Agroecology Initiative

Context Document [Tunisia]

Context Assessment for Transformation in the Tunisian Agroecological Living Landscape

Véronique Alary, Aymen Frija, Hassen Ouerghemmi, Zied Idoudi, Udo Rudiger, Mourad Rekik, Asma Souissi, Boubaker Dhehibi, Haithem Bahri, Insaf Mekki, Wael Toukabri, Meriem Barbouchi, Mohamed Annabi, Ajmi Larbi, Mahdi Fendri, and Hatem Cheikh M'hamed

November 2023

The purpose of this Context Assessment is threefold: first, to characterize the environmental, social, economic, and political contexts of the Tunisian Agroecological Living Landscape (ALL); second, to understand the data and information currently available in the sub-region of this ALL; and third, to characterize the extent to which agroecological principles are already being employed locally at the ALL level. This report constitutes a basis of information and discussion to conduct an impact assessment. It is also valuable to all WPs in the Initiative as it provides critical quantitative and qualitative data and information regarding capacity assessment, policy influence, and other environmental attributes that can guide the implementation and impact of the Initiative in 2023–2024.

This Context Assessment in Tunisia has been elaborated from primary and secondary sources of data. The primary sources came from focus groups and formal and informal interviews conducted in the target area from June to December 2022 as part of WP 1 and WP 4 activities. The secondary sources came from previous research and development projects in addition to formal and grey literature and technical reports and policy documents. This report will be enriched with a household survey planned during the first quarter of 2023.

This report contributes to Output 2.1, Baseline – current conditions of agricultural systems of smallholder farmers in each ALL; Output 1.1 on establishment of the ALL; and Output 4.1 on the identification of policies and local institutions and their role in agroecological transition pathways.

The CGIAR Initiative on Transformational Agroecology across Food, Land, and Water Systems develops and scales agroecological innovations with small-scale farmers and other food system actors in seven low- and middle-income countries. It is one of 32 initiatives of CGIAR, a global research partnership for a food-secure future, dedicated to transforming food, land, and water systems in a climate crisis.

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INITIATIVE ON
Agroecology

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Executive summary

Key highlights of the document

The CGIAR Initiative on Agroecology is built around the concept and approach of an Agroecological Living Landscape as a means to integrate social systems and ecosystems at one site to implement and test the agroecological transition. The Tunisian ALL over the Kef-Siliana transect is characterized by deep soil erosion problems and effects of climate change (Attiaoui and Boufateh, 2019). Conventional practices such as field crop monoculture and deep plowing persist and aggravate soil and land degradation in the zone, phenomena that are also exacerbated by rising population and difficult geographic characteristics. Moreover, a significant percentage of cropped land is unsuitable for agricultural activities, which expedites its degradation. This problem of land and soil degradation through erosion constitutes the core concern for the co-design of agronomic and livestock management practices and this is linked to the agroecological principles of soil and plant biodiversity in synergy with livestock activities, one of the livelihoods for resilience in the Tunisian ALL.

> “Currently, regional policies have shifted from a participatory approach toward an inclusive and sustainable value chain perspective.

From a political perspective, land, water, and forest conservation are among the top priorities of national policies. Despite the early care about these key resources, limited progress in terms of policy design, implementation, and effectiveness has been recorded. New challenges of climate change, resource scarcity (and degradation), and social pressure are adding more complexity to policymaking and implementation. Currently, regional policies have shifted from a participatory approach toward an inclusive and sustainable value chain perspective. A focus on value chains has been seen, since the late 2000s, as a means to stimulate local economic and social dynamics, while keeping a focus on resource protection and preservation. The lack of strong administrative expertise on value chains in the regions (and locally) made it difficult to properly implement and use this approach for local development in rural areas.

Relevance to the major outcomes of the Initiative on Agroecology

Cultivated soil health has been defined as the capacity of soil to function within land-use constraints while maintaining agricultural production for sustainable food systems along the agroecological transition. Therefore, the success of maintaining or enhancing soil health (and more generally ecosystem health) depends on our understanding of how the soil responds to agricultural land use in interaction with livestock management.

The motivation for farmers to investigate soil health is based on the goal of improving productivity sustainably and this involves an integrated assessment of the physical, biological, and chemical components of soil. In this context, soil health can be assessed mainly through soil properties that are sensitive to changes in management practices such as tillage, crop rotation, cover crops, organic matter additions, and livestock grazing that strongly influence soil quality components and thus crop performance. Social organizations and policies are key factors and key influencers of the capacity to follow these innovative pathways.

To design more appropriate research and facilitate communication with farmers, it is necessary to understand their knowledge, perceptions, and assessments of soil and soil fertility, economic diversification, and the relative resilience of each activity facing climate change.

The transition of rural territories in Tunisia is considered to be potentially supported by the creation and reinforcement of farmers’ collectives such as SMSA or GDA that are the more recent forms of cooperatives in Tunisia. These structures are susceptible to breaking with the logic of “control” of the rural population that has prevailed for more than a century in these territories and re-drawing the political programs and the roles of key actors.

Potential users of the document

This document will be shared and enriched with the knowledge of research and development actors involved in the Tunisian ALL to cross and combine the several perspectives (ecological, agronomic, socioeconomic, and political) to have an integrated and common vision of the zone and its potential future pathways. In this way, this review document will feed the Tunisian theory of change in the Initiative.

It will also serve as a basis to co-conceive the core indicators for the agroecological transition linked to the Tunisian theory of change. A preliminary set of indicators has already been proposed.

Zied Idoudi / ICARDA

Acronyms

ALL.. Agroecological Living Landscape

CRDA... Commissariat Régional pour le Développement Agricole

CTV..................................... Centre Technique de Vulgarisation

DG ACTA..................Direction Générale de l'Aménagement et de Conservation des Terres Agricoles

FO ....farmers' organization

GDA........................ Groupement de Développement Agricole (Agricultural Development Group)

GIZ .... Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency of International Cooperation)

ICARDA............................ International Center for Agricultural Research in the Dry Areas

IFAD............. International Fund for Agricultural Development

INRAT .... Institut National de la Recherche Agronomique de Tunisie

INRGREF .... Institut National de Recherches en Génie Rural, Eaux et Forêts

OEP...................................... Office de l'Elevage et du Pâturage

ONAGRI ....Observatoire National de l'Agriculture

SMSA............................... Société Mutuelle de Service Agricole

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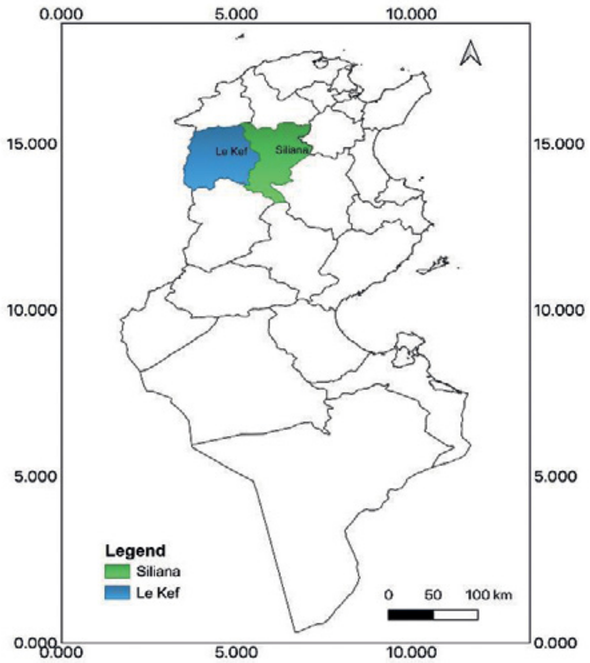
Description of the Agroecological Living Landscape

Location of the Agroecological Living Landscape

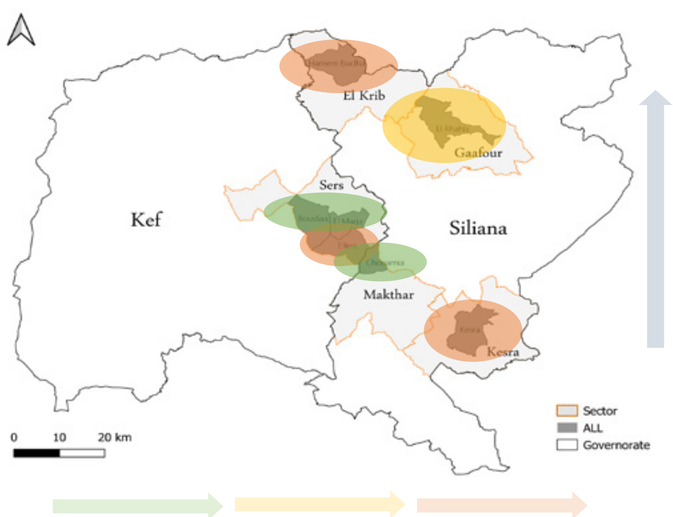
The Tunisian Agroecological Living Landscape (ALL), called Tunisian Kef-Siliana transect, is located in the semi-arid zone of northwestern Tunisia identified as a priority zone by the national partners during the national inception workshop of the Initiative on Agroecology in 2021 and where mixed cereal-tree-small-ruminant (sheep and goat) systems prevailed **(Figure 1).**

Figure 1. The Tunisian Kef-Siliana transect localization in the northwest of Tunisia
(Source: Authors)



The Tunisian ALL was first composed of four farmers' organizations (FOs) in the targeted zone that were selected along a gradient of partnerships (with international, national, and local partners) and agroecological (AE) technical packages. The gradient of partnerships allows testing how the degree of fairness, connectivity, and participation built over the years will influence the AE transition envisioned in the Initiative. Three axes of AE transition pathways were pre-identified: (i) the integration of crop-livestock systems from seed multiplication to animal product valorization toward more autonomous systems resilient to climate and price uncertainties, (ii) the valorization of olive products and by-products in agroforestry systems through product certification and wider by-product valorization, and (iii) the promotion of local products (including honey and carob) in the agroforestry system as paths of diversification and gender inclusion. These three AE transition pathways can often be combined at the farm or landscape level linked to family activities and their agricultural pattern.

Along with the process of ALL characterization conducted with local and national partners, two new FOs joined the ALL at the end of 2022. This process led us to consider our Living Landscape as a dynamic social living lab embedded in the geographic transect Kef-Siliana. This geographic transect covers a diversity of landscapes, including the plains dominated by cereal-olive-small-ruminant systems to the mountainous areas where silvopastoral activities, with diversified tree plantations and forest, became dominant. **(Figure 2)** is a representation of the Living Landscape in the selected transect.



Covering **a gradient of agroecological contexts** of mixed tree-crop-livestock systems in a semi-arid zone, from mountainous to plain zones.

Gradient of AE packages and partnerships from relatively long-existing partnership and AE packages (from 2018, in green) to recent partnerships and AE packages (from 2021, in yellow) to new partners, new AE packages (from 2022, in orange).

Figure 2. Localization of the Tunisian ALL composed of six farmers' organizations in 2023 (Source: Authors)

The farmers' organizations embedded in the Living Landscape have two main legal forms: SMSA (Société Mutuelle de Services Agricoles) and GDA (Groupement de Développement Agricole). From a governmental point of view,

> "*The Law 2005 defines SMSAs as companies with variable capital and shareholders constituted by natural and/or legal persons carrying out an agricultural activity, fishing, or provision of agricultural services in the area of intervention of the society. The form of company with variable capital and shareholders is a logical consequence of the principle of free membership and withdrawal and open doors that govern societies/cooperatives*"

(citation translated from Belhaj Rhouma et al., 2018, p. 14).

In addition, the GDAs are considered democratically legitimized local structures, gathering owners and users of natural and agricultural resources with some collective activities. They can also manage specific natural resources on behalf of the state. However, unlike SMSA farmers' organizations, they cannot conduct commercial and lucrative (profit-oriented) activities.

The two old FOs (i.e., SMSA Chouarnia and GDA Sers) embarked on previous projects that have been part of a research and development project called CLCA-2 – "Use of conservation agriculture in crop-livestock systems in the drylands," coordinated by ICARDA and funded by IFAD during 2018–2021. The main activities developed during that project involved the following:

- The implementation and management of zero and minimum tillage, crop diversification and rotation with forage mixtures, integration of key legume forage crops, etc.
- The introduction of small machines, including mobile grinders, handheld seeders, pelleting machines, seed-cleaning machines, etc., aiming to valorize the crop residues from olive production, cactus, wheat bran, etc., and making them available for animal feeding.

The SMSA El Rhahla is one of the studied zones of the project PROSOL (Protection et réhabilitation des sols dégradés en Tunisie), coordinated by the GIZ and DG ACTA,[1] around the improvement of natural resource management, focusing on scaling of soil and water conservation techniques. The partnership was being built over 2020–2022. In partnership with the national Office of Livestock and Pastureland (Office de l'Elevage et du Pâturage, OEP) in the El Rhahla FO, the PROSOL project has developed on-farm trials of feed crops, especially *Sulla* and forage mixtures, on very degraded lands for animal feeding.

A new FO, SMSA Kouzira, was selected based on its willingness to develop specific markets around its local products such as honey, fig confiture, and good-quality olive oil. Moreover, this SMSA comprises a majority of young people (40% of the members are less than 35 years old) and women representing about 70% of the total number of supporters.

These four FOs were the core of the ALL to co-conceive and implement technical and organizational innovations along three key products and commodities:

1. Animal products from seed multiplication and forage production/feedstock (with crop/tree residues) to dairy and meat product marketing; here, we consider the feed-food system.
2. Olive tree integration with all the other agricultural activities (livestock-cereal) through recycling of by-products, which can support input minimization and sustainable intensification.
3. Honey and carob products are increasingly in demand and can be produced with good quality in the mountainous agroforestry systems.

In cooperation with a national partner, Institut de l'Olivier, and its partners, the Tunisian ALL has been extended to two new FOs, Elless and Hamam Badhia, in the ALL. These two FOs complement our work on olive oil certification and marketing, in addition to valorization and recycling olive tree by-products for biofertilization, among others. These additional FOs have been selected because of the unique characteristics of their olive oil, which, despite its premium quality, remains undervalued in the market. Labels and certifications are thus early steps for such market integration and product valuation.

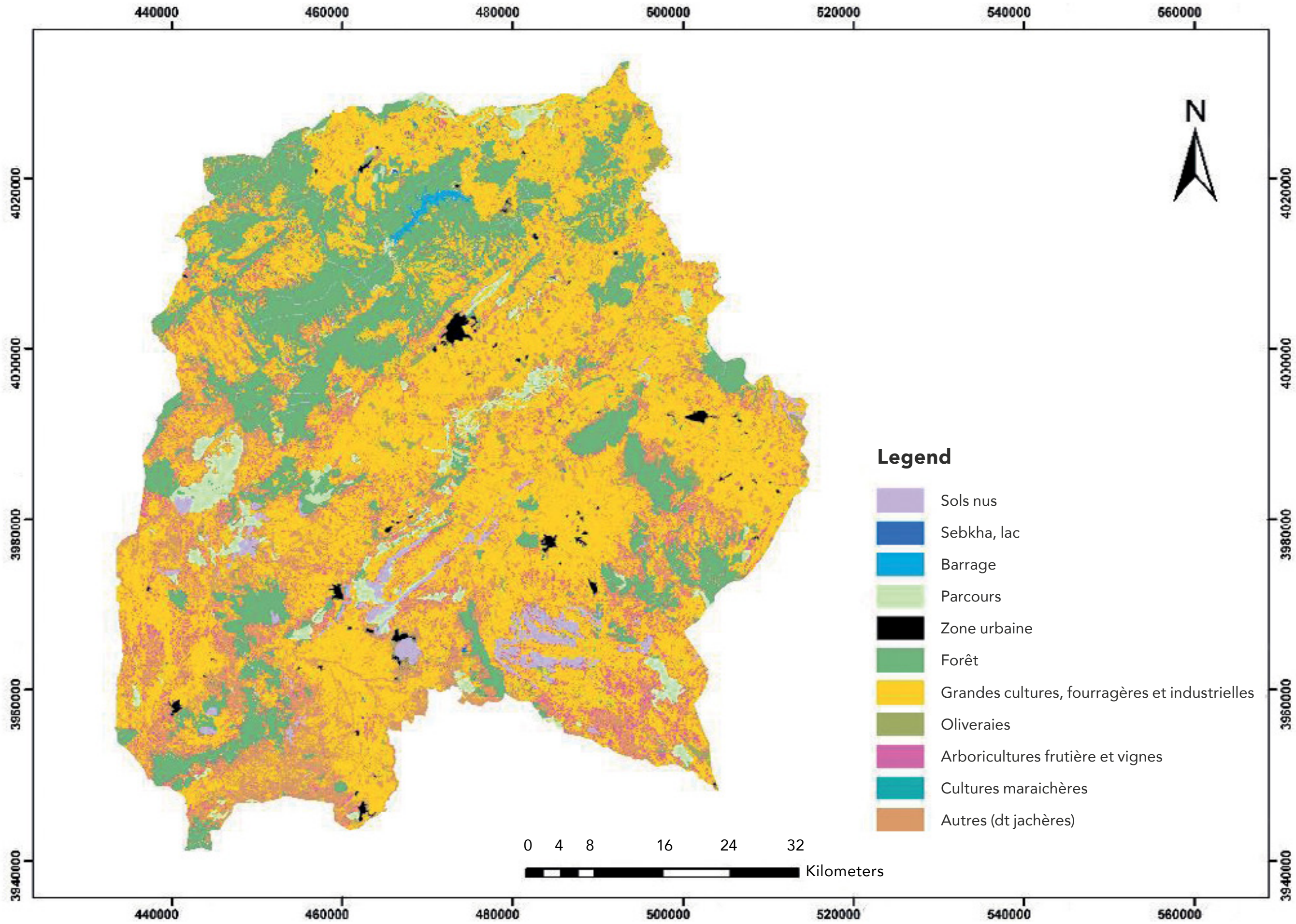
Finally, the Tunisian ALL comprises six FOs and each would be representative of several value chains (mostly for now – will be confirmed later – milk/meat, olive oil, and honey), and each could illustrate various strengths and weaknesses in terms of agroecological principles. We will then search for complementary investments in each of these FOs and will try to find a way to connect them to create a larger and more harmonious ALL.

Environmental context

Topography, soil, and agricultural land use in the Tunisian ALL

The Kef-Siliana transect covers two governorates characterized by a rugged relief and compartmentalized with mountain ranges, high and medium plateaus, and alluvial plains. Between the plains and the mountainous slopes of hard rock, the crusted glacis constitutes transitional areas very affected by water erosion (see **Figures 3 and 4**).

