# Sustainable Silvopastoral Restoration to Promote Ecosystem Services in Tunisia

Final Report

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**ABBREVIATION**

CBO: Community Based Organization

CES: Conservation des Eaux et du Sol

CRDA: Commissariat Régional de Development Agricole

DGF: Direction Générale des Forets

DMY: Dry Matter Yield

ESAM: Ecole Supérieur d'Agriculture de Mateur

FAO: Food and Agriculture Organization of the UN

ICARDA: International Center for Agricultural Research in the Dry Areas

INRGREF: National Institute for Research in Rural Engineering, Water and Forests

LoA: Letter of Agreement

MOA: Memorandum of Agreement

MOAg: Ministry of Agriculture

OEP: Office de l'Elevage et des Pâturages

OM: Organic Matter

PV: Pastoral Value

TD: Tunisian Dinar

USD: United States Dollar

WHT: Water Harvesting Techniques

WUE: Water Use Efficiency

## EXECUTIVE SUMMARY

Silvopastoral systems hold enormous promise for addressing multiple issues facing livestock farmers in semi-arid regions of the Middle-East Near-Africa (MENA) region. Whole, the mismanagement of natural resources and other socioeconomic aspects led to a major degradation of the natural resource base. There are many million hectares affected by desertification, where annual pasture production does not exceed a few dozen kg DM/ha. This has given rise to the need to implement sustainable silvopastoral practices, which incorporate the planting and growth of native vegetation as well as utilization by livestock in a manner which integrates the future productive capacity of such systems. Thus, the successful establishment and management of silvopastoral systems, a mutually beneficial practice of integrating trees, forage, and the grazing of domesticated animals, has the potential to provide multiple ecosystem services and outputs for rural communities. For these systems to be sustainable, the participation of both men and women should be ensured to harness innovative capacities and create long-term mitigation effects of climate change and increasing human pressure. This report provides an early assessment (after 18 months) of adopting a participatory/multidisciplinary approach for implementing a silvopastoral production system to promote the delivery of ecosystem services in Sbaihia, Zaghouan, Tunisia. Over time the benefits/impacts of the various interventions would increase as the afforestation efforts (shrubs and trees) will be fully established and ready for use.

The impact of sustainable silvopastoral practices of reseeding ecosystems with a native biannual forage legume species (sulla) on services such as grazing biomass for livestock, soil and water conservation was assessed. With respect to shrubs (e.g. Oldman salt bush, tree medic and cactus pear) survival rates have been estimated at 85% at least 18-months after their transplantation. For all recorded parameters, the highest values were recorded in the sulla reseeded plots. For example, the dry matter yield of sulla reseeded plots was double ($p<0.001$) that of both scarified and control plots in the 2018 and 2019 sampling periods. In the second year, under favorable conditions, the biomass recorded at the improved site (sulla reseeding) was 10 times higher than the farm level (control). These results confirm that implementing a silvopastoral system improves the pastoral value of the natural ecosystems through increasing the provision of services (e.g. increased forage supply made available, enhanced livestock productivity, increased soil vegetation cover reducing erosion, increased species richness, etc.). For the restored pilot site, in 2019, the cost of livestock feeding dropped significantly to 0.35 TD per day per head (0.12 USD) in 2019 while at the farm level the cost of feeding without access to the silvopastoral site (control) is estimated at 0.9 TD (0.3 USD) per day per head.

To reduce soil erosion through water flowing downslope and to increase water conservation, different type of structures were constructed. These structures included bench terraces and stone gabions to reduce the speed of water flow downslope and to capture soil flowing downslope. Four stone gabions were constructed while manual benches were implemented in an area of 40 ha. Based on calculations done after heavy rainfall events in October 2018, the four stone gabions and the manual benches thus far have preserved at least 4800 T/ha/year of soil from erosion, while storing at least 280 $m^3$ of water to be used to irrigate shrub species planted on these ditches, as well as reducing runoff water loss by approximately

800 $m^3$/ha. Over time, the benefits of diversifying well adapted forage species will be fully integrated with the feeding systems of livestock, yielding more benefits from the silvopastoral approach. Also, planting forage legume species, such as sulla, is expected to enhance soil fertility.

At total of 15 capacity development events and meetings with local community were executed, where a total of 492 participants consisting local farmers, extension staff, local authority and students have been equipped with skills and information concerning sustainably managing silvopastoral systems. From this total, at least 40% of the participants were women, achieving one of the targets of this project to promote inclusiveness by empowering the participation of women in farming activities within the Sbaihia area and beyond. As part of the capacity building activities, a new initiative aimed at increasing the awareness about conservation of our natural resource base and best practices targeted 40 primary school pupils. This activity was important to introduce natural resource conservation with focus on afforestation to elementary school pupils at a young age to build their interest and involvement.

The successful collaboration, at the national and regional level, among the Directorate General of Forests (DGF) of the Ministry of Agriculture, the Regional Commissariat of Agricultural Development (CRDA) of Zaghouan (represented by the forest service and the water and soils conservation service), the Higher School of Agriculture of Mateur (ESAM), the National Institute for Research in Rural Engineering, Water and Forests (INRGREF), the Community Based Organization (CBO) and the communities and farmers will ensure the sustainability of the work undertaken within the framework of this project.

For the overall success of the silvopastoral pilot site, there is a need to establish an effective and well-managed community-based organization (CBO). The CBO will ensure the implementation of a management plan for the whole site, as well as a strategic grazing management plan necessary to protect sustainable productivity of the pilot site. With the intended opening of the site for grazing at fall of 2019, the management plan will establish the carrying capacity and implement the payment for ecosystem services before allowing grazing from the community; the payment will contribute to maintaining the site. Due to the great potential registered so far at this pilot site, the aim is to outscale this system to other areas within Tunisia for the benefit of improving the livelihoods of smallholder farmers.

# INTRODUCTION

A high proportion of Tunisia's land mass is at risk of desertification caused by degradation of natural resources (Escadafal et al. 1997). In particular, ecosystem deterioration, as indicated by the declining productivity and plant diversity, is just one of the problems which has resulted in substantial decrease in flora richness, biomass and pastoral value (Escadafal et al. 1997). However, conversion of natural ecosystems to farmland, exploitation through selective harvesting, fuel wood removal, charcoal production and livestock overgrazing are also major causes of degradation, habitat change and biodiversity loss (Escadafal et al. 1997). Disturbances created by these activities can impair ecosystem dynamics, structure and composition at the local and regional scales, lead to degraded plant community structure, and reduce ecological resilience (Haile et al. 2010). Mismanagement of natural resources has also contributed to degradation and exposed ecosystems to climate change, leading to high levels of food insecurity, conflict and reduced livelihood options for pastoralists smallholder farmers (Harvey et al. 2014). The vulnerability of these communities to extreme climatic events, i.e. recurrent droughts, heat waves, water scarcity is increasing and will have significant implications for out-migration. Farming and animal husbandry under such challenges will require integrated and multidisciplinary approaches.

Silvopasture combines trees with forage (pasture) and livestock production. Silvopasture can be established by adding trees to existing pasture, or by thinning an existing forest stand and adding (or improving) a forage component (Jose et al. 2018). Silvopasture is an agro-ecological practice ideal for arid and semi-arid environments (Haile et al. 2010). This practice can be used to rehabilitate natural pastures – both in terms of productivity as well as well as species composition or biodiversity. Combined with the diversification of forage crops in multi-crop systems, silvopasture systems improve forage quality, extend the grazing system, improve the organic layer of the soil by preventing soil erosion and contribute towards organic matter production. This is achieved through increased water infiltration in the micro-catchments provided by shrubs and trees. Finally, the canopy of shrubs/trees within a silvopasture creates micro-habitats and a refuge for native species and presents a way to sequester carbon and still allow for the grazing of livestock (Haile et al. 2010). As a result, it is a system that addresses multiple problems while generating multiple benefits.

Well-managed silvopastoral production systems will 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 habitats for flora and fauna (Haile et al. 2010). Therefore, the aim of this pilot initiative was to adopt a participatory/multidisciplinary approach toward sustainable restoration of a silvopastoral production system to promote the delivery of ecosystem services in Sbaihia community, Zaghouan governorate, Tunisia.

## OVERALL GOAL AND SPECIFIC OBJECTIVES

The overall goal of this pilot initiative was to sustainably manage a silvopastoral production system and improve the livelihood of the local communities. The specific objectives include:

- Increase the forage and livestock production in agro-silvopastoral production systems.
- Alleviate grazing land degradation
- Reduce water erosion
- Conserve the natural resource base (flora, fauna, soil and water)
- Develop the linkages between seasonal fodder/forage production and livestock husbandry.
- Increase community resilience, income and capacity of the local population
- Improve livelihood of agro-silvopastoral communities
- Create a silvopasture demonstration site as an example of this type of management approach.

## EXPECTED OUTPUTS

- Reseeding and planting of fodder shrubs in the targeted degraded ecosystems with full participation of local communities implemented.
- Targeted silvopastoral site(s) better managed and contributes to improving the livelihoods of local communities.
- Reduced vulnerability to climate change in livestock production.
- Increased level of awareness and understanding will lead to better involvement, effective participation, and better decision making and commitment to the sustainable management of silvopastoral production system.

## PROJECT ACTIVITIES

Based on the agreement, ICARDA (service provider) carried out the following activities:

- Characterization of the site for appropriate intervention
- Selection and transplanting of appropriate shrub and tree species with high nutritive value and palatability
- Reseeding using native species such as sulla (*Hedysarum coronarium*)
- Grazing management including estimating carrying capacity
- Ecosystem inventorying and monitoring
- Implementation, monitoring and maintenance of water harvesting interventions
- On the job training for national staff
- Preparation of publications, i.e. pamphlets, posters
- Submit quarterly progress reports starting from the date of entry into force of the Agreement, and
- Submit final technical and financial report (final report).

# SITE CHARACTERIZATION

## Governorate of Zaghouan

The governorate of Zaghouan occupies 1.8% of Tunisia (i.e. a total area of 2,820 $km^2$) (Figure 1). It has a population of at least 176, 945 people (contributing 1.6% to the total national population), of which 49.8% are male and 50.2% female. Of the total population, a slightly higher proportion in Zaghouan is rural (56.26%), compared to 43.73% urban population. This governorate is classified as a semi-arid region with cold and temperate winters (mean temperatures of 4°C), and hot and dry summers (average temperatures of 35°C). The annual long-term average precipitation is 450 mm. A significant portion of the land area in Zaghouan is occupied by agriculture, with 282,000 ha in total subdivided into 185 000 ha of arable land, and 87,000 ha of rangelands as well as forested area.

While a high proportion of the total area is agricultural, employment in this governorate is dominated by service providers (37.3% of the total population is employed by this sector), manufacturing (34.3%), other sectors (15.3%) and agriculture employing the lowest proportion of the population (13.1%). The cultivated area is mostly dedicated towards growing plants that play an important role in improving the livelihoods of the rural population, such as olive trees, forage crops, legume crops, cereals, vegetables and fruit trees. For example, in 2016; olive trees were grown on 54,607 ha, forage crops (such as ryegrass) on 23,788 ha, legumes (such as alfalfa and vetch) on 1,776 ha, cereals (such as wheat and barley) on 70,700 ha, vegetables (such as cowpeas and tomatoes) on 3,702 ha, and fruit trees (such as grapes and citrus trees) on 6,426 ha. The irrigated land in Zaghouan is mostly on public lands (8 760 ha in total is irrigated), while the private irrigated land is approximately 1,688 ha. The livestock population in Zaghouan is dominated by cattle and small ruminants (goats and sheep). For example, in 2017, the total number of cattle was 23,470, while sheep totalled 37,260 and goats were 43,740 in total.

Agricultural productivity in Zaghouan is aimed at sustaining the families through providing food as well improving the livelihoods of the rural population through the selling of agricultural products such as milk and vegetables. In 2017, honey production was 75 tons, milk production 24,100 tons, olives 47,425 tons and vegetable production yielded 139,163 tons.



Figure 1.Location of Zaghouan governorate within Tunisia and the Sbaihia pilot site within the governorate of Zaghouan

## Target site Sbaihia

The project targeted an important ecosystem in the MENA region (Figure 2), where the agro-silvopastoral production system is essential for the livelihood of the farming communities. This region, amongst others, is also susceptible to the threat of climate change, and the frequency of extreme weather events is growing and continuing to affect the productivity, profitability and sustainability of agricultural production systems with major implications for diversity in family diet and nutrition. Over seventy households inhabit the area with an average of 5 persons per family. The main income is generated through extensive small ruminant production and olive production.

