



# REACT 4MED

## Agro-ecological restoration actions for the Mediterranean

Guidebook for practitioners



# PRIMA

PARTNERSHIP FOR RESEARCH AND INNOVATION  
IN THE MEDITERRANEAN AREA



## **Hellenic Mediterranean University (HMU),**

Estavromenos, 71410 Heraklion, Greece

### **Contact information:**

#### **Prof. Thrassyvoulos Manios,**

*Department of Agriculture School of Agricultural Science  
Vassilis Papazisis Building,  
e-mail: tmanios@hmu.gr, landline: + 30 2810 379456*

#### **Asst. Prof. Ioannis Daliakopoulos,**

*Department of Agriculture, School of Agricultural Science,  
Vassilis Papazisis Building,  
e-mail: idaliak@hmu.gr, landline: +30 2810379482*

### **Funding Disclaimer**

*The project "Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean" (REACT4MED, grant agreement 2122) is funded by the Partnership for Research and Innovation in the Mediterranean Area (PRIMA). PRIMA is a public-public institutionalized Article 185 European Partnership between the European Union and Participating States. The aim of PRIMA is to build research and innovation capacities and develop knowledge and common innovative solutions in the Mediterranean area. PRIMA is a ten-year initiative (2018-2028), partly funded by EU's research and innovation programme Horizon 2020 and Horizon Europe*

Contact Information

<https://react4med.eu/>, [info@react4med.eu](mailto:info@react4med.eu), social media: [@react4med](https://twitter.com/react4med)

## Contributors

**Introduction:** Aris Koutroulis, Raissa Ulbrich

**Context descriptions:** Aris Koutroulis

**Italy:** Daniela D'Agostino, Enrico Perrino

**Türkiye:** Perihan Tari Akap

**Egypt:** ElSayed ElHabasha

**Spain:** Artemi Cerda

**Israel:** Ghadir Zbedat

**Cyprus:** Adriana Bruggeman, Christos Zoumides

**Greece:** Giannis Louloudakis

**Morocco:** Rachid Mrabet

**LandDS:** Elena Matta

## Editors:

Evelyn Lukat, Raissa Ulbrich

## Design:

Danai Kalergi



## Partners:



Stay in touch through our website:

[www.react4med.eu](http://www.react4med.eu)

## Foreword

Open this book anywhere and you will notice the same guiding impulse: turning hard won knowledge into practical momentum. The pages that follow are neither a conventional scientific report nor a glossy collection of success stories; they are a working manual for everyone committed to restoring Mediterranean lands and livelihoods at scale.

What sets this volume apart is its refusal to treat land degradation as a purely biophysical phenomenon. Every chapter reminds us that soils are living systems embedded in equally living communities. Whether describing conservation agriculture in Morocco or food forests in Israel, the human dimension is in the foreground: brave women taking decisions for their families' health and livelihood, young land managers and entrepreneurs that experiment with agrotourism or investing in organic agriculture. The result is a narrative of hope rooted in tangible, replicable experience.

As coordinators of REACT4MED, we are particularly encouraged by three features that run through the book:

- Evidence before prescription: each practice is backed by quantitative indicators allowing readers to weigh trade-offs transparently.
- Interdisciplinary rigour: Agronomy, Hydro meteorology, Computer Science, Economics, and Social Sciences cross-pollinate each other on every page, mirroring the complexity of the real world.
- Scalability and feasibility by design: from the very first pilot plot, scientists and stakeholders asked not only "Where do we want to be in 50 years from now?" but also "What will this take and who must be involved to achieve this vision?"

For policymakers, this book offers a menu of shovel-ready interventions tied to measurable co-benefits: carbon sequestration, biodiversity gains, sustainable yields and long-term livelihood security. For investors, public or private, it lays out the business case for land restoration grounded in robust cost-benefit analysis. For land managers, extension officers, and community leaders, it is a practical handbook written in accessible language and illustrated with real-world successes.

But perhaps the book's greatest contribution is less technical and more cultural: it rekindles the Mediterranean tradition of stewardship. By honouring ancient techniques - now widely recognised agroecological practices - while embracing cutting-edge digital tools, it charts a path that is at once innovative and rooted in place. In doing so, it invites every reader to see themselves not as passive observers of environmental decline, but as active agents of renewal.

We commend our REACT4MED teammates, the contributing stakeholders, the many researchers who collaborated for this book, and PRIMA for making this project possible. May the insights gathered here inspire bold action - on the farm, in the marketplace, and in the halls of government - so that Mediterranean landscapes remain fertile, resilient, and vibrant for generations to come.

*On behalf of the REACT4MED Consortium,*

**Ioannis Daliakopoulos**

*Asst. Professor, Department of Agriculture,  
Hellenic Mediterranean University*

**Thrassyvoulos Manios,**

*Professor, Department of Agriculture,  
Hellenic Mediterranean University*

*July 29, 2025*





## Table of contents

|      |   |    |
|------|---|----|
| 1.   | Preparing the ground: Introduction .....  | 6  |
| 2.   | Planting the seeds of change: Restoration actions .....   | 8  |
| 2.1. | Natural water retention: Organic farming and integrated crop management in table<br>grape production .....          | 8  |
| 2.2. | Effective drainage and improvement practices .....  | 12 |
| 2.3. | Restoring salt-affected agricultural lands .....  | 16 |
| 2.4. | Revitalising olive orchards:<br>The impact of chipped pruned branches in Mediterranean groves and vineyards .....   | 19 |
| 2.5. | Grounded in heritage, growing for the future: Agricultural mountain terraces with<br>drystone retention walls ..... | 24 |
| 2.6. | Tradition meets the future: Conservation agriculture for healthy soils<br>and healthy livelihoods .....             | 29 |
| 2.7. | Diverse yields: Agroforestry to protect soils and livelihoods.....  | 33 |
| 2.8. | Improving soils and biodiversity with food forests .....  | 36 |
| 3.   | Spreading the fruits of knowledge: Supporting informed land management<br>with LanDS .....                          | 40 |



