FASTER

Farmers' Adaptation and Sustainability in Tunisia through Excellence in Research

ATLAS FOR ADAPTATION TO CLIMATE CHANGE IN TUNISIAN AGRICULTURE

FASTER FAS Living Lab co-designed proposals

EC Grant Agreement n. 810812

CONTRIBUTION

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EXECUTIVE SUMMARY

The H2020 project FASTER, Farmers' Adaptation and Sustainability in Tunisia through Excellence in Research, aims to reinforce research and knowledge transfer capacity of INRGREF related to innovative land, water and forest management strategies in the view of adaptation to climate change and to promote the adoption of research results in the agricultural sector by strengthening the Tunisian Farm Advisory System (FAS). To meet these objectives, FASTER Project developed a Living lab process, fostering interactions between researchers, experts, FAS agents and practitioners specifically to co-design opportunities for adaptation in the agricultural sector of Northwest Tunisia. The over 200 participants in the Living Lab activities are interested actors from all the collaborating organizations, active in the field of adaptation to climate change in water, soil and forest management, as well as actors engaged in farm advisory practices, concerned about transferring this knowledge to farmers. International partners CREAF and Lund University collaborated to provide both technical advice and academic support to the drafting process, through the elaboration of guidelines, roadmaps, meetings and direct contact with factsheet authors. The present Atlas for Adaptation to Climate Change in Tunisian Agriculture: FASTER Living Lab co-designed proposals presents the full set of factsheets obtained in a ready to use format.

PREFACE

The impact of climate change seriously disrupts economic activities in both developed and developing countries. This is a globally recognized threat humanity is facing. International collaboration, awareness of adequate solutions, use of new technologies, knowledge transfer and democratization of science are essential to face the main challenges and hope for a better future. Today, it is undisputedly necessary to impulse adaptation to climate change, because on one hand it cannot be avoided and on the other, anticipatory adaptation is more effective and less costly.

These concerns inspired the elaboration of this Atlas for Adaptation to Climate Change in Tunisian Agriculture, which is a testimonial of the work that has been conducted within a living lab community particularly interested and passionate about its role to boost innovation in the agricultural sector. The whole process was carried out in northern Tunisia as part of the FASTER EU H2020 project. The Atlas brings together scientific solutions, good practices and traditional know-how summarized in 60 technical sheets. The approach that was taken to accomplish this work was based on creative processes that allowed everyone to be innovative. All participants had the opportunity to genuinely voice their contributions.

The Atlas can be considered as a reference for adaptation to climate change within the agricultural sector, tackling a variety of topics in different fields of interest (water resources, soil management, forestry, crop production, rural economy, cattle's raising, fisheries, etc.). The document provides key measures, contributes to transfer practical solutions and disseminates specific scientific knowledge. The information gathered within the Atlas can contribute to enhancing adaptive capacity of Tunisian agriculture. In fact, once considered and implemented, the solutions might decrease the amount of damage, help to respond promptly in the aftermath of hazards, reduce vulnerabilities and promote sustainable development. Moreover, it could inspire and encourage decision makers to formulate robust national adaptation policies.

It is also crucial to improve the adaptive capacity of the Tunisian socio-economic system and sustain the nation in view of climate change. This involves several components. We can mention reducing poverty and inequalities between population groups, improving information exchange, education and infrastructure. Valorising the local experience accumulated, the active participation of the parties concerned as well as the improvement of institutional capacities are important components to be considered as well. All these aspects listed are key in terms of reducing vulnerability and grasping opportunities to face climate change. In addition, we evoke the adaptive strategies that integrate technology and the promotion of sustainable development in the context of the current global economy. The latter considers, among other things, the impact of climate change as a large-scale integrated strategy. This seems to be an excellent framework for countries striving for better prosperity and welfare.

Finally, I strongly believe that the document will be very useful for the living lab community in their current and future missions. In fact, we are at a time when co-creation and open innovation must play an increasingly important role in the design and implementation of agricultural policies. Furthermore, the Atlas will be an inspiring example to produce more knowledge to be made available to different communities in various fields of work to face challenges and promote increased resilience to climate change and variability.

I'm so grateful to be given this opportunity to get involved in this work, so that I can continue serving the agricultural community in this crucial context related to climate change.

Thank you all for your trust

Sihem Jebari
FASTER Project Coordinator

FASTER PROJECT

Farmers’ Adaptation and Sustainability in Tunisia through Excellence in Research

The H2020 project FASTER, Farmers’ Adaptation and Sustainability in Tunisia through Excellence in Research, aims to reinforce research and knowledge transfer capacity of INRGREF related to innovative land, water and forest management strategies in the view of adaptation to climate change and to promote the adoption of research results in the agriculture sector by strengthening the Tunisian Farm Advisory System (FAS).

To achieve these objectives, FASTER project invested its efforts to increase INRGREF’s research excellence through tailored capacity building programs for researchers, including specialised trainings and staff exchanges, as well as cross cutting multidisciplinary courses providing research excellence tools aiming at increasing the number of peer-review publications and successful elaboration of international competitive projects. The process also increased the internationalization and positioning of INRGREF through strengthening partnerships with leading research organizations through institutional networking and knowledge transfer.

In order to enable the application of innovative solutions, ensuring latest research results on innovative land, water and forest management strategies are shared and integrated into best practices in the agriculture sector, the project created a living lab engaging a multi-stakeholder platform including experts, practitioners and farm advisory agents able to mainstream key messages to farmers and decision makers.

Capacity bulding

- Cross-cutting training
- Research excellence training
- Specialized training
- Mobility program

Creating a living lab

- Living Lab for co-creation
- Summer school
- Multi-stakeholder platform
- E-learning platform
- Factsheets and video tutorials

Enhancing sustainability

- Indicators of excellence
- Institutional networking
- New research approaches
- Government agreements
- Job Bank

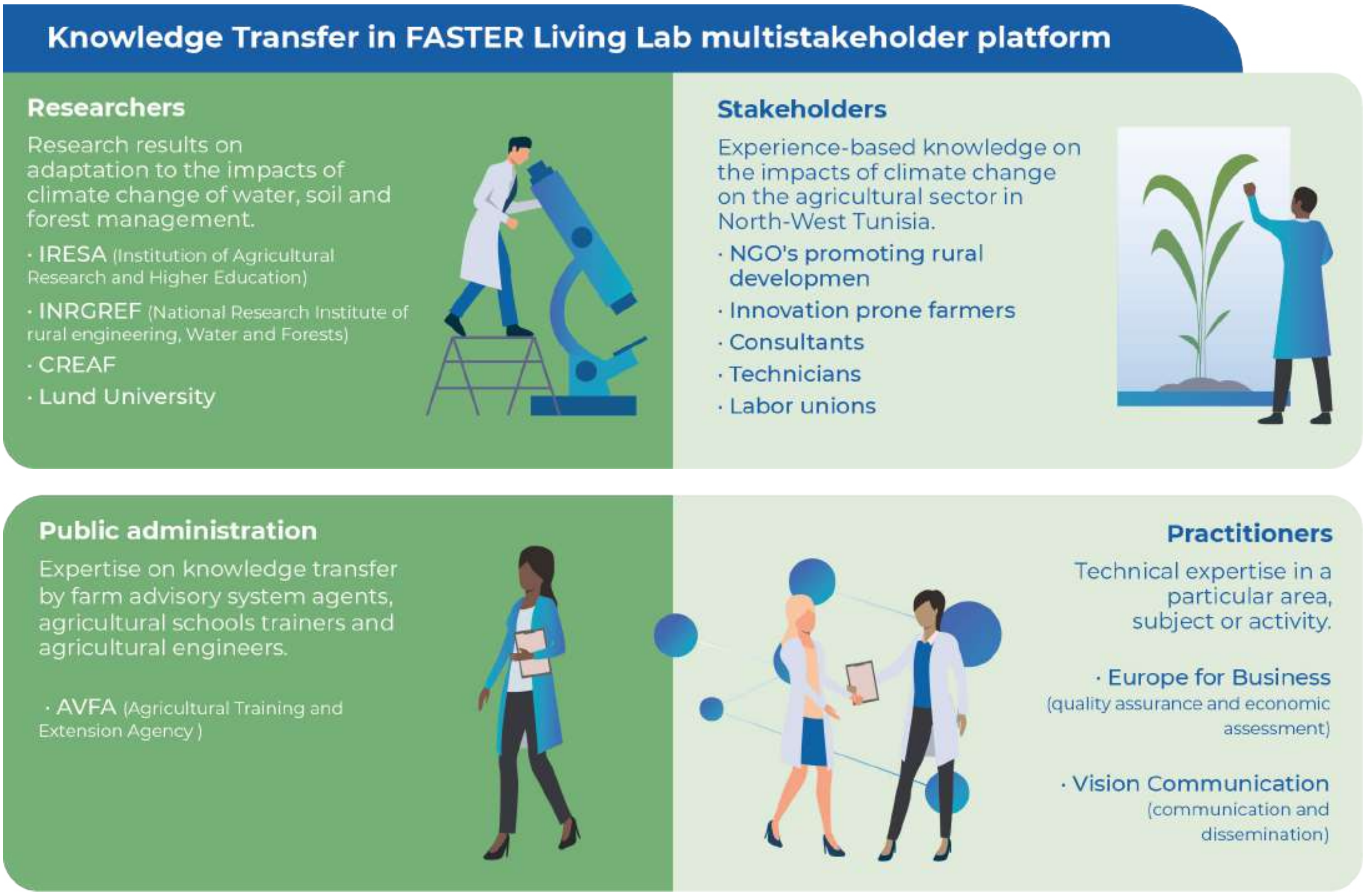
The FASTER consortium integrates seven European and Tunisian partners: two EU research institutions with established scientific excellence, CREAF (centre for terrestrial ecology) and the Lund University (water engineering and middle east studies), ensured the capacity building of researchers and technicians at INRGREF and IRESA. The Tunisian Agriculture Extension and Training Agency AVFA established a liaison with the agricultural sector of North West region, including producer organizations, innovation prone farmers and local rural development agencies. Furthermore, Europe for Business provided innovation management strategies and promoted the creation of a job bank, as well as the digital E-learning platform for knowledge sharing, and Vision Communication ensured that all key messages were correctly conveyed to the target audiences and results adequately disseminated.

THE FASTER LIVING LAB APPROACH

Living labs are a tool for promoting open innovation, an approach designed to enhance cooperation between multiple actors sharing a same stake, such as researchers, public administration, companies, end- users, and other stakeholders. Despite the multiple different implementations, living labs share certain common elements that are central to the approach: the establishment of a co-creation process engaging a multi-stakeholder platform of different professional profiles, adopting multiple methodologies aiming at sharing knowledge with end users who contribute with real life experience based knowledge.

FASTER Project living lab focuses on knowledge transfer on adaptation to climate change strategies between researchers in the field of water, soil and forest management, and practitioners engaged in Farm Advisory System in Tunisia.

The living FAS-Lab aims to provide an opportunity to take up research results into professional praxis, creating a dynamic tool allowing researchers and practitioners of different profiles to reflect on the challenges of adaptation and co-produce key messages on possible solutions in the context of North West Tunisian agriculture.



Knowledge Transfer in FASTER Living Lab multistakeholder platform

Researchers

Research results on adaptation to the impacts of climate change of water, soil and forest management.

- IRESA (Institution of Agricultural Research and Higher Education)
- INRGREF (National Research Institute of rural engineering, Water and Forests)
- CREAF
- Lund University

Stakeholders

Experience-based knowledge on the impacts of climate change on the agricultural sector in North-West Tunisia.

- NGO's promoting rural developmen
- Innovation prone farmers
- Consultants
- Technicians
- Labor unions

Public administration

Expertise on knowledge transfer by farm advisory system agents, agricultural schools trainers and agricultural engineers.

- AVFA (Agricultural Training and Extension Agency)

Practitioners

Technical expertise in a particular area, subject or activity.

- Europe for Business (quality assurance and economic assessment)
- Vision Communication (communication and dissemination)

The Faster living lab approach included different key actions:

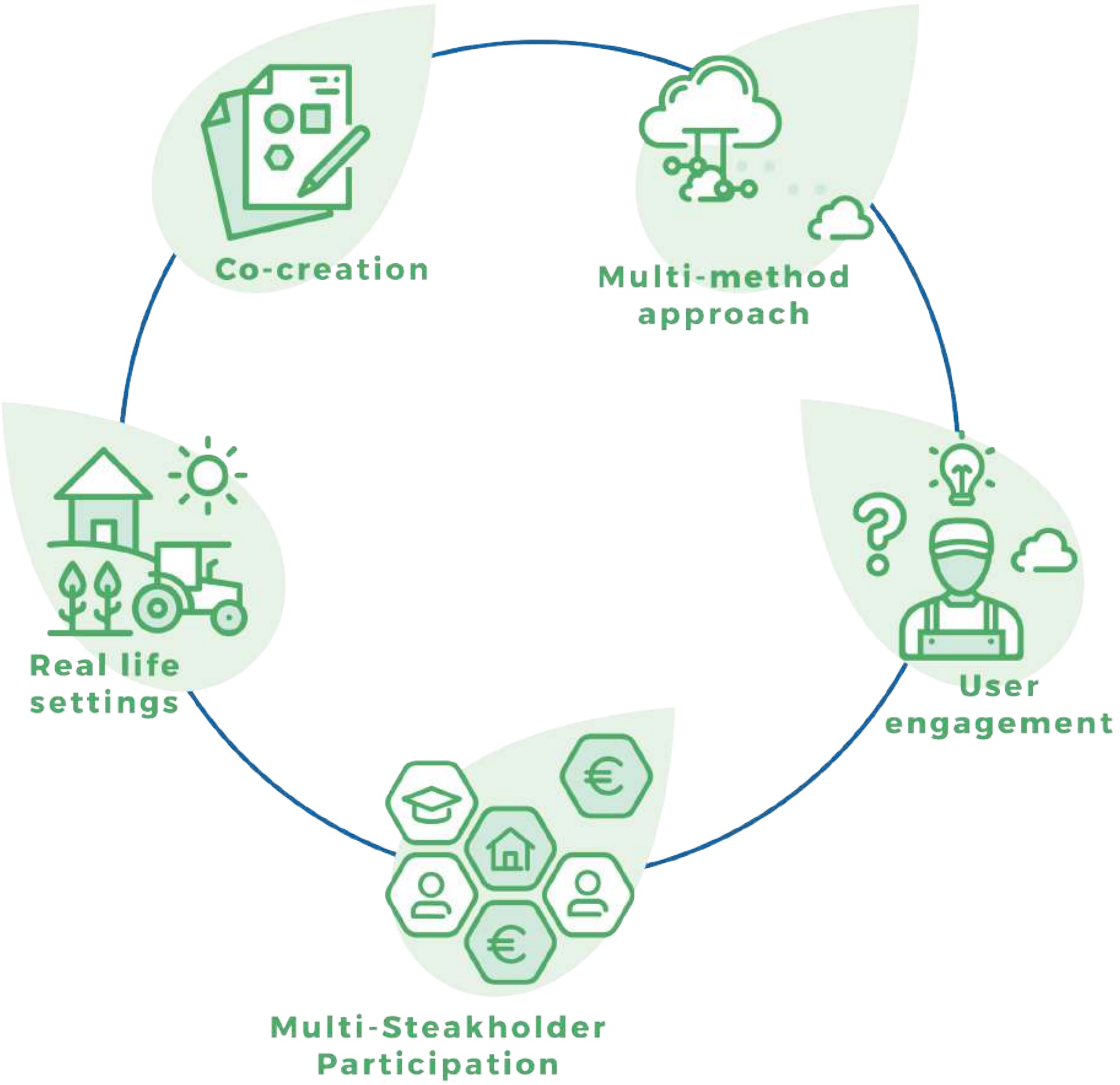
- Designing factsheets including adaptation measures related to climate change adaptation in water, soil and forest management, fishery and crop production.

- Training for FAS Agents on climate change adaptation concepts and approaches through a tailored summer school program.

- Disseminating the knowledge contained in the factsheets and establish a sound communication strategy targeting farmers and professionals interested in applying the innovative solutions proposed.

- Field visits to innovation prone farmers and local rural development agencies to share knowledge on adaptation measures and how they deal with the impacts of climate change locally.

FASTER Living Lab



THE FASTER LIVING LAB DYNAMICS

FASTER Living Lab methodology

Who is engaged?

FASTER Living Lab relays on a Multi-stakeholder Platform including 370 contacts (researchers, public administration, stakeholders and practitioners), from which potential participants to different activities are selected.

How is it organised?

Faster Living Lab Committee

Thematic working groups

Innovation prone farmers

What activities are developed?

Co-design and knowledge sharing

2 Spring schooltrainings

Communication and dissemination

Field visits

LIVING LAB PROCESS
Activities

Step 1 | **Identification of Living Lab leaders and participants**
Step 2 | **Preparatory meeting**
Step 3 | **Co-design Workshop**
Step 4 | **Factsheets finalisation**
Step 5 | **Factsheets validation**
Step 6 | **Factsheets presentations**
Step 7 | **Communication campaign to FAS agents**

The Living Lab developed its process of interactions between researchers, experts, FAS agents and practitioners specifically to co-design opportunities for adaptation in the agricultural sector of North West Tunisia. In particular, the living lab activities focused on the governorates of Bizerte, Beja and Jendouba, an area about 15% of the national territory representing one quarter of the best agricultural land and richest forests in the country. The region produces about 20% of the national agricultural production (cereal, crop market, red meat, and wood) but faces significant challenges due to the impact of climate change, such as erosion and flooding, aggravated by anthropic activities. Furthermore, a lack of regional development and the high unemployment rate induce migrations that affect nearly all of its urban and rural areas.

In order to scope the specific activities and elaborate a protocol for building the FAS lab process, the project gathered knowledge on the state of the art of Tunisian FAS and current adaptation policies for the sector, as well as main challenges and priorities through direct dialogue with actors engaged in FAS. The FAS lab dynamics were established through a series of meetings, interviews, events, trainings and other interactive formats engaging a broad range of professional profiles, creating new relations and networks for collaboration.

The process produced a set of factsheets containing tailored information on natural resources management solutions addressing both decision makers, fostering an integrated approach for adaptation in policy making, as well as FAS agents, tackling agronomic and technical aspects for enhancing transformation of current practices aiming at reducing vulnerability to the impacts of climate change.

The FAS Lab process was structured in accordance with 5 main fields of interest: soil, water and forest management, crop production and fisheries. In each of these fields, a set of sub-topics were identified, inviting living lab participants to focus on a variety of concrete aspects like in example forest exploitation, water economy or soil fertility. Each working group integrated at least 3 participants with diverse professional profiles, sharing their knowledge and collaborating to crystallize the main key messages into the factsheet format.

A team of living lab leaders coordinated the working groups activities, including actors from the project consortium (INRGREF, IRESA, AVFA) as well as local partners, such as farmer unions, Professional organization, local FAS agent, regional developers (CRDAs), private advisories, practitioners from different agencies. The over 200 participants in the living lab activities are interested actors from all the collaborating organizations, active in the field of adaptation to climate change in water, soil and forest management, as well as actors engaged in farm advisory practices, concerned about transferring this knowledge to farmers. International partners CREAF and Lund University collaborated to provide both technical advice and academic support to the drafting process, through the elaboration of guidelines, roadmaps, meetings and direct contact with factsheet authors.

Participants were invited to engage with the process by sharing their knowledge and fostering the uptake of opportunities from the local context to enhance the impact of the living lab activities. Efforts invested by Tunisian partners allowed organising field visits and interviews with innovation prone farmers and organizations promoting rural innovation in the region have contributed framing the information into the real-world setting. The contingency of the COVID19 pandemic has reduced the face-to-face events and the process was established virtually, enhancing the eLearning platform with tools allowing structured interaction between participants of the living lab working groups.

The living lab groups refined the information obtained to close the editing of their factsheets, and the FASTER living lab committee validated all the information included.

During the FASTER's Summer School program an initial set of Living Lab factsheets could be presented by the authors to various influential researchers, experts, farm advisory agents, and Tunisian professionals from the agricultural sector, providing the opportunity to exchange their knowledge and good practices with a broader audience. The consortium gathered the feedback from the participants and the comments from the invited experts to translate them into an updated version of the factsheets.

In order for the full set of factsheets to reach the target audience, namely the farmers and the decision-makers, FASTER partners designed a specific FAS Communication Strategy. The efforts focused on improving the communication skills of FAS agents towards farmers and provide support for implementing the suggestions promoting adaptation to climate change. The strategy hinges on three key stages:

1. Instruction

Capacitating the FAS Agents how improve their communication skills to transmit the factsheets' content to the farmers.

2. Implementation

Application of FAS Agents' communication efforts using the tools developed.

3. Evaluation

Assessment of implemented actions and further coaching.

THE FASTER LIVING LAB VISION

The living lab dynamics established during the development of FASTER project needs to be further consolidated to foster and sustain the relations established between the actors engaged and flourish into innovative developments, including new project proposals, collaborations, transfer of knowledge and technology, replication of the approach and promote the adoption of solutions obtained into the different contexts of Tunisian agriculture. Tailored communication channels between researchers and practitioners will be supported by project partners as to sustain collaborations established by the project and foster further interactions in the future.

The E-learning platform will ensure availability to a board public of capacitation materials produced, as well as audiovisuals depicting all trainings performed. The 4 modules included in the platform address different target audiences (researchers, experts, consultants, technicians and farm advisory agents) and offer a portfolio of resources for knowledge transfer available after the FATER project's end. All participants in the living lab process have access to the platform and can contribute disseminating the knowledge and references included. The living lab communication strategy can further support this task, as the tools developed can be easily taken up by FAS agents and interested actors who were not engaged in the project during its implementation.

The integration of concepts and analytical methodologies concerning adaptation to climate change into real-world dynamics is crucial for ensuring increased wellbeing of local population and safeguarding the ecological balance and functionality of the water bodies, soil and forests in the region. Therefore, FASTER project partners aim to undertake specific actions to address policy makers, inviting them to acknowledge the FASTER project approach and results, as well as to put into value the opportunities for improved rural development generated by the process.

FASTER CO-DESIGNED FACTSHEETS

on adaptation for the Tunisian Farm Advisory System

In the following sections the full set of factsheets are presented, edited in a ready to use format published in digital and printed format as to facilitate dissemination and adoption. The factsheets focus mainly on several topics in 5 fields of interest: water, soil and forest management, as well as agricultural production and fisheries. Table 1 presents an overview of all the factsheets co-produced in the dynamic framework of the FASTER Living Lab.

FIELD OF INTEREST	TOPIC	TITLE	TARGET AUDIENCE
Water Management	Water economy	Irrigation water pricing	Decision Makers
	Water governance	Collective groundwater management	
	Supply and infrastructure	Managed aquifer recharge	
	Flooding	Flood risk management by participatory approach	
	Flood / Drought	Optimization of surface water allocation using the WEAP model	
	Flooding	Early warning system using-band weather radar and modeling for prevention and control of floods	
	Water quality	Participatory water quality monitoring	
	Water quality	Agricultural reuse of wastewater from Aousja treatment plant	
	Agricultural Practices	Improved soil by mitigating hydromorphy	
	Drainage	Avoiding hydromorphy by improving soil drainage	
	Water governance	Sustainable management of cropping systems under saline stress (Korba and Beni Khalled)	
	Water governance	Land-use management using satellite imagery	
	Water harvesting	Coupling GIS and Multi-Criteria Analysis for rainwater harvesting	
	Water resources monitoring	Participatory monitoring of river flows	
	Drought	Spatial decision support system for Ichkeul Basin	
	Water management	Sustainable management of water resources by improving field observations	
	Water management	Capacity building program for improved irrigation management	FAS agents and farmers
	Water management at the plot	IREY irrigation management	

FIELD OF INTEREST	TOPIC	TITLE	TARGET AUDIENCE
Water Management	Water management	Direct sowing to improve water management	FAS agents and farmers
	Water saving	Improved resilience of vegetable crops to water stress	
	On farm water management	Better irrigation water quality for potatoes	
	Saving irrigation water	Improving the efficiency of water use by underground drip irrigation	
	Runoff collection	Rainwater harvesting: single basins	
	Water management at the plot	Improving the efficiency of water use by underground drip irrigation	
Soil Management	Soil erosion	Vegetation improvement to combat sand erosion	Decision Makers
	Supply and infrastructure	Soil terracing to reduce erosion	
	Soil erosion	Decision support tool: water erosion modelling	
	Soil erosion	Fight against erosion and forest landslides in the Attatfa valley	FAS agents and farmers
	Soil fertility	Soil fertility improvement using earthworms	
	Soil fertility	Soil salinity mitigation	
	Soil fertility	Phytoremediation to treat polluted soil	
	Soil fertility	Diagnosis of the bio-fertility of agricultural soils	
	Soil fertility	Biochar to improve quality of soil	
Forest Management	Forest exploitation	Sustainable exploitation strategy for Lentisk pistachio (Pistacia lentiscus)	Decision Makers
	Forest exploitation	Exploitation strategy for the preservation of forest resources in Kroumirie (North-West Tunisia)	
	Forest conservation	Prevention and management of wildfires in Kroumirie area	
	Forest exploitation	Non-Wood Forest Products action plan for rural women in Aindraham	
	Beekeeping	Adaptation strategy for beekeeping in Tunisia	
	Conservation of forests	General overview of the phytosanitary state of Tunisian oak groves	
	Forest conservation	Improvement of private rangelands by the Office for Livestock and Pasture (OEP)	

FIELD OF INTEREST	TOPIC	TITLE	TARGET AUDIENCE
Forest Management	Drought	Improve knowledge and practices for adapting forests to drought	Decision Makers
	Forest exploitation	Enhancing the role of local populations into agroforestry	
	Silvo-pastorage	Contribution of Silvopastoral Systems in Northern in Tunisia to sustainable development and biodiversity management	
	Forest conservation	Valuing carbon stocks in the understory vegetation	
	Forestry economy	Remote sensing for estimating Rosemary (Rosmarinus officinalis L.) biomass	
	Silvopastoralism	Increased cork quality through symbiotic association techniques in Khroumirie (Jendouba)	FAS agents and farmers
	Forest conservation	Eucalypt in the Tunisian arid region: diversity and valorization for beekeeping	
	Forest conservation	Regeneration of the carob tree (Ceratonia siliqua)	
	Forest conservation	Regeneration of Argyrolobium uniflorum in Tunisia	
Fishery	Artisanal fishing	Strengthening cystoseira towards sustainable fishing	Decision Makers
	Fishing of exotic species	Strengthening cystoseira towards sustainable fishing	
	Artesanal fishery	Co-management program for the Marine Protected Area of Tabarka	
Agricultural production	Plant protection	Preservation of fig trees (Ficus carica L.) germplasm in the North-West of Tunisia	Decision Makers
	Crop protection	Cytisus villosus seeds: a forest regeneration alternative	
	Water quality	Agricultural reuse of sewage sludge at Beja governorate	
	Livestock management	Optimization of lactation management of the Sicilo-Sarde breed	FAS agents and farmers
	Livestock management	Good practices for mechanical milking of Sicilo-Sarde sheep	
	Livestock management	Valorising local feed resources for small ruminants	
	Farms and Farming Systems	Ficus carica L. drying in Tunisia: current status and future prospects	
	Silvopastoralism	Extended cropping of Phalaris (Phalaris aquatica L.) for adapting Sylvo-pasturage to drought	
	Genetic improvement	Promotion of triticale genotypes adapted to marginal areas located in northern Tunisia	

