, with survival of seedlings above 75% for each species (Fig. 1).

Figure 1: Seedling growth in Elobeid Research Station nursery of seven different tree/shrub species after germination and viability testing.

Table 2: Seed testing results from the Elobeid Research Station

Species	Local name	Locality	Purity (%)	Moisture (%)	Viability (%)	Germination (%)
Acacia senegal	Hashab	Umkreidem	98	4.8	94	87
Acacia tortillis	Sayal	Greigkh	97	5.6	92	84
Faedherbia albida	Haraz	Debeibat	98	5.3	97	79
Moringa olifera	Rawag	Elobeid	97	6.1	96	91
Grewia tenax	Godeim	Abu haraz	97	5.7	97	77
Acacia mellifera	Kitir	Elsemeih	96	6.2	96	85
Ziziphus spinachristi	sidir	elhegeina	95	6.7	96	78

Distribution of seedlings to the communities

In order to distribute seedlings, farmers were evaluated based on certain criteria before they received the seedlings. These criteria were the farmer's ability to protect the seedlings from browsing (through structures such as fencing), as well as the farmers' ability to irrigate the seedlings in order to aid establishment. Accordingly, all farmers who received seedlings had to be evaluated based on meeting these specific criteria. A total of 480 seedlings were distributed to 80 families.

Establishment levels of distributed seedlings

A year after the seedlings were distributed to farmers in Faris, a follow-up field visit in 2017 demonstrated that there was high survival and establishment rates across all species (Table 3). A total of 72 farmers transplanted the seedlings, with the total number of seedlings transplanting equaling 4380 (Table 3). Survival rate of all species was higher than 75% (Fig. 2), with most of the farmers able to employ the full use of fences for protection against browsing (Fig. 3).

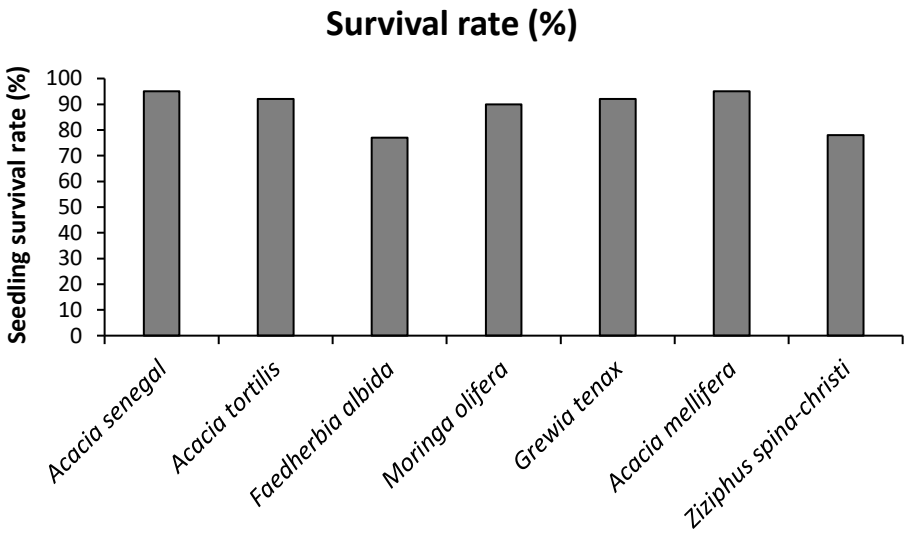

Figure 2: The survival rate of the different species in 2017, a year after planting in Faris village, North Kordofan.

Table 3: The survival rates of tree species a year after the transplanted seedlings were distributed to farmers in 2016 in Faris village in North Kordofan, Sudan.

Species	No. of seedlings distributed	Survival rate (%)	No. of farmers who planted the species
Acacia senegal	1300	95	13
Acacia tortilis	500	92	12
Faedherbia albida	430	77	10
Moringa olifera	150	90	5
Grewia tenax	800	92	10
Acacia mellifera	750	95	10
Ziziphus spina-christi	450	78	12
Total	**4380**		**72**

Figure 3: The established seeds in Faris village, a year after planting (2017), with farmers demonstrating their use of fences to protect seedlings from browsing at the early establishment phase.

Proposed utilization of tree biomass as fodder

While survival rates of the transplanted seedlings are high in North Kordofan, it is still early to ascertain the amount of biomass these trees will produce to potentially cover the feed gap during the dry seasons for livestock. However, the expectation is that once having established, farmers will prune trees through harvesting tree branches. In the process, at least 50% of foliage will be left, which will enable trees to photosynthesize and regrow. Harvested tree branches may then be fed directly to the animal or stored for later use, when the rangeland

forage would be low. As the trees planted are resprouters, the expectation is that tree regrowth will be supported by the availability of rainfall, resulting in continued harvesting of the regrowth material as livestock forage.