1 Direction Generale de l'Aménagement et de la Conservation des Terres Agricoles.



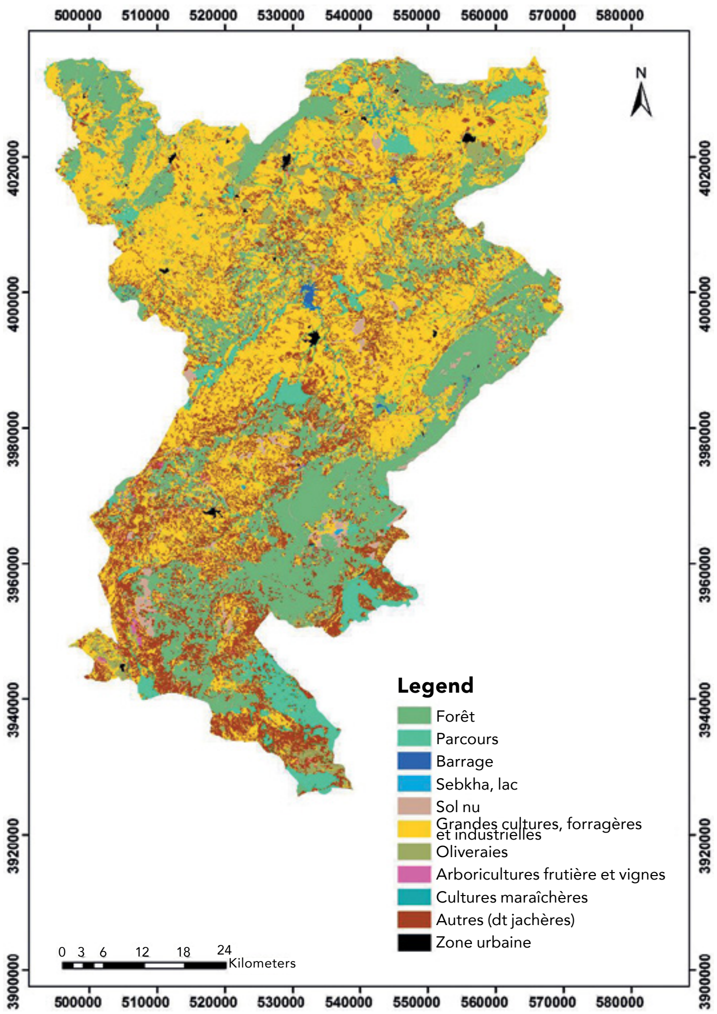
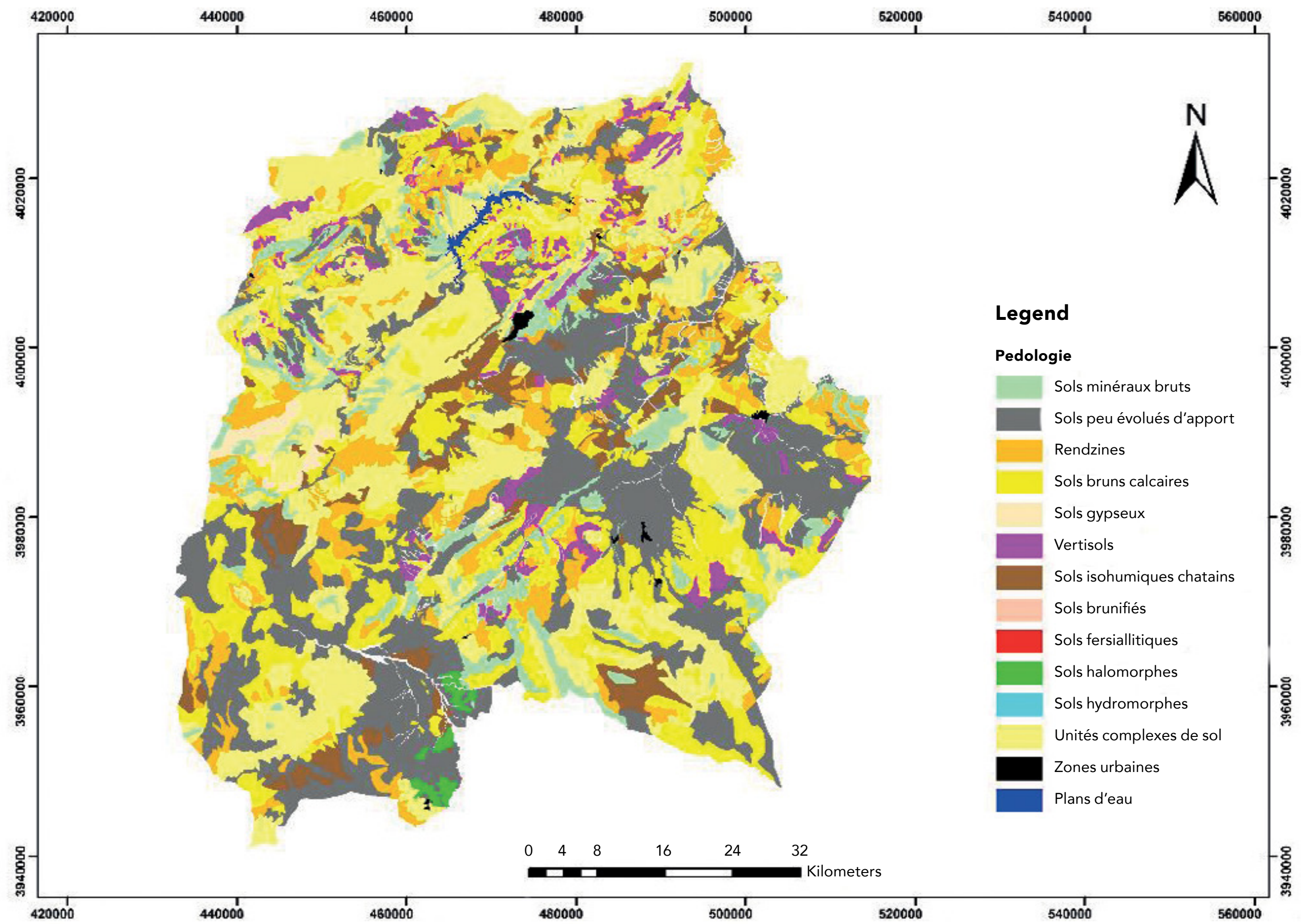


Figure 3. Land-use map of Kef (above) and Siliana governorates (below), Tunisia.

Source: *ICARDA (2021).*



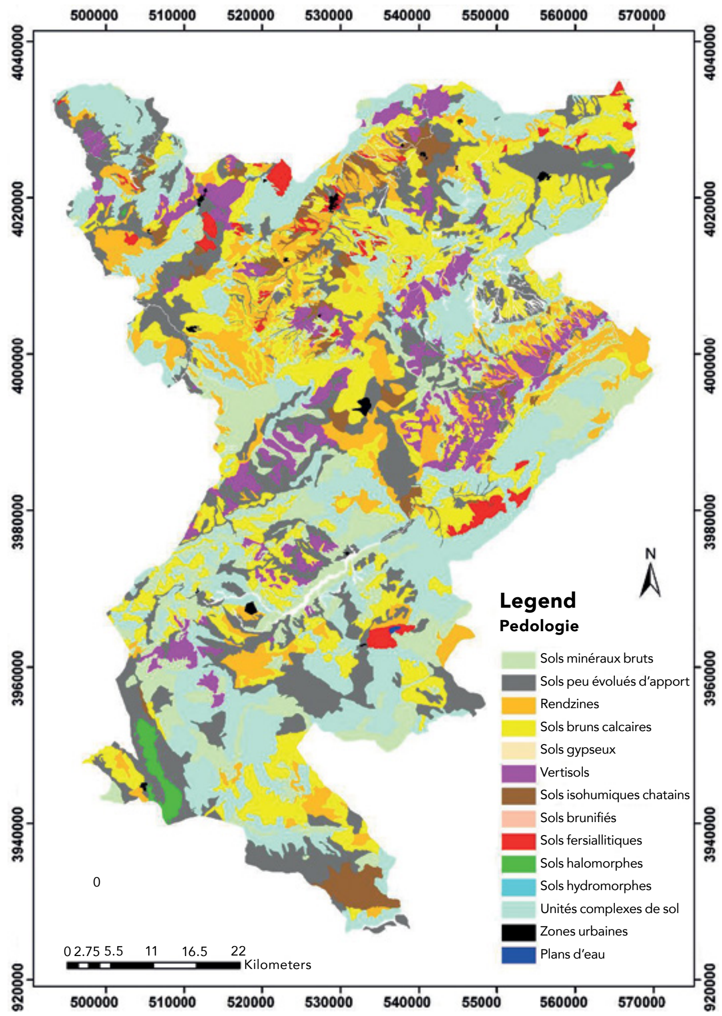


Figure 4. Agricultural soil map of Kef and Siliana governorates, Tunisia.

Source: *ICARDA (2021).*

Several studies were conducted to assess soil health in the Siliana and Kef regions using different soil indicators (physical, chemical, and biological) (see Annex 2). The results of these studies showed that the indicators N, P, K, organic matter (OM) content, and structural stability were negatively affected by cultural practices. They bring evidence that soil health can be improved significantly by decreasing tillage intensity, planting cover crops, and keeping crop residue, and that biological soil health indicators associated with labile carbon and nitrogen are most affected by management practices such as tillage intensity.

However, some conventional practices such as field crop monoculture and deep plowing persist and aggravate soil and land degradation in the northwestern area of Tunisia, negative impacts that are exacerbated by rising population and difficult geographic characteristics (Fouzai et al., 2018; Attiaoui and Boufateh, 2019). A huge percentage of cropped land is unsuitable for agricultural activities, which expedites its degradation. This problem of land and soil degradation through erosion is also aggravated by overgrazing and pressure on the different topographic features, as they are all easily accessible to livestock (Jendoubi et al., 2019).

State of natural resources, including current exploitation/use

Table 1 presents the natural resources in the Tunisian ALL. The two governorates have a noble forestry ecosystem with cork oak, Zen oak, and holm oak, among others, with a production function, but also with functions of protection for soils and surface formations on slopes and protection of downstream infrastructure (dams). This ecosystem also has a role in improving the regime of water sources and maintenance of rare species, while contributing through its permanence to the maintenance of the environmental quality in the mountainous zones. Nonetheless, this forestry ecosystem is subject to strong human and animal pressure. This pressure resulted in (1) a decline in cork oak forests; (2) a higher load per hectare from two pastoral livestock units per year in 1942 to about five in 1995 (based on the national inventory from the Inventaire Forestier et Pastoral National, IFPN); (3) the high frequency of conflicts and infractions in pasturelands (80% of the total infractions); and (4) overgrazing in forest rangelands, with rates of 50% to 78% (reaching about 3.7 sheep/ha).

Table 1. Information and data related to forest cover and its trend.

Siliana Governorate	Kef Governorate
Forest covers 20% of the agricultural lands (Atlas Siliana, 2013). Because of the relief and the natural landscape of the governorate of Siliana as well as its low rate of urbanization, wildlife has been able to develop and conserve itself. This situation allowed the continuity of hunting activity. The main species hunted are wild boar, thrushes, and starlings.	A significant plant cover extends over 24.3% of the region and consists of 102,000 ha of forest (Aleppo pine, holm oak, cork oak), or about 13% of Tunisian forests, and 22,000 ha of rangeland. From 2001 to 2020, Kef lost 3,000 ha of tree cover, which is equivalent to a 19% decrease in tree cover since 2000. The Sers sector land use can be described as follows: 91% arable land, 4.8% forest, and 4.2% rangeland (Atlas Kef, 2015).

Source: *ICARDA (2010); Atlas Kef (2015).*

In addition, the natural environment of Siliana Governorate is characterized by a poor vegetation cover associated with the presence of water erosion, which is considered very severe and threatening to soil quality. During the last decades, with the intensification of land use and urbanization, other problems have appeared, including flooding, sanitation, and waste management (Atlas Siliana, 2013).

For Kef Governorate, 61% of the total area is affected by severe and moderate erosion. Three-quarters of the lands are also threatened by desertification. Many problems related to waste management result from poor infrastructure (Atlas Kef, 2015).

At a more local level in the ALL, these six sites are exposed to many risks, as shown in **Table 2**.

Table 2: The main risks at the four sites of the ALL, Tunisia

Site	Sector	Erosion risk	Desertification	Flooding risk	Pollution and waste management
El Rhahla	Gaafour	High exposure	NA	High	Sanitation problems
Kouzira	Kesra	High exposure	NA	Medium	NA
Chouarnia	Makthar	High exposure	NA	Medium	Sanitation problems
Hamam Badhia	Krib	Medium to low exposure	NA	Medium	NA
Sers/Elless	Sers	Medium exposure	Medium exposure	NA	Poor waste management

Source: *Atlas Siliana (2013); Atlas Kef (2015).*

In the Tunisian ALL, forms of degradation appear as garrigue and steppe formations. These are located on the lands of rangelands and are usually the most exposed to human and livestock pressure.

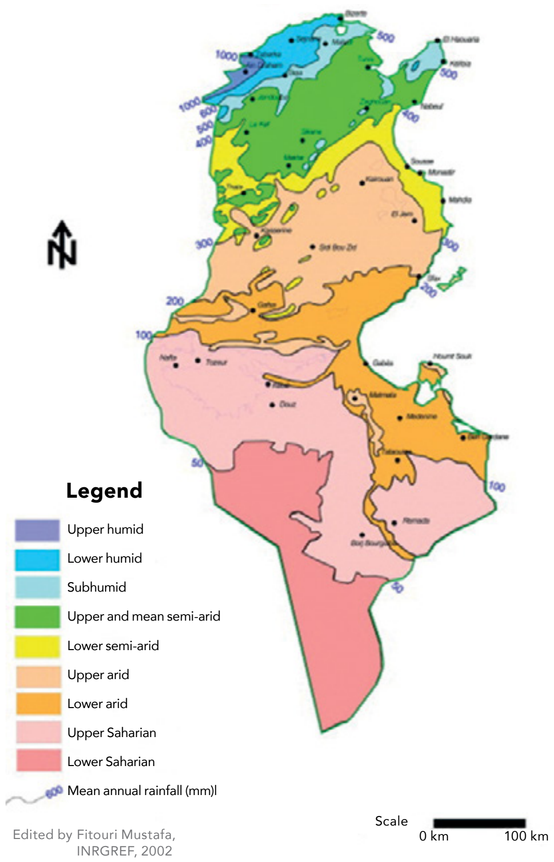
In summary, the natural environment is exposed to various risks, such as water erosion and flooding, aggravated by increasingly accentuated anthropogenic practices. Water erosion is severe there and is sometimes associated with landslides. The rugged nature of the relief, the rocky outcrops' tender; irregular, and often torrential rainfall; the density of the hydrographic network; and the weakness in certain areas of the vegetation cover are conditions that favor hydric erosion. Running water that is difficult to control and natural conditions favorable to flood risks characterize the region.

Climatic characteristics of the Kef-Siliana transect in Tunisia

Nationally, the northern region, which benefits from the Mediterranean environment, has moderate, wet winters and warm, dry summers, with an average annual rainfall of 600 mm. The central area has precipitation from 200 to 400 mm/year, where the bioclimatic stage varies from semiarid to arid climate, and is characterized by some relatively hot temperatures, especially in summer. The climate of the rest of the country varies from arid to Saharian characterized by hot temperatures as well as a large volume of irregular precipitation rarely exceeding 100 mm (**Figure 5**) (Mansour and Hachicha, 2014).

All over the country, from the north to the south, respectively, annual evaporation varies from 1,300 mm to even in excess of 2,500 mm. Also, drought periods registered and experienced can be restricted to one or more regions but they can be generalized for the whole country with variability in terms of duration and intensity (Louati and Bucknall, 2009).

Figure 5. Bioclimatic map of Tunisia.



Source: *INRGREF (2002).*

Siliana Governorate is characterized by a continental climate with an average annual rainfall varying from 350 to 550 mm during the 2017–2018 season. The lowest average temperatures in Siliana during the same season are recorded from 3.2 to 13.0°C, while the highest is from 17.9 to 35.7°C (ODNO, 2018a), up to a monthly mean of 38°C in July 2022. As a result of precipitation and temperature variability, the climate is quite contrasting in Siliana, which is explained by the influence of the relief. The mountainous massifs of the northwestern part of the governorate are considered a semi-arid zone, as are the southern mountainous sectors. In between, the other parts of the governorate have an arid climate, which is more significant in the far southern parts where the lowest amounts of rainfall and highest temperatures are registered (Atlas Siliana, 2013).

In Kef Governorate, the average annual rainfall varied from 350 to 450 mm during the 2017–2018 season. The lowest mean temperature in Kef recorded during the same season was 7.3°C (January), while the highest was 26.5°C (July) (ODNO, 2018b). This governorate belongs largely to the bioclimatic semi-arid stage. However, some areas in its southwest are part of the bioclimatic arid stage and others in the north belong to the sub-humid stage. Overall, it has a continental climate with cold and harsh winters and minimum temperatures among the lowest in Tunisia (Atlas Kef, 2015).

In summary, the bioclimatic context of these two governorates (Siliana and Kef) is similar and comparable, and we can consider this transect as a homogeneous entity with some internal differences.

At a more local level in the Tunisian ALL, the six sites are semi-arid areas with limited precipitation as shown in **Table 3**.

Table 3: Precipitation means in the Tunisian ALL over the period 2010–2018.

Site	Sector	Precipitation (mm) (annual mean 2010-2011)	Precipitation (mm) (annual mean 2017-2018)	Bioclimatic stage
El Rhahla	Gaafour	433 (Atlas Siliana, 2013)	496 (ODNO, 2018a).	Semi-arid medium
Kouzira	Kesra	429 (Atlas Siliana, 2013)	429 (ODNO, 2018a).	Semi-arid upper
Chouarnia	Makthar	494 (Atlas Siliana, 2013)	494 (ODNO, 2018a).	Semi-arid upper
Hamam Badhia	Krib	543 (Atlas Siliana, 2013)	NA	Semi-arid upper
Sers/Elless	Sers	405 (Atlas Kef, 2015)	384 (ODNO, 2018b).	Semi-arid medium

Water availability for production

Siliana Governorate has benefited from three large dams associated with 38 hill dams that have a retention and reserve capacity of 55 Mm^3. In addition to the dams, Siliana is rich in hill lakes, having 138 hill lakes with 10 Mm^3 capacity (Atlas Siliana, 2013). For groundwater, 4,167 surface wells and 373 deep wells are exploited. Especially in the Tunisian ALL, we have contrasting situations. For instance, in the Gaafour sector (SMSA Chouarnia), 2,081 ha are irrigated (mainly public perimeter). For the Kesra sector, the irrigated area is more limited, with a total surface of 198 ha (mainly public). In Makthar (SMSA Rhahla), the irrigated perimeter of 922 ha is under a private regime (ODNO, 2018a). The Krib delegation (SMSA Hamam Badhia) benefits from a network of eight hill lakes and one hill dam.

Kef Governorate has a network of 24 hill dams, 71 hill lakes, and only one large dam. The quantity of surface water mobilized represents only 70% of the mobilizable resources, which shows the rather important potential of surface water. For groundwater, the water table is overexploited while the deep-water table is underexploited (Atlas Kef, 2013).

In Sers, we found three hill dams and six hill lakes. In this same area, 2,850 ha are irrigated (private irrigated perimeter), mainly (2,000 ha) from surface wells. Some 354 ha are irrigated as part of the public irrigated area. Kef has 4,685 surface wells and 537 deep wells, of which 1,012 and 71, respectively, are in Sers (ODNO,2018b).

In summary, the northwestern zone of Tunisia, which contains the six sites of the ALL, is considered the most important area for olive cultivation and rainfed cereals. This transect is one of the most vulnerable regions, characterized as having excessive climatic variability. Drought and water scarcity are the main risks to agriculture and the natural environment, and they influence yield. The high temperatures also affect crops in terms of production and growth cycle. The impact of growth cycle shortening can affect yield both quantitatively and qualitatively as a consequence of damage sustained during flowering and grain filling. All these events and experiences could influence the agricultural calendar (starting from sowing and going until crop harvesting) (Mansour and Hachicha, 2014).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Economic context

Key farming systems

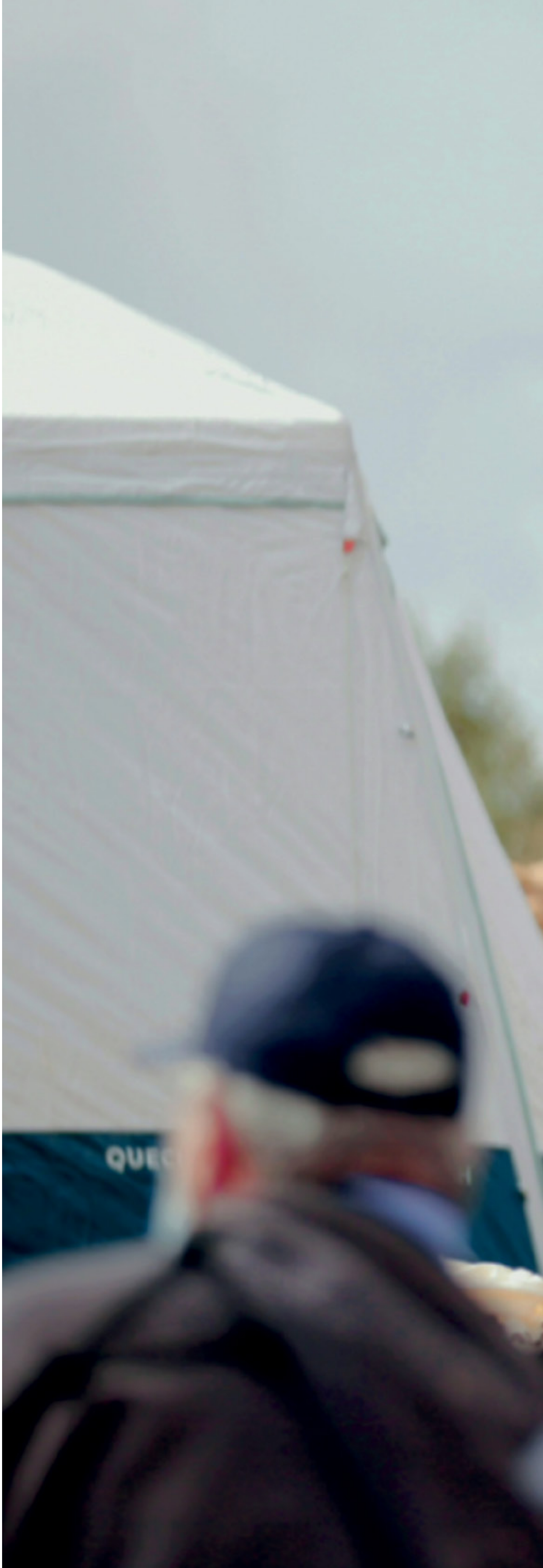
According to the survey on farm structures in 2004–2005 (MARH, 2006), Kef Governorate is characterized by a predominance of small-scale farming systems. Over all the governorate, 35% have less than 5 ha and 58% have less than 10 ha. Farms with 100 ha or more represent 3% of the number of farms and 35% of the agricultural area. The Kef region remains marked by the predominance of cereal activities based on a production system that is not very intensive and strongly depends on climatic hazards. As a result, crop yields have remained low (14 to 16 q/ha) and the annual production of cereals is quite uncertain. Practiced according to an unfavorable crop rotation and technical knowhow, this monoculture most often leads to soil exhaustion (loss of fertility) and erosion (61% of the total area of the governorate is affected by moderate to severe erosion).