## 1. Preparing the ground: Introduction

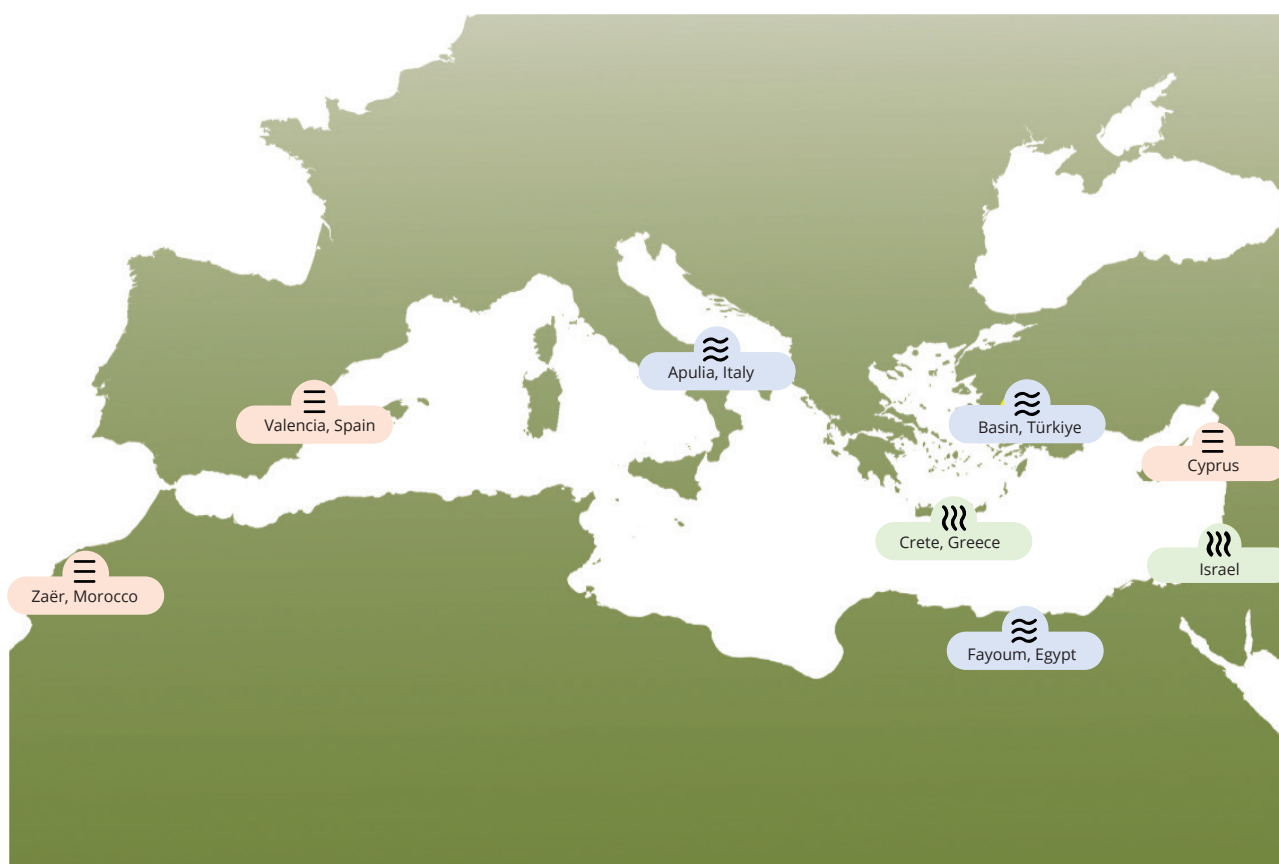
The Mediterranean region stands at a crossroads. Farmers, land users, and communities across the region are grappling with increasingly difficult conditions. Hotter summers, unpredictable rainfall, degraded soils, and mounting pressure on water resources. **These are not isolated events.** They are part of a larger transformation, driven by both climate change and long-term changes in how people live and work that are altering landscapes and livelihoods from the coastal plains of Morocco to the mountain slopes of Cyprus.

In recent years, parts of the Mediterranean region have already warmed by up to 3°C compared to preindustrial times. Rainfall patterns have shifted, with some areas facing prolonged dry periods and others experiencing more intense storms. These trends are not just meteorological as they carry real consequences for the land. Soils are drying out, erosion is accelerating, and salinity is becoming a growing problem. These changes mean greater uncertainty, reduced yields, and more difficulty sustaining agricultural land.

At the same time, the region is experiencing demographic and economic growth. Urban areas are expanding, and competition for natural resources is increasing. While agricultural landscapes have remained largely stable in terms of surface area, their character is changing. The pressure to produce more on the same land is rising, while the cost of land degradation is becoming harder to ignore.

Looking ahead, the situation is likely to get more challenging. Projections show that if greenhouse gas emissions continue on their current path, average temperatures could rise by as much as 4.6°C by the end of the century. Droughts will likely become more frequent and intense. Soil degradation could significantly reduce productivity and resilience of farms across the region, putting both farmers' livelihoods and food security at risk. At the same time, economic scenarios range from modest growth to rapid expansion, adding further complexity to land and water use decisions. But within these challenges lies opportunity. The REACT4MED project advocates for good agricultural practices that rebuild soil health and deliver reliable harvests, securing productivity and profits while preserving vital natural resources. Across the eight pilot areas of the REACT4MED project, in Türkiye, Morocco, Israel, Egypt, Cyprus, Greece, Spain, and Italy, farmers, local authorities, businesses and researchers are working together to identify what works, what needs to change, and how to build resilience from the ground up. These areas represent a mosaic of conditions: from family-run vineyards in Italy facing water shortages, to olive groves in Spain battling erosion, to silvopastoral systems in Crete reviving depleted soils.





| Pilot Areas                           | Category of restoration action      | Restoration action                             | Main problem                    |   |
|---------------------------------------|-------------------------------------|--|---------------------------------|---|
| Stornara and Tara, Apulia, Italy      | Water management and irrigation     | Organic farming and integrated crop management | High water consumption          | ☞ |
| Lower Gediz River Basin, Türkiye      | Water management and irrigation     | Drainage and soil melioration                  | Salinisation of soil            |   |
| Tamia region, Fayoum, Egypt           | Water management and irrigation     | Drainage and soil melioration                  | Salinisation of soil            |   |
| Canyoles River Basin, Valencia, Spain | Soil and erosion protection         | Mulching                                       | Water erosion                   | ≡ |
| Troodos Mountains, Cyprus             | Soil and erosion protection         | Terracing                                      | Soil erosion                    |   |
| Zaër, Morocco                         | Soil and erosion protection         | Conservation agriculture                       | Soil depletion                  |   |
| Crete, Greece                         | Multifunctionality and biodiversity | Agroforestry                                   | Biodiversity loss, soil erosion | ☞ |
| Bethlehem of Galilee, Israel          | Multifunctionality and biodiversity | Food forest                                    | Biodiversity loss               |   |

Together with farmers, REACT4MED aims to regenerate soils, use water more efficiently, and restore local biodiversity so that farmland remains productive and resilient. As the climate grows hotter and drier, these benefits become essential to secure harvests and protect livelihoods.

In this guidebook, you will find portraits of suitable practices under various conditions in the eight pilot areas accompanied by information on implementation. Join us as we explore these solutions and witness the positive change happening on the ground!

## 2. Planting the seeds of change: Restoration actions

### 2.1. Natural water retention: Organic farming and integrated crop management in table grape production

**Case:** Stornara and Tara, Puglia, Italy

#### Restoration action category:

irrigation management (incl. water supply, drainage)

#### Measures included:

- Soil cover
- Soil fertility
- Soil surface treatment
- Change in management
- Layout according to natural and human environment

#### Description of technology:

Implementing a production system that minimises disease and pest incidence reduces pesticide use without sacrificing crop productivity. This approach views the vineyard as an ecosystem, optimising resources to enhance cultivar biodiversity and decrease pest and disease pressure. Plant diversity is increased through local wild plants typical of the Mediterranean Basin along field edges, which help control pathogen populations.

#### Main purposes:

- prevent (avoid) or reduce land degradation; restore/rehabilitate land
- (reverse land degradation) (soil, water, vegetation)
- conserve ecosystem
- preserve/ improve biodiversity

#### Main benefits

- Increased water retention
- Decreased risk for salinisation
- Higher market prices for organically grown produce

### Agriculture in a changing climate

In Southern Italy, farmers are likely to face rising temperatures and declining summer rainfall, with projections indicating more frequent and severe droughts by mid-century. This is expected to impact water availability for viticulture and other crops, while exacerbating soil degradation in already vulnerable areas. Socioeconomic projections suggest moderate urban expansion and shifts in labour markets that may further pressure traditional agricultural systems. Adapting irrigation practices and enhancing soil moisture retention will be vital for sustaining yields and quality.

#### The pilot area in the Stornara and Tara region: A profile

In the Stornara and Tara region, agricultural practices are shaped by a maritime Mediterranean bioclimate characterised by average annual rainfall of 550 mm, predominantly occurring in winter and autumn. The main crops cultivated include citrus, table grapes, stone fruit, olives, and summer vegetables, which are produced for large market chains and export markets. Irrigation is essential from April to September due to frequent summer droughts and sandy soils with low water retention capacity.

The farming landscape is fragmented, with small farms averaging two to three hectares, larger farms spanning 10 to 30 hectares, and a few exceeding 100 hectares. Many farms are family-run as side businesses, with aging farmers often lacking successors. While agricultural activities are predominantly managed by men, women frequently assist during harvests or in food processing.