As a management tool for improving biomass yield in the planted trees in North Kordofan, trees of bigger size are proposed for harvest, as these potentially produce many coppice shoots, while increasing the height at which trees are harvested will also increase the number of coppice shoots produced (Shackleton, 2001). However, harvesting trees of bigger size should be done with caution considering that larger trees create a microhabitat for micro-organisms. Cutting larger trees also reduces sexual reproduction because larger trees have higher seed production compared to smaller trees. It also creates bigger patches, thus exposing the soil to *e.g.* soil erosion (Franklin and Forman, 1987). Cutting trees increases the availability of water and nutrients by removing the lower quality and older stems to focus growth on future tree parts, and it also increases light penetration to underlying vegetation (Boivin-Chabot et al. 2004). As such, if a coppice cycle is managed for the planted trees, this will maintain the diversity of the ecosystem structure, and will attract to many different plants and animals such as birds, which would aid seed dispersal (Fuller and Warren, 1990).

Selective and sustainable cutting should also include different harvesting intensities leaving branches with leaf material. This way, trees will be able to recover lost biomass through photosynthesis. Trees should also be harvested at different times of the year, and because the regenerative capacity of trees varies with time of the year it is cut (Kozlowski, 2002), trees will recover at different times enabling a harvestable biomass to be available in rotational manner. When harvesting, the availability of resources, the rate of harvesting and the cyclic renewal of available resources such as moisture will need to be considered (Gaugris et al. 2008). Management of these planted trees/shrubs should focus on strategies that do not significantly reduce biomass, or severely affect their regeneration or recruitment potential.

CACTUS INTRODUCTION AND EVALUATION

Livestock form the main subsector of agriculture in Sudan, and contribute to the livelihood of the majority of the population (Elmagboul, 2015). Livestock production in Sudan is based mainly on traditional pastoral production systems, as 90 % of the livestock in Sudan belong to this system (Fashir et al., 2015). However, this sector is affected by land degradation, civil wars, agricultural expansion, overutilization and climate change, which reduce the size and availability of grazeable areas (Fashir et al. 2015). All these factors have negatively impacted on the feed availability for the livestock (Elmagboul, 2015). Since the arid zones are less suitable for crop production due to inherent soil constraints like low water retention, sandy texture, shallow depth, occurrence of rocks and stones, there is a need to find new feed resources that can be adapted to the arid environments, such as in Sudan (Nefzaoui and Ben Salem, 2002).

Certain species of forage value and economic importance, such as spineless cactus, grow well under the dry and arid conditions, thus augmenting forage production in drought prone regions because of its drought tolerance and palatability (Nefzaoui and Ben Salem, 2002). Besides its fodder value, cactus fruits and other plant-parts are used for human consumption, as well as value-added products and cactus also has a great potential for arresting soil erosion and carbon sequestration (Ochoa, 1994; Tegegne, 2001). Cactus pear (*Opuntia ficus indica* L.) is a xerophytic plant species, widely cultivated in arid and semi-arid regions worldwide (Nefzaoui et al., 2014). As most of species belonging to the Cactacee family, *O. ficus-indica* (OFI) exhibits Crassulacean Acid Metabolism (CAM), with nocturnal stomata opening and CO_2 uptake occurring typically from dusk to dawn (Nefzaoui et al., 2014).

Cactus is a very productive plant, as it can produce 180 t ha^{-1} $year^{-1}$, which is equal to 20 t dry matter ha^{-1} $year^{-1}$ under natural conditions (Dubeux et al. 2015). Under sufficient irrigation, this productivity can reach 40 t dry matter ha^{-1} $year^{-1}$ when the water is not limiting (García de Cortázar and Nobel, 1991). The high water content in cactus can help to solve the challenging of supplying water to livestock in dry areas (Dubeux et al. 2015), and cactus is also high in sugars, ash and vitamins A and C, but are low in crude protein (CP) and fibre (Nefzaoui et al., 2014). Cactus exhibit a high Ca to P ratio and are highly palatable (Tegegne, 2001; Nefzaoui and Ben Salem, 2002). Depending on species and cultivars, ash content ranges between 100 to 250 g/kg DM but often exceeds 200 g/kg DM (Dubeux et al. 2015).

In order to increase feed availability for small ruminants and to reduce the feed gap in North Kordofan State (Sudan), cactus was introduced to Elobeid Research Station to achieve these objectives:

- Evaluate and identify accessions that are highly adaptable, resulting in high yields, under the conditions in North Kordofan,
- Develop an efficient cactus-based agro-forestry system,
- Develop a field gene bank for supplying cactus planting material (the most adapted accessions) to farmers in order to disseminate cactus plantations and to increase feed availability,
- Standardization of animal feeding practices.
- Extension and awareness program on cactus as an alternative feed for livestock among various stakeholders.

Cactus introduction:

Thirty-one promising accessions were introduced from Jordan (Table 4, Fig. 4 and 5), with three pads from each accession planted in Elobeid Research Station during the third week of October (2016).

Table 4: The name of cactus accessions sent from the Jordan genebank (with their initial origin) and number of pads planted from each accession.