WATER MANAGEMENT

IRRIGATION WATER PRICING

objective: promote water use efficiency by better irrigation water pricing

keywords: water use efficiency, irrigation water, water pricing

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Water scarcity

TOPIC: Water economy

Tunisia is currently facing increased water scarcity, limited supply of water resources, and increased competition over water among various sectors (mainly industry, domestic, and agriculture). Over 75% of the available water in Tunisia are used for irrigation. This large volume of water is, however, used inefficiently. Climate change is expected to increase water scarcity and markedly reduce irrigation water availability.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Given the increasing scarcity of water in Tunisia, it is recommended to introduce efficient tariff systems for different production systems and irrigated areas. Water productivity can be considered as a criterion for irrigation water pricing. This is expected to enhance water allocations based on output performances and contribute to the national efforts for better valuing water and other natural resources. Stochastic frontier production function approach (SFA) can be used for this purpose. SFA assumes that the residual from the simple regression approach can be divided into two factors, statistical error and inefficiency. Inefficiency is assumed to be non-negative (a utility that has zero inefficiency is on the efficiency frontier) and follows a particular statistical distribution. Water and other inputs and production should be used as data for econometric agricultural production function analysis. In the current fact sheet, we illustrate this pricing method to adapt to climate change. Improvement of water use efficiency and crop price are needed for increasing climate change adaptation and maintaining irrigation sustainability in the country.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Application of higher irrigation water fees is definitely feasible for present production systems but need, however, to be accompanied by increased incentives for water use efficiency in addition to better market integration of farmers. This requires optimized management practices of irrigation water at field level and enhancement of farmers' technical and organizational capacities for the marketing of their products. Through a case study, data were collected from a sample of 42 citrus farmers located in the Cap-Bon region in Northeastern Tunisia. The proposed intervention is more likely to be adopted by farmers who are satisfied by the regularity of water supply as compared to farmers suffering from irregular supply. The concept can be applied when water resources come from several sources such as wells and canals that enhances sustainability. Challenges include low pricing of water, lack of strict regulation of water use, and farmers' lack of awareness of the water scarcity. However, if these challenges can be dealt with, the method can be upscaled and used as an efficient policy to tackle climate change. Expected impacts are more resilient farming and less water demand.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
INRGREF	*Research and methodological development. Development of a web-interface for the automatic calculation of water use efficiency and water price at the level of irrigated areas.*
CRDA	*Train GDA to collect technical and economic data from individual farmers. Provide assistance for collection of primary and secondary data.*
Ministry of Agriculture. DGGR	*Decision making to adopt the tool/method/approach* *Provide administrative and institutional backup for the data collection by CRDA and other affiliated administrations and sub-directorates.*
GDA	*Collect data about water use by individual farmers and other economic data and send it to central administration for calculations of water use efficiency and water valuation.*

AUTHORS

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COLLECTIVE GROUNDWATER MANAGEMENT

objective: improve water management by collective irrigation water management

keywords: collective action, shallow aquifers, self-regulation

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Water scarcity

TOPIC: Water governance

Water scarcity is a main climate change challenge with increasing demand resulting from the growing population, accelerating economic development, and rapid urbanization. The transfer of the management of collective irrigation schemes to Water User Associations (WUAs) is meant to stimulate water productivity using farmers' participation, and thereby simultaneously achieving economic and ecological benefits. A recent analysis of the various groundwater management instruments by Frija et al. (2008) showed that instruments for encouraging self-governance are largely absent in Tunisia. Participation and collective groundwater management by WUAs for shallow aquifers are nowadays increasingly advocated as a complement to groundwater regulation (Frija et al., 2016). It offers great potential for climate change adaptation.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Participation and collective management by water users offers tremendous potential for effective groundwater management. The management of the Bsissi groundwater table (Oued el Akarit), located in the North Gabès region, constitutes a pilot experiment, original and unique on a national and even Mediterranean level, of participatory management of a common resource (Leghrissi, 2012; Frija et al., 2016). Overuse of groundwater a concerted and participatory management was established through the creation of a specific Agricultural Development Group (GDA), the "Group for the Development, Monitoring and Exploitation of the Bsissi-Oued El Akarit Water Table". The function of this association of users is to monitor the users' water consumption by controlling the pumping rates allocated within the authorized perimeter, and to monitor the piezometric level of the water table (Abidi and Ghoudi, 2011). Positive and encouraging results have emerged from this new instrument, such as reducing the number of illegal wells, freezing the construction of new boreholes, and reducing the volumes withdrawn. However, this experience remains novel and unique in Tunisia.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Collective groundwater management has the potential to substantially reduce groundwater demand. Impacts of collective management can reduce the volumes of water for irrigation. To avoid chronic overexploitation of the resource, a no-go zone was delimited in March 1987 by Decree No. 87-480 (Abidi and Ghoudi, 2011). This restriction made it possible to reduce water withdrawals for a time, but also fuelled conflicts between users. In any case, established concerted and participatory management of water tables are expected to lead to:

- Plugging of illegal wells and freezing of new borehole constructions
- Decreasing groundwater volumes withdrawn for irrigation
- Preservation of groundwater resources
- Stronger social and economic coherence of water users and farmers in view of climate change.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍂
	Flexible	🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Research institute	*Conceptualization and evaluation*
CRDA	*Control and monitoring of groundwater tables*
GDA	*Monitoring and control of the activity of creating water points within the scope of intervention*
AVFA	*Upscaling*

AUTHORS

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General water association meeting to discuss electrification of wells

Commercial shop of the water user association

Farmers´ meeting to visualize use of meteorological data

Project description for pilot project created by the water user association at Bssissi

FASTER
Farmers' Adaptation and Sustainability in Tunisia through Excellence in Research

MANAGED AQUIFER RECHARGE

objective: promote groundwater recharge using treated wastewater

keywords: wastewater reuse, infiltration, groundwater

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Green Solution	Water scarcity

TOPIC: Supply and infrastructure

The availability of water resources is declining, while the demand for water continues to increase for the agricultural sector and drinking water supply in the context of climate change hazards (increasing frequency of extreme weather events (drought and floods; Besbes et al., 2019). Therefore, groundwater is suffering from overexploitation that has led to a decrease in groundwater levels and quality. Managed Artificial groundwater Recharge (MAR) with conventional and/or treated wastewater (TWW) is generally used to cope with groundwater depletion and seawater intrusion caused by over-extraction. It is also considered a measure for adaptation to climate change.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Several techniques are used in MAR such as surface infiltration and vadose-zone or well injection. The main problem limiting the performance of MAR is clogging of the infiltration surface due to suspended solids and/or biomass deposit. Therefore, a pre-treatment is required before using water for MAR and regular drying of the infiltration surface must be carried out to minimize clogging and maintain high infiltration rates. Surface infiltration and well injection are widely used in Tunisia where about 40 MCM per year are used for MAR. The MAR with conventional water started in Tunisia at the beginning of the 1970s (Bouri and Ben Dhia, 2010) and has been practiced in the regions of Kairouan, Zaghouan, Ben Arous, and Cap Bon. Conversely, MAR with TWW has been applied only at two sites in the Cap Bon region namely Souhil since 1985, and Korba since 2008. Both projects aim to cope with saline water intrusion and are mainly instructive in this regard (Jarraya Horriche et al., 2020). However, the quality of TWW was a limiting factor to the success of the technique in Korba region (Jarraya Horriche et al., 2020). In any case, upscaling of MAR with TWW is an important climate change adaptation.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED		
	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

Groundwater in the Bizerte region (e.g., the Aousja/Ghar El Melh aquifer is deteriorating in quality due to agricultural and industrial pollution and marine intrusion. The karstic aquifers, usually less exploited than the porous aquifers, are beginning to be overexploited. In the Beja Governorate, there is declining rainfall recharge, and aquifers in Thibaris are being overexploited. Thus, MAR should also be considered in Northern regions of the country. The expected impacts of MAR would be a better groundwater balance between recharge and abstraction. As well, the increasing risks for saltwater intrusion in view of climate change would decrease. Thus, there are obvious advantages of MAR.

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
ONAS Ministry of the Environment	*Quality of wastewater treated in reuse standards*
Ministry of Agriculture	*Guiding the use of wastewater in agriculture*
Ministry of Health	*Checking health standars*
ANME	*Coordinating energy use*
AED	*Coordinating reuse*

AUTHORS

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FLOOD RISK MANAGEMENT BY PARTICIPATORY APPROACH

objective: improve flood risk management by better early warning systems and a participatory approach

keywords: flood protection, climate vulnerability, flood risk

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Green Solution	Extreme events (Floods)

TOPIC: Flooding

Climate change is expected to increase both magnitude and frequency of flooding. The North-West region has been affected by violent floods during the last two decades: 2000 and 2015 in Boussalem, 2003 and 2011 throughout the Medjerda valley, and 2017 and 2019 in Jendouba. This situation is aggravated by the vulnerability of the environment (Oueslati, 1999), the great climatic variability (>150 mm/24 hrs, Ain Draham), and unsuitable development plans and management of the hydraulic infrastructure (e.g., river fattening). Current flood management practices require new technological monitoring tools. Data from the Disaster Loss Database (DESINVENTAR) reveal that the country has been affected by nearly 2,500 disasters over the past 30 years (1980-2013).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To remedy increasing flood problems, we propose a new strategic planning based on actions that take into consideration all economic, social, and environmental aspects. There is high demand for strengthening local surveillance and early warning networks. The planned actions will provide support to all stakeholders and authorities (national, regional, and local), population in risk areas, and general civil society and provide technically feasible, socially acceptable, and economically profitable solutions (minimization of the costs of compensation for citizens). Involved stakeholders should prepare for the planned actions by adopting a shared participatory approach based on good governance. Actions which take into consideration all the normative, regulatory, institutional, and technical (strengthening and scientific aspects) will be performed on a scale of priority in terms of planning and implementation.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Various partnership projects and programs have studied implementation of actions and activities related to aspects of flood risk management and climate change (PNUD, 2013; PNUD/DG ECHO, 2018a; b). Capacity building in terms of training and development of risk mapping, planning, and development, will lead to local strategies for action plans as well as emergency preparedness and response. At Ghardimaou, a monitoring system was reinforced at a measurement station for Oued Medjerda. This will lead to a much more alert situation in terms of flood risk management. Arrangements and acquisitions leading to implementation of pilot projects related to weather stations and early warning systems (EWS) can prevent flood hazards and lead to better risk management. Actions related to communication, education, and environmental awareness for the benefit of the various stakeholders will lead to identifying risk management deficiencies.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍂
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 No 🍂

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of local affairs and environment	*Capacity building*
INRGREF	*Research*
ISA chott mariem	*Research*
ISIER	*Research*
Arrondissement CES	*Capacity building, field execution*
Equipment Ministry	*Capacity building, field execution*

AUTHORS

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OPTIMIZATION OF SURFACE WATER ALLOCATION USING THE WEAP MODEL

objective: improve water management and water allocation by WEAP modelling

keywords: surface water, integrated water management, allocation of water resources

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Water scarcity

TOPIC: Flood / Drought

In the Maghreb and North Africa, interannual climate variability leads to serious impacts on agriculture through long episodes of drought (Mougou et al., 2011). Impacts are expected to increase due to predicted climate change. The decrease in water availability will have a direct impact on the agricultural sector and may endanger socio-economic development and social stability in Tunisia where rain-fed agriculture represents the main occupation with means of subsistence in the region. Climatic periodicity shows a recurrence of 3, 5, and 10 years (Benzarti and Habaieb 2001). This periodicity increases the vulnerability of food security caused by periodic less supply of water. As a result, agricultural productivity decreases in terms of quantity and quality. This has a direct impact on economic growth leading to social and environmental degradation. As the population continues to grow, the effective use and management of water resources demand are essential that takes into account the needs of current and future users. In addition, a suitable management tool should be used. Faced with this difficulty, the deployment of new technologies to optimize the management of water demand remains a substantial obligation.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Over the past decade, an integrated approach to water development has emerged which has placed water supply projects in the context of demand, water quality, and ecosystem preservation. A technological approach to governance and rationalization of water resources during periods of drought is essential. The WEAP (Water Evaluation And Planning) model, applied to the region downstream from Nebhana (Project AGIRE II, MARHP-GIZ) that deals with water allocation between different users and managing conflicts of water supply during drought has yielded significant results. It uses an integrated approach to simulate water systems and develop policy orientation. As a tool for water policy analysis, WEAP assesses a full range of water development and management options, and considers multiple competitive uses of water systems. The WEAP model can take into account the impacts of climate change and water scarcity. Indeed, the application of this model in the Tunisian central-eastern region has given promising results. The transfer of this model to the north, north-west region will help water resources management. This will optimize the management of irrigation water demand. It is suggested to establish an advisory service composed of monitoring, forecasting, and warning system to optimize agricultural productivity during periods of drought while using the same amount of water but in a more aware way and adapted to each type of agricultural product. The technological solution consists in introducing all data (agricultural, meteorological, hydrological, nature and quality of cultivated soils, etc.). These data will be integrated into the WEAP model to generate simulations of possible distribution of existing water resources in a territory which will serve as a decision-making aid.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

During periods of drought, managing the demand for water resources is crucial. The WEAP during periods of drought. The decision support tool (WEAP model) will have a direct impact on agricultural productivity in terms of quantity and quality. Water resources management simulations will help decision-makers to:

- Plan detailed water allocations in terms of quantity and quality;
- Establish agricultural cultivation plans by zone based on concrete data such as: rainfall, types of soil, meteorological conditions, water salinity, etc;

This approach will subsequently help decision-makers to establish communication bridges to farmers, civil society, unions, and the public according to concrete figures and facts of the country's water situation.

This participatory approach will help to establish a governance mechanism for water resources that is sustainable, transparent, and adapted to each situation. This will have a direct impact on economic growth and will promote social and environmental recovery.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Farmers	• *Align with decisions produced through WEAP*
GDA	• *Collect and update observations and communicate them periodically to CRDA and MARHP*
Civil Society	• *Raise awareness among farmers, industry and citizens of the scarcity of water and the need to rationalize them* • *Observe and suggest adjustments*
Government	• *Adopt WEAP simulations for decision support* • *Provide an environment of transparency regarding the governance of water and encourage all stakeholders to participate individually.*
Industry (agro-producers)	• *Align with government decisions and agricultural production plans*
Citizens	• *Rationalize the use and consumption of water*

AUTHORS

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EARLY WARNING SYSTEM USING X-BAND WEATHER RADAR AND MODELING FOR PREVENTION AND CONTROL OF FLOODS

objective: improve flood risk management by combining radar data with rainfall-runoff modelling

keywords: flood, remote sensing, modeling

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Extreme events (Floods)

TOPIC: Flooding

The north-west of Tunisia is often subject to torrential rains. Due to climate change, the occurrence of rainfall of this type has become more and more common. With the absence of cross-border hydrological data exchange (flows, water levels, precipitation), the establishment of an early warning system upstream is considered essential. Indeed, any information on the existence of a flood wave upstream could be used in terms of gaining time to rescue the vulnerable population and save infrastructure and property downstream in risk of flooding.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Early warning systems are designed primarily to warn decision-makers to act in time and take the necessary precautions to mitigate flooding. Through the combination of radar images provided by an X-band type radar and a rainfall-runoff hydrological model, quantification of peak flows at different stations and propagation of the flood wave can be calculated before reaching sensitive areas. This can be used to decide on how to operate the downstream regulating dams and possible release of water. Additional work on the mapping of flood zones at different return periods constitutes added value of such systems. A system like this is being put in place at Neber (Governorate of Kef). Similar systems at other flood vulnerable locations would mitigate flood risk due to climate change.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The Tunisian state follows a compensation policy based on the assessment of post-flood damage, something that opens the door to any type of bad governance practice, especially since it weighs heavily on the national budget. Resorting to a preventive strategy prohibiting any type of illegal agricultural or urban establishment in areas subject to the risk of flooding remains essential. Adjustment of the delimitation of vulnerable areas is supported by the implementation of the early warning system. It should be accompanied by the promulgation of regulatory texts that will improve its sustainability.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED		
	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of agriculture	*Responsible for the protection of the DPH and host of the project*
INM	*Stakeholder responsible for data quality*
Ministry of the Interior	*Monitoring of illicit installations*
Ministry of Equipment	*Lifting works in urban areas*

AUTHORS

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REFERENCES

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PARTICIPATORY WATER QUALITY MONITORING

objective: promote water use efficiency by participatory water quality monitoring

keywords: citizen science, water quality monitoring, water quality test strips and kits

Target	Decision Makers
Field of interest	Water Management
Type of adaptation measure	Grey Solution
Climate challenge addressed	Water scarcity

TOPIC: Water quality

Pressure on water resources jeopardizes reaching the UN-Sustainable Development Goal 6 (SDG6) for clean water and sanitation and Goal 13 (SDG13) for taking urgent action to combat climate change and its impacts. Water resources management in Tunisia has repeatedly been confronted with the impact of climate change. The water quality monitoring capacity in Tunisia is poor. Citizen Science (CS) has been evolving during the last years as an innovative approach of environmental monitoring and capacity building of hydrosystems using smart and low cost-effective technologies as tools for data collection (Fehri et al., 2020a; Fehri et al., 2020b; Chaabane et al., 2021; Fehri, 2021; Slama, 2021). Here we address the process of decision makers to involve citizens in water quality monitoring.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Unclear responsibilities among multiple stakeholders in the water sector and non-availability of water quality data create problems for water related decision-making processes. Citizen involvement in water quality monitoring (WQM) is considered a novel approach of data collection and capacity building. It was applied and validated in a pilot region of the Medjerda watershed (Chaabane et al., 2020; Chaabane et al., 2021; Fehri, 2021; Slama, 2021). These studies focused on the monitoring of chemical water quality parameters using water test strips and kits compared to standard laboratory analytical methods at 20 sites along the Medjerda River. Site selection was based on the required spatial distribution of the volunteering citizens. The engaged volunteers were academics, students, and administrative staff. It would be appropriate to also involve farmers, water operators, and civil society organizations. A short training program ensures a good reliability of test strips and kits readings (Figure 1). Citizen science WQM provides reliable, rapid, environmentally eco-friendly, low cost alternative and simple data collection using water strips. Also, kit tests can be used by citizens.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Citizen science (CS) has attracted increasing interest among public authorities at all levels, who themselves are trying to make policy processes more accountable and knowledge-based to citizens. CS-based WQM programs give opportunities related to environmental monitoring and reporting, data collection, and single out potential benefits in terms of stronger links between CS and climate change adaptation and mitigation measures. CS-based WQM can improve conservation efforts by knowledge, encouraging public action, supporting science and public involvement as a powerful tool for tackling climate change challenges. Knowledge exchange of water resources management enabled via regional, national, and international stakeholders can facilitate disaster response in the hydrosphere by tackling the impacts of climate change. CS offers a cost-efficient additional source of knowledge and feedback in water monitoring and its implementation policies by including non-traditional data sources, analytical capacities, and engaging citizens. CS-based environmental monitoring can generate potentially big benefits (Fehri, 2021).

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of Agriculture, Water Resources and Fisheries (MARH)	*Integration of current legislation*
Regional Agricultural Services (CRDAs)	*Database implementation* *Decision making*
Farmers	*Data collection and agricultural practices*
NGOs, GDAs,...	
Technical staff of CRDA	
Scientists	*Data collection, validation and valorization*

AUTHORS

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Figure 1. Involvement of stakeholders in water quality programs.

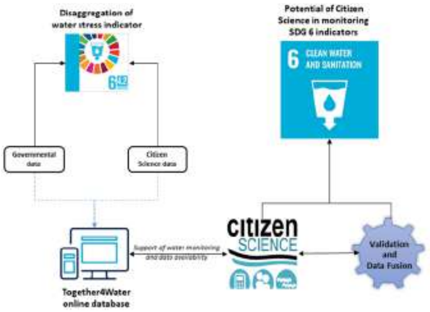

Figure 2. Citizen science-based environmental monitoring potential benefits (Fehri, 2021).

AGRICULTURAL REUSE OF WASTEWATER FROM AOUSJA TREATMENT PLANT

objective: improve reuse in agriculture by improving treatment of wastewater

keywords: northeast Tunisia, wastewater treatment, reuse of treated wastewater

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Grey Solution	Water efficiency

TOPIC: Water quality

Rapid urbanization and climate change are increasing the pressure on the freshwater resources in Tunisia. The increasing demand of water and decreasing water resources have resulted in over exploitation of groundwater, especially for agricultural purposes. Treated wastewater (TWW) reuse in agriculture is considered an efficient tool for managing water resources, stemming from the need for a regulated supply that compensates for water shortages caused by seasonality or the irregular availability of other water sources for crop irrigation throughout the hydrological year. TWW can ensure the balance of the natural water cycle and preserve resources by reducing untreated discharge into the natural environment (Bouchet, 2008). Currently, in Tunisia, however, the environmental performance of the wastewater treatment systems is not optimal and sufficient to treat the constantly increasing volumes of wastewater produced which can threaten public health, ecosystem, soil fertility, and crop yield. A total flow of about 21.2 Mm3/year of treated effluent (approximately 8%) is being reused for irrigation in agriculture.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Slaughterhouse wastewater (SWW) discharged into the network of Aousja WWTP (Fig. 1) needs a specific treatment to assure pollution reduction and a sustainable and safe discharge to the environment. Therefore, the treatment and final disposal of SWW are a public health necessity as it is characterized by high organic content in terms of biological and chemical oxygen demand, total suspended matter, nitrogen, chloride, and microbiological load. High concentrations of BOD5 and COD in the effluent are the result of poor performance of the plant. Thus, there are needs to assess shortcomings of the different treatment stages of the plant and suggest improvements. The National Sanitation Utility (ONAS) has planned a partial rehabilitation of the pretreatment to remove coarse and suspended pollutants and aerators equipment (fine air bubble system instead of brushes) for secondary treatment to improve the TWW quality. It is recommended to apply a complementary treatment of effluents. After improvement of the TWW quality, submarine emission will take place of the effluent through a long pipeline in deeper sea regions. This will allow for effective dilution.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Besides benefits associated with increasing water availability for irrigation, better reuse of TWW can provide positive environmental impacts, and contribute to improved water quality of the receiving water. This represents a shared gain and significant synergy between urban, agricultural, industrial water use and the environment. Most of the research in the field has focused on hazards associated with TWW quality and efficiency of WWTPs, reuse and its social acceptability to establish standards and assessment of wastewater risks related to its reuse. Less effort has been spent on the economic aspects of this type of plant compared to ordinary secondary treatment and that additional treatment asks for additional investment and operation costs that can produce environmental benefits and increase the financial sustainability of water reuse. Thus, surveys need to be conducted with farmers to assess barriers that can prevent the appropriate progress of the proposed solutions. In the case of the Aousja plant improved treatment solutions need to be studied together with estimated costs and farmer's acceptability to use treated wastewater in agriculture.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED		
	Causes a transformation (societal, economic, institutional, etc.)	🍂
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 No 🍂

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
National Sanitation Utility (ONAS)	*Responsible for the country's wastewater infrastructure. It collects, treats and discharges municipal (and some industrial) effluents and sells (heavily subsidised) treated wastewater for reuse.*
Regional Offices of Agriculture Development (CRDA)	*Regional Offices of Agriculture Development (CRDA) Under the Ministry of Agriculture. They are in charge of implementing government agricultural policy, water and soil conservation, and responsible for the distribution of treated wastewater to irrigate perimeters through pumping stations and a supply network while coordinating the monitoring of water quality.*

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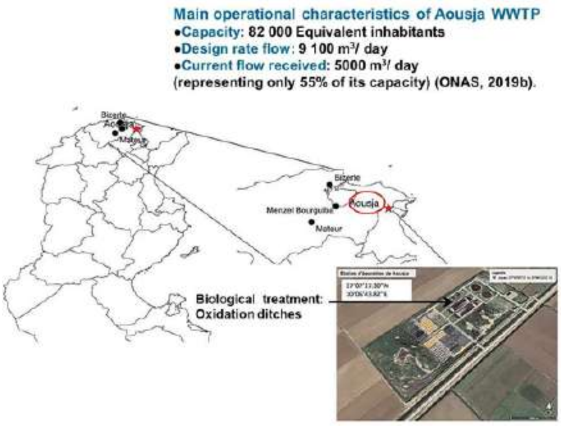

Main operational characteristics of Aousja WWTP
- **Capacity:** 82 000 Equivalent inhabitants
- **Design rate flow:** 9 100 m³/ day
- **Current flow received:** 5000 m³/ day

(representing only 55% of its capacity) (ONAS, 2019b).

Figure 1. Location of the Aousja wastewater treatment plant, in the governorate of Bizerte

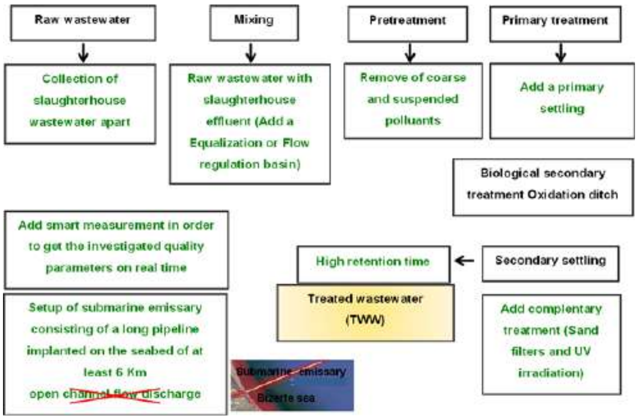

Figure 2. Schematic of Aousja WWTP with technical potential solutions to improve treatment.