The irrigation consortium Consorzio di Bonifica Stornara e Tara manages the water distribution using a pressurised and gravity-fed system. Farmers rely on irrigation from April to September, but the current delivery schedule (water provided every 10 days) is inadequate, as sandy soils lose water within two to three days. Consequently, aquifer irrigation and unlicensed wells are widely used, worsening groundwater depletion and salinisation. Farmers and the consortium face conflicts over water allocation, as the schedule currently does not meet farmers' needs. The region faces significant challenges related to water scarcity, exacerbated by an inadequate irrigation schedule and resulting conflicts.

| Climate   |   |
|---|---|
| Annual rainfall   | 584 mm                                      |
| Average annual temperature  | 15.8°C                                      |
| Reference meteorological station  | Castellaneta (Taranto),                     |
| Agro-climatic zone  | semi-arid                                   |
| Topography  |   |
| Slopes on average   | gentle (3-5%)                               |
| Landforms   | valley floors                               |
| Altitudinal zone  | < 100 m asl                                 |
| Soils   |   |
| Soil depth on average   | very deep (> 120 cm)                        |
| Soil texture (topsoil)  | medium (loamy, silty)<br>fine/ heavy (clay) |
| Topsoil organic matter  | medium (1-3%)                               |
| Soil texture (> 20 cm below surface)  | medium (loamy, silty)<br>fine/ heavy (clay) |
| Water   |   |
| Water supply for the land on which the technology is applied  | full irrigation                             |
| Groundwater table   | 5 - 50 m                                    |
| Availability of surface water   | medium (e.g. not available year-round)      |
| Water quality (untreated)   | for agricultural use only                   |
| Water quality refers to   | both ground and surface water               |
| Salinity  | is a problem                                |
| Biodiversity  |   |
| Species diversity   | low   |
| Habitat diversity   | low   |
| <b>Further information</b>  |   |
| <p>Plant biodiversity is currently limited to weed species due to intensive management practices on the studied farms. Nearby areas showcase a variety of plant communities, including meadows, garrigues, and oak forests. To address these issues, we propose introducing green infrastructures that are rich in native plants, specifically adapted to the region's climatic conditions.</p> |   |



Within the REACT4MED project, the research team of CIHEAM collaborated with several family businesses to optimise water retention to improve water availability on the farms. The restoration action aims to improve soil water-holding capacity by focusing on organic agricultural production and integrated crop management. Through organic farming practices, soil organic matter is increased, enhancing water retention. Integrating native species into the farming system increases resilience for pests and diseases. The ultimate goal is to transition from traditional cultivation systems to organic farming while promoting biodiversity conservation within agricultural production.

### **In practice: The example of the Diomede family in the Consortium Stornara and Tara**

The Marinella farm, owned by the Diomede family, is managed by two young agricultural entrepreneurs who cultivate table grapes. With their strong belief in organic farming, they chose table grape varieties that have a lower water demand and at the same time respond to the growing demand in high-quality grapes.

In the area of Stornara and Tara, most farmers are members of the consortium that manages their water supply. The consortium also serves as an institutional hub for coordinating action and decision-making with the Apulia region local Government and research institutions. Dr. Giovanni Merlino, Director of the consortium, supported the REACT4MED project with his place-based knowledge and facilitated collaboration with local farmers.

### **Organic farming and integrated crop management: Implementation steps**

Effective management should treat the vineyard as an agro-ecosystem, where all resources are used efficiently to support a diverse range of plant species. To address the limited water availability, integrated crop management and a shift towards organic production are viable restoration actions.

Both management options require information about how the farming system can be supported through natural means. For that, substantial knowledge of natural processes is essential and requires a high willingness to learn. Establishing contact with farmers already using organic methods is crucial in the initial stages. Furthermore, engaging with farm advisors and organic farming networks facilitates the transition and provides a valuable support system for addressing any questions or challenges.

Once the knowledge base is built, the most appropriate practices should be tested on a small scale to ensure their suitability for local conditions. Following successful trials and the design of a management plan, the entire farm can be converted.



Bare soil in table grape production increases soil erosion and water evaporation

### **Benefits of organic farming and integrated crop management**

Organic viticulture emphasises environmentally friendly practices to support a balanced ecosystem, which includes a diversity of fauna, flora, plant species, and microorganisms. This approach contrasts with conventional viticulture, which relies on synthetic pesticides to maintain balance in monoculture systems, such as vineyards dominated by table grapes.

Organic farming methods help reduce the use of approved pesticides and enhance soil health by applying mulches, cover crops, organic enrichments, and cultivation techniques. These practices improve soil structure, foster beneficial interactions among soil components, and contribute to long-term productivity. The Marinella farm exemplifies this effort, employing measures such as minimal tillage, high-quality fertilisers, and efficient irrigation management.



Farmer Mr. Diomede (left) and researcher Pandi Zdruli

## Key benefits of the restoration action include:

- Improved ecosystem health and reduced reliance on synthetic inputs through biodiversity conservation, mitigating the domination of single species.
- Enhanced soil health through improved soil structures, water retention and nutrient cycling.
- Increased market value for organically grown produce, providing economic advantages to farmers.

The included measures (see table) not only support environmental sustainability but also provide a model for responsible agricultural practices in vineyard management.

| Measure  | Benefit   |
|--|---|
| <b>Reducing soil-turning activities</b>  | Maintains the natural soil structure and leads to increased water retention.                                      |
| <b>Enhancing plant diversity by planting local aromatic and medicinal plants along field edges</b>                   | Reduces harmful pathogens and avoids chemical inputs to the farm. This, in turn, lowers the risk of salinisation. |
| <b>Abstinence from mineral fertilisers</b>   | Lowers the risk of salinisation.  |
| <b>Using compost and manure as fertilisers</b>   | Increases soil organic matter and water retention. Lowers the risk of salinisation.                               |
| <b>Covering bare soils by intercropping or mulching</b>  | Decreases evaporation. Increases soil organic matter, water retention and overall soil health.                    |
| <b>Preventing excessive water accumulation in the fields through the adoption of canalisations and well recovery</b> | Lowers the risk of salinisation.  |

## Contact

Practitioners interested in the restoration action can contact the Diomede farm with the help of the Consortium of Stornara and Tara (Director: Dr. Giovanni Merlino)

Consorzio di Bonifica Stornara e Tara. Viale Magna Grecia 240, 74121 – Taranto.  
Tel. (+39) 099 7357111.  
e-mail: [consorzio@bonificastornaratara.it](mailto:consorzio@bonificastornaratara.it).  
Sito web: <http://www.bonificastornaratara.it/>

Azienda Diomede.  
<https://www.instagram.com/marinellafrutta/>  
Istituto Agronomico Mediterraneo di Bari.  
<https://www.iamb.it/>.  
Via Ceglie 9, 70010 Valenzano (Bari).  
e-mail: [iamdir@iamb.it](mailto:iamdir@iamb.it)

## Further information

<https://feder.bio/>

<https://www.regione.puglia.it/web/osservatorio-agricoltura-biologica/linee-guida>

<https://www.agricolturaorganica.org/>

## 2.2. Effective drainage and improvement practice



**Case:** Lower Gediz River Basin, Türkiye

### Restoration action category:

Irrigation management, water diversion and drainage, surface water management

### Measures included:

- Design of drainage system adapted to field slope and soil
- Change in management: crop rotation, improved irrigation/drainage schedule

### Description of technology

Installation of a subsurface drainage system, application of leaching water, and introduction of crop rotation on agricultural land in the lower Gediz River Basin to reduce soil salinity and waterlogging. This restoration action improves soil and crop health and increases yields, rehabilitating salinity-affected degraded land.