Number	Accession Name	Number of Pads
1	J_ Jalpa__Mexico	3
2	V1_ COPENA V1_Mexico	3
3	F1_COPENA F1__Mexico	3
4	9_ FOZA9__Mexico	3
5	10_ FOZA10_Mexico	3
6	Zastron 4 _Sicilia ITALY	3
7	Blue Motto _Sicilia ITALY	3
8	Roly Poly _Sicilia ITALY	3
9	2_21_68	3
10	2_25_15	3
11	2_11_85	3
12	2_17_25	3
13	Nitrogen_Tunisia	3
14	4_Mexico_73049	3

15	15_Sicile Le folin_Sarson_73063	3
16	31_Burbank Azrou_Algeria_69223	3
17	20_Sbeitla_Sbeitla_74071	3
18	34_Caref 58_Algeria_69219	3
19	46_Mornag B_Tunis_74076	3
20	6_Ain Boudriess_Tunis_96245	3
21	32_Matmata_Tunisia_69242	3
22	19_Algeria_69200	3
23	8_Leavis_New Mexico_74010	3
24	32_Morocco_74001	3
25	13_Bab Toza_Morocco_74115	3
26	22_El Bouroug_Morocco_75018	3
27	2_Leavis SP5_New Mexico_74112	3
28	24_Tunisia_73058	3
29	26_Djebel Bargou_Tunisia_68247	3
30	42_Mornag_Tunisia_74077	3
31	Jordan_1	3

However, there was a delay in dispatching the plant material (fresh cactus pads) from the airport, causing severe damage (rotting) to cactus pads. This delay caused a loss of at least 43% of the total plant material sent from Jordan (40 pads).

Figure 4: The planting of the different cactus accession pads in the Elobeid Research Station.

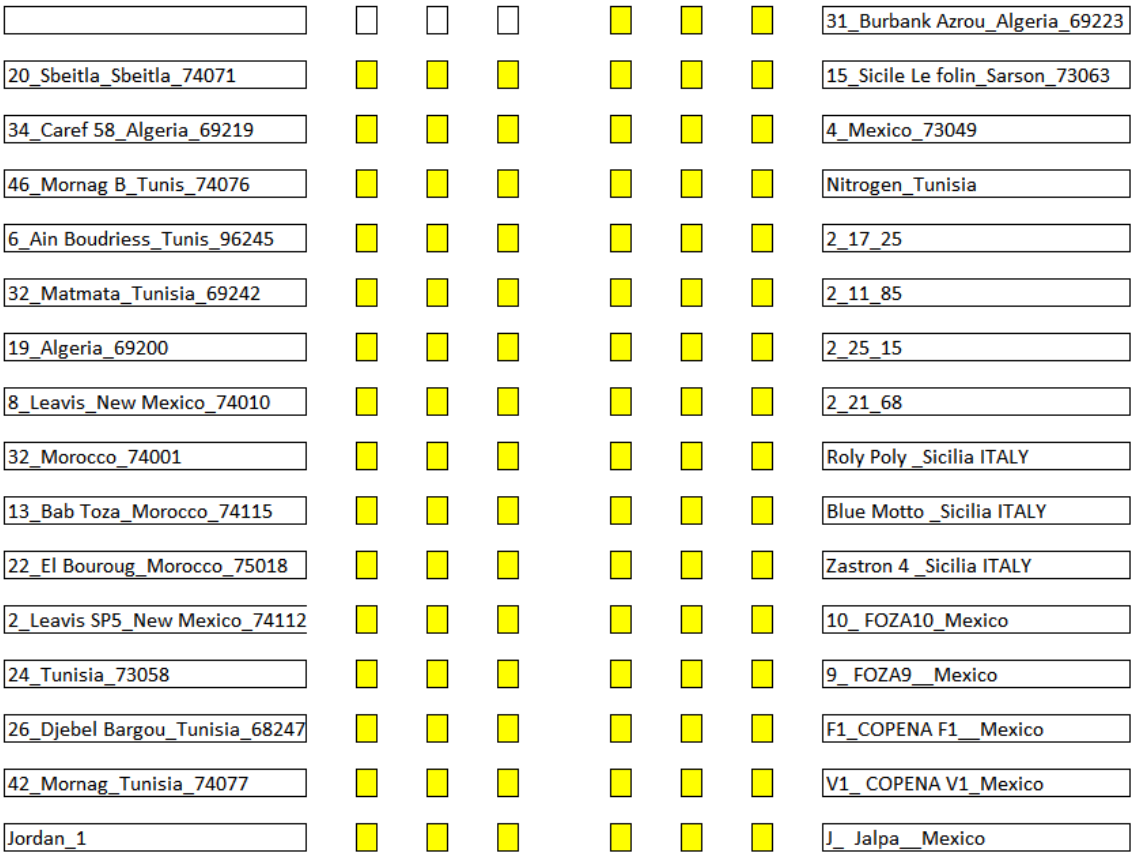

Figure 5: The cactus field genebank layout in Obeid station.

Cactus accessions were evaluated over time, and Table 5 shows the performance of the planted accessions in the first quarter of 2017. Accessions from Italy and Jordan recorded excellent performance in terms of growth condition, health of the plant in general, as well as the size of the pads. This is in comparison to accessions from Tunisia and Morocco (Table 5).