Figure 2. Images of the target site before intervention: Sbaihia pilot site, Tunisia (November 2017)

The area of Sbaihia, approximately 4,500 ha in size, is located at the edge of the forest zone which occupies the upper parts of the Sbaihia watershed (Figure 2). The Sbaihia Zone is located in the semi-arid upper bioclimatic stage with mild winter characterized by highly variable and fluctuating rainfall with an average lower than 400 mm/year. The wettest month is January and the driest month is July. The average minimum of the coldest month (January) is 5.6°C and the average maximum of the warmest month (July) is 35.6°C. Taking into account

the sector of Jimla, which covers an area of 7,593 ha; the land use of this sector is as follows (according to the National Forest and Pastoral Inventory (2010): cropland (including fruit growing and agroforestry) 3,999 ha (52.7%) and forest formations (all species) 3,394 ha (44.7% of the area of the sector).

The extensive farming is dominated by ruminant livestock (especially small ruminants), which are mainly reared by smallholder farmers. According to the Regional Commissariat for Agricultural Development (RCAD), the livestock number is about 3,030 sheep, 1,390 heads of cattle and 1,220 goats. Livestock is of the extensive type and herds are fed mainly from scrubland forest trails, fallow and stubble without movement outside the watershed. Moreover, according to the RCAD, forage resources cover only 60% of the needs of the livestock herds that are increasing the possibilities of overgrazing the rangelands. Pastoral resources consist of fodder production of forest rangelands, natural grasslands and residues of cereal crops.

The importance of the areas of land used by agriculture and the topographic configuration of these agricultural lands, imply that the area has a high potential for use in pastoral practices. The development potential in the area also includes the continuation of the olive (*Olea europaea*) and carob tree (*Ceratonia siliqua*) planting efforts on farmers' land to increase their economic performance. Currently, there is a large group of women who work in the collection of rosemary, lentisk, pennyroyal for the distillation of floral water and essential oil. The CBO has a modern distiller it uses to process raw materials harvested by women and produce floral waters and essential oils. The CBO is also making efforts to market these products through participating in various fairs in the country.

## Climate condition for 2017/18 – 2018/19

Most of MENA region is generally experiencing harsh arid or semi-arid climates with low and unpredictable precipitation, as well as fluctuations in temperature levels. The target site is no exception as during the 2017/18 agriculture calendar, the rainfall recorded represented only 60% of the long-term average (Figure 3). The drought conditions negatively impacted the germination, establishment and growth of the planted species. During the period 2018/2019 (from September to March), the rainfall levels recorded were representative of the long-term average, although with fluctuations regarding the monthly amounts received (Figure 3).

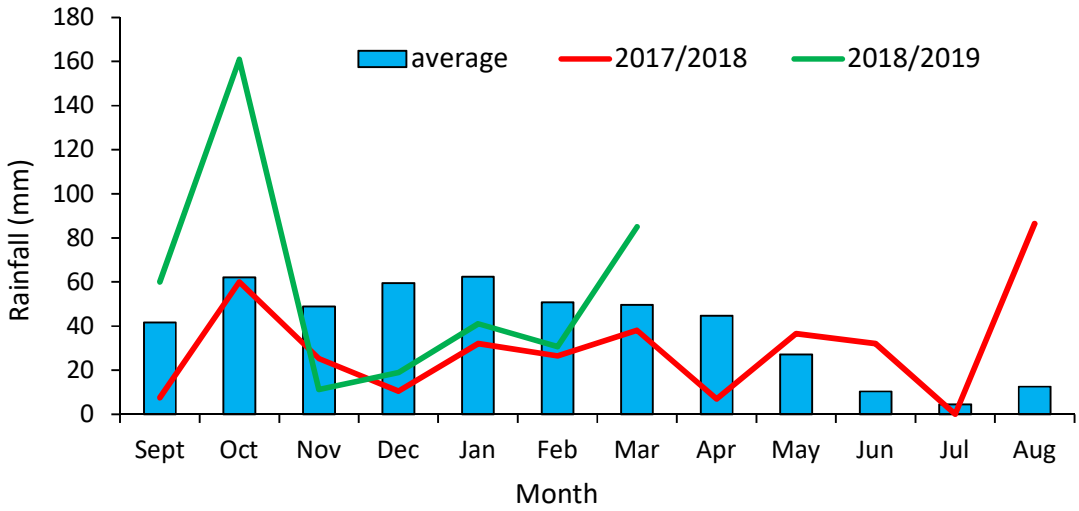


Figure 3**.** Long term monthly average rainfall (20-year) and the rainfall received during the two data collection periods: Sbaihia pilot site, Tunisia (September - Jun 2018 and September - March 2019)

### Land tenure

In Tunisia, rangelands cover approximately 5,566,180 ha, including 2,500,000 ha of collective land, 1,285,000 ha of private land, 970,000 ha of forest rangelands, 743,300 ha of *Stipa tenacissima* based rangelands and 67,880 ha of state-owned land. Under the collective land, over 2 M ha (36% of the total rangeland area in the country) are under the supervision of the forestry department (DGF). The target site of Sbaihia fitted this category and presented an opportunity to demonstrate the approach of working with local community and institutions, as well as an integrated technical package for wider dissemination to large areas within Tunisia. Therefore, a memorandum of agreement (MOA) was signed between the department of forestry (Direction General des Forets "DGF" and ICARDA with detailed a working plan, designating managing the silvopastoral site to the DGF.

## PROJECT ACTIVITIES & ACHIEVEMENTS

### Shrub and tree transplanting (afforestation)

#### Importance of afforestation

To reduce the effects of degradation and its adverse influence on forage production and natural resources, rehabilitation approaches such as planting trees/shrubs are particularly necessary (Osman et al 2006). Planting shrubs/trees also provides a large amount of fodder for livestock, combats desertification and plays a key role in natural resource conservation (Degen et al 1995; Franzel et al 2014). Furthermore, trees and shrubs have the facilitative effect on the establishment of understory seedlings in environments that are characterized by harsh environmental conditions (Scholes and Archer 1997). They also reduce solar radiation and soil temperature, conserve moisture and enrich the soil nutrient content

(Scholes and Archer 1997). In providing goods (especially forage for livestock and carbon sequestration), trees/shrubs in arid zones boost poverty alleviation strategies and reduce food insecurity (Franzel et al 2014).

The integration of tree/shrub through agroforestry has the potential to improve both sustainability and profitability of utilizing a piece of land, thus improving the livelihoods of small holder farmers (Hadri and Guellouz 2011; Franzel et al 2014). Tree/shrub plantation is also beneficial in creating microhabitats for vertebrate and invertebrate fauna, thus increasing the possibilities of seed dispersal (Franzel et al 2014). Most trees/shrubs in the arid and semiarid areas are resilient, thus able to recover after multiple grazing/browsing events (Scholes and Archer 1997). Their high biomass ensures that they can be harvested and stored, so that livestock can have alternative feed sources in the dry and barren periods (Franzel et al 2014).

Tree/shrub plantation benefits:

- Able to valorise marginal water not usable for conventional crops
- Several trees/shrubs are drought and cold tolerant
- Useful for soil and water conservation
- Are excellent for feeding livestock during drought and when no natural vegetation is available (gap in feeding)
- High survival rate if implemented correctly.

To control the spread of ecosystem degradation and reduce its adverse influence on forage production and natural resource degradation, planting of trees/shrubs is particularly necessary. Such a practice provides a large amount of fodder for livestock, combats desertification, and plays a key role in natural resource conservation. Furthermore, trees and shrubs have a facilitative effect on the establishment of understory seedlings in environments that are characterized by harsh environmental conditions. They also reduce solar radiation and soil temperature, conserve moisture, and enrich the soil nutrient content.

## Materials and methods

The selection and choice of species to plant in the pilot site was made in consultation with all concerned stakeholders. The needs of the region were discussed during meetings and field days. The following drought tolerant species were chosen for transplanting: cactus pear (*Opuntia ficus-indica*), old man saltbush (*Atriplex nummularia*), carob tree (*Ceratonia siliqua*) and tree medick (*Medicago arborea*). These species survive under harsh conditions due to their morphological and genetic characteristics permitting them to withstand prolonged droughts, interrupted by irregular occurrence of often light rainfall.

- **Cactus pads transplantation**

Cactus pads, which were over a year old and sourced from the Office of Livestock and Pasture (OEP), were harvested from the mother plants in March 2018. The pads were air-dried by placing them under a shade for a period of 10 days. Drying was meant to heal the areas where the pads were cut off from the mother plant, and the drying avoided wilting the pads. Because parts of the target site were too steep to plant shrubs that require irrigation during

establishment phase, cactus pads were planted between March to April 2018 on these areas since they require low investments in terms of inputs during the spring season (Figure 4). The spacing between the cladodes was 1.5 m apart in rows and the rows were at least 3 to 3.5 m apart. This spacing varied according to the condition of the field. A total of 1,800 double cladodes were planted in Sbaihia.

Figure 4**.** The landscape of the area (rough terrain and steep slope) where cactus pads were planted in Sbaihia pilot site, Tunisia (left image spring 2018 and right image spring 2019)

- **Seedling (shrubs/trees) transplantation**

Based on seedling availability in public nurseries, this activity was initiated during the month of March 2018. Seedlings of *Ceratonia siliqua* (300 seedlings), commonly known as the carob tree or carob bush, from Arabic خَرُّوبٌ (kharrūb), were planted on the slopes to consolidate soil and water conservation (Figure 5). This way, erosion on the hill slopes was expected to be significantly reduced. Seedlings of species *Medicago arborea* (200 seedlings), and *Atriplex nummularia* (300 seedlings), sourced from the Forest Service public nurseries, were also planted on the sides of the slopes to reduce soil erosion and to consolidate the water harvesting structures. To get maximum profit from the runoff, seedlings were transplanted in constructed micro-catchments, with a spacing of least 1.5 m apart. Due to the steepness of the slopes, spacing between rows varied between 2 to 3 m. The micro-catchments were established using tools that are readily available and can be implemented on land slopes with variable soil depth. Seedlings were irrigated immediately after transplanting.

Figure 5. Planting of carob trees in water harvesting structures in Sbaihia pilot site, Tunisia (Fall 2018)

In December 2018, the following additional fodder shrubs were planted:

- 300 of *Atriplex nummularia*
- 300 of *Medicago arborea* (tree medick)
- 200 of *Ceratonia siliqua* (carob tree)

- **Distribution of cactus cladodes and shrub seedlings to local farmers**

An additional quantity of 3,200 cladodes of spineless cactus, 300, 200 and 300 seedlings respectively of carob tree, tree medic and Atriplex were freely distributed to the local community surrounding the pilot site (40 households) for them to transplant in their private areas (Figure 6). In December 2018, an additional 150 seedlings of Atriplex and 60 seedlings of tree medic, century plant (*Agave* spp., 50) and lentisk (140) (*Pistacia lentiscus*) were also distributed to local community members (27 households benefited). The seedlings were purchased from the OEP nursery of Saouaf and planted in semi-circle water harvesting structures.

- **Selection criteria of community members**

Community members were selected based on the following criteria:

- Private property should be surrounding the pilot site,
- Willingness of farmers to take care of the seedlings through irrigation and prevention of browsing,
- Willingness to apply technical backstopping provided by the multidisciplinary team.

Members who met these conditions were then freely offered plant material as follows:

- Farmers owning a flock of sheep, goats and cattle with more than 20 heads received between 50-60 seedlings of each shrub species and at least 500 cactus cladodes.
- Households with smaller herd size received a lower allocation of seedlings (between 20-50 seedlings of each species) and cactus cladodes (between 300-400 cladodes).

Figure 6. Seedlings offered to farmers to plant in their farms in Sbaihia pilot site, Tunisia (Winter 2018)

## Preliminary results

The selected shrubs/trees are well adapted to the agro-ecological conditions of the target site. In addition, the timing of transplantation was executed during the fall/winter season to coincide with rainy season. In case of signs of water stress (especially during the summer season), irrigation was provided (15 L/plant). The survival rate (%) of shrub/trees were estimated 18-months after transplanting (Figure 7).