### Main purposes

- Improve production
- Prevent, reduce land degradation; rehabilitate land
- Create beneficial economic impact
- Reduce risk of disasters
- Adapt to climate change

### Main benefits

- Soil restoration and improvement
- Increased agricultural productivity
- Improved water management
- Reduced risk of crop loss due to floods and excessive soil moisture

## Agriculture in a changing climate

In Türkiye's Mediterranean region, future climate scenarios point to hotter, drier summers and increased variability in rainfall. These shifts could intensify salinisation and reduce freshwater availability, especially in lowland agricultural zones. At the same time, demographic changes and moderate economic growth are anticipated, influencing land use patterns and water demand. For farmers, these trends mean a pressing need to improve drainage systems, manage salinity, and explore drought-resilient crop options.

### The pilot area in the lower Gediz River Basin: A profile

The Menemen Plain experiences a Mediterranean climate, with hot, dry summers and mild, rainy winters. Total annual precipitation is 531 mm, with half of its amount occurring in winter and only 3 percent in summer.

The average temperature is 16°C, and the average relative humidity is 57 percent. Humidity peaks in December and reaches its lowest levels in July. The Menemen district lies downstream of the Gediz River, where the main agricultural challenges are soil salinity and alkalinity, caused by irrigation practices and saltwater intrusion. Most farmers in the area grow cotton. However, none have yet been able to successfully implement measures to combat soil degradation.

A key issue is the absence of an effective drainage system, which would remove water before it evaporates and leaves salts behind. Responsibility for drainage infrastructure lies with the Department of Agriculture. To address alkalinity, some farmers have applied gypsum, with limited success.

| Climate  |                                  |
|--|----------------------------------|
| <b>Annual rainfall</b>   | 501-750 mm                       |
| <b>Reference meteorological station</b>  | UTAEM Meteorological Station     |
| <b>Agro-climatic zone</b>  | sub-humid semi-arid              |
| <b>Topography</b>  |                                  |
| <b>Slopes on average</b>   | flat (0-2%)                      |
| <b>Landforms</b>   | plateau/ plains<br>valley floors |
| <b>Altitudinal zone</b>  | < 100 m asl                      |
| <b>The technology is specifically applied in</b>   | not relevant                     |
| Soils  |                                  |
| <b>Soil depth on average</b>   | very deep (> 120 cm)             |
| <b>Soil texture (topsoil)</b>  | medium (loamy, silty)            |
| <b>Topsoil organic matter</b>  | medium (1-3%)<br>low (<1%)       |
| <b>Soil texture (&gt; 20 cm below surface)</b>   | medium (loamy, silty)            |
| Water  |                                  |
| <b>Water supply for the land on which the technology is applied</b>  | full irrigation                  |
| <b>Groundwater table</b>   | < 5 m                            |
| <b>Availability of surface water</b>   | good (e.g. available year-round) |
| <b>Water quality (untreated)</b>   | for agricultural use only        |
| <b>Water quality refers to</b>   | surface water                    |
| <b>Salinity</b>  | is a problem                     |
| <b>Further information</b>   |                                  |
| Seasonal fluctuations in both surface and groundwater levels occur due to irrigation practices and rainfall variability. Main sources of pollution are agricultural runoff and return flow from irrigation, leading to increased salinity in surface and groundwater. Flooding may happen episodically after heavy irrigation or rainfall, especially when drainage is insufficient.   |                                  |
| Biodiversity   |                                  |
| <b>Species diversity</b>   | low                              |
| <b>Habitat diversity</b>   | low                              |
| <b>Further information</b>   |                                  |
| Species and habitat diversity in the demonstration field are low due to intensive agricultural use and monocropping. Natural vegetation is almost absent, with the land mainly planted with crops such as cotton or tomato. Occasional field margins and irrigation ditches may support some weedy or ruderal plant species, but overall biodiversity is well below the regional average for natural or semi-natural habitats. |                                  |



## In practice: The example of Mehmet

Mehmet is a dedicated farmer from Menemen, Izmir. On 30 hectares of arable land, he cultivates wheat, cotton, corn, peas, melons, and tomatoes. For three generations, his family has relied on farming, facing persistent challenges due to the region's arid climate and saline coastal soils. Mehmet's family farm is a small to medium-sized business, but he distinguishes himself through his openness to new ideas and enthusiasm for research. Since the 1980s, Mehmet has worked to restore unproductive land for agriculture. Always seeking innovation, he collaborates with UTAEM in the React4Med project, serving as a role model for fellow farmers.

## Effective drainage and improvement practices: Implementation steps

To implement this restoration action elsewhere, the first step is to assess the severity of soil salinity and identify areas with inadequate drainage. Flat landscapes with a high groundwater level or proximity to the sea are particularly at risk. Installing a subsurface drainage system is essential to remove excess salts and lower the groundwater level. After drainage is established, washing the soil with high-quality water is necessary to leach accumulated salts.

Next, incorporate well-composted farmyard manure to rebuild organic matter and improve soil structure. This supports microbial activity and enhances nutrient availability. In the following years, the introduction of a drip irrigation system is recommended to deliver water precisely to the root zone, preventing further salt accumulation and reducing water use.

Ongoing maintenance includes regular inspection of drainage functionality, avoidance of over-irrigation, and annual application of organic matter to sustain improvements. Success depends on careful monitoring, farmer engagement, and adaptation to local conditions such as soil texture, water availability, and crop selection.

## Benefits

This restoration action provides multiple short- and long-term benefits for both farmers and the environment. In the short term, the installation of proper drainage systems and application of soil improvers such as well-composted manure immediately enhance soil aeration, reduce salinity, and increase crop productivity. Improved irrigation efficiency through drip systems also lowers water use and input costs.

In the long term, the build-up of soil organic matter leads to better soil structure, higher water retention, and increased resilience to drought.



Farmer Mehmet on his field.

Reduced dependence on chemical fertilisers supports healthier soils and limits environmental pollution. For land users, these improvements mean more stable yields and a more sustainable farming system.

Ecologically, restoring soil health supports biodiversity, particularly beneficial soil organisms and pollinators. Cleaner water drainage improves water quality in nearby ecosystems. The combined improvements promote sustainable land use, preserve landscape aesthetics, and open the door to future opportunities like agritourism. This restoration approach contributes to climate resilience and long-term food security in Mediterranean farming systems.



A view of the installation process of a subsurface drainage system using specialised machinery. The yellow drainage trencher is laying perforated pipes underground to improve soil conditions and prevent waterlogging and salinity problems in the field.

## Contact

**Name:** Dr. Funda Kidođlu

**E-Mail:** funda.kidoglu@tarimorman.gov.tr

**Name:** Dr. Perihan Tarı Akap

**E-Mail:** perihan.akap@utaem.gov.tr

International Agricultural Research  
and Training Center (UTAEM),

**Address:** Camikebir Mah. Maltepe Yolu

No: 27/1 Menemen-İzmir/Türkiye.

## Further information

*Information about training programs, ongoing research, and agricultural innovation support in Türkiye.*

<https://www.utaem.gov.tr>

*Information on available agricultural subsidies and soil improvement supports in Türkiye. Tarım ve Orman Bakanlığı – Tarımsal Desteklemeler:*

<https://www.tarimorman.gov.tr/Konular/Tarimsal-Desteklemeler>



A section of the field before the restoration activities, displaying uneven plant growth due to soil salinity

## 2.3 Restoring salt-affected agricultural lands



**Case:** Tamia, Fayoum, Egypt

### Restoration action category:

Integrated soil fertility management, improved plant varieties, water diversion and drainage

### Measures included:

- Monitoring and analysis of soil
- Change in management: adapted varieties, organic fertilisation, mulching, improved drainage

### Description of technology

The restoration action takes a comprehensive approach to tackling soil salinisation, including assessment of soil and water quality, installation of drainage systems, selection of salt-tolerant crops, use of organic and biofertilisers, mulching, and active farmer involvement. These measures aim to improve soil health, boost crop productivity, and promote sustainable land use under saline conditions.