Table 5: Cactus accessions performance under North Kordofan State conditions

Number	Species	Pad 1	Pad 2	Pad 3
1	J_ Jalpa__Mexico	D	D	E
2	V1_ COPENA V1_Mexico	D	D	E
3	F1_COPENA F1__Mexico	D	D	D
4	9_ FOZA9__Mexico	D	D	P
5	10_ FOZA10_Mexico	E	E	P
6	Zastron 4 _Sicilia ITALY	D	E	P
7	Blue Motto _Sicilia ITALY	E	E	E

8	Roly Poly _Sicilia ITALY	E	E	E
9	2_21_68	E	E	G
10	2_25_15	D	D	E
11	2_11_85	D	D	E
12	2_17_25	D	E	E
13	N	E	E	E
14	4_Mexico_73049	E	D	D
15	15_Sicile Le folin_Sarson_73063	D	E	E
16	31_Burbank Azrou_Algeria_69223	D	D	E
17	20_Sbeitla_Sbeitla_74071	P	E	D
18	34_Caref 58_Algeria_69219	E	D	D
19	46_Mornag B_Tunis_74076	D	G	D
20	6_Ain Boudriess_Tunis_96245	D	D	E
21	32_Matmata_Tunisia_69242	E	D	D
22	19_Algeria_69200	D	D	D
23	8_Leavis_New Mexico_74010	D	D	D
24	32_Morocco_74001	D	D	D
25	13_Bab Toza_Morocco_74115	E	E	D
26	22_El Bouroug_Morocco_75018	D	D	D
27	2_Leavis SP5_New Mexico_74112	D	E	D
28	24_Tunisia_73058	D	D	D
29	26_Djebel Bargou_Tunisia_68247	D	D	D
30	42_Mornag_Tunisia_74077	D	D	D
31	Jordan_1	E	E	E

(E: Excellent performance, G: Good performance, P: poor performance, D: Dead)

The number of cladodes totally produced per planted pad, in the first quarter of 2017 were also determined (Table 6). Accessions from Italy (e.g. Roly Poly _Sicilia ITALY) produced the highest number of cladodes per pad (a total 45 cladodes) in the first quarter of 2017 (Table 6), compared with some accessions from Mexico (e.g. F1_COPENA F1__Mexico), which produced no cladodes from the pads planted.

Table 6: Total number of the produced cladodes of all cactus accessions planted in Elobeid Research Station

Number	Species	Pad 1	Pad 2	Pad 3
1	J_ Jalpa__Mexico	0	0	3
2	V1_ COPENA V1_Mexico	0	0	11
3	F1_COPENA F1__Mexico	0	0	0
4	9_ FOZA9__Mexico	0	0	4
5	10_ FOZA10_Mexico	13	16	10
6	Zastron 4 _Sicilia ITALY	3	12	6
7	Blue Motto _Sicilia ITALY	14	16	9
8	Roly Poly _Sicilia ITALY	15	18	12
9	2_21_68	3	17	5
10	2_25_15	0	0	13
11	2_11_85	0	0	10
12	2_17_25	0	4	4
13	N	22	21	13
14	4_Mexico_73049	5	0	0
15	15_Sicile Le folin_Sarson_73063	0	18	28
16	31_Burbank Azrou_Algeria_69223	0	0	4
17	20_Sbeitla_Sbeitla_74071	13	7	0
18	34_Caref 58_Algeria_69219	9	9	0
19	46_Mornag B_Tunis_74076	0	3	0
20	6_Ain Boudriess_Tunis_96245	0	0	0
21	32_Matmata_Tunisia_69242	13	0	0
22	19_Algeria_69200	0	0	0
23	8_Leavis_New Mexico_74010	0	0	0
24	32_Morocco_74001	0	0	0
25	13_Bab Toza_Morocco_74115	17	17	0
26	22_El Bouroug_Morocco_75018	0	0	0
27	2_Leavis SP5_New Mexico_74112	0	11	0
28	24_Tunisia_73058	0	0	0
29	26_Djebel Bargou_Tunisia_68247	0	0	0
30	42_Mornag_Tunisia_74077	0	0	0
31	Jordan_1	7	14	3

CAPACITY BUILDING

Al Obiad Research Station cactus field day (8 November 2017)

To raise awareness of the target local communities about cactus as a new adapted evergreen fodder crop, a field day was organized at the Elobeid Research Station. This event brought together representative farmers from three villages (Om Oushoush, Om Shoujera and Faris), researchers from ARC and researchers from ICARDA. The knowledge-sharing event consisted of different sets of activities involving provision of awareness of cactus crop; field visits and interactions – including a demonstration session on how to plant a cactus pad; presentations followed by discussions of the multipurpose use of cactus.