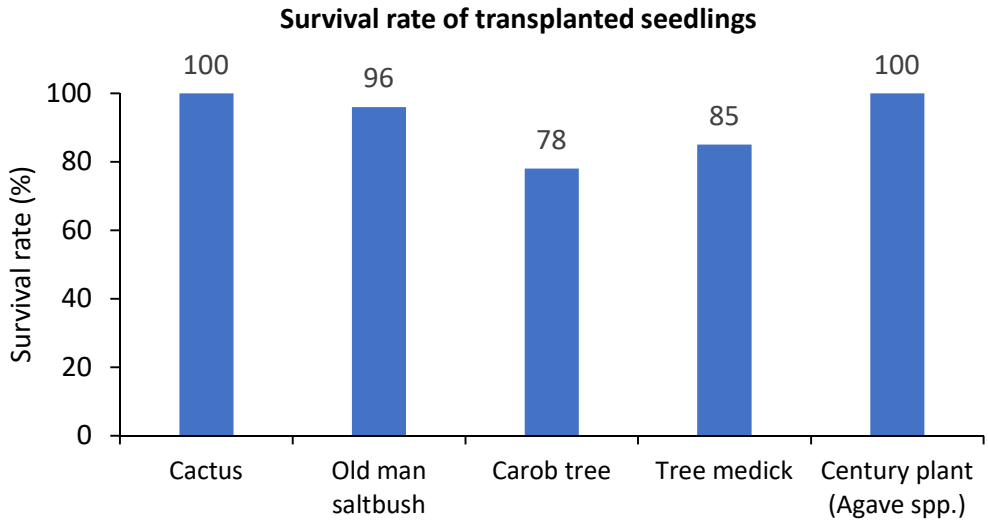


Figure 7. Survival rates of the transplanted seedlings at Sbaihia pilot site, Tunisia (2018)

## Reseeding using native species such as sulla (*Hedysarum coronarium*)

### Importance of sulla

Sulla is a drought-resistant species which is native to the Mediterranean (Bennett et al 2001). It is a biennial or short-lived perennial, semi-erect to erect growing and its height ranges between 0.3 and 2 m (Niezen et al 2002). It is deeply rooted (over 2 m) with numerous secondary roots, and it is also a melliferous plant (15 hives/ha). Its flowering begins in early spring, mellifluous inflorescences being racemes with up to 35 florets, ranging from dark red to purple pink. It prefers well-drained, medium-to fine-textured soils (Bennett et al 2001). Also, this species prefers slightly acid to alkaline soils (5.5-8.5), sandy loams, loams to clays, although higher growth is achieved on the more alkaline soils. Sulla is a highly palatable, nutritious and productive forage for ruminant production (Molle et al 2003). It is cultivated throughout the Mediterranean basin, where it is extensively grown as a 2-year forage crop for grazing and/or hay and/or silage production (Niezen et al 2002). The species plays a key role in cereal-based systems of semi-arid regions, particularly in organic and low-input agriculture, and is commonly used to enhance the productivity and sustainability of farming systems (*e.g.* as a nitrogen supply and to maintain soil organic matter).

One of the main values of sulla is its low water requirements, coupled with its ability to provide large amounts of palatable forage in steppe areas (Molle et al 2003). There has been a growing interest in sulla due to its excellent adaptability to marginal and drought-prone environments, versatility as a good quality, high-protein forage crop, and its moderate levels of condensed tannins beneficial to ruminant production. However, despite the importance of this species, few studies have been reported for sulla plantation and production in marginal lands.

### Experiment # 1: Effect of tillage practices on Sulla production and its impact on soil properties

**Study objectives**

The objectives of this study were to (i) evaluate how tillage practices affect yield of sulla, (ii) determine the effects of sulla plantation and tillage practices on soil properties.

**Experimental design**

The study consisted of three treatments: i) sulla reseeding following soil scarification, ii) soil scarification and iii) control (neither scarification nor sulla reseeding). The trial was laid out as a randomized block design with six replicates. The experiment was established in December 2017 at the Sbaihia site located at Zaghouan governorate. Sulla seeds were purchased from the Office of Livestock and Pasture farm in Fritissa with the following characteristics: 69% germination capacity, 89% specific purity and 10.94 ± 0.31 g per 1 000 grain weight. When reseeding the pilot site with forage grasses and legumes for the first time in December 2017, the top soil was first scarified using a tractor and then the seed broadcast by hand. After seeding, the soil was rolled by the tractor to ensure seed contact with the soil. The following grass species were broadcast on site;

- *Festuca arundinacea* (Fescue 20 kg) (5 kg/ha) on 0.4 ha,
- *Hedysarum coronarium* (sulla 1600 kg) (40 kg/ha) on 40 ha of area.

Seeds were manually sown after scarifying the soil on December 13, 2017 at 40 kg/ha seeding rate (Figure 8).

Figure 8**.** Site preparation and hand broadcasting of sulla seeds at Sbaihia pilot site, Tunisia (2017)

Vegetation characteristics were measured monthly from January to May in 2018 and from January to March in 2019, through randomly placing 10 quadrats of 1 x 1 m within each treatment plot. The following parameters were determined: dry matter yield (DMY), rain use efficiency (RUE), pastoral value (PV) and the soil organic matter content (OM). For estimating the DMY, standing plants were clipped at ground level within each quadrat and weighed before oven-drying at 85$^{o}$C for 24 h. The average dry matter was calculated in tons/ha of dry matter yield, while the biodiversity index (H') was determined according to the method of Roggero et al (2002). The pastoral value was determined according to Pittarello et al. (2018), while rain use efficiency was determined according to Howell (2001). To estimate soil OM, ten surface soil (i.e., 0–15 cm depth) samples were randomly taken from each treatment plot before initiation of the trial in December 2017 and after the growing season of sulla in May 2018. On each sampling date, the soil samples were bulked by treatment, air-dried and sieved for laboratory analyses. The soil samples were analysed for organic matter (OM) according to Nelson and Sommers (1996).

Within the pilot site, approximately 50 ha were hand sown with sulla seeds for improving the vegetation cover and distribution within the pilot site in Sbaihia on the first week of October 2018. A total of 3.7 tons of sulla seed was commercially purchased (only 0.5 ton was paid by the project, the rest was paid for by the DGF), 2 tons were used in the pilot site and 1.7 tons were distributed to local community members for this second reseeding.

**Impacts**

The results obtained show that despite the low rainfall amount recorded during the cropping season 2017/18 (only 275 mm), when compared with the long-term average total rainfall amount (474 mm) in the pilot site, technical interventions (soil surface scarification and sulla reseeding) generated higher yields than the control treatment. The rainfall received so far for

the 2018/2019 season (425 mm) and the results on biomass production reflect this, with biomass higher in the 2018/2019 season than the 2017/2018 season. Vegetation cover (%) and bare ground (%) differed between the scarified and control plots, with plant cover higher (*p<0.001*) (average of two seasons 2017-2018, 2018-2019) in plots scarified than non-scarified plots (Figure 9). Scarifying the soil increased total plant cover by at least 25% when compared to the control treatment. This can be explained by the fact that in arid and semi-arid regions, where moisture availability is the critical limiting factor, scarifying the soil broke the crusted layer for higher soil moisture infiltration and seed emergence compared to the non-scarified soil.

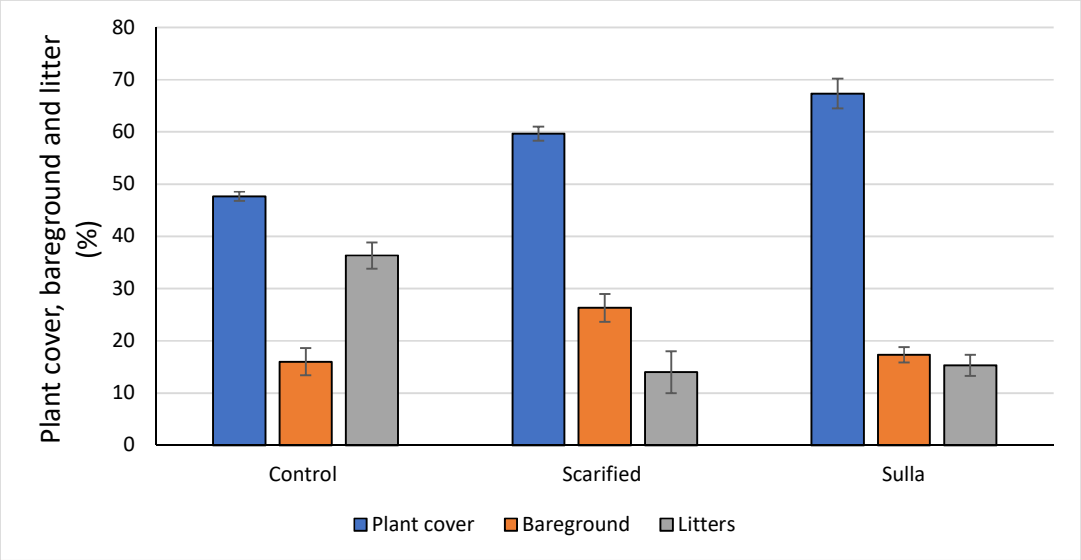


Figure 9. Percent plant cover, bare ground and litter in sulla reseeded, scarified and control plots in Sbaihia pilot site, Tunisia (values are average of two seasons 2017/2018 and 2018/2019)

For all scored parameters, the highest values were recorded in the sulla reseeded plots. The biomass yield of the sulla reseeded plots was double (*p<0.001*) that from both scarified and control plots (Figure 10).

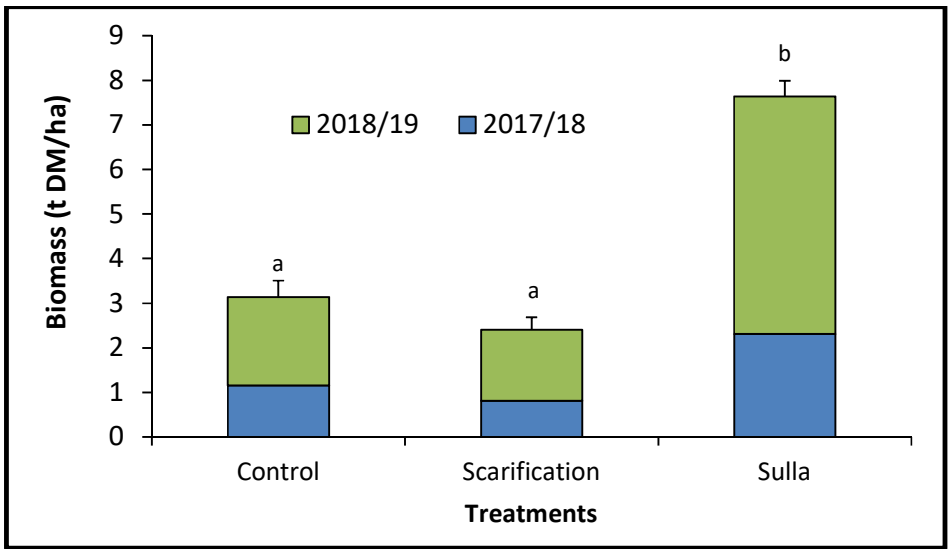


Figure 10. Biomass productivity (t DM/ha) of sulla reseeded, scarified and control plots 2017-2018 and the 2018-2019 seasons in Sbaihia, Tunisia

The rain use efficiency followed the same trend and recorded the highest value in sulla reseeded plots followed by scarification treatments (Figure 11). These results indicate the importance of the plant cover to increase water infiltration and to reduce the water erosion.

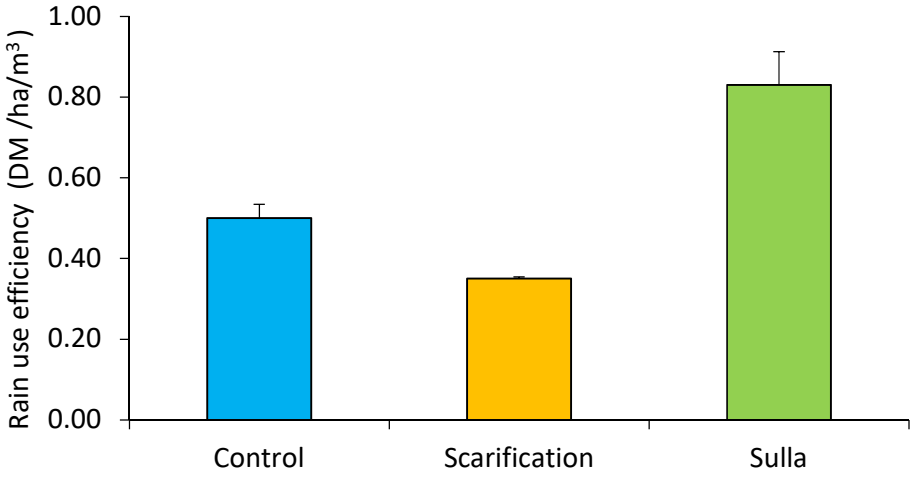


Figure 11. Estimate of rain use efficiency in sulla reseeded, scarified and control vegetation samples in Sbaihia pilot site, Tunisia (Spring 2018)

The pastoral value is an index that summarizes forage yield, quality, and palatability for livestock. It was calculated according to the following formula:

$$PV = 0.2 \sum PIi \times SCi$$

where: $SC_i$ is the species contribution to total plant cover (Argenti and Lombardi 2012), and $PI_i$ is the palatability index, ranging from 0 to 5, which summarizes the forage value of each species in the rangeland (Bagella et al. 2013).

The pastoral value was also higher ($p<0.001$) in sulla reseeded plots (42.5%) compared to the scarified and control plots (Figure 12). At the time of sampling, results indicate higher ($p<0.001$) soil OM (2.78%) in sulla planted plots compared to the scarified plots (1.25%) and the control plots (1.98%).

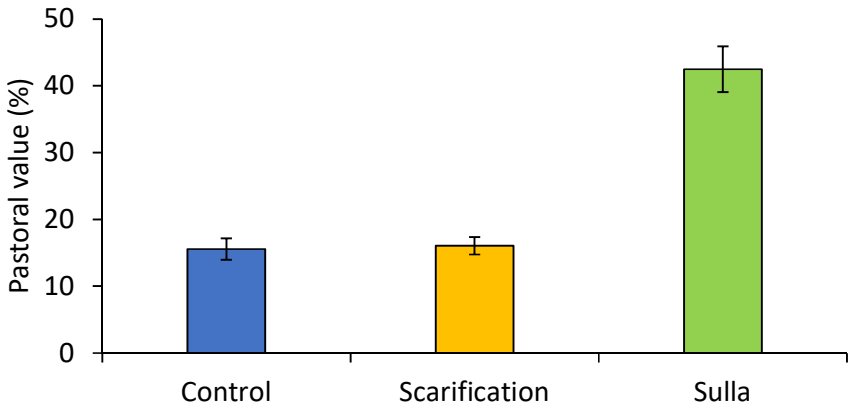


Figure 12**.** Effect of sulla reseeding, scarification on the pastoral value comparing to control in Sbaihia pilot site, Tunisia (Spring 2018)

Despite the relatively low amount of rainfall recorded during the first experimental growing season, the results do suggest that reseeding of sulla significantly improved the production and nutritive value of the natural rangelands. The low soil organic matter in scarified plots could be explained by the fact that the period of growth has not been long enough for it to have any positive effect on soil properties. This is in comparison to the control plots which had been left undisturbed for a while, thus developing and storing more carbon than the tilled plots. However, the expectation is that the sulla positively influenced soil chemical and physical properties, mainly through the nitrogen fixation process.

## Experiment # 2: Impact of sulla reseeding on the biomass production, biodiversity and vegetation cover

**Study Objectives**

The objectives of this study are two folds:

- to investigate the impact of sulla reseeding on the biomass production, biodiversity and vegetation and
- to compare improved site with reseeding to a protected site (no grazing) and an open site to grazing (control)

**Study design**

Three different treatments were considered including 1) plots reseeded with sulla in fall 2018, 2) plots that were protected from grazing for the last two years (protected plots), and 3) plots subjected to grazing (control).

**Data collection**

The changes in vegetation characteristics were monitored during the peak of the growing season in spring 2019, when growth of annual vegetation is at its prime. The sampling consisted of three 100-m long transects in each site. Vegetation cover and species composition were estimated using the line intercept method as described by Daget and Poissonet (1971). Each of the 100 hits/line within each transect was recorded according to plant species and type of ground touched (stones, wind veil, crust, or litter).

Using the data from the line intercept method, all recorded species were placed into 5 classes: Class 5, 4, 3, 2, 1 and 0 represent: extremely palatable, high palatable, palatable, low palatable, poorly palatable or occasionally palatable, Not palatable respectively. Annual plant density was estimated by establishing five quadrats (1 $m^2$) per line transect per plot. Plant density was then estimated through counting the number of individuals and dividing by the quadrat's area. Biomass production was estimated by clipping the vegetation inside 5 quadrats of 1$m^2$ each for annual species and by clipping the potentially grazeable biomass (Figure 13). The total biomass of perennial species was estimated by multiplying the mean available biomass/individual by the density of the species.

**Statistical analysis**

A general linear model, with plant species cover, aboveground biomass and density (annual and perennial species) as continuous variables, was used to evaluate the effects of different silvopasture managements. The data was analyzed using IBM SPSS-Statistics version 20. Differences between means were considered significant if P values were ≤ 0.05. Means and standard error values are reported in each figure.

Figure 13. Sampling and data collection within sulla reseeded site at Sbaihia pilot site, Tunisia (Spring 2019)

**Total percent ground cover**

The results of ground cover for the three treatments are presented in Figure.14. Reseeded sulla and protected plots recorded 100% plant cover while the open to grazing (control) plots had 59% plant cover. With respect to ground cover, the sulla reseeded and protected plots were dominated by litter (98% and 94% respectively), in contrast bareground was as expected very high within the control plots (69%). On the other hand, the percentage of stones was the highest in the control plots, whereas there no differences were found between the plots reseeded with Sulla and the protected plots as both recorded 1% of stone cover.

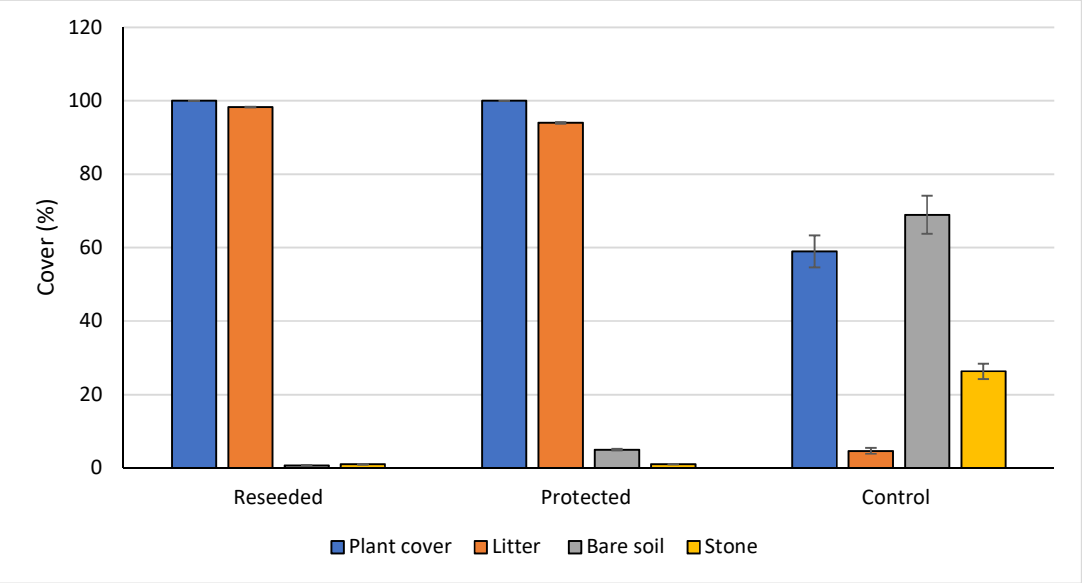


Figure 14. Variation of total plant cover in relation to different intervention management applied in Sabiha pilot site, Tunisia (Spring 2019)

**Species richness and palatability class**

Species richness was affected by the management (reseeding, protection and open to grazing). Species richness varied from 77 species in the protected rangelands and 30 species in the Sulla reseeded plots. Species richness was lowest in freely grazed plots (20 species). Effects of management mode were observed on species palatability class, in total there were 5 high palatable species were found in the protected plots comparing to 3 high palatable species documented in the reseeded plots. Moreover, 5 palatable species recorded mainly in the protected plots there was only one palatable species: *Picris cupuligera* observed in both the reseeded and the control plots. In contrast, 70% of the species recorded in the control and reseeded plots were classified under poorly palatable or unpalatable comparing to 63% in the protected plots. Table 1. presents species richness per treatment and palatability class per species.

Table 1. Species richness per treatment and palatability class per species as recorded at Sbaihia pilot site, Tunisia (Spring 2019)

| Species richness | | | | | |
|---|---|---|---|---|---|
| Reseeded | Palatability | Protected | Palatability | Control | Palatability |
| *Hedysarum coronarium* | 5 | *Cynodon dactylon* | 5 | *Picris cupuligera* | 4 |
| *Plantago albicans* | 5 | *Dactylis glomerata* | 5 | *Anacyclus clavatus* | 3 |
| *Vicia sativa* | 5 | *Hedysarum coronarium* | 5 | *Medicago minima* | 3 |
| *Picris cupuligera* | 4 | *Plantago albicans* | 5 | *Plantago afra* | 3 |
| *Aegilops geniculata* | 3 | *Scorzonera undulata* | 5 | *Plantago lanceolata* | 3 |
| *Hedysarum spinosissimum* | 3 | *Avena sterilis* | 4 | *Trifolium stellatum* | 3 |
| *Medicago minima* | 3 | *Olea europaea* | 4 | *Bromus erectus* | 2 |
| *Plantago lanceolata* | 3 | *Picris cupuligera* | 4 | *Convolvulus althaeoides* | 2 |
| *Acacia saligna* | 2 | *Salvia verbenaca* | 4 | *Erodium malacoides* | 2 |
| *Anagallis arvensis* | 2 | *Stipa parviflora* | 4 | *Stipa capensis* | 2 |
| *Anthyllis tetraphylla* | 2 | *Aegilops geniculata* | 3 | *Carduus macrocephalus* | 1 |
| *Calendula arvensis* | 2 | *Aegilops ovata* | 3 | *Centaurea sicula* | 1 |
| *Calicotome villosa* | 2 | *Anacyclus clavatus* | 3 | *Daucus muricatus* | 1 |
| *Convolvulus althaeoides* | 2 | *Coronilla juncea* | 3 | *Echium plantagineum* | 1 |
| *Erodium malacoides* | 2 | *Crataegus azarolus* | 3 | *Filago pygmaea* | 1 |
| *Helminthotheca aculeata* | 2 | *Globularia alypum* | 3 | *Filago pyramidata* | 1 |
| *Scabiosa atropurpurea* | 2 | *Hedysarum spinosissimum* | 3 | *Glebionis coronaria* | 1 |
| *Stipa capensis* | 2 | *Hordeum marinum* | 3 | *Hypericum tomentosum* | 1 |
| *Tordylium apulum* | 2 | *Hypochaeris radicata* | 3 | *Silybum eburneum* | 1 |
| *Urospermum dalechampii* | 2 | *Juniperus phoenicea* | 3 | *Atractylis cancellata* | 0 |
| *Allium roseum* | 1 | *Linaria laxiflora* | 3 | | |
| *Convolvulus tricolor* | 1 | *Lotus pedunculatus* | 3 | | |
| *Galactites tomentosus* | 1 | *Medicago minima* | 3 | | |
| *Silybum eburneum* | 1 | *Phalaris minor* | 3 | | |
| *Sinapis arvensis* | 1 | *Plantago afra* | 3 | | |
| *Stachys ocymastrum* | 1 | *Plantago lanceolata* | 3 | | |
| *Atractylis cancellata* | 0 | *Rosmarinus officinalis* | 3 | | |
| *Euphorbia exigua* | 0 | *Trifolium stellatum* | 3 | | |
| *Malva sylvestris* | 0 | *Acacia saligna* | 2 | | |
| *Pallenis maritima* | 0 | *Agrostis semiverticillata* | 2 | | |
| | | *Anagallis arvensis* | 2 | | |
| | | *Astragalus armatus* | 2 | | |
| | | *Astragalus corrugatus* | 2 | | |
| | | *Bromus madritensis* | 2 | | |
| | | *Calendula arvensis* | 2 | | |
| | | *Calicotome villosa* | 2 | | |
| | | *Chrysanthemum corymbosum* | 2 | | |
| | | *Chrysanthemum macrotum* | 2 | | |