IMPROVED SOIL BY MITIGATING HYDROMORPHY

objective: mitigate soil hydromorphy by improving soil drainage

keywords: hydromorphy, drainage, waterlogging

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Grey Solution	Water efficiency

TOPIC: Agricultural Practices

Climate change projections have highlighted the risk of soil hydromorphy and soil salinization. Hydromorphy of agricultural land is a critical challenge for farmers mainly due to the water table capillary rise by excess of irrigation during the summer period (Ben Hassine, 2005) and overflowing rivers occurring during the rainy period especially when the rainfall exceeds 1000 mm/year. The heavy fine-textured soils and the inefficient drainage networks are accentuating this phenomenon. Agricultural activities are hindered both due to the lack of root oxygenation and of farming machinery, leading to an overall crop yield decrease. About 25 to 50% of losses were estimated during 2017-2018, mainly on vegetables (potato, watermelon, onion and artichokes).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Drainage systems installed in hydromorphic agricultural land allow evacuation of excess water resulting in an improvement of the soil quality and the crop system sustainability (Bernard, 2020). About 28% of the useful agricultural area in the main irrigated public perimeters (IPPs) of Jendouba Governorate (Bouheurtma complex and Souk Essebt) have a drainage system installed since the 80's. But due to the lack of maintenance and cleaning of the drains and the water table rising control, the cultivation of sensitive crops to water logging, hydromorphy remains a challenge. The solutions proposed for these IPPs are mainly: (1) enhance sugar beet cultivation at the head of rotation and introduce short-cycle varieties to avoid hypoxic stress, (2) strengthen the water table monitoring network through setting up piezometers and establishing periodic measurement campaigns in autumn and spring in the most critical areas suffering from hydromorphism, (3) carrying out an annual cleaning and recalibration of open and buried drains, and (4) prohibit the discharge of domestic waste into ditches.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Figure 1
Water table rising in the hydromorphic soil at El Araya-Boussalem (Ghazouani et al., 2016)

Figure 2
Recovered soils after drainage network installation at El Araya- Boussalem (Ghazouani et al., 2018)

Strengthening drain networks will contribute to the desalination of agricultural lands by limiting permanent waterlogging, improving agricultural activity, and intensifying land use (Slama et al., 2005; Bernard, 2020). Results have shown that installation of polyvinyl chloride drains, or annular drains placed 24 to 40 m apart at 1.4 m depth in clayey-silty soils reduced the water table rising and the water stagnation impediment (Figure 1, 2). Simultaneously, the salt quantity is reduced allowing farmers to cultivate abandoned land. Social activity is enhanced, and farmers' incomes are improved.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🟢🟢🟢
	Reduces resource consumption	🔴
	Improves ecosystem health and functionality	🟢🟢🟢
	Adopts a multisectoral approach	🟢🟢
	Flexible	🟢
	Robust	🟢🟢

Yes high 🟢🟢🟢 Yes medium 🟢🟢 Yes Low 🟢 No 🔴

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
General (DGPA)	*In the Ministry of Agriculture, responsible for developing agricultural strategy to support sugar beet cultivation and introduce short-cycle varieties to avoid water stagnation.*
General Direction of Rural Engineering (DGGR)	*In the Ministry of Agriculture, a policy-making body responsible for developing policy strategy and funding rehabilitation of irrigated perimeters. It monitors and evaluates irrigation agricultural sanitation projects.*
Regional Offices of Agriculture Development (CRDA)	*In the Ministry of Agriculture, they are in charge of implementing government agricultural policy, they oversee water and soil, responsible for planning and organizing tasks of maintenance, rehabilitation of drainage network and control of water table level rising.*

AUTHORS

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AVOIDING HYDROMORPHY BY IMPROVING SOIL DRAINAGE

objective: mitigate soil hydromorphy by improving soil drainage

keywords: hydromorphy, drainage, waterlogging

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Grey Solution	Irrigation

TOPIC: Drainage

Climate change projections have highlighted the risk of soil hydromorphy and soil salinization (USAID, 2018). Hydromorphy of agricultural land is a critical challenge for farmers mainly due to the water table capillary rise by excess of irrigation during the summer period (Ben Hassine, 2005; Bernard, 2020) and overflowing rivers occurring during the rainy period especially when the rainfall exceeds 600 mm/year in the irrigated perimeter of Teskraya (CRDA-Bizerte, 2017). The heavy fine-textured soils and the inefficient drainage networks are accentuating this phenomenon (SCET, 2016-2017). Agricultural activity is hindered both due to the lack of root oxygenation and of farming machinery, leading to an overall crop yield decrease (FAO and ITPS, 2015). Yield losses were registered, mainly for vegetables (tomato, onion, and artichokes).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Drainage systems installed in hydromorphic agricultural land allow evacuation of excess water resulting in an improvement of the soil quality and the crop system sustainability (Bernard, 2020). About 30% of the useful agricultural area of the main irrigated public perimeters (IPPs) of Bizerte Governorate (Tobias, Utique Nouvelle, Ghezala, and Teskraya) have a drainage system installed in the 80's (SCET, 2016-2017) but due to the lack of maintenance and cleaning of the drains, their age, their size and the nature of the materials used, hydromorphy remains a challenge. The solutions proposed for these IPPs are mainly: (1) carrying out an annual cleaning of open and buried drains accompanied by rehabilitation tests, (2) a setup of evacuation pipes in the main collectors (3) substitution of defective drains and clay made ones by polyvinyl chloride (PVC) matter, (4) check the sizing of the pre-existing buried drainage network, (5) replace the open drainage ditches with buried collectors, and (6) rehabilitate or strengthen the water table monitoring network through setting up new piezometers in critical areas suffering from hydromorphism (SCET, 2016-2017). Finally, it is equally recommended to practice subsoiling, deep plowing, and manure amendment in plots. Similarly, characteristics of the drainage slope should not be changed.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Improving drain networks will contribute efficiently to the desalination of agricultural lands by limiting permanent waterlogging, improving agricultural activity, and intensifying land use (Slama et al., 2005; Bernard, 2020). In this context, main successful results obtained from an experiment undertaken in the lower valley of the Medjerda in Cherfech region located in the north of Tunisia showed that the installation of drains placed 40 m apart at 1.5 m depth in clayey-silty soils reduced the water table rising and the water stagnation impediment (CRUESI, 1970). Also, the recovery of agriculture and hydromorphic and salty soils, located in Utique in the governorate of Bizerte, was carried out by installing well-sized drains, plowing the soil, and applying leaching (CRUESI, 1968). Nevertheless, planning drain densification, their rehabilitation, and the maintenance of the drainage networks are not systematically organized due to unforeseen actions on the network and lacking funds to pay the contractors.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍁
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃
	Flexible	🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍁

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
General Direction of Rural Engineering (DGGR)	*Under the Ministry of Agriculture, a policy-making body responsible for developing policy strategy and finding funds to intensify rehabilitation and irrigated perimeters. It monitors and evaluates irrigation agricultural sanitation projects.*
Regional Offices of Agriculture Development of Bizerte (CRDA-Bizerte)	*Under the Ministry of Agriculture, they are in charge of implementing government agricultural policy, they oversee water and soil, responsible for planning and organizing tasks of maintenance, rehabilitation of drainage network and control of water table level rising.*
General Direction of Agriculture Production (DGPA)	*Under the Ministry of Agriculture, responsible for developing agricultural strategy to support sugar beet cultivation and introduce crops tolerant to temporary water stagnation.*

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Figure 1: Artichoke field on hydromorphic soil with a non-functional drainage system: Tobias perimeter (Askri, 2021).

Figure 2: Unmaintained open ditch invaded by reeds: Tobias perimeter (Askri, 2021).

SUSTAINABLE MANAGEMENT OF CROPPING SYSTEMS UNDER SALINE STRESS (KORBA AND BENI KHALLED)

objective: improve crop production in view of soil salinization

keywords: climate change, water stress, salinity

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Green Solution	Water efficiency

TOPIC: Water governance

Tunisia has a particularly variable climate which is vulnerable to climate change. According to the German Agency for Technical Cooperation, the impact of climate change in Tunisia will cause an increase of 1.1° C in average annual temperature and a considerable decrease in annual precipitation (GTZ, 2007). In Cap Bon, groundwater is the main source of irrigation (Lachaal et al., 2016). However, the overexploitation of groundwater, over the last century, has led to a drop in the water level in the boreholes and a considerable deterioration in water quality with an increase in salinity (Lachaal et al, 2016). The objective of this study is to find out whether fresh water from the north is sufficient for the water needs of crops in the irrigated area of Korba and Béni Khalled.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Soil salinization can be managed by combining observations of soil and water observations and solute and salt transport modeling in soil. The adaptation is:

- Reduce salinity in the soil while limiting water loss;
- Management of irrigation with salt water and fresh water;
- Safeguarding of strategic crops with a good yield;
- Avoid overexploitation of aquifers in order to limit marine intrusion into coastal aquifers;
- Avoid wasting northern water (Canal Mejreda);
- Efficient use of cropping systems to limit water loss by evaporation and reduce salinity in the soil.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

- Ensure the safeguard of strategic crops in the region (citrus fruits and vegetable crops: Strawberry, pepper and tomato)
- Saving the environment (groundwater and soil)
- Save water
- Ensure a good yield to farmers and therefore a good income

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of Agriculture	*Provide the means and popularization*
Farmers	*Cooperation*
Researchers	*Propose solutions*

AUTHORS

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LAND-USE MANAGEMENT USING SATELLITE IMAGERY

objective: improve land and water management by use of satellite imagery

keywords: water resources, cartography, land-use classification from satellite images

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Water scarcity

TOPIC: Water governance

The availability of irrigation water is becoming an essential factor in maintaining the fragile balance of oasis production systems. The water is often fossil, and the use means mining of the resource with no or little sustainability. Water deficit is particularly marked because of the continuous extensions of new plantations that systematically need more water leading to new private boreholes. The Kébili peninsula is suffering from an increasing number of illegal boreholes. Illegal boreholes are particularly numerous in the Nefzaoua area that corresponds to about 7000 ha (PANLCD, 2006).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The method involves mapping of land use using satellite images (Landsat, SPOT, Sentinel-2, Ikonos...) to reveal new private plantations of palm groves during the period from 2008 to 2014 over the entire study area.

The implementation of the methodology includes the following different phases:

- GIS data collection and acquisition of IKONOS-2 satellite images;
- Digital processing of IKONOS-2 satellite images;
- Map the private extensions of the oases for the year 2014;
- Field validation mission of the limits of the private extensions of the oases;
- Editing maps of private expansions at 1/5000 scale.
- Vegetation indices (NDVI, SAVI, etc.) are used to extract the different classes of land use.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃

The private oases of the governorate of Kebili have multiplied and this study makes it possible to locate these extensions to be able to study their impacts on the water resources of the region.

Therefore, it will be possible for decision-makers to take the necessary measures especially if these extensions develop in a rapid way.

The expected results are mapping of the extensions of the oases of Nefzaoua between 2008 and 2014 and the production of a land use map of the oases for the year 2014.It serves to identify the state of private extensions in the Nefzaoua area in 2014 (Kébili Governorate). Ultimately, in the northern regions, this same method can be used.

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
CNCT (National Center for Cartography and remote sensing)	*Develop two cartographic products from very high spatial resolution images.*
DGRE (General Directorate of Water Resources)	*Quality control of produced maps and database*
CRDA Kebili (Regional Commissariat for Agricultural Development of Kebili)	*Inventory and data collection*

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COUPLING GIS AND MULTI-CRITERIA ANALYSIS FOR RAINWATER HARVESTING

objective: improving water management by coupling GIS and statistics

keywords: climate change, RWH techniques, suitable sites

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Water scarcity

TOPIC: Water harvesting

Climate change is the major challenge faced by farmers who rely on rainfed farming in arid and semi-arid regions (Adham et al., 2016). They will have to cope with increased risk arising from more frequent extreme events and poor intra-seasonal rainfall distribution (Barros et al., 2014). Several adaptation measures are being promoted, such as the use of different crops or crop varieties, soil conservation, changing crops calendars, and irrigation (Bryan et al., 2009), but these options may not all be viable choices for smallholder farming either due to their high costs, technical restrictions, or even cultural limitations (Adger et al., 2012). Thus, rainwater harvesting (RWH) techniques could help mitigate the impacts of climate changes on crop production (Lebel et al., 2015).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

This solution enables water managers to better identify suitable sites for RWH techniques by integrating biophysical and socio-economic criteria using the Analytical Hierarchy Process (AHP) combined with Geographic Information System (GIS). This study shows the importance of including stakeholders' objectives and constraints in the identification of potential sites for rainwater harvesting techniques which is absent in most previous studies. The iterative nature, the capabilities of participatory GIS approach, and the empowerment of local communities are the main indispensable features of this approach and a successful and sustainable implementation of RWH interventions.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The economic, social, and environmental impacts expected are to increase soil fertility and crops production, to minimize production costs, the creation of employment and to fight against rural exodus.

This approach will assist in prioritizing technologies in area where two or more technologies fall under the same location.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED		
	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Researchers from IRA Medenine	*Execution*
Engineers from CRDA Medenine	*Facilitator*

AUTHORS

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PARTICIPATORY MONITORING OF RIVER FLOWS

objective: to improve water management by participatory approach

keywords: citizen science, participatory approach, water resources monitoring

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Green Solution	Water scarcity

TOPIC: Water resources monitoring

Water users in northwestern Tunisia, like the Medjerda watershed, are increasingly withdrawing water from water supplies. This is a response to the effects of climate change that are causing greater variability. These samples result in an increase in the state of stress over time (Fehri et al., 2020). The involvement of citizens, in a participatory manner, is likely to help raise awareness among water users. The use of Global System for Mobile (GSM) communication has been validated in the region of Medjez El Bab by the involvement of citizen groups (Fehri et al., 2020a; Fehri, 2021). The objective of this sheet is to capitalize on these achievements and to be used in the north-west for monitoring droughts or floods.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The involvement of citizens in the process of collecting water-related data, as a source of additional information to traditional observations, is likely to improve the spatial and temporal resolution of water resources monitoring. It will also make stakeholders and users aware of the constraints weighing on the water sector. The participatory monitoring approach improves the integrated management of water resources. Citizens can contribute to the collection of flow data through mobile applications. In times of drought, this is likely to make them aware of the state of the resource and to better understand, and even adhere to, water management programs. During periods of high water and flooding, participants in the program will be alerted at the appropriate time. The technical services of the Ministry of Agriculture and educational and research establishments are creating a site, facilitating training sessions for the benefit of volunteers, and creating and maintaining a platform to host observations. Members feed the data collection device and will benefit from the information.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

The proposed solution is innovative for the water sector for Tunisia. The participatory approach should be involved in integrated water resources management programs, especially in the context of water scarcity associated with climate change. Indeed, the stakeholder engagement and buy-in approach (water users, technicians, researchers, decision-makers and civil society) contributes to a better understanding of the vulnerability of the hydrological system and therefore their greater responsibility. This is an essential aspect in the context of the transition that Tunisia is going through (Fehri et al., 2017). The actions relating to the management program would be better respected and therefore could better achieve their purpose, especially during periods of increasingly severe water scarcity. Another impact is the flood warning and warning through the strengthening and densification of official hydrometric stations and access to information from all stakeholders.

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Tunisian Ministry of Agriculture (Technical directorates)	• *Adoption of the device* • *Establishment of a data collection and alert platform (drought or flood)* • *Platform management*
CRDA (Technical directorates)	• *Data collection* • *Establishment of measurement site*
Stakeholders (GDA, farmers, civil society)	• *Data collection* • *Access to data relating to the hydrosystem*
Tunisian Union of Agriculture and Fisheries	*Participation in the installation and management of sites*
Researchers	• *Data valorisation* • *Data collection*

AUTHORS

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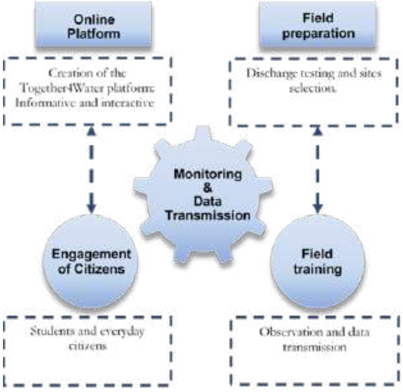

Figure 1. Implementation of the participatory flow collection approach according to Fehri et al. (2020b).

SPATIAL DECISION SUPPORT SYSTEM FOR ICHKEUL BASIN

objective: improving Ichkeul Basin water management by decision support system

keywords: spatial decision support system, ichkeul watershed, water management

Target	Decision Makers
Field of interest	Water Management
Type of adaptation measure	Soft Solution
Climate challenge addressed	Water scarcity

TOPIC: Drought

Ichkeul Basin water management has a significant impact on the biodiversity of Lake Ichkeul and the surrounding marshes. Three constructed dams in the basin have had considerable reduction in freshwater inflow. Three other dams are planned to meet the growing demand for drinking water and irrigation. In addition, a lock has been built to control the exchange of water between Lake Ichkeul and the Bizerte Lagoon. The 3 dams in operation are intended to transfer part of the water of northern Tunisia towards Tunis, Cap-Bon, and the center of the country (reduction of 157 million m3 of fresh water). The basin also contains numerous hill dams, a hundred hill lakes, and the sanitation of a 15,000 ha plain to the south-west of the lake (ANPE, 2009). Climate change impacts are likely to increase the need for freshwater and induce ecological, hydrological, and chemical modifications in the entire basin system.

To reduce these impacts and safeguard an ecosystem balance, a regulation structure was built at the outlet of Lake Ichkeul in the Wadi Tinja called "Lock of Tinja" to control the entry and exit of water from Lake Ichkeul. As a result, the natural ecological cycle of the lake is based on an alternation of periods of low salinity (winter) and periods of rising salinity (summer). The construction, however, caused eutrophication in the lake and along the Wadi Tinja during the period of closure, as well as the accumulation of sediment upstream of the Lock (Barek, 2001). The partial closure of the lock was partly responsible for the decrease in the recruitment of fry and juveniles in the lake causing a decrease in fish production). The management of the Ichkeul Basin is hampered by the lack of material, financial, and human resources. This lack is felt at the level of surveillance, development, and ecological monitoring.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Research results from the Integrated Management of Water Resources of the Ichkeul Watershed Project GIRE-ECO ICHKEUL (2009/2011) ("Wetland International" program) allowed a spatial decision support system to be developed to integrate socio-economic aspects, sustainability of water resources, and the ecology of Lake Ichkeul and its marshes. In order to improve water management to meet the freshwater needs of the Ichkeul ecosystem this decision support tool should be improved, including parameters and dynamics of physical environment criteria and main characteristics of erosion.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The improved decision support system can help managers and decision-makers to improve their management methods. Scientific field monitoring would enable providing valuable data for water management o and tailored troubleshooting for safeguarding fauna and flora and avoid the silting up of the lake. The improved decision support tool can contribute raising awareness in local communities in the basin, including women, enhancing rational water management. This awareness should be carried out by associations with an environmental connotation, given that the political changes underway since 2011 in Tunisia constitute an opportunity to better adapt the legislation towards a better role of associations in environmental governance in general and in the management of natural sites in particular (the Tunisian Health and Environment Association (ATSE) and the Women's Association for Local Development).

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍂
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍂
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 No 🍂

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
The Ministry of Agriculture	*Check dams-database*
ANPE, National Environmental Protection Agency	*Environmental governance*
The Self-Development Support Association (ASAD)	
Agricultural Development Groups (GDA)	
The Women's Association for Local Development	
l'Association Tunisienne Santé et Environnement (ATSE)	

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SUSTAINABLE MANAGEMENT OF WATER RESOURCES BY IMPROVING FIELD OBSERVATIONS

objective: improving water management by improved observation system

keywords: integrated management of water resources IWRM, intelligent monitoring system, spatial data

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Water Management	Soft Solution	Water scarcity

TOPIC: Water management

Tunisia is characterized by rainfall irregularity and by the random succession of dry years with a deficit and rainy years with a surplus. Under the effects of climate change, this irregularity will be accentuated with an increase in temperature and a decrease in rainfall, combined with longer droughts alternating with larger floods. In a context of scarcity and the risks of climate change, the management of water resources has become a major concern. Tunisia is among the countries least endowed with water resources (Nefzi, 2012) in the Mediterranean basin. Several national and regional studies highlight the risks of a significant drop in water resources (-30% for groundwater resources and -5% for surface water), and the degradation of the quality of irrigation water (Ben Nouna et al., 2018). The underground water resources of the lower Medjerda valley are increasingly in demand due to the rapid growth in their use. Water managers need newer and more accurate data to assess the condition of groundwater to deal with adverse situations such as drought and loss of pumping in agriculture and domestic water supply.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The activities of the SMART IWRM Medjerda project (2020-2022) suggest the urgent need to support the management of groundwater resources in the lower valley of the Medjerda basin based on the principles of IWRM through three main pillars: initial global assessment of the availability and quality of groundwater resources, data management & numerical simulation of water resources and capacity development. An intelligent monitoring system is available and should be applied by installing sensors that calculate soil moisture, plant water demand, estimated groundwater recharge and other parameters, as well as other data, such as land observation data allowing to study the spatiotemporal history of land use etc. Local stakeholder engagement is crucial, as to enable the use of available information.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

The implementation of SMART IWRM Medjerda project results would allow to estimate withdrawals and monitoring of water use in irrigated areas. Stakeholders, like researchers, population, engineers, would then be able to use geospatial systems and benefit from improved data access. The approach is expected to impact also the effectiveness of stakeholder engagement, especially rural women, but administrative constraints for involving people in the adoption of the participatory approach will need to be addressed to ensure success.

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
CNCT (National Center for Cartography and remotee sensing)	*Develop two cartographic products from very high spatial resolution images*
CRDA Bizerte (Regional Commissariat for Agricultural Development of Bizerte)	*Inventory and data collection*
The Ministry of Agriculture	*Quality control*

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CAPACITY BUILDING PROGRAM FOR IMPROVED IRRIGATION MANAGEMENT

objective: promote water use efficiency by training and capacity building

keywords: water user associations, irrigation management, capacity building

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Water Management	Soft Solution	Water scarcity

TOPIC: Water governance

The increase in drought and flooding episodes is harming local crop production, especially in low-altitude areas where subsistence agriculture is practiced. In Tunisia, as in many developing countries, agriculture is mainly rainfed, therefore dependent on the climate and on the seasonal to interannual variability that is affecting the production. Climate change has brought about a disruption of rainfall patterns, an increasingly late start of the rainy season, sudden interruption of rain, and recurring extreme phenomena. These changes are causing serious problems for local agricultural producers in the preparation, planning, and conduct of agricultural activities. Many of these problems can be mitigated by improved water governance as a soft solution to facilitate better management of water resources.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Raising awareness and building knowledge about the expected impacts of climate change and the need to adapt are the starting point for capacity building efforts. Capacity building is an integral part of the adaptation cycle. To this aim, flexible training and capacity building programmes are an integral part of the process to develop:

- Awareness among different stakeholders on irrigation modernization; Capacity of public institutions (ministries, general basin directorates or irrigation agencies) in O&M and irrigation management;
- Extensive farmer training programmes on the O&M of new techniques and on-farm irrigation water management, as well as on irrigated agriculture farming practices in areas where irrigation conservation techniques are implemented;
- Extensive farmer training programmes on technical itineraries of short-cycle varieties, production of organic fertilizers (especially composting), techniques for producing market garden crops, and seeds for short-cycle varieties;
- Managerial and technical skills of water user associations (WUAs) and irrigation agencies and conflict management skills.

Different types of activities can support capacity building such as targeted events, debates, information sharing through web platforms and portals, newsletters, reports, policy briefs, videos, brochures, projects, etc. There are different modes of capacity building such as education, training, networking, specific coaching and technical assistance.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Governance for adaptation to climate change (CC) in Tunisia can be improved thanks to strengthening farmers' and WUAs staff/members managerial skills and knowledge on adaptation to climate change. The program would also enhance institutional capacities of the Ministry of Agriculture to implement sound governance strategies to reduce vulnerability of the sector. The key impact of the capacity building program would foster the organization of relevant actors and coordination in terms of implementation of adaptation measures. Results would be expected after the program delivery (between 1 and 3 years), but capacity building material should be updated regularly to allow educational institutions sustaining the impact,over time.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Reduce energy consumption	🍃🍃🍃
	Reduce water demand	🍃🍃🍃
	Improve health of ecosystems and functionality	🍃🍃🍃
	Synergistic with other sectors	🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

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IREY IRRIGATION MANAGEMENT

objective: promote water use efficiency by better estimation of irrigation water needs

keywords: irrigation managment, smart application, climate change

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Water Management	Soft Solution	Irrigation

TOPIC: Water management at the plot

In Tunisia, field crops represent the most important agricultural product both in terms of the number of farmers and their driving role in the national economy. However, Tunisia has scarce water resources. The irregularity of rainfall, which characterizes the Mediterranean climate, can cause certain years of deficit, resulting in significant drops in yields and therefore in agricultural production. Thus, adaptation to climate change is important especially for the irrigated sector. In this regard, the National Institute of Arable Crops (INGC) has implemented a program which has the overall objective of improving the yield in irrigated areas, and improving the efficiency of water use and therefore water productivity through the development of decision support tools.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Description of the adaptation approach, technology or strategic management for adaptation

IREY (remote irrigation application tool), commissioned in 2015 by the National Institute of Field Cultures (INGC) as the first remote irrigation tool in Tunisia presented in two versions: Mobile and Web, concerns only field crops, available at the link http://irey.ingc.com.tn/. The model is based on daily calculation of the water balance. The climatic data requested by the application to calculate the balance are daily rainfall and evapotranspiration. A digital soil map identifying the Tunisian territory by type and physical properties of the soil, used by IREY according to the geolocation of the plot to be managed. Soil data relates to the type and physical properties of the soil. The input variables of IREY which concern the crop are type of crop, date of sowing, stage of growth, and crop coefficient. The application begins with the collection of information and input variables from users, either via the web or smartphone. The data collection will take place at the level of the platform itself. To increase the meteorological network handled by IREY, satellite climate data from Wapor, NASA POWER, and Climate Engine platforms cover the entire Tunisian bioclimatic zone. These satellite products offer a daily update of satellite climate databases free of charge, and at all points of the Tunisian territory. The updates provided by the use of satellite climate data from Wapor platforms allow IREY-extension to intervene in real time with the right dose of irrigation in the event of a water deficit. This intervention considers the plant's need in terms of degree day of growth and, therefore, in terms of the amount of heat required during the vegetative stage of the plant, which exactly defines the concept of precision irrigation.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The management of irrigation by IREY presents several objectives such as avoiding water stress over the entire crop cycle and when water is available, and its cost is affordable. It can thus maximize yield and quality when agricultural production includes periods of water restriction. The IREY can distribute the irrigations over the entire crop cycle. Imposing a reduced level of water consumption on the plant, it is necessary that the available soil water storage is exhausted (supply management). Thus improving water productivity.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃
	Synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

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DIRECT SOWING TO IMPROVE WATER MANAGEMENT

objective: improve water management by direct sowing

keywords: water deficit, soil water storage, conservation farming

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Water Management	Soft Solution	Crop change

TOPIC: Water management

In Tunisia, the intensification of agriculture, with agricultural practices that often have negative environmental effects, has accentuated erosion and consequently increased the rate of degradation of soil fertility. In view of climate change and high-intensity rainfall this process is more and more pronounced, making the management of water and soil in agriculture more and more complicated. Tunisian agriculture faces the challenge to increase production in quantity and quality, while preserving natural resources and with less rainwater.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To fight against this increasing degradation of Tunisian soils, many initiatives have been carried out since 1999 to develop conservation agriculture in Tunisia. The direct sowing system was particularly introduced for this purpose. Direct sowing means that the seeds are placed directly in unworked soil, covered by plant residues. It is thus defined by a total absence of tillage (no turning over, no de-compacting, no preparation of the seedbed, and no ploughing to preserve the natural biological and microbiological activity. Direct sowing is based on these four principles.

Thus, any improper application will negatively affect the success of this system:
- Avoid ploughing
- Continuously cover the soil with crop residue
- Seed directly on the soil using suitable tools
- Control weeds without disturbing the soil
- No mechanical soil intervention by tillage

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The main objective of no-till seeding techniques is to conserve, improve and use natural resources in a more efficient way through the integrated management of soil, water, biological agents and inputs of external products. . The ultimate goal is to achieve sustainable agriculture that does not degrade natural resources, without giving up on maintaining production levels. These techniques can be more or less elaborated, ranging from simple mulching to perennials permanently covering the ground. As to foster adoption, agronomic, technical and economic adjustments need to be established at farms level, requiring more or less demanding preconditions depending on the degree of technicality targeted, the initial fertility of the soils and the level of intensification of the agricultural operation (Raunet et al., 1998). Its dissemination requires taking into account the specificity of the rural context with its opportunities and constraints such as the complementarity of livestock and agriculture in production systems, the low level of intensification of rain-fed agriculture and the low level of awareness of farmers and all stakeholders in the agricultural sector to innovations (Zaghouane, 2006).

The adoption of simplified cultivation techniques and direct sowing can contribute to overcoming the challenges related to climate change, globalization and price fluctuations and high costs of production factors in tunisian agriculture (Elaissaoui et al., 2009; Elbrahli, 2009; Elbrahli et al., 2009).

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃
	Synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

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IMPROVED RESILIENCE OF VEGETABLE CROPS TO WATER STRESS

objective: improve vegetable crops by better irrigation and soil management

keywords: water insecurity, vegetable crops, adaptation

Target	**Field of interest**	**Type of adaptation measure**	**Climate challenge addressed**
FAS agents and farmers	Water Management	Green Solution	Water scarcity

TOPIC: Water saving

Agricultural productivity, food, and water security face enormous challenges with climate change. The scarcity of rainfall, rising temperature, and widespread drought are major consequences of climate change. The region of Sidi Bouzid faces drawdown and overexploitation of groundwater and illegal well drilling. The general goal is to ensure saving of water during the irrigation of crops while preserving as much as possible the quality and yield parameters of the crops. Vegetable crops in the area of Sidi Bouzid represent 18% of national vegetable production. The vegetable crops sector, nevertheless suffers from water scarcity problems.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Various applied water stress remedies are suggested such as grafting, soil amendment with compost, biochar, biofertilizer together with organic, inorganic and microbial biostimulants. The remedies can alleviate the water stress of crops and they contribute to increasing the amount of water available in the root zone, increasing yield and improving the storage of water, and soil water availability (by restoring the vitality and structure of impoverished soils, especially sandy soils, and consequently increasing its water retention) (Rady et al., 2019; Elzaawely et al., 2018). Water saving applied under controlled conditions to avoid consequences on yield, crop growth, and others may be a good option.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃
	Decreases water demand	🍃🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

The expected impacts of the method are:

- Creation of new agri-business in the production and establishment of production units for compost, biochar, and biostimulants.

- Increased productivity and quality of vegetable crops with reasonable irrigation.
- Increase in profitability for the farmer and consequently improved financial situation of farmers.
- Lower irrigation costs (labour and equipment) and preservation of water resources.
- Control available water resources and ensure their preservation.

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BETTER IRRIGATION WATER QUALITY FOR POTATOES

objective: improve potato crops by improving irrigation water quality

keywords: water deficit, salinity, irrigation scheduling threshold

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Water Management	Grey Solution	Irrigation

TOPIC: On farm water management

In semiarid Tunisia, 70 to 80% of water resources are used by the agricultural sector. According to climate change scenarios for the Mediterranean region (Ghazouani and al., 2019), the annual precipitation and the number of rainy days will decrease. As a result, problems related to the lack of water will be accentuated. In Tunisia, the potato occupies 7% of irrigated areas and produces 360,000 tonnes per year. Potatoes are planted from November to April to promote export to Europe. Under the semiarid climate of central Tunisia, winter and autumn rainfall helps to meet part of the plant water demand (Ghazouani and al., 2019) . However, from the beginning of April, temperatures tend to increase and the amount of precipitation to decrease. This time of year coincides with the full development stage, which is most sensitive to water stress. Thus, the potato crop must be properly irrigated to avoid any problem during tuberization. However, in areas characterized by poor water availability, farmers are forced to use saline water or reduce irrigation doses (Latrech et al, 2018)

Under these conditions, the irrigation schedule must consider the dependence of the yield on water quality and the irrigation dose, to optimize the efficiency of water use and limit soil salinization (Ghazouani et al., 2017) .

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The method allows a significant saving on water use from irrigation. A delay in the sowing date results in a shorter growth cycle, due to the increased demand for evapotranspiration. In the absence of salt stress, it is desirable to anticipate the sowing date, to take advantage of the beneficial contribution of the rains. The dose and quality of irrigation water affect agronomic parameters (root depth and leaf area). More precisely, a reduction of 100 mm in the irrigation reduces yield with about 17.0 ton/ha for good quality water and about 12.0 ton/ha for poor water quality. Further, an increase in electrical conductivity of 1.0 dS/m produces a reduction in water use efficiency of about 10%. The following conditions should be met for scheduling the irrigation of the potato:

- The value 65.6 KPa is the critical threshold of soil matric potential (corresponding to a value of 0.4 of crop leaf water index) for scheduling irrigation with good quality water, in sandy loam soil under the semi-arid climate of central Tunisia.
- When using salt water, the soil matrix potential threshold should be reduced to 43.7 KPa and the crop water index to 0.3.
- When salt water is used for irrigation, the irrigation doses must completely replenish the root zone in order to avoid water deficits linked to the osmotic potential and to ensure leaching of the salt.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The challenges relating to the “food-water-energy” system require a systematic approach and integration at different scales to solve the problems of food production, environmental degradation, and energy use. The impacts of this solution will allow us to better understand the effect of climate variability, including water deficit and salt stress on the potato production system. This will make it possible to meet national goals of: reduction in demand for conventional water, use of marginal water, preservation of the soil, improvement of irrigation management, and preservation of the environment by reducing the salinization of groundwater. The approach is part of an effort to improve agricultural production, and thus the standard living of the farmer community by the least expensive technical means.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🟢🟢
	Decreases water demand	🟢🟢
	Increases health and functionality of ecosystems	🟢🟢🟢
	Synergetic with other sectors	🔴
	Flexible	🟢🟢
	Robust	🔴

Yes high 🟢🟢🟢 Yes medium 🟢🟢 No 🔴

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IRRIGATION DEFICIT MANAGEMENT BY PARTIAL DRYING OF SEASONAL POTATOES

objective: improve potato production by deficit irrigation

keywords: irrigation deficit, saving irrigation water, electric pumping energy

Target	**Field of interest**	**Type of adaptation measure**	**Climate challenge addressed**
FAS agents and farmers	Water Management	Green Solution	Irrigation

TOPIC: Saving irrigation water

The availability of water resources in Tunisia is subject to increasing pressure from demand for irrigation water. Particularly, the semiarid and arid regions of the country, exhibit an imperative need for an urgent and innovative solution to the management of irrigation water under conditions of limited water availability. Resorting to the concept of deficit irrigation may constitute a rigorous solution for this. The emerging indirect advantages of this innovative technology can constitute an advantage of saving electric pumping energy and limiting the pollution of groundwater by agricultural inputs of chemicals.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Among the variants of deficit irrigation, partial root drying (PRD) (Fig. 1) (which requires alternating irrigation with 50% of the maximum evaporation (ETM) to either side of the plant's root system) leads to a reduction in transpiration, with an insignificant impact on yield. The work carried out by Ben Nouna et al. (2014, 2016) confirms the practical advantages of this technology in the case of growing seasonal potatoes. In fact, its application at plot scale and in the agro-climatic conditions of semiarid regions of Tunisia of limited water availability, has made it possible to achieve a substantial saving in irrigation water (Fig. 2) and electric pumping power (Fig. 3). The method provides an irrigation water saving regime of 50% of the ETM at the early tuberization-maturity stage of a seasonal potato crop (Spunta variety) (Fig. 4), a surface drip irrigation system, and an alternating irrigation frequency of 6 days in the event of strong climatic demand and 10 days in the event of average climatic demand.

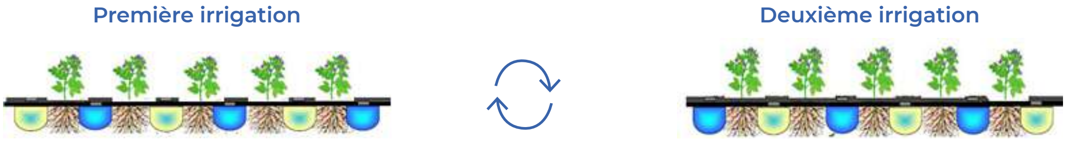

Figure 1. Experimental setup of an irrigation system by partial drying of the roots of potato.

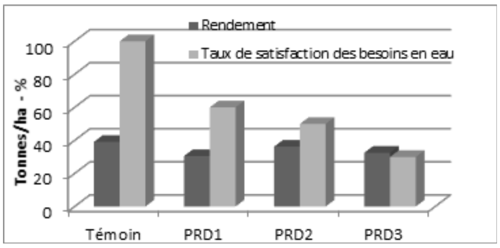

Figure 2: Tuber yield and rate of satisfaction of water needs compared to ETM, (early tuberization-maturity period) according to the deficit irrigation treatments

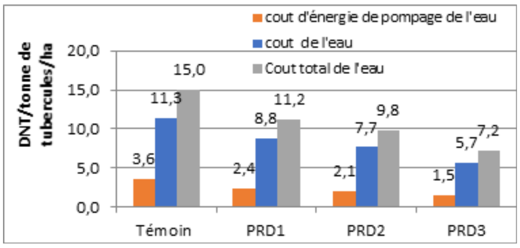

Figure 3: Reduction in water and energy costs depending on the treatment of the deficit irrigation

Figure 4. Experimental site testing of potato

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The results obtained from the application of this technology, show a stability of the average yields of fresh matter of the tubers compared to the conventional irrigation with the ETM (control) and an advantage of saving water in the order of 50%. To assess the economic benefit of this innovative irrigation technology, we measured its impact on the energy cost of pumping water, and the total cost of water per tonne of tubers produced. The assessment shows an average reduction in the cost of water and its pumping energy cost of about 39%.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃🍃
	Decreases water demand	🍃🍃🍃
	Increases health and functionality of ecosystems	🍃🍃
	Synergetic with other sectors	🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

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RAINWATER HARVESTING: SINGLE BASINS

objective: promote rainwater harvesting by single tree basins

keywords: rainwater harvesting, soil moisture, runoff collection

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Water Management	Green Solution	Rainwater harvesting

TOPIC: Runoff collection

Tunisia is strongly affected by aridity over most of the territory. Climate change projections exacerbate this situation, thus impacting the sustainability of agricultural productivity (National Strategy). Water deficit in the rugged physical environment in northern Tunisia will increase in the future. Hence there is urgency to implement actions to improve the adaptive capacities of populations and natural systems to decreased rainfall and runoff. There are several techniques that can help mitigate this. In the below we present a traditional farming practice and strategy that can contribute to adaptation to climate change.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The technique of rainwater collection in single plot basins is an old farming practice applied in arid central Tunisia. It consists of creating a crescent-shaped micro-basin located around the stem of individual trees so that rain and runoff are channelled into the basin. The realization of individual basins, arranged in staggered rows, associated with shrub plantations, in particular olive trees, is an appropriate solution on sloping land both to retain runoff water and to increase agricultural production in the rainwater collection system (Mastour, 2017).

The technique is performed manually as follows:

- Tie a cord to the trunk of, e.g., the olive tree to make a semicircle with the same radius as the top of the tree.
- Dig a 10 to 20 cm deep ditch around the tree. Its shape should be concave, semicircle, and upstream.
- Put large stones in the ditch according to availability.
- Backfill the ridges of the basin to a height of 0.2 to 0.6 m.

Photo: Single rainwater harvesting basin with olive tree.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The technique improves the water balance, soil fertility, and olive production, controls erosion, protects downstream infrastructure, reduces the extent of flooding and contributes to carbon sequestration by increasing biomass. Experiments have shown that the basin improves the soil moisture level by 28%, provides olive trees with an additional water supply varying between 29 and 84 mm, and increases the organic matter rate by 8% and fine soil element content by 18% (INRGREF, 2017).

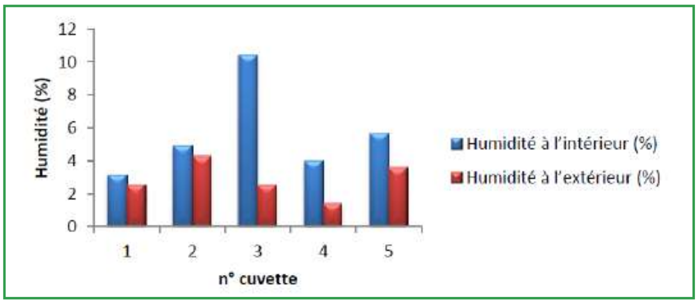

Figure 1: Example of soil water content inside and outside of the basin.

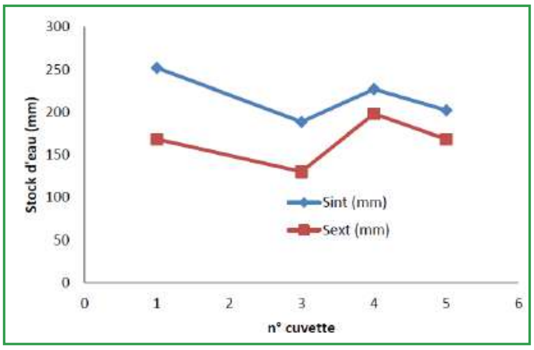

Figure 2: Variation of soil water storage in the 0-50 cm soil layer inside and outside of the basin.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍂
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 No 🍂

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REFERENCES

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IMPROVING THE EFFICIENCY OF WATER USE BY UNDERGROUND DRIP IRRIGATION

objective: improve agricultural production by underground drip irrigation

keywords: irrigation ramp depth, current evaporation, current transpiration

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Water Management	Green Solution	Irrigation

TOPIC: Water management at the plot

In Tunisia, the increased water needs of the industrial and domestic sectors, the rapid expansion of irrigated agriculture as well as the strengthening of the agricultural sector contribute to a constant increase in water demand. Currently, agriculture alone consumes 83% of available water resources (Ghazouani et al., 2016). Tunisia is classified among the countries vulnerable to climate change. Projections for 2100 show an increase in average annual temperatures of 3°C and a decrease in annual precipitation of 20%. Currently, irrigated agriculture covers 7% of the cultivated area and contributes about 33% to national agricultural production (Zairi et al., 2003). Future projections indicate the need to strengthen the role of irrigated agriculture to reach 50% of national agricultural production (FAO, 2005). While on the one hand it is possible to increase water availability by using unconventional water, such as treated wastewater or brackish water, the adoption of new strategies aimed at improving the efficiency of use can play a key role in agricultural and economic development (Ghazouani et al., 2019). In this context, rational use of efficient irrigation such as drip irrigation can help increase the efficiency of irrigation water use.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The main objective of the approach is to assess the optimal depth of irrigation supply using in situ measurements and Hydrus 2D simulation model for eggplant (Solanum melongena L.) crop. The crop was planted in sandy loam soil, semiarid climate, and irrigated with a drip irrigation system. First, the performance of Hydrus-2D was evaluated based on a comparison between simulated and measured water content in two experimental plots. In the plots, irrigation pipes were placed on the surface of the soil and at a depth of 20 cm (underground drip irrigation,). Once the Hydrus 2D software was properly calibrated, a series of scenarios was simulated to identify the optimal position of the irrigation dripper. These scenarios were developed to compare the effect of three soil depths of the irrigation dripper (5, 15, and 45 cm) for water use efficiency. This was expressed as the ratio of simulated transpiration to the total amount of irrigation water supplied during the entire growing season. According to the scenarios examined, the evaporation from the soil decreases as the depth of the irrigation dripper increases. The efficiency of water use tends to increase as the lateral depth increases from 0 to 20 cm. Burying deeper than 20 cm from soil surface implies an increase in the loss of water through drainage and therefore a decrease in the efficiency of water use.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The approach is part of the search for irrigation strategies aimed at increasing the efficiency of water use in a context of water stress and climate change. The choice of underground drip irrigation (SDI), with ramps installed near the root zone, makes it possible to supply water directly to the roots of the plants and to preserve a relatively dry soil surface, to reduce losses by evaporation. In particular, the depth of the irrigation booms depends on the characteristics of the crop, soil, and climate, as well as farmers' preferences and water quality. Usually, the depth varies between 0.02 and 0.70 m, for shallow root horticultural crops, while the deeper values are applied to systems intended for use over several years or when tillage is practiced. The correct choice of the burial depth of the irrigation boom will affect germination, crop yield, and fertilizer use efficiency. This will contribute to the improvement of the farmer's net profit and his gross income because of the reduction in input costs. In addition, this approach will allow for reduction of fertilizer leaching, soil salinization, and improvement of current plant transpiration in a context of climate change.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃
	Synergetic with other sectors	🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

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SOIL MANAGEMENT

VEGETATION IMPROVEMENT TO COMBAT SAND EROSION

objective: combat soil erosion by improving vegetation cover

keywords: vegetation fixation, climate change, sand erosion

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Soil Management	Green Solution	Erosion

TOPIC: Soil erosion

The coastal dunes of the North (Bizerte to Tabarka) are subject to wind and water erosion that threatens the functioning of the natural ecosystem (Bounouh, 2010). Wind erosion is one of the causes of the vulnerability of the flora and fauna of the dunes in Tunisia. These ecosystems are threatened by strong demographic pressure and by the establishment of tourist and urban areas. Therefore, the fixation of the dunes has high priority. This action is an important adaptation measure against effects of climate change.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The aim of the method of combating sand erosion from wind threat is to limit the risk for transport of particles and to control the distribution of sand during deposition and accumulation and above all to fixate it on site. This is provided by these methods:

Mechanical control for fixating mobile sand and dunes in the short and medium term by:
- Installation of a trapezoidal Tabias, 2 m high using heavy machinery,
- Installation of fence by:
  - » preparing 1.50 m and 2 m long branches at the site.
  - » digging a ditch of at least 60 cm at the installed Tabia.
  - » placing branches inside the ditch followed by adequate soil filling.
- Preparing a grid to the area, fixed using branches of length between 1.50 m and 2 m, installed in ditches at least 40 cm deep. The dimension of the grid is 10 m x 10 m.

Biological control methods consist of developing a permanent plant cover. They follow the mechanical techniques of stabilization and fixing of sand and dunes whose effects are temporary.
- Planting density: 2 m x 2 m, i.e., 2,500 plants per hectare, only Acacia Cyanophylla and Acacia Cyclops are used for fixing coastal dunes, followed by plantations of Maritime Pine, Eucalyptus and Pine Pinion.
- Planting holes: (40 cm X 40 cm X 40 cm).
- Planting period: 1st half of November until the end of March the following year.

These actions require regular maintenance (raising fences, correcting cords, etc.).

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The impacts can be summarized as environmental, economic, and social:

Environmental impacts
- Rehabilitation, protection, and conservation of existing natural ecosystems
- Land protection

Economic impacts

- Protection of basic infrastructure (roads, dams, built-up areas, channels, etc.)
- Increase in the profitability of soils
- Agricultural development of land

Social

- Social stability and improved income for households and farmers

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
General Directorate of Forests	*Administrative and technical management*
INRGREF	*Research*
Regional Commissariats for Agricultural Development (CRDA) of Jendouba, Béja and Bizerte	*Management*
GDA (organized local population)	*Benefit, user, PPP, ...*
Farmer/SMSA	*Benefit, user, PPP, ...*
ISPT	*Research*

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Photo: State of the coastal dunes of Tabarka, 2011

SOIL TERRACING TO REDUCE EROSION

objective: to reduce erosion by soil terracing

keywords: water erosion, runoff management, sediment retention

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Soil Management	Green Solution	Erosion

TOPIC: Supply and infrastructure

Heavy rainfall with subsequent intense runoff, erodes the soil and removes organic matter it contains (Lugato et al., 2018). Climate change is worsening this land degradation, especially in arid and semiarid areas (IPCC, 2019; Panagos et al., 2020). Water erosion is serious in arid and semiarid Tunisia. Most watersheds are characterized by severe specific soil degradation exceeding 2000 ton/km^2/year. Soil erosion can be mitigated using sustainable land management techniques. Among these techniques, soil terracing presents an interesting response to climate change. The method can collect water and sediments and result in increased groundwater recharge. At the same time evaporation decreases which also mitigates climate change.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The terraces are soil established perpendicular to the slope to store runoff and improve infiltration (Jebari, 2001). They are intended to reduce the runoff length of the slope and to intercept surface runoff before it reaches erosive speed. As well, they collect sediments and nutrients.

The soil terrace generally comprises 3 elements (Figure 1):

1. The ditch: with a maximum width of 5 of the impluvium (inter-terrace), with a slope between 0 and 1%.
2. The upstream and downstream 2/3 slope.
3. The area of the upstream impluvium is close to the ridge which could receive additional water by drainage during rainfall.

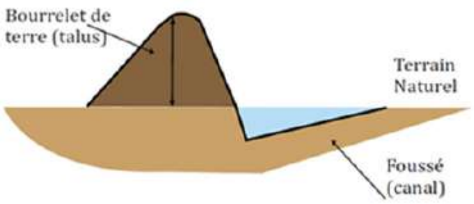

Figure 1, Schematic of design of a soil terrace.

Proper location and designed terraces help to slow down the runoff erosion in small watersheds and store surface water for agriculture (DGACTA, 2017). To ensure the resilience of these structures for agricultural land, it is advisable to consolidate them with fruit or fodder plantations. These plantations can contribute to the economic development of these structures.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The terraces will infiltrate almost all runoff when they are optimally located in the landscape. As well, all sediments will be retained upstream the terraces and hinder erosion. Therefore, they help to improve agricultural yield (Jebari, 2003). Studies have indicated that the local terraces, established on approximately 50% of the watershed area, reduced surface runoff by about 19% and sediment yield by about 22%. Moreover, the terraces intercept runoff and hold it for several days. Infiltration is increased and the gradual sedimentation that occurs upstream of the terraces improves the quality of the soil and promotes successive revegetation. Close to farms, terraces increase agricultural area and land productivity by collecting runoff and reducing winds by trees planted on them.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
ONAS Ministry of the Environment	*Quality of wastewater treated in reuse standards*
Ministry of Agriculture	*Project partner*
Ministry of Health	*Project partner*
ANME	*Project partner*
AED	*Project partner*

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DECISION SUPPORT TOOL: WATER EROSION MODELLING

objective: improve spatial modeling of soil erosion

keywords: climate adaptation, soil erosion, river basin management

Target	**Field of interest**	**Type of adaptation measure**	**Climate challenge addressed**
Decision Makers	Soil Management	Soft Solution	Erosion

TOPIC: Soil erosion

The INM (2015) climate forecasts indicate a probable rise in temperatures of +1.1°C in 2030 and 2.1°C in 2050 and a decrease in average annual precipitation of 2 to 16% by 2050. This will decrease the availability of surface water resources that are already scarce and an increase in the vulnerability of ecosystems, which already present a state of advanced degradation due to anthropogenic pressure (MEDCC, 2020). All these factors accelerate water erosion and the sedimentation of hydraulic structures. Consequently, actors in the agricultural world and political decision-makers are increasingly calling for research on possible ways of adapting agricultural practices to future climate change (DGACTA, 2017). Thus, adaptation requires a detailed understanding and anticipation of the likely impacts of climate change on a small scale such as a watershed.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The mitigation of vulnerability to climate change is aimed at improving the adaptive capacity of the population, ecosystems, natural resources, and livelihoods through a set of techniques and approaches integrated into the prospect of reducing their exposure, sensitivity and vulnerability to climatic hazards and extreme phenomena. This will be achieved by adopting prediction tools to ensure sustainable land development. To predict the evolution of soil erosion, and thus facilitate management, researchers have developed different types of models. Even more, these tools are needed to predict the adverse effects of climate change. We expect a reduction in erosion through simulation of future scenarios for appropriate choice of decision support management techniques. The RUSLE model makes it possible to establish an erosion risk map at the watershed level and to know the quantities of soil (in tonnes/ha) that can be detached annually for each pixel in a given sector. As a result, it is possible to locate areas of strong water erosion requiring priority intervention. Moreover, this approach helps prevent the consequences of this phenomenon by taking the necessary development measures and keeping the land loss rates below a tolerable limit value.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Quantification of spatial soil erosion is an essential approach for understanding the processes underway in watersheds. The implementation of the Universal Soil Loss Equation using a geographic information system makes it possible to obtain a quantitative estimate of the eroded spaces. The results showed that the combined effect of climate change and land use degradation estimates an increase in soil loss of 29% by 2030. Even more, the consideration of developments in a context of climate change allows the reduction of the rates concerning the areas threatened by an average to strong erosion of respectively 62% to more than 36% (CRDA, 2017).

Modeling allows rural planning and agricultural development practitioners to measure soil erosion more quickly and at low cost, and therefore to propose more appropriate solutions for conserving water and soil resources (Khemiri and Jebari, 2020). This approach helps guide rural development agents to define where hydro-agricultural and anti-erosion facilities should be installed as a priority, but also to study the consequences of climate change on agricultural landscapes. However, it remains to promote a transfer of these findings from agricultural development research, for applications to wider areas.17).

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of Agriculture, Hydraulic Resources and Fisheries	*Programming, decision-making, funding*
General Directorate of Development and Conservation of Agricultural Lands	*Technical direction of execution and monitoring evaluation*
Researchers	*Improved model, reduce uncertainty*
CRDA	*Data collection, Modeling*
Population	*Identify the risks associated with climate change*

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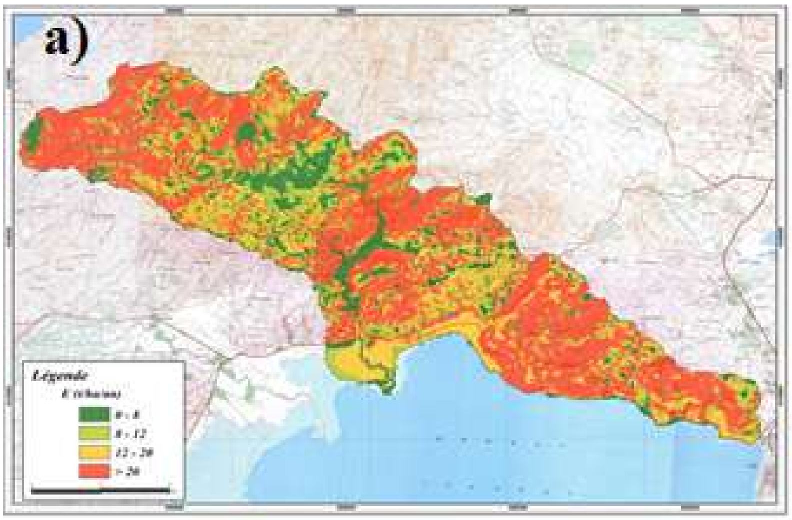

Assessment of soil losses with CES development (INRGREF, 2017).

Simulation of soil loss taking into account climate change impact by 2030. (INRGREF, 2017).

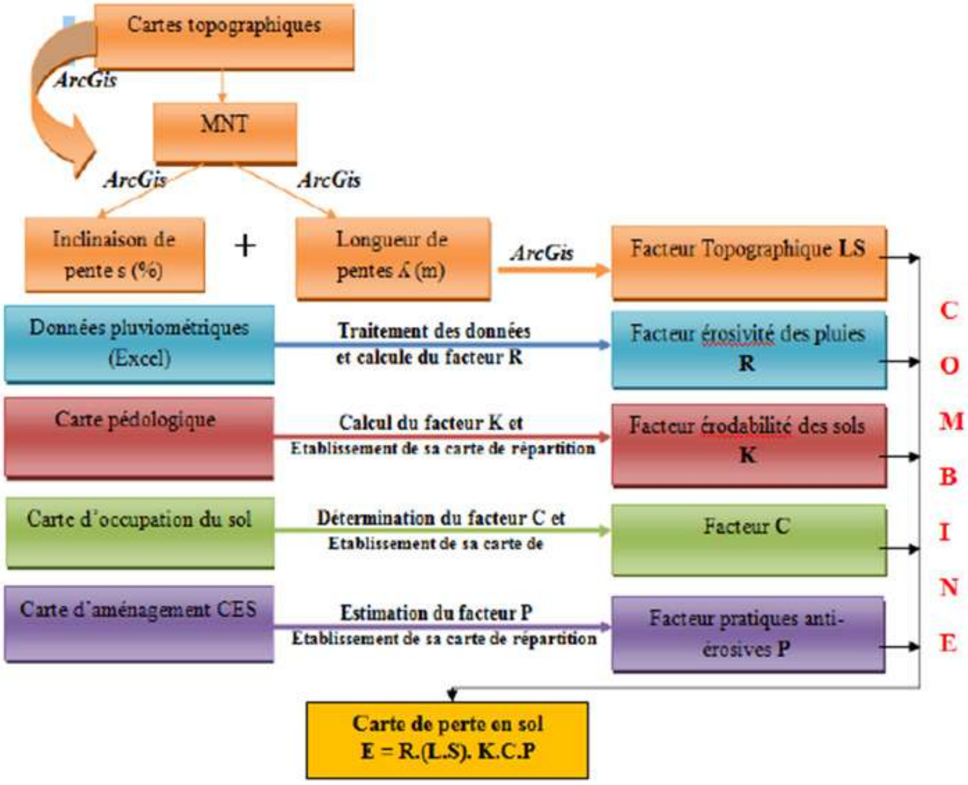

Figure: Methodical approach of the RUSLE model

FIGHT AGAINST EROSION AND FOREST LANDSLIDES IN THE ATTATFA VALLEY

objective: mitigate soil erosion and landslides by vegetation cover

keywords: conservation of forest land, soil fertility, valuation of the forest

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Soil Management	Green Solution	Erosion

TOPIC: Soil erosion

The Attatfa Valley area is affected by strong and destructive erosion of soils and natural resources that even may threaten human life. The geology, morphology and intensive rainfall combined with irrational anthropogenic management, constitute the ingredients of the destruction of this environment given the context of current climate change. Many forms of erosion are observed in this valley: gullying, landslides, and mass detachment. Soil erosion has important social impacts such as unemployment of young people and especially rural women, disappearance of the category of small producers, youth migration, in combination with reduction of forest land, impoverishment of soil and disappearance of species such as the Zen oak.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The proposed measures against erosion constitute creation of small hill lakes for the protection of water resources. Besides this, flow of small rivers and wadis in the area need to be controlled and prevented from erosion of riverbanks and riversides. Biological measures against erosion include introduction of the plant Chrysopogon zizanioides, which has been introduced in Tunisia and seems to be well suited to protect sloping land against water erosion. Other plants effective in protecting sloping marly soils may be Sulla species that can fix agricultural land and besides be used for livestock feeding.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

In the Attatfa Valley an area of about 300 ha requires protective measures against erosion, 10 ha are threatened by landslides, and 60 ha by mudslides. In Dar Fatma about 25% of the land area is threatened with landslides. Erosion problems also concern about 100 ha in Sra Rebah. Impact of soil conservation is effective and has an impact not only on the environment since at the same time conservation of water occurs and has positive economic impact for the inhabitants. In Dar Fatma about 50 ha private land have been improved and had a positive impact on soils, and agricultural yields.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

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SOIL FERTILITY IMPROVEMENT USING EARTHWORMS

objective: improve soil fertility using earthworms

keywords: soil structure, soil fauna, soil fertility

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Soil Management	Green Solution	Desertification

TOPIC: Soil fertility

Rising temperature, more frequent heat waves, and more severe droughts are signs of climate change. This leads to impoverishment of soils regarding organic matter, reduced soil development and above all, reduction in diversity and functioning of soil organisms. For this, it is important to maintain adequate soil properties to allow for active life and biodiversity of soil fauna and flora. Indeed, earthworms are among the most important actors in maintaining both the structure and fertility of soils (Boughattas et al., 2017; Boughattas et al., 2018). Therefore, their presence and thriving in the soil are of great importance for soil fertility.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To maintain adequate biological activity in agricultural soils, it is important to reduce the application of pesticides and herbicides (Hattab et al., 2015). In addition, the contribution of organic matter is vital for preservation of soil fertility. Conservation agriculture places soil at the heart of its production system. It plays a decisive role in keeping important earthworms in the soil. On the one hand this means to avoid excessive consumption of organic matter by reducing or even eliminating tillage, and on the other hand by increasing the production of organic matter during the year by a plant cover (Bahri et al., 2019). In this same context, organic farming, thanks to its principles of non-use of chemical fertilizers and chemical pesticides, makes it possible to maintain the health of agricultural soils and to promote diversity of earthworm populations (Hattab et al., 2020). For irrigated soils, it is necessary to control and monitor the quality of the water over time, particularly in the case of irrigation with treated wastewater which may have negative effects on biological activity in the soil (Mkhinini et al., 2020).

Example of earthworm Eisenia andrei (original photo).

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Developing the natural fertility of soils is, besides direct economic benefits, means of improving production in terms of environmental quality and nutrition of agricultural products (Boughattas et al., 2018; Hattab et al., 2020). Enhancement of the biological activity, undisturbed by deep and/or repeated mechanical interventions, results in establishment of a permanent and continuous porosity that improves infiltration and soil water storage, allowing for transport of gases, roots, and soil biota. The improved structural quality enhances the development of crops and their capacity to resist stress and diseases (Bahri et al., 2019). Thus, improving the structure of the soil increases water retention capacity and availability of water to the plant. In this context, earthworm activity helps defragment organic matter, supply nutrients to the plant, and consequently an increase in agricultural productivity in spite of climate change.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

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SOIL SALINITY MITIGATION

objective: improve agricultural production by soil salinity mitigation

keywords: waterlogging, salinization, soil improvement

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Soil Management	Green Solution	Salinity

TOPIC: Soil fertility

A short paragraph that describes how the issue addressed in the datasheet relates to climate change. You can describe current risks and predicted trends, citing scientific information if available. (Maximum 750 characters)

In Tunisia, in addition to the aridity of the climate and the relatively limited renewable water resources of modest quality (50% have a salinity level higher than 1.5 g/l), the use of brackish water for irrigation has generated salinization and degradation of the fertility of about 50% of the irrigated soils (DGACTA, 2007). Climate change, characterized by an increase in temperature and a decrease in rainfall, is an additional risk factor for salinization of irrigated soils (Selim Abou Lila et al., 2019). It is therefore important to develop recommendations to irrigated soil managers and farmers for better soil and water management to reduce risks of salinization and degradation of soil fertility irrigated with marginal water.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To reduce the risk of degradation of soil fertility, it is recommended to apply the following procedure (Figure 1):

- Before cultivation, perform physicochemical analyses of the root layer for the choice of crops (e.g., salinity tolerance), estimate of leaching, and nutrient requirements.
- Carry out a temporal monitoring of water content and salinity of soils for better water and soil management (Zemni et al., 2019; Slama et al., 2019).
- Avoid sprinkler irrigation when water is salty (risk of toxicity and crop burn). In case of drip irrigation, it is advisable to practice surface irrigation (flood irrigation) at least once a year to leach excess salts accumulated at the edges of the moisture bulb.
- For waterlogged soils, construction and maintenance of drainage networks are essential to reduce the risk of crop damage and soil salinization. In presence of a shallow (<1.5 m) and saline water table, it is advisable to install a network of piezometers for control and monitoring of the water table (depth and salinity) to predict and avoid an excessive rise of water table and soil salinization.

Figure 1. Monitoring of water (surface water table, drainage, irrigation) and soil properties for the zoning of units with different degrees of risk of soil salinization in the irrigated perimeter of Kalaat al Andalous (Bouksila et al., 2013).

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The spatiotemporal monitoring of the properties of shallow groundwater table, physicochemical properties of the soils as well as agricultural practices (irrigation system, etc.), allow us to determine factors of soil degradation, risks for salinity, and waterlogging (Figure 1). The zoning of these homogeneous soil units allows managers of irrigated areas and farmers to target the operations to be carried out to reduce the risks of falling soil fertility, choice of crops (depending on their tolerance to salinity) as well as rational management of water (water requirements, management, and irrigation system) and soils (tillage, fertilization, etc.). Several studies carried out in Tunisia have shown that the shallow groundwater table constitutes an important risk factor in the salinization of irrigated soils (Hemdane and Mami, 1976; Bouksila 1992, 2011). Therefore, for hydromorphic soils, the installation and maintenance of effective drainage networks are essential to reduce the risks of damage of crops, loss of soil fertility, and agricultural production. This reduces the risks of degradation of soil fertility, as well as a deterioration of farmers' income.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

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PHYTOREMEDIATION TO TREAT POLLUTED SOIL

objective: improve polluted soils by phytoremediation

keywords: soil decontamination, soil fertility, phytoremediation

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Soil Management	Green Solution	Soil fertility loss

TOPIC: Soil fertility

The intensification of human activities, especially industrial and agricultural endeavors through climate change, has contributed to the contamination of agricultural soils by trace metal elements. Among the innovative remediation strategies, are phytoremediation, i.e., the use of chlorophyll plants and their associated microbiotas to eliminate, contain or make environmental contaminants less toxic (Helaoui et al., 2020a; Hattab et al., 2020a; Hattab et al., 2014). Alfalfa (Medicago sativa L.) is a legume with nodules that fix atmospheric nitrogen to the roots. These alfalfa / bacteria symbioses constitute a biological source of nitrogen for plants grown in contaminated soils (Hattab et al., 2016) that increase the accumulation of toxic elements in plant biomass (Helaoui et al., 2020).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Phytoremediation is a technique for treating polluted soils. It is based on the ability of certain plants to extract pollutants from their substrate and accumulate these in their biomass (Helaoui et al., 2020a). Through the creation of a dense and perennial vegetation cover, phytoremediation is performed by plants to reduce the bioavailability of toxic pollutants, to immobilize the polluting compounds or to store these elements in the plant system. In addition, the vegetation cover minimizes wind erosion as well as direct contact between animals and pollutants. It also helps prevent the dispersion of pollutants in surface and groundwater (Sousou et al., 2014). Phytoremediation techniques are mainly applied on moderately deep silty to sandy soils (about 50 cm) and when polluted surfaces are large. Beyond this depth, it is best to use trees or excavate land to manage them. In addition, the choice of technologies and plants used depends on the agronomic characteristics of the site and the type of pollution. The steps for each technique are as follows:

- Site survey: physicochemical analyses of the soil (toxic elements, OM, etc.),
- Site preparation (clearing, etc.),
- Selection of varieties and possible amendments,
- Sowing, planting, maintenance,
- Harvest and recovery of biomass,
- Monitoring and surveillance of the culture.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Alfalfa is a Fabaceae (legume) capable of fixing 100 kg/ha of atmospheric nitrogen via Rhizobium agrobacteria thanks to its well-developed root system and nodules rich in nitrogen fixing bacteria (Helaoui et al., 2020a). Hence, alfalfa improves the structure of degraded soils. From an eco-toxicological point of view, alfalfa has been described as a plant that phytostabilises trace metal elements such as Cd, Cu, Pb, and Ni. It acts as a pumping and filtration system with inherent accumulation and degradation capabilities. The roots can alter and/or displace toxic elements against significant chemical gradients (Sousou et al., 2014). However, phytoremediation has limitations. On the one hand, the effectiveness of this technique is limited by the biomass (aerial and root) of the remedial plants and by the climate. An unfavourable climate limits plant growth and the production of plant biomass. On the other hand, phytoremediation involves slow processes: several years are needed to clean up a hazardous waste site (Hattab et al., 2013).

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

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Photo: La luzerne

DIAGNOSIS OF THE BIO-FERTILITY OF AGRICULTURAL SOILS

objective: improve soil fertility by diagnostic methods

keywords: soil bio-fertility, soil quality bioindicators, soil fauna

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Soil Management	Soft Solution	Soil fertility loss

TOPIC: Soil fertility

Soil represents the most important reservoir of biodiversity on our planet (Brown et al., 2000), particularly in micro and macro-organisms. These two elements constitute the essential link in soil biofertility, also called biological fertility. Biofertility is often also referred to as the biological quality of soils. This refers to the abundance, diversity and activity of living organisms that participate in the functioning of the soil. Consequently, the soil constitutes a living and dynamic entity, in perpetual evolution, which can be disturbed by many factors; among which are anthropogenic pressures which are becoming more and more worrying. For example, agricultural soils are affected by inputs of trace metal elements, through organic and mineral fertilizers, soil improvers, plant protection products, and the spreading of sewage sludge (Boughattas et al., 2016; Hattab et al., 2020).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Soil biofertility can be estimated from direct or indirect measurements of various indicators of its functioning and condition. For this, the agricultural soil biomonitoring approach was developed using soil bioindicators. Soil bioindicators integrate all environmental stresses (pollution, physical condition of the soil, climatic variations, biological modifications) and provide information on the overall condition of the soil. According to Bispo et al. (2009), a soil quality bioindicator should have the following characteristics:

- Be known scientifically (its biology and ecology must be mastered);
- Be linked to ecosystem functions;
- Integrate physical, chemical and biological properties or processes of the soil;
- Be able to report in particular on the methods of soil management and the different types of soil pollution;
- Have measurement qualities (precision, reliability, robustness);
- Be validated (know the amplitude of the responses linked to natural variations);
- Be easy to use and inexpensive (sampling and determination).
- Several soil biological actors are potential bioindicators of soil quality. These can be either microscopic, such as enzymes and soil bacteria, or macroscopic such as earthworms.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

It is with a view to diagnosing soil quality, monitoring, and ensuring protection actions as well as their management, that it is necessary to define indicators which make it possible to both identify and to quantify disturbances, soil transformations and impacts on ecosystems. For all these reasons, biological indicators have been developed to predict the quality of the soil because the biological parameters integrate all the environmental stresses (chemical pollution, physical state of the soil, climatic variations, biological modifications, etc.) and provide information on the overall state of the soil (Boughattas et al., 2016; Boughattas et al., 2018). The diagnosis of soil biofertility can predict the effect of disturbances and climate change and prevent their short- and long-term impacts. Therefore, measures should be taken to improve the biofertility of soils and reduce the adverse effects of climate change such as the provision of organic amendments and the reduction of the contribution of agricultural inputs.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃
	Decreases water demand	🍃
	Increases health and functionality of ecosystems	🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍂
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

AUTHORS

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1: CRRGC Béja | 2: ISA Chatt Mariem | 3: INRGREF | 4: ODESYPANO | 5: DGACTA

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BIOCHAR TO IMPROVE QUALITY OF SOIL

objective: improve soil fertility using biochar

keywords: biochar, soil fertility, water retention capacity

Target	**Field of interest**	**Type of adaptation measure**	**Climate challenge addressed**
FAS agents and farmers	Soil Management	Green Solution	Soil fertility loss

TOPIC: Soil fertility

Research into cultivation practices to alleviate the harmful effects of climate change such as water stress and the depletion of organic matter is a national priority. Adding biochar during fertilization can improve the agronomic performance of crops and compensate for climate change. Biochar recovers raw materials such as agricultural waste, animal manure, and paper products. Thus, it is a way of transforming waste into useful substances with added value. In addition, the addition of biochar can decrease the use of chemical fertilizers and combat soil degradation and groundwater pollution (Lehman et al., 2011; Dai et al., 2020).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Biochars are porous substances rich in carbon. The physicochemical properties of biochars depend on the type of biomass used (nature and state, raw or treated, etc.) as well as on the operating conditions of the pyrolysis process. From a chemical point of view, biochar is a matrix composed mainly of carbon (C: 70-90% by dry mass) (Xu et al., 2017). After carbon, the most abundant elements are oxygen and hydrogen. For agricultural application, Baldock and Smernik (2002) recommend using biochars with molar ratios O/C <0.2 and H/C <0.4. In addition to the carbon fraction, biochars have a relatively high mineral content. It is essentially composed of alkali metals (K and Na) and alkaline earth metals (Mg and Ca). Biochars can be produced from several biomasses: sewage sludge, wheat straw, pruning wood, etc. The conditions of formation are similar to those of charcoal production during a forest or field fire (Schmidt and Noackou, 2000) during charcoal in traditional coal pits. The application rate of biochar varies depending on the crop, the species, the physicochemical properties of the soil. The applied percentages vary from 1 to 10% per kg of soil.

Spreading biochar in the field.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Adding biochar to agricultural soils as amendments can induce potential changes in the physical, chemical, and microbiological properties of soils (Verheijen et al., 2010). The parameters directly affected are mainly porosity, bulk density, aggregate stability, hydraulic conductivity, water and nutrient retention capacity, soil cation exchange capacity (CEC), soil pH, composition, and microbial activity (Verheijen et al., 2010). Most of these trials has shown an overall beneficial effect on plant growth and crop yields. These effects depend both on the type of biochar used (raw material and pyrolysis operating conditions), added dose, type of agricultural soil, climate as well as the species of the plant sown or cultivated.

The use of biochar will have impacts on:

- Soil management methods that mitigate the effect of climate change and improve agricultural performance while reducing the supply of fertilizers.
- The design of cultivation techniques and irrigation methods adapted for farmers.

The biochar addition will improve and stabilize the productivity and quality of agricultural products, hence improving economic profitability.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃🍃
	Decreases water demand	🍃🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

AUTHORS

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FOREST MANAGEMENT

SUSTAINABLE EXPLOITATION STRATEGY FOR LENTISK PISTACHIO (PISTACIA LENTISCUS), AN AROMATIC AND MEDICINAL PLANT UNDER THREAT

objective: Improve exploitation practices of lentisk covered areas to avoid global change induced degradation

keywords: lentisk pistachio, aromatic and medicinal plants, decline

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft Solution	Pests

TOPIC: Forest exploitation

Pistacia lentiscus, or lentisk, is a natural mastic tree widely present in the forested areas of North Tunisia, covering an estimated area of 69,000 ha; 25,172 ha of which are located in the Bizerte region (DGF, 2010). Known for its medicinal and ornamental properties, this species is currently widely exploited. The regression of areas covered with lentisk and total biomass loss are due to inconvenient silvicultural practices, overexploitation both by harvesting and grazing, aggravated by the effects of climate change. These difficult conditions induce increased pest outbreaks such as Orgya trigotephras (Ezzine et al., 2012).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To improve the current exploitation of areas covered with lentisk, a tailored strategy should be developed together with the professionals of the sector, including a set of key actions:

- Creation of pilot orchards to improve productivity and quality of the final product.
- Elaboration of guidelines for the adoption of best practices for lentisk exploitation.
- Multiplication by layering in the nursery and row planting of pistacia lentiscus in cleared areas.
- Promotion of the use of lentisk in wildfire prevention interventions, such as firebreaks.
- Promotion of silvicultural interventions in natural areas covered with lentisk, such as regeneration cuts, thinning cuts, pruning, etc.
- Improvement of pruning methods which favour exploitation.
- Promotion of biological control of pests.
- Planting alternative fodder crops in grazed areas where lentisk is present .
- Capacity building of lentisk sectors' workforce
- Improvement of operating equipment such as ladders, vibrating rakes, presses or stills.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Mastic harvesting is a tradition in Tunisia, and plays an important economic role by helping to improve household income in certain forest areas. For example, in the Kroumirie-Mogods area, on average 60 liters of oil per year can be produced and sold at a price of 4000 DT, generating employment opportunities, especially for rural women. The suggested strategic actions would raise awareness of the importance of natural heritage conservation in the region and encourage the settlement of rural populations. The preservation of lentisk covered areas would have a great impact on reducing the vulnerability of the Kroumirie forests, as well as on socio-economic-political benefits at local, national and even international level (Mezni et al, 2015).

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🟩
	Reduces resource consumption	🟥
	Improves ecosystem health and functionality	🟩🟩
	Adopts a multisectoral approach	🟥
	Flexible	🟩🟩🟩
	Robust	🟩🟩

Yes high 🟩🟩🟩 Yes medium 🟩🟩 Yes Low 🟩 No 🟥

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
AVFA (agricultural extension and training agency)	*Training and extension*
INRGREF	*Research, reinforcement*
DGF (General Directorate of Forests) and Forest districts	*Management*
Population	*Awareness, participation and reinforcement*
Non-governmental organizations	*Awareness rising*

AUTHORS

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1: CFPA, Rimel | 2: INRGREF | 3: ISA Chott-Mariem | 4: Arrondissement Forêt Bizerte | 5: arrondissement vulgarisation, Bizerte

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hydrolat

essential oil

Photo: Distillation and extration of essential oils

EXPLOITATION STRATEGY FOR THE PRESERVATION OF FOREST RESOURCES IN KROUMIRIE (NORTH-WEST TUNISIA)

objective: to improve the conservation of valuable forest resources in Kroumirie through a tailored exploitation strategy engaging small-scale local business and local development cooperatives (GDAs)

keywords: sustainable exploitation, forest resources, North-West Tunisia

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft Solution	Global change

TOPIC: Forest exploitation

Forest ecosystems are of great ecological importance and represent a major economic and social resource in Tunisia (GIZ, 2014). However, climate change threatens these forests by thermal, water, and new biotic stresses (Ben Yahia, 2017, Manai, 2017). In example, in the Kroumirie forest, the combined effects of fire, anthropogenic action, and pest attacks lead to a decline of forest stands suitable for timber production (Hasnaoui, 2008). Tackling these challenges is currently limited by constraints such as budget, personal resources, and logistics that hinder local managers to adequately intervene.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

In order to improve the conservation of valuable forest resources in Kroumirie, an exploitation strategy should be put in place, aiming to overcome the current constraints. This strategy should underpin development plans, contributing to improve control and implementation of interventions, provide tailored management tools and be supported by an annual budget. The strategy should also entail improvements of current basic infrastructure for forest management, such as fire trenches, forest tracks, etc. Furthermore, small-scale local business and local development cooperatives (GDAs) should be strongly engaged in the design and implementation of the strategy and establish co-management dynamics.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Improved exploitation strategies for the Kroumirie forest is expected to reduce the vulnerability of the local timber sector both to climate change and human induced stressors. An improved management strategy could enhance better maintenance for the forest ecosystems, reducing the incidence of pests and forest fires. Enhanced health of the Kroumirie forest could stabilise the availability of raw material (firewood, pasture etc) and improve timber quality, essential for the local logging industry. In order for these practices to be sustainable and avoid over-exploitation, the engagement of small local businesses and agricultural development groups (GDAs) specializing in forestry could foster new jobs to be created, at the same time as extending reforestation sites and maintenance of young tree plantations.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Tabarka Forest Service	*Management*
INRGREF	*Research*
Ain Drahem and Jendouba Forest Districts	*Management*
General Directorate of Forests	*Management*

AUTHORS

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1: Service forêt Tabarka | 2:INRGREF | 3:DGF | 4: Arrondissement Jendouba | 5: service forêt Tabarka | 6: Service forêt Ain Drahem

REFERENCES

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- *Manaii Y. (2017) : Etude des lépidoptères défoliateurs des chênes au Nord-Ouest de la Tunisie : Biodiversité et interactions insectes/plantes hôtes. Thèse de Doctorat en Sciences Biologiques, Faculté des Sciences de Tunis, 271p.*

PREVENTION AND MANAGEMENT OF WILDFIRES IN KROUMIRIE AREA

objective: to preserve forest ecosystems by developing an early warning system and improve communication channels for fire prevention and extinction in the Kroumirie area

keywords: drought, fire, forest

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft solution	Wildfire

TOPIC: Forest conservation

The reduction in precipitation due to climate change has created drought conditions exacerbated by increasing air temperatures (number of rainy days <120). The very diverse and pyrophilic Kroumirie area forest ecosystems are threatened by increased frequency and intensity droughts (Ben Yahia, 2017). Specific impacts remain uncertain in terms of species resilience, while the increased risk of wildfires has a high degree of certainty. Forest fires have become very frequent during the last decade (89 ± 42.2 ha in Jendouba, 44 ± 33.8 ha in Béja and 36 ± 25.03 ha in Bizerte), annually devastating 114 ± 76.2 ha in Jendouba 307.9 ± 303.5 and ha in Béjà, 685.9 ± 1290.4 ha in Bizerte (DGF, 2021). The wildfire risk period extends from June 1st to October 31st and fires mainly occur between July and August (Sebei, 2015).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To adapt Kroumirie forests to increased wildfire risk, improved management strategies are needed for safeguarding, preserving and protecting forests through:

- Establishing a common digital platform to monitor wildfire risks, fire detection and allow early warning (Early Warning System).
- Developing wildfire sensitivity maps of forest formations in Kroumirie, based on the flammability of species and climate change related parameters.
- Reviewing and updating forest development and management plans taking into account the socio-economic environment.
- Improvement of firefighting forestry arrangements, such as tracks, trench by fire, creation of hilly lakes, fuel removal, lookout posts, paths, etc.
- Rehabilitating communication networks (binoculars, staff map, radio transmission, first intervention kit, smartphone application) and strengthening the monitoring system relating to forest protection within the General Directorate of Forests (DGF), providing further training and support to DGF staff.
- Strengthen vigilance at all levels throughout the year.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Improved wildfire management would reduce vulnerability of forests in the Kroumirie area by both strengthening prevention and early warning can effectively limit fire damage. Increased forest management would also help improve forest health, tailoring interventions in accordance to the information made available, such as limiting fuel and the proliferation of pyrophilic tree species based on the sensitivity maps.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🟢🟢
	Reduces resource consumption	🔴
	Improves ecosystem health and functionality	🟢🟢
	Adopts a multisectoral approach	🟢🟢🟢
	Flexible	🟢🟢🟢
	Robust	🟢🟢

Yes high 🟢🟢🟢 Yes medium 🟢🟢 No 🔴

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
INRGREF	*Research, reinforcement*
General Directorate of Forests (DGF)	*Central authority*
Ministry of Local Affairs and Environment (ME)	*Reinforcement*
Forest districts	*Local authority*
Population	*Awareness, participation and reinforcement*
Non-governmental organizations	*Sensitization*
The competent services belonging to the Ministry of the Interior (military, national guard)	*Intervention and protection*

AUTHORS

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1: INRGREF | 2: DGF | 3: MALE | 4: Arrondissement Jendouba | 5: Arrondissement Ain Drahem | 6: Arrondissement Béjà | 7: Protection civile

REFERENCES

Fig 1: Early warning system (photos taken by kaouther Ben Yahia, 2021)

NON-WOOD FOREST PRODUCTS ACTION PLAN FOR RURAL WOMEN IN AINDRAHAM

objective: to promote capacity building and innovation for rural women exploiting aromatic and medicinal plants

keywords: non-wood forest products, exploitation, rural woman

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft Solution	Extreme events (Droughts)

TOPIC: Forest exploitation

Forests and mountain agriculture in Tunisia are among the most sensitive environments to climate change, especially to the impacts of drought. In the forests of Aindraham, most common forest exploitation is generally based on spontaneous plants (rosemary, thyme, myrtle, mastic, etc.) used in the elaboration of aromatic and medicinal products. Certain climatic conditions not only affect the quantities produced but also its quality, inducing marketing difficulties. Under these conditions, economic performance is particularly hindered due to an imbalance between demand and available resources in forest (BM study, 2018).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Tailored support from the administration is very much needed to put Aindraham forest aromatic and medicinal products into value. Therefore, a specific action plan should be promoted, aiming at:

- Improving communication within the GDA (Agricultural Development Group) and its relationship with the population, enhancing harmonisation of efforts and better results.
- Establishing capacity building programs for rural women fostering innovative approaches and management of non-wood forest products, including advisory and support on marketing of products obtained.
- Develop an awareness campaign promoting good practices, both at collecting and processing the products.
- Domestication of certain aromatic and medicinal plants in order to reduce the exploitation rate of the forests and rationalize its use (i.e. Agricultural Development Group Tbainia pilot case,2013).
- Development of congestion models empowering the socio-professional organizations for a good governance of forest resources.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The aromatic and medicinal plants sector is a strong non-wood forestry sector in Tunisia. Currently, the sector contributes 0.8% in the formation of agricultural income, represents 1% of forest exploitation activities and generates the equivalent of 250,000 working days (2013 APIA study cited in the WB study, 2018). The elaboration of aromatic and medicinal products has a great potential to create jobs and a stable income especially for rural women, fostering empowerment and a sense of belonging, as well as a motivation to preserve natural and cultural heritage in the face of climate change.

Promoting this sector can help strengthen gender equality, in example increasing the female members of socio-professional organizations, although more efforts need to be made to ensure their presence in higher professional positions. Furthermore, the aromatic and medicinal sector contributes to the value of local products and know-how, generating opportunities that can mitigate the rural exodus.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🟩🟩🟩
	Reduces resource consumption	🟥
	Improves ecosystem health and functionality	🟩
	Adopts a multisectoral approach	🟩🟩
	Flexible	🟩🟩🟩
	Robust	🟩🟩

Yes high 🟩🟩🟩 Yes medium 🟩🟩 Yes Low 🟩 No 🟥

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of agriculture/DGF	*Promote the integration of innovative legislation for community development in relation to concessions, auctions and mutual agreements for exploitation, in order to better promote medicinal plants and forest conservation*
GDAP	*Group for agriculture development*
Rural women	*Awarness of the importance of the conservation of the forests of Ain Draham and the sustainable use of aromatic and medicinal plant resources*
ONG	*Support pilot operations for rural women in vulnerable forest areas by encouraging women to consolidate their sources of income (case of GDA Tbainia)*

AUTHORS

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https://youtu.be/x9Op-NW_u70 *Video valorisation of forest products in the North-West September 2004, (Rapport de la BM,2018), (Rapport APIA, 2013).*

ADAPTATION STRATEGY FOR BEEKEEPING IN TUNISIA

objective: to protect bee colonies in Tunisia by establishing an adaptation strategy for the sector, including reforestation projects and enhanced beehive management practices

keywords: beekeeping, honey plants, global change

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Green Solution	Forest degradation

TOPIC: Beekeeping

Beekeeping and the honey production sector is severely affected by the destruction of habitats and decline in biodiversity due to deforestation, industrialization, extension of agriculture, intensification of pesticides used and generalized overexploitation of natural resources. Additionally, climate change causes a desynchronization of plant-bee communities, as seasonal climate variations induce advanced or delayed flowering periods affecting pollination, an essential process for maintaining biodiversity, feeding the bees and the survival of the colony. Indeed, these changes impact food networks for the bees, hindering the population to correctly develop, inducing bee colonies to migrate or disappear, as well as exposing bees to pests and predators.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

In order to protect bee colonies in Tunisia it is crucial to establish an adaptation strategy for the sector, including:

- Reforestation projects to diversity tree species in accordance to their flowering period, ensuring these are staggered throughout the year.
- Promote melliferous species, native nectarifers and pollinators such as aromatic and medicinal plants, fodder plants, etc...
- Establish a pollen repository, a flowering calendar and a mapping of the melliferous flora.
- Develop organic and environmentally friendly agricultural practices, promoting biodiversity and an integrated fight against bee diseases, parasites and predators.
- Address bee mortality through innovation, such as SMART hives, that are connected, monitored continuously to identify environmental conditions, detect interferences and monitor bee health.
- Include all stakeholders in the beekeeping value chain in the adaptation strategy.
- Rationalize the management of beehives, through enhancing transhumance in the same biogeographical region. This is also important to maintain the product's traceability and certifications, such as the Protected Designation of Origin (PDO).

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Beekeeping can provide interesting economic results for local communities and productivity of the sector can be enhanced by diversifying melliferous plants and their extension in the region. The honey produced can benefit from product valorisation strategies, such as an AOC (Appellation of Controlled Origin) and GI (Geographical Indication) or transformation in the food industry, cosmetics, etc., as well as improved quality standard monitoring programs, such as through physico-chemical and melissopalynological characterization (Ben Haj Jilani, 2008; Ben Haj Jilani et al. 2008). Enhancing the beekeeping sector can induce improved forest conservation and sustainability of ecosystems in the region.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Agricultural Ministry	*Professional organization of the population, Coordination between institutions*
Ministries of Finances and Agricultural	*Implementation of strategic incentive measures*
Ministry of Agriculture and the Ministry of Higher Education.	*Increase collaboration between national and international organizations, organizations and university networks*

AUTHORS

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1: CRDA Bizerte | 2: INAT | 3: INRGREF | 4: ESA Chott Mariem

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GENERAL OVERVIEW OF THE PHYTOSANITARY STATE OF TUNISIAN OAK GROVES

objective: establish a monitoring program for cor oak forests to help managers to design and implement more adequate silvicultural interventions

keywords: decay, oak grove, surveillance

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Green Solution	Forest degradation

TOPIC: Conservation of Forests

The state of forest ecosystems in Tunisia, has undergone severe impacts due to:

- The decline of oak forests due to xylophagous agents (fungal defoliators).
- The lack of natural regeneration and the difficulties for establishing artificial regeneration programs.
- The destructive and disruptive actions by livestock herding which further weaken the trees and their vulnerability to pests
- Severe summer drought episodes due to climate change

As to face these challenges, managers should encourage reforestation programs with indigenous and productive broadleaf species that have cultural value with the local population.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Specific monitoring programs should be put in place to consolidate previous research results (Hasnaoui, 2008) and further understand the different correlations between the factors intervening in the decline of the species in question. Factors such as geographic and orographic characteristics of the area; physic-chemical composition of the soil; silvicultural factors related to the stands and the health conditions of decaying trees should be monitored periodically (once a year) between July 1 to the end of September by a multidisciplinary team. The program should ensure the analysis of soil and leaf samples from healthy and decaying trees, as well as samples of wood, bark, cork leaves, branches, logs, etc. showing symptoms of dieback, generally coupled with pathogens. The program needs to engage a laboratory able to perform all analysis and should include the installation of a meteorological station to include climatic variables in the scheme.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The decline of oak forests induces production losses as well as environmental impacts. The installation of the proposed monitoring program will help managers to design and implement more adequate silvicultural interventions, such as sanitary cuttings and regeneration cutting. Cooperation between managers and researchers in the program would allow better forest heritage, water and soil conservation. Improved management can have an important impact ensuring better cork quality and quantity and firewood production, contributing to reducing the rural exodus and establishing the population within their natural productive heritage and enhancing local economic development.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
DGF (General Directorate of Forest)	*Coordination between service of forest and the team of researcher*
ISP Tabarka	*Scientific research*
Regional Forest Services	*Facilitation of the work on forests for the whole team*

AUTHORS

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IMPROVEMENT OF PRIVATE RANGELANDS BY THE OFFICE FOR LIVESTOCK AND PASTURE (OEP)

objective: to consolidate and further develop a methodological and technical package for combating desertification and rehabilitating degraded rangelands

keywords: Office of Livestock and Pastures (OEP), private rangelands, overgrazing

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Green Solution	Forest degradation

TOPIC: Forest conservation

Forests and rangelands occupy nearly 5.7 million ha (1/3 S.T) in Tunisia and are located mainly in arid and semi-arid areas that are strongly impacted by rising temperatures due to climate change (variable annual increase of 2 ° C and 2.3 ° C by 2050), a decrease average annual rainfall (estimated at 5 to 10% in 2050), a decrease in water stocks, a high concentration of CO2 as well as extreme phenomena such as heat waves and torrential rainfall. At the level of forest and pastoral ecosystems, the aforementioned impacts result in degradation and increased loss of biodiversity, exacerbated by the strong anthropogenic pressure of current overgrazing.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Reforestation and activities to reduce forest and rangeland degradation are key for adaptation to climate change. The pastoral improvement program on private rangelands carried out by the OEP since 1990 as part of the national strategy for reforestation, the fight against desertification and the conservation of water and soil, represents an important technical potential for reducing vulnerability in the region. Participatory experiments on natural resources management in pastoral areas conducted by the OEP allowed the development of a methodological and technical package for combating desertification and rehabilitating degraded rangelands, as well as relevant management and monitoring-evaluation tools. The package should be further promoted and consolidated, including

- Research and adoption of promising pastoral species
- Establishment of a seed multiplication program
- Intensification of cactus cultivation and increased planting densities
- Introduction of small mechanization for crushing cactus rackets (time saving, full rations, etc.).

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The impacts observed by the evaluation mission entrusted to the CNEA from 2005 to 2007 can be taken as a reference for expected results of the program, indicating improvements of livestock food availability from 10 to 30% and farm revenues from 35 to 45%, as well as the creation of jobs in the community worth

4.13 million JT and renovated business dynamics. Moreover, the methodological and technical package has the potential to perform significant impacts on soil dynamics, such as reducing erosion and sediment loss, fix wadi banks, increasing soil water retention and improved tip resistance values These improvements can also induce the reappearance of rare pastoral species.

Obstacles	Solutions
Scattered and small farms	Closer cooperation
Low production of local pastoral seeds	Good organization of the seed sector
Low budget	• More interest in the sector by the government • Elaboration of project proposals for external funding
Insufficient qualified staff	Establishment of a graduate school for the specialty
Changing attitudes and perspectives of pastoralists	Use of incentives such as payment for environmental services

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🟩
	Reduces resource consumption	🟥
	Improves ecosystem health and functionality	🟩🟩
	Adopts a multisectoral approach	🟩🟩🟩
	Flexible	🟩🟩🟩
	Robust	🟩🟩🟩

Yes high 🟩🟩🟩 Yes medium 🟩🟩 Yes Low 🟩 No 🟥

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of agriculture	*Strategies, funding, legislation ...*
General Directorate of Forests DGF	*Forest area management*
General Directorate of Agricultural Land Development and Conservation DGACTA	*Water and soil conservation techniques*
National Institute of Agronomic Research of Tunisia INRAT Arid zones institute	Implementation of new techniques, species and practices and participation in their dissemination on a larger scale

AUTHORS

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IMPROVE KNOWLEDGE AND PRACTICES FOR ADAPTING FORESTS TO DROUGHT

objective: establish a science based forest management plan including specific studies to design adaptation options to drought

keywords: forests, drought, management

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft Solution	Extreme events (Droughts)

TOPIC: Drought

The climate of Tunisia is very irregular, with a modest amount and large spatial and temporal rainfall variability. A normal consequence of this variability is the occurrence of drought. In Tunisia, the series of tree growth rings over the past 1,000 years suggest that droughts occur periodically on average every 20 years or more, and episodes can last between two to four consecutive years. Nevertheless, climate change is foreseen to worsen drought risk, increasing degradation and decline of Tunisian forests. Several studies have examined this phenomenon and its impact on Tunisian forests (Ben Jamaa, 2014; Touhami et al., 2019), indicating a decline in tree growth and a reduction in the yield of pine forests, also triggering increased fuel for forest fires (Fkiri et al 2018, 2020).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Maintaining the structure and function of Tunisian forests is a major challenge for forest managers dealing with drought. Additional empirical studies and experiments focused on both adaptation goals and responses are needed to improve the scientific basis for elaborating adaptation strategies as well as developing effective plans and guidelines to improve natural resources management (soil, plants and water). Specific research needs to be proposed, developed and promoted to allow explaining and understanding the forests' response to extreme droughts. For example, characterizing the physiological response of trees to water stress (water dynamics in tree metabolism by measuring water potential, the efficiency of water use, hydraulic conductivity, evapotranspiration (ET), standardised precipitation index (SPI), etc. In the same line, dendronological and climatological analysis at different temporal and spatial scales would assess the response of forest species to climate change. On the practitioner's side, improved management solutions, such as the introduction of versatile trees or shrubs, would contribute to generating resilience by strengthening soil moisture conservation.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Drought will have major environmental, economic and social impacts. Therefore, the suggested improvements in forestry management plans and guidelines will help reduce the economic impacts of drought, by reducing the loss of income due to the degradation of trees and wood production. Science based planning would have repercussions on the rural community also reducing impacts on non-timber forest products (PNFL). These are of particular importance for providing food, medicine, fodder, etc., increasing the income of rural communities and creating jobs. Protecting forests from the effects of drought can therefore protect society against economic loss, conflicts on water resource use, reduced leisure activities, etc. Additionally, better planning would ensure the preservation and enhancement of biodiversity, thus reducing the decline of forest species and contributing to fighting against forest fires.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
The Ministry of Agriculture	*Promote the incorporation of an effective strategy to protect the forest ecosystem and increase investments in forest management that are directly linked to the development of communities and the environment.*
Forestry Department	*Forest management practices can partially mitigate the effects of drought by reducing stand density, selecting drought tolerant species and genotypes. Planting trees that require less water and are more drought tolerant.*
The indigenous / local community	*Identify drought impact indicators for the community, plan a public awareness and education campaign*
Research institutes	*Create a database on drought resistant species for reforestation programs*

AUTHORS

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ENHANCING THE ROLE OF LOCAL POPULATIONS INTO AGROFORESTRY

objective: create a multi-stakeholder platform for developing participatory agroforestry community development plan

keywords: participatory approach, agroforestry, sustainable development

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft Solution	Global change

TOPIC: Forest exploitation

Climate change has affected agriculture sectors in the mountainous and forest areas of the governorate of Béja in different ways: fluctuation of cereal production from one year to another, productivity reduction of rangelands due to the disappearance of certain spontaneous species, insufficient quantities of irrigation water, in between others. These challenges have led local populations to exert more pressure on forest resources to meet the needs of families and their livestock. Thanks to the participatory approach adopted by ODESYPANO in the mountainous and forest areas of the governorate of Béja the community development plan (CDP) identified agroforestry as a key element to face the challenge of ecosystem degradation, as well as improving the living conditions of populations and their sources of income.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Agroforestry is proposed as a solution that can play a double role in enhancing both forest protection and sustainable exploitation in the medium and long term, diversifying means of subsistence for local populations and reducing vulnerability to the impacts of climate change. The local specificity of agroforestry systems imperatively requires an integrated approach for its development and successful adoption. Therefore, the creation of a multi stakeholder platform would ensure better collaboration between all development partners, including the rural population for supervising the implementation of the content of the CDP.

These commitments should be materialized by an annual program contract co-signed by all concerned.

Accompanying and support measures are necessary for this model to succeed, such as:

- Resolution of land tenure constraints,
- Development research linked to agroforestry systems;
- The establishment of a monitoring and evaluation system.

Below, illustrations of some agro-forestry practices in the governorate of Béja:

Agro-forestry perimeter (olive-almond tree)

Agroforestry (olive tree - bean)

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

From a profitability standpoint, agroforestry is a practice that offers several benefits. It has a positive impact on crop diversification, with higher combined yields (trees, crops and / or livestock). It promotes local development by increasing the income of residents and conserving the environment.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
The North West silvopastoral development office (ODESYPANO)	*The objective of ODESYPANO is to improve the socio-economic conditions of the rural population in the northwest of the country and to promote better protection and management of natural resources through an integrated participatory approach to community development. Agroforestry is one of the activities of its projects.*
Forestry Department Forest districts in the regional agricultural development commissions (C.R.D.A)	*The missions are: i) the management, conservation and protection of the State forest domain as well as land subject to the forest regime, ii) the promotion of forestry and pastoral activities in the agricultural sector, iii) the socio-economic development of forest communities, and iv) development and implementation of forest management plans.*
The Livestock and Pastures Office (O.E.P)	*Its interventions only affect the specific aspects of agroforestry, which are limited to the improvement of herbaceous ranges and the planting of fodder shrubs.*

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CONTRIBUTION OF SILVOPASTORAL SYSTEMS IN NORTHERN IN TUNISIA TO SUSTAINABLE DEVELOPMENT AND BIODIVERSITY MANAGEMENT

objective: establish tailored management solutions to increase resilience of silvopastoral systems in Northern Tunisia and sustain local socio economy

keywords: silvopastoral system, rangeland rehabilitation, sustainable development

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Green Solution	Extreme events (Droughts)

TOPIC: Silvo-pastorage

Interannual climate variability and long drought episodes cause severe impacts on silvopastoral systems and rangelands in Tunisia. Decreasing water availability has a direct impact on pastures, rangelands and the forest sector, endangering socio economic development and social stability in North West Tunisia. Overgrazing, mutilation of Zeen oak and cork oak trees and land clearing are among the anthropogenic actions that worsen the situation of forest rangelands.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

In order to reduce the pressure on forest resources and slow down the process of accelerated degradation of the wooded environment, tailored management solutions should be established, providing both fodder production and ecosystem protection. Research performed at the Tegma forest area showed that specific rehabilitation of the ecosystem and best practices should be designed in accordance with local pedoclimatic conditions, increasing silvopastoral systems' resilience . The establishment of natural regeneration, assisted natural regeneration and artificial rehabilitation (Ben Rhouma and Souissi, 2004) programs, including the establishment of permanent grasslands, increased forage resources production can reduce the vulnerability of rangelands in the region

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The impact of improved management design, more suitable to local pedoclimatic conditions, can provide fodder production from shrubs, the herbaceous carpet and the acorns of the Tegma forest. Acorns also have an excellent net energy content which can be estimated at 0.9 UF / Kg of dry matter (Kayouli, 2001). The fodder production of acorns can be estimated at 1900 / ha / year (Mechergui R 2020).

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
National National Research Institute of Rural Engineering, Water and Forests (INRGREF)	*To exchange scientific Results and scientific and technical collaboration*
General Directorate of forests DGF	*Disseminate good management and ecological implication of the silvopastoral system to preserve biodiversity and sustainable management in Tunisia*
CRDA centre for rural development Jendouba	*To practice and Develop knowledge of silvopastoral ecosystems, climate change, and breeding, livestocks plant relationships*
OEP office for livestock and pasture	*Improvement silvopastoral system in Jendouba*
National Institute of Agronomic Research of Tunis, (INRAT)	*To scientific collaborate*

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VALUING CARBON STOCKS IN THE UNDERSTORY VEGETATION

objective: set up a participatory forest management program promoting agroforestry, enhancing carbon stocks quantification in shrubs and the economic valorization of ecosystem services in Tunisian cork oak forest to improve local resilience

keywords: climate change mitigation, shrubs, sustainable agroforestry

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Soft Solution	Desertification

TOPIC: Forest conservation

Tunisian forests are particularly vulnerable to climate change due to their location on the southern side of the Mediterranean basin and resilience is severely affected by the pressure exerted by the local populations' resource extraction (Khalfaouiet al., 2020). Recently, the international community focused on trying to limit CO2 emissions by promoting climate change adaptation and mitigation policies including the estimation of the carbon stocks in Mediterranean region.

Gaps in these accounting processes should be addressed, like for example the carbon stock assessment of shrub land is scarce, especially in Tunisia.

Nevertheless, hrubs are intermediate stages in the dynamics towards desertification or mature wooded formations and provide a range of non-timber products and non-market ecosystem services that usually lead to its underestimation (Daly-Hassen et al., 2009).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

A participatory forest management program enhancing actions to strengthen the available database on carbon stocks quantification in shrubs and on the economic evaluation of ecosystem services in Tunisian cork oak forest can improve local resilience. Raising awareness through trainings and workshops about the profitability of shrubs exploitation to provide wood and non-wood products (oil, essential oil, beekeeping, etc.) and promoting agroforestry systems would allow forest dwellers to better contribute to the conservation of the ecosystem. Therefore, it is crucial to involve local people in decision-making, to recognize their claims and negotiate exploitation agreements allowing storing carbon dioxide and biodiversity conservation.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Mitigation options involving carbon sequestration into the ecosystems is commonly perceived as a potentially inexpensive option with high environmental and socio-economic benefits. Agreements integrating the different stakeholder perceptions would ensure that participation of people living close to the forest is genuinely voluntary and that compensation for lost profits is sufficient. Moreover, improved data availability related to fresh and dry mass allocation among plant organs (roots, wood and leaves) could be valuable to better use shrubs (Stiti et al., 2016). For instance, Erica arborea roots provide briar pipe, and Arbutus unedo, Myrtus communis and Pistacia lentiscus are suitable for medicinal and aromatic uses. These data have a significant economic impact for smallholders, new startups and local populations. They must find niches in which they can effectively compete in the rapidly growing urban, rural and export markets. In fact, Essential Oils (EO) export represented 1% of Tunisian exports in 2014 (Taghouti& Daly-Hassen, 2018).This approach maintains genetic resources by putting their use into value and helps to reduce poverty.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃🍃
	Improves ecosystem health and functionality	🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of Agriculture	*To foster integration of new legislation and take optimal countermeasures for community development, poverty eradication and biodiversity conservation.*
Forest services	*To manage ecosystems and forests to avoid extinction or degradation/ Greening of deserted mountain areas by involving local population.*
Local population	*To act while being aware of the importance of the conservation of ecosystems and the sustainable use of resources.*
Research institutes	*To provide database on carbon stocks in forests and ecosystems/ Propose alternatives of management for climate change mitigation*
Smallholders	*To create jobs in vulnerable forest areas by encouraging the population to vary their sources of income*

AUTHORS

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1: INRGREF | 2: DGF | 3: Ain Draham division-Tabarka

REMOTE SENSING FOR ESTIMATING ROSEMARY (ROSMARINUS OFFICINALIS L.) BIOMASS

objective: obtain valuable information on ecosystem recovery in areas affected by wildfires by estimating the rosemary biomass through remote sensing

keywords: remote sensing, rosemary, fire

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Forest Management	Green Solution	Wildfire

TOPIC: Forestry economy

Increased wildfire risk induced by climate change is particularly high in the area of Siliana, especially in the delegation of Bargou, where forests extend over nearly 140.000 hectares, corresponding approximately to 30% of the area of this governorate.

Indeed, fires devastated 1.415 hectares of woodland and undergrowth through summer 2017. Less than three years after the fires, it was possible to observe how the herbaceous cover settled down, constituting a landscape of herbaceous plants (rosemary, horehound, etc...) covering the affected soil.

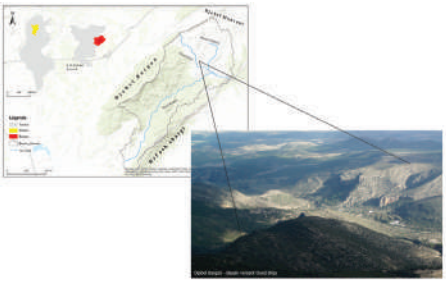

Figure 1: Geographical location of Djebel Bargou – Drija wadi watershed

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Geo-spatial technologies, such as remote sensing, are a suitable tool for estimating the rosemary biomass and so provide valuable information on ecosystem recovery, especially in distant locations such as semi-arid areas.

The use of these modelling tools can provide key information for developing forest management plans by integrating the appropriate spatial change of r rosemary biomass development and determination of regenerative species in the oued Driji watershed (Figure 2).

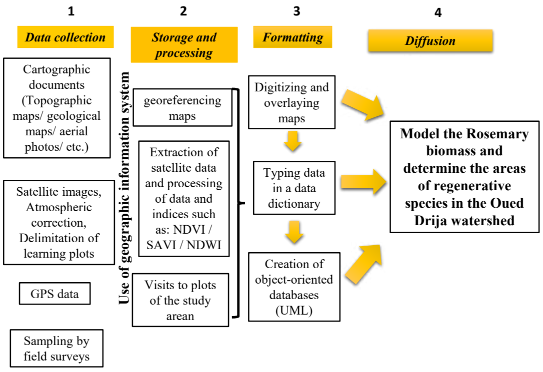

Figure 2: Diagram of geographic information system and remote sensing processes use for rosemary biomass modelling and determination of regenerative species in the oued Driji watershed

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

In the forests of Djebel Bargou, untouched by fires and the neighboring fields, agricultural activities are encouraged by the abundant rainfall. These forests, like all those in the governorate, continue to generate significant economic returns. The impact of improved forest management on sustainable harvesting and use of forest biomass for commercial, economic, social and ecological purposes could help in facing unemployment rates, enhance the energy autonomy of the remote mountain villages, and reduce the Mediterranean forest fire risk.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
INRGREF	*Applied research*
Forest Exploitation Management (REF) Ministry of Agriculture	*Users*
Municipality of Bargou	*Socio-economic*
Forest subdivision of Bargou	*Field Execution*

AUTHORS

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1: INRGREF | 2: Forest exploitation authority - Ministry of Agriculture.

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INCREASED CORK QUALITY THROUGH SYMBIOTIC ASSOCIATION TECHNIQUES IN KHROUMIRIE (JENDOUBA)

objective: improve the marketability and quality of cork through symbiotic association techniques with Cytisus villosus and Cistus Monspelliensis

keywords: cytisus villosus, cork oak, silvopastoralism

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Forest Management	Green Solution	Global change

TOPIC: Silvopastoralism

Cork oak forests in Kroumirie are currently degrading severely. Species' decrease of productivity and increased tree mortality are accentuated during these last decades both by climate change induced pressures, such as decrease in summer rainfall and higher temperatures, fires and pests, as well as by human induced factors, such as overexploitation and bad practices.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The association of cork oak with autochthonous plant species, such as Cytisus villosus and Cistus Monspelliensis could positively influence its growth and productivity (acorns and cork) by providing the nutrients necessary for its survival in the face of climatic constraints. Research based on monitoring key parameters, such as Structural, Phenological and physiological parameters, as well as cork productivity and quality (porosity, humidity, durability....) shows that these symbiotic associations can significantly enhance cork oak ecosystem health, tree growth and water efficiency.

Photos: Cytisus villosus

Therefore, cultivating Cytisus legume in nurseries and its introduction into management plans mainly in the degraded cork oak areas is highly recommended.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Cork demand from industries is increasingly focused on high-quality performance for perfect preservation of wines, especially appellation wines. Each year, manufacturers such as the Cork New Society in Tabarka buy he right to harvest cork directly from the tree from the owners of cork oaks, by establishing agreements with the local forest management administration (DGF Direction Générale de la Forêt) The partnership with the DGF is essential to promote the suggested symbiotic association via the new proposed development plans.

Long-term results of the improved cork oak forest management practices can contribute to empower local populations and manufacturers engaged in this business, improving the market position of this industry and stabilizing revenues. The symbiontic relations established help reducing the vulnerability of cork oak forests in the region.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍂
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃
	Flexible	🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

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EUCALYPT IN THE TUNISIAN ARID REGION: DIVERSITY AND VALORIZATION FOR BEEKEEPING

objective: eliminating the use of a single species in reforestation programs diversifying forest ecosystems for ecological and socio-economic interests

keywords: eucalyptus sp., arid regions, beekeeping interests

Target
FAS agents and farmers

Field of interest
Forest Management

Type of adaptation measure
Green Solution

Climate challenge addressed
Forest degradation

TOPIC: Forest conservation

Eucalyptus forests planted for its melliferous interests in southern Tunisia are affected by the impacts of aridity and climate change. Monoculture Eucalyptus now occupies 27% of the plantations found in the region, increasing vulnerability to extreme climatic conditions and pests. However, research results from pilots in the region of Zerkine show that within the Eucalyptus genus resilience varies greatly between species, and some have greater tolerance than others in terms of their survival rate, height of plant and flowering precocity.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Species	Presence in this region (+, +/-, -)	Flowering abundance (+, +/-, -)	Quality of pollen and nectar for bees (N, P, NP ou NU)
E. camaldulensis	+	+	NP
E. torquata	+	+	NP
E. occidentalis	+	+	NP
E. microtheca	+	+	NP
E. torwood	-	+	NP
E. gracilis	-	-	NP
E. brokwayi	-	-	NU
E. gomphocephala	+	-	NP
E. salmonophloia	-	-	NP
E. astringens	-	+/-	NP
E. lesouefii	-	+/-	NU
E. oleosa	+/-	+	NP
E. salubris	+/-	+	NP
E. diversifolia	+/-	+	NP
E. flocktoniea	-	+	NU
E. sargentii	-	+	NU
E. transcontinantalis	-	+	NU

Table 1. Presence of species in the region, flowering abundance and honey interests
(+: high, +/-: medium, -: low, N: rich in nectar, P: rich in Pollen, p: less pollen, NU: data unavailable).

To take advantage of the great diversity observed in this genus and identify the most adapted species, researchers, foresters, beekeepers and professional associations, such as Ruchers de l'Oasis - RDO, should collaborate to use the most suitable Eucalyptus species. At first the species presenting an abundant flowering spread over several months should be identified, selected in conditions of acute stress; thus a stock of seeds of these species can then be created and multiplied in nurseries. Sixteen species and one hybrid have been identified in the Gabès region (table 1). E. camaldulensis, E. torquata, E. microtheca and E. occidentalis showed the lowest dieback rate and high pest resistance in arid conditions, while E. camaldulensis, E. torquata, E. microtheca, E. occidentalis, E. oleosa and E. flocktoniae, have shown abundant and long flowering periods. Therefore, to diversify current plantations and avoid monoculture in future programs is essential to boost resilience and reduce vulnerability in beekeeping to climate change.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

This activity aims, in the short term, to analyze the relationship between climate change and the identified pests as well as to improve the region's richness in honey forest plants. This wealth improves honey production among beekeepers, and this improvement would directly impact the local socio-economy. Thus, this collaboration could contribute to eliminating the use of a single species in reforestation programs and to diversify forest ecosystems for ecological and socio-economic interests.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍂
	Decreases water demand	🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍂
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes Low 🍃 No 🍂

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Figure 5. Measurements of Eucalyptus plants in the Zerkine experimental plot.

REGENERATION OF THE CAROB TREE (CERATONIA SILIQUA)

objective: contribute to improving the regeneration and forster cultivatin of the carob tree (Ceratonia siliqua), a species native to Tunisia and resilient to drought

keywords: regeneration, seed multiplication, dormancy

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Forest Management	Green Solution	Extreme events (Droughts)

TOPIC: Forest conservation

The impacts of climate change are particularly intense Mediterranean region (Pouffary et al., 2018) and it is important to adapt to the consequences of these changes on forest species. In particular, the carob tree (Ceratonia siliqua), an agro-sylvo-pastoral species with enormous socio-economic and ecological interests (Hariri et al., 2009; Sbay and Lamhamedi, 2015), is highly resilient to water constraints and has a positive impact on soil fixation (MAPM / DERD, 2007). The carob tree and has a great potential for reducing forest vulnerability, but it remains very little considered in reforestation efforts in Tunisia. The major challenges related to increasing the agronomic use of this species is related to multiplication methods, while economic exploitation of the carob is constrained by time needed between the establishment of the tree and production of fruits.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Improvements in sexual multiplication by applying innovative pre-treatments on the seeds can significantly increase seedling rates. These techniques include mechanical scarification of the seeds, soaking in sulfuric acid or in hot water and in potassium nitrate with different concentrations for different durations.

Furthermore, improved agronomic practices, such as the selection of those varieties most resistant to environmental stressors, or avoiding planting male and female plants in the same agricultural land as to hinder pollination, can significantly improve the production of carob.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

(a) Leaves *(b) seeds* *(c) pods* *(d) adultcarobtree*

Photos by Zouaoui Refka, 2021

The scale of application of the carob tree includes wood industry (quality wood); ornamentation and landscape (Batlle and Tous., 1997); economy, food, medicine and cosmetics (whole pods, pulp, seeds and gum) (El Batal et al, 2013); ecology (protection of soils against degradation) (Sbay and Lamhamedi, 2015); pastoral and melliferous (Hariri et al., 2009), and is particularly interesting in dry regions and in areas where desertification processes are becoming increasingly alarming (Ait Chitt et al., 2007). Tunisia currently produces only 3% of the world carob production, therefore, it should revalue and encourage its cultivation potentiating the national economy (list of priority projects) (Khaldi, 2012). The carob tree can provide a vital resource to many Mediterranean peoples (Baumel et al., 2017), as it is a cheap source of carbohydrates, and it's is being explored as a material for producing bioethanol (Turhan et al., 2010).

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Reduces energy consumption	🟥
	Reduces water demand	🟥
	Increases health and functionality of ecosystems	🟩🟩
	Is synergetic with other sectors	🟩🟩🟩
	Flexible	🟩
	Robust	🟩🟩

Yes high 🟩🟩🟩 Yes medium 🟩🟩 Yes Low 🟩 No 🟥

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REGENERATION OF ARGYROLOBIUM UNIFLORUM IN TUNISIA

objective: enhance the germination rate of Argyrolobium uniflorum for the restoration of pastoral lands

keywords: regeneration, threatened species, enhanced germination

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Forest Management	Green Solution	Crop change

TOPIC: Forest conservation

In Tunisia, the degradation of natural vegetation cover is due more to human action than to climate change over the past years (SAMEF / APAL, 2015; Zouaoui, 2018). The combination of factors, such as the extension of cropland, as well as the quantitative and qualitative destruction of the plant cover, generated an accelerated regression of pastoral lands. Various plants, including seeds, fruits and leaves are used in pastoralism, such as Argyrolobium unuflorum. Under natural conditions, the germination of this species is staggered over time and occurs within the fruit. However, in these conditions the germination rate of seeds does not exceed 10% (Neffati, 1994).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

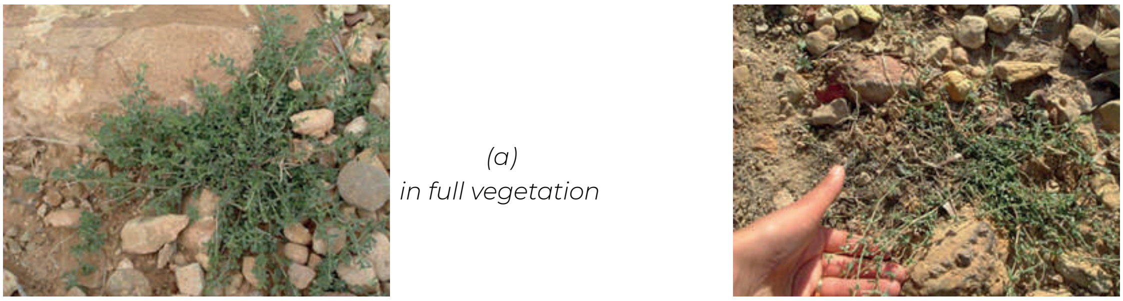
The low germination rate of Argyrolobium uniflorum in its natural state prompted researchers to enhance the process by applying various pretreatments under controlled conditions such as soaking in boiling water, sulfuric acid for 1 hour and manual scarification.

The innovative feature of enhanced germination rates is that this species can be a solution for feeding the herds and replace other species when absent.

Argyrolobium uniflorum is highly palatable by cattle (Chaieb and Boukhris, 1998; Zouaoui, 2007) and is characterized by its ability to provide green matter, a large quantity of pods spread over the whole year (Oueld Sidi Mohamed, 1998) and a high quantity of dry matter (> 80%) (Floret et al. Pantanier, 1982). It can be established in a range of soils, varying from very dense rocky soil to sandy loam soil with low organic matter (Zaouali, 1999).

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Argyrolobium uniflorum is characterized by its great ability to produce seeds during the period between April and May (Neffati, 1994; Zaouali, 1999). The multiplication of the species as well as its cultivation in agricultural land leads to the creation of grazing lands with very rapid regeneration, which can be a solution for the livestock of families in rural areas. Positive economic and social impacts are expected if propagation of Argyrolobium uniflorum would be promoted in management and development programs of pastoral areas especially targeting small family farms (small plots), improving the living conditions of rural populations creating sheep, goats and cattle herding related jobs. In addition, these grazing lands help to fight erosion agricultural soils.



(a)
in full vegetation

(b)
drying out

Figure 1. Argyrolobium uniflorum feet in their natural state (Photos by Zouaoui Refka, 2013)

(a)
Pods

(b)
seeds

Figure 2. Pods (a) and seeds (b) of Argyrolobium uniflorum (Photos by Zouaoui Refka, 2021)

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Reduces energy consumption	🟥
	Reduces water demand	🟥
	Improve sanitary conditions and ecosystem functionality (resilience)	🟩🟩🟩
	Synergistic with other sectors	🟩🟩🟩
	Flexible	🟩🟩🟩
	Robust	🟩🟩🟩

Yes high 🟩🟩🟩 No 🟥

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FISHERY

STRENGTHENING CYSTOSEIRA TOWARDS SUSTAINABLE FISHING

objective: protect and extend cystoseira meadows for increasing local fish stocks by developing a tailored capacity building protocol

keywords: biodiversity, sustainable fishing, capacity building

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Fishery	Soft Solution	Global change

TOPIC: Artisanal fishing

Cystoseira is an aquatic flora species that plays a key role in improving the marine trophic chain, thus enhancing coastal primary productivity. In the North of Tunisia, climate change has contributed to a massive loss of these algae (Bouafif et al. 2014), and is affecting fishing yield. Despite all efforts to properly manage marine ecosystems and mitigate climate change the loss of biodiversity and the degradation of flora is ongoing. Therefore, innovative management policies should be put in place, capitalizing innovative knowledge, such as the experience of the EU funded "AFRIMED" Project (http://www.afrimed-project.eu/).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

A tailored protocol for strengthening the flora affected by climate change in the future protected areas of Tabarka and Cap Zbib are needed to protect and recover fish stocks..
The protocol of interventions should be co-produced by a multidisciplinary team of experts resulting in clear guidelines able to strongly improve the state of the flora, and particularly the cystoseira, in the area (Merces Project, 2020). The protocol should include:

- Capacity building of advisors and trainers to use tools available to spatially prioritize reinforcement efforts under current and future conditions.
- Carry out field experiments and develop effective methods, and establish an outreach campaign for its adoption by advisors and fishermen.
- Raise awareness among artisanal fishing communities for the preservation of flora.
- Encourage fishermen to use selective, responsible and profitable fishing techniques.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍂
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍂

Yes high 🍃🍃🍃 Yes medium 🍃🍃 No 🍂

For envisioning the potential impact of enhancing cystoseira the EU funded the "AFRIMED" Project (http://www.afrimed-project.eu/) can be taken as a reference. The tailored protocol for the future protected areas of Tabarka and Cape Zbib Bizerte can contribute improving he extension of Cystoseira meadows,and considerably impact biodiversity and fish production. positiverepercussions on exploitable coastal fish stocks can benefit fishermen in the region. The transfer of these experiences provided by trainers and advisors will develop good practices for the sustainable preservation of the environment in fishing communities, and . collaboration between the various stakeholders will ensure the sustainability of results

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of Agriculture (General Directorate of Fisheries and Aquaculture & General Directorate of Legal Affairs)	*Provide the legal and legislative framework facilitating the action of strengthening (transplantation)*
National Institute of Marine Sciences and Technologies (INSTM)	*Scientific approach and monitoring of descriptive parameters of climate change (physico-chemical parameter and stock assessment)*
Coastal Protection and Planning Agency (APAL)	*Establish a national plan for the conservation and improvement of aquatic flora*
Agricultural Extension and Training Agency (AVFA)	*Support for raising awareness among fishermen (technical and environmental aspects)*
Tunisian Union of Agriculture and Fisheries (UTAP)	*Support, consultation and awareness*
Interprofessional Group of Fishery Products GIPP	*Contribution to the promotion of fishery products*
Fisheries Development Group	*Organization of awareness days on the profile of fishermen and fishermen's wives.*

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PARTICIPATORY MONITORING OF BIO-INVASIONS IN THE TUNISIAN FISHERY SECTOR

objective: enhance participatory monitoring of biological invasions and develop adaptation strategies for local fishing communities

keywords: Invasive non-indigenous species, Small-scale fisheries monitoring

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Fishery	Soft Solution	Global change

TOPIC: Fishing of exotic species

Today, Mediterranean small-scale fisheries are in crisis; competing uses, a reduction in fish stocks, and the deterioration of coastal ecosystems have led to the decline in fish production. Climate change related impacts such as water temperature increase, acidification, sea level rise, and impacts of invasive species are all threats to the sustainability of a small-scale fishing activity. Paradoxically, some of these changes can be taken as an advantage for the fishing sector, as is the case of invasive species proliferation, when these can be considered as a potential new product. In the Mediterranean in general and in Tunisia in particular, the flow of exotic species has experienced an unprecedented expansion over the last 2 decades and the impacts on ecosystems, native species and economic activities are increasingly felt. In Tunisia, the total number of exotic animal species reported up to 2019 is 185, including 158 animal species. Among the species reported, more than half are already established (Ounifi-Ben Amor et al., 2016; Boussellaa et al., 2016; Ghanem et al., 2016; Capapé et al., 2018; Bdioui et al., 2019; Ben Jarray et al., 2019; Ben Souissi et al., 2019; Chammem et al., 2019).

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Bioinvasions are not considered as unavoidable and adaptation measures are already in place, but improved information management is needed to gain a better understanding of its dynamics. A comprehensive database including historical monitoring data, as well as biological data on life traits and genetic diversity of target populations would allow a) to identify and confirm the transfer routes and to assess the dispersal capacities of these species, b) to characterise the nature of interactions between the invasive species and the artisanal fishing activity in particular; and c) to determine the impacts on the Tunisian fishery sector. This new approach would allow the development of improved fishing techniques, able to anticipate the impacts of invasive species and foster adaptation. A living-lab for participatory monitoring of biological invasions at national as well as regional levels should be created, gathering multidisciplinary and multi-national research institutions, policy makers, administrations and fishermen. This would help collecting information,extending the monitoring program and the early-warming system at larger scale.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The monitoring program would provide improved information useful to prioritise and tailor the strategies against the spread of bioinvasions. It would allow to transfer crucial information to at least 25% of artisanal fishermen helping to prevent, detect early and react quickly to biological invasions, providing data on key factors such as: number of exotic and invasive species, dispersal capacities and invasion routes. The monitoring program can empower the National Research Institute on Marine Sciences and Technologies' team to conduct improved studies on biological invasions, as well as exploring viable options to include the 6 main invasive species as part of the local economy and incorporating them into the local culinary culture and so making them an important source of local in-come.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍂
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
National Institute of Marine Sciences and Technologies (INSTM)	*To Ensure scientific research activities*
Agricultural Extension and Training Agency (AVFA)	*To Develop popularization actions and awareness campaigns among fishermen*
General Directorate of Fisheries and Aquaculture (DGPAq)	*To ensure Administrative tasks*
Tunisian Union of Agriculture and Fisheries (UTAP)	*Profession-Fishermen (Principal actor)*
Interprofessional Group of Fishery Products (GIPP)	*To Help with marketing, export promotion Valuating activities*

AUTHORS

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CO-MANAGEMENT PROGRAM FOR THE MARINE PROTECTED AREA OF TABARKA

objective: sustain the tabarka fishing community through improved and diversified markets and the reduction of fish stocks overexploitation

keywords: artisanal fishermen of Tabarka, illegal fishing, co-management

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Fishery	Soft Solution	Global change

TOPIC: Artesanal fishery

The impact of climate change, combined with illegal fishing and overexploitation of fish stocks has led to a reduction of certain fish populations and, during the last decade, the production of the fishing sector has decreased. In fact, the coastal fishing production in North West Tunisia has declined from 1040 T to 920 T (2010-2018).

The reduction of exploitable stocks affects artisanal fishermens' revenues in general and those of the Tabarka region in particular. In order to keep up their revenue, the artisanal fishing sector intensified fishing efforts as to maintain revenues. With the aim to face this complex challenge, the creation of a Marine Protected Area is planned, and related management strategies are currently under development.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The engagement of artisanal fishermen in the planned Marine Protected Area of Tabarka management program aims to strengthen the fight against illegal fishing in the region and contribute regenerating fish stocks. Indeed, since 2019 the Group of Artisanal Fishermen of Tabarka has contributed to assessing fish stocks and helped authorities to curb infringements.The suggested co-management program should aim at providing awareness raising campaigns on the importance of protecting fish stocks for the sector, delivering capacity building programs on improved fishing techniques, as well as fostering innovations for artisanal fishing products to be better transformed and valorised, ensuring a diversification of income generation for the fishing community in Tabarka. Furthermore, the implementation of a digital system providing sales price information and online auction is suggested for improved market access and positioning. Active engagement of the Tunisian extension service in disseminating key information would allow reaching the professionals of the sectors in the region.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The expected impacts of the co-management plan are oriented at sustaining the fishing community in Tabarka, fostering a sustainable future for local society. Improved fishing techniques and market information are expected to stabilise revenues, supported by enhanced processing techniques and promotion of fishery products. The program aims to sustain professionals by reducing bad practices and uncontrolled fish stock exploitation.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃🍃
	Adopts a multisectoral approach	🍃
	Flexible	🍃🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
Ministry of Agriculture (General Directorate of Fisheries and Aquaculture & General Directorate of Legal Affairs)	• *Revision of the legal and legislative framework (Introduction of alternative activities such as pesca-tourism)* • *Strengthen the resilience of fishing communities in the face of climate change*
National Institute of Marine Sciences and Technologies (INSTM)	• *Scientific approach and monitoring to mitigate the impact of climate change on fishing communities*
Coastal Protection and Planning Agency (APAL)	• *Establish a national plan to fight against the phenomenon of coastal erosion and the destruction of plant cover*
Agricultural Extension and Training Agency (AVFA)	• *Awareness raising and capacity building* • *Technical training for the development of fishing gear* • *Technical training for the processing and enhancement of fishery products*
Tunisian Union of Agriculture and Fisheries (UTAP)	• *Support, consultation and awareness*
Interprofessional Group of Fishery Products (GIPP)	• *Contribution to the promotion of fishery products* • *Participation in the development of applications for access to digital information*
Fisheries Development Group	• *Organization of fishermen and fishermen's wives* • *Participation in the assessment of stocks* • *Participation in the preservation of the future AMPC*

AUTHORS

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AGRICULTURAL PRODUCTION

PRESERVATION OF FIG TREES (FICUS CARICA L.) GERMPLASM IN THE NORTH-WEST OF TUNISIA

objective: create an integrated strategy to preserve fig genetic diversity in Djebba region

keywords: Ficus Carica L., diversification, preservation

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Agricultural Production	Green Solution	Genetic erosion

TOPIC: Plant protection

The fig (Ficus carica L.) is one of the oldest fruit trees cultivated in Tunisia, especially in the Djebba region, but many specific fig genotypes are threatened by genetic erosion (Gaaliche et al., 2012). Different research projects (Mars et al., 2009; Gaaliche et al., 2012; Gaaliche et al., 2017) identified the male (caprifig) and female fig cultivars available today, and found some of them are already very rare although they have very interesting qualities, such as fruit size, profichis productivity, and richness in pollen and blastophaga, as well as different sensitivity to extreme temperatures. Therefore, genetic diversity can help fig tree farms facing the impacts of increased extreme conditions due to climate change in the region, such as cold and hot winds (Sirocco), summer rains, hail and frost. These climate phenomena exacerbate the effects of other impacts due to farming practices, such as soil compaction, though soil, water scarcity and soil erosion due to runoff. It is crucial to protect the phytogenetic patrimony for reducing the vulnerability to climate change of this important production sector.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The strategy proposed for protecting the genetic diversity of fig germplasm in the north-west of Tunisia should be focused on two types of actions:

Upstream action: researchers and farm extension institutions, supported by private operators, should further develop the prospection and characterization of available cultivars and multiply those most threatened through creating wood yards and a research unit for phylogenetic identification and multiplication. The action would need to be underpinned by more in depth studies on the pedo-climatic adaptation capacity of the most threatened fig cultivars, and the definition of the optimal specific micro-climate and farming practices needed for its preservation.

Downstream action: fig tree operators and farmers, supported by local authorities, should invest efforts to design sustainable solutions to ensure water availability for irrigating fig trees in the summer season. Provided this action is essential for plant productivity, irrigation would allow farmers to improve revenues and to continue agriculture activity using threatened cultivars. Furthermore, applying research results and the extension of new agronomic practices, such as the creation of forest microclimates aiming to shelter caprifig trees and sensitive fig cultivars from extreme climate phenomena, would help support farmers and fig operators also engaging young entrepreneurs.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

The preservation of fig cultivars in the north-west of Tunisia is of great importance for the national patrimony of natural resources. This fruit tree constitutes a pillar for adaptation and maintaining the environmental balance in the region, characterized by very rough lands and shallow soil that is vulnerable for erosion and water scarcity. Furthermore, the fig sector constitutes one of the most important agricultural activities in the northwest of Tunisia, especially in the area of Djebba (Mars et al., 2008). Local population has consolidated know-how that should be shared with young people and women active in production, helping to reduce rural exodus by consolidating the economic and social dynamics around fig tree cultivation. The development of industrial or artisanal processing units is essential to balance market supply and demand.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
The PAMPAT project (Project for Market Access of Typical Agrofood Products)	*The financial support*
National Agricultural Research Institute of Tunisia (INRAT)	*Disseminate the appropriate cultural practices to preserve and improve fig genetic resources in the north west of Tunisia*
Farmers	*Support for the successful prospection's completion and fig cultivars identification*
Mutual Society of Agricultural Services (SMSA)-Djebba Fruits	*Develop knowledge of fig co-products valorization*

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Bouhouli Soltani Hemri Zergui

Photo : Genetic diversity of some fig cultivars cultivated in the northwest of Tunisia.

CYTISUS VILLOSUS SEEDS: A FOREST REGENERATION ALTERNATIVE

objective: reduce vulnerability of cork oak forests through the introduction of Cytisus villosus in restoration programmes

keywords: Cytisus villosus seeds, germination, forest management

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Agricultural Production	Green Solution	Forest degradation

TOPIC: Crop protection

In Tunisia, rising temperatures associated with climate change are expected to decrease the forest land areas and lands suitable for agriculture, shorten the length of growing seasons and reduce crop yields. For instance, these effects of climate change are severe for Cork oak forests, like in Kroumirie in the north west of Tunisia. These numerous environmental challenges generate tradeoffs between various conflicting priorities, ranging from promoting economic diversification, ensuring food security and furthering environmental protection and biodiversity conservation. Forest restoration is key for adaptation and research shows that the selection and introduction of herbaceous and woody leguminous species - native, spontaneous or introduced - can be used in rehabilitation programs for degraded and damaged cork oak forests by climate change.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Hairybroom (Cytisus villosus Pourr., syn. Cytisus triflorus L´Hérit) is a perennial shrub of the Fabaceae family within the tribe Genisteae. This legume has beneficial biological features for revegetation programmes and the association of Cytisus with cork oak can increase soil fertility and the primary productivity of the forest ecosystem. A conservation program for Cytisus species should be established, based on scientific information obtained from several trials of different protocols, allowing to improve the current multiplication technique of Cytisus villosus seeds, its cultivation and its subsequent introduction into forest management programs.

Cytisus Villosus seeds

Cytisus villosus seedlings after germination and transplanting in a nursery

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Recent research aiming to test the impact of this type of plant association on the loss of hydraulic conductance (Ennajah et al., 2020) on morphological (height, circumference) and ecophysiological (stomatal conductance, transpiration) parameters (Ennajah et al., 2018) suggest that cork oaks associated with leguminous species exhibit a better eco-physiological behavior. Cork oak is one of the main species of Mediterranean ecosystem woodland and has high socioeconomic and environmental values. The suggested management program would allow to reduce cork oak forest degradation due to climate change and ameliorate ecological stress due to overexploitation through the transference of new agricultural practices and the valorisation of new forest resources by improving livelihoods and engaging rural women in the conservation of genetic resources.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃🍃🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
General Directorate of Forests DGF	• *Strengthen the legumes introduction in degraded forest areas.* • *Reinforcing Silvicultural approaches for mixed-species like Cytisus/cork species.*
Ministry of Agriculture	*Financing of small projects for the multiplication of Cytisus villosus and its valorization.*

AUTHORS

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AGRICULTURAL REUSE OF SEWAGE SLUDGE AT BEJA GOVERNORATE

objective: to identify difficulties that limit the sewage sludge agricultural reuse and to determine the possible solutions to bypass them by involving state establishments, in order to promote the agricultural valuation of this by-product of wastewater treatment, in compliance with good sanitary practices

keywords: Northwest Tunisia, water treatment, sewage sludge reuse

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
Decision Makers	Agricultural Production	Green Solution	Water scarcity

TOPIC: Water quality

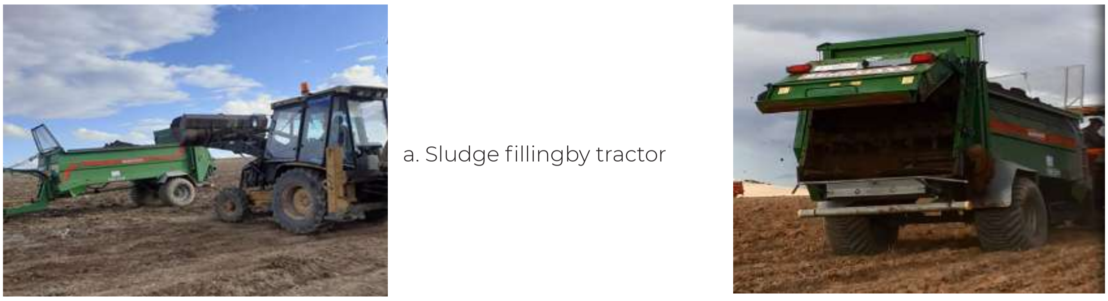
To face climate change, the UN SDG no 6 is directly focused on water treatment, emphasizing the management and treatment of sewage sludge (Milin et al., 2016). The Tunisian national strategy aims to reuse sludge in agriculture, cement production, renewable energy by anaerobic digestion (ONAS, 2015). Currently, only 2,500 tons of sludge are reused out of a total of 82,000 m3/year of dried sludge produced by solar exposure in beds from 122 wastewater treatment plants (ONAS, 2019). Moreover, since 2016 a sewage sludge production increase has been recorded compared to a decrease in the reuse in agriculture (ONAS, 2016, 2017, 2018, 2019).In Beja region, which is one of the largest agricultural production areas in Northwestern Tunisia,all dried sewage sludge produced by five wastewater treatment plants was analyzed for physicochemical and microbiological quality (INNORPI, 2002) and potential for agricultural reuse. During 2019-2021, 9 farmers here expressed interest to use sludge as fertilizer, but they only received a part of the requested quantity (CRDA, 2021). The demand for sludge is mainly due to the unavailability of chemical fertilizerssuch as ammonium nitrates and diammonium phosphate (DAP).However, there is an imbalance between demand and supplyof sludge.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

To mitigate the imbalance between farmers' demand and insufficient quantity of dried sewage sludge produced by the wastewater treatment plants in Beja region, state agencies should develop, lead, and coordinate the following:

1. The National Sanitation Utility (ONAS) could:
   a. Increase the quantity of naturally dried sludge produced in the treatment plants. Improved drying beds can be achieved by changing drainage layers formed by sand and gravel to avoid drain clogging, depending on drying bed technical status.
   b. Provide safe transport and temporary storage for sewage sludge (ignition and biological reactivation)to Beja from other regions with less demand for agricultural reuse.

2. The Ministry of Agriculture could through the Regional Offices of Agricultural Development (CRDA):
   a. Promote reliable sludge control for good sanitary practices and organize capacity building for farmers regarding reuse of sludge.
   b. Encourage farmers to reuse sludge as fertilizer. CRDA has, e.g., adequate equipment for transporting sludge to farmers (Figure 1).



a. Sludge fillingby tractor

b. Sludge amendment by spreader

Figure 1. Spreading sludge on a field in “Monchar” (North Beja)

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Sludge reuse has several potential benefits, e.g., providing plant nutrients, organic matter which plays a key role in retaining good soil structure and water-holding capacity (Defra, 2007), and controlling its pH (Ati, 2010; Amri, 2020). Thus, reuse of sewage sludge will improve organic matter, structure, water retention, and pH. However, the presence of heavy metals is a main disadvantage. Metal accumulation in the soil is an irreversible process with negative consequences in the long-term (Drouiche, 2012).From an environmental point of view, rational reuse of sewage sludge contributes to the reduction of pollution risks due to that toxicity can be minimized by building up soil organic matter (Ashraf et al., 2014). A proper balance needs experimental verification (Barriuso et al., 1994) which can be determined by agricultural research institutes such as INRGREF, INRAT, and CRRGCB.From an economic and social point of view, the use of sewage sludge can increase returns at the scale of a farm (Amri, 2020). Indeed, compared to non-amended soil, the organic nitrogen and carbon contents will increase (Lakhdaret al., 2010).Sludge is inexpensive compared to other chemical and organic fertilizers. Accordingly, a reduction in production costs combined with an increase in land profitability should make it possible to raise the farmer’s income, to promote living conditions and to stabilize the rural population, and thus reducing the problem of rural exodus. In the rural city of Ouardanine, environmental degradation due to untreated sewage discharge combined with limited employment opportunities contributed to many local youths leaving the town. The creation in 1993 of a wastewater treatment plant that serves about 3,400 households improved the environment. At present, an amount of 2050 t/year of sludge is produced and about 105 t/year are reused in a free-of-charge pilot program (peach, olive, grape, and grenades: Drechsel & Hanjra, 2018). Key drivers for its success were:

- A clear regulatory framework permitting reuse for a wide variety of seasonal and perennial crops.
- Governmental will, financial support, and inter-institutional cooperation down to user associations.
- Early participation of the users.

Here we report the adaptation indicators identified for each solution during the living lab workshop.

APPROACH PROPOSED	Causes a transformation (societal, economic, institutional, etc.)	🍃🍃
	Reduces resource consumption	🍃
	Improves ecosystem health and functionality	🍃
	Adopts a multisectoral approach	🍃🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

ACTORS AND ROLES

ACTOR ENGAGED	ROLE
National Sanitation Office	*To provide the necessary data*
Ministry of agriculture	*To provide information on the state of the art*
INRGREF	*Research, analysis and data processing*
INRAT	*Socio-economic study*

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OPTIMIZATION OF LACTATION MANAGEMENT OF THE SICILO-SARDE BREED

objective: consolidate Silico-Sarde breed sheep herding by improving milk production and introducing best practices

keywords: Sicilo-Sarde, dairy performance, food safety

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Agricultural Production	Soft Solution	Global change

TOPIC: Livestock management

In the past in Tunisia and the rest of North Africa, dairy sheep were only represented by the Sicilo-Sarde breed, but its population collapsed to less than 0.5% of the total number of sheep in the 1990s. Amongst other reasons, zootechnical deficiencies of breeding practices lead production to fall down to 50-100 l / lactation, putting the sustainability of the small cheese production sector in danger. However, this breed displays unique traits such as disease resistance and / or tolerance to extreme weather conditions, useful in dealing with the impacts of climate change. Lactation of dairy ewes is usually operated with an initial suckling period of about two and a half months, followed after weaning the lambs by an exclusive milking period. The suckling period can be mixed (suckling and one milking per day) in order to eliminate the excess milk not suckled by the lambs. Urgent adjustments are needed to current lactation practices in order to improve the dairy vocation of this breed.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

For maximising the potential of the Sicilo-Sarde sheep productivity, optimizing the start of lactation is key. Therefore, from the start of lactation (from the third day after birth), mixed suckling (partial suckling and a daily single milking) can be practiced in order to minimize the residual milk not suckled by the lambs, to maintain the milk secretion, and as a result, absorb the drop in production conventionally observed during the transition from suckling to milking. In practice, the lambs suckle their mothers all day and they are separated in the evening to milk the ewes in the morning. Lambs could be weaned as soon as they are three times their birth weight. Hence the possibility of adopting early weaning at five / six weeks of age for the Sicilo-Sarde breed.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Research results (Aloulou, 2020) indicate that during the lactation phase, the Sicilo-Sarde breed has significant milk potential (1.4 l / d; Aloulou et al., 2018) and early weaning has allowed an increase in the quantity of marketed milk (+50 %) compared to weaning at 60 d without affecting the growth of lambs (228 g / d; Aloulou et al., 2019). Furthermore, mixed suckling and the early start of milking make it possible to increase the quantity of milk produced (Figure 1; Aloulou et al., 2019)

The adoption of the mixed sukling technique and early weaning boosted the true dairy potential of the Sicilo-Sarde breed, both in terms of milk production (Aloulou, 2020) and the cheese yield (Hamdi et al., 2018). These results could make it possible to improve the profitability of livestock, strengthening the adaptation capacity of rural populations, as well as to protect this adaptive animal breed.

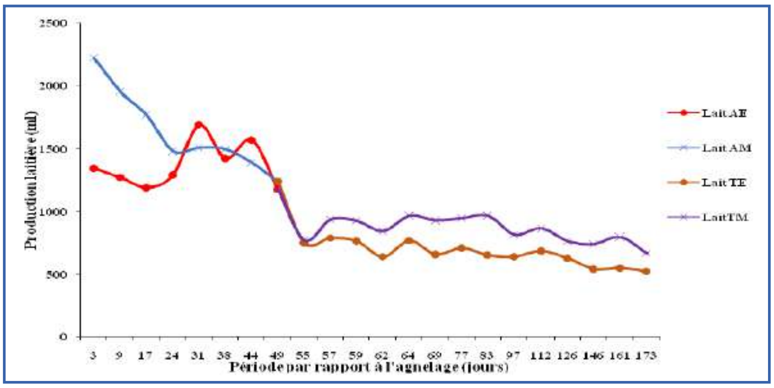

Figure 1: Evolution of the milk production of the Sicilo-Sardinian ewe during the lactation phase (AE Milk and AM Milk) and the exclusive milking period (TE Milk and TM Milk) according to the lactation method (Exclusive vs. Mixed)

With: AE Milk: Breastfeeding Milk in Exclusive mode; Milk AM: Breastfeeding Milk in Mixed mode; Milk TE: Milking Milk in Exclusive mode; Milk TM: Milking milk in Mixed mode.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍂
	Decreases water demand	🍂
	Increases health and functionality of ecosystems	🍂
	Is synergetic with other sectors	🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

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GOOD PRACTICES FOR MECHANICAL MILKING OF SICILO-SARDE SHEEP

objective: promote the breeding of locally relevant and adaptive silico sarde sheep by improved milk production

keywords: dairy aptitude, mechanical milking, durability

Target	**Field of interest**	**Type of adaptation measure**	**Climate challenge addressed**
FAS agents and farmers	Agricultural Production	Soft Solution	Global change

TOPIC: Livestock management

Current milking practices for the Sicilo-Sarde sheep breed is affected both by management and climate change induced challenges, reducing efficiency of milk ejection. On the one hand, inappropriate operating settings cause an average of 25% of residual milk to remain in ewes after milking and increases the risk of mastitis, and, on the other, increased temperatures induced by climate change affect breeding and milk production in the region. These inefficiencies compromise milk quality, reducing its aptitude for consumption and transformation, thus farms revenues. Therefore, to reduce the vulnerability of the Sicilo-Sarde sheep milk production it is important to optimize the breeding and milking conditions in order to limit the loss of milk and improve ewe health.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Data on the mechanical milking of the Sicilo-Sardinian ewes are particularly scarce, and solid benchmarks for this breed are lacking. An efficient and adequate milking process should include:

- Adequate management of the milking site: facilitated mobility of animals, improved hygiene and environmental conditions (noise, temperature), as well as a correct dimensioning of milking units and personnel
- Correct operational settings, such as developing a benchmark on the vacuum and pulse settings of milking machines suitable for this breed, while considering the anatomical and physiological characteristics of the udder of the Sicilo-Sardinian sheep.
- Appropriate preparation of the udder to promote stimulation, quick installation of the teat cups on clean ewes, ensure vacuum cut-off before removing the teat cups, complete emptying of the udder and disinfection

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

In order to preserve and promote the breeding of Sicilo-Sarde sheep, the only sheep breed specialized for dairy in North Africa, it is key to continue the research and extension to farmers of best practices able to increase the level of milk production and promote the adoption of mechanical milking.

The adoption of best practices for optimising technical and hygienic conditions of the milking process would ensure a:

- Good adaptation of the ewe to mechanical milking.
- Increase in the quantity of milk marketed.
- Better hygienic and sanitary quality of the milk produced.
- Reduction of production costs and working time.
- Guarantee of good mammary health of the animals.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🟩🟩
	Decreases water demand	🟥
	Increases health and functionality of ecosystems	🟩🟩🟩
	Is synergetic with other sectors	🟩🟩🟩
	Flexible	🟩🟩
	Robust	🟩🟩

Yes high 🟩🟩🟩 Yes medium 🟩🟩 No 🟥

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VALORISING LOCAL FEED RESOURCES FOR SMALL RUMINANTS

objective: improve livestock feeding and avoid overgrazing through local fodder production

keywords: small ruminants, local alternative resources, durability

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Agricultural Production	Green Solution	Global change

TOPIC: Livestock management

In Tunisia, the feeding of small ruminants is based primarily on natural resources (rangelands, fallows, stubble, etc.) which are not available throughout the year. The difficult climatic conditions marked by prolonged periods of drought and overgrazing have resulted in the reduction of rangelands and their degradation. Therefore, breeders find themselves forced to fatten their animals in the sheepfold with a large supply of concentrated feed. In addition, the prices of imported raw materials (soybeans, corn and barley) have at least tripled during the last two decades. Herders are thus faced with high production costs, low productivity and difficult living conditions.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The major challenge for breeders is to find new alternatives to the traditional ingredients of animal fodder that could compete on the market in terms of nutritional quality that are produced in ecologically sustainable ways by using simple and inexpensive techniques. In other words, it is about maximizing the value of local fodder resources given the low incomes of pastoralists in rural areas and limited access to the national and international market. Certain local fodder resources have been identified as promising alternatives to imported sources due to their high protein content, such as legumes (Acacia, Atriplex, Medicago Arborea, Grass pea,...). Also, other less rich fodder resources (wheat bran, olive pomace, tomato and beet pulp, etc.) can be used and enhanced, in order to reduce food costs, especially in times of scarcity in regions characterized by a forage deficit.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Research results obtained for lambs reared on a rangeland improved by Medicago Arborea showed better growth performance (105 vs. 84 g / d) and lean meat rich in Omega 3 fatty acids compared to lambs raised in sheepfold with oat hay (Hamdi, 2017). Also, Friha et al. (2019) have shown that driving ewe lambs on a rangeland rich in halophyte plants yielded performance comparable to those of ewe lambs reared in sheepfolds with straw (92 vs. 96 g / d). This confirms that the rehabilitation of the rangelands makes it possible to improve the productivity of the farms and to guarantee the good nutritional quality of the products.

Also, supplementing rations with olive cake (20% DM ration) had no negative effect on lamb performance as well as on carcass and meat quality (Hamdi et al. , 2016). Thus, the use of olive cake in animal feed with well-studied incorporation rates makes it possible to reduce production costs and reduce environmental pollution.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🔴
	Decreases water demand	🔴
	Increases health and functionality of ecosystems	🟢🟢🟢
	Is synergetic with other sectors	🟢🟢🟢
	Flexible	🟢🟢
	Robust	🟢🟢

Yes high 🟢🟢🟢 Yes medium 🟢🟢 No 🔴

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FICUS CARICA L. DRYING IN TUNISIA: CURRENT STATUS AND FUTURE PROSPECTS

objective: enhance innovation in Ficus carica L. processing to sustain a climate resilient sector

keywords: Ficus carica L., processing, sun drying

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Agricultural Production	Green Solution	Crop vulnerability

TOPIC: Farms and Farming Systems

Fig tree (Ficus carica L.) is a fruit species resilient to the impacts of climate change and well adapted to the agro-ecological conditions of Tunisia, covering an area of 30,000 ha with an average annual production of 27,000 tonnes (Ministère de l'Agriculture, 2020).

Figs are rich in nutrients and are consumed fresh (Bither or Karmous) or dried (''Chriha ''). Drying has proven to be a reliable preservation method for figs, in terms of technical feasibility and nutritional quality. Prospections carried out by Gaaliche et al. (2012) in central and northern Tunisia showed that a total percentage of 54% of farmers sun-dry figs. About 70% of farmers confirmed that the "Halfa" plant is preferred for drying and performs the best quality of "Chriha" in terms of taste and flavour. The quality of dried fig fruits is highly dependent on climatic conditions, and fig cultivars can be cultivated under a wider range of ecological conditions (Gaaliche et al., 2011). The drying time generally varies from 10 to 20 days and depends on the temperature, humidity and the degree of fig fruit maturity. Remarkably only 10% of farmers sell their products at the local market.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

Despite its socio-economic and cultural importance, drying figs is still traditional in Tunisia and should be modernised for economic and especially public health reasons.

Therefore, the objective of this proposal is to analyse the current situation of fig orchards in Tunisia, in particular the drying and conservation techniques, the problems associated with fig drying and the possibilities of modernizing fig drying techniques. The creation of drying and conservation units would enhance the sector, as well as developing new cultivars that will adapt to broader ecological conditions and to diversify the product range.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Fig production is a highly resilient sector of tunisian agriculture and largely sustains rural communities, especially in marginal areas. Improvements of drying techniques can enhance production processes and market access, therefore extending the use of this crop in the region. Dried figs are mostly produced with low-input management systems, can be easily stored and supply functional phytochemicals. The total production is rather limited and to address the demands of the consumers, safe and high quality dried figs or derived products should be supplied to the world market.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🔴
	Decreases water demand	🟢
	Increases health and functionality of ecosystems	🔴
	Is synergetic with other sectors	🔴
	Flexible	🟢🟢
	Robust	🟢🟢🟢

Yes high 🟢🟢🟢 Yes medium 🟢🟢 Yes Low 🟢 No 🔴

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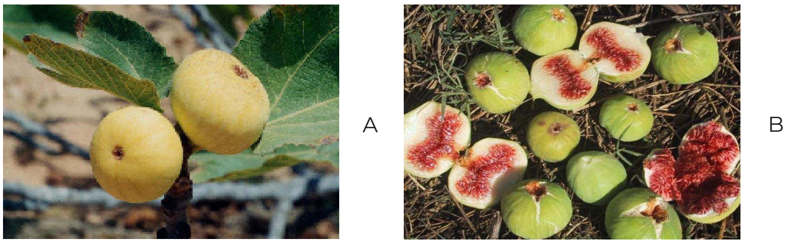

Photo 1 : Example of suitable fig cultivars for drying (A: cv. Bidhi and B : cv. Khedri)

Photo 2 : Sun drying of figs (cv. Bidhi) on palms

EXTENDED CROPPING OF PHALARIS (PHALARIS AQUATICA L.) FOR ADAPTING SYLVO-PASTURAGE TO DROUGHT

objective: extend the use of Phalaris (Phalaris aquatica L.) for pasture grasslands in Tunisia as an adaptation option against the impacts of drought on silvo-pasturage

keywords: perennial grass, Phalaris aquatica, forage production

Target	Field of interest	Type of adaptation measure	Climate challenge addressed
FAS agents and farmers	Agricultural Production	Green Solution	Extreme events (Droughts)

TOPIC: Silvopastoralism

Livestock production plays a very important socio-economic role in Tunisia, but limited access to year-round forage is a major constraint to obtain better marketable, diversified and profitable products. Perennial grasses, such as Phalaris (Phalaris aquatica L.), provide crucial ecosystem services including carbon sequestration, soil protection and enrichment and preservation of biodiversity (Gaujour et al. 2012). This species is native to the Mediterranean region, but is affected by local genetic erosion due to irregular rainfall, overgrazing, reduction of rangeland extensions and neglected forage exploitations.

Phalaris attracts growing interest due to its high drought-resistance as well as its suitability for abandoned marginal land where excessive salinity and low moisture levels limit plant growth.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

The use of Phalaris (Phalaris aquatica L.) for pasture grasslands in Tunisia can be an impactful adaptation option against the impacts of drought as it allows to extend and regularize the feeding season. The species is characterised by fast regrowth at the onset of autumn rains and very efficient exploitation of residual moisture in late spring, increasing its resilience to water shortage. Under current climate change scenarios for Tunisia, longer and more severe droughts are foreseen, increased adoption of Phalaris is highly recommended for creating sustainable grasslands. In Northern Tunisia, the perennial forage grasses already constitute an important winter crop, widely used in pasture, lawns and hays and can be successfully established by conventional or by direct seeding pasture establishment techniques.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

A successfully established, vigorous and well managed perennial pasture can be expected to survive drought episodes, sustain increased livestock production and provide environmental benefits for many years. The adoption of perennial grass systems in Tunisia can enhance production, food security and rural livelihoods and foster farming systems to deliver multiple economic, environmental and social benefits. In addition, perennials also have lower water needs than annual grassland species and reduce the risks of soil erosion, as well as the costs associated with tilling and sowing.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍂
	Decreases water demand	🍃
	Increases health and functionality of ecosystems	🍃🍃🍃
	Is synergetic with other sectors	🍃🍃
	Flexible	🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃 No 🍂

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PROMOTION OF TRITICALE GENOTYPES ADAPTED TO MARGINAL AREAS LOCATED IN NORTHERN TUNISIA

objective: to increase the local production of triticale to reduce forage import and adapt local livestock to impacts of climate change

keywords: triticale genotypes, marginal areas, northern Tunisia

Target	**Field of interest**	**Type of adaptation measure**	**Climate challenge addressed**
FAS agents and farmers	Agricultural Production	Green Solution	Genetic erosion

TOPIC: Genetic improvement

Climate change predictions in the Mediterranean basin foresee faster warming trends than in most other areas in the world, associated with reduced rainfall during the growth season. The Mediterranean area is therefore an advanced field laboratory to study and model climate change impact on ecosystems (José et al.,2021). As considerable uncertainty remains in understanding and modelling how relevant processes will affect crop production and the risk of crop mortality under a changing climate. In Tunisia, although livestock production is becoming increasingly intensified, forage crop areas have remained constant over the last decade and the contribution of forage crops to livestock feeding is limited (Jaouad, 2010). To manage the required animal feed, increasing quantities of maize and barley are imported, placing a strong pressure on the farms' balance of expenditures. In this context the need to develop new varieties rises, fostering crops that are adaptable to the environmental conditions of north west Tunisia (subhumid (Béja)-humid (Sedjnéne)-semi-arid (Oued Mliz)) and more efficient than the traditional varieties.

DESCRIPTION OF THE ADAPTATION APPROACH OR POLICY STRATEGY

In order to reduce forage importations, triticale, a new cereal characterized by high productivity and adaptation to different environments, could be an alternative crop (Hulse and Spurgeon., l974). Research on a collection of twenty-three varieties of triticale within three different environments located in northern Tunisia namely Oued-Beja, Sedjenane and Oued-Mliz highlighted that there is an important variability in the genotypes behavior between sites. Furthermore, findings remark the excellent performance of some triticale and allow us to identify the most productive varieties (POLLMER and SARDEV) that can easily adapt to these marginal areas.

EXPECTED IMPACTS TO TACKLE THE CLIMATE CHANGE RELATED CHALLENGE

Baraket et al, 2015 indicate that the new varieties such as COPI, LIRON, POLLMER, SPHD, SARDEV and DIS have better agro-biological features than the local varieties. Research findings indicate that the CIMMYT line "SARDEV" is characterized by features allowing its dual purpose exploitation (grains and grass). The findings contribute to focusing on the triticale behavior in Tunisian agro-climate system, supporting the relevance of farming such cereal for the required feed production within the framework of the increasing limitations imposed by climate change.

Here we report the adaptation indicators identified for each solution during the Living Lab workshop.

APPROACH PROPOSED	Decreases energy consumption	🍃
	Decreases water demand	🍃🍃🍃
	Increases health and functionality of ecosystems	🍃🍃
	Is synergetic with other sectors	🍃🍃🍃
	Flexible	🍃🍃🍃
	Robust	🍃🍃🍃

Yes high 🍃🍃🍃 Yes medium 🍃🍃 Yes Low 🍃

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