The visit started on Wednesday morning, with the ARC colleagues welcoming the farmers and acknowledging their willingness to spare their busy harvest time by participating in this event. After that, farmers were given a short introduction about the purpose of the field day and about the activities undertaken in the station as well as the cactus crop use and importance. Then all participants were taken through a tour of the pilot cactus accession conservation farms, where participants had the opportunity to see the cactus plantation, performance as well as its adaptability. The farms are preserving 31 cactus accessions for multiplication and distribution to the farmers so that it (cactus) covers the feed gap for livestock during the very dry summer periods.

Farmers observed the performance of the different accessions and were informed about the basic requirements of this crop (Fig. 6). Farmers also witnessed a demonstration on how to plant a cactus pad, in terms of pad positioning and the estimation of the depth of burying the pad. Farmers were also shown the ideal planting design (in terms of placement of the cladodes), as well as possible planting methods and combinations for successful cactus growth and eventual maximum production. Although farmers have generally accepted the spineless cactus, they indicated their initial thought of cactus as more of a weed than an important livestock feed. They indicated that they have seen the spiny cactus used for fencing and decoration, but not for feeding livestock.

Figure 6: A demonstration of the growth performance and adaptability of different cactus accessions to local farmers at the Elobeid Research Station.

After the visit to the cactus farm, the farmers were shown the ARC nursery, where seedlings are being raised for distribution to the three villages (Fig. 7). The species being raised in plastic bags in the nursery include *Acacia seyal* and *Moringa oleifera* (commonly called moringa). The seed collection, seed storage, planting and taking care of the nursery seedlings were also explained to the farmers. The farmers also visited the seed storage facility in the nursery (Fig. 6), where seeds for the nursery species, as well as baobab (*Adansonia digitata*) and *Terminalia laxiflora* (among other species) are stored for conservation as well as for growing in the nursery for distribution to farmers. After seed collection, the seeds are exposed to cold stratification (a process of subjecting seeds to both cold and moist conditions) through storing them in a 5 ^{0}C room, as well as scarification. This way, the seeds' dormancy is also broken during the storage process.

Figure 7: A demonstration of emerged seedling species and tour of the seed storage facilities in the Elobeid Research Station nursery.

Al Obiad Station cactus seminar- farmers (8 November 2017)

The farmers then attended a seminar discussing the multipurpose use of cactus (for fodder, as a drought tolerant species for rangeland rehabilitation and for humans to obtain fruits for consumption and selling and for producing oil, among other by-products) (Fig. 8). The handling and processing of cactus after harvesting and chopping for livestock, as well as the fruits for human consumption were also demonstrated to the farmers through visuals from the seminar. By-products from cactus such oil and skin remedies were also shown to the farmers, who were impressed (Fig. 8). After the seminar, farmers were able to ask relevant questions and raise their concerns about cactus as a feeding alternative for their livestock, which were addressed accordingly (list of participants is in Annex 1).

Figure 8: Farmers attending a seminar highlighting the importance of cactus, its benefits and by-products obtained from it. The seminar was an interactive presentation between farmers and researchers, creating an informative environment.

Al Obiad Station cactus seminar- researchers (9 November 2017)

A number of researchers and employees from various research bodies (Ministry of Agriculture employees, University of Elobeid employees, ARC researchers and extension workers) within the state of Kordofan were invited to attend a seminar on cactus and its role as a multipurpose plant (Fig. 9). Just as was done for the farmers, the researchers and government officials were taken through the procedure undertaken when planting cactus, from the collection of the cactus cladodes, to its storage and eventually planting. The researchers were also shown the ideal planting design (in terms of placement of the cladodes), as well as possible planting methods and combinations for successful cactus growth and eventual maximum production. The products and by-products obtained from cactus (fruits, oil and skim products) were also well explained during this seminar (Fig. 9), demonstrating the wide role possibly played by cactus. The seminar was

also engaging as a number of questions were asked, and there was extended interaction as the researchers were keen to know more about cactus. The researchers and employees were impressed and indicated that their initial thoughts of cactus, as being invasive and problematic, had been changed after attending this seminar (list of participants is in Annex 2).

Figure 9: The participation of Ministry of Agriculture and University of Elobeid employees, ARC researchers and extension workers in a seminar detailing the use, benefits and by products of cactus and its cultivation.

Faris village agroforestry field day (9 November 2017)

After the seminar, ICARDA researchers headed to Faris village, where a field day facilitated by ARC colleagues took place. Farmers from Om Oushoush and Om Shoujera were invited to Faris to participate in this event, with the aim to demonstrate to them the progress made by Faris

farmers with regards to seedling/tree growth and its benefits (Fig. 10). The total number of the participants in this event was more than 50 participants (the list of participants is in Annex 3). After welcoming the participants, Dr. Ahmed Lazim (ARC colleague) and Mr. Jamal (the community leader) gave an overview about the visit's objectives of the visit to farmers from Om Oushoush and Om Shoujera. Mr. Jamal briefed the visiting farmers about the experience of planting shrubs in Faris, emphasizing how important this initiative is towards securing at least part of their animal feed. He thanked ACR and ICARDA for assistance with establishing seedlings and encouraged farmers from Om Oushoush and Om Shoujera to adopt this approach due to the high demand for feed, good performance as well as the high adaptation of the seedling species.

Mr. Jamal informed the participants about their visit to the Elobeid Research Station, the benefits of cactus as a promising feed crop that survives under harsh conditions and also requested the ARC and ICARDA researchers to urgently provide cactus pads for planting purposes. A representative farmer from Om Shoujera (Mr. Mouhamed) thanked the organizers for the opportunity to participate and learn about the activities and experience from Faris farmers. He highlighted the importance of such events in exchanging knowledge and skills and increasing the capability of farmers to adopt new technologies. A reciprocal visit of farmers from Faris to Om Shoujera was proposed in order to continue pass on more information to Om Shoujera farmers. Sawsan (ICARDA) thanked the participants for coming, explaining the advantages of shrub planting and possible ways to expand it (Fig. 10).

A discussion among the participants took place and most of the farmers were interested in getting more seedlings, as the numbers distributed last year were not adequate. The second activity of the visit to Faris was a follow-up tour to assess seedling growth in some places where farmers planted shrubs previously distributed to them. Shrubs appeared to be growing well and the farmers were quite happy about them. Most of the farmers in Faris have employed the use of fences to protect the trees from any form of browsing, so as to ensure maximum establishment. Most farmers in Faris requested their keen interest to receive cactus from the ARC so as to plant and use it as a livestock feed. Farmers from Om Oushoush and Om Shoujera mentioned that they were impressed by what farmers in Faris were doing, and they are keen to have similar activities

in their villages. The last activity was to prepare a list of the shrubs that farmers are interested in planting in the new season.


Figure 10: A visit to Faris by Om Oushoush and Om Shoujera farmers/villagers, ARC and ICARDA researchers as a follow-up on shrub growth and establishment of previously distributed seedlings. Farmers have used fencing to prevent browsing of seedlings during the establishment phase.

Om Oushoush village agroforestry field day (9 November 2017)

After Faris, a meeting was held with farmers at the Om Oushoush village (Fig. 11). There was a low attendance here due to farmer commitments (harvesting their produce in the field). Here, farmers were also informed about the potential benefits of planting multipurpose shrubs such as *Acacia seyal* as well as cactus (Fig. 11). In Om Oushoush, the farmers raised concerns regarding protecting the growing seedlings and eventual shrubs from early browsing by camels and goats. This is because their village is considered as a passage for the nomadic camels, which browse on trees and cultivation fields of villagers, discouraging farmers from planting seedlings. The ARC suggested that they would hold discussions with the Forest Services/Department so as to assign a guard where seedlings are planted, to prevent browsing. The ARC also suggested that another farmer meeting will be held when farmers conclude their harvesting activities in the field. This meeting will register the number of farmers interested in receiving seedlings from the ARC (the list of participants is in Annex 4).

Figure 11: The visit to Om Oushoush by ICARDA and ARC staff. The visit was set-up to inform farmers about the benefits of planting multipurpose shrubs towards livestock feed and rangeland rehabilitation.

Om Shoujiera village agroforestry field day (9 November 2017)

On Friday November 10th, another field day was held in Om Shoujera village (Fig. 12). This event witnessed a high attendance by farmers (more than 210 farmers, Annex 5 for list of participants). After briefing field day participants about the purpose of the meeting, Dr. Lazim highlighted the benefits of planting multipurpose shrubs for both livestock and human benefit as well as the willingness of the research station to provide the community with seedlings. The research station would also provide the required information regarding the establishment and management requirements. Sawsan (ICARDA) welcomed the participants and briefed them about the groundbreaking role by ICARDA and ARC aimed at assisting and encouraging farmers to explore new options for fodder production.

Mr. Mouhamed, the village representative from Om Shoujera who had visited the research station and Faris village, explained how Faris farmers had taken up to the activity of planting seedlings, and how successful the trees were growing under the challenging conditions. Mr. Mouhamed informed the participants about his visit to the research station and told the farmers about cactus, describing its uses and benefits of cultivating it.

The high turnout and the enthusiasm of farmers enabled researchers from ICARDA and the ARC to fully engage with the farmers, discussing issues related to rangeland rehabilitation through the use of multipurpose shrubs. This interaction with farmers was necessary so as to give them background information concerning the use of multipurpose shrubs. The visit and discussion with the Om Shoujera farmers were concluded by registering the individual households and farmers interested in receiving and growing the shrub seedlings. There was high turnout of women, who showed enthusiasm and willingness to participate in the activities. Farmers in this village mentioned their interest in reviving a nursery close to their village so as to maintain it and distribute seedlings to other farmers.

Figure 12: The visit to Om Shoujera by ICARDA and ARC research staff. Farmers turned out in numbers and were equipped with information regarding progress made by Faris farmers in terms of seedling growth and establishment, as well potential benefits of cultivating cactus.

To reflect the high interest from the research institutes and the local communities in the Kordofan region, the Kordofan local radio arranged for in interview with ICARDA and ARC researchers (Fig. 13). The questions were mainly about the importance and benefits of cactus, and how farmers could potentially adopt this fodder crop for their benefit. In addition to this, the interview highlighted the importance and the role of the research institutes as well as the collaboration with International Organizations like ICARDA to introduce new technologies that enhance farmers' income, as well as livelihoods.

Figure 13: Kordofan local radio station personnel interviewing ICARDA and ARC research staff concerning the benefits of cactus and how it has the potential to contribute towards improving farmers' livelihoods.

CONCLUSIONS, RECOMMENDATIONS AND PLANS FOR 2018

Throughout the interaction with farmers, there has been a keen interest on the potential use and adaptation of cactus and the seedlings from the different species. This suggests that there is a need for follow-up activities, which be useful in distributing cactus and more seedlings to other villages where this outreach has not reached. However, there will be a need to educate the farmers more concerning cactus and how it can be processed (chopping and conserving), once ready for harvesting. Farmers will also need more information and educating concerning how to integrate cactus within the livestock rations, when supplementing the animals in the dry season, considering that cactus needs to be integrated with other feeds in a ration. Farmers will also need information concerning how best to harvest the established trees, in order to manage a sustainable coppice regeneration cycle.

Researchers at the ARC will make a follow-up after farmers are finished with the harvesting of farm produce in order to distribute more seedlings, while the nursery close to the ARC campus in Elobeid will need expansion as well as improved maintenance. The ARC researchers mentioned the need for financial support so as to expand the nursery and also to maintain it. There were suggestions that students from the Kordofan State University or the University of Elobeid will be allocated projects within the ARC station in line with cactus cultivation, as well as the planting of multipurpose shrubs.

Farmers were advised to employ the full use of fencing the planted seedlings in order to ensure establishment. This would prevent browsing by livestock and camels at the critical stage of seedling establishment. The ARC requested a chopping machine so as to act as a demonstration for farmers on how to process the harvested pads. The ARC researchers also requested a sign post and labels for the cactus assertions, so as to easily identify them.

In 2018, leaf samples of key tree species planted in the nursery will be collected from mature trees in the rangeland, in surrounding areas close to the research station. Samples will be ground and prepared for foliar nutrient analysis, before being to a lab in Addis Ababa for analysis. The results from this analysis will be useful in computing the contribution of tree species (in terms of their nutrient status) towards the diets of livestock in North Kordofan. In 2018, more seedlings will be germinated in the nursery so as to have their ready supply in order to distribute to farmers, should a need arise. During this year also, farmers in need of seedlings for transplanting will be identified in the other villages (Om Shoujiera and Om Oushoush), based on the selection criteria already explained previously. As well as distributing seedlings, farmers in need of cactus for planting will also be identified and, possibly, trained on how to plant the pads before distributing the pads.

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ANNEXES

Annex 1: Al Obiad station Field day (8 November 2017) participant's list

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Al Obiad station Field day (8 November 2017)

Participants list

#	NAME	SIGNATURE
1	جمال إسحق عبدالله	فارس
2	الرشيد يحي خليل	فارس
3	فوزية موسى أحمد	فارس
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5	محمد ابراهيم آدم	أم شجيرة
6	هواء الحنى عبدالله	أم شجيرة
7	فاطمة محمد ابراهيم	أم شجيرة
8	أم رحمة حسن محمد	أم عشوش
9	إسماعيل مكى حمد	أم عشوش
10	ابراهيم حمد أحمد	أم عشوش
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12	عبدعبدالله [illegible]	محطة البحوث
13	[illegible]	محطة البحوث
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16	باب الله محمد الغالى	محطة البحوث
17	جعفر خيرى حماد	محطة بحوث الرهيد
18		
19		
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Annex 2: Al Obiad station Cactus presentation (9 November 2017) participant's list

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Al Obiad station - Cactus presentation
9 November 2017

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Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Al Obiad station - Cactus presentation
9 November 2017

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Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Al Obiad station - Cactus presentation
9 November 2017

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Annex 3: Faris village Silvopastoral Field day (9 November 2017) participant's list

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Faris village Silvopastoral Field day

(9 November 2017)

Participants list

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1	إسماعيل مكي حمد	
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3	ابراهيم محمد أحمد	
4	شمس الدين حمزه خليل	
5	الرشيد يحي خليل يحي	
6	خليل موسى عيسى	
7	ناصر يحي ابراهيم	
8	ملك يحي ابراهيم	
9	جمال إسحق	
10	نزار جمال إسحق	
11	حنة خليل	
12		
13	أم رحمة حسن محمد	
14	حواء الطيب عبدالله	
15	عائشة عثمان يعقوب	
16	خديجة خليل يحي	
17	نجوى آدم محمود	
18	أم سلمة يحي محمد	
19	فاطمة آدم عثمان	
20	مريم محمد عبدالله	

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Faris village Silvopastoral Field day

(9 November 2017)