### Main purposes

- Improve production
- Prevent, reduce land degradation; rehabilitate land

### Main benefits

- Enhanced crop performance under saline conditions
- Improved soil structure and organic content
- Improved water retention and drought resistance
- Improved water quality through cleaner drainage

## Agriculture in a changing climate

Egypt's Nile Delta is expected to experience compounded pressures from rising temperatures, reduced precipitation, and sea level rise, all threatening agricultural productivity and soil quality. Intensified salinisation and water scarcity will pose significant risks for smallholders. Coupled with rapid population growth and urbanisation, the competition for land and water resources will increase sharply. This calls for more efficient irrigation, drainage infrastructure, and integrated land use strategies to safeguard agricultural livelihoods.

### The pilot area in Tamia in Fayoum: A profile

The Fayoum governorate, situated approximately 90 kilometres southwest of Cairo, Egypt, is a geographically unique and increasingly important agricultural region. This large depression occupies a portion of the Eocene limestone plateau, marking the northern edge of the western desert. Fayoum's agricultural lands hold significant economic and environmental value, effectively extending the fertile environment of the Nile River – both in terms of soil formation and water resources. However, this delicate ecosystem, shaped by the interplay between the Nile and the surrounding desert, is facing increasing pressures.

Intensive agricultural practices, coupled with several contributing factors, are leading to the degradation of both soil and water quality within the Fayoum depression. The alluvial aquifer is under considerable stress from agricultural runoff, the widespread use of agrochemicals (fertilisers and pesticides), and the disposal of wastewater. Specifically, issues like mismanagement of agricultural inputs, the practice of reusing drainage water for irrigation, improper wastewater disposal, and a lack of comprehensive land use planning all contribute to this degradation.

This is particularly evident in the Tamia area, covering approximately 344.4 km<sup>2</sup>, where a recent assessment revealed a widespread issue of soil salinity. Analysis indicates that Electrical Conductivity (ECe) levels in Tamia soils range from 1.22 to 22.4 dS m<sup>-1</sup>, with a staggering 91.5 percent of soils exhibiting ECe levels exceeding 4 dS m<sup>-1</sup>. This confirms that salt-affected soils are prevalent throughout the region.

Further complicating matters, approximately 94.5 percent of Tamia soils are calcareous – containing over 10 percent calcium carbonate (CaCO<sub>3</sub>) – due to the underlying geological parent material. A small but significant portion of soils (3.25 percent) have a pH above 8.00, and nearly 4 percent have a



Description of the problem situation

organic matter content remains consistently low, seldom exceeding 1 percent, further diminishing soil health. Soil texture varies, ranging from clay to sandy, but is generally classified as sandy-loam.

These factors – salinisation, alkalinisation, high calcium carbonate content, low organic matter, inadequate drainage, a high groundwater level, and the resulting root-zone salinity – collectively represent the key constraints to sustainable agriculture in Tamia, severely limiting crop production. The widespread practice of irrigating with a mixture of Nile water and agricultural drainage water exacerbates these problems.

## Restoring salt-affected agricultural lands: Implementation steps

In the Tamia District, a combination of measures needs to be implemented in order to counteract the ongoing salinisation of agricultural soils and to increase overall productivity:

1. Characterisation of the soil and water quality, where different samples from the soil and water are analysed to determine the present state of the soil. This provides insights into the soil's texture and structure, as well as its water-holding capacity.
2. Dealing with soil salinisation, the installation and proper maintenance of a functioning subsurface drainage system is paramount to leach accumulated salts from the soil and to prevent salt built-up.
3. Selecting appropriate crops is crucial: Specifically, salt-tolerant varieties and genotypes that can grow economically under soil salinity conditions and are suitable for the pilot area. Suitable crops are for example sugar beet, Napier grass, sunflower, barley, sorghum and wheat that can be cultivated in different seasons to increase the soil productivity and profitability.
4. The application of organic and biofertilisers can increase the tolerance of the cultivated crops to the saline water. Added during soil preparation and cultivation, organic and biofertilisers improve the soil texture, microbial activity, aeration and soil minerals content as well as their availability. Increasing the tolerance of the cultivated crops to the saline conditions can yield a higher productivity.
5. Mulching: Organic mulches can suppress annual weeds and offer important benefits, such as organic matter, nutrients, moisture conservation, soil protection, and moderation of soil temperature. Hay, straw, and cover crops are among the most versatile and widely used organic mulches. They can suppress weed germination and emergence when applied at reasonable rates, are easy to apply and reduce evaporative losses of soil moisture.
6. Diligent monitoring and active involvement of farmers is required to respond to the conditions on site and steadily improve the quality of the soil.

### Benefits

The described restoration action delivers several benefits to both farmers and the local ecosystem. Installing appropriate subsurface drainage systems helps leach accumulated salts from the soil, reducing salinity levels and improving soil aeration.

This, combined with the use of salt-tolerant crops and genotypes, enhances plant resilience to saline conditions and abiotic stress, leading to improved crop performance and higher short-term productivity.

The application of organic and biofertilisers during soil preparation and cultivation improves soil structure, increases organic matter, enhances microbial activity, and boosts the availability of soil nutrients. These changes contribute to better water retention and increased drought resistance. Organic mulching further supports these outcomes by conserving soil moisture, suppressing weeds, and moderating soil temperature.

Cleaner drainage water resulting from appropriate water management improves the quality of water entering surrounding ecosystems. Together, these measures support more sustainable land use and contribute to long-term productivity and resilience in Mediterranean farming systems.

### Contact

**Prof. Dr. Elsayed Elhabbasha,**

Professor at NRC and the scientific consultant of Participatory Development Solution EIMahrousa PDS, Egypt, sayedhabasha@yahoo.com.

**Dr. Ahmed Faris, Associate**

Professor at NRC, and the scientific consultant of Participatory Development Solution EIMahrousa PDS, Egypt, ahmedfaris30@yahoo.com

## 2.4 Revitalising olive orchards: The impact of chipped pruned branches in Mediterranean groves and vineyards



**Case:** Valencia, La Costera and La Safor districts, Spain

### Restoration action category:

Improved ground/ vegetation cover, ecosystem-based disaster risk reduction

### Measures included:

- Soil cover
- Soil fertility
- Change in management: No tillage

### Description of technology:

Chipped branches from pruning in plantations are used as mulch to cover the soil surface instead of burning them. This alternative management technique

### Main purposes

- avoid or reduce land degradation; restore degraded land
- improve biodiversity
- reduce risk of disasters (droughts, floods, landslides and fires)
- adapt to climate change (resilience to droughts, heavy rainfall events)
- mitigate climate change and its impacts

### Main benefits

- Reduces surface runoff and protects from erosive rainfall
- Improves soil qualities (organic matter, aggregate stability, water infiltration, moisture retention, biodiversity)
- Moderates summer temperatures
- Decreases management costs
- Adapted to legal fire restrictions
- Enhanced aesthetic and cultural value of the landscape
- Creates habitats

## Agriculture in a changing climate

Southern Spain faces escalating challenges from climate change, particularly higher temperatures, reduced precipitation, and greater drought frequency. These stressors will exacerbate soil erosion and threaten the viability of dryland farming systems. Economic trends suggest a dual movement of rural decline and tourism-driven

growth, which may shift priorities away from traditional land uses. Farmers will need to adopt erosion control measures and diversify income sources to remain resilient.

| Climate   |   |
|---|---|
| <b>Annual rainfall</b>  | 600-350 mm  |
| <b>Specifications on rainfall</b>                                   | Mediterranean, drought in summer  |
| <b>Name of the reference meteorological station</b>                 | Moixent, Font de la Figuera Xativa, Canals; Montesa   |
| <b>Specifications/ comments on climate:</b>                         | 16-12 °C average annual temperature   |
| <b>Agro-climatic zone</b>   | sub-humid<br>semi-arid  |
| <b>Thermal climate class</b>  | temperate (Transition zone between semi-arid and sub-humid)   |
| Topography  |   |
| <b>Slopes on average</b>  | applied on all slopes   |
| <b>Landforms</b>  | applied on all landforms  |
| <b>Altitudinal zone</b>   | 101-500 m asl<br>500-1,000 m asl  |
| <b>The technology is specifically applied in</b>                    | convex situations (ridge – diversion of water flow)<br>concave situations (depression – conversion of water flow) |
| Soils   |   |
| <b>Soil depth on average</b>  | very shallow (0-20 cm)<br>shallow (21-50 cm)  |
| <b>Soil texture (topsoil)</b>                                       | coarse/ light (sandy)<br>medium (loamy, silty)  |
| <b>Topsoil organic matter</b>                                       | medium (1-3%)<br>low (< 1%)   |
| <b>Soil texture (&gt; 20 cm below surface)</b>                      | coarse/ light (sandy)<br>medium (loamy, silty)  |
| <b>Soil types</b>   | Cambisols, Luvisols, Terra Rosa, Litosols   |
| Water   |   |
| <b>Water supply for the land on which the technology is applied</b> | rainfed<br>drip irrigation  |
| <b>Groundwater table</b>  | 5-50 m<br>> 50 m  |
| <b>Availability of surface water</b>                                | poor/ none  |
| <b>Water quality (untreated)</b>                                    | for agricultural use only   |
| <b>Water quality refers to</b>                                      | surface water   |
| <b>Salinity</b>   | increased due to irrigation   |
| <b>Flooding of the area</b>   | occurs episodically   |
| <b>Biodiversity</b>   |   |
| <b>Species diversity</b>  | high  |
| <b>Habitat diversity</b>  | high  |
| Further information   |   |
| High biodiversity due to mosaic-type landscape                      |   |

## The pilot area in the Canyoles River Basin: A profile

The Canyoles River Basin is situated in the region of Valencia, Spain. Over the past thirty years, a shift from a traditional Mediterranean rainfed agriculture to mechanised production of citrus and persimmon coupled with drip irrigation and the application of herbicides led to a critical degradation of the soils. Soil compaction increased and soil erosion and runoff were enhanced by the uncovered soils. At the same time, the increased water demand and use of wells for the drip irrigation has resulted in aquifer depletion. Furthermore, the traditional agriculture terraces were removed, resulting in larger fields on slopes with bare soils which additionally exacerbated soil erosion. Already, climate change affects the seasonal distribution of the rainfall. More frequent heavy precipitation events further add to current soil erosion rates.



The soils in many orchards are uncovered. Exposing the soils to the impact of erosive climate conditions.

Nestled in the upper reaches of the Canyoles River watershed, the municipality of Font de la Figuera sits at an elevation of 588 m asl (38.80°N, 0.88°W) and basks in a Mediterranean dry climate. The region receives an average annual rainfall of just 432 mm and has a potential evapotranspiration rate of 1350 mm/year, thus, this semi-arid region presents unique challenges for agriculture. During the year, temperatures in Font de la Figuera average around 14 °C, with July and August bringing summer highs of 25 °C, while January sees cooler winter lows of about 8.5 °C. A long summer drought lasting approximately four months, combined with frequent drought periods, adds to the challenges faced by local farmers striving for productivity. While irrigation might seem to be a viable solution, the threats of salinisation and groundwater depletion make it essential to explore alternative water management strategies.

The technique of applying chipped pruned branches as mulch has proven effective in enhancing soil water availability. The application case described here comprises over 1,000 sites

evenly spread over an area of about 100 km<sup>2</sup>. Mulching with chipped pruned branches was introduced through recent land users' innovation and research activities. In 2023, new experimental areas were implemented, while others exist since 1993. The agricultural landscape is a mix of large properties, typically used for cereals and vineyards, and smaller farms with olive, almond, and vineyard plantations.



The Asensi family in their orchard

## In practice: The example of the Asensi family

In the sun-drenched fields of Font de la Figuera in the València Province of Eastern Spain, the Asensi family is forging a new chapter in sustainable agriculture. Manuel Asensi and his son Manel manage a sprawling estate with 51 hectares of olive plantations and 202 hectares of cereals and sunflowers, cultivated on land belonging to family and friends. Without their unwavering commitment, these agricultural fields might have fallen into neglect.

Both are full-time farmers specialising in rainfed agriculture, producing premium organic olive oil without the use of irrigation. Over the past 30 years, they have planted more than 12,000 trees, primarily olives, as well as hedgerows with forest and fruit trees to enhance local biodiversity. Manuel began farming 40 years ago, amid the aftermath of intensive chemical farming that had left the soils degraded and weary. Faced with challenges like over-ploughing, soil crusting, and a stark lack of organic matter, he set out on a path to soil restoration. Today, these same soils have transformed into a lively ecosystem. Innovative practices such as mulching with chipped pruned branches, incorporating weeds and catch crops, and applying manure - while maintaining a pesticide-free approach - have continuously revitalised the local traditional Mediterranean mosaic landscape.



Tractor chopping the tree branches.

The family's agricultural success is closely tied to the forward-thinking ideas of Gabriel Asensi, the, 94-year-old grandfather. Manuel Asensi introduced modern practices such as catch crops, cover crops, and mulching with pruned branches, all while carefully integrating mechanisation and continuous improvements on the farm. His insightful guidance, combined with his father's innovative spirit, has created a farming legacy for Manel, the eager 24-year-old heir to the Asensi farming tradition. Through their collective efforts, they have shifted land management practices, turning once-degraded land into a thriving ecosystem that flourishes under rainfed conditions. For the Asensi family, incorporating chipped pruned branches is only one part of a broader initiative to develop sustainable olive oil production under the guidance of the "La Viña" cooperative. Producing organic olive oil has not only supported environmental goals but also earned premium prices, contributing to the economic success of their agricultural practices.

Today, the agricultural landscape supports not only profitable olive production, but also a picturesque blend of cereals, sunflowers, vineyards, almonds, and patches of Aleppo pine forest. Together, these elements form a scenic and biodiverse traditional Mediterranean landscape, demonstrating the Asensi family's commitment to sustain both their heritage and the land they cherish.

### **Applying chipped pruned branches: Implementation steps**

The use of chipped pruned branches in rainfed olive plantations requires a tractor equipped with chipping machinery. After pruning, the cut branches are collected in the spaces between the rows of olive trees, forming a line. The tractor then processes the branches, typically requiring two passes to effectively chop them.

This method is well suited to rainfed agricultural systems, where the low tree density and open spaces between rows provide sufficient room for the machinery to operate.

The resulting mulch incorporates litter from weeds, catch crops, cover crops, and the leaves

and branches of the olive trees, contributing to soil health and moisture retention. Chipping usually occurs after the pruning season in winter, and farmers have the flexibility to chop the branches either immediately or weeks later. This allows them to manage the timing of the operation efficiently.

Traditionally, cut branches used to be burnt in order to prevent pests and maintain a bare soil appearance, which many considered to be more aesthetic. However, rising labour costs for burning, the dependence on specific weather conditions as well as municipal restrictions against open fires (to prevent wildfires) rendered this approach unviable. Initially, one challenge for mulching with chipped pruned branches were the costs of the machinery. Nowadays, subsidies for acquiring such equipment have significantly reduced the financial burden, making this strategy more accessible.

### **Benefits**

Using chipped pruned branches as mulch offers numerous benefits for sustainable agriculture. As a nature-based solution, it imitates natural processes, such as the formation of a litter layer found in forest soils. It adds organic matter to the soil, provides habitats for microorganisms, moderates soil summer peak temperatures, and enhances soil moisture retention. The mulch layer improves infiltration rates, reduces surface runoff and soil erosion, and fosters soil biodiversity by supporting soil biota.