Siliana Governorate is characterized by a high population density, given its climatic and soil constraints. The scarcity of land translates into fragmented land and low operating areas (an average of 17 ha per farm and 75% of the farms have less than 10 ha). This scarcity of agricultural land is to be compared with the existence of a still significant national forest, in particular in the delegations of Kesra, Rouhia, and Bargou (21% of the area of the governorate). Dry cultivation is nevertheless always subject to climatic hazards. Production and yield can vary up to 6 times from one year to the next (from 2–3 qt/ha to 19–20 qt/ha). Finally, technical progress has been concentrated geographically (plains) and socially (large- and medium-sized enterprises).

The vast majority of the rural population, except those benefiting from irrigation projects, has found it impossible to intensify their production systems. To cope with the demographic growth, which is relatively low but still significant, producers have had to increase the pressure on natural resources, pressure that has traditionally resulted in a decrease in the fertility of agricultural soils, overgrazing, and increased water-borne erosion.

Cereal cultivation for own consumption dominates. Arboriculture (olive, fig, peach, and apple) is present, for both self-consumption and marketing. This agriculture experiences the same problems as those mentioned for farms outside forest areas: lack of fertility, sensitivity to drought, and risk of erosion.

Farms in agro-pastoral areas, outside the forest domain, face the degradation of rangelands, a decrease in the fertility of agricultural soils, and a very strong erosion of hydraulic origin. These farms are essentially based on cereal agriculture in association with extensive livestock farming. Cereal cultivation and the tillage on which it depends promote erosion. Erosion has significant consequences on the siltation of many dams in the region. The protection of these dams by the development of soil and water conservation techniques (CES) is a necessity. Apart from their mechanical aspects, the soils are often poorly suited to cereals; here, too sensitive to drought. Yields are usually low to very low.



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Overall, three production systems prevail in the Kef-Siliana transect:

- Dry cereal-based systems with cereal rotation, low integration of fodder crops, sheep activity, olive or fig trees, and existence of a small number of dairy cows on the household farm.
- Agrosilvopastoral farms dominated by extensive management of sheep and goats based on pastoral resources; this system can be integrated with dry cereal-based systems.
- In a few areas, irrigated systems with market gardening intercropped with arboriculture, but not a real intensification of crop rotation, and the development of dairy cow activity.

Major agricultural commodities and livestock

Table 4 gives a brief description of the farming systems at the first four sites of the ALL in Tunisia based on a focus group characterization of the ALL realized in September 2022. This characterization of the farming systems will be improved through a farm typology based on a household survey that will be reported at the end of 2023.

However, we can see that the main agricultural commodities are cereals, mainly wheat for food consumption and barley for feed consumption, and trees, with olive and fig trees. We can also find other plant and tree varieties such as almonds and apples for tree plantations and Gramineae and legumes such as vetch and Sulla. These two varieties have been developed over the past 10 years within several projects such as CLCA and PROSOL.

In the irrigated perimeters, farmers also developed vegetable crops mainly for sale.

The quasi-totality of the farming systems also includes ruminants, mainly cows for dairy products in the most favorable zone with irrigation facilities and sheep and goats in the less favorable zones, with sheep mainly for meat and goats for milk and meat. Except in the pastureland, manure is also collected and used on agricultural lands. In addition, the majority of farms raise poultry, mainly to cover the need for eggs and meat at the family level.

Other activities such as beekeeping are developing in the zone and constitute a non-negligible source of income.

Table 4: Some general characteristics of farming systems based on the farmer organization characterization (derived from the focus group, WP 1, 2022, see Annex 1).

	GDA Sers	SMSA Rhahla (Ankoud El Khir)	SMSA Kouzira	SMSA Chouarnia (ETTAWEN)
Number of members	6	3 + 1 employees	3	9
Number of supporters	55	27	114	120
Number of beneficiaries	55	100	240	500
% less than 35 years old	20	11	40	40
Livestock system	Small-ruminant breeders (owning fewer than 20 sheep and goats) represent 20% of supporters; breeders owning from 20 to 35 heads represent 60%; and 20% are big breeders. Bovine breeders owning fewer than 8 cows represent 60% of supporters; more than 35% have from 8 to 15 cows; and less than 5% have more than 15 cows.	Only 5 supporters have from 1 to 3 cows. More than 50% of supporters are small-ruminant breeders (average of 50 animals).		Lamb fattening and breeding (cattle and small ruminants). About 80% of members have from 20 to 50 heads of small ruminants and about 4 cows (Brown Swiss).
Crop system	The average farm size of supporters is - 2.0–2.5 ha in irrigated area and/or - 3 ha in rainfed areas. All of them have less than 10 ha. Some are renting land.	50% of supporters have a minimum of 5–6 ha (rainfed). Others have from 15 to 20 ha (rainfed). Cereal crops: wheat and barley. Olive trees: from 100 to 400 trees.	Most supporters own from 0.5 to 5.0 ha (diversified family farming). 20% have more than 5 ha. All-access to irrigation (natural springs in the village). Crops: cereal (wheat and barley). The olive trees are planted on collective land.	Field crops, especially wheat and barley. Olive trees (an average of 150 per farmer). 80% of supporters own or rent fewer than 20 ha (rainfed). 15% own more than 20 ha (rainfed). 5% have more than 200 ha (irrigated).
Other activities	Beekeeping, poultry, saffron and vegetable production		Fig trees, cherry trees Beekeeping	

Market information for both inputs and outputs

Agricultural inputs are largely subsidized and so the input market is largely controlled by the government through parastatal enterprises or government agencies, especially for fertilizer and seed. Other sectors have known a certain liberalization such as in the sector of chemical products for weed and pest control.

The majority of agricultural products are marketed through local markets (souks) and the prices follow the rules of supply and demand (i.e., their prices are determined by market forces). In addition, the marketing of agricultural products that are considered strategic goods such as grain and its by-products is regulated by the government through public enterprises. For instance, cereals are exclusively sold to the state-owned Cereals Office, with a monopoly on buying locally produced cereal grains and importing cereals from the international market. The Office National de l'Huile is in charge of buying and exporting locally produced olive oil and importing vegetable oil. For cereals and oil, the prices are guaranteed at the farm level; government agencies have the responsibility to secure the supply through storage capacity at the national level. In addition, raw milk is mainly sold to dairy cooperatives and collectors who supply dairy processing units. However, for strategic and non-strategic goods, illegal or parallel markets are tolerated.

So, at the ALL level, we can distinguish two types of markets: the local market in the commune, where farmers can find the majority of inputs for agricultural activities and sell some agricultural outputs, and the regional markets, especially for live animals.

Table 5 gives the average distance of the communes involved in the Tunisian ALL from the regional markets in the two governorates. The main market day in the region is Thursday although farmers can sell or purchase outside the region.

Table 5: Distance of the sites from the main regional markets (in km).

Distance matrix (km)	Sers	Kef	Makthar	Kesra	Gaafour	Krib	Siliana
Siliana	40	95	35	43	36	51	0
Gaafour	50	82	69	80	0	20	36
Kesra	55	101	18	0	80	96	43
Makthar	35	81	0	18	69	88	35
Kef	30	0	81	101	82	46	95
Sers	0	30	35	55	50	42	40
Krib	42	46	88	96	20	0	51

Source: *ODNO (2018a,b).*

Key factors affecting agricultural productivity

Along the Kef-Siliana transect, land degradation and soil erosion are the most severe natural and anthropic factors affecting agricultural productivity. As mentioned above, the landscape is characterized by steep slopes and several ravines caused by all types of erosion. Based on a survey conducted within the SWC@scale/PROSOL project Towards the Effective Scaling of Soil and Water Conservation Technologies under Different Agroecosystems in North and Central West Tunisia (2020–2023), 62% of the respondents are suffering from extreme water erosion problems, especially during the autumn rainy season when soils are bare. Also, farmers consider that wind erosion has the same impact on their land, especially during summertime with hot southerly winds (Frija et al., 2022).

Another key limiting factor is the low and variable precipitation, especially in the seeding season (November) and before flowering, especially for olive trees (February and March) and wheat (April).

Land fragmentation with population growth is another critical limiting factor that threatens the socioeconomic viability of farms and the social transfer of a viable piece of land to the next generation. Furthermore, this problem leads to a significant rural exodus of the young generation.

Faced with these natural factors that are exacerbated by the anthropic land pressure (with less than 5 ha on average per farm), the weakness and lack of training in extension service development make farmers feel often alone to face these natural challenges. Moreover, land degradation and erosion reduction need important infrastructure investments that require state interventions through national or international projects.

Finally, the recent cereal crisis caused by the Ukraine-Russia war exacerbated the problem of the dependence of the agricultural sector on feeds and concentrates in the international market. The current shortage of cereals and concentrates combined with price increases in legal and illegal markets caused some farmers to decrease or even abandon some livestock activities, especially dairy cows.

Agricultural financing

Agricultural financing is usually done through the government with special interest rates and conditions for the agricultural sector. The national bank for the sector, Banque Nationale Agricole (BNA), is the main lending institution. This government bank also provides credit to medium-to-large farms, with a system of monitoring and supervision of loan uses. About 120 regional offices exist, with a majority in the northern part of the country.

The BNA also manages special funds such as the Special Fund for Agricultural Development (FOSDA), founded in 1963, based on government budget allowances. It constitutes a major credit source for the agricultural sector. The main issues of the agricultural credit system are (as mentioned by Thabet et al., 1998): "(1) The existence of a multitude of agricultural credit lines with different lending conditions and interest rates; and (2) late payments that make debtors ineligible for credit." In addition, some special bank systems have been developed to facilitate credit access for small and medium farmers. This kind of credit remains under the supervision of the Ministry of Agriculture, with support and training from agricultural services. Other credit systems are based on giving in-kind to small farmers by government agencies such as the National Grain Board (Cereals Office) or parastatal enterprises.

“Some special bank systems have been developed to facilitate credit access for small and medium farmers.

However, this formal credit remains the financial fund for medium-to-large farmers. According to ONAGRI (2006), 87.5% of the farms nationally haven't asked for agricultural credit and 6.2% have asked for a credit that has been refused. So, in total, only 6.3% received a formal credit. The demand for credit for agricultural campaigns and investment involved 29.9% and 18.4% of large farms (>100 ha) and only 3.7% and 5.2% of small-scale farms (less than 5 ha), respectively, in 2006.

During the focus groups conducted in September 2022 in the Tunisian ALL, other sources of credit systems were identified, such as:

- Union Tunisienne de Solidarité Sociale (UTSS) provides small credit amounts from TND 3,000 to 5,000 per person without an interest rate; the main conditions are to follow training sessions on education, health, and social issues.
- Association Syres pour le Développement, which is an association of civil society that gives credit with 5% interest to invest in dairy cows (condition: follow training with a certificate; be a landowner).
- Enda Tamweel is a microfinance institution based in Tunisia that offers financial services for micro-entrepreneurs with an interest rate of 25%. The main advantage is that the conditions of access are easy without special guarantees.

Physical and human assets and land tenure situation

In the Tunisian ALL, the main physical assets of farmers are land and livestock in the two governorates (**Table 6**). A total of 98% and 70% of the family farms in the two governorates depended on only on-farm activities for their subsistence in 2004.

Small livestock holdings (2 to 3 cattle, 14 sheep, and 3 goats on average) account for 83.5% of the total livestock and represent 67% of the cattle population, 52% of the sheep population, and 59% of the goat population.

Small-scale family farming covers 78% of the total number of agricultural holdings and only 43% of the total agricultural area (Marzin et al., 2016). A total of 66.8% of the small family farms had an area of less than 5 ha and 86.7% had an area of less than 10 ha in 2014.

Table 6: Various indicators regarding farm activities and assets.

	Governorate level		Farm level (average)	
	Kef	**Siliana**	**Kef**	**Siliana**
Number of farms	18,110	19,400		
Total agricultural area (000 ha)	387	346		
Only one parcel	52%	76%		
Land in inheritance	91%	80%		
Agricultural land				
SAU (ha)	380,000	334,000	21	17
Dryland (%)	61%	75%		
Mixed dry-irrigated lands	39%	25%		
Cereal land	75%	57%		
Legumes	–	<2%		
Fodder crops	10%	17%		
Vegetable crops	2%	1%		
Fruit trees	12–13%	25%		
Livestock				
Cattle	26,200	31,700	1	2
Sheep	335,000	295,000	18	15
Goats	18,900	34,600	1	2
Equipment				
Access to drinking water	25%	29%		
Access to electricity	81%	89%		
Tractors	2,600	2,000		
Activities				
Number of households living entirely from agricultural activities on their farms	17,800	13,600		
Without non-agricultural lucrative activities	75%	55%		
Human and social				
Cannot read or write	40%	45%		
Social services				
Access to cooperative services	<2%	<2%		
Access to GDA services	<1%	<1%		
Access to GIC (Groupements d'Intérêt Collectif) services	<1%	<1%		

Sources: *Atlas Siliana, 2013; Atlas Kef, 2015; ODNO, 2018*

Tables 7 and 8 show different configurations of farm scale according to the four sites composing the Tunisian ALL in 2022, from a large majority of small-scale farms in Chouarnia and Kesra to a more diversified profile in Sers and El Rhahla, even if the majority of farms have less than 10 ha.

Land tenure has evolved from the 1960s dominated by the cooperative system and state farms to land privatization during the 1970s. Nowadays, we can mention at least three kinds of land ownership: (1) state ownership or state farms to secure some strategic goods, (2) private ownership for the majority of cultivated lands by family or entrepreneurial farms, and (3) collective or state land ownership for pastureland and forest.

Land ownership is mainly nuclear family ownership transmitted between generations or joint/undivided ownership, with more than two adults living in separate households. Undivided ownership is very frequent. Land transactions exist but are not generalized.

Table 7: Percentage of small and very small farms (less than 5 ha in rainfed zone).

Site	Level of information	% of farms <10 ha
El Rhahla	Gaafour (sector level)	46.6
Kouzira	Kesra (sector level)	72.5
Chouarnia	Makthar (sector level)	80.4
Sers	Kef (governorate level)	58.6

Table 8: Number of female animal heads by species at each site in the ALL, Tunisia.

Site	Level of information 2018	Sheep	Beehives	Cattle (pure)	Cattle (local)
El Rhahla	Gaafour (sector level)	16,198	1,300	170	556
Kouzira	Kesra (sector level)	18,906	1,800	30	280
Chouarnia	Makthar (sector level)	22,670	1,300	396	1,173
Sers/Elless	Sers (governorate level)	22,451	28	445	672
Hamam Badhia	Krib (delegation level)	29,500	NA	1,260	2,750

Source: *Atlas Siliana (2013).*

Land tenure has evolved from the 1960s dominated by the cooperative system and state farms to land privatization during the 1970s. Nowadays, we can mention at least three kinds of land ownership: (1) state ownership or state farms to secure some strategic goods, (2) private ownership for the majority of cultivated lands by family or entrepreneurial farms, and (3) collective or state land ownership for pastureland and forest.

Land ownership is mainly nuclear family ownership transmitted between generations or joint/undivided ownership, with more than two adults living in separate households. Undivided ownership is very frequent. Land transactions exist but are not generalized.

Supportive infrastructure (roads, electricity, storage)

Table 9 gives a first overview of supportive infrastructure in the Tunisian ALL in terms of roads, electricity access, and drinking water access. If the electricity network is well developed in the ALL, we can see contrasting access to drinking water, especially with a lower level in Sers than at the other sites. Also, if the sectors of Sers and Gaafour are well covered by roads, the sectors of Makthar and Kesra located in more accidented relief zones are less accessible.

Table 9: Infrastructure access at the four sites of the ALL in Tunisia.

Sites	Sers/Elless	Makthar	Kesra	Gaafour	Krib
Road network (km)	244	85	53	112	116
Electricity access (%)	99.3	98.3	97.5	97.7	98.2%
Access to water (%)	71.3	86.4	96.6	88.9	96.5%
Poverty (poor families)	1,363	1,511	1,032	1,030	NA
Unemployment rate (%)	27	13.5	11.2	17	17.8 (2004)

Social context

Household structure and size, rural employment, and poverty

Nationally, the average rural household size decreased from 5.7 persons per household in 1975 to 4.3 per household in 2014 (data from the Recensement Général sur la Population et l'Emploi, RGPH, 2014, cited by Marzin et al., 2016). In 2004–2005, family labor covered 77.5% of agricultural work days, complete with 9% for occasional workers and 13.5% for permanent employees. However, these official statistics hide the huge contribution of women as occasional workers in the agricultural sector. This increasing contribution of women can be attributed to the growing involvement of men in multiple non-farm activities and also the disinterest of youth in manual agricultural tasks. We can also link this disinterest to the growing level of education of the young generation, with at least 50% with a primary certificate. Vice versa, the increased mechanization of agricultural work, notably plowing, had led to a significant decrease in the number of permanently paid workers, except for entrepreneurial farms. Cited in Marzin et al. (2016), "According to the population census conducted by the National Institute of Statistics (INS), female employment in agriculture rose from 13.56% of the total agricultural employment in 1975 to 20.1% in 1985, 29% in 2005, and 36% in 2012."

In 2004–2005, the average pluri-activity was estimated at 48.6%, up to 55.4% for small-scale farms of less than 5 ha, and can represent up to 66% of the total income on irrigated holdings and up to 90% of total income in rainfed holdings in the south (Chebbi et al., 2019).

“ This increasing contribution of women can be attributed to the growing involvement of men in multiple non-farm activities and also the disinterest of youth in manual agricultural tasks

The national poverty rate decreased from 25.4% in 2000 to 15.2% in 2015 and 13.8% in 2019 (World Bank, 2022). However, rural areas have about 23% of the poor vis-à-vis only 9% in urban areas. Moreover, this decline could be attributed to a national cash transfer program. However, the growing challenge would be labor productivity for the young generation to cover the costs of intergenerational solidarity (Marzin et al., 2016).

Contrary to the overall trend nationally, the rural areas of the Tunisian ALL are experiencing difficulties linked in particular to the rural lifestyle and the lack of infrastructure, especially in education and health (**Tables 10 and 11**). The human potential, composed mainly of young people, suffers from a high illiteracy rate and a low level of schooling. Poverty and the lack of transportation associated with the high unemployment rate are the main characteristics of these areas (Shimi, 2014).

Table 10: Access to education and culture at the four sites of the ALL in Tunisia.

Sites	Sers	Makthar	Kesra	Gaafour	Krib
Primary schools	16	23	14	13	18
Students/professor	13.8	12.6	14.2	13.9	
Cultural associations	5	5	1	4	
Persons per chair in library	103	106	142	99	

Source: *ODNO (2018a,b).*

Table 11: Health access at the four sites of the ALL in Tunisia.

Sites	Sers	Makthar	Kesra	Gaafour	Krib
Population per medical doctor	4,651	3,440	3,650	3,540	
Medical beds per 1,000	0.30	1.37	0.60	1.41	

Source: *ODNO (2018a,b).*

Community leadership in the ALL context

The community is composed of large families, themselves gathering in a set of households that compose the central decision unit for land and farm activity management. The community leadership is mainly organized at the village (*douar*) level with a local representative (*Omda*) at the interface between the community and the administration.

A second layer of leadership involves the associations, farmers' associations such as SMSA or GDA with a president, and supporters or social associations. An FO (GDA or SMSA) is usually created at the level of a social community and an agroecological area, both not necessarily homogeneous. For example, the GDA Sers is composed of women with and without irrigation systems, without necessarily sharing the same local network (neighboring). In addition, the SMSA Rhahla comprises members of the same extended family. The social composition of this SMSA can cause problems when seeking to scale concerns because of past social tensions with other extended families. So, an FO is embedded in a diverse social system and ecosystem case by case. Considering six FOs with various social and technical histories can allow capturing agroecological transition dynamics according to a certain diversity of social and policy configurations. Women are usually well represented as supporters or beneficiaries in the FOs. For example, in the Tunisian ALL, women represent from 20% to 50% of the beneficiaries in mixed FOs, and one FO is managed completely by women and the supporters are all women. So, FOs such as SMSA and GDA not based on land ownership constitute interesting social spaces for women's empowerment.

FOs and individual farmers with land assets are supported by CTV (Centre Technique de Vulgarisation) through the CRDA (Commissariat Régional pour le Développement Agricole).

Migration

Nationally, migration movements between major regions are quite significant and migrants leave the western and southern regions of the country (called "repulsive poles") to settle in the District of Tunis or the northeastern and central-eastern regions ("attractive poles"). These movements are explained by the decline in agricultural productivity and income from agricultural activities and the fragmentation of agricultural land (Chebbi et al., 2019).

Regionally, the migration balance was negative during the last decade as we see in **Table 12**.

In the Tunisian ALL, the departure of the young generation was a common concern raised by people of the four sites during the focus groups (WP 1, Visioning).

Table 12: Migration balance in the Kef-Siliana transect.

Migration balance	2014-2019	2019-2024 (prevision)
Kef Governorate	-6,135	-4,462
Siliana Governorate	-6,431	-4,677

Source: *ODNO (2018a,b).*

Political context

A brief review of national policies over the last 15 years oriented to sustainable development

In 2007, Tunisia developed a national strategy for adaptation to climate change for the agricultural sector. Following the revolution of 2011, the country began a series of studies to develop a comprehensive national strategy on climate change (UNFCCC, 2014). In 2011, the government published a Livre Blanc to promote a new regional development strategy in Tunisia to upgrade backward regions by diminishing socioeconomic inequalities. One of the main drivers was to be connecting the lagging areas to the advanced areas to exploit the spillover and diffusion effects between the regions. Politicians used to call this policy "positive discrimination" in favor of the least marginalized country areas, which are mostly rural with extreme poverty and low provision of public infrastructure (and services). This was also a first step toward the promotion of the "social and solidarity economic" law,[2] which was promulgated by the parliament in 2020. A major (IFAD) development investment program,[3] based on opportunities created by this law, was launched to promote social and solidarity enterprising in central Tunisia with a total investment of USD 51 million, aiming at directly benefiting 16,800 households in the region of Kairouan. Although the law exists in draft form, it has not yet been officially published, voted on, or accepted in its full version. This created a legal and procedural vacuum preventing the realization of the potential benefits of this social and solidarity economy in Tunisia. The delayed publication and prioritization of this law can also be attributed to shifting political dynamics. The government's attention might be redirected toward addressing more immediate and pressing concerns.

The agricultural policy adopted under the 12th Plan (2010–2014) sought to respond to a certain number of sectoral challenges, such as (1) rational and sustainable exploitation of natural resources and their protection against overuse and degradation; (2) consolidation of food security in addition to social security, especially about decreasing unemployment rates and migration in rural areas; (3) upgrading of the competitiveness of the agricultural sector in the face of challenges of domestic market liberalization and standard requirements of international markets; and (4) the intensification of farmers' aggregation into different forms of associations and organizations, including mutual service companies (types of small cooperatives), specialized inter-professional groups, and agricultural development groups (non-profit farmers' associations aiming at facilitating collective management of natural resources). This last program aimed at facilitating farmers' access to agricultural supply of inputs and services, marketing and value chain integration, access to public research and extension systems, and smooth (and efficient) technology transfer approaches.

2 Law n° 2020-30 du 30 juin 2020, regarding the «économie sociale et solidaire». Reference to this law in the public official journal/law book can be found at https://bit.ly/40D4yQE

3 The program is entitled "Economic, Social and Solidarity Project (IESS-Kairouan)" and can be found here: https://www.ifad.org/ar/web/operations/-/project/2000002075

Zied Idoudi / ICARDA

A final objective of this development plan was to (5) improve the profitability of agricultural activity, which can make it more attractive for investments and thus higher added value and consolidated growth over years, etc. In addition, there was a growing recognition of the need to take up other emerging themes, such as the inequalities and marginalization of some regions of the country, employment in rural areas (in particular for young people), and the weakness of farmers' organizations as well as the pressure on natural resources (soil, water) and purchasing power, thus affecting food security and human health. The previous policy objectives of the 12th Plan (2010–2014) recognized these weaknesses and were trying to support a transition pathway toward a more efficient and sustainable agricultural sector.

The following five-year economic and social development plan for the period 2016–2020 (13th development plan) aims at "*Increasing the agricultural sector's contribution to the national development effort.*" Seven strategic axes have been considered as a priority for policymakers:

1. The development of natural resources, their sustainability, and the mitigation of the impacts of climate change
2. The regularization of key problematic land tenure situations that are leading to land insecurity and a respective lack of private investments, whose objective is to also cope with the fragmentation of agricultural land and allow the optimization of the exploitation of public/collective lands
3. Promotion of agricultural production systems, strengthening their competitiveness, developing their capacity of resilience to climate hazards, and ensuring their sustainability
4. Stimulation of private agricultural investments and their related financing services and schemes
5. Promotion of small-scale agriculture, family farming, and strengthening its role in rural development
6. Promotion and dissemination of knowledge and innovation in the agricultural sector
7. Improving governance in the agricultural and fishery sectors.

A strategy for the development of the organic agricultural sector had been elaborated for the five-year plan 2016–2020. This strategy aimed to strengthen the contribution of professionals in the organic agricultural sector and to work on major axes such as the added value of the sector, the preservation of the environment, and health. Along this line, the label "Bio Tunisia" was established with the promulgation of Decree No. 2010-1547 of 21 June 2010.

A water and soil conservation strategy has been defined and promulgated to address adaptation to climate change and biodiversity protection (Sghaier and Neffati, 2017). The 2050 global strategic framework for the new Agricultural Land Conservation and Conservation Strategy (ACTA) was as follows: "*Prosperous rural areas, having supported their development in productive agriculture sustainably managing natural resources, and resilient to climate change, established through SWC production-oriented practices that are implemented and shared by farmers*" (DGACTA/MARHP, EU, 2017). Within the DG ACTA (2050) strategy that promotes agroecological practices (conservation agriculture, agroforestry, simplified crop techniques, no-till, direct seeding, permanent soil cover, etc.), agroecology is identified as a means to cope with water erosion, improve soil quality, and consequently contribute to an increase in agricultural yields.

> " The same ACTA 2050 Strategy recognized the need to develop innovative business models (based on social promotion and support for collective development of investment proposals by local communities) to support and sustain the scaling of agroecological practices and innovations

In addition, the National Strategy for Sustainable Development (NSSD) (ME, 2011) highlighted the first challenge – "to establish sustainable consumption and production" – and has included in its strategic choices "Promoting friendly farming ecological balance and adapted to changing climate." Challenge 3 of the strategy was to "sustainably manage natural resources," one of whose strategic choices is the conservation of biodiversity. The same ACTA 2050 strategy[4] recognized the need to develop innovative business models (based on social promotion and support for collective development of investment proposals by local communities) to support and sustain the scaling of agroecological practices and innovations.

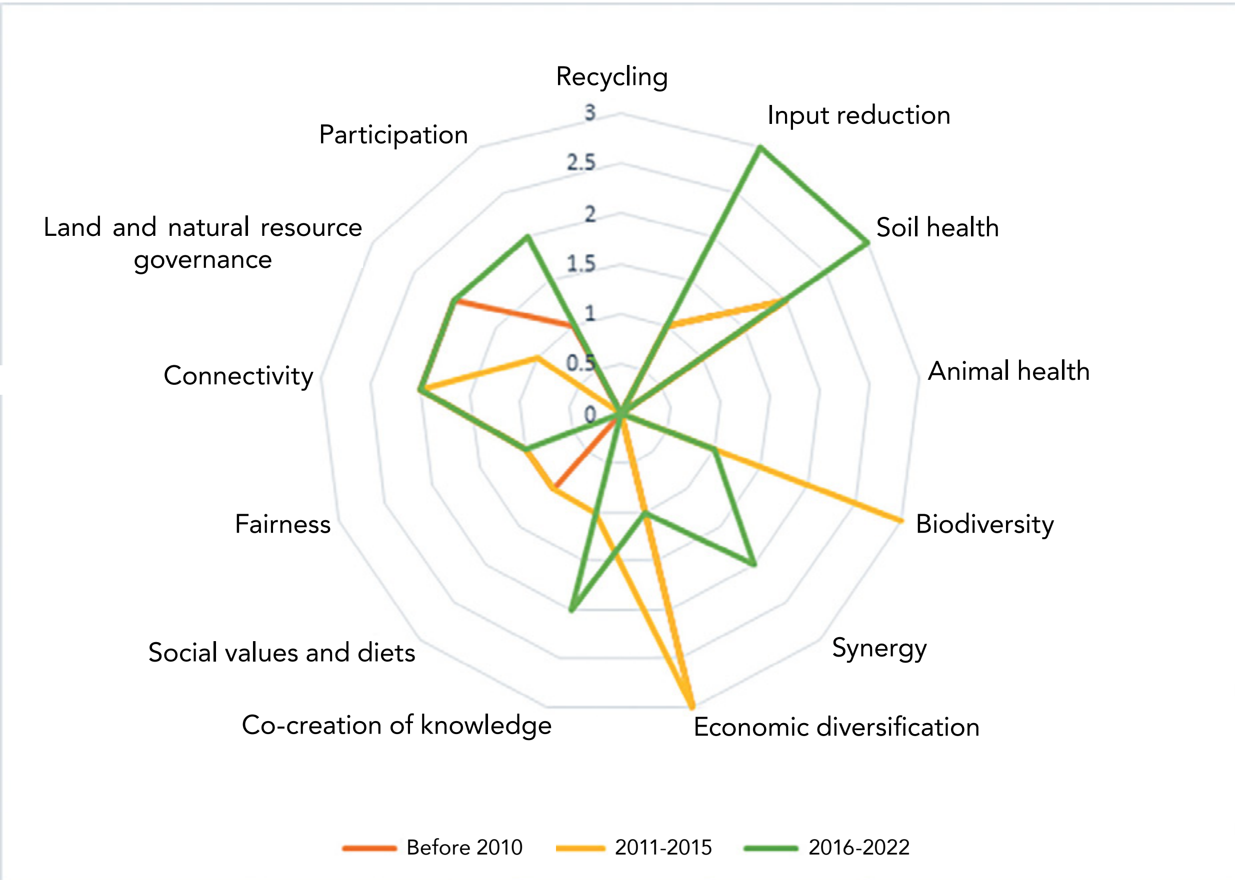
Tunisia's Ministry of Environment and Sustainable Development submitted the country's INDC in August 2015: "*Overall, the INDC is a well-crafted policy document, which presents a 41% decrease in its carbon intensity emissions target by 2030 (starting year 2010) covering the energy, industrial processes, agriculture, forestry and other land use, and waste sectors*" (Ministère de l'Environnement et du Développement Durable, 2015). It outlines funding needs of more than USD 17.5 billion for the period 2015–2030, primarily for implementation of the Tunisian Solar Plan, a transformational electricity sector plan for renewable (mostly solar) energy use in rural areas (for agricultural activities), which is also being widely supported by the national policy.

4 A summary description of the strategy can be found at http://www.onagri.nat.tn/uploads/docagri/167-AG.pdf.

In 2018, the agricultural research priorities for 2030 had been set by IRESA[5] following a participatory approach that involved farmers and farmers' organizations and development, extension, and research actors. Targeting research for impact, constraints and research needs communicated by farmers had been transformed into research themes that were grouped into six priority research programs: *(1) improvement of the efficiency of production systems and development of their resilience, (2) protection of natural resources in the context of climate change, (3) improvement of fishery and aquaculture production systems, (4) better management of forests and collective rangelands, (5) empowerment of rural populations and agricultural policies, and (6) farmers' organizations and promotion of agricultural and fishery value chains. Agroecology is among the research priorities.* In addition, IRESA has been coordinating since 2018 the reform of the training programs of the engineering cycle for seven disciplines. The objective of this work was to update these programs based on the needs and expectations of the socioeconomic environment and emerging challenges such as climate change. Agroecology has been included in education programs. Therefore, the targeted deliverables are skills and training referential. These efforts are promoted by IRESA and its institutions to render research more impactful in the agricultural sector and to improve the employability of agricultural diploma holders. Furthermore, co-generation and sharing of knowledge are both subjects of high interest to policymakers in Tunisia, who are working on finding innovative and effective approaches for technology transfer and for filling the gap between research and development. The Initiative on Agroecology has a role in many national and regional (African) dialogues aiming at enhancing the co-design and transfer of technological innovations.

Based on this rapid review of agricultural and environmental policies and their main priorities, we have allocated one or zero to each principle of the AE framework when a given policy addresses or does not address the principle. **Figure 6** gives an overview of the main principles guiding the national policies for the three successive periods over the last 15 years.

Figure 6. Agroecological principles considered in different national policies for the three periods, with three programs before 2010, five programs for 2011–2015, and three programs for 2016–2022.



A list of the considered policies in this analysis and their respective (relation) mapping to the different agroecological principles can be found in **Table 13**.

5 More information about these priorities can be found at http://www.iresa.agrinet.tn/announce/PrioritesRechercheAgricole%202030.pdf

Table 13. A first list of national policies promulgated in Tunisia over the last 15 years and their respective (relation) mapping to the different agroecological principles.

Review	Year	Recycling	Input reduction	Soil health	Animal health	Biodiversity	Synergy	Economic diversification	Co-creation of knowledge	Social values and diets	Fairness	Connectivity	Land and natural resource governance	Participation
National strategy for adaptation to climate change for the agricultural sector	**2007**													
Agricultural policy adopted under the 12th Plan (2010-2014)	**2010**													
A label 'Bio Tunisia' has been established under the promulgation of Decree No. 2010-1547 of 21 June 2010	**2010**													
Livre Blanc' as a new regional development strategy in Tunisia	**2011**													
National Strategy for Sustainable Development (NSSD) (ME, 2011)	**2011**													
Comprehensive national strategy on climate change (UNFCCC, 2014).	**2014**													
A strategy for the development of the organic agriculture sector has been elaborated for the five-year plan 2015-2020.	**2015**													
Country's INDC	**2015**													
Five-year economic and social development plan for the period 2016-2020	**2016**													
2050 global strategic framework for the new Agricultural Land Conservation and Conservation Strategy (ACTA)	**2017**													
Agricultural research priorities for horizon 2030 had been set up by IRESA	**2018**													

Regional policies

Land, water, and forest conservation are now among the top priorities of national policies. Despite the early concern about these central resources, limited progress in terms of policy design, implementation, and effectiveness had been recorded. New challenges related to the frequency of extreme climate events, resource scarcity (and degradation), and social pressure are adding more complexity to policymaking and implementation.

A participatory approach has been used at the regional and local levels since the early 1980s, in which the local communities have been considered as the central players of any development action, and were consulted (mapped/identified) before undertaking development actions and investments. This has led to mixed performance and results, with some cases of success and others of failure.

Policies in the regions have now shifted from a participatory approach toward an inclusive and sustainable value chain (VC) perspective. A focus on value chains has been seen (since late 2000) as a means to stimulate local economic and social dynamics while keeping a focus on resource protection and preservation. The lack of strong administrative expertise on value chains in the regions (and locally) made it difficult to properly implement and use this approach for local development in rural areas. Thus, the outcomes of these policies (and in current development and investment programs) were also mixed, at least so far.

As a complement to the value chain approach, the transition of territories in the Tunisian mountains is considered to be potentially supported by the creation and reinforcement of farmers' collectives. These structures are susceptible to breaking with the logic of "control" of the rural population that has prevailed for more than a century in these territories.

At a more local level, the Tunisian ALL is concerned with some regional development programs as described above (value chains, social enterprising, ACTA 2050 for soil and water protection through sustainable financing models, etc.) in addition to other direct incentives (subsidies) provided especially to farmers operating under irrigated conditions (having access to a private or collective source of water). A national inventory of ongoing AE projects (WP 5) shows that these zones (Siliana and Kef) are already the local target of other programs (**Table 14**).

Table 14: Development projects or initiatives in the Tunisian ALL (linked to WP 5).

Name of initiative	Type of initiative	Project activities were conducted to address AE principles?	Intervention logic
PROSOL	**Project**	Reinforcement of adoption of soil and water conservation practices at local level	Innovations for farmers
PROFITS	**Project**	The development of agricultural and forestry sectors as a lever for the socioeconomic development of vulnerable areas to strengthen and energize inclusive territorial development processes	Value chains
PACTE	**Project**	Territorial management of AE practices	Multi-stakeholder platforms
IAAA	**Project**	Innovations in the agricultural and agri-food sectors have contributed to sustainable rural development in some rural areas; scaling up, capitalization, anchoring, and sustainability of promoted innovations	Value chains

Mapping regional policy actors involved in the ALL in Tunisia

Here, we propose to start figuring out the policy involvement of the 500 stakeholders who already participated in the different events of the Initiative on Agroecology (either for coordination and planning meetings or for focus groups, trainings, and policy dialogues) (**Figure 7**). Proxy variables to reflect the level of policy involvement and influence of these involved actors were developed. The four (policy-oriented) dummy variables each represent one of the following categories of actors:

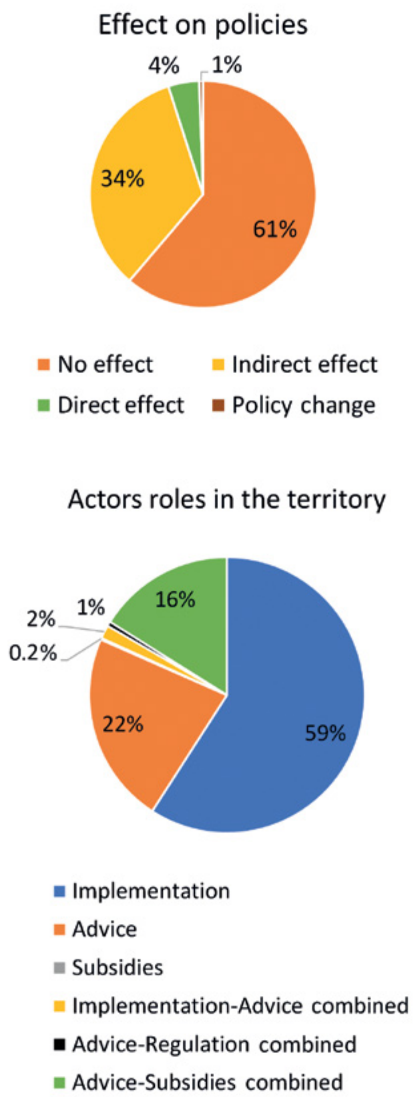
- No policy influence
- Indirect policy influence
- Direct policy influence
- Policy changers/drafters

Descriptive statistics of these variables for the total sample of 500 involved stakeholders generated some insightful information, which can be used during the remaining initiative implementation period for active policy engagement and changes. The results of this "policy-oriented stakeholders' mapping" exercise are shown below.

Figure 8 shows that 61% of the involved (beneficiary and participant) actors in the different Agroecology Initiative activities have no policy influence. These are mostly farmers and farmers' associations, which are supposed to be "policy-takers" because of their low level of organization and lobbying, respectively. Some 34% and 4% of the actors involved have indirect and direct policy influence, respectively. Finally, only 0.5% of the involved actors are actually "policy changers." This shows that more efforts need to be made to increase the participation and engagement of actors who have a direct effect on policy changes, including actual policymakers and changers in Tunisia.

Figure 7. Typology of (about 500) participants (and beneficiary) stakeholders and actors involved in the activities of the Initiative on Agroecology in Tunisia.

Figure 8. Stakeholders' mapping from a policy-oriented perspective (left) and based on their respective roles in the Tunisian ALL.

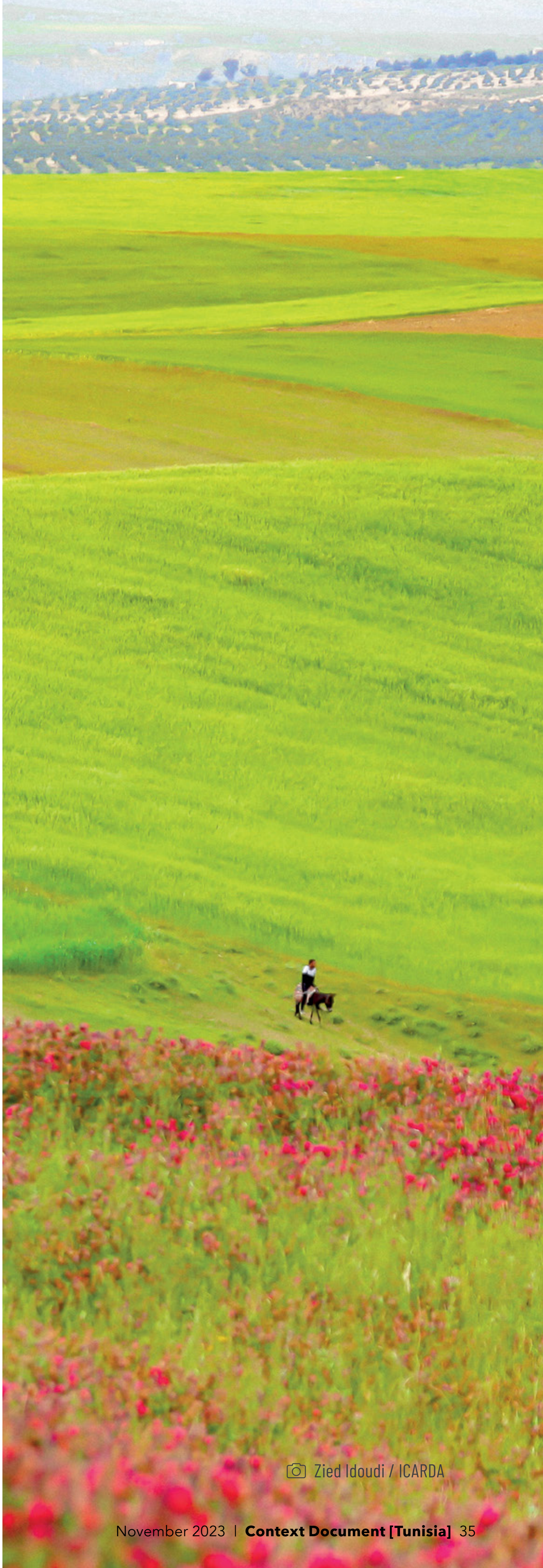


The same 500 actors were also characterized based on their respective roles in terms of territorial development. Each of these actors, depending on their administrative position (or type of activity locally), was given one of the following functions (Schulp et al., 2022)[6]:

- Implementation
- Advice
- Subsidies
- Implementation-advice combined
- Advice-regulation combined
- Advice-subsidies combined

Results of the territorial analysis show that most of the involved actors in our ALL in Tunisia are working on implementation, advice, and advice-subsidies combined, respectively.

6 Schulp CJ; Komossa F; Scherer L; van der Zanden EH; Debolini M; Piorr A. 2022. The role of different types of actors in the future of sustainable agriculture in a Dutch peri-urban area. *Environmental Management* 1-19.



The current state of agroecological principles in the ALL

Recycling

Principle: The recycling principle aims to enhance the use and valorization of local renewable resources (nutrients, biomass, or water) while respecting as far as possible the resource cycles (Wezel et al., 2020). The recycling principle can be extended to seed and breed renewal management at the farm or agroecosystem level (FAO, 2019).

In the Tunisian ALL: The targeted farm systems in the Tunisian ALL are fundamentally mixed integrated crop-tree-livestock systems in which the crop residues from annual and perennial crops are used in the feeding management of animals, which in turn provide a part of the nutrients (mainly manure) for soil fertility management (that can be captured by the percentage of crop residues in the feed requirement or the percentage organic fertilizer in total N supply for soil fertilization management). Over the past 20 years, national and international research have sought to optimize this biomass valorization. For example, at the end of the 1990s, ICARDA, through the Maghreb-Mashreq project (1995–2005), conducted research and development activities to valorize the cactus pads and the feed blocks made from crop and tree residues in the feed requirement of small ruminants. This research was conducted in mixed crop-livestock systems in the central part of Tunisia. If the feed block technology has not obtained the expected success, the use of cactus pads has become a common practice. More recently, in the Tunisian ALL, we can cite the adaptation of mechanization through the pellet machines in the PROSOL project (2020–2023) for increasing the consumption rate (and decreasing feed wastage) and enhancing the palatability of crop residues. This technology allows valorizing tree and crop residues, especially olive pomaces and stems. The CLCA project (2017–2022) proposed and developed grazing practices in agricultural conservation innovation (conservation agriculture) allowing both to valorize the vegetable biomass in the plot and to enhance soil fertility through manure. In parallel, in the whole country, we can see increasing research work on water recycling through increasing water storing or exploring the governance and social challenges in the use of treated wastewater in agriculture (Bahri and Brissaud, 1996; Brahim-Neji et al., 2014; Frascari et al., 2018).

Gaps

Relating to the use and valorization of local renewable resources, if the desk review of past and recent projects put the accent on feed rations using local resources, the majority of the feed rations were obtained with a staple feed such as barley for small ruminants and concentrates for cattle, without envisaging a substitution of these products that depend partially on importation. A few pieces of literature tried to gain an idea about potential valorization through the complementarity of crop and tree residues between regions. Generally, little is known about the income generation of the exchange of by-products largely considered as sub-products. From farmers' perspectives, the use of residues or manure was largely considered a traditional practice to face shocks and not an innovative practice to support sustainable agro-food transformation.

Regarding seed and breed renewal management at the farm or agroecosystem level that represents traditional practices largely practiced by women, up to recently, this domain was not the priority of national research focusing on seed and breed performance more than renewal management.

The main issues in recycling wastewater in agriculture come from two orders: the local organization between farmers and the high development (not always controlled) of private wells and forages.

Priority-innovations

Because of the dramatic increase in cereal prices in Tunisia since 2022 (linked to the Russia-Ukraine war), the feed supply of livestock is widely threatened. If farms have started to destock animals, regional and national government agencies are actively seeking all opportunities to substitute these structural cereal imports with local and national production. Notably, they would like to emphasize leguminous crops such as Sulla or vetch producing a large amount of biomass. Also, national research institutes such as Institut de l'Olivier work on the technologies of compost and biofertilization to decrease chemical fertilizer purchases. These different options also aim to meet the increasing challenge of climate change with repetitive droughts in semi-arid areas.

In addition to these options that will be further investigated and supported by the Initiative on Agroecology, we proposed to explore plant species and agronomic practices (such as legume-Gramineae associations and intercropping with fruit trees) that produce both food and feed nutrients. The multiple crop and tree residues (such as barley bran, straw, olive pomaces and stems, etc.) can be recycled through grinders and pellet machines to constitute nutritive feed rations for animals as a substitute for concentrates or grains. The recycling activities with the crop and tree residues will be assessed at the farm and local (or regional) level to favor complementarities and economic valorization through market or social exchanges.

Water recycling will not be directly addressed in the Tunisian ALL knowing that the majority of the rural communities in the ALL are in the rainfall zone with little or no water supplementation. If drought is one of the main concerns, the Initiative proposed to focus on practices to cope with it.

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Input reduction

Principle: The input reduction principle proposes to decrease the use of chemical inputs that negatively affect human, animal, and soil health and to increase the self-sufficiency and resilience of rural families by decreasing the dependency on purchased inputs. This input reduction is part of the research on economic efficiency by seeking to optimize production with minimum inputs.

In the Tunisian ALL: As in the majority of North African countries, mixed crop-livestock systems strongly depend on barley grain for sheep and goats, concentrates for cattle, and chemical fertilizer or treatment for crops. The use of these inputs has been intensified to increase production and ensure relative food autonomy (inspired by the Green Revolution). However, this increase in input use largely depends on input importation nationally and agricultural subsidies at the farm level. Now, with the world price increase for cereals and fertilizer and the financial crisis in Tunisia, this model is strongly questioned and challenged.

Moreover, Tunisia is familiar with the dramatic sequence of dry years in the semi-arid zones where the main production of grain cereals, meat, and milk for domestic consumption and olives for exportation is concentrated. The water concern is not new. Research on water use and efficiency has been strongly developed in Tunisia. The majority of this work sought to quantify how much water use could be diminished without altering the production level and quantities of other inputs used (Dhehibi et al., 2007; Frija et al., 2012; Chebil et al., 2014).

Gaps

However, the reality is quite contrasting when comparing rainfed and irrigated zones. If the irrigated zone has known an increasing use of chemical inputs, especially for vegetable crops, the use of external inputs has remained relatively low in the rainfed zone, notably linked to the permanent risk of drought. The main input is grain subsidies to feed the animals. So, in this rainfed system, the main input reduction practices should not be sought automatically in the reduction of input use but rather in the substitution of high-cost inputs by low-cost inputs.

Priority innovations

In the Initiative on Agroecology, priority has been given to innovations that decrease the dependence on purchased inputs, with permanent attention given to soil fertility maintenance. For that, we propose to work on manure collection and its valorization through compost and the use of biofertilizers. These technologies, especially compost, received the maximum score for demand in the Tunisian ALL during a regional meeting with five of the six farmers' organizations in the ALL (regional meeting with the six FOs in February 2023).

A second axis is for agronomic practices, notably legume-cereal association and rotation, to increase biomass production for both feed reduction for livestock maintenance and soil preservation.

Alternative practices such as pastureland improvement through tree plantations (cactus, carob) are explored. The objective is to increase feed autonomy and preserve the natural environment.

Soil health

Principle: The soil health principle aims at improving organic matter management and soil biological activity to favor vegetation growth.

Tunisian ALL: Several studies were conducted to assess soil health along the Kef-Siliana transect (Tunisian ALL) using different soil indicators (physical, chemical, and biological). Soil texture was investigated in the study of Moussaoui et al. (2010) as a physical indicator to evaluate the impact of land degradation by erosion in the Siliana region. Masghouni (2018) also studied the effect of vegetation cover on soil properties in the Siliana region. The results of this work showed that soil under plant cover positively affects physical, chemical, and biological indicators. Other work has focused on the effect of minimum tillage or reduced tillage on physical, chemical, and biological indicators in both the Kef and Siliana regions (Jemai et al., 2012, 2013). The results of this work showed that soil health can be improved by reducing tillage intensity, planting cover crops, and keeping crop residues and that biological soil health indicators associated with labile carbon and nitrogen are most affected by management practices such as tillage intensity. Allani et al. (2022) showed that the factors that influence the dynamics of nitrogen and phosphorus at this study site are essentially the physicochemical properties of the soil, such as texture, clay content, structure, and soil nature.

“The results of this work showed that soil under plant cover positively affects physical, chemical, and biological indicators.

In the Kef region, Rezgui et al. (2014) studied the effect of tillage and crop type on physical soil properties such as bulk density, structural stability, soil moisture, and porosity. Indeed, no-tillage enriches the soil with organic matter and therefore improves structural stability. However, the cultivated species significantly affected the physical and water parameters of the soil. The highest values of bulk density and structural stability were observed at the level of Faba bean crop conducted in no-tillage. This species benefited more from the effect of straw residues left by the previous durum wheat crop.

In summary, “*Results from the CLCA project in Tunisia showed that CA can increase yields a few years after adoption and make crops more resilient to changing climatic conditions (Cheikh M'hamed et al., 2018; Bahri et al., 2019). CA can reduce drought effects through better water storage and availability during the crop-growing season in wheat-based systems (Mrabet et al., 2022)*” (citation by Dhehibi et al., 2023).

Gaps

Soil health and its management through agronomic practices has been comprehensively studied over the last decades, notably linked to soil fertility degradation that constitutes one of the major problems in the zone. However, the alternative plant species or practices proposed over the different projects (for example, CLCA, 2017–2022) require significant support in seed supply and machines.

Second, if the majority of soil health indicators were addressed in the Kef and Siliana regions by physical indicators (such as texture, structure, bulk density, porosity, and soil moisture), chemical indicators (such as soil organic matter content, CEC, nitrogen content, phosphorus content, potassium content, and $CaCO_3$ content), and biological indicators (such as microbial biomass and microbial biomass activity), all these indicators have been determined by researchers for specific purposes and do not reflect farmers' knowledge. It is therefore imperative to study the farmers' perception of the indicators of the health of their soil.

Priority innovations

First, crop-livestock integration and diversification can play a role in enhancing soil health through organic matter (soil structure), worms, and microbial flora (soil texture and biology). Intercropping systems, agricultural conservation, and soil conservation practices allow the conservation of soil humidity and activity. All these options will be explored and re-modeled with farmers according to their needs and practices to fit better with their priorities and constraints. Second, we propose to study the farmers' perception of soil health to share a common language between research and development and facilitate the transfer of agronomic innovations to farmers.

Animal health

Principle: The animal health principle covers two dimensions: health and welfare (Wezel, 2020; FAO, 2019). Animal health by itself is indicative of the capacity of the animals to fulfill their normal functions (also viewed as the absence of diseases) although the animal welfare approach focuses on the well-being of animals in terms of living conditions and treatment (and then refers to the satisfaction of the physiological and behavioral needs of animals).

Tunisian ALL: Until recently, animal health in Tunisia was mainly a matter of the veterinary services organized in 2001 under three main organizations:

1. La Direction de la Santé Animale (DSA) is in charge of the control of animal diseases in terms of the design of strategies and guidelines, evaluation of animal health programs, management and promotion of epidemiological surveillance networks, and control and supervision of the practice of veterinary medicine.
2. La Direction de la Normalisation et du Contrôle Sanitaire aux Frontières (DNCSF) sets out health rules and regulations for animals and animal products for export and import, and ensures epidemiological vigilance of transboundary animal diseases.
3. La Direction du Contrôle des Produits Animaux et de la Qualité (DCPAQ) is in charge of defining quality criteria for animals, animal products and their derivatives, fodder, and additives. In 2014, the National Animal Health Surveillance Center (Centre Nationale de Veille Zoosanitaire, CNVZ) was created.

Each animal production district (called APA) is divided into a specific number of districts, corresponding to the division of the governorate into delegations. Each APA is defined according to the number of animals and includes one or two delegations under the general direction of CRDA. This APA covers both animal production and health.

> “ Many international programs have been implemented to strengthen the national framework and network of animal health.

Many international programs have been implemented to strengthen the national framework and network of animal health. We can mention two twin programs with the European Union in 2012 and 2022. However, from a rapid appraisal assessment of the animal health situation in Tunisia (Gharbi et al., 2020), one major issue was that “The farmers do not know against which diseases their animals are protected and when these vaccines expire” (p. 6). Also, it is mentioned that “The relation between the farmers and the veterinarians (field or governmental) is still very archaic and simple” (p. 7). So, at the interface with farms, the CLCA project organized specific training on animal feed and animal health. This training was conceived under the new approach of OneHealth to promote an integrated approach to health linked to animal management and their environment.

Gaps

When it comes to transitioning toward more agroecological practices in the area of animal health, the main idea is that we expect farms to decrease their reliance on classic tools/means that might affect ecosystems as well as human health. In other words, we should target innovations that aim to solve animal health problems without affecting human and environmental health.

Priority innovations

To close the gap, different research and development axes will be explored in the Initiative on Agroecology, such as

1. Introducing new/improved schemes for vaccination against major pathogens. The transition here is the gradual move from chemical and antibiotic treatments toward vaccinations.
2. Using acaricides and anthelmintic molecules with the lowest withdrawal periods for meat and milk (safer products).
3. Using acaricides and anthelmintic molecules that are less detrimental to the environment (fewer residues in soil and water; example of the effect of the molecule ivermectin on soil health).
4. Adopting new hygienic practices to diminish the use of chemicals against pathogens and disease vectors; such new practices mean less use of chemicals and their effectiveness can be assessed by their effect on the incidence of respiratory diseases, neonatal mortality, and incidence of udder diseases.
5. Adopting improved, integrated herd-health strategies for the control of endemic diseases with decreased reliance on the use of chemicals (for instance, adopting an integrated and rational program of preventive anthelmintic treatments at local/community levels to prioritize strategic treatments and significantly decrease risks of strong infections).

The level of complexity to implement and assess such practices is variable. However, increasing awareness among the target communities and the main players in the field of animal health will help to push these concerns toward the desired agroecological transition. Research to fill some gaps is also required, especially when it comes to points 4 and 5.

Biodiversity

Principle: The biodiversity principle aims at enhancing the diversity of plant and animal species to maintain the overall agroecosystem according to the principle of the diverse functional contribution of each species to the ecosystem.

In the Tunisian ALL, the main crop-tree-livestock system is composed of some subsystem species diversity such as wheat, barley, vetch, or other annual crops in the crop subsystem; sheep, goats, cattle, or even bee species in the livestock subsystem; and olive with fig or almond trees for tree plantations. To this farm diversity, we can observe biodiversity in common spaces such as forests or pasturelands. Erouissi et

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al. (2011) also analyzed the biodiversity of soil invertebrates to compare different agronomic practices such as conventional vs. no-tillage (NT) management. The results showed that NT enhanced the soil fauna populations either in diversity or in abundance at the targeted sites of Kef and Siliana.

Gaps

If the diversity of plants and animals is a characteristic and component of the mixed crop-tree-livestock systems in the semiarid zones of Tunisia, AE transformation seeks to favor the synergies between organisms and their functions. The second gap is the recognition and valorization of this biodiversity. In an olive-growing context characterized by the co-existence of various intensive and extensive cultivation systems, several traditional olive-growing regions, such as those concerning the Initiative on Agroecology in the north of Tunisia, require new techniques to be able to subsist in a competitive market. Low yields, traditional agronomic practices, lack of water availability, small size, and in some cases age of plantations (several hundred or even thousands of years old) are among the most important reasons that make it necessary to look for new forms of valorization. The specialization of olive-growing activity based on existing local resources and taking into account the particular socioeconomic context is suitable for many northern areas such as Ellès-Sers (Le Kef). However, the conservation of this biodiversity requires more knowledge and organization.

Priority innovations

Biodiversity will be addressed through the use of multi-species in crop, tree, and livestock systems and the degree of association and/or integration at the plot/farm level. In association with the soil health principle, the diversity of plant species and plant-soil-microorganism interactions promote soil biodiversity. This multi-species diversity will also be analyzed regarding the sensitivity and resilience of the introduced or developed species to dry events. Second, pastureland constitutes a reserve of biomass and healthy plants for ruminants and humans to improve nutrient availability (including healthy products such as medicinal plants, natural honey, etc.). Finally, the Initiative on Agroecology also proposed to valorize the local knowledge around traditional plants and trees such as carob in Kesra or melliferous plants in the forests to feed animals.

In the olive sector, biodiversity conservation requires several tasks linked to identifying, describing, and using the existing local genetic resources, often represented by a limited number of specimens of ancestral cultivars. Linked to other agroecological principles (such as the connectivity principle), we propose to explore and seek the implementation of any form of labeling, such as geographical indications, that takes into account local practices and environment.

Synergy

Principle: The synergy principle supposes positive ecological interactions from the diversification and integration of species and practices in agroecosystems.

In the Tunisian ALL, these positive ecological interactions in the agroecosystems have been mainly studied through different agronomic practices such as cereal-legume associations, rotation, or plowing practices and their positive ecological interactions, in particular on soil health (see Dhehibi et al., 2023). Other research work highlighted the positive contribution of livestock integration thanks to manure and the role of animals in biodiversity preservation through grazing practices. Beekeeping is also a major activity in the Tunisian ALL that favors synergies among plants, animals, and humans.


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Gaps

Linked to past evidence that diverse crop rotations and their integration over time support plant diversity, which helps break up soil-borne pest and disease life cycles, improve crop health, help manage weeds, diminish nutrient losses from soil, and improve soil health (Larkin, 2015), agronomic research needs to invest in more complex cropping systems with diverse plants in time and space to support diverse food webs and energy chains essential for cropping systems and microbial activity in soil.

Priority innovations

This synergy will be addressed through different mechanisms:

1. At the farm level, diverse crop rotations and associations will be co-conceived with farmers and analyzed in terms of energy chains (mainly biomass production) and microbial activity in soil.
2. Healthy soil requires active decomposition, nutrient cycling, and soil functions, which can be accomplished with crop rotations, cover crops, and organic matter amendments. Therefore, technological packages including agronomic practices and soil nutrient management practices will be co-conceived.
3. At the territorial level, livestock grazing management enhances ecological balance/interactions (synergy) and is usually integrated into a mixed feeding system (linked to the crop system). This enhances complementarity between agroecosystems.

Economic diversification

Principle: The economic diversification principle is part of the portfolio theory to manage social, economic, and environmental risks.

In the Tunisian ALL, small mixed-farming systems, operating on less than 10 ha (MARH, 2006), represent 75–85% of the agricultural land and these systems produce more than 80% of the agricultural products (Marzin et al., 2017). Economic diversification is the basis of the resilience and adaptation of these small-scale farms to ensure rural livelihood in this semi-arid environment where rainfall variability is high and permanent (as shown in similar agro-zones of Tunisia, Alary et al., 2022a, but also in various contexts, Alary et al, 2019; 2022b). Economic diversification has been mainly studied in terms of the contribution of crop, livestock, and off-farm activities to income source diversity, but also in terms of assets and net safety.

Gaps

Despite the important and recognized role of economic diversification in the resilience and adaptation of rural families in the semi-arid areas of Tunisia, this diversification is mainly addressed in terms of final outputs and products, and often ignored or underestimated is the contribution of co- or by-products derived from the crop-tree-livestock integration that generate a flux of items that generate indirect non-monetary economic value. Moreover, the evaluation of this diversification is often done at one time. This approach underestimates the total output of this diversification over time in a resilience perspective.

Priority innovations

This economic diversification will be addressed through the diversification of economic activities (at the farm and off-farm level) and their seasonal and annual economic contribution to cover the multiple nature of domestic and agricultural expenses in the short, medium, and long term. Thus, economic diversification is viewed as a means to address the adaptive capacity of family farms and their viability.

Co-creation of knowledge

Principle: The co-creation of knowledge principle aims to enhance and valorize traditional and scientific knowledge at the local level by improving horizontal exchanges (i.e., between peers or farmer-to-farmer exchanges). FAO (2019) also included the notion of access to agroecological knowledge through its transfer. Furthermore, and in complement to Wezel (2020) and FAO's delineation of the principles, we can cite the work of Folke et al. (2002) and Berkes (2007) that emphasized the human arrangements and the co-learning processes that support people living in harsh and uncertain environments.

> "In the decade of the 2010s, the co-creation of knowledge progressively took into consideration the local knowledge of farms to co-conceive adapted innovations.

In the Tunisian ALL, if this principle constitutes a permanent concern of the different research and development initiatives implemented in Tunisia over the last two decades (see WP 5 literature review of projects), it has become more and more central and strategic in the most recent ones and it changed perspectives. In the decade of the 2000s, the co-creation of knowledge focused on the sharing of knowledge by enhancing farmer-to-farm interactions and exchanges, notably by organizing farm visits, on-farm demonstrations, etc. In the decade of the 2010s, the co-creation of knowledge progressively took into consideration the local knowledge of farms to co-conceive adapted innovations. In this process, participatory approaches and platforms have become a key research approach to achieve this objective. At the Tunisian ALL sites, we can mention two projects based on this approach: the PACTE project, which implements innovations based on participatory approaches and platforms (co-creation), and the CLCA project, which has developed knowledge hubs as a final product of the project to ensure the scaling out of the cumulated knowledge (transfer) (Frija et Idoudi, 2020). This knowledge has become a reference in the implementation of the innovation process in the PROSOL project.

Gaps

If these last two examples clearly show a keen interest in research approaches to enhance the innovation process through participation and involvement of stakeholders embedding in the co-creation of knowledge principle, the lack of financing and/or motivation of staff in government agencies or the absence of networks with the private sector constitutes a major constraint to facilitating the innovation process, thus requiring more involvement and engagement from the private and public sector.

Priority innovations

In the Initiative on Agroecology, the co-creation of knowledge is mainly supported by the ALL organization and the participatory visioning and innovation co-designing that allow us to set the priorities and innovations to achieve them. In the first step, the six sites that have been selected covered a set of agroecological practices that offer an opportunity for farmers to enrich each other. Thus, the ALL can be considered as a vehicle to facilitate the transmission of knowledge from one site to another. Second, the process of visioning and innovation co-design allows us to use a mixture of traditional and scientific knowledge to co-design the innovations. Over time, we propose to monitor the change in agronomic practices toward agroecological transformation at and between each site to assess the knowledge sharing in the Living Landscape, focusing on the knowledge transfer and its transformation in the ALL. In each step of the ALL establishment, local and regional government agencies are associated. One main challenge is to give a concrete place and role to the private sector, notably through business model development.

Social values and diets

Principle: The social values and diets principle aims at developing agroecological transitions with respect to cultural values (based on identity and tradition) and culinary preferences while providing appropriate healthy and diversified diets. FAO (2019) provided insights into the mechanisms to decrease vulnerability regarding food security.

In the Tunisian ALL, social values and diets have often been often approached positively by highlighting Mediterranean diets based on olive oil (Thabet et al., 1994). Recent studies reveal the dramatic increase in obesity and chronic diseases in Tunisia such as overnutrition, which has risen to a higher rate (37.2% among women aged 18 years and over), and undernutrition (with 8.4% of children under 5 years stunted and 2.1% suffering from wasting) (Global Nutrition Report,

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2021). Micronutrient deficiencies such as vitamins A and D and iron deficiency anemia (Doggui et al, 2021; Salem et al, 2021) indicate poor-quality diets with possibly low nutrient density. Of the nutrition strategy indicators listed for Tunisia, no food-based dietary guidelines have been implemented. Adult females overall have a higher rate of both underweight and overweight (obesity) than their male counterparts (Global Nutrition Report, 2021), which indicates gender imbalance in nutritional status, with women being more adversely affected than their male counterparts. Women farmers' empowerment has been shown to influence the dietary diversity of women and their households positively in Tunisia (Kruse, 2019) and elsewhere (Sraboni et al., 2014; Malapit and Quisumbing, 2015).

Gaps

However, if the role of women in enhancing social values and diets is well recognized, and even if improving agricultural practices and production can lead to improved nutrition for family members whose children are suffering, it is not a piece of evidence everywhere and every time (Dury et al., 2015; Atta-Krah et al, 2022).

Priority innovations

In this domain, the Initiative on Agroecology in the Tunisian ALL proposes to focus on (1) the diversity of diets and diet composition building on local food commodities (related to vegetables, cereal, animal products, etc.); (2) knowledge of the nutritional facts of such food products (source of information related to healthy food, the best frequency at which to eat meat?, Which foods can negatively affect health?); and (3) social and gender equity in terms of consumption of such food products (linked to the fairness principle). Another axis of research and development will be the promotion of traditional products, of which smallholders are the main producers and of which niche products with high added value are a component, to maintain and develop demand. Two co-identified local products that have been targeted in the visioning process are carob and honey.

Fairness

Principle: The fairness principle aims at enhancing living conditions and equity regarding economic exchanges, employment, and even treatment of intellectual property rights.

In the Tunisian ALL, the question of fairness or inequity is/has been mainly addressed in terms of inequity of access to assets and decision-making at the household level (notably between men and women) (Najjar et al., 2019) or lack of information (Dhehibi et al., 2020), which also extends to access to extension services or markets in two governorates of Tunisia (Zaghouan and Kairouan) with similar mixed farming systems.

Gaps

We can observe that few studies address the problems of market access according to agroecological or conventional agricultural products. Without official recognition of local products or low-input products with characteristics similar to those of agroecological products, the added-value distribution does not allow giving value to the agricultural work and knowledge embedded in each product. Moreover, some of these local products such as carob are highly demanded at the international market with high value.

Priority innovations

In the Tunisian ALL, we propose to look at

1. Farm-gate versus market prices of agroecological produce, especially for products of "terroir" such as honey and dairy products.
2. Added-value distribution along the value chains, for instance, between farmers and intermediaries.
3. Access to valuable market information.
4. Wages/employment for agricultural workers along agroecological value chains by gender and age.

Connectivity

Principle: The connectivity principle aims at ensuring exchange and confidence between actors. This principle highlights the proximity and confidence between producers and consumers that should result from short chains or organizations.

> “ In the GDA Sers, women have created their selling point to valorize local dairy products (cheese).

In the Tunisian ALL, some local farm organizations (such as SMSA or GDA) started to value their local products. We can cite the honey or fig hams in the SMSA Kesra. In the GDA Sers, women have created their selling point to valorize local dairy products (cheese). Some of these activities are supported by national or international projects such as CLCA in Sers that indirectly seek to improve dairy production through feeding management of dairy cattle.

Gaps

In the Tunisian ALL and more generally in the country, if we can note an increasing interest in local products in large urban areas such as Tunis, Sousse, or Sfax, the lack of a network or knowledge of modern tools (digital tools) to capture demand out of their commune constitutes a major break in their initiative.

Priority innovations

In the Initiative on Agroecology, connectivity will be assessed both along the agroecological value chains from producers to consumers and in the ALL among the multiple actors engaged (considering the involvement of women and youth). At these two levels, we will consider different factors that can influence the degree of connectivity, such as proximity and facilities/infrastructure, the nature of the link (exchange of goods or services such as information or labor), and the frequency and intensity of the links.

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Land and natural resource governance

Principle: The land and natural resource governance principle focuses on institutional or organizational arrangements to sustain and even improve natural resource and land management. Natural resources include soil, water, and genetic resources. By management, we mean access to and use of resources. Governance also means institutional arrangements that recognize and support the role and responsibilities of all types of farmers, including small family farmers.

In the Tunisian ALL, the majority of agricultural land is under the statute of private land. For private land, one of the major problems is soil degradation, mainly erosion. Thus, many projects, such as PROSOL in Tunisia, seek to preserve soil with conservation techniques such as the Sulla plantation in Rhahla community or agroforestry techniques such as those in Kairouan (neighborhood governorate). Forests that represent about one-quarter of the area in the two targeted governorates are mainly managed by the state. In the forest, farmers can have access to and practice picking activities. Forest management is mainly piloted by the Direction Générale des Forêts, without farmers' involvement, although they are the first users of the biodiversity of these forest spaces.

Gaps

If several research and development projects, mainly in partnership with the DG-ACTA, sought to develop soil and water conservation techniques to limit and even decrease land degradation, the lack of financing over the long term or concertation with farmers beyond the targeted farmers or associations limits the impact and area of intervention.

Priority innovations

In the Tunisian ALL, we propose to favor farmers' involvement in soil and water conservation techniques to decrease soil erosion and water shortage by working on agronomic practices such as cereal-legume associations or plowing practices (through minimum tillage) that have already shown a positive impact on soil preservation. Working on these practices, however, needs to co-conceive their integration with the fully integrated system, notably by rational use of residues for animals. Another perspective on natural resource governance will be to work on residue management at the territorial level to favor compost activities for soil fertility management.

Participation

Principle: The participation principle is based on the involvement and inclusiveness of all farmers in social organization and decision-making processes in food systems. This participation also means institutional arrangements that recognize and support the role and responsibilities of all types of farmers, including small family farmers.

In the Tunisian ALL, the main organizational structures that compose the ALL are farm organizations such as GDA and SMSA. These organizational structures are considered the main actionable network to support a stakeholders' platform with the public and private sector (see Frija et Idoudi, 2020).

Gaps

These organizations, however, suffer from a lack of knowledge or a network to be the motor of their development. In the majority of cases, they are receptors of national and international support with few initiatives on their own.

Priority innovations

Participation through the Initiative on Agroecology will be addressed at the farm and FO levels through the effective participation of individuals in the ALL (according to sex and age) in the decision-making processes from the co-design to the implementation of agroecological principles.

Next steps

This contextualization document is considered as a preliminary document that covers the different dimensions and domains of agroecology, but also identifies the gaps in terms of knowledge that need to be considered in the agroecological transitions co-built with actors engaged in the Tunisian Living Landscape. The description of each agroecological principle and its potential content in the Tunisian ALL also constituted a basis of knowledge for co-designing the technical and organizational innovation packages that will be implemented with stakeholders.

Zied Idoudi / ICARDA

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Annex 1. Characteristics, partnerships, and challenges of the basic organizations (GDA, SMSA) in the Tunisian ALLs

Team report: Udo Rudiger, Asmaa Soussi, Véronique Alary, Hassen Ouerghemmi (ICARDA)

As proposed in the "Guidelines and suggestions for stakeholder mapping and existing initiative assessment as part of WP 1," based on draft 23/08 proposed by Bernard Triomphe and Nadia Bergamini, we have used and adapted "Appendix 2: Fiche for organizing the basics of an organization" to collect the first data on the Tunisian ALL. The guideline of this diagnostic proposes four sections:

1. Describe the key characteristics of each STH or initiative (Who? How are they organized? Composition?), their main activities, and their area of influence.
2. Explore the diversity of the key partners. This information will contribute to the STH mapping.
3. Discuss the main issues/challenges and their propositions to see how the agroecological approach could meet their needs.
4. Describe the main farm activities that will be used as the main basic elements of the description of agriculture today in the Visioning.

Worksheet GDA Sers

Table 1: General information.

Features/characteristics	Organization: GDA femmes rurales Sers
Type of organization (e.g., academia, NGO, FO, private sector, etc.)	Agricultural Development Group (GDA)
Purpose and objectives (why?)	Empowerment of rural women Encouraging women to participate in sustainable rural development Capacity building and consolidation of negotiation power Foster livestock production and local products Group marketing/bulk sales with the sale of products of "terroir" coming out of the GDA (indirect beneficiaries)
When created	2015
Size/membership (GDA members (steering committee) + supporters + beneficiaries + clarifier) Number of women Number of youths (less than 35 years old)	6 members and about 55 supporters All supporters are women; 20% of them are less than 35 years old. About 40 supporters in El Marja irrigated perimeter, 15 supporters in rainfed area in Bouslia
Area of influence (geographic zone/area) Main farm activities of supporters in the target area (main farm activities, av. farm size of GDA supporters, % of large farms)	Sers (El Marja and Bouslia) Breeding: Small-ruminant breeders (owning less than 20 sheep and goats) represent 20% of supporters, breeders owning from 20 to 35 heads represent 60%, and 20% are big breeders. Bovine breeders owning fewer than 8 cows represent 60% of supporters, more than 35% have from 8 to 15 cows, and less than 5% of supporters have more than 15 cows Cereal cultivation: The average farm size of supporters is from 2.0 to 2.5 ha in irrigated areas and 3 ha in rainfed areas. All of them have less than 10 ha. Some are renting land. Beekeeping, poultry, saffron, and vegetable production

Features/characteristics	Organization: GDA femmes rurales Sers
Main lines of work and activities GDA activities	**Local artisanal food production:** cereal products (couscous, m'hamsa, bsissa), piment, spices, dried mint, garlic, dried tomato, saffron) **Dairy production:** about 50 L of milk are transformed daily to gouda, ricotta, mozzarella, yogurt, butter, cottage cheese, and spicy cheese **Commercialization:** going directly (from producers to consumers) in the GDA store inaugurated in June 2022 **Mechanization:** providing access to grinder, pellet machine, and handheld seeder **Forage seeds:** coordinating distribution of forage seeds **Access to finance:** collaborating with UTSS for micro-credit (agricultural inputs) **Capital development:** participating in different trainings on FBS, milk and cheese production, beekeeping, etc., by GIZ and AVFA **Digitalization:** receiving technical SMS for agricultural advice
Key GDA technical staff: How many? Profiles and topics/themes on which they work? Stability/turnover	The president (every three years, a new president is elected), one treasurer, four administrative members, and three controllers Two custodians recruited and paid for by CRDA that is offering the store and the guardians. However, the GDA might have to start paying the guardians soon instead of the CRDA. Procedures to recruit a woman for store management is in progress.
Funding sources (public, projects, etc.), stability of funding over time, importance of external funding	The annual subscription fee of members is TND 20 per year. The GDA funds managed annually do not exceed TND 800 or 900. However, GDA supporters can benefit from several credits reaching TND 5,000 dinars through NGOs such as the Tunisian Union of Social Solidarity (UTSS) and micro-credit associations such as Enda and Syres. Other associations such as Seine- maritime and the organizations GIZ, AISSA, and ICARDA provide some equipment (e.g., cheese processing, small-scale mechanization, mobile phones) and training (10% of sales contribute to GDA functioning).
How are main decisions made? Comments? Assemblée avec qui?	Decisions are made during meetings with supporters.
Any significant recent (past few years) changes in the way the organization works?	No
Are there any documents you might share with us to understand your organization or its line of work?	There are no reports, just some financial records and personal notes taken by the president.
Miscellaneous observations	One of the controllers mentioned the need to have more knowledge of conflict management.


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Table 2: Who are your key partners?

	Partner 1: **CRDA**	Partner 2: **OEP**	Partner 3 **UTSS: Tunisian Union of Social Solidarity**	Partner 4: **Microfinance associations such as Enda and Syres**	Partner 5: **ICARDA**
Main purpose (1)	Providing the GDA store building, providing cars to visit fairs Providing advice CTV provides room for training	Experimenting with new practices such as forage mixtures (vetch/oats/triticale), capacity building, providing new leguminous forage seeds, technical monitoring and demonstration, providing car for participants at trainings and workshops	Providing funding (grant loans without interest) Providing a meeting room for meetings and trainings on social and health topics.	Providing funding (credit, 5% interest rate at Syres, 25% interest rate at Enda) Providing dairy cows with credit (5% interest) based on certified training	Experimenting with new practices (forage seed mixture, SMS, small-scale mechanization)
Type of collaboration (2)	Bilateral agreement	Bilateral agreement	Through a formal bilateral agreement	Bilateral agreement	Through projects
How important is it for your organization? (3)	Vital	Important	Important	Important	Important
What key activities do you implement together? (4)	Coordination and joint planning (store inauguration, visit to many fairs, agricultural extension)	Training events, coordination, and joint planning Encouraging farmers to produce their own seeds	Commercial relationship (providing cows or small ruminants with credit and 0% interest)	Syres commercial relationship (providing cows with credit and 5% interest)	Training events, trials
What type of approach is the collaboration based upon? (5)	Provider	Provider, transfer of technology, capacity building	Service provider	Service provider	Action research, transfer of technology, capacity building
How satisfied are you with the collaboration? (6)	Excellent	Excellent	Excellent	Good	Excellent
Observations		Supply fodder seeds, technical follow-up, choice of cereal-legume combinations, demonstration days	Provide social services (free medical checkup for women against breast cancer, psychological assistance, education advice, domestic violence awareness)	Enda interest rate: 25% Syres interest rate: 5%	Providing equipment…, meteorological station, seeds, training

(1) For example, accessing or providing funding, seeking or providing advice and building capacity, experimenting with new practices, exchanging information, etc.

(2) For example, ad hoc, through a formal bilateral agreement, through projects, as part of a multi-STH arena of some sort, linkage to input or output market (as provider, as buyer).

(3) Importance: 1 = marginal, 2 = regular, 3 = important, 4 = vital.

(4) For example, training events, trials, coordination and joint planning, developing proposals, commercial relationship (buying or selling inputs or products), policy dialogue, etc. It can be more than one type of activities.

(5) Such as service provider, co-conception, action research, transfer of technology, capacity building, etc.

(6) Satisfaction: 1 = poor, 2 = regular, 3 = good, 4 = excellent.

Table 3: Main challenges and constraints of the main farm activities.

Main farm activities	Who is concerned (type of farm size, gender, how many farms, etc.)?	Identified problems	Causes	What are your proposed activities to face the problem?	Link of the proposed activities with agroecological transformation (Fill by the research team)
Fodder crops	All supporters	Drought, unavailability of seeds, in particular legume forage seeds	Climate change Only 12 women have collected seeds Lack of availability of legume seeds	Training about mechanical production and harvest of seeds Association choices of crops/vegetables	Land preservation (less use of fertilizer) Biodiversity and sustainability: adaptive management (seed production for next seasons) Co-creation of knowledge
Breeding: small-ruminant cattle breeding	All	Very expensive feeding Overgrazing Spiny cactus Dust problem	Unavailability of feed products (and expensive) Lack of grazing space Grinder is very heavy to move so not all GDA members can use it. The breed Queue fine de l'ouest is non-milk-producing.	Having more grinders to better recover cactus and other biomass waste Silage production and storage in plastic bags Introduction of dairy sheep breeds Cactus?	Valorization of cactus and waste from Pruning of olive trees, etc. (recycling)
Transformation: cheese production Artisanal food products (cereal-based products, eggs, spices, mint, garlic, dried tomato)	Five supporters Majority of supporters	Commercialization issues. They have capacity to transform up to 500 L, but they are transforming 50 L. Commercialization	Small village No market access outside the region (for milk and cheese: very perishable products difficult to store) Milk price The cooling chain of milk from farm to cheese-processing unit/store is not functioning well. Issues of recognition, competition, etc.	Marketing activities (developing flyers with products, radio spots, Facebook adds) "Depot/vente" – place products in small shops in Sers Partners for commercialization outside the village Test milk solar-cooling units (from ex-GIZ project) Exchange with other GDA	Connectivity (producer-consumer) Diversified diet Tradition Economic diversification
Beekeeping	Four to five supporters	Most hives died due to drought	No bee plants, no food for bees	Introduction of "arbre melifere" – trees providing food for bees	Animal welfare Biodiversity
Poultry	All supporters have from 15 to 20 hens, turkeys, etc.	Diseases and high mortality in summer	They cannot identify the disease to give the right treatment.	Veterinary assistance Training of farmers on chicken diseases and treatment Use the selling point for eggs	Animal welfare

Worksheet SMSA Ankoud El Khir (Rhahla)

Table 1: General information.

Features/characteristics	Organization: SMSA Ankoud El Khir, Gaafour, Siliana
Type of organization (e.g., academia, NGO, FO, private sector, etc.)	SMSA
Purpose and objectives (why?)	Facilitate access to inputs for supporters Agricultural machinery services in the region "United farmers are stronger"
When created	2022 (they are still waiting for authorization from the governorate for the sale of treatments, fertilizer, and feed)
Size/membership (GDA members (steering committee) + supporters + beneficiaries + clarifier) Number of women Number of youths (less than 35 years old)	3 members (president, vice president, and treasurer), 1 employee, 27 supporters, and a total of 100 beneficiaries 3 women 10 to 12 of the supporters are less than 35 years old.
Area of influence (geographic zone/area) Main farm activities of supporters in the target area (main farm activities, av. farm size of GDA supporters, % of large farms)	Gaafour/Seliana 50% of supporters have a minimum of 5 or 6 ha (rainfed). Others have from 15 to 20 ha (rainfed). Only five supporters have from one to three cows. More than 50% of supporters are small-ruminant breeders (average of 50 animals). Cereal crops: wheat and barley Olive trees (from 100 to 400 trees for each supporter)
Main lines of work and activities GDA activities	Agricultural machinery services (seed cleaning, treatment, and grinder?) Supply of forage and leguminous seed associations (vetch-oat, vetch-triticale, triticale, oat) Sale of agricultural inputs (fertilizer and feed)
Key SMSA technical staff: How many? Profiles and topics/themes on which they work? Stability/turnover	Three administrative volunteers (elected president, vice president, and treasurer) The technician (employee) taking care of agricultural machinery services
Funding sources (public, projects, etc.), stability of funding over time, importance of external funding	TND 14,500 (actions) A total capital of TND 29,000 (supporters have paid just half of their actions for the moment); no annual fees; only ICARDA (no other donor)
How are main decisions made? Comments? Assemblée avec qui?	Members' meetings every 2 months (supporters don't come even if they are invited), general assembly
Any significant recent (past few years) changes in the way the organization works?	No
Are there any documents you might share with us to understand your organization or its line of work?	Just meeting minutes and register for use of machinery Certificate for right to sell ammonite
Miscellaneous observations	

Table 2: Who are your key partners?

	Partner 1: **OEP**	Partner 2: **ICARDA**	Partner 3: **CRDA**	Partner 4: **GIZ**	Partner 5: **INRAT**
Main purpose (1)	Seed supply Training (Sulla and cattle feeding rations) as new practice	Experimenting with new practices, providing equipment	Providing advice and equipment, building capacity	Building capacity through training in cattle breeding	Installation of a demonstration plot of a vetch-oat association Supplying seeds of vetch, triticale, and oat
Type of collaboration (2)	Through projects	Through projects	Ad hoc	Bilateral agreement	Transfer of technical package through projects
How important is it for your organization? (3)	Important	Important	Marginal	Regular	Important
What key activities do you implement together? (4)	Training events	Training events		Training events	Training events, trials on soil erosion and cultivation methods (minimum tillage, CA)
What type of approach is the collaboration based upon? (5)	Service provider, capacity building	Action research		Capacity building	Action research
How satisfied are you with the collaboration? (6)	Excellent	Excellent	Poor	Regular	Good
Observations				The training is non-certifying, so it does not allow participants access to microfinance to buy cattle.	

(1) For example, accessing or providing funding, seeking or providing advice and building capacity, experimenting with new practices, exchanging information, etc.

(2) For example, ad hoc, through a formal bilateral agreement, through projects, as part of a multi-STH arena of some sort, linkage to input or output market (as provider, as buyer).

(3) Importance: 1 = marginal, 2 = regular, 3 = important, 4 = vital.

(4) For example, training events, trials, coordination and joint planning, developing proposals, commercial relationship (buying or selling inputs or products), policy dialogue, etc. It can be more than one type of activities.

(5) Such as service provider, co-conception, action research, transfer of technology, capacity building, etc.

(6) Satisfaction: 1 = poor, 2 = regular, 3 = good, 4 = excellent.

Table 3: Main challenges and constraints of the main farm activities.

Main farm activities	Who is concerned (type of farm size, gender, how many farms, etc.)?	Identified problems	Causes	What are your proposed activities to face the problem?	Link of the proposed activities with agroecological transformation (Fill by the research team)
Cereal crops	All supporters	Seeds and fertilizer are unavailable (especially wheat, DAP, super 45) when needed. Erosion	Fertilizer is sold only to wholesalers	Own seed multiplication for future campaigns Purchase and sale of 100 t of fertilizer Direct seeding against erosion	Biodiversity
Cattle farming	Only five supporters	Most supporters want to start cattle breeding but they have no access to microfinancing.	The training they received from GIZ is not certifying. Most of them cannot attend training far from the village.	They are looking for AVFA training. With an AVFA training certificate, they can obtain credit from MFI for cattle.	Sharing knowledge Economic diversification
Small-ruminant breeding	All supporters	Unavailable and very expensive pellets and grains Subvention quota is too low		Producing their own animal feed Receiving wheat bran and barley grain quota as SMSA	Synergy Recycling
Olive trees	All supporters	Diseases Bad or no olive tree pruning Erosion Drought	No knowledge of diseases and treatment	Training about olive tree pruning and disease treatment	

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Worksheet SMSA Kouzira

Table 1: General information.

Features/characteristics	Organization: SMSA Kouzira in Kesra, Siliana
Type of organization (e.g., academia, NGO, FO, private sector, etc.)	SMSA
Purpose and objectives (why?)	Direct marketing of figs in Tunis wholesale market, bulk sale, contract farming Beekeepers' assistance They have the objective of obtaining organic certification for honey creation by an oil mill?
When created	2020
Size/membership Number of women Number of youths (less than 35 years old)	114 supporters (70% are women and more than 40% are less than 35 years old) A total of 240 beneficiaries (114 + 126) 3 members
Area of influence (geographic zone/area) Main farm activities of supporters in the target area (main farm activities, av. farm size of GDA supporters; % of large farms)	Kesra Fig trees, olive trees, cherry trees Beekeeping Cereals Most supporters own 0.5–5.0 ha (diversified family farming). A total of 20% of supporters have more than 5 ha; all have access to irrigation (natural spring in the village). Olive trees are planted on collective land.
Main lines of work and activities GDA activities	Fig commercialization Beekeeping training and coaching Replacement of hives
Key SMSA technical staff: How many? Profiles and topics/themes on which they work? Stability/turn-over	The president, a general secretary, and a technical director. 20 volunteers, 1 treasurer, 6 beekeepers responsible for marketing of honey, a coordinator (forest engineer) – no employees
Funding sources (public, projects, etc.), stability of funding over time, importance of external funding	TND 8,500 (1 share costs TND 10). 70% produced honey. The project Profits provided the SMSA with 640 hives. Part of honey return goes into the SMSA budget.
How are main decisions made? Comments? Assemblée avec qui?	Decisions are made at board level (meetings are held every 1–2 months).
Any significant recent (past few years) changes in the way the organization works?	No
Are there any documents you might share with us to understand your organization or its line of work?	Minutes and financial reports
Miscellaneous observations	There is a conflict between GDA and SMSA.

Table 2: Who are your key partners?

	Partner 1: **Profits**	Partner 2: **CRDA**	Partner 3: **The governorate**	Partner 4: **Municipality**	Partner 5: **Emtiaz Association**
Main purpose (1)	Establishment of a promised oil mill did not take place. Providing 640 hives	Providing advice and building capacity	Networking	Providing funding (a plot to install the olive mill), but finally the plot was not a property of the municipality and the process stopped.	Microfinance TND 2,000–3,000 With 6% interest
Type of collaboration (2)	Through projects	Bilateral agreement	Ad hoc	Bilateral agreement	Bilateral agreement
How important is it for your organization? (3)	Marginal	Regular	Regular	Regular	Important
What key activities do you implement together? (4)	Training for farmers	Two days of training on organic beekeeping with the CTAB	Information about land that the SMSA can have to install the olive mill		Providing funding to small beekeepers
What type of approach is the collaboration based upon? (5)	Service provider	Capacity building	Coordination and joint planning	Coordination and joint planning	Service provider
How satisfied are you with the collaboration? (6)	Poor	Good	Good	Good	Excellent
Observations		The training was after the hive distribution, so it was not useful. A lot of beekeepers lost a big part of their hives.			

(1) For example, accessing or providing funding, seeking or providing advice and building capacity, experimenting with new practices, exchanging information, etc.

(2) For example, ad hoc, through a formal bilateral agreement, through projects, as part of a multi-STH arena of some sort, linkage to input or output market (as provider, as buyer).

(3) Importance: 1 = marginal, 2 = regular, 3 = important, 4 = vital.

(4) For example, training events, trials, coordination and joint planning, developing proposals, commercial relationship (buying or selling inputs or products), policy dialogue, etc. It can be more than one type of activities.

(5) Such as service provider, co-conception, action research, transfer of technology, capacity building, etc.

(6) Satisfaction: 1 = poor, 2 = regular, 3 = good, 4 = excellent.

Table 3: Main challenges and constraints of the main farm activities.

Main farm activities	Who is concerned (type of farm size, gender, how many farms, etc.)?	Identified problems	Causes	What are your proposed activities to face the problem?	Link of the proposed activities with agroecological transformation (Fill by the research team)
Fig trees	All	Pollination problems Commercialization problem More than 64 local varieties of figs might disappear. Drought	Male trees are not synchronized with some fig varieties because of the climate. Highly perishable varieties Consumers want only black variety.	The SMSA is guiding farmers to plant male vines in an area where the microclimate is adequate. Transformation unit for fig products (dried figs, confiture, syrup) Direct marketing CDO/traceability	Biodiversity
Beekeeping	56 beekeepers	Commercialization Transhumance (transportation cost) Mortality and diseases Organic certification cost	Consumer trust problem and absence of organic certification or a brand	Purchase of a truck for transhumance Collective treatment Plantation of melliferous plants such as Sulla Bio-certification (is expensive at TND 80)	Biodiversity Synergy
Olive trees	All	No oil mill in the region Seasonality No pruning of trees	Harvest with sticks damages trees Fear of pruning	Installation of an oil mill Training on pruning Severe pruning to renew very old trees Grinder/chopper for olive residues to produce compost	

Worksheet SMSA ETTAWEN (Chouarnia)

Table 1: General information.

Features/characteristics	Organization: SMSA ETTAWEN in Makther, Siliana
Type of organization (e.g., academia, NGO, FO, private sector, etc.)	SMSA
Purpose and objectives (why?)	Providing farmers with seed treatments, fertilizer, feed products, and machinery services (cleaning seeds, etc.) Training, especially for young people and women Development of direct seeding in the region, and areas of vetch and fenugreek seeds
When created	2017
Size/membership Number of women Number of youths (less than 35 years old)	9 members, including 3 women 120 supporters (50% are women and 40% are less than 35 years) More than 500 beneficiaries of non-subsidized products and machinery services. Only supporters can buy subsidized products.
Area of influence (geographic zone/area) Main farm activities of supporters in the target area (main farm activities, av. farm size of GDA supporters; % of large farms)	Chouarnia and all the delegates of Makther Field crops, especially wheat and barley Lamb fattening and breeding (cattle and small ruminants), an average of 80% of members have from 20 to 50 heads of small ruminants and 4 cows. Olive trees (an average of 150 per farmer) 80% of supporters own or rent less than 20 ha (rainfed); 15% of supporters own more than 20 ha (rainfed), including 5% having more than 200 ha (irrigated).
Main lines of work and activities GDA activities	Agricultural services such as seed supply, seed treatment, feed information, follow-up of farmers Agricultural machinery services (seed cleaning, feed grinding, feed pelleting) Ensuring subsidized seeds and animal feed
Key SMSA technical staff: How many? Profiles and topics/themes on which they work? Stability/turn-over	Voluntary work carried out by members based on the principle of tour de rôle One technician paid by farmers according to the service
Funding sources (public, projects, etc.), stability of funding over time, importance of external funding	Self-financing; only shares, no annual membership fees, no financial constraints; when needed, supporters pay spontaneously Planning each June after harvesting Some project support: Profits, ICARDA
How are main decisions made? Comments? Assemblée avec qui?	All supporters attend an annual planning meeting (June).
Any significant recent (past few years) changes in the way the organization works?	Lack of feed + fertilizer (DAP) implies some changes. Change in cooperation -> some cultivate together
Are there any documents you might share with us to understand your organization or its line of work?	Minutes for meetings, annual report
Miscellaneous observations	Some supporters are looking for training about manure-processing techniques (how to valorize it, how to better preserve it, its transformation into powder, etc.).

Table 2: Who are your key partners?

	Partner 1: **ICARDA**	Partner 2: **INRAT**	Partner 3: **INGC**	Partner 4: **OEP**	Partner 5: **Private suppliers**
Main purpose (1)	Providing equipment and fodder seeds Direct sowing Training	Direct sowing, providing seeder Training on direct seeding Seed provider	Training on cereals SMS (providing advice and building capacity)	Recycling of by-products (cactus) Training (cattle feeding)	Providing (with credit) fertilizer, feed products, treatments, metallic threads, etc.
Type of collaboration (2)	Through projects	Through projects	Through projects?	As part of a multi-STH arena of some sort? Co-conception	Providers
How important is it for your organization? (3)	Vital	Important	Vital	Vital	Vital
What key activities do you implement together? (4)	Training events, trials	Training events, trials Seeder equipment	Training events	Beekeeping training Sulla seed provision Providing subsided feed products Training about composition of pellet rations	Commercial relationship
What type of approach is the collaboration based upon? (5)	Action research	Action research	Capacity building	Transfer of technology, capacity building, as service provider	As service provider
How satisfied are you with the collaboration? (6)	Excellent	Excellent	Good	Excellent	Excellent
Observations	NB: Profits provides 380-volt access needed for feed production line, but poor relations.				

(1) *For example, accessing or providing funding, seeking or providing advice and building capacity, experimenting with new practices, exchanging information, etc.*

(2) *For example, ad hoc, through a formal bilateral agreement, through projects, as part of a multi-STH arena of some sort, linkage to input or output market (as provider, as buyer).*

(3) *Importance: 1 = marginal, 2 = regular, 3 = important, 4 = vital.*

(4) *For example, training events, trials, coordination and joint planning, developing proposals, commercial relationship (buying or selling inputs or products), policy dialogue, etc. It can be more than one type of activities.*

(5) *Such as service provider, co-conception, action research, transfer of technology, capacity building, etc.*

(6) *Satisfaction: 1 = poor, 2 = regular, 3 = good, 4 = excellent.*

Table 3: Main challenges and constraints of the main farm activities.

Main farm activities	Who is concerned (type of farm size, gender, how many farms, etc.)?	Identified problems	Causes	What are your proposed activities to face the problem?
Cereal crops	All supporters	Direct-sowing equipment is not available. Unavailable treatments and fertilizer	The equipment is CRDA property. Lack of fertilizer in the market and high prices	For the next campaign, the SMSA will use the CRDA seeder, with early and proper request letter. Making feedstock
Breeding Cattle (Brown-Swiss) Lamb fattening	Majority of supporters	Imported feed concentrates are very expensive and some products are not available.		Processing of products such as cactus, tomato wastes, and sugar beet wastes into feed pellets. Having their own feed production line with grinder, mixer, and pelleting machine. Manure stockage
Olive trees	All supporters	No treatments against Amra disease Drought Problem of dams not protected (irrigation issues)	Climate change	

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Annex 2. Review of soil health indicators in the El Kef-Siliana transect

Project team: Haithem Bahri, Isaf Mekki, Wael Toukabri, Mereiem Barbouchi, Mohamed Annabi, Hatem Cheikh M'Hamed), Review report, December 2022

Overview

Soils constitute a major reservoir of global biodiversity. Living soil organisms play an important role in processes such as decomposition, nitrogen fixation, and the regulation of greenhouse gas emissions. Soils are also a large store of carbon, contributing to climate change mitigation (FAO, 2020). Carbon sequestration in agricultural soils also contributes to improved soil quality, agricultural productivity, biodiversity, and water conservation, and thus greater resilience to climate change (Ghimire et al., 2022).

The soil is a complex and dynamic system. It represents a precious resource that needs to be protected to ensure agricultural ecosystem sustainability. Soil health includes physical, biological, and chemical aspects. In terms of physical aspects, healthy soils are free of compaction, erosion, clogging, and crusting. Regarding biological and chemical aspects, healthy soils exhibit balanced nutrients and are not polluted by toxic substances. Healthy soils also host a diversity of living organisms, including bacteria, fungi, other microorganisms, invertebrates, and some vertebrate animals. Healthy soils continuously provide ecosystem services, such as food and biomass production, including in agriculture and forestry; water absorption, storage, and filtering; and transformation of nutrients and substances, thus protecting groundwater (Toor et al., 2021).

Healthy soil functions as part of an ecosystem, supports crop productivity, maintains environmental quality, and promotes plant and animal health. The Global Soil Health (GSH) assessment characterizes soils by indicators related to physical, biological, and chemical components (Figure A2-1) (Moebius-Clune et al., 2016). These indicators allow the measurement of one or more soil properties essential to the healthy functioning of the soil, which are sensitive to changes in soil processes and reflect the relationships between biological, chemical, and physical properties. Indicators, calculated values, and estimated statistics relative to a threshold level are being increasingly used across biological, environmental, economic, social, institutional, and political disciplines to assess current conditions or trends of soil health. Currently, soil health monitoring relies on soil health indicators. These indicators can be used as an indirect measure of soil function, serving to assess soil quality or health and its direction of change with time, by linking functional relationships among measurable attributes and monitoring for sustainable land management, including environmental impacts. According to the National Resource Conservation Service (NRCS), "indicators are measurable properties of soil or plants that provide clues about how well the soil can function."

Indicators need to be easy to measure through either qualitative or quantitative techniques. Once the indicators are gathered, you can evaluate patterns and compare results to neighboring fields or prior years to gauge how soil quality has changed.

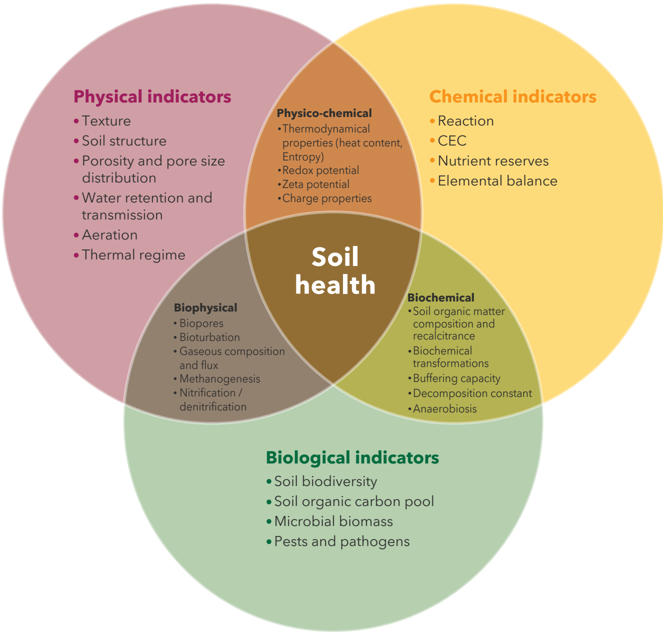

Figure A2-1: Soil quality indicators include a range of soil physical, chemical, and biological characteristics. Soil quality indicators can help in guiding restoration, predominantly with respect to understanding the role of soil properties and plant-soil relationships that promote revegetation and enhance soil ecosystem function.

Soil physical indicators

Soil physical properties provide information related to water and air movement through the soil as well as conditions affecting germination, root growth, and erosion processes. Many soil physical properties thus form the foundation of other chemical and biological processes, which might be further governed by climate, landscape position, and land use. A range of soil physical properties are highlighted as potential soil health indicators, and key soil physical indicators in relation to climate change include soil structure, water infiltration, bulk density, rooting depth, and soil surface cover, which are discussed below.

Soil structure (aggregate stability, porosity)

Soil aggregates are soil particles bound together. Stability refers to the ability of the soil aggregates to maintain their form despite disturbances caused by tilling, water, or wind. Changes in soil aggregate stability are indicators of improved soil health, organic matter content, biological activity, and nutrient cycling.

This is considered a useful soil health indicator since it is involved in maintaining important ecosystem functions in soil, including organic carbon (C) accumulation, infiltration capacity, movement and storage of water, and root and microbial community activity. It can also be used to measure soil resistance to erosion and management changes. Because of its association with the storage of soil organic carbon (SOC) and water, its measurement can be useful to guide climate adaptation strategies, especially in areas that are likely to experience high and intense rainfall and consequently increased erosion events. Since aggregate stability is measured in many different ways, standardized procedures are required within a soil health monitoring framework under climate change scenarios.

Porosity, a measure of the void spaces in a material as a fraction (volume of voids to that of the total volume), and pore size distribution provide a direct quantitative estimate of the ability of a soil to store root-zone water and air necessary for plant growth. Pore characteristics are strongly linked to soil physical quality. Bulk density and microporosity are functions of pore volume, while soil porosity and water release characteristics directly influence a range of soil physical indices, including soil aeration capacity, plant available water capacity, and relative field capacity. Since root development and soil enzyme activities are closely related to soil porosity and pore size distribution and because future climate change scenarios (e.g., elevated CO_2 and temperature, and variable and extreme rainfall events) might alter root development and soil biological activities, soil porosity and pore size distribution and consequently soil functions are likely to be affected in unexpected directions.

Available water capacity

Water capacity is the maximum amount of water stored in the soil for the plant. It's crucial to plant health when water is needed by the plant between irrigations or rainstorms.

Much of this depends on innate soil texture but it can be affected by the amount of soil organic matter and soil aggregation, both of which can increase water holding capacity.

Bulk density

Bulk density is an indicator of soil compaction. When soils are too compact, this might restrict root growth, which ultimately affects plant growth and crop yield. Additional dangers are increased runoff, erosion, and waterlogged soils.

It is considered as a useful indicator for assessing soil health with respect to soil functions such as aeration and infiltration. Since bulk density is in general negatively correlated with soil organic matter or SOC content, the loss of organic C from increased decomposition due to elevated temperatures might lead to an increase in bulk density and hence make soil more prone to compaction via land management activities and climate change stresses, for example, from variable and high-intensity rainfall and drought events.

> “ Water capacity is the maximum amount of water stored in the soil for the plant.

Rooting depth

Rooting depth is considered an important indicator of soil health, since changes in this property are likely to affect plant available water capacity, subsoil salinity, SOC content, or other properties to indicate physicochemical constraints in the soil profile. Under prolonged drought, the impact of subsoil constraints such as salinity and high chloride concentrations is likely to be greater on plant available water and hence plant productivity. Also, Birkas et al. (2008) included rooting depth as a soil health parameter for monitoring of soil condition and plant growth under extreme drought and variable rainfall events to indicate the potential for adaptability to and mitigation of climate stresses through alteration of rooting depth.

Soil surface cover

Soil surface cover provides a range of important ecological functions, including protection of the soil surface by dissipating raindrop impact energy, soil stabilization, reduction in erodible surface area, water and nutrient retention, C fixation, and, in some instances, N fixation and support of native seed germination.

Soil structural conditions such as soil crust and soil seal formation, primarily related to sodicity, are also indicators that could be used to characterize soil health under climate change. The formation of soil crusts and seals can affect a range of soil processes, such as water infiltration, oxygen diffusion, runoff, surface water evaporation, and wind erosion. A range of methods exist to measure their thickness and strength, although research effort is needed to relate these properties to soil processes affecting ecosystem functions and plant productivity, as well as to evaluate their role in mitigating adverse climate change impacts, thereby assisting in climate change adaptation.

Soil chemical indicators

Chemical indicators can provide a perspective on the following functions: promoting biodiversity; filtering, buffering, degrading, and detoxifying organic and inorganic materials; controlling water and solute flow; cycling carbon and nutrients; and physical foundation for plants, animals, and humans.

pH

Soil pH, a function of parent material, time of weathering, vegetation, and climate, is considered as one of the dominant chemical indicators of soil health, identifying trends in change for a range of soil biological and chemical functions, including acidification, salinization, crop performance, nutrient availability and cycling, and biological activity. Soil pH has thus been included in integrative soil health tests to assess the effects of land-use changes and agricultural practices.

Electrical conductivity

Soil electrical conductivity (EC), a measure of salt concentration, is considered an easily measured, reliable indicator of soil health. It can inform trends in salinity, crop performance, nutrient cycling (particularly nitrate), and biological activity, and, along with pH, can act as a surrogate measure of soil structural decline, especially in sodic soils. Electrical conductivity has been used as a chemical indicator to inform soil biological quality in response to crop management practices. Clearly, there is a need for comprehensive assessment of the influence of drivers of climate change on soil EC as an important soil health indicator in different ecosystems.

Soil nutrient availabilities

Measurement of extractable nutrients can provide an indication of a soil's capacity to support plant growth; conversely, it can identify critical or threshold values for environmental hazard assessment. Nutrient cycling, especially N, is intimately linked to soil organic C cycling. Drivers of climate change such as elevated temperatures, variable precipitation, and atmospheric N deposition are thus likely to affect N cycling and possibly the cycling of other plant available nutrients such as phosphorus and sulfur, although the direction and exact magnitude of change in plant available nutrients need to be investigated in detail.

Soil biological indicators

The soil is teeming with billions of soil organisms. Some of these organisms are observable with the naked eye (earthworms, millipedes, spiders, mites, reptiles, and mammals), others are microscopic (archaea, bacteria, fungi, nematodes, and protozoa).

These organisms play a key role in functions related to crop and plant health, including nutrient cycling, making nutrients available to the plant, nurturing soil structure, degrading soil pollutants, and breaking down organic matter.

Soil organic matter

The main indicators for evaluating SOM status include SOC, since it comprises about 50% of SOM; organic N, since it is closely associated with organic C and is the most important nutrient for plant productivity; and readily mineralizable C and N. As SOM drives the majority of soil functions, decreases in SOM can lead to a decrease in fertility and biodiversity as well as a loss of soil structure, resulting in decreased water holding capacity, increased risk of erosion and increased bulk density, and hence soil compaction. Land-use and management practices that lead to a buildup of SOM will help in absorbing CO_2 from the atmosphere, thus mitigating global warming. By increasing water storage, SOM can play an important role in mitigating flooding impacts following extreme rainfall events, while storing water in the event of droughts and thus increasing soil resilience.

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Soil microbiome

Soil microbes are involved in actually making soil work. Soil microbes break down organic matter, cycle all nutrients, build soil structure, build soil organic matter, increase water holding capacity, suppress disease, and more. All of these affect important crop measurements such as crop yield and resilience when faced with environmental stress.

Soil enzymes

Soil enzymes play a role in the decomposition and release of plant-available nutrients. They are derived from living and dead microbes (archaea, bacteria, fungi, nematodes, and protozoa), plant roots and residues, and soil organisms (nematodes, millipedes, insects, mites, spiders, reptiles).

Interpreting soil health indicator values and determining soil health score

When soil health indicators are combined into different scoring systems, often using complicated formulas to generate weighted values, they can be used to ultimately produce an index for assessment. This soil health assessment aims to enhance end-user knowledge to improve effective soil management. Thus, an aggregated representation of assessment results of different soil parameters, or a soil health index, is desirable. However, choosing indicators is a daunting task since it is difficult to determine which indicators and threshold values of those indicators would be the best representation of a particular soil type or best way to assess the effectiveness of management practices to improve soil health. The rule of the thumb is to select indicators depending on soil management and specific soil functions that need attention for a particular soil type (Hubanks et al., 2018). Although it might be exciting to use a comprehensive list of soil health indicators to build an index, that is expensive and impractical. Many studies have indicated that selecting a few indicators is much more effective in detecting management impacts on soil quality (Andrews et al., 2002; Hubanks et al., 2018; Lima et al., 2013). Thus, a minimum set of easy indicators is more appropriate for use in assessment and to construct a soil health index that will be easy to interpret and use.

Field practices to improve soil health

Sustainable agriculture is underpinned by preserving and protecting two natural resources: soil and water. This implies that improving soil health is achieved by using field practices that enhance physical, chemical, and biological properties. Soil health field practices are based on four basic soil principles: (1) minimize soil disturbance, (2) keep soil covered, (3) maximize the period of living root growth, and (4) maximize plant biodiversity (USDA-NRCS, 2018). Building soil organic matter is increasingly recognized and viewed as the key principle of soil health improvement strategies. These four soil health principles essentially guide the broader framework for all soil health management practices.

Principle 1: Minimize soil disturbance. Soil disturbance can be physical, chemical, or biological. Physical soil disturbance is caused by conventional tillage systems involving primary operations such as soil loosening, weed removal, and incorporating fertilizer and amendments, and secondary operations such as seedbed preparation before planting crops. Chemical disturbance includes fertilizer and pesticide applications (USDA-NRCS, 2018).

Biological disturbance involves overgrazing animals and monocultures, which can lead to compaction and biological imbalance, decreased root mass, and increased runoff (Larkin, 2015).

Principle 2: Keep soil covered. When either living plants or plant residues protect soils, there is a significant decrease in erosion and increases in microbial activity, organic matter, and soil fertility. Cover crops keep the soil covered during periods of time (i.e., winter) when cash crops are not growing. Thus, cover crops protect the soil, decrease erosion, and enhance organic matter due to biomass addition. Other benefits of using cover crops are increased water infiltration, decreased nutrient loss, increased number of mycorrhizae, and weed, pest, and disease control (Sarrantonio and Gallandt, 2003). Cover crop residue also minimizes the impact of raindrops on the soil surface and serves as a habitat and food source for soil microbes. Cover crops also add carbon into the soil and help tie up nutrients, especially by scavenging nitrogen from the soil during winter (Hubbard et al., 2013). Cover crops can prevent some nutrient loss and recycle nitrogen, eventually releasing the nitrogen from the residue as soil organisms begin the decomposition process.

Principle 3: Maximize the period of living root growth. Keeping living roots with cover crops and perennial crops helps sustain the microbial population in the soil. When plants are alive, they produce sugars through photosynthesis, which are then released and lost in the soil through the roots. Live roots in the soil provide those exudates to the microbes to stimulate more activity, which leads to faster decomposition and contributes to nutrient cycling in soils. Thus, growing plants throughout the year, such as long-season crops, crop rotations, and cover crops, can provide multiple benefits for soil health.

Principle 4: Maximize plant diversity. The diversity of plant species and plant-soil-microorganism interactions promotes soil biodiversity. Healthy soil requires active decomposition, nutrient cycling, and soil functions, which can be accomplished with crop rotations, cover crops, and organic matter amendments. Diverse crop rotations offer plant diversity, which helps break up soil-borne pest and disease life cycles, improve crop health, manage weeds, decrease nutrient losses from soils, and improve soil health (Larkin, 2015). Diverse plants in time and space in cropping systems release sugars, which support diverse food webs and energy chains essential for cropping systems and microbial activity in soils.

Current research findings related to soil health indicators in Siliana and Kef governorates.

Several studies were conducted to assess soil health in Siliana and Kef regions using different soil indicators (physical, chemical, and biological).

Soil texture was investigated in the study of Moussaoui et al. (2010) as a physical indicator to evaluate the impact of land degradation by erosion in the Siliana region. In the same study, chemical indicators, including mineral nitrogen content, phosphorus, potassium, and soil pH, as well as organic matter content as a biological indicator were also used to assess the soil fertility of Siliana affected by erosion.

Masghouni (2018) studied the effect of vegetation cover on soil properties in the Siliana region. In this work, physical, chemical, and biological indicators were chosen. The physical indicators were water retention and structural stability. Chemical indicators were OM content, total nitrogen, phosphorus, and exchangeable potassium. For biological indicators, microbial respiration, microbial and fungal biomass, denitrifying activity, and the number of earthworms were considered. The results of this work showed that soil under plant cover positively affects physical, chemical, and biological indicators.

> “The results of this work showed that soil under plant cover positively affects physical, chemical, and biological indicators.

Other work has studied the effect of minimum tillage or reduced tillage on physical, chemical, and biological indicators in the Kef and Siliana regions (Boudabbous, 2009; Jemai et al., 2012; Jemai et al., 2013). The results of this work showed that the indicators N, P, K, OM content, and structural stability are affected by cultural practices. In fact, under a reduced tillage system, residue decomposes more slowly. One reason is that fewer aggregates are broken with less intensive tillage, so less organic matter is exposed to decomposition. A second reason is that reduced tillage can make soil temperatures slightly cooler, which helps to preserve more organic matter because the residue is not rapidly decomposed. Moreover, reduced tillage does not disrupt earthworm burrowing and helps protect the network created by mycorrhizal fungi that connects them to their host plant. Leaving residue on the soil surface also acts as a barrier against raindrops and wind that could cause erosion. Overall, these studies suggest that soil health can be improved by decreasing tillage intensity, planting cover crops, and keeping crop residue, and that biological soil health indicators associated with labile carbon and nitrogen are most affected by management practices such as tillage intensity. Therefore, soil health indicators are sensitive to agronomic management systems.

Also, aggregate stability and organic matter are used as physical and biological indicators to study the effect of land-use systems in the northwest region (Bouajila and Gallali, 2010). Results showed that the most stable samples were derived from a carbonated horizon. In carbonated soils, in addition to organic matter and clay, $CaCO_3$ was considered an important agent of aggregation. In contrast, where soils were characterized by sandy texture and a low amount of $CaCO_3$, organic matter was the principal agent of aggregate stability. Therefore, soil aggregate stability and soil organic carbon fraction could be used as indicators for applying the most appropriate management practices to increase soil sustainability.

Allani et al. (2022) studied the distribution of nitrogen and phosphorus in agricultural soils in the Siliana region in order to optimize fertilizer application. In fact, soil microbiota is extremely sensitive to nutrient doses. With optimum nutrients, plants grow quickly and better withstand pest damage, and soil microbes and soil fauna thrive optimally for maintaining necessary soil functions. Results showed that variation in the content of essential elements such as nitrogen and phosphorus and in the physicochemical parameters of the soil is significantly related to the seasonal contrast and to the depth of the soil horizon (Allani et al., 2022). Laterally, the variation is slight, and it seems to be related to the homogenization of the studied soil. This is related to the dynamics of nitrogen and phosphorus in vertebrate agricultural soil. Thus, it is time to properly manage agricultural practices and the rates with which fertilizer is added to the soil. The factors that influence the dynamics of nitrogen and phosphorus at this study site are essentially the physicochemical properties of the soil, such as texture, clay content, structure, and soil nature.

In the Kef region, Rezgui et al. (2014) studied the effect of tillage and crop type on physical soil properties such as bulk density, structural stability, soil moisture, and porosity. Results of this study indicate that, for the two types of crops, no-tillage increased the bulk density, structural stability, and moisture of the soil by 5%, 75%, and 19%, respectively. On the other hand, sowing with reverse sowing increased the total porosity by 10%, an increase of 29% compared to direct sowing. Indeed, no-tillage enriches the soil with organic matter and therefore improves structural stability. It makes it possible to increase the proportion of medium pores (from 0.2 to 50.0 μm) in the surface layers of the soil (<20 cm) to the detriment of macropores, without increasing total porosity. The effect of tillage mode on physical characteristics differs with soil depth. At the surface (0–15 cm), no-tillage increased the bulk density and soil moisture. This technique limits the impact of precipitation on the physical state of the soil. From 15 to 30 cm, the structural stability was maximal. This rhizosphere is usually richer in organic colloids produced by microorganisms. These substances help cement the soil particles together. At depth, conventional plowing with reverse plowing increased bulk density and decreased porosity. Unsuitable cultivation practices promote consolidation of the 30–40-cm horizon that has not been worked, which constitutes a real constraint to the hydrodynamic functioning of the soil and to root development. This layer has undergone a cumulative effect of the passage of machines and has remained unchanged with its massive structure constituting a real obstacle to any vertical evolution. In addition to tillage, it appears that organic matter on the soil surface caused an amplification of biological activity that increased porosity. The cultivated species significantly affected the physical and water parameters of the soil. The highest values of bulk density and structural stability were observed at the level of faba bean conducted with no-tillage. This species benefited more from the effect of straw residues left by the previous durum wheat crop.

In these two regions, Siliana and Kef, Erouissi et al. (2011) were interested in biological indicators such as soil invertebrates to compare conventional and no-tillage management. No-till (NT) systems have less mechanical mixing of crop residues with soil minerals than conventional-till (CT) systems. Thus, NT systems are likely undisturbed ecosystems and might depend more on soil organisms for proper functioning. The results showed that NT enhanced soil fauna populations either in diversity or in abundance in the two regions (Figure A2-2), which confirms the negative effect of CT on richness and diversity of the soil fauna community in relation to NT systems. The negative impact of CT on ecosystem engineers and functional guilds (arthropods and earthworms) was also clear in this study. The move from CT to NT improved soil biological components, which could be explained by two factors: the change in soil properties and the decreased number of machine passes over the field; thus, a lack of disturbance.

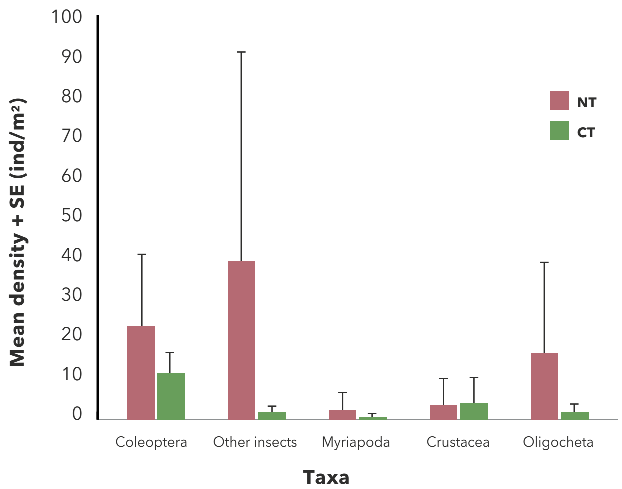

Figure A2-2: Distribution (mean density + SE) of soil invertebrates (major groups) as a function of the soil management system. Soil invertebrates were captured for each tillage system (CT or NT) four times; at two sites (Mahassen and Krib).

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When residues are left on the soil surface, the ecosystem engineers (worms and other organisms) and litter transformers can become much more important than in disturbed ecosystems (residues incorporated). Ben Moussa-Machraoui et al. (2010) showed that, under semi-arid conditions in northwestern Tunisia (Kef, Siliana), NT improved soil properties when compared with CT. NT significantly, improved soil content, especially for K, K_2O, P_2O_5, and N. The same authors indicated that clay and silt soils can be affected over a short time by tillage management. Soil organic matter showed higher values under NT, but the results were not significantly different from those of CT. However, under NT agroecosystems, earthworms and microarthropods played a dominant role in organic matter decay, and therefore nutrient flux patterns. Moreover, the soil fauna of natural ecosystems influences organic matter decay and mineralization processes, bringing about a better availability of nutrients in the soil.

Ben Moussa-Machraoui et al. (2010) also found that cation exchange capacity (CEC) is a good indicator of the degree of mineral fertility of soil. It depends on the soil texture as well as the amount of SOM (Figure A2-3). In their findings, the CEC values were slightly higher in NT than in CT. Also, the N content for both sites was significantly greater under NT than under CT. Soil and crop management practices might alter the quantity, quality, and placement of plant residues that influence soil C and N fractions.

Dridi and Guedari (2019) studied the dynamics of nitrogen mineralization as an indicator of plant growth in the Kef region in order to classify the soils according to their potentially mineralizable nitrogen and kinetics and to identify the effect of other soil properties on nitrogen content. The results showed that nitrogen content decreased with depth following different patterns depending on the soil type. The highest content of inorganic nitrogen was recorded in a Calcisol because of high organic carbon and nitrogen amounts and low C:N ratio throughout the profile. The lowest content was recorded in a Luvisol because of its large clay-silt fraction and low pH, especially at depth. The vertical distribution of ammonium and nitrate contents showed marked monthly variations. The laboratory results presented the following decreasing order of potentially mineralizable nitrogen and kinetics: Calcisol > Vertisol > Cambisol > Luvisol, and revealed two fractions constituting organic nitrogen supplies: an active fraction with a rapid mineralization and a passive fraction slowed down by clays and resistant to biodegradation.

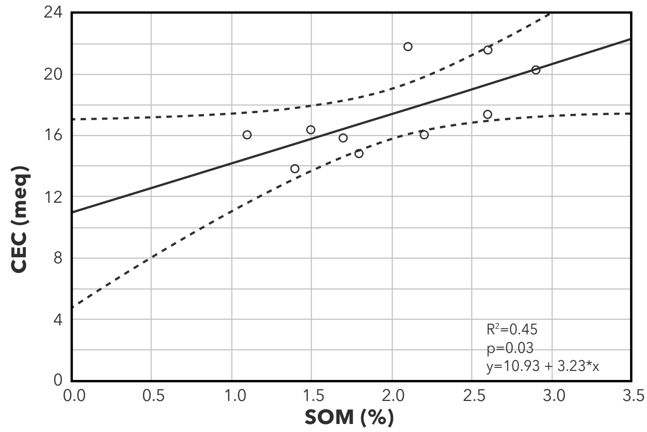

Figure A2-3: Correlation of SOM content with CEC values at two sites (Mahassen and Krib) and for all crops and tillage systems. The straight line indicates the confidence interval at 95%.

Conclusions

The majority of soil health indicators were addressed in the Kef and Siliana regions by physical indicators such as texture, structure, bulk density, porosity, and soil moisture; chemical indicators such as soil organic matter content, CEC, nitrogen, phosphorus, potassium, and $CaCO_3$ content; and biological indicators such as microbial biomass and microbial biomass activity, but all these indicators have been used by researchers for specific purposes and do not reflect the knowledge of farmers. It is therefore imperative to study farmers' perceptions of the indicators of their soil health.

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We would like to thank all funders who support this research through their contributions to the CGIAR Trust Fund: *www.cgiar.org/funders*.

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