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23	أميرة ناصر حسن	
24	مريم آدم يعقوب	
25	أمونة عثمان محمد هنا	
26	هلمة ناصر عبدالله	
27	آمنة مقدم خليل	
28	فاطمة محمد ابراهيم	
29	عائشة بحي خليل	
30	علوية بحي خليل	
31	سلمية جمال إسحاق	
32	سعدية محمد	
33	عوزية موسى محمد	
34		
35	بحي خليل محمد	
36		
37		
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39	عائشة عثمان	
40	د. أحمد محمد مصطفى لازم	

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Faris village Silvopastoral Field day

(9 November 2017)

Participants list

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43	عبد الله حسن علي	
44	باب الله محمد الفكي	
45	زكي خلف الله علي	
46	عزه مصطفى عوض	
47	عاطف محمد محمود	
48	عباد حسن ليس	
49	عمر عبد الله بخيت	
50	أحمد محمد مركي	
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Annex 4: Om Oushoush village Silvopastoral Field day (9 November 2017) participant's list

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Oushoush village Silvopastoral Field day

(9 November 2017)

Participants list

#	NAME	SIGNATURE
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
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19		
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Annex 5: Om Shoujiera village Silvopastoral Field day (9 November 2017 participant's list

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Shoujiera village Silvopastoral Field day
(10 November 2017)
Participants list

#	NAME	#	NAME
1	عبدالله الحاج سالم	21	
2	ملكي موسى بايكر	22	
3	محي الدين علي صالح	23	
4	محمد اللقاني محمد ابراهيم	24	
5	صالح علي صالح	25	
6	عزيزة دفع الله أحمد	26	
7	هديه ابراهيم محمد سعد	27	
8	إيمان آدم محمد	28	
9	مروة دفع الله أحمد	29	
10	إسماعيل أحمد عبدالرحمن	30	
11	الصادق البشاري عبدالهادي	31	
12	صباح سالم بايكر	32	
13	مسعوده صالح ابكر كباية	33	
14	طارق حسن عثمان	34	
15		35	
16		36	
17		37	
18		38	
19		39	
20		40	

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Shoujiera village Silvopastoral Field day
(10 November 2017)
Participants list

#	NAME	#	NAME
41		61	
42		62	
43		63	
44		64	
45		65	
46		66	
47		67	
48		68	
49		69	
50		70	
51		71	
52		72	
53		73	
54		74	
55		75	
56		76	
57		77	
58		78	
59		79	
60		80	

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Shoujiera village Silvopastoral Field day
(10 November 2017)
Participants list

#	NAME	#	NAME
81		101	
82		102	
83		103	
84		104	
85		105	
86		106	
87		107	
88		108	
89		109	
90		110	
91		111	
92		112	
93		113	
94		114	
95		115	
96		116	
97		117	
98		118	
99		119	
100		120	

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Shoujiera village Silvopastoral Field day
(10 November 2017)
Participants list

#	NAME	#	NAME
121	يسرا موسى حسن	141	ابراهيم سعد ابراهيم
122	عائشة محمود	142	الصادق سعد ابراهيم
123	فاطمة حسن دليل	143	الدهري مكي ابراهيم
124	جمعة محمد الشقيع	144	عبد الرحمن عبد الأذى عبد الرحمن
125	عبد العزيز الدهري	145	علي صالح سعد
126	سالم جامع	146	الصفو مكي ادريس
127	حسن موسى حسن	147	حواء الصفي عبد الله
128	عبد الحليم الحاج سالم	148	محمد ابراهيم آدم
129	أم الحسين إسماعيل آدم	149	حسن دليل حسن
130	حواء ادريس الحاج	150	سيد محمد دفع الله
131	موسى عيد حمد	151	حيرغني علي محمد ابراهيم
132	إيمان فضل مكي	152	سعدة ادريس الحاج
133	دليل موسى حسن دليل	153	فاطمة آدم محمد
134	ابراهيم السيد مكي	154	هدية محمد إسماعيل
135	عبد الحليم سالم بابكر	155	محمد الصادق ثيران
136	ابراهيم	156	هدية سعد محمد سعد
137	عاصم عبد الله سليمان	157	آم خير موسى محمد يدوك
138	فاطمة محمد ابراهيم	158	حلاء موسى محمد يدوك
139	حسين جامع سالم	159	فضيلة محمد حامد
140	إسماعيل الصادق فضل	160	شادية دهري مكي

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Shoujiera village Silvopastoral Field day
(10 November 2017)
Participants list

#	NAME	#	NAME
161		181	
162		182	
163		183	
164		184	
165		185	
166		186	
167		187	
168		188	
169		189	
170		190	
171		191	
172		192	
173		193	
174		194	
175		195	
176		196	
177		197	
178		198	
179		199	
180		200	

Integrated crop-rangeland-livestock management to improve system's productivity and to build resilience of agro-pastoral systems in semi-arid North Kordofan-Sudan

Om Shoujiera village Silvopastoral Field day
(10 November 2017)
Participants list

#	NAME	#	NAME
201		221	
202		222	
203		223	
204		224	
205		225	
206		226	
207		227	
208		228	
209		229	
210		230	
211		231	
212		232	
213		233	
214		234	
215		235	
216		236	
217		237	
218		238	
219		239	
220		240	