Chipped pruned branches play a critical role in restoring agricultural soils and ecosystems in the Valencia region but also in other semi-arid regions in the Mediterranean. Beyond soil health, these practices benefit local wildlife, providing improved habitats for birds, rodents, amphibians, insects, reptiles, and especially bees. They also enhance the aesthetic and cultural value of the landscape, reviving the beauty of traditional rainfed agricultural land cultivated since Roman times. This restored landscape has additionally fostered recreational activities, including agritourism, further integrating sustainability with economic and cultural development.

## Contact

**Name:** Artemi Cerdà  
Address: Universidad de Valencia, Blasco Ibàñez 28,  
46010 Valencia Spain  
**E-Mail:** [artemio.cerda@uv.es](mailto:artemio.cerda@uv.es)  
<https://twitter.com/ArtemioCerdà>  
[linkedin.com/in/artemi-cerdà-b52943267](https://www.linkedin.com/in/artemi-cerdà-b52943267)

Artemi Cerdà is on  
Facebook @artemi cerda  
<https://www.facebook.com/artemi.cerda>  
tik tok @artemicerda  
bluesky @artemi.cerda.bsky.social

**Name:** Manuel Asensi  
**E-Mail:** [llomalta@gmail.com](mailto:llomalta@gmail.com)  
Manuel Asensi is on  
**Instagram:** llomalta and eco.asensi  
**Facebook:** Manuel Asensi

## Further information

Soil erosion and degradation research group:  
<https://soilerosion.eu/>  
**SEDERero contact:** <https://x.com/SEDERero/>

**Videos:**  
<https://x.com/SEDERero/status/1902905153390272892>  
[https://www.apuntmedia.es/noticies/societat/artemi-cerda-l-abandonament-massiu-mon-rural-duent-als-incendis-vivint\\_1\\_1538200.html](https://www.apuntmedia.es/noticies/societat/artemi-cerda-l-abandonament-massiu-mon-rural-duent-als-incendis-vivint_1_1538200.html)

*Cerdà, A., Rodrigo-Comino, J., Giménez-Morera, A., & Keesstra, S. D. (2017). An economic, perception and biophysical approach to the use of oat straw as mulch in Mediterranean rainfed agriculture land. Ecological Engineering, 108, 162-171.*

*Cerdà, A., Rodrigo-Comino, J., Giménez-Morera, A., Novara, A., Pulido, M., Kapović-Solomun, M., & Keesstra, S. D. (2018). Policies can help to apply successful strategies to control soil and water losses. The case of chipped pruned branches (CPB) in Mediterranean citrus plantations. Land use policy, 75, 734-745.*

*Cerdà, A., González-Pelayo, Ó., Giménez-Morera, A., Jordán, A., Pereira, P., Novara, A., ... & Ritsema, C. J. (2016). Use of barley straw residues to avoid high erosion and runoff rates on persimmon plantations in Eastern Spain under low frequency-high magnitude simulated rainfall events. Soil Research, 54(2), 154-165.*

*Keesstra, S. D., Rodrigo-Comino, J., Novara, A., Giménez-Morera, A., Pulido, M., Di Prima, S., & Cerdà, A. (2019). Straw mulch as a sustainable solution to decrease runoff and erosion in glyphosate-treated clementine plantations in Eastern Spain. An assessment using rainfall simulation experiments. Catena, 174, 95-103.*



## 2.5 Grounded in heritage, growing for the future: Agricultural mountain terraces with drystone retention walls



**Case:** Troodos Mountains, Cyprus

### Restoration action category:

Cross-slope measure

### Measures included:

- Terraces

### Description of technology

Establishment and restoration of agricultural drystone terraces in mountainous regions involves repairing and maintaining drystone walls to fulfil their agro-ecological and hydrological functions, i.e., to prevent soil erosion, retain soil moisture, and support sustainable agriculture on steep mountain slopes. This technology is critical in Mediterranean mountain areas, including the Troodos Mountains in Cyprus, where it helps in land conservation and agricultural productivity.

### Main purposes:

- prevent or reduce land degradation;
- restore/rehabilitate land (reverse land degradation) (soil, water, vegetation)

### Main benefits

- Provide arable land
- Reduce soil erosion and surface runoff
- Increased agricultural productivity
- Improved water management

### Agriculture in a changing climate

Cyprus is projected to warm considerably, with rainfall becoming even more erratic and concentrated in short periods. These changes increase the risk of both drought and flash flooding. Water availability for irrigation will become less reliable, especially in upland agricultural areas.

At the same time, land abandonment and urban sprawl are expected to alter land use dynamics. Traditional water-saving techniques and landscape restoration approaches will be key to adapting effectively.



Collapsing drystone wall

| Climate   |   |
|---|---|
| <b>Annual rainfall</b>  | 500 - 750 mm  |
| <b>Specifications on rainfall</b>   | main rainfall season: October to May  |
| <b>Further information</b>  |   |
| Subtropics (< 1000 m asl) – temperate (> 1000 m asl)  |   |
| Troodos experiences a wide range of temperatures, from daily averages as low as -2°C in the winter months at the highest altitudes to peaks of 32°C during summer at lower elevations.  |   |
| <b>Agro-climatic zone</b>   | sub-humid<br>semi-arid  |
| Topography  |   |
| <b>Slopes on average</b>  | hilly (16-30%)<br>steep (31-60%)  |
| <b>Landforms</b>  | mountain slopes<br>hill slopes  |
| <b>Altitudinal zone</b>   | 501 - 1000 m asl<br>1001 - 1500 m asl   |
| <b>Soils</b>  |   |
| <b>Soil depth on average</b>  | shallow (21-50 cm)<br>moderately deep (51-80 cm)  |
| <b>Soil texture (topsoil)</b>   | coarse/ light (sandy)<br>medium (loamy, silty)  |
| <b>Topsoil organic matter</b>   | high (> 3%)<br>medium (1-3%)  |
| <b>Soil texture (&gt; 20 cm below surface)</b>  | coarse/ light (sandy)<br>medium (loamy, silty)  |
| <b>Further information</b>  |   |
| Soil carbonate is rare on the Ophiolite lithologies of the Troodos mountains, pH values of the top 25 cm soil mainly range between 5.0 and 8.0 in a diversity of land cover units (Cohen et al., 2012) and soils are dominated by coarse (> 2 mm) fragments (Camera et al., 2017).  |   |
| Water   |   |
| <b>Water supply for the land on which the technology is applied</b>   | mixed rainfed-irrigated:<br>traditional vineyards were rainfed; new vineyards are equipped with irrigation systems and grapes are irrigated at critical growth stages |
| <b>Groundwater table</b>  | > 50 m  |
| <b>Availability of surface water</b>  | medium (e.g. not available year-round)  |
| <b>Water quality (untreated)</b>  | good drinking water   |
| <b>Water quality refers to</b>  | both ground and surface water   |
| Biodiversity  |   |
| <b>Species diversity</b>  | medium  |
| <b>Habitat diversity</b>  | medium  |
| <b>Further information</b>  |   |
| The Troodos Mountains, especially the Troodos National Forest Park, span 9,147 hectares and host around 750 plant species, including 12 endemics, alongside notable fauna like the Griffon Vulture, Bonelli's Eagle, Cyprus Warbler, and Cyprus mouflon. Its varied habitats and geology make it vital for biodiversity conservation in Cyprus. |   |





### The pilot area in the Troodos Mountains: A profile

With an average slope of 31 percent, agriculture in the Troodos Mountain region typically relies on drystone terraces. Farmers produce grapes, apples, cherries, peaches and nuts (e. g. almonds and hazelnuts) and, to a lesser extent, citrus and olive. Cyprus' agriculture is challenged by an ageing farm population, with an average farmer age of 59 years. Due to small farm sizes (around three hectare), land fragmentation also poses a challenge. The ageing farming population and land fragmentation are more profound in the Troodos Mountains than in the plain. The remaining farmers are unable to maintain production on existing farmland, leading to widespread abandonment of fields. Owing to the lack of maintenance, soil erosion and degradation of abandoned drystone terraces can be observed throughout the mountains, sometimes leading to the complete collapse of once productive hillsides. A recent development is the use of diggers and bulldozers to construct new terraces in many areas in the Troodos Mountains. This new technique is not regulated and the absence of guidelines for designing sustainable terrace slopes sometimes results in costly construction and maintenance as well as increased costs for agricultural production. In some cases, the mechanised construction of terraces leads to adverse environmental impacts. As a consequence, despite the fact that drystone constructions are on the list of Intangible Heritage recognised by UNESCO, current developments lead to soil erosion and the loss of traditional knowledge.

### In practice: Reviving the slopes of the Troodos Mountains

Drystone terraces are applied throughout the Troodos Mountains, characterised by steep slopes and a semi-arid climate with seasonal rainfall ranging from 500 to 750 mm per year. They reflect the area's agricultural heritage and exemplify a well-adapted nature-based solution.

However, the Troodos Mountains face the critical issue of agricultural abandonment, highlighted by a sharp decline in cultivated land in recent decades, driven by urbanisation and high farming costs. Consequently, many mountain terraces have been abandoned, and drystone walls remain unmaintained, sometimes causing a domino effect of collapsing terraces. The abandonment of terraced plots also implies a gradual loss of the indigenous and intangible knowledge regarding the construction and maintenance of drystone walls. Despite these socioeconomic challenges, drystone terraces remain a vital part of the landscape, reflecting a long-standing tradition of sustainable land management. Over the past decade, there is a gradual, renewed interest in terrace farming especially for wine grape production. Unlike traditional drystone terraces, modern terraces established by wineries are built using heavy machinery. They tend to cover large, uniform parts of slopes. In addition, drystone walls are often constructed by winery workers that may lack the expertise required, and consequently the walls are prone to collapsing after intense rainfall events. These new practices are currently the research focus of the Cyprus Institute research team as part of PRIMA-REACT4MED project, especially the hydrological and structural stability characteristics.

The primary purpose of the drystone terraces is to mitigate soil erosion, enhance soil moisture retention, and create viable agricultural land on steep slopes. At the same time, these terraces serve secondary purposes, such as conserving the cultural heritage of the local communities, supporting biodiversity by creating habitats for various species, and maintaining the productive capacity of the soil.



Victoras Finoloulos

Victoras Finopoulos is a passionate winemaker and vineyard manager in the high Marathasa valley of the Troodos Mountains, Cyprus. On steep, south-facing terraced slopes, supported by newly developed and traditional drystone retention walls, he is patiently establishing modern vineyards and awakening old ones that once flourished. After first discovering wine as a child in Hungary, Victoras trained in Agronomy, Viticulture and Oenology in Montpellier and Bordeaux, before working on harvests in Alentejo (Portugal), Chablis (France) and Marlborough (New Zealand). Today he manages the Marathasa Wines vineyards, growing mostly indigenous varieties such as Xynisteri and Maratheftiko alongside carefully chosen international grapes. His guiding principles are constant sensory contact with the wine, the terraced land and the vines; regular tasting of the wine and multiple visits to the same terraces throughout the day to understand how vines respond to varying conditions – from morning dew, midday heat and cool mountain nights. This hands-on approach informs low-input practices that conserve scarce water and sustain the vines in stony soils. His broader vision is to enhance soil health and stability in newly developed terraced vineyards by following different agro-ecological practices. Other than maintaining the drystone walls, he has been applying cover cropping and chopped vine prunings to improve soil health, prevent soil erosion and retain water in the terraced vineyards.

### **Agricultural mountain terraces with drystone retention walls: Implementation steps**

The establishment and restoration of agricultural terraces with drystone walls is a technology applied in many mountain regions, including the Troodos Mountains of Cyprus. This involves the construction and maintenance of terraces supported by walls built with natural stones arranged without the use of any mortar. The basic principles of establishing terraces with drystone walls are similar across the region, while the exact size and form of terraces and walls are determined by site-specific characteristics; slope, elevation, geology (type of available stones as construction material), soils, crop type, etc. These terraces are essential for creating arable land on steep mountain slopes, reducing soil erosion, and retaining soil moisture, thus supporting sustainable agricultural practices in mountain environments.

Establishing and maintaining these terraces involves several major activities and inputs. The key activities include land levelling, foundation preparation, stone collection and transfer, and the actual construction of the stone walls. These activities are typically carried out in early autumn or late spring. Manual labour is the main input, making the process very costly. Based on the latest (2024) estimates, the establishment of drystone terraces per square metre ranges between €64.29/m<sup>2</sup> (for plots < 500 m asl) and €107.97/m<sup>2</sup>

(for plots ≥ 800 m asl and slope gradient ≥30°).

The main characteristics of this technology include the use of locally sourced rocks, typically gabbro and diabase, to construct drystone walls that support the agricultural terraces. The terraces are built along contour lines to form nearly level platforms, which vary in width from 1 to 3 metres for narrow terraces to 3 to 6 metres for medium-base terraces, while the height ranges from 0.75 to 2 metres. Occasionally, terraces can be wider (e.g., 20 metres in gentler slopes) and higher (i.e., more than 2 metres in steep slopes), depending on the slope's steepness and morphology. The construction process involves careful selection and placement of stones: large, irregular stones are used for the foundations, while more regular stones form the walls. Smaller stones are inserted between the larger stones to enhance the structure's stability, while long and relatively flat stones are used at the upper end of the walls, i.e. what locals call the "crown" of drystone walls. The walls are built with a slight inward incline to ensure stability and facilitate water drainage through the structure.

Land users and farm managers often cite the high labour and maintenance costs as significant disadvantages. Community-based approaches have been promoted, encouraging collective efforts in terrace maintenance. Skill development and professional training of younger mountain farmers, farm workers and terrace builders is lacking and needs to be provided by agricultural extension services and technical schools in collaboration with drystone experts, geo-engineers and landscape architects.

### **Benefits**

The benefits of this technology are multifaceted. Environmentally, the terraces significantly reduce soil erosion and surface runoff, improve soil moisture retention, and enhance sediment retention. This leads to increased agricultural productivity and improved water management. Socioeconomically, they provide vital arable land to sustain farm income and crop yields. Culturally, the terraces preserve a part of the local heritage and landscape aesthetics; in the past, this practice was used to foster community engagement in sustainable land management practices.



Construction of drystone walls



## Contact

Contact person of the research team of The Cyprus Institute

**Name:** Christos Zoumides

**E-Mail:** c.zoumides@cyi.ac.cy

Contact person in the Marathasa valley of the Troodos Mountains

**Name:** Victoras Finopoulos

**E-Mail:** foinos@mail.com **Further information**  
*Manual for the construction of mountain drystone terraces in Cyprus (in Greek):* [https://3pro-troodos.cyi.ac.cy/images/deliverables/D2.3c\\_ManualDrystoneTerraces.pdf](https://3pro-troodos.cyi.ac.cy/images/deliverables/D2.3c_ManualDrystoneTerraces.pdf)

*Information on available agricultural subsidy schemes under Cyprus' Common Agricultural Policy Strategic Plan 2023-2027:* <http://www.cap.gov.cy/moa/cap/cap.nsf/home/home?openform>

*Scientific publications related to agricultural mountain terraces in Troodos, Cyprus:*

Camera, C., Djuma, H., Bruggeman, A., Zoumides, C., Eliades, M., Charalