Progress Highlights

January 2022 – August 2022

ICARDA

Science for resilient livelihoods in dry areas

Soil Protection and Rehabilitation of Degraded Soil for Food Security – ProSol

Towards the Effective Scaling of Soil and Water Conservation Technologies under Different Agroecosystems in North and Central West Tunisia – SWC@Scale

Photo Credit: ICARDA/Zied Idoudi

This document reports the progress and highlights for the period January 2022 to August 2022 of the SWC@Scale Project. It provides information on the various activities undertaken during the mentioned period.

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Background

The objective of this project agreement is to inform the ProSol project (led by DGACTA – Tunisian Ministry of Agriculture, Hydraulic Resources and Fisheries, and the GIZ) on the best scaling pathways for enhanced Soil and Water Conservation technologies (SWCT) through a set of research and "research for development" activities.

The project is expected to mainstream existing conceptual and practical knowledge to support the effective implementation of the ProSol program and provide additional practical guidance to ACTA 2050 strategy. Specific objectives include: i) generating scientific measures and evidence on the benefits of selected SWCT; ii) co-developing and designing a practical and comprehensive scaling approach of SWCT that can fit in the PADIT structure; iii) implementing the scaling approach in the priority areas defined by the DGACTA for a subset of SWCTs promoted by the ProSol program; iv) developing an impact assessment framework compatible with the type of SWCT being implemented; and finally v) Capacity development.

The project combines research, research for development, monitoring and evaluation, and capacity development interventions into four components with a set of specific activities developed under each of them.

In addition to creating local adoption dynamics of enhanced soil and water conservation practices in the sites where the project will be implemented, and to the other indirect outcomes such as the enhanced social networking and learning in these locations and beyond, this project further intends to achieve the following target outputs:

- A tested methodological guide for developing scaling road maps and activities will be validated and documented for wider use by the ProSol program and other related projects,
- A simple tool for identifying scaling readiness and scaling road map will be provided for wider use at local level,

- One SWCT innovation platforms is installed, functional, and self-sustained; and another IP is converted into enhanced knowledge hub thus contributing to the self-sustainable scaling of SWCT,
- At least 750 farmers and 100 extension agents (public and private) will be directly reached through project activities until the end of the project,
- At least 10,000 farmers are reached indirectly through farmer-to-farmer extension and media (fb, SMS, videos, etc),
- 30% of the reached farmers have adopted the technology until the end of the project,
- At least 35% of project beneficiaries are women and youth,
- At least 100 engineers and private leader farmers successfully followed the ICARDA/ProSOL e-learning modules and get their online certificates,
- At least 1,500 ha of degraded land will be restored,

Progress & Performance

The SWC@Scale Project has concentrated its efforts and investments in two different sites, which are Siliana, Northwest Tunisia (for the Cereal-based farming system) and Central West Tunisia at the governorate of "Kairouan" (for the Olive-livestock farming system) Tunisia. The intervention approach was based in the co-design of a sociotechnical bundle of innovations suitable and appropriate for the production systems in place. Such a bundle of innovations would ensure synergies between long-term objectives of soil and water conservation, and short-term objective of farmers related to the profitability of the innovations to be adopted. In both project sites, the implementing period from January to August 2022" was marked by the rapid implementation of the scaling road maps for both targeted agricultural farming systems. These road maps were co-developed with national and local partners including farmers' cooperatives and representatives of rural communities in both sites at the end of the Year 2021. The reporting period was also devoted to strengthening the already established scaling and knowledge hubs at the community level, which will be an important participatory co-designing and co-learning platform needed for better appropriation of the project innovations after its closure (Mars 2023). Sections of this report will reflect on the progress made from this perspective. In the next sections of this report, we report the progress of the project for each planned activity under each of the project components. The project performance can be assessed by comparing what was achieved against what was planned as described in the approved initial project proposal.

During this third reporting semester of the project (which also corresponds to the second part of the first cropping season 2021-22), the project resources were mostly devoted to:

- Support and sustain the created knowledge hubs (KH) with the aim to provide farmers with an understanding of the key context-specific evidence and knowledge associated with the implemented "Integrated Soil-Friendly Sociotechnical Package" – (Assuming that collective actions and investments improve farmer capacity to access and adopt SWCT, and encourage them to lead the piloting of the implemented innovations,
- Continuous on-farm experimentation for finetuning SWCT, this includes:
  I. Assessing the impact of the SWC practices promoted within the project on water use efficiency , soil fertility and erosion at farm and landscape levels, and on improving productivity in different agroecosystems (cereal and olive farming systems). This includes the monitoring of experimental plots, the analysis and development of a database on selected environmental indicators and economic evaluation of these SWC practices. This will generate scientific evidence about their short-term economic benefits in comparison to other conventional systems.
  II. Testing appropriate forage species and mixtures under the different context of cereal and olive-based farming systems and assessing their performances and implications on the livestock system's component.
- Organizing communities into associations which can support collective action and adoption of the soil-related innovations to be introduced (case of Rhahla community, Siliana) and proceeding with in-depth inventory of administrative and organizational capacities of local communities (and associations in place) thus leading to the co-development of an empowerment strategy of these associations aiming at enhancing the membership and representativeness of the existing cooperatives in the selected sites/communities.
- Trainings and capacity development of local extension agents and leader farmers, with the purpose of enhancing self-sustained extension services locally,
- Introducing affordable and context-adapted machines for improving livestock and crop production efficiency and for developing local seeds systems
- Increasing the Focus on Gender Inclusion and Women participation to the ProSol project,
- Undertaking synthesis of lessons learned and documenting outputs from the demonstrations into knowledge products which can be used as science-based evidence for extension as well as for policy dialogues.

Intervention Landscape at El Rhahla Site, Gaafour – Siliana, 2021

Stakeholder Engagement: Together as One

In both SWC@Scale target sites (Kairouan and Siliana), many meetings, workshops, field days, and trainings were organized during the season 2021-22 to secure stakeholder engagement at both national and regional levels. Capacity development events were held to better expose all stakeholders to the concepts of participatory co-design of Integrated soil-friendly sociotechnical package for system transformation. Different national partners have been engaged and participated in the different phases of the project. These include IRESA institutions, such as INRAT and INRGREF (which also received funds for the implementation of some research activities), and other local, regional, and national development institutions such as: DGACTA, OEP and their regional departments (Siliana, Kef, Kairouan), CRDA-s Siliana & Kef, ESAK, CTPTA, and Farmers associations – mainly, SMSA-s Ankoud Al Khaier & Ettaouen in Siliana district, GDA Seres in Kef, and GDA El Khol in Kairouan. The second part of the 2021-22 cropping season was also much focusing on strengthening social networks of local communities (knowledge hubs and platforms) through a set of networking events aiming at connecting these hubs with wider local and regional, research and development stakeholders including private enterprises and local manufacturers with a converging mission and interest – especially in the fields of forage production (Cotugrain) and feed processing small-scale mechanization (Jouhaina society, SFEMI enterprise, Ettayech Society).The objective was to also build local partnerships and enhance the social portfolio of local farmers with proximate development (public and private) actors, which can be of great utility to the communities after the end of the project.

Stakeholders' engagement was also structured around the sociotechnical packages developed and promoted locally in both project locations. For each of the innovations composing the promoted packages, there was a need to involve different partners either for training activities, co-design and manufacturing of machines, experimentation on SWCT, farm seeds production, animal feeding, etc.

Three types of private actors (seed production, seed cleaning and treatment, feed processing) were engaged in the SWC@Scale / ProSol project, and the reason is to enhance farmers networks with relevant private input and services suppliers currently operating in the market and who can be relevant for the type of mixed crop-livestock innovations needed in our sites.

Robust Bundle of Innovations & Dual Entry Points for System Transformation

Defining Trade-Offs for R4D Projects

Tradeoffs occur when resources are limited and when their usage/allocation between different purposes need prioritization. Given that most of natural resources are managed at different levels (farm to landscape), stakeholders involved in decision making about resource allocation would be many and their priorities are sometime different and conflictual (resource conservation vs productivity; short term profit vs long term resource restoration, etc.).

Consequently, compromises, about resource use and allocation, which satisfies all actors were needed. This is the typical case for soil resources for example, where farmers are looking at the soil as a support for their crop and livestock production (and short-term income generation – or production cost reduction), while it also has to be treated as a resource essential for food security which needs to be preserved (and restored) for future generation.

Dealing with tradeoffs in R4D projects needs careful consideration of priorities for key influencing actors, and the development of tailored solutions (innovations/practices/packages) which tackles of most of these priorities. This can be done through:

- Either promoting a single practice which is proved to have positive short- and long-term impacts and both environmental and economic benefits, at the same time (it satisfies two or more conflictual objectives at the same time); or
- Develop a tailored package of **COMPLEMENTARY** innovations, which are co-designed (fit into a system perspective) and carefully sequenced over time, in such a way that all stakeholders objectives will be met in a compromised and economically and environmentally efficient way.

For both El Rhahla and El Khol sites, the effort of the PROSOL team was devoted to identifying solutions (or set of solutions) which satisfies more than a single objective (or priority) at a time. This takes us to the discussion of a new concept advanced in this study, on identification and use of “Dual (multi) entry points” approaches for tackling tradeoffs in complex socioecological systems.

Principles for Soil-Oriented Sociotechnical Bundles of Innovation: The Concept Of "Dual-Entry Points"

The design of the relevant "sociotechnical" bundle of innovations to be introduced in the study area was made based on an in-depth diagnostic of the existing socioecological systems components (and practices), technical and institutional constraints, and farmers expectations and preferences in terms of system transformation. To that we added experts' opinion and diagnostic of the whole landscape degradation hotspots, and suggestions for feasible solutions (possible practices which could contribute to reduce soil degradation in our case). Given that we are operating in a R4D perspective, some of the suggested innovations (to be considered among the final innovation package to be introduced in each region) were planned to be tested and piloted in local conditions. Many field visits, focus groups discussions and meetings with communities were organized to collect the data needed for this diagnostic. A separate farm survey was also done with a set of **65 farmers** from both regions, to provide better insights and statistics about the agricultural production systems in place.

Based on the previous diagnostic, the project team identified two entry points – social & biophysical entry points as suggested in **Figure 1** which may contribute to sustain the scaling and adoption of the innovations packages to be suggested (and piloted in Year-I). This "entry points" perspective led to the development of three packaging criteria, which are at the basis of our system intervention (and package design): **i)** First criteria is related to the "motivation and engagement of private farmers to the suggested innovations", this suggests that our practices and innovations need to be flexible, affordable, and feasible from farmers perspective, and thus ensure satisfaction of short term interests (benefit) of these important actors; **ii)** the second criteria refers to the need for the suggested practices (to be bundled), to have positive (short or long term) environmental impacts; and **iii)** a third packaging criteria is that "innovations suggested as relevant for both entry points have to be meaningful and complementary once packaged together" (complement each other).

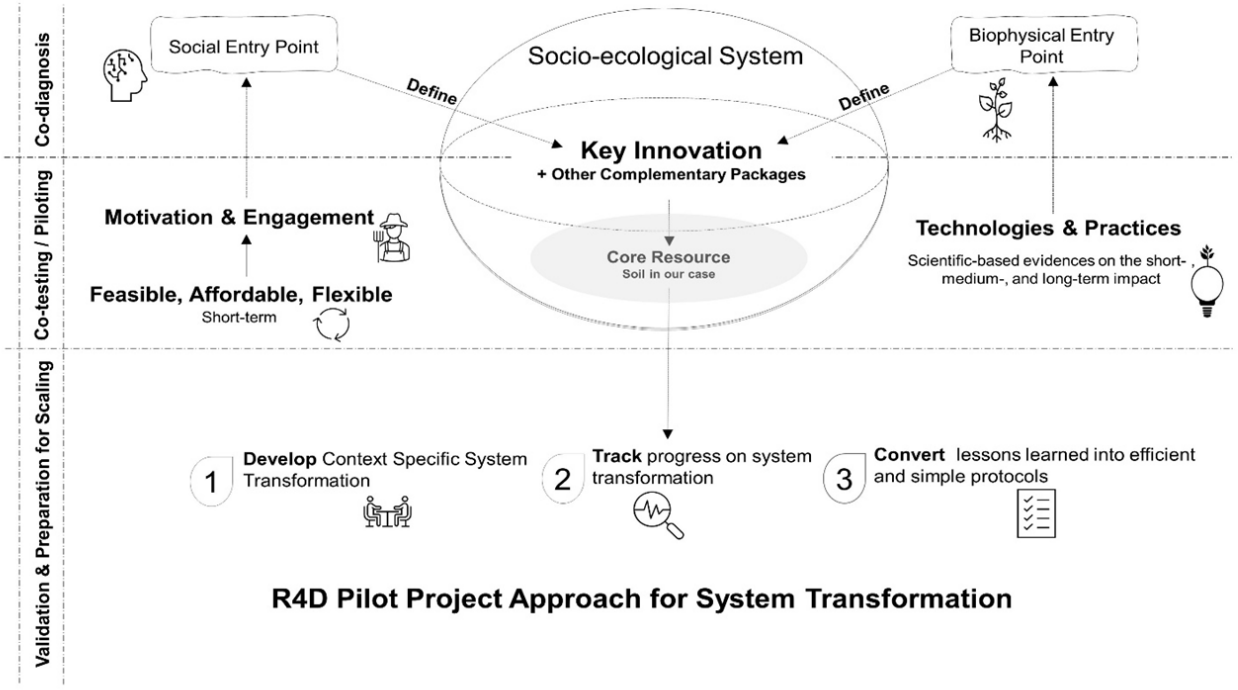

Figure 1. Dual entry point principle and criteria for the design of (context specific) soil friendly sociotechnical bundle of innovations – Frija A., & Idoudi Z., 2022

Scaling road map for agroecological innovations needs to consider a set of principles in order to be effectively implemented and successful. In this SWC@Scale / PROSOL project, we considered a set of principles **(Figure 2)** to practically tackle tradeoffs related to the piloting and scaling of the SWCT in coherence with the scaling road maps that were already co-developed with communities. and partners:

- To proper define your **entry points** for socioecological transformation and to consider entry points for social and ecological systems, separately,
- **Feasibility** of the innovations to be suggested (packaged) to farmers for adoption and scaling,
- **Flexibility** of interventions where we let farmers decide what is more appropriate for them to adopt from the package we propose,
- To **package** your innovations: a bundle of innovations is more efficient to scale compared to a focus on a single innovation,
- Careful consideration of time **sequencing** of interventions (what comes first what comes next?),
- Build local **partnership** to enhance the social portfolio of local farmers with proximate development (public and private) actors,
- **Capacity Development** task force with focus on local extension leaders (farmers and extensionists), with the purpose of enhancing self-sustained extension services within the communities.

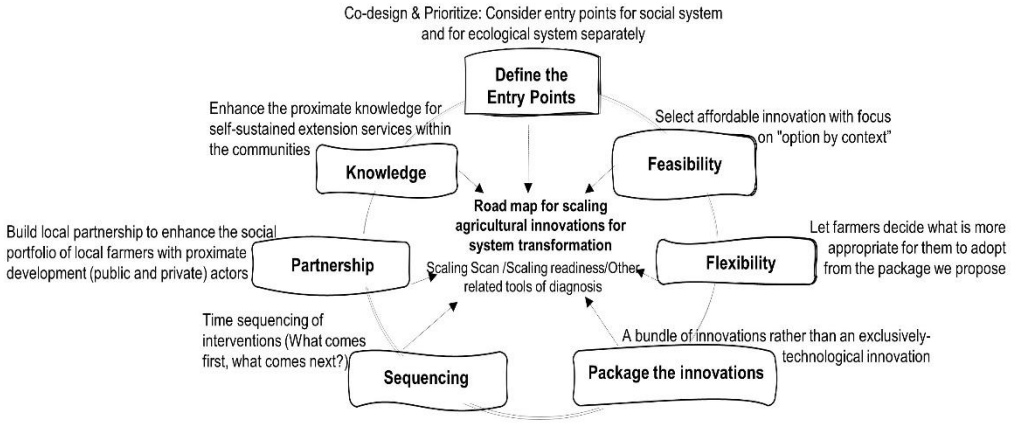

Figure 2. Refinement and Scaling of Agricultural Technologies and Practices – Frija A., & Idoudi Z., 2022

With these criteria in mind and given the need for testing and piloting during the first year of the project, the following "bundle of innovations" has been co-designed and implemented in both project sites:

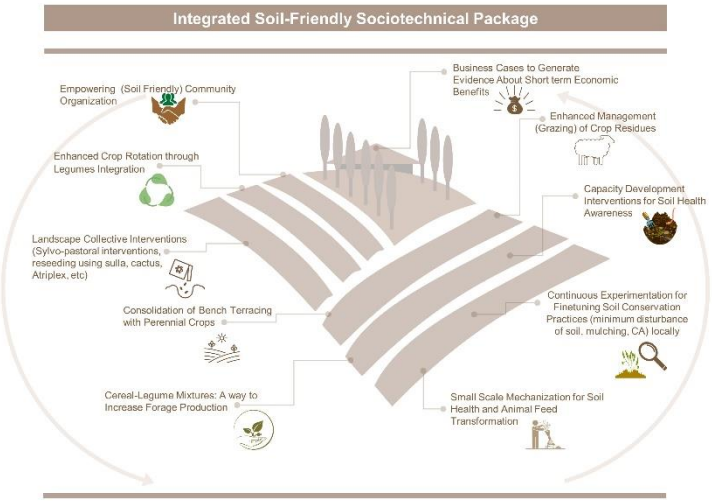

Figure 3. Designed bundle of innovations which was tested and piloted for the case of Rhahla site, Siliana, Northwestern Tunisia
Frija A., & Idoudi Z., 2022

The package includes technical core innovations: crop rotation using forage mixtures and legume forages (given that we are focusing on mixed crop-livestock systems), complemented with small scale mechanization for soil health and animal feed transformation (to manage biomass abundance during pick seasons and produce feeding stocks), consolidation of bench terracing with perennial crops (using Sulla), landscape collective interventions (reseeding using Sulla, etc.), enhanced grazing practices of crop residues and new crops introduced in the rotation. To these technical interventions we also planned for two complementary social and organizational innovations. These includes organization of local communities into farmers cooperatives and enhancing the collective investments of the community farmers into joint productive assets.

Given the fact that some of the suggested innovations are new to the studied regions, we therefore complemented our interventions with a set of demonstration plots in addition to capacity development activities and trainings to the community farmers and their proximity extension agents. All of the above suggested interventions were packaged and sequenced, as illustrated in **Figure 3**. For the case of Rhahla and El Khol sites, most of the above innovations were implemented, and the remaining ones will follow this season 2022-23, including seeds cleaning, pellet production etc.

A Focus on Organizational Innovations and Knowledge Management Investments: Consolidating Local Knowledge Hubs (KH)

Knowledge Hubs have been created in El Rhahla, Siliana according to the guidelines previously published by Frija & Idoudi., 2020. Some investments in basic infrastructure, community organizations (assistance to create a formal cooperative), and trainings (on key soil and agroecological practices, object of our sociotechnical bundle) were provided. In the site of Rhahla, Siliana, demonstrations and experiments were installed and have been used to enhance the demand for the promoted technologies. This was so far successful in terms of raising farmers interest and demand for these soil and water conservation practices. Furthermore, a sub-set of leader farmers is now very well trained on the key soil and water conservation practices introduced to the region and are already playing a good role in extension locally.

The SMSA of Rhahla obtained now different certifications and authorizations needed to be able to trade feed and fertilizers (which was not easy at all and needed a significant help from the ProSol project). Next steps of empowerment of this OPA are as follows:

- Training on collective use of the donated equipment, especially for seed cleaning, feed manufacturing, and biomass grinding and use. Some early trainings on the seed cleaning machines started already for vetch seeds,
- Support the SMSA in creating innovative contractual arrangements with its farmers for the production of good quality forage and legume seeds,

- Link the SMSA with private companies purchasing forage seeds in bulk,
- Link the SMSA with wholesale input providers,
- Enhance the rate of adherence and membership of local communities to the SMSA (encourage farmers from neighboring areas to adhere to the SMSA),
- Enhance women participation and membership to the SMSA,
- Create a women farmers GDA in the region to support women trainings, investments (micro-crédits) and income generating activities,
- Production of good quality of forage and legume seeds.

In El Khol region, Kairouan, the situation was complicated: the GDA had already been created and was operational. The GDA has been playing a crucial role in irrigation water management, particularly for the management of water from a mountainous artificial lake. However, the GDA was suffering from deep structural problems, including level of farmers education, level of participation in collective actions, rigid (top-down) hierarchy, etc. Similar investments were made in the GDA of El khol as in SMSA Rhahla, but some elements of the sociotechnical bundle of innovations implemented was not very successful, particularly the cultivation of Sulla, which did not give good results. A report from the forage agronomist of the project will provide a detailed technical reason for this failure. The most successful innovation introduced was the cultivation of forage mixtures in alley cropping, between lines of olive trees. Results were very good (in terms of biomass and yield), but problems of mechanization for biomass harvesting and conservation emerged and are to be further explored/solved during the season of 2022-23. To conclude, the site of El Khol was supported with some key interventions which certainly have good potential for impact on the farming systems and resources in place, but this site cannot be considered as an advanced knowledge hub yet given the lack of additional investments for human development and training of leader farmers. This is due to the fact that El Khol GDA is far from proximity extension agents and its social connections is very low.

Validate the Established Integrated Soil-Friendly Sociotechnical Bundle for Wider Scaling in Both Agroecosystems

Once the remaining demonstrations and capacity development activities will be finalized, the SWC@scale team will turn to data collection from the field/farmers in order to demonstrate the social, environmental, economic, and institutional impact of the implementation of the co-designed bundles of sociotechnical innovations.

The impact assessment will be mostly focusing on assessing the impact of our intervention on key indicators such as: i) system transformation, ii) resource conservation, iii) sustainability spillovers after the project ending, and iv) level of appropriation of the project investment; technologies adoption; and change of attitudes and perception.

This activity is not yet fully implemented, but early thinking and conceptualization have been initiated. We particularly started thinking about the relevant post-project indicators to be collected and monitored in both project sites.

Early indicators of system transformation – as initially observed in the field, but need stronger confirmation through data collection end of this year 2022 – are as follows:

Resulting Transformation

- Development of contract farming between farmers and their associations,
- Increase of collective investments (due to farmers organization into associations),
- Increased trend towards commercial activities (sheep and beef fattening), due to the increase of forage availability,
- Increased awareness about environmental and soil health through confirmed adoption of (forage) legume rotations (Self production and storage of forage seeds increased),
- Increased exchange of information across communities and with locally empowered extension actors led to increased demand on agricultural innovation,
- Raised interest for restoration of collective grazing areas (with Cactus, Sulla, Atriplex, Carob trees, etc.),
- Increase of women engagement and leadership into the farmers associations (transformation of social norms),

Intervention Landscape at El Rhahla Site, Gaafour – Siliana, 2022

Participatory On-Farm Research

Experimental Plot of durum wheat under conservation agriculture/No-Till – El Rhahala, Siliana/Northeast Tunisia – 2022

Testing Smart Agricultural Practices for Sustainable Management of Natural Resources – Soil & Water

Context

Soil degradation and water scarcity are the main challenges of the cereal & olive-based farming systems in the semi-arid and arid regions. In Tunisia, the problem of soil erosion is more pronounced in the northern and central parts of the country given the frequent slopes in the landscapes. It is reported that out of approximately 3 million hectares, 1.5 million are severely affected by a strong to average soil erosion (Kefi et al., 2012). Conventional renewable water resources in Tunisia are estimated to be around 359 m^3 per habitant-year in 2020. Out of 36 billion m^3 of total water per year received on the Tunisian territory, around 11 billion m^3 are stored, annually in different soils, forests, and rangelands. This type of water (also called green water) is usually lost by evaporation due to intensive soil tillage for crop production, which then results in very low Water Use Efficiencies (WUE).

Context-Specific smart agricultural practices such as reduced tillage, residue cover, and proper rotation helps to minimize soil loss, improve soil health, and enhance WUE. Crop rotations based on crop diversification and Conservation Agriculture (CA) systems are considered as promising options to enhance crop production and preserve natural resources, especially soil and water. In term of agronomic aspects, forage mixtures (Vetch*Triticale) are considered as good option for diversifying crop rotations and increasing cereal production and improve the integration of livestock mainly composed of small ruminants.

With regards to environment aspects, especially soil degradation due to water erosion, CA based on no-tillage (No-Till) and/or minimum tillage (Min-Till) appears as an alternative to conventional tillage (CT) for limiting soil degradation and enhancing WUE.

To verify the effect of these practices on agronomic performances of cereal and forage crops, water use efficiency, and soil erosion, participatory on farm experiments were conducted during the cropping season 2021-22 in both project sites: Al Rhahla (Gaafour/Siliana, Cereal-based farming System) and Oued EL Gsab/Sod El Gorri (Oueslatia/Kairouan, Olive-based production system), respectively. Main Results are illustrated in **Table 1**. Data, protocols, preliminary analysis, and detailed results will be presented in the upcoming annual report (December 2022).

Table 1. Assessment of the effect of reducing tillage on crop yield, water use efficiency (WUE), and soil erosion

Agricultural Production System		Cereal based Farming System (Al Rhahla Experimentation)				Olive based Farming System (Sod El Gorri Experimentation)			
Treatment		CT (Control)	No-Till	Min-Till	%	CT (Control)	No-Till	Min-Till	%
Biological Yield (t ha^{-1})	Oat pure stand	-	-	-	-	1.60	1.77	1.56	10
	Oat with Olive Trees	-	-	-	-	1.35	1.14	1.32	16
	Vetch*Triticale pure stand	-	-	-	-	0.90	1.16	0.79	22
	Vetch*Triticale with Olive Trees	-	-	-	-	1.09	1.45	1.15	25
	Durum Wheat	7.19	8.61	10.28	30	-	-	-	-
Grain Yield (t ha^{-1}) – Durum Wheat		2.48	2.98	3.49	29	-	-	-	-
WUE (kg mm^{-1} ha^{-1})	Oat pure stand	-	-	-	-	5.63	6.22	5.49	9.5
	Oat with Olive Trees	-	-	-	-	4.76	4.00	4.64	2.5
	Durum Wheat – Biological Yield	27.89	33.37	39.86	30	-	-	-	-
	Durum Wheat – Grain Yield	9.60	11.56	13.51	29	-	-	-	-
Soil Loss (t ha^{-1})		4.3	1.4	4.7	67.44	0.5	1.3	0.7	61.53
Runoff Coefficient (%)		4.7	6.4	5.1		14.1	18.6	6.3	4.5

Preliminary Result from Trials

Yield Performance

In Kairouan Governorate, the cropping season 2021-22 is considered as dry especially in the district of Oueslatia (Oued El Gsab Site) where experiment was installed; the seasonal cumulative rainfall was not sufficient (294 mm from the first of September 2021 to the 30th of June 2022) to obtain good yields. Also, rainfall was poorly distributed during the growing season, about 66 % of the rainfall occurred during the mid-season (March 2022) and very little rainfall occurred in early crop growth and late season in this site. Within the olive-based farming system and despite the impact of drought, the biological yield of Oat planted in pure stand was higher (1.77 t ha^{-1}) under No-Till compared to CT (1.6 t ha^{-1}) and Min-till (1.56 t ha^{-1}) – recording around 10% and 12 % increase compared to CT and Min-Till, respectively. Biological yield was determined after crops harvest at maturity stage. For Oat planted between the rows of olive trees, the biological yield was higher under CT treatment (1.35 t ha^{-1}), followed by Min-Till (1.32 t ha^{-1}), and lowest under No-Till (1.14 t ha^{-1}). For the cereal-legume mixture "Vetch-Triticale", the biological yield was higher under No-Till treatment in both comparative plots; "Planted in Pure stand" vs "Planted between the rows of olive trees" – a significant increase of biological yield by 22 % and 32 % was found under No-Till compared to CT and Min-Till, respectively, in the "pure stand" plot. Similarly, the biological yield of vetch triticale cultivated between the rows of olive trees was significantly higher with 25 % under No-Till (1.16 t ha^{-1}) compared to CT (0.93 t ha^{-1}).

Within the Cereal based farming system in Rhahla Site, Governorate of Siliana, participatory on-farm evaluation results showed that biological and grain yields (t ha^{-1}) for cereal crops mainly durum wheat varied across treatments. The biological yield of durum wheat was significantly higher, with around 30 %, under Min-Till (10.28 t ha^{-1}) compared to CT (7.2 t ha^{-1}) and a 16 % increase under Min-Till was recorded compared to No-Till treatment (8.6 t ha^{-1}). The grain yield of durum wheat was 29 % and significantly higher with 14 % under Min-Till (3.48 t ha^{-1}) compared to CT (2.47 t ha^{-1}) and No-Till (2.98 t ha^{-1}), respectively. The grain yields recorded is considered a rather good yield compared to the average yield recorded in the area of Rhahla (0.6 t ha^{-1}) although the cropping season was not favorable given that annual rainfall and its monthly distribution were non favorable for cereal crops in Rhahla site. Results showed also that in addition to the tested SWC practices, adopting integrated improved crop management system is needed to enhance the agronomic performance at landscape level.

Water Use Efficiency

The agronomic evaluation also focused on WUE of cereal crops (durum wheat and Oat). In this context, WUE was determined as: [WUE (kg ha^{-1} mm^{-1}) = grain yield (kg ha^{-1}) / annual rainfall from sowing to harvest (mm)] for WUE grain & [WUE (kg ha^{-1} mm^{-1}) = biological yield (kg ha^{-1}) / annual rainfall from sowing to harvest (mm)] for WUE-biological yield, and is calculated for all experimental plots under No-Till, CT and Min-Till implemented in the framework of the project in both project sites.

Results of the first year showed that in Oued El Gsab site, Kairouan Governorate the WUE-biological yield is very low under all systems (No-Till, CT, Min-Till) for oat crop. Preliminary promising results suggest a slight improvement of 12 % and 9.5 % under No-Till system (6.22 kg ha^{-1} mm^{-1}) compared to Min-Till (5.49 kg ha^{-1} mm^{-1}) and CT (5.63 kg ha^{-1} mm^{-1}) systems respectively when the crop is cultivated in pure stand. WUE of oat were 4.76 kg ha^{-1} mm^{-1} and 4.64 kg ha^{-1} mm^{-1} and 4.0 kg ha^{-1} mm^{-1} under CT, Min-Till and No-Till systems respectively when it is planted between the rows of olive trees. In Rhahla site, Siliana Governorate, results showed that WUE-biological of durum wheat (kg ha^{-1} mm^{-1}) increased under Min-Till system (39.86 kg ha^{-1} mm^{-1}) by 16 % and 30 % compared to No-Till (33.37 kg mm^{-1} ha^{-1}) and CT (27.89 kg mm^{-1} ha^{-1}) systems. WUE-grain of durum wheat was higher under Min-Till (13.51 kg ha^{-1} mm^{-1}) treatment compared to No-Till (11.56 kg ha^{-1} mm^{-1}) and CT (9.60 kg ha^{-1} mm^{-1}) treatments respectively.

- **Soil Loss**

Soil sampling from Rhahla Site, Siliana – Northwest Tunisia - 2022

To assess the impact of no-tillage (No-Till) and/or minimum tillage (Min-Till) in reducing soil loss compared to conventionally tilled fields (CT), the INRGREF and INRAT team installed two experiments using Wischmeier protocol in both project sites (Al Rhahla, Gaafour – Siliana, Oued El Gsab, Oueslatia – Kairouan) for assessing soil erosion. Nine (9) Wischmeyer plots were installed in each site (three plots under No-Till, three plots under Min-Till, and three plots under CT as control).

In Rhahla site, the amount of soil loss was measured at three (3) different times during the cropping season, i.e., in November, January, and March **(Figure 4)**. The results showed that soil loss due to erosion was reduced by 67.4 % under No-till (1.4 t ha^{-1}) compared to the conventional farmer's practice (4.3 t ha^{-1}). Similarly, In Oued El Gsab Site, soil erosion monitoring was assessed using the same Wischmeier protocol. Two sampling points were recorded. Each sampling point cumulates the erosion process because of the precipitation quantity recorded during the study period. In this site, the reduction rate of soil loss in CT plot compared to No-Till was 61.5 %.