| Species richness | | | | |
|---|---|---|---|---|
| Reseeded | Palatability | Reseeded | Palatability | Reseeded |
| | | *Convolvulus althaeoides* | 2 | |
| | | *Fumana thymifolia* | 2 | |
| | | *Helminthotheca aculeata* | 2 | |
| | | *Lycium europaeum* | 2 | |
| | | *Lygeum spartum* | 2 | |
| | | *Phagnalon saxatile* | 2 | |
| | | *Plantago major* | 2 | |
| | | *Scabiosa atropurpurea* | 2 | |
| | | *Stipa capensis* | 2 | |
| | | *Teucrium polium* | 2 | |
| | | *Tordylium apulum* | 2 | |
| | | *Trifolium ligusticum* | 2 | |
| | | *Urospermum dalechampii* | 2 | |
| | | *Allium ampeloprasum* | 1 | |
| | | *Asparagus albus* | 1 | |
| | | *Carduus macrocephalus* | 1 | |
| | | *Centaurea sicula* | 1 | |
| | | *Convolvulus tricolor* | 1 | |
| | | *Daucus muricatus* | 1 | |
| | | *Galactites tomentosus* | 1 | |
| | | *Glebionis coronaria* | 1 | |
| | | *Lobularia maritima* | 1 | |
| | | *Reseda alba* | 1 | |
| | | *Silybum eburneum* | 1 | |
| | | *Sinapis arvensis* | 1 | |
| | | *Stachys ocymastrum* | 1 | |
| | | *Thymbra capitata* | 1 | |
| | | *Ajuga iva* | 0 | |
| | | *Atractylis cancellata* | 0 | |
| | | *Borago officinalis* | 0 | |
| | | *Cistus monspeliensis* | 0 | |
| | | *Echinops spinosissimus* | 0 | |
| | | *Eryngium campestre* | 0 | |
| | | *Euphorbia helioscopia* | 0 | |
| | | *Malva sylvestris* | 0 | |
| | | *Marrubium vulgare* | 0 | |
| | | *Oxalis pes-caprae* | 0 | |
| | | *Pallenis maritima* | 0 | |
| | | *Urginea maritima* | 0 | |

**Biomass and plant density**

Significant differences were found among the three managements modes in terms of biomass production. The estimated biomass for the reseeded plots was four times higher than the biomass production in the protected plots and ten times higher than the biomass in the control plots (Figure 15). Likewise, the type of management significantly affected plant density. The highest density was recorded in the protected plots, followed by the control plots and the lowest plant density was recorded in the reseeded plots. This is attributed to the fact that Sulla dominated the area (Table 2).

Table 2. Plant density (plant/$m^2$) in relation to different relation to different intervention management modes applied in Sbaihia pilot site, Tunisia (Spring 2019)

| Species | Reseeded | Protected | Control |
|---|---|---|---|
| *Hedysarum coronarium* | 8.0 | 6.0 | 1.0 |
| *Coronilla juncea* | 4.4 | 0.0 | 0 |
| *Helminthotheca aculeata* | 3.4 | 3.2 | 0 |
| *Galactites tomentosus* | 2.4 | 6.8 | 0 |
| *Sinapis arvensis* | 1.2 | 0.8 | 0 |
| *Stipa capensis* | 1.0 | 4.2 | 0.4 |
| *Plantago lanceolata* | 1.0 | 2.6 | 0.2 |
| *Anacyclus clavatus* | 0.8 | 0.4 | 0.2 |
| *Scabiosa atropurpurea* | 0.8 | 0 | 0.0 |
| *Atractylis cancellata* | 0.2 | 0.2 | 2.8 |
| *Convolvulus althaeoides* | 0.2 | 0.0 | 5.6 |
| *Calendula arvensis* | 0 | 5.6 | 0 |
| *Pallenis maritima* | 0 | 0.6 | 0 |
| *Picris cupuligera* | 0 | 0.4 | 0 |
| *Picris cupuligera* | 0 | 0 | 8.6 |
| *Bromus erectus* | 0 | 0 | 4.6 |
| *Trifolium stellatum* | 0 | 0 | 1.6 |
| *Filago pygmaea* | 0 | 0 | 1.4 |
| *Carduus macrocephalus* | 0 | 0 | 1.0 |
| *Plantago afra* | 0 | 0 | 0.8 |
| *Daucus muricatus* | 0 | 0 | 0.2 |
| *Erodium malacoides* | 0 | 0 | 0.2 |
| *Glebionis coronaria* | 0 | 0 | 0.2 |
| *Hedysarum spinosissimum* | 0 | 0 | 0.2 |
| *Silybum eburneum* | 0 | 0 | 0.2 |
| *Total* | 23.4 | 30.8 | 29.2 |

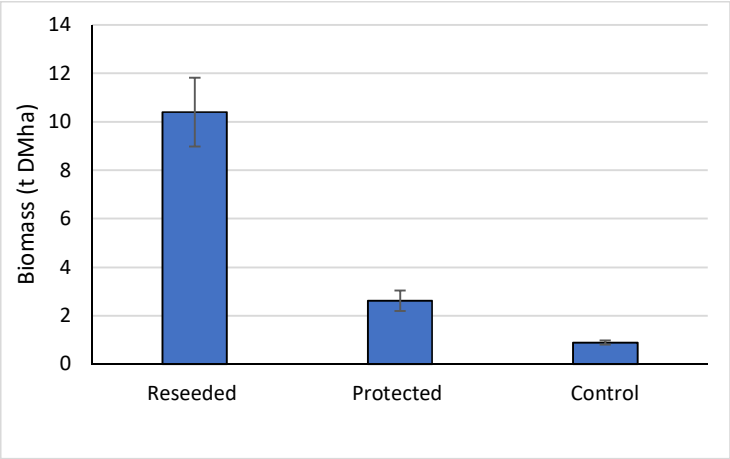


Figure 15. Variation of biomass production in relation to different intervention management modes applied in Sbaihia pilot site, Tunisia (Spring 2019)

**Impacts**

The results obtained clearly indicate how management interventions affected positively the plant cover, biomass production plant density and species richness, and palatability class. Plots reseeded with Sulla generated higher yields and less plant density than both protected and control plots, and it increased the litter cover (%) which would lead to higher organic matter in the soil. The reseeded were more homogeneous especially that the environmental conditions for sulla growth were less stressful in 2018/19 (enough rainfall, absence of competition, abundant soil nutrients). These conditions may have been more beneficial to the large-seeded of Sulla than the spontaneous vegetation enabled Sulla dominate the area at high biomass and cover, lowering the diversity and function of the other spontaneous vegetation however, still the palatability class of the species recorded in the plots reseeded with Sulla is higher than the ones recorded in the control, this is very important to enhance the quality of the biomass in terms of feeding value. On the hand, compared to other ecosystems, the protected area was less disturbed, which was reflected by higher heterogeneity and diversity of species. Nevertheless, reaching a 10 tDM/ha of good quality forage legume is significant gain that can contribute the fill the feed gap and helps to enhance the income of the livestock keepers.

## Grazing management of the rehabilitated area

### Importance of grazing management

A silvopastoral production system involves the integration of forage production (reseeding, planting trees or shrubs, etc.) and livestock grazing in a sustainable manner. Grazers are important regulators of ecosystem processes in grazing ecosystems as they increase forage concentration, grazing efficiency, forage nutrient concentration and above-ground plant production (Teague et al 2011). Therefore, the pilot site was divided into several paddocks based on the following uniform criteria:

- Landscape (topography)

- Dominant species
- Natural “existing” boundary

In order to avoid overgrazing and to also follow a rational grazing system that can improve pasture production, utilization and persistence, the site was divided in consultation with the concerned parties (extension, DGF and the local community). However, the subdividing of the pilot site this way is subject to revision depending on the vegetation growth (year) and the number and type of animals allowed to graze at any particular time. Sulla should be browsed moderately to ensure root development and ideal plant population for seed production in the second year (Neal et al., 2009). After browsing, at least 40% of biomass should remain to avoid delay in regrowth. The browsed sulla plant will have several advantages when compared with the grazed herbaceous plant, because woody plants have stem cambia with almost unlimited sources of new growing points that are completely protected from damage by browsing (Rutherford, 1979). The objective of this study was to estimate feeding cost reduction between improved rangeland compared to natural degraded rangeland (control).

## Materials and methods

After several meetings among the various stakeholders involved, a joint decision was made to open the site for grazing. The decision to open the site for grazing was requested by the community itself due to the great need of feed resources in the region resulting from three years of drought affecting most of Tunisia. Figure 16 shows the project intervention and Table 3 shows the total areas where sulla was reseeded.

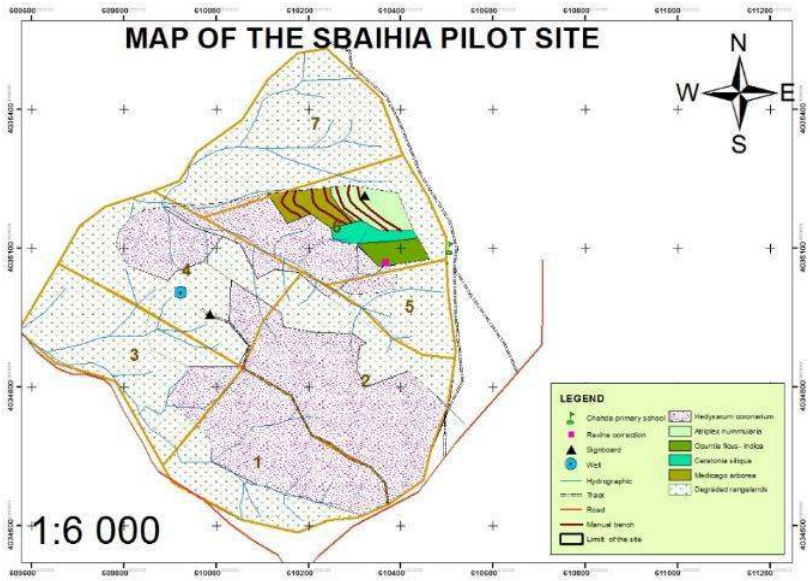


Figure 16**.** The location of the grazed plots located in Sbaihia pilot site, Tunisia (Spring 2018)

Table 3**.** The total area (ha) reseeded with sulla and rangelands in Sbaihia pilot site, Tunisia (Spring 2018)

| | Plot Number | | | | Total |
|---|---|---|---|---|---|
| **Utilization** | **1** | **2** | **3** | **4** | |
| **Sulla** | 6.3 | 7.8 | 1.3 | 2.3 | 17.7 |
| **Rangelands** | 3.2 | 3.8 | 7.4 | 8 | 22.4 |
| **Total** | 9.5 | 11.6 | 8.7 | 10.3 | 40.1 |

The number of livestock and the duration of grazing were calculated based on the biomass estimates of the pilot site and the rangelands under consideration. The community actively participated in the control and selection of farmers involved in the grazing operation, with at least 120 members of the community providing animals. The site was divided into 7 plots. During spring 2018, grazing was allowed in plots 1, 2, 3 and 4 and restricted in plots 5, 6, and 7 and it lasted for one month. This means that only four plots from the seven (total) was exposed to grazing the 3 others was for control and scientific demonstrations. Grazing started at the flowering stage of sulla plants (Figure 17). During the second year (2018/2019), the site was divided into two sections. One section was used as cut and carry (April 2019). The other section was left to complete its cycle (seed production) and then it will be also cut as straw.

Figure 17**.** Livestock grazing in the rehabilitated rangelands of Sbaihia pilot site, Tunisia (Spring 2018)

## Impacts

During the dry season when there is nothing to graze the cost of feeding is estimated at 2.7 Tunisian Dinar (TD) per day per head (>1 USD/ sheep) to cover the cost of purchased hay and concentrates. When livestock keepers let their animal graze on natural rangeland vegetation, they have to supplement their animals with hay and concentrates which is estimated at about 1.17 TD/day/head (0.44 USD). For the improved ecosystem (sulla reseeded) of the Sbaihia pilot site, the cost of livestock feeding dropped significantly to 0.35 TD per day per head ($0.13 USD) in 2019. Under this scenario, livestock keepers were able to save almost 2.35 TD/day/head (0.88 USD) compared to when no grazing. This is one of the main reasons behind the high adoption rate of reseeding degraded areas with sulla by the community in Sbaihia as it was profitable in terms of feed cost reduction.

The first-year grazing trial showed that proper understanding among the various stakeholders including local communities for the grazing management is crucial to ensure long-term sustainability of the restoration effort. Therefore, more awareness of the local community to

the importance of the stocking rate and grazing duration should be raised to avoid any future misuse. Future grazing will follow the regulations in place put forward by the DGF which include paying a fee per head per day.

## Soil and water conservation measures

### Importance of soil and water conservation measures

Soil erosion not only reduces soil fertility, crop production, and biodiversity but also alters water quality and increases risks of global climate change and food insecurity (Blanco-Canqui and Lal, 2010). Therefore, soil conservation contributes towards increasing crop yields, reducing water pollution, and mitigating concentration of greenhouse gases in the atmosphere (Reij et al 2013). The experimental site in Chahda in the region of Oued Sbaihia is strongly threatened by water and soil erosion because of the steepness of the slopes and lack of adequate soil cover. The purpose of this study was to develop the watershed in order to protect farmlands from bank widening and flooding. The study area has a fairly strong relief with a remarkable gully density. The watershed is located in the Jimla sector of the Zaghouan delegation, 12 km from the city of Zaghouan. The watershed is undeveloped and requires treatment and management. Based on the map generated in ArcGIS, the watershed was shown to be covered by a 5% slope in at least 50% of the total watershed area.

The descriptions, area and measurements of the selected watershed is presented in Table 4.

Table 4. Characteristics of the target watershed of Jimla, Sbaihia pilot site, Tunisia

| Designation | Unit | Value | Note |
|---|---|---|---|
| Watershed area (S) | $km^2$ | 1 | |
| Watershed perimeter (P) | km | 3.78 | |
| Length of the main talweg: Lt | km | 1.135 | |
| Maximum altitude (Hmax) | m | 218 | |
| Minimum altitude (Hmin) | m | 150 | |
| Compactness index (Kc) | | 1 | Circular Watershed |
| Specific altitude difference (Ds) | m/km | 125 | Strong relief |
| Concentration time (GIANDOTTI) | (h) | 0.73 | |

Given the morphological characteristics of the watershed, the study area was developed by two techniques:

- manual benches were proposed for an area of 70 ha.
- ravines were corrected by biological or mechanical treatment:
    - Treatment of non-deep ravine heads by biological fixation, which was done by silvopastoral species- smooth or thorny cactus (according to the species availability).
    - Treatment of deep ravine heads to stop upstream regression by watershed treatment using gabion thresholds.

The cost of each treatment is displayed in Table 5.

Table 5. Summary of the soil and water conservation activities and the cost of each treatment in Sbaihia pilot site, Tunisia

| Activities | Unit | Area | Cost (000 TD) |
|---|---|---|---|
| Manual benches | ha | 70 | 105,000 |
| Benches consolidation | ha | 50 | 30,000 |
| Biological threshold | ha | 20 | 28,000 |
| Threshold in gabion | unit | 5 | 50,000 |
| **Total** | | | **213,000 (USD 71,000)** |

The contribution of the administration (Tunisian Ministry of Agriculture) was 143,000 TD (equivalent to ~ 60,000 USD), while the contribution of the project (purchase of cactus and gabion threshold) was 70,000 TD (equivalent to ~ 30,000 USD).

## Materials and methods

- **Gabion technique:**

Stone gabions were constructed in some sections of the eroded areas at the project site. The gabions were constructed to trap soil and water flowing downstream and to also reduce the effects of runoff on the soil. Four gabions were constructed (Figure 18).

Figure 18. Stone gabions constructed within the Sbaihia pilot site, Tunisia (Winter 2019)

- **Manual benches technique**

In addition to the gabion technique to reduce soil degradation, ten manual land benches were implemented to further increase soil and water conservation (Figure 19).

Figure 19**.** Benches constructed manually at Sbaihia pilot site, Tunisia (Winter 2018)

## Impacts

- **Gabion technique:**

With a depth around 4 m for the 2nd four gabions, and an average width of 4 m and 7 m and with a dissipation basin of 5 $m^2$, the land loss was calculated based on the FAO formula:

(Es (t / ha / year) = Fm * C1 * C2 * C3

With C1 = 1.1, the soil is a loamy type, C2 = 0.8 Coef Depth of SBV Slope C3 = 0.6 it is a course. With an average rainfall of 400mm / year, the four gabions have preserved at least 4800T / ha / year of soil from erosion. The constructed gabions are expected to significantly reduce the runoff as well as to trap the soil carried downslope by runoff.

- **Manual benches technique**

The manual benches covered an area of 70 ha while the actual area of this benches was 3.5 ha with a total distance of 700 m, these benches can store a volume of 280 $m^3$ water that will be used for the species planted on these ditches and increase the water balance and reduce runoff water loss by at least 800 $m^3$/ha. The water balance is established for a given place and period by comparing the inflow and loss of water in that place and for that period. Direct measurements were taken after the October 2018 rains of the bordering ravine adjacent (control) to the managed gabion. There was a soil loss of 48 $m^3$ equivalent to 72t. The manual ditches and soil dams reduced the quantity of soil erosion by around 186 t/ha/year.

With a total distance of 700 m and a water retention capacity of 0.4$m^2$/m, the total water harvesting was estimated at 280 $m^3$/year. This water quantity is sufficient for irrigating all planted trees and shrubs on the border of the manual land benches installed in this site.

The calculation method is as follows:
The volume of water lost by runoff (V) was calculated using the below formula

V= C*[Rainfall (mm)* Area ($m^2$)/1000]
Where the C is the runoff coefficient, the value for the bare rangelands is 0.55, while after intervention this value becomes 0.35.
The estimated volume of water lost by runoff in the bare rangelands
V1 = 0.55*[400*35000/1000)] = 7700 $m^3$
The estimated volume of water lost by runoff after intervention
V1 = 0.35*[400*35000/1000)] = 4900 $m^3$
Reduction of water loss per ha by runoff because of the manual benches (R):
R = (V1 - V2) /3.5 = 7700 – 4900 = 800 $m^3$/ha

Based on calculations done after heavy rainfall events in October 2018, the four stone gabions and the manual benches thus far have preserved at least 4800 T/ha/year of soil from erosion, while storing at least 280 $m^3$ of water to be used to irrigate shrub species planted on these ditches, as well as reducing runoff water loss by approximately 800 $m^3$/ha.

## MEETINGS AND CAPACITY DEVELOPMENT BUILDING

Organizing field days and workshops in communities is important in bringing new ideas, resources and opportunities towards attaining community empowerment (Mathie and Cunningham, 2003). Such events create new ties among the members of a community, leading to new norms of trust and cooperation, as well as new activities and collective action that could be beneficial for the community (Haines 2009). Hosting field days and workshops is also critical as this foster collaborative relation between and amongst residents, as well as institutions involved in project implementation and establishment (Mathie and Cunningham 2005). Capacity development of communities results in community members to be well represented in critical decision-making processes, thus enforcing community-based and –controlled initiatives, which have the potential to devolve responsibility of resource management to local levels, as well as mobilizing institutional resources such as local government, formal community-based organizations and private enterprises (Gittell and Vidal 1998).

The capacity development activities carried out up to the March 2019 are presented in Table 6 and explained in detail in the text. A total of fifteen events were conducted covering various themes linked to the sustainable development of silvopastoral production systems in the dry areas. The emphasis was on the pilot site of Sbaihia (Zaghouan, Tunisia). The target participants were mainly from the local community, but we included the local authority, extension specialists and university students. In addition, a new initiative aimed at increasing the awareness about conservation of the natural resource base and best practices and targeting elementary school pupils.

Table 6. Meetings and capacity development events carried out since the beginning of the sustainable silvopastoral restoration project in Sbaihia pilot site, Tunisia

| Event name & location | Date | Theme | Number of participants |
|---|---|---|---|
| Field day: Awareness about sustainable silvopastoral development | 8-Dec-17 | Develop an action plan for the project | 36 |
| Meeting at CBO (Sbaihia) | 13-Dec-2017 | Awareness about project and involvement of farmers in the project activities | 8 |
| Field day: Sulla distribution & agronomic practices | 20-Dec-17 | Train community members on the cultivation, use and management of multipurpose shrubs and trees | 36 |
| Field day: Use of multi-purpose shrubs/trees | 28-Mar-18 | Introduce farmers to the cultivation and exploitation of sulla | 15 |
| Training Course: Sustainable silvopastoral development | 4-Apr-18 | Raise awareness and enhance the capacity of graduate students about the sustainable Silvopasture system management | 18 |
| Field day: Environmental Education and Awareness in schools | 10-Apr-18 | Educate and inform pupils in the school about the importance of trees towards sustaining human livelihoods | 40 |
| Field Visit: FAO Representative Visit to the Sustainable Silvopastoral Restoration to Promote Ecosystem Services Project Site in Tunisia | 2-May-18 | Update and evaluate project progress | 18 |
| Field day: Rational grazing management (Sbaihia) | 3-May-18 | Inform the Sbaihia community about the importance of sustainably grazing rangelands | 19 |
| Training workshop: Participatory approach, local development and basic organizations workshop report | 7-May-18 | Train participants on participatory approach and local development | 25 |
| Training Course: Water and soil conservation training | 5-Jul-18 | Train participants on water and soil conservation techniques | 19 |
| Workshop: National Tree Festival | 13-Nov-18 | Raise awareness about the forest importance and management | 82 |

| Event name & location | Date | Theme | Number of participants |
|---|---|---|---|
| Training Course: Rangelands Plant Terminology and Basic Plant Identification | 11-Dec-18 | Train participants on plant collection, identification and conservation | 32 |
| Field visit ESAM: Livestock and Forage production | 13-Feb-19 | Inform participants about scientific and agricultural activities | 24 |
| Workshop: Sustainable Management of Silvopastoral Ecosystems | 26-Feb-19 | Enhance information and capacity of DGF staff on sustainable management of silvopastoral ecosystems | 82 |
| Student engagement | Along with Project life | Each student tackled one aspect of the silvopastoral production system as part of their thesis or project. | 6 |
| Evaluation workshop: Sustainable Silvopastoral Restoration to Promote Ecosystem Services in Tunisia Project Evaluation Workshop | 21-Mar-19 | Evaluate project achievements and decide on future site management | 32 |

## Inception workshop

The Letter of Agreement (LoA) between FAO and ICARDA was signed on the 21st of November 2017. In order to launch the project, an inception workshop was scheduled for Friday 8th December 2017 at Dar Zaghouan, Tunisia and it was attended by 36 participants (Figure 20). Mr. Hamza (DG of CRDA of Zaghouan) who chaired the meeting, welcomed all participants (mainly ICARDA scientists and the guests of Zaghouan) and expressed the willingness of the CRDA to strengthen the collaboration with all stakeholders including the international (FAO and ICARDA), national (DGF, ESA Mateur, INRGREF) and local CBO organizations. Dr. Mounir Louhaichi (ICARDA) presented ICARDA's mandate and thanked CRDA and DGF for their efforts in organizing this inception workshop and all participants for attending the workshop. He also acknowledged FAO for funding this pilot operation, which will be scaled out to other countries across the MENA region once the targeted objectives are met.

Figure 20. Attendants of the inception workshop in Dar Zaghouan, Tunisia (December 2017)

Mr. Jamel Kailene (Sous-Director of Rangelands at the DGF within the MoA) expressed the willingness of DGF to strongly collaborate and put all its efforts to guarantee the success of this project. He presented the agenda of the workshop, the project goals and main activities. At the end of the workshop the participants agreed to take on the action points more information can be found on minutes of the Inception workshop. In the afternoon, the project team made a field visit to the target site. The visit was aimed at initiating the implementation of the workplan (prepare soil for reseeding before the rainy season).
During the workshop the project leader, Dr. Mounir Louhaichi (ICARDA), was interviewed by the African Tunisian Press (ATP). This interview was later broadcasted on the national radio and posted at the ATP website in 3 languages:

- https://www.tap.info.tn/fr/Portail-R%C3%A9gions/9644544-zaghouan-icarda **(French)**
- https://www.tap.info.tn/en/Portal-Regions/9644661-zaghouan-icarda **(English)**
- https://www.tap.info.tn/ar/%D9%88%D9%8A%D8%A8-%D8%B3%D9%8A%D8%AA-%D8%AC%D9%87%D8%A7%D8%AA-Portal-Regions/9644187-%D8%B2%D8%BA%D9%88%D8%A7%D9%86-%D8%A7%D9%84%D9%85%D8%B1%D9%83%D8%B2 **(Arabic)**

## Meeting at CBO of Oued Sbaihia

A meeting with the local CBO of Oued Sbaihia was held on 13 December 2017 to increase the awareness about the project and the role and involvement of farmers in the project activities. During this meeting, required information regarding the number of families, number of women involved in the CBO were collected. Also, it was agreed on distribution of 1-ton sulla seeds among interested households (HHs), based on the number of farmers interested in

sulla. During the meeting, the list of beneficiaries was drafted and shared. Furthermore, it was agreed to organize a training day for farmers who will benefit from distributing sulla.

## Field day: Agronomic practices of sulla cultivation

A sulla training day was organized on the 20th of December 2017 in the local GFDA Ouled Sbaihia, Zaghouan, with a total number of 35 participants. The objective of the sulla training day was to raise awareness, promote and educate communal farmers on the benefits of planting this native shrub as well as to distribute its seeds to participants. The anticipation was that after growing sulla, participant farmers would notice the significant changes in the rangeland health as well as considerable reductions in the feed gap demand for their livestock. The training focused on sulla cultivation from soil preparation for sowing to harvesting and fodder conservation. Since the training was interactive, all farmers were given an opportunity to share their knowledge on sulla with the trainer and the other participants. The farmers in Sbaihia had indigenous knowledge of sulla cultivation and acknowledged that it is ideal for animal feeding (sheep, goat and cattle) as well as for soil protection (reinforcement in organic matter and protection against water erosion). However, farmers had no knowledge of its exploitation and its conservation. They stated that the obstacle they have encountered is the unavailability of sulla seeds in the market, which is causing the low cultivation of sulla in the region. After the training, farmers wishing to cultivate sulla received free sulla seeds provided by GFDA varying between 20 kg, 40 kg and 80 kg for sowing areas varying between 0.5 ha, 1 ha and 2 ha. Information and the event agenda, list of participants can be found in the training report.

## Field day: Use of multi-purpose shrubs/trees

A farmer's field day was organized on the 28th of March 2018 at Community based Organization of Oued Sbaihia, Tunisia (Figure 21). Training of group of 15 farmers was facilitated by Dr. Slim Slim who presented the main aim of the training as to highlight the role of the multipurpose trees, benefits uses and environmental impact. During this event, Dr. Slim mentioned the main three trees species the project is working on: carob tree, *Atriplex nummularia* and *Medicago arborea*. These three species have adaptations that help them survive and thrive under Zaghouan and arid conditions. He explained and demonstrate ideal planting methods for the seedlings and the best agronomic practices to insure good growth of seedlings. Many questions were asked by the participants regarding the requirements of these trees and when to start utilizing these trees, which were answered by Dr. Slim. Participants showed great interest to grow these trees and asked how to get the seedings, with each farmer receiving seedling of the three species to plant them in their lands. Detailed information can be found in the report of this event.


Figure 21. Participants during the multipurpose field day Sbaihia pilot site, Tunisia (March 2018)

## Training course: sustainable silvopastoral development

A student field visit day was organized for 19 participants from the Higher School of Agriculture of Mateur as part of their training in water and soil conservation. The Sbaihia region is an area constantly exposed to different forms of erosion as a result of the steepness of the slopes and lack of adequate soil cover. Dr Slim gave a brief talk about the different techniques employed when rehabilitating a degraded rangeland. He also highlighted the need to conserve natural resources such as soil and to preserve water, especially in a water scarce region such as the Middle-East North Africa region. Students were then taken to the site, where soil and water conservation structures have been constructed (Figure 22). The constructed gabions in Chahda pilot site are expected to significantly reduce the runoff as well as to trap the soil carried downslope by runoff, tangible results will be recorded during the following rainy season report about this event is available online.

Figure 22. Students field visit to the silvopastoral Sbaihia pilot site, Tunisia (April 2018)

## Field day: environmental education and awareness in schools

The event was organized on the 10th of April 2018 at Chehda Primary School in Sbaihia, Zaghouan (Figure 23). A total of at least 40 pupils attended this field day, facilitated by Mr Jamel (Director- Directorate General of Forestry). The main aim of this field day was to educate and inform pupils in the school about the importance of trees towards sustaining human livelihoods and the role of trees in the ecosystem. Mr Klaine mentioned that the field day also targeted practical demonstrations and participation of school pupils on the planting

of seedlings in the rangeland surrounding their communities. After introducing and giving a detailed discussion (in simple terms for the pupils to understand) about the role of trees and shrubs for ecosystem service provision and their role in rehabilitating degraded ecosystems, booklets with information describing how humans should sustainably use trees for a better tomorrow were distributed to the pupils. These booklets were describing trees and their benefit in simple terms, understandable to primary school pupils. The process of transplanting seedlings was then described to the pupils who then went on to participate in the seedling transplanting and watering in nearby rangelands. After transplanting, students then watered the seedlings to boost their survival. In total, the pupils transplanted 120 shrub seedlings. With the cooperation of the primary school teacher present during the field day, it was agreed that pupils would maintain the seedlings, mainly through watering during certain periods after school. To motivate pupils, incentives were offered to them so that they participated fully while also committing to taking care of the seedlings detailed report can be found here.

Figure 23. Participation of pupils in the Chahda Primary School field day in Sbaihia pilot site, Tunisia (April 2018)

## Field visit: Visit of the FAO Forestry Officer to the pilot site

The Food and Agriculture Organization of the U.N (FAO) Forestry Officer, Mr. Abdel Hamied Hamid, concluded two days visit to Tunis, during which he held meetings with Government and development partners and travelled to FAO- Sustainable Silvopastoral Restoration to Promote Ecosystem Services in Tunisia project site to get first-hand experience of the activities and progress related to this project (Figure 24). A roundtable meeting was also held in the Directorate-General for Forestry (DGF) with participation of Mr. Salem Trigui (Director General of DGF), Mr. Jamel Kailene (Director General of Forestry), and Dr. Mounir Louhaichi (ICARDA representative) to exchange impressions about the development challenges of the FAO Project. The following day, the FAO Forestry Officer visited the Sbaihia site to evaluate the progress made during the first four months of the project and discuss the future workplan. During his visit, he also met with the local authority representing the Ministry of Agriculture

in Zaghouan. The community members were able to discuss the various challenges they face regarding the status of the rangelands surrounding their communities. During the discussion, community members also expressed enthusiasm and hope that the pilot site/initiative in Sbaihia will also yield more initiatives similar to the current one for their benefit, because their livelihoods depend on the healthy status of the rangelands. Mr. Abdelhamid was then taken on a tour to the pilot site, where he was shown the progress made in the project. The visit by Mr. Abdelhamid was beneficial for the pilot operation team, because Mr. Abdelhamid was able to give his opinion and valuable feedback on where the site operation team could improve their activities to improve the overall impact of the project. The report on this visit is available online.

Figure 24. Visit of Mr Abdelhamid (FAO Representative) to Sbaihia pilot site, Tunisia (May 2018)

## Field day: Rational grazing management (Sbaihia)

A grazing field day was held in Sbaihia Site (Zaghouan) on the 3rd May 2018, attended by 19 participants (Figure 25). Dr. Slim and Mr. Kailene highlighted that the objectives of the field day were to inform the Sbaihia community about the importance of sustainably grazing rangelands as well as the ecological relationships within grazing systems. Dr. Slim and Mr. Kailene further mentioned the need to integrate livestock in the management of rangelands, because they play a pivotal role in seed dispersal and nutrient deposits though their urine and faeces (Bauer and Hoye, 2014). In the pilot site in Sbaihia, the role of adopting a participatory approach involving the local community as well as the research organizations (e.g. ICARDA and the FAO) was also discussed as a critical strategy towards ensuring the community involvement in managing the rangelands. Such a process of engaging the local community to identify and select potential rangeland management approach, based on their indigenous knowledge, also provides an opportunity for community empowerment and reduces the risk of the pilot site in Sbaihia being viewed as irrelevant by the local community.

The community members welcomed this idea and felt that it was necessary to incorporate their opinion in managing developmental initiatives in their region as they need empowerment to sustain their livelihoods. During the discussion, Dr. Slim also proposed that animals in the site should not exceed 400 animals, while grazing/browsing in the pilot site should not exceed a period of 30-days. This was suggested to ensure that vegetation is given enough time to recover from the herbivory. The importance of formulating a rotational grazing scheme to improve the management of communal rangelands was also discussed. The community members were encouraged to avoid letting the livestock graze in the

protected planted area as well as the experimental plot, because vegetation in these areas was still not well developed. After the discussion, the participants were then taken on a tour to the planted area and experimental site.

Figure 25. The participants in the grazing field day in Sbaihia pilot site, Tunisia (May 2018)

## Training workshop: Participatory approach, local development and basic organizations

A five-day training workshop (7-12 May 2018) was organized within the framework of the collaboration between the DGF (Forestry General Directorate/ Ministry of Agriculture Water Resources and Fisheries, Tunisia) and ICARDA (Figure 26). This workshop focused on appropriation and application of a participatory approach and targeted 25 participants (including 6 females) from General Directorate of Forestry (DGF) in addition to representatives of the Office of Grazing and Livestock (OEP), the Research Institute in Rural Engineering, Water and Forests (INGREF) and the Integrated Landscape Management Project Management Unit (UGO) as key technical partners. The training workshop was divided into theoretical and practical sessions conducted in groups on topics related to real study cases as the participants were brought to share their acquired knowledge and their respective experiences during groups' sessions. On Thursday, May 10 a field visit was organized to the Ouled Sbaihia site. It consisted of a practical exercise where participants were asked to practice group moderation (data collection and analysis of the functioning of the CBO with discussions of development perspectives). The program consisted of two sessions:

1. The first session involved explaining to the participants the role of the project in the Sbaihia community and the potential future benefits of the project towards improving the livelihoods of the local community. This exercise was moderated by Dr. Slim, who also answered questions regarding the expectations of the community members regarding improving their livelihoods or sustaining themselves.
2. A second exercise was carried out with the CBO to clarify the functioning of CBO and its role in the project site development and management.
   More information can be found in the workshop report.

Figure 26. Participants in the field exercise on participatory approach, local development and basic organizations in Sbaihia pilot site, Tunisia (May 2018)

## Training Course on soil and water conservation

The training day on water and soil conservation was organized on the 5th of July 2018 at Vincci Flora Park Hotel (Hammamet – Tunisia) and attended by 20 participants (Figure 27). This training was facilitated by Mr Jamel (Director- Directorate General of Forestry) who introduced the main objectives of the training to highlight the importance of water and soil conservation in improving pastoral rangelands. Mr. Bechir Tarchi (Director- CRDA Zaghouan) presented the main water and soil conservation activities in the project site in Zaghouan and the expected environmental improvement that will result from this intervention. Dr Slim Slim (ESA Mateur) presented the main advantages of sulla cultivation to improve rangelands, enhance the soil quality and provide feed for animals. All the participants were invited to see the intervention in the project site. More details can be found in the field day report.


Figure 27. Participants during the training course on water and soil conservation in Hammamet, Tunisia (July 2018)

## Workshop: National tree festival

Within the activities of the week of the forest, the celebration of the National Day of the tree for the year 2018 was conducted on 13 November 2018 at the National Institute of Agricultural Sciences in Tunisia, where a national forum on the partnership was held to support forestry and pastoral activities (Figure 28). About 80 participants from the various concerned departments and institutions attended the forum including representatives of: The Food and Agriculture Organization of the United Nations, the German International Cooperation Agency, and ICARDA in addition to representatives of associations and non-governmental organizations. The workshop program included four interventions: supporting

urban afforestation, Program and the agreement between the General Directorate of Forests and the Tunis Dream Cooperative; Forests sustainability; and support the forest farming: Analysis of the value chain of the Carob tree system. The tree festival day followed by exhibition of different tree/shrub species and products to stimulate the interest of different participants, so that they would adopt planting multipurpose trees/shrubs. More information in the workshop report.

Figure 28. Participants during the National Tree Festival in Tunisia (November 2018)

## Training Course: Rangelands plant terminology and basic plant identification

The training course was held between 11-14 December 2018 to develop and improve the capabilities of 32 engineers and technicians in the Office of Livestock and Pasture (OEP, Tunisia) and other governmental departments/Universities on the identification and classification of rangeland plants (Figure 29). The course targeted conducting field surveys and statistical analyses to identify plant species and the vegetation communities they belong to. The training course was designed to include the scientific basis of plant classification, rangeland biodiversity, presentation and characterization of the most important pastoral plants in Tunisia's rangelands. The course also included rangeland plant collection and conservation, and the different methods of identifying vegetation communities based on field measurements and statistical analysis. The participants representing several institutions: technical staff from the Office de l'Elevage de des Pâturages (OEP), graduate students from the Ecole Supérieure d'Agriculture de Mateur (ESA Mateur), Commissariat Régional de Développement Agricole (CRDA), Direction Générale de la Pêche et de l'Aquaculture (DGPA) and La Banque Nationale des Gènes (BNG). This course included one field trip where participants, collected samples and practiced the steps of plant identification. During this course, participants agreed to start establishing an herbarium for the Tunisian flora in each region, prepare a simple manual to help the technical staff who are interested in plant identification and to also prepare a manual covering different techniques for rangeland inventorying. This manual will help technical staff to perform their work properly and to improve the accuracy of the data collected by staff and preparing a digital herbarium of

Tunisian flora, initially focusing in Tataouine, Southern Tunisia. The details about this training, agenda, outcomes and discussion is provided in the training report.


Figure 29. Participants during the plant identification course held in Hammamet, Tunisia (December 2018)

## Field visit to the ESAM: Livestock and forage production

A farmers training day was organized on the 13th of February 2019 at Higher School of Agriculture of Mateur (Mateur – Tunisia) (Figure 30). The training of 24 farmers was facilitated by Dr. Slim Slim (Director of Studies and Internships - Higher School of Agriculture of Mateur). Dr. Slim introduced the objective of the training as to educate participants about the different components and activities of Higher School of Agriculture of Mateur and the role of the educational farm of animal production and crop production. Participants had the opportunity to visit the depot of agricultural machinery and mainly the forage harvesters and the sheep and goat shepherds. A discussion was held about feeding, health care and reproduction for better management to optimize livestock production. Participants then visited the rabbit hutch for general recognition of the new techniques of breeding. Participants were informed about the main advantages of beekeeping to encourage the Oued Sbaihia farmers to practice beekeeping for a better valorization of the space and better income. The process of making silage through fermentation under anaerobic conditions and how this process keeps fresh fodder from decomposing and maintains the nutrient quality, was also explained to the participants. The last stop enabled participants to have the opportunity to see the new varieties of cereals and pulses (pea, oats, wheat, sulla, faba bean, lentils, beet sugar, etc.) and

recognized the importance of using certified varieties. More details are available in the training report.

Figure 30. Participants during the farmers' field day visit to the Higher School of Agriculture of Mateur, Tunisia (February 2019)

## Training workshop: Sustainable management of silvopastoral ecosystems

The workshop was held on the 26th of February 2019 at the National Center of Agriculture Studies in Tunis, where 88 participants attended this workshop, which was opened by Mr TRIGUI Salem (General Director of Forest). He welcomed the participants and introduced the main aim of the workshop, which was to exchange knowledge and experiences in the establishment and management of silvopastoral ecosystems in Tunisia (Figure 31). The workshop was facilitated by Mr Jamel KAILENE (Director- Directorate General of Forestry) and it had four themes as the basis for discussion:

Evolution of forestry and pastoral policies in Tunisia; pastoral ecosystems in Tunisia; rangeland development approaches in Tunisia; and the legal and regulatory framework for management of the silvopastoral ecosystems.

There were fruitful discussions that took place and many recommendations were agreed on. More details can be found in the workshop report.

Figure 31. Participants during the sustainable management of silvopastoral ecosystems, Tunisia (February 2019)

## Student engagement with this pilot study

Six studies were carried out in the pilot project by 6 university students from different higher education institutions in Tunisia:

- 1st study: Prospecting, collecting, identifying and evaluating some local ecotypes of *Hedysarum carnosum* Desf. (PhD student name: Oumaima Ben Romdhane from Institut National Agronomique de Tunis).
- 2nd study: Study of water and soil conservation arrangements in the Sbaihia region, (student name: Rabeb El Mouaddab from the Higher School of Agriculture of Mograne).
- 3rd study: Study of the forage value of the carob tree (student name: Houda from The University of Sciences of Bizerte).
- 4th study: Pastoral improvement of the Sbaihia region using spineless cactus (student name: Fadwa Messoudi, from The INA Tunis).
- 5th study: Evaluation of forest rangeland Improvement in the Sbaihia (student name: Amal Nsairi, from the Higher School of Agriculture of Mateur).
- 6th study: Evaluation of silvopastoral Improvement in the Sbaihia- Region-Zaghouan (student name: Taheni Souf, from the Higher School of Agriculture of Mateur).

## Evaluation workshop: main achievements

A two-day evaluation workshop was held toward the end of March 2019 to present main achievements and agree on a road map on the steps needed to sustain pilot site (Figure 32). The Evaluation Workshop was opened with the welcoming of the participants by Mr Jamel Kailene from the Forestry Department (DGF focal point). The representative of FAO in north Africa introduced the day's activities by highlighting that the aim of such initiatives was to contribute to solutions to eradicate extreme poverty for smallholder farmers. He also noted the collaboration for the pilot site of different partners (public sector associations and farmer organizations) which has been important in improving the success of the pilot site and also presented a short video to the participants. Dr Mounir Louhaichi informed the participants that the project is in its final stages and the work is in progress. He also informed participants that this pilot site would be an example for other places within Tunisia and in the MENA region. He also highlighted how the silvopastoral site has resulted in several social and environments benefits for the local community. The CRDA (Zaghouan) thanked all the partners in the pilot operation for the important work done and he noted the CES and pastoral improvement accomplished in the region of Sbaihia and the successful collaboration with the local population shown throughout the period of implementing the pilot site. During the presentation sessions, Dr Mounir (ICARDA project leader) gave an overview presentation of the silvopastoral pilot project, where he highlighted the project's objectives and its achievements thus far. He also highlighted some of the challenges encountered during the project and possible approaches for dealing with such future challenges. Mr Jamel followed the introduction from Dr Mounir by highlighting the best practices needed when implementing a silvopastoral system. These involve the ideal plant

species to choose, the management of a site once planted and when to possibly implement utilization of ecosystem services within the silvopastoral site. Mr Bechir then presented to workshop participants the best practices for soil and water conservation practices. This involved detailing the soil and water conservation strategies such as constructing gabions and water harvesting structures such as semi-circle bunds and stone bunds. In most cases, Mr Bechir (Head of the water and soil conservation, CRDA Zaghouan) highlighted the need to combine soil and water conservation practices with shrub/tree growing to maximize on the potential of water harvested in the structures. The details about the discussions took place during this day is included in the workshop report.

Figure 32. Participants during the project evaluation workshop on sustainable silvopastoral restoration to promote ecosystem services in Sbaihia pilot site, Tunisia (March 2019)

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## ISI Publications

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Mounir Louhaichi, Jamel Kailene, Serkan Ates, Slim Slim, Mouldi Gamoun, Hloniphani Peter Moyo, Bechir Tarchi, Sawsan Hassan, Oumeima Ben Rhomdhane, Azaiez Ouled Belgacem. 2019. Silvopastoral Systems and Climate Change Mitigation in Central Tunisia. Agroforestry Conference. June 24-27, 2019, Oregon State University in Corvallis, Oregon.

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## SUMMARY TABLE OF PLANNED VERSUS ACCOMPLISHED ACTIVITIES

Table 7. Summary of planned versus accomplished activities related to sustainable silvopastoral restoration to promote ecosystem services

| Activities | Planned | Accomplished | Comments |
|---|---|---|---|
| Inception Workshop | 1 | 100% | |
| Livelihoods characterization and collecting baseline information | | 100% | Survey |
| Implement soil and water conservation practices (water harvesting techniques) | 1 | 400% | 4 gabions and 2 benches |
| Reseeding using native species such as sulla (*Hedysarum coronarium*) | 1 | 200% | Done wherever landscape permits<br>Due to drought in 1st year, we had to reseed 2nd year |
| Selection and transplanting of appropriate shrub and tree species with high nutritive value and palatability | NA | 100% | 5 species were transplanted |
| Preparation of seedlings (nursery) to be transplanted next fall season | NA | 100% | Same as above |
| Rangeland inventorying and monitoring (spring season) | 1 | 100% | For 2nd year because of the project final date (31 March 2019), sampling was done after project end date |
| Capacity development (group training, on the job training, etc.) | 10 events | 150% | 15 events were completed (see Table 4) |
| Preparation of publications, i.e. pamphlets, posters. | 3 | 300% | 1 ISI paper<br>4 Factsheets about silvopastoral species<br>1 Flier about project<br>4 Conference papers |
| Submit quarterly progress reports starting from the date of entry into force of the Agreement | 4 | 100% | |
| Preparation and submission of annual technical and financial reports | 1 | 100% | |

## CHALLENGES MET DURING IMPLEMENTATION

Several challenges were met during the implementation of the projects which were addressed (Table 8).

Table 8. Challenges encountered and solutions

| Challenges faced during implementation | How they were overcome |
|---|---|
| **Starting date of the project:** As indicated in the letter of agreement (LOA) the signature date was 21 November 2017. The memorandum of agreement (MOA) with the Tunisian partner (DGF) was signed on 15 March 2018. This delay hindered optimum start of the field activities knowing that the rainy season starts in Sept/Oct in Tunisia. Under the condition of Zaghouan governorate, sulla should be planted no later than November to take advantage of the early rain. | Used another source of funding "CGIAR Research Program (CRP) on Livestock" to initiate project activities (inception workshop, capacity development, acquisition of seeds and reseeding of sulla). |
| **Severe drought** in the first year (2017/2018): The rainfall recorded represented only 60% of the long-term average. The drought condition was disappointing as it negatively impacted the germination, establishment and growth of the planted species. | Selected drought tolerant shrub and tree species. In addition, we had to irrigate during the summer season.<br>For the sulla we had to reseed in year 2. |
| **Low budget and costly water and soil conservation interventions** (gabions and benches) | Rely on national budget to cover real cost of soil and water conservation (CES) |
| **Low capacity**: the concept of silvopastoral production system is new to the local authorities and community. | Increase awareness of key stakeholders. Over 10 events were conducted over the course of the project. |
| **Lack of integration and trust** among various departments and stakeholders. | Succeeded in creating a friendly environment where concerned departments worked together for the first time. |
| **Ending date of the project** on 31 March 2019 did not allow to assess real impact of the project as the peak standing crop is during spring (April/May). | The project activities will continue including maintenance of plantations (irrigation and replacement of missing). |
| **Short project lifetime**: Any restoration of degraded ecosystems takes time. So, it is difficult to show impact in an 18$^{th}$ months project especially when the site is so degraded and the 1$^{st}$ year was dry. | The project monitoring and evaluation will continue using available resources while seeking additional funds. |
| **Lack of effective community** (CBO). This is a key element for the sustainability of the pilot site. | Plans are underway to create a new CBO responsible for the sustainable management of the pilot site in collaboration with concerned departments from the MOAg. |

## RECOMMENDATIONS AND FUTURE PROSPECTS

With the increasing human population and effects of climate change putting pressure on natural resources, their management requires a wide range of radical reforms, chief amongst them the granting of a considerable degree of local discretion over environmental decision making and a degree of competence, confidence and political sophistication by local institutions With reference to the pilot site in Sbaihia, it is important to establish a community-based organization (CBO) which will closely monitor and manage the site and protect its continued supply of ecosystem and environmental services. The CBO will establish the productivity of the site through monitoring the carrying capacity before implementing grazing. The CBO will also establish a payment for ecosystem services for community people intending to graze their livestock on site, which will contribute towards maintaining this site. Incorporating the participation of the local community will ensure that management of the area represents indigenous knowledge that has evolved over time, is based on local experience, uses local resources and is adapted to local conditions.

Restoration of degraded silvopastoral landscape is a long-term commitment and cannot be accomplished during an 18 months project. It is true also that donors or international organization cannot support these efforts in the long run. However, given the promising results achieved in a relatively short term, it was clear that the national programs (Forestry, Water and Soil Conservation) related to the Ministry of Agriculture are keen not only to maintain this site but also to replicate this experience in similar silvopastoral systems in Tunisia.

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