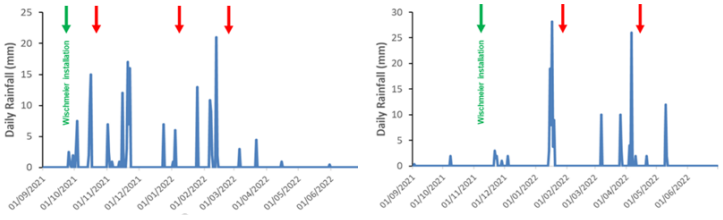

Figure 4. Daily rainfall amount on El Rhahla (left) and Oued El Gsab farms (right). Sampling times are denoted by red arrows

The measurement of soil runoff is measured directly in the field and is expressed by the runoff ratio (%), which is calculated as the ratio between the runoff volume (mm) and the rainfall volume (mm). In Oued Elgsab/Sod El Gorri Site, significant difference in runoff coefficient was observed among the tested treatments: runoff coefficient was higher under No-tillage (+4.5 % than in CT) followed by CT (14 %) and lowest under Min-tillage (**Table 1**). in Rhahla Site, no significant effect of reducing tillage on the runoff coefficient was recorded during this first cropping.

We hence conclude that at the end of the current project in March 2023, results from these two (2) sites related to soil erosion, agronomic performance, and water use efficiency will provide invaluable information to support the assessment of the impact of these smart agricultural practices on natural resources in diverse farming agroecosystems in North and Central West Tunisia. However, it is evident that longer term and repetitive observations are needed to detect differences in reducing soil erosion, enhancing WUE, and boosting productivity.

The established structures (Wischmeyer) to monitor erosion in target sites will also generate data to estimate soil erosion by using plot modeling tools that can be extrapolated to landscape level. A spatial soil erosion simulation at the landscape level (RUSLE) is planned for the upcoming cropping season 2022-23 to assess the impact of the promoted SWC practices using different scenarios on soil loss at the watershed level of Rhahala – covering an area of 2,000 ha.

Performance of Legume and Cereal-Legume Mixture in the Cereal Mono-Cropping Rotation

Vetch-Oat-Triticale plot in El Khol Site, Kairouan – 2022

On-farm Demonstration/Evaluation of Different Forage Combinations

Oat is the commonly grown cereal forage in the project target regions. The nutritional quality of this cereal forage is not sufficient to cover the livestock nutritional requirements, and farmers have to rely on cereal grains and commercial concentrates, hence making livestock enterprise very costly and unsustainable. Mixing cereal with forage legumes is one of the practices for producing high-quality, balanced feed for livestock and may have production, quality, and environmental benefits.

The main advantage of mixtures is higher forage production and quality compared to monoculture, reduced nitrogen inputs and feed cost, and sustaining good soil health.

To upgrade farmers knowledge on annual cereal-legume mixtures, increase the quantity and quality of forage production and enhance soil quality and diversify the crop rotation system, around 80 demo- experimental- and multiplication- plots with a total area of 82.5 hectares were directly implemented by the project thus benefiting 42 farmers in both project locations. During 2021-2022, the project team succeeded to evaluate and validate several possible crop mixtures combinations. A total of 28 on-farm trials were monitored in both sites to evaluate the cultivated mixture combinations under the context of both sites. The evaluated mixtures are as follows:

- **V+O:** Vetch (70 %)+Oat (30 %),
- **V+T:** Vetch (60 %)+Triticale (40 %),
- **V+O+T:** Vetch (70 %)+Triticale (20 %)+Oat (10 %),
- **V+O+T+F:** Vetch (40 %)+Oat (10 %)+Triticale (20 %)+Fenugreek (30 %).

Preliminary results showed that across different sites and farms (**Figure 5**) all forage combinations performed well with average biomass production of 6.22 tons of Dry Matter (DM) per hectare. Forage yields were significantly different between both sites (7 t DM ha^{-1} in Khol site versus 5.3 t DM ha^{-1} in Rhahla). These production levels are relatively high considering bioclimatic conditions of both sites. Among the four combinations of crop mixtures, the combination of V+O+T+F produced higher biomass with an average yield of more than 8.5 t DM ha^{-1} compared to the other mixtures (average 6 t DM ha^{-1}, V+O, V+T and V+O+T). However, the legume proportion in the harvested crop mixture biomass was found to be significantly depending on the type of crop mixture sown. In general, legume percentage in the harvested biomass was as high as 52 % in V+T and then decreased to 38 %, 31% and 6 % for V+O, V+O+T and V+O+T+F, respectively. The legume percentage was higher in Rhahala site compared to el Khol site where the preceding crop was a vegetable; or faba bean.

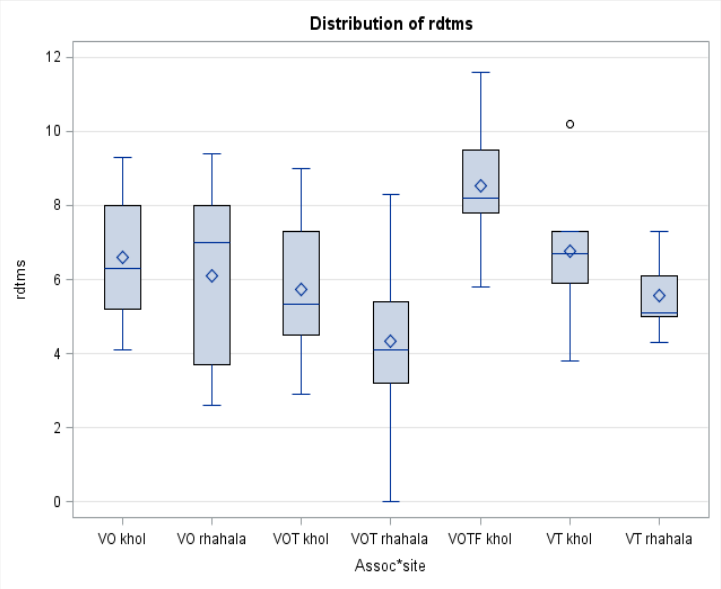

Figure 5. DM Yield distribution for 4 forage mixtures crops in both project sites

(**VO:** Vetch+Oat, **VT:** Vetch+Triticale, **VOT:** Vetch+Oat+Triticale, **VOTF:** Vetch+Oat+Triticale+Fenugreek, **Assoc:** Association (in French language = Mixture in English)

The high soil OM and nitrogen content after vegetables is detrimental to initial legume growth, which exposes them to a strong cereal competition during the spring period. Overall, proportion of weeds remained low (< 13 %) for all on-farm trials suggesting the natural suppressive weed control ability of crop mixtures compared to monocrops. This result will be communicated to different stakeholders such as OEP and the private seed company in Tunisia (COTUGRAIN) for promoting technologies at scale starting in the coming cropping season with the objective to market the forage mixtures validated by the project in both contexts.

Mowing of Forage Associations between the Rows of Olive and Almond Trees in El Khol Site, Kairouan – 2022

Additional participatory on-farm evaluation related to common & narbon vetch and triticale was conducted during 2021-22 cropping season in both project sites and the harvest data is under analysis and will be presented in the next report. The introduction of these monocrops is intended for seed production with the purpose to empower farmers regarding seeds and create sustainable adoption dynamics in the targeted communities . The project team is also planning to monitor and analyze soil nitrogen content induced by the cereal-legume mixtures and evaluate their nutritional value.

An additional livestock related activity was also implemented to measure performance indicators of a flock of sheep which was fattened with forage mixtures (for the Aid period in July 2022). One of the farmers who volunteered his plot for cultivating vetch, was interested to fatten his sheep (designated for Aid) over a period of 2 month using vetch biomass as replacement of concentrates. Body condition scores of the selected sheep to be fattened, as well as their daily growth rates were measured over 2 months. Results are under analysis and will be shared in the next report. This activity aims at demonstrating the benefits of this forage legume on livestock to farmers, in addition to the benefits to soil. It is very important for us to illustrate our recommendations through demonstrations, which are critical for convincing the target farmers and communities.


Sulla inflorescences in El Rhahla Site, Siliana – 2022

Photo Credit: ICARDA/Zied Idoudi

Innovative Rhizobial Inoculants for Sustaining Legume Productivity and Soil Fertility

Sulla (*Hedysarum coronarium L.*) can play a significant role in alleviating poverty for many needy families in some rural areas of Tunisia, where livestock is essential for the livelihood of households and communities. Good agronomic performances of Sulla under marginal and drought-prone environments, and its diversified uses are very promising. After being extensively grown as a 2-year (bi-annual) forage crop, Sulla plots can produce a substantial amount of biomass for either grazing, cut and carry, silage, or even hay production. Sulla is also a high-protein forage crop with low water requirements. In cereal-based systems of semi-arid regions, similar to El Rhahla Site, Sulla can be used to enhance productivity and sustainability of the crop livestock integrated farming system through nitrogen fixation and maintaining soil organic matters. With root depth exceeding two meters and numerous secondary roots, Sulla presents a smart solution for effective biological fixation of sloping land (Louhaichi et al., 2018) to slow down the escalating soil erosion in the region and improve soil health at farm and landscape scale.

Six (06) on-farm participatory field trials covering a total area of 10 hectares were set up on September 2021 in Rhahla site with a sowing rate of 40 kg ha^{-1} aiming at promoting Sulla as a "soft on farm" option for i) Biomass provision to meet livestock dietary needs, to provide soil cover for consolidation of mechanical bench terracing, and to minimize soil disturbance in the sloped plots; ii) Landscape-level restoration of soil by promoting Sulla at the community and scale level in the second year of the project. Research for development activity was undertaken during the season of 2021-22 to i) test and demonstrate the use of bio-stimulants for enhancing Sulla growth in the specific sites of Rhahla and El Khol, while testing possible ways to improving nutrient use efficiency and resistance to abiotic and biotic stresses in the site and ii) increase the dissemination and adoption rate of inoculation practice by using the implemented demonstration plots for training of farmers.

Increase in soil organic matters (SOM), total Nitrogen, assimilable Phosphorus, exchangeable (available) Potassium and biomass productivity and decrease in soil erosion are the major performance indicators targeted by the project. In 2021-22, assessment of those indicators in Sulla plots (in both Siliana and Kairouan) were initiated by INRAT team with the participation of farmers. To assess the chemical and biological properties (variability) of the soil in each on-farm trial (and over time during the cropping season), soil samples from six (06) experimental plots (including plots for control) were collected and analyzed . The chemical and biological properties of soil samples are highly variable as illustrated in **Table 2**. The chemical properties of the soils, i.e., total Nitrogen, assimilable Phosphorus, exchangeable Potassium, are also variable. Similarly, soil organic matter contents are different across the different plots and were found to be very low (< 1 %). With regard to biological properties, a total absence of rhizobia was recorded in all selected plots. This characterization will be used as a baseline to see how inoculation practice of Sulla would help to improve these different characteristics in short- , medium-, and long-term in our specific sites.


Biological Consolidation of Bench Terracing using Sulla, El Rhahla, Siliana - 2022

Photo Credit: ICARDA/Zied Idoudi

Table 2. Chemical and Biological Properties of the studied plots in El Rhahla Site – Siliana District, Tunisia

On-Farm Participatory Plot	Plot	Chemical Properties of the Studied Soils							Biological Properties	
		SOM (%)	Total Nitrogen (%)	Assimilable Phosphorus (ppm)	Exchangeable Potassium (ppm)	Active Limestone (%)	pH	Salinity ($g\ l^{-1}$)	Rhizobia counting/g dry soil	Total bacteria counting/g dry soil
F*-I (8 ha)	F-I1(Control)	0.46	1.28	58.56	130.03	35.50	8.17	0.15	0	$1.9\ 10^5$
	F-I2 (Inoculated)	0.50	1.34	82.53	148.03	32.50	7.98	0.16	$4.6\ 10^4$	$3.8\ 10^5$
F-II (1 ha)	F-II3 (Control)	0.68	1.30	62.00	143.00	34.00	8.50	0.16	0	$1.3\ 10^5$
	F-II4 (Inoculated)	0.70	4.05	84.00	151.00	35.50	8.06	0.15	$1.7\ 10^4$	$2.2\ 10^5$
F-III (1 ha)	F-III5 (Control)	0.59	0.90	75.42	139.00	38.00	8.05	0.16	0	$1.1\ 10^5$
	F-III6 (Inoculated)	0.60	0.97	79.50	144.00	37.50	7.96	0.14	$2.9\ 10^4$	$2.1\ 10^5$

*F: Farmer (we have considered three farmers, where I, II, and III refer to farmers 1, 2, and 3 respectively).

For each on-farm trial, seeds were inoculated with contextually specific rhizobial inoculation (*Rhizobium sullae*) produced at the lab of INRAT based on specific chemical and biological properties of each plot (rhizobia inoculator was produced by mixing appropriate doses of solid inoculants with 200 ml of 1 % (w/v) gum arabic solution (as a sticker) and 40 kg of seeds per hectare). Non-inoculated seeds were planted in neighboring plots with the same sowing rate as control. Preliminary results suggest a slight improvement in total Nitrogen in the three treatments after five months of planting, compared to the controls. A significant improvement of assimilable phosphorus and exchangeable potassium was recorded in all inoculated plots compared to the control ones. The total bacteria content was also the highest under the inoculated plots – recording around 100 % increase compared to the controls.

Plants were harvested 37 to 53 days after inoculation. They were examined for nodulation. The rhizobial strain used had nodulated the sulla plants. The inoculated plants had an abundance of large and widely distributed pink nodules with a dark green color and grew with great vigor. The non-inoculated sulla plants were not nodulated.

To verify the effect of Rhizobial inoculation on the biomass productivity in the different established trials , INRAT team had monitored a set of agronomic parameters to assess the growth levels of Sulla, including i) emergence rate and ii) the growth rate and fresh weight of plants as global indicators of spring growth (end of May). Crop samples were collected at the full flowering spring stage and analyzed in all experimental plots including control (non-inoculated) ones. Results of plant height, stem thickness, vegetative fresh biomass of Sulla at mowing, and plant nitrogen content are shown in Figure 6 below. A significant increase of plant height, stem thickness, vegetative fresh biomass and shoot nitrogen by 40.87 %, 54.74 %, 75.77 % and 41.43 %, respectively, was found in the inoculated plots compared to the control plots (**Figure 6**).

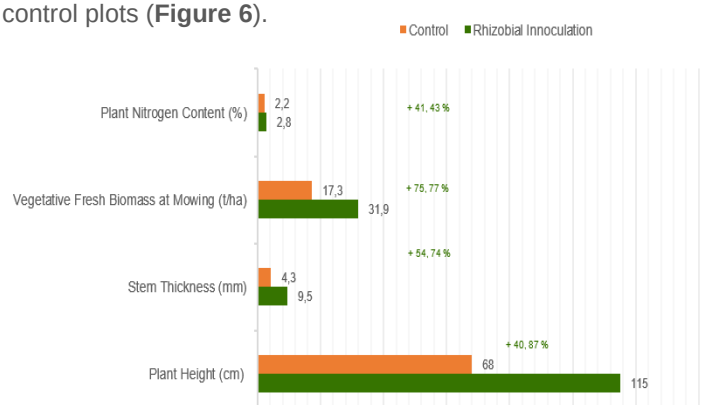

Figure 6. Plant Height (cm), Stem Thickness (mm), Vegetative Fresh Biomass at mowing (t/ha), and Plant Nitrogen Content (%) under Inoculated and Non-inoculated Plots, in Rhahla site, Tunisia

Monitoring of Sulla growth, El Rhahla – Siliana , 2022

Several capacity development events including field days, on the job training and workshops on forage crops and its use for sustainable intensification of mixed farming systems – especially sulla crop and its rhizobial inoculation - were organized in the project sites thus reaching more than **100** farmers, local extension agents, private sectors and young scientists from different research and development institutes such as OEP, CRDA-s Kef, Siliana and Beja, INRAT, INRGREF, ESA-K, DGACTA, INGC, DGPA, ESA-Mograne, etc. in Rhahla site, the on-farm participatory trials were also established as a learning platform where farmers were able to evaluate the technology from seeding to harvesting.

Farmer's attitude towards Sulla and the use of Rhizobial inoculant was positively affected, due to many reasons, but most importantly due to its impact on soil health in terms of nitrogen content (equivalent of 0.7 tons ammonium of nitrate per hectare after two years of Sulla installment).

Biological fixation of Sloping Land Using Sulla, El Rhahla – Siliana , 2022

The honey that is obtained from Sulla is very rich in nutrients, enzymes, and vitamins - El Rhahla – Siliana , 2022

"I have tried Sulla inoculated with bacteria, and I planted 8 ha for my animals, but also for better consolidating my terraces in the slopped plots, and for nitrogen fixation in my land, which is already of low fertility levels. I wanted to show to my neighbor farmers that there is no need to rest your plots as fallow, you can better plant it with Sulla, and then plant your cereal crops barley or wheat, which will be more productive" said Mr. Rzig Rahali president of SMSA Ankoud Al Khaier in El Rhahla Site – Siliana District. "I have a very good production of biomass from Sulla plots now and this is surprising us and making us happy. This plot where I planted Sulla was not even properly producing Barley because my land is not fertile. For me, I can now support 20 to 30 head of sheep with one ha of Sulla in my farm." Rahali added proudly. During this cropping season, the farmer succeeded in harvesting 250 bales of hay per hectare, a quantity that will help him to reduce the feeding costs of his livestock.

"To me, I planted Sulla crop because of its many benefits such as protection against erosion, strengthening the soil (fertility), it's benefits for our bees. We also learned from the project that Sulla would improve the nitrogen content in our soil by keeping the equivalent of 700 Kg of Ammonium of nitrate in one ha of soil after 2 years of cultivation, and that's very important for us to reduce the cost of our fertilization in the following years. After two years of Sulla, you can then cultivate barley, wheat or whatever you need." Explained Mr. Yassine Rahali who acts as the SMSA's Vice-president.

Extension of the Sulla area is now (spontaneously) planned by farmers. ICARDA, INRAT and OEP will continue to support this dynamic especially in Siliana site.

Context-Specific Technical Recommendations for Effective Management of Sulla Crop in Rhahla, Siliana

- The pre-sowing plowing at a depth of 20 to 25 cm and seed bed preparation is very important step for successful plant establishment,
- Avoid sowing sulla seeds at a depth exceeding 2 cm,
- The date of sowing should be between September 15th and October 15th to have an early emergence and avoid low temperatures,
- Respect the sowing rate of 40 kg/ha with an adjustment of the sowing machine after drying the seeds coated by the inoculum,
- It is advisable to apply phosphate fertilizer during soil preparation to ensure a better root growth (based on soil analysis),
- Do not add nitrogen fertilizer that hinders the nitrogen fixation activity of Rhizobia,
- Ensure control of parasitic weeds in January: Select Super / focus Ultra = grass control, Glyphosate = pre-sowing (total herbicide) ; Basagran = 3 leaf stages (broadleaf weeds),
- The first year of the cycle crop, do not graze directly and cut when the plant reaches 40-45 cm,
- To produce seeds in the second year, we recommend direct grazing or cutting in November / December to improve the branching of the buds and increase the number of flowers.

Preserving Rangelands for Communities and Climate

Rangeland Health Assessment of El Khol Site, Kairouan – Central West Tunisia

Intervention Landscape at El Khol Site, Hadjeb Layoun – Kairouan - 2021

In arid and semi-arid areas, rangelands play a vital role and contribute to the livelihood of millions of people worldwide. They offer wide range of service provision such as food security and poverty alleviation – In addition to provide ecological, environmental, and economic functions, rangelands are the main feed resource for traditional livestock systems in many countries of the world.

In Tunisia, more than 33% of the total area is considered as rangeland, mean annual rainfall of less than 200 mm, are now grazed continuously without any restriction. However, the area of natural rangelands has considerably decreased due to continuous degradation caused by, amongst other things, overgrazing and agriculture expansion (Ouled Belgacem and Louhaichi 2013; Gamoun 2014). Historically Central Tunisia, rangelands have contributed significantly to household food security and continue to do so today, along with other agricultural activities such as livestock production. Although the pastoral system has changed to agro-pastoral system and the flock management became more and more independent of rangelands' resources, small farmers are still users of rangelands and will remain so forever, despite their continuous degradation driven by anthropogenic and environmental conditions. To alleviate degradation proper management of rangelands is needed using a combination of sustainable rangeland management practices.

In this context, a field evaluation of the rangeland health of El Khol Site was undertaken early September 2022 by the ICARDA Rangeland Ecology and Forage (REF) team aiming at i) examining the ecological status of rangelands and the spatial patterns of vegetation diversity and ii) providing context-specific recommendations to mitigate and reverse rangeland damage in El Khol landscape, Central Tunisia.

El-Khol site (35°29'07.78"N 9°29'08.71"E) covers about 74 ha. The site is mainly utilized by an agro-pastoral community, which consists of 17 households. Land is mainly used for tree growing, crop cultivation, and livestock grazing (cattle, goat, sheep). The region holds diverse areas and habitats including plains, mountains, lakes, and marshes. The climate is arid, with variable rainfall of approximately 308 mm/year on average.

Soils are silty-clay, clay, and sandy silty, fertile but mostly degraded due to water erosion.

The assessment of the status of the rangeland conditions was conducted based on visual observations that reflect the key indicators of the rangeland health in El Khol area – including plant species composition, spreading/presence of invasive and unpalatable species, homogeneity. In-depth key informant interviews were also conducted with people from the community to better understand the social-ecosystem state and how farmers are using their collective rangeland areas.

Key Finding

Status of rangelands

Depending on the livestock grazing pressure and landscape topography, two Homogenous Vegetation Units (HVU's) were identified in El-Khol site including *Tamarix gallia* community and *Astragalus armatus steppes* describing the status of rangelands were encountered **(Figure 7)**.

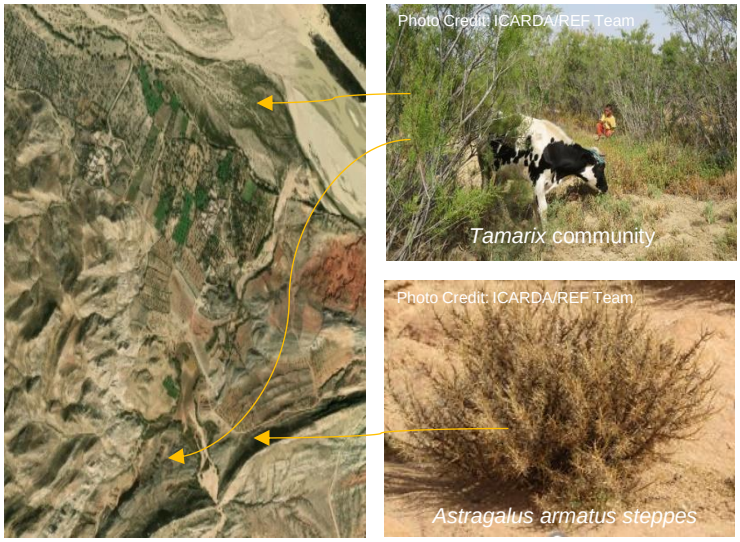

Figure 7. Site Characterization of El Khol – Hajeb Layoun, Kairouan

Mountainous Rangelands

Rangeland was invaded by unpalatable species *Astragalus armatus* due to overgrazing. This species is collected mainly by women then used to burn the spines of Cactus so that animals can eat it, El Khol – Kairouan, 2022

This landscape is dominated by *Astragalus armatus steppes*. This invasive spiny species alone colonizes vast areas. The perennial plant cover "considered as an indicator of rangeland health" has been declining steadily over the last three decades. This results in a large-scale replacement of the native vegetation dominance toward invasive and unpalatable plant species such as *Astragalus armatus* (Jauffret and Visser, 2003). The presence of some tufts of alfa (*Stipa tenacissima*) and some individual species of *Rosmarinus officinalis* is evidence that *Astragalus* has replaced *Stipa tenacissima*.

The biodiversity loss, forage biomass reduction, and soil erosion are the main effects induced by consequence of overgrazing (caused by extensive livestock farming and esparto grass harvesting) has led to the encroachment of unpalatable species and invasive species such as *Astragalus armatus* and *Peganum harmala*.

To mitigate or reverse degradation of these rangelands, the only intervention that took place during the last few decades was cactus pear plantation. Unfortunately, instead of introducing spinless cactus, the spiny cactus was used, and this would add burden on farmers since they cannot feed cladodes directly to their animals. Spiny cactus needs to be burned first to get rid of the spines. In addition, it is not recommended to plant cactus pear over a large area, simply because cactus pear is fed using cut and carry method and cannot be fed alone as it should be mixed with other roughage.

Cactus Pear Plantation, El Khol – Kairouan, 2022

Lowland (Wadi)

Cattle grazing under dense stands of Tamarix gallica where some native vegetations are present, such as Juncus maritimus, El Khol – Kairouan, 2022

The vast salt landscape depressions and Wadis are dominated mostly by *Tamarix gallica* associated with some other species such as *Atriplex halimus*, *Juncus maritimus*, *Halocnemum strobilaceum* and *Aeluropus littoralis*. *Tamarix gallica* is an unpalatable species, but sometimes is grazed by cattle. During our visit, we observed cattle looking for dense stands of Tamarisk where this species is associated with native vegetation is present, such as Juncus maritimus.

Sustainable Rangeland Management Pathway: Recommendations for El Khol Site

The rangelands of El Khol site are characterized by mountainous landscape (steep slope) coupled with continuous grazing; both factors favor the risk of soil erosion especially after heavy rains. To alleviate further degradation of these rangelands, certain management practices are recommended:

- Establishment of water harvesting structures (terraces or contours) to reduce soil erosion and increase the rate of water infiltration.
- Associated with water harvesting techniques, planting species along the contour's lines can offer the best practices to alleviate soil erosion and to insure a superior capacity to capture water, organic matter and sediment. For stabilizing steep slopes, grasses like Stipa tenacissima and Lygeum spartum work quite well within these management practices.
- Well scheduled rangeland resting (protection from grazing) is a cost-effective tool to allow recovery of vegetation.
- Minimize livestock grazing pressure when the soil is wet to maintain the native plant communities such as Stipa tenacissima and Rosmarinus officinalis.
- Introduction of certain rangeland species such as Atriplex halimus
- Cactus pear is a viable option to reduce the pressure on rangelands by providing a rich diet in carbohydrates, water, and vitamins. Therefore, it is recommended to plant spineless cactus pear near the dwellings and at high density. This way the cactus is protected from direct grazing, it is easy to access and for readily available to mix with other feed resources.
- Capacity development, raising awareness, sharing knowledge, and experiences among the various actors are vital to build trust and guaranty long term rehabilitation sustainability.

Key Component of the Sociotechnical Bundle of Innovations: Small Scale Mechanization for Natural Resources Management and Conservation

The objective of small mechanization, as introduced in the innovation packages promoted in both sites, is to complement other key innovations and enhance their efficiency and sustainability. This is the case for grinders and pellet machines, which aims at processing (grinding) the excess of biomass generated from the promoted crop mixtures plots cultivated by farmers and storing them under appropriate pelleting form (using the pellet machines). Sustaining the adoption of legume forage crops and crop mixtures rotations also assumes that farmers have easy and reliable access to seeds in the following seasons. That is where the small machines for cleaning and treating seeds of different crops have been introduced and served so far for treating more than 24 tons of seeds (after only 5 months of being made available to farmers' cooperative in Rhahla, for example). This will enhance the availability of seeds for the member (and non-members beneficiaries) farmers for the next season 2022-23 and will contribute to enhance the sustainability of SWC@Scale-ProSol intervention in the mentioned site.

Overall, the considered KHs in this project have benefited from one seed cleaning and treatment unit, three feed choppers and grinders, two small and one large feed pellet machine. We are expecting about **300 farmers** to benefit this year from these machines (cleaning and treatment of their seeds, grinding of their crop residues, manufacturing, or purchase of animal pellet feed, etc. Farmers associations which benefited from these machines were further trained on proper tools to register and record all beneficiary farmers from these machines. The recording will be used at the end of the cropping season 2022-23 for reporting of additional beneficiaries from our project activities.

In relation to the pellet machines, a socioeconomic study was done by the ICARDA SWC@Scale / ProSol team to assess the costs/benefits of using this type of machine in the Tunisian context. The study was based on previous data (2019-21) collected from previous projects but will provide a string evidence and guidance about the profitability of investing in these machines, either collectively or individually. **Tables 3** and **4** below shows some economic results from five case studies, where the pellet machines were previously donated and being used. The economic and financial calculations reveal that locally made feed pellets have reasonable and encouraging upfront cost of investment. The elaboration of business model for feed pellets machines suggests the potential profitability of investing in this type of machinery within the crop-livestock farming systems.

Farmers being trained on use of mobile grinder and pellet machine, El Khol Site – 2022

Table 3. Feed pellet composition ingredients and formulas, as collected from various users (farmer organizations, development organizations and other private users)

Feed pellet composition ingredients (as suggested by **El** Rhahla farmers, based on possible available ingredients in 2020/2021)	Feed pellet formulas (%) (SMSA Ankoud El Khaier)
Cereal bran (%)	20
Barley grain (%)	30
Maize (corn) (%)	26
Soybeans (%)	20
MVM—mineral-vitamin supplement (%)	4
Total average cost (TND/metric ton)	956.8

Source: SWC@Scale, CLCA, and CRP-Livestock Projects Team—Tunisia (2021).
Note: 1 Tunisian dinar (TND) = 0.32 US$ (average January–August 2022).

Table 4. Locally manufactured feed pellet business plan for the case of SMSA Ankoud El Khaier – economic & financial indicators

Item	Indicators	SMSA Ankoud El Khaier (Large pellet machine)
	Production cost (TND/ton)	965.80
	Production per year (tons)	1200
	Selling price (TND/ton)	Not commercialized Max +4%
Non-Discounted Profitability Criteria	Average net profit (TND/year)	13422.12
	Profitability index (PI) (1 + (net present value / initial investment))	10.43
	Payback period (years)	0.52
	Return on investment (ROI)	37.81%
	Break-even analysis—ROS (Return on sales per dinar invested)	2.30%
Discounted Profitability Criteria	Net present value (TND)	84954.80
	Benefit cost ratio (BCR)	9.43
	Internal rate of return (IRR) (%)	Very high

Source: Own elaboration based on data collected from pellet machine beneficiaries (2022).
Note: Tons are metric tons

In addition to the previous machines, the project team also worked on additional mechanized solutions for seeds sowing, especially in small plots where excessive ploughing is not needed, and where farmers are still sowing with hands. A set of 100 handheld precision seeders were purchased and being distributed to farmers in the project sites and to other national partners (OEP) promoting the up scaling of forage crops in small plots in Tunisia. These seeders are being used by private farmers and detailed report about their use for 2022-23 will be provided in the next project report.

Cleaning and treatment machine, El Rhahla – 2022

Training on the Use of Handheld seeder for OEP staff, Kairouan – 2022

Increasing the Focus on Social Inclusion and Women Empowerment: "Leaving No-one Behind"

To unlock the potential of women and youth in the project, significant efforts were made by ICARDA and NARES teams during the cropping season 2021-22, to reach a target of 35% of women and youth as beneficiaries of our interventions. Several activities were implemented during this cropping season to empower rural women based on their needs and for paving the way for promoting entrepreneurship and rural agribusinesses for young people including females. These activities were divided into three main types:

- Improving women's access to information and technologies: by offering suitable technical information that is relevant for their production systems and involving women farmers in training and field days,
- Work on reducing women's workloads and stimulating collective and social entrepreneurship: by the introduction of small-scale machines such as mobile seed cleaning & treatment machines, mobile feed grinders, pelleting machines, and manual seeders – that can help them raise efficiencies and productivity, and where we make sure women are well integrated as beneficiaries of equipment and also of trainings,
- Strengthening women's leadership within the communities by supporting women's associations and involving women in existing associations as well as by hosting some of our SWC trials at women farms.

A "Bundled Digital Extension Approach" offering soil friendly productive information for women farmers and youth

To enhance the capacity of women farmers accessing to suitable technical information which are relevant for their small-scale farming systems and to increase their awareness about different problems and solutions to soil and water conservation in particular, and diversification and sustainable intensification of production systems in general – the SWC@Scale / ProSol team developed a specific digital dissemination activity based on text messages that convey basic knowledge on enhanced practices such as i) Forage crops cultivation and integration in crop rotation to enhance soil fertility and crops productivity, ii) Conservation agriculture for enhanced soil and water use efficiency, iii) Animal health for profitable livestock, and iv) Importance and benefits of farmers organization into associations and cooperatives. The ongoing activity has been targeting **730 farmers** in the project intervention areas of which at least **200 are women**. Careful consideration was given to the inclusion of youth in this activity. Youth considered in this activity are about 30% of the total sample. Around 203 SMS messages were co-elaborated and are now being sent to farmers at proper relevant timing. At this stage, a total of **36,121 SMS** messages were sent to the total 730 farmers, delivering 56 agricultural advisory messages on the above agricultural topics and technologies. All these aspects would enhance the capacity of the considered women farmers to cope with climate change and adapt their practices into a more resilient way.

Table 5. Digital extension: types of themes of the SMS texts sent to farmers (Using gender neutral language and spoken Arabic)

Organizations and Collective Action 49 SMS	■ The different types of professional organizations and associated activities and objectives ■ The roles and different ways of functioning of various rural organizations ■ Rights and duties of members and management
Animal health 58 SMS	■ Types of small ruminant disease and bacterial infections, symptoms, risks for contamination, with a focus on prevention and treatment ■ Reminders about a disease during its peak period
Conservation Agriculture 46 SMS	■ Agricultural, economic, and environmental benefits of CA ■ CA farming techniques, e.g., farming to reduce erosion, maintain soil fertility, and reduce the effects of climate change
Animal Feeding 50 SMS	■ Importance of a balanced diet / Importance of fodder, diversification, and intensification of fodder crops ■ Benefits of using a mechanical chopper ■ Introduction and use of new feeding technologies

Source: Dina Najjar et all, ICARDA - 2022

Affordable Context-adapted technologies tailored to women's needs, reducing drudgery, and stimulating entrepreneurship and social businesses within communities

Through the SWC@Scale / ProSol Project, ICARDA and its national partners provided farmer cooperatives and individual farmers in the project target areas with hand-held seeders, mobile seed cleaning & treatment machine, mobile feed grinders and pelleting machines. Women farmers were directly and indirectly considered among the beneficiaries.

Based on the official demand of the Tunisian Livestock and Pasture Bureau (OEP), 1**00** units of handheld seeders were purchased and are being currently distributed in the different project areas mainly (Siliana, Kef, Kairouan) and other locations that were identified by the project national partner OEP – with the purpose to support small scale farmers – owner of tiny, uneven, and fragmented land plots and especially women farmers given the fact that they are seeding manually and without mechanization. The other advantage of this user-friendly and cost-effective innovation is time saving and more efficient and precise seedling rates (decreases the quantity of seeds used).

It can also spray chemical fertilizers without women farmer's skin being in contact with the product, thus reducing health risks. From the 100 handheld precision seeders, 25 units were assigned to all regional departments of OEP to generate the demand and train farmers on the well-use of the machine to enhance forage-based crop rotation. A training of **23** extension agents from OEP at EL Green Station – Kairouan was organized in April 2022 and led to the implementation of 14 field days and trainings conducted by some of OEP agents in their intervention areas including the project target sites . A total of **319 farmers** of which **33%** are **women (80)**, have benefited from these capacity Development interventions.

In order to reduce feed waste, improve ruminant nutrition and growth rates, and reduces drudgery for women farmers, an imported feed pelleting machine and a mobile grinder machine locally manufactured were donated to the Agricultural Development Group of Seres (GDA Sers) – a female farming association of **58 members** established in 2015 in the village of Sers, in the semi-arid governorate of Kef in northwestern Tunisia. The GDA primarily focuses on boosting the milk production of small and large ruminants (goats, sheep, and cows) and marketing dairy-based products. Appropriate training on the use of these machines was conducted for the GDA members and both machines are now being used by women farmers on a weekly rotation basis. As preliminary observation based on their feedback, both machines improve farmers' income and quality of life via better feeding efficiency and reduced levels of hard manual work. The same approach was implemented for GDA El Khol where the same machines were distributed for the same purpose. In Rhahla Site, a mobile-motorized seed cleaning and treatment machine was donated to the cooperative "SMSA Ankoud El Khaier", in addition to the pellet and mobile grinder machine. This machine will enable farmers to efficiently clean and treat wheat, barley, vetch, and other forage seeds – a previously grueling manual task handled to women. By introducing this machine, we expect over **150 women** (at least one from each household) from El Rhahla location will directly or indirectly benefit. The machine is also key for sustainable access to forage seeds after the end of our project.

Grinder is being used by Female farmers at GDA Sers, Kef – 2022

Strengthening women's leadership within the communities

During the 2021-22 cropping season, the project team was focusing on actively involving women farmers in the different capacity development (CapDev) events such as workshops, trainings, focus groups, field days and on the job-trainings. Forty eight **(48)** CapDev events were implemented at national and regional levels in different project sites – where a total of **718 participant units** (some participants attended many events) consisting of local farmers, extension staff, local authority, experts, researchers, policy-makers and students have been provided with skills and information concerning: i) the different innovations of the project sociotechnical bundle, ii) smart agricultural practices (conservation agriculture and minimum soil disturbance, iii) small scale mechanization and processing of agricultural inputs, iv) best agricultural SWC practices, v) forage crops including forage mixtures and sulla cultivation, vi) crop rotation, vii) knowledge hub concept for self-sustained scaling of viii) communities' organization including procedures and steps to set up a smallholder Farmers' association (SMSA/GDA), etc. From this total, at least **40 %** of the participants were women and youth (<35 year), of which **132 are women farmers** – thus contributing to one of the targets of this project to promote gender inclusiveness and strengthen women's leadership. Such activities are partly contributing to changing social norms, especially in location where these CapDev event have been traditionally only devoted to men.

Focus Group with Women Farmers in E Rhahla Site, Siliana – 2022

In June 2022, a series of focus groups have been also conducted in El Rhahla site with 33 women farmers. The focus groups attempted to understand gender roles and needs in integrated livestock-crop farming systems in place as well as understanding the possible income-generating activities that could fit their needs. Additional activities for capacity building needs were identified and planned for the remaining period of the project including:

- Increase of women participation to key relevant trainings about the different innovations of the project through exclusively women-oriented trainings on i) herd health management, ii) feeding and processing of agricultural product, iii) forage production and crop rotation, iv) seed multiplication, etc.
- Creating a new women farmers' association in El Rhahla site: this activity has been already initiated with the support of the project. A Specialist in "Organization, Management Accounting and Fiscality of Agricultural Professional Structures GDA-SMSA" was recruited to follow and assist the creation process. A total of **25 women farmers** were engaged as a starting group to create a GDA having in its agenda a strong focus on promoting agroecological practices and enhancing women integration into local value chains through small investments related to income-generating activities such as valorization of local products, essential oils and floral waters, beekeeping, poultry farming and sheep keeping, etc.
- More involvement of women farmers in farm trials on CA and community-based forage seeds production: Although the project closes officially in March 2023, we took the strategic decision to put in place a 2nd cropping season in both project sites (El Rhahla and Elkhol), hence increasing the demande of the promoted SWC technologies and the availability of forage seeds.

For the upcoming cropping season, the project will implement additional **33 demonstration plots with 33 women farmers** in El Rhahla site.

Initiating the creation of Women Farmers GDA in E Rhahla Site, Siliana – 2022

Knowledge for Success in Scaling Soil and Water Conservation Technologies

Knowledge Provision and Capacity Lifting

- **Capacity Development**

During the cropping season 2021-22, the SWC@Scale / ProSol team was engaged in substantial capacity development activities using the most appropriate methods such as workshops, training, information events and more technical field days related to the different elements of the sociotechnical package promoted. More than 48 face-to-face events were held in the different project locations.

Since the beginning of the project, at least 718 people including 40% females were reported to have benefited from the program's capacity development efforts. For short-term CapDev events, the beneficiaries included farmers and farmer groups (418 male from which 132 are women), scientists, and R&D personnel from national agricultural research, and extension systems (NARES), academic institutions, development organizations and the private sector among others. For long-term training, 03 MSc students enjoyed more intensive support. Students have also benefited from the project short-term trainings.

- **Specific E-learning Modules for SWCT**

E-Learning experienced a huge boost across the globe, especially during the COVID-19 pandemic when it showed its efficiency to upgrade knowledge. In response, the capacity development activities of the project in collaboration with INRAT, INRGREF set-up three e-learning modules (in French language). The modules were related to "Conservation Agriculture (CA)", "Agroecology" and "Soil Health". A series of training workshops were organized to introduce AVFA trainers and extension agents to the three modules.

More than **52** people benefited from these modules and received their online certificates so far. The modules are openly accessible through the ICARDA E-Learning platform which currently has over 70 courses and 1100 users in different languages and is continuously growing.

In collaboration with the GIZ ProSol project team a simple ICARDA e-learning platform inscription guide has been developed and shared with potential users. Sharing the guide and the links of the e-learning modules in different social media will surely increase the number of certified beneficiaries. By March 2023, we expect that the number of certified trainees will exceed 100 trainees.

The project performance can be assessed by comparing what was achieved against what was supposed to be achieved as described above and by attempting to show the level of progress using these indicators. The distribution of these indicators "Committed *vs* Achieved" is illustrated in **Figure 8** (Below).

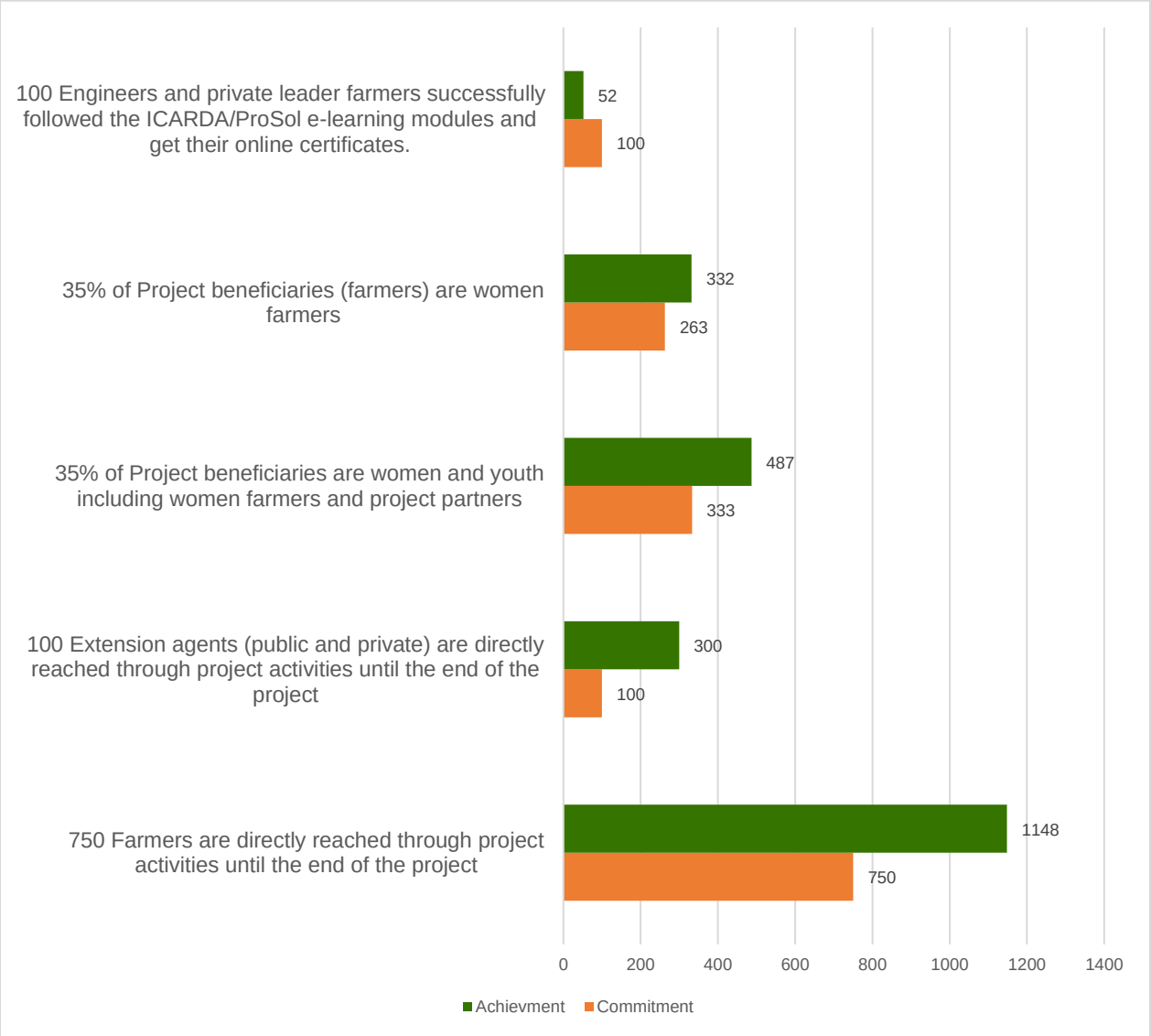

Figure 8. Project Achievement *vs* Commitment

2021-22 Major Knowledge Products & Tools

Knowledge Product/Tool Title	Type	Brief description	Status/Link
Low-Cost Machinery for Better Rural Livelihoods in Tunisia	Blog	The Blog shows how ICARDA's context-adapted technologies and machines significantly improve the livelihoods of dryland small-landholders and pastoralists – the hardest hit by intensifying climate change and global shocks.	Published/Link
Social Soil		This blog shed lights on how the project researches and designs a sociotechnical package of affordable and scalable Soil and Water Conservation Technologies (SWCT) to improve soil fertility in diverse farming agroecosystems in North and Central West Tunisia.	Published/Link
Integrated Sociotechnical Package for Soil Restoration in El Rhahla Landscape, Central West Tunisia	Video	"Integrated Sociotechnical Package for Soil Restoration in El Rhahla Landscape, Central West Tunisia" is a short movie documenting the project approaches and its main interventions related to the sociotechnical bundle of innovation undertaken by the project in El Rhahla site – it also presents a series of testimonies on (i) the challenges farmers are facing, (ii) the solutions brought by the SWC@Scale project to face these challenges and (iii) how these solutions can improve the livelihood of famers in the crop-livestock farming system.	Draft (In progress)
Refinement and scaling of inclusive agroecological innovations for livestock management, crop rotations, and soil conservation in semiarid south Mediterranean regions	Conference Presentation	The objective of this work is to i) present a socio-technical package of agroecological interventions that are already being tested for this type of mixed farming system in the semi-arid area of Tunisia, and ii) illustrate the scope and mechanisms for scaling up this package. Results further illustrate the key factors that have led to a change in attitude and behaviour among local actors and farmers towards a better co-generation, co-sharing, and adoption of agroecological principles at farm, community, and landscape levels. This work was presented at the Tropentag 2022 conference in Prague Czech University of Life Sciences Prague Czech Republic September 14-16	Published/Link
Scaling agroecological packages for soil and water conservation in mixed crop livestock systems in Tunisia		This work shows opportunities and constraints related to the scaling of soil and water conservation technological packages in Tunisia. This poster was delivered during the Tropentag 2022 conference in Prague Czech University of Life Sciences Prague Czech Republic September 14-16	Published/Link
Manufactured feed-pellets and business plan for empowering small-scale farmers to improve their livelihoods: Cost-driven and sustainable solutions for crop-livestock farming systems in Tunisia	R4D Initiative/Brief	The purpose of this brief is to assess the profitability of manufactured feed-pellets machinery practices by diversified categories of stakeholders (private farmer, community-based organizations, private sector, and development organizations) through a comprehensive business plan. It shows to what extent this type of projects could be profitable for small-scale farmers, making it easy secure to obtain credit facilities from the public or private institutions.	Finalized and not yet published
Economics Evaluation Methods of Soil and Water Conservation Techniques	Guide	The aim of this guideline is to provide a synthesis on the different practical methods and frameworks used to economically assess and evaluate soil and water conservation techniques. It also provides an insight on the behavioral factors affecting the soil and water conservation decision making with special attention to the long-term perspective of the economic implication of soil and water conservation investments.	Draft (In Progress)

2021-22 Major Knowledge Products & Tools (Cont'd)

Knowledge Product/Tool Title	*Type*	Brief description	Status/Link
Scaling Scan Tool – Soft Version	*Tool*		Finalized and used for implementing scaling road maps in both project target sites Link
Demo-plots follow-up Instrument tool		This survey instrument tool was designed to collect information at the plot level.	Finalized
Smart ODK Application to monitor demonstration and experimental plots		Under the SWC@Scale / ProSol project, ICARDA team have been developing a simple and nice ODK form, which is highly useful to follow and monitor all "demonstration plots" we have under this project (more than 80). The nice thing is that the tool captures the location of the plot, a small description, and you can use it each time you visit the plot to take a photo and insert simple management keywords. In this way, you can track the evolvement of your plots and analyze failure and success.	Finalized
Additional knowledge products related i) Land degradation and water scarcity in Tunisia, ii) Diversified and integrated crop Rotation for sustainable production system, iii) Reseeding using Sulla, a native legume forage species (Hedysarum Coronarium) and its rhizobial inoculation process, iv) Cereal-legume mixtures as a way to increase forage production, diversify rotation system, boost yields, and improve productivity, v) Small scale mechanization for soil health and animal feed transformation, vi) Soil health as a foundation to sustainable food systems, vii) Economic benefits of applying soil health practices, and viii) Involving rural community in addressing soil degradation problems and restoring soil health and fertility – and one leaflet on the description of SWC@Scale project (in French).	*Technical flyers and posters*	Are now available in the project website	Link to the Project Website
Videos, and other SWC@Scale/ProSol Knowledge products on social media	*Social Media*	These are different videos, and other social media products announced and published by ICARDA and/or its national partners in Tunisia on the social media. Examples: https://twitter.com/ICARDA/status/1470722387989700608 https://twitter.com/ICARDA/status/1472475601261019137 https://www.facebook.com/166091433517809/posts/4328073987319512/. + Link	

Recap on the Main Project Achievement

Achievements so far on project indicators is as indicated in the below table (detailed explanation of progress by activity, leading to the below progress on indicators, was explained in the previous sections).

Indicator	Overall Progress
A tested methodological guide for developing scaling road maps and activities will be validated and documented for wider use by the ProSol program and other related projects.	The guide has been issued and used for implementation and piloting. Insights and lessons are being recorded and reported. We are still far from validation, but we will certainly pause and reflect about this methodology in the coming three months, before we finally report it at the end of the project.
A simple tool for identifying scaling readiness and scaling road map will be provided for wider use at local level.	The tool (scaling scan lite version) was developed and tested. It was also shared widely with national regional and local partners. The tool can be found here. Scaling Scan Dashboard (shinyapps.io) Results from this tool can be found in the previous progress report (12 months).
On SWCT innovation platforms is installed, functional, and self-sustained; and another is converted into enhanced knowledge hub thus contributing to the self-sustainable scaling of sustainable production packages.	KH created and operational in Siliana: One innovation platform was already fully installed and is efficiently operational (El Rhahla SMSA, Siliana). This SMSA was created with main objective of enhancing agricultural productivity in addition to soil conservation and agroecology promotion, which is not usual to find in Tunisia. Extensive interventions were able to convert this SMSA to a significant knowledge hub for soil and water conservation practices relevant for the cereal-sheep farming systems in the region, The GDA of El Khol was converted into active innovation platform. This can be seen through the extensive networking activities organized for this community, which started now working with OEP Kairouan, DGACTA, CRDA, CTV Hajeb Layoun, etc.
At least 750 farmers and 100 extension agents (public and private) will be directly reached through project activities until the end of the project.	A total of 1148 farmers was recorded as beneficiary of our different trainings and interventions, until August 2022. Confirmation of this number will be done after final recording of all pending presence sheets into the M&E excel templates of GIZ, 300 extension agents and partners representatives benefited from our different interventions, field days, trainings, and other capacity development events. This number is up to August 2022 and is recorded in the M&E excel template of GIZ/PROSOL.
At least 10,000 farmers are reached indirectly through farmer-to-farmer extension and media (fb, radio, etc)	A lot of social media blogs and products have been circulated on the web during the previous 9 months. These concerns all our intervention in the regions but also collaborations with other national partners. The number of “views”, “impressions”, and shares of these social media products and other knowledge products is now estimated at about 4500 indirect beneficiaries reached by the project. More accurate assessment will be made by the Comms team of ICARDA and will be provided in the coming reports. Within the project more than 1148 farmers were directly exposed to the project activities and most of them were head of household i.e., additional 5740 household members should have been indirectly influenced by the project activities [(1148*5); 5 average household size in Tunisia, source INS).
30% of the reached farmers have adopted the technology until the end of the project	This will be confirmed through a final field survey which will be conducted between November-March 2023.
At least 35% of project beneficiaries are women and youth	332 of beneficiaries are women and youth. This number this number the committed 35% of beneficiaries.
At least 100 engineers and private leader farmers successfully followed the ICARDA/ProSol e-learning modules and get their online certificates.	A total of 52 engineers were successfully following the e-learning modules and got their certificates: 18 participants obtained ICARDA certificates in Agroecology, 16 in CA and 18 in soil health. ICARDA team will see how to increase this number up in the remaining period of the project.
At least 1,500 ha of degraded land will be restored	The project directly implemented demonstration and multiplication plots covering 82.5 ha in both target sites.

Recap on the Main Project Achievement (Cont'd)

Indicator	Overall Progress
At least 1,500 ha of degraded land will be restored **(Cont'd)**	The Project succeeded in producing more than 26 tons of forage crops and forage mixtures (produced by partner farmers and GDA to be sowing the cropping season 2022-23). This quantity will cover an area of 232 hectares. Almost 24 tons of seeds of wheat, barley and legumes crops were cleaned using the cleaning and treatment unit. These quantities will cover at least 185 hectares in the project target sites. A spatial soil erosion simulation at the landscape level (RUSLE) is planned for the upcoming cropping season 2022-23 to assess the impact of the promoted SWC practices using different scenarios on soil loss at the watershed level of Rhahala – covering an area of 2,000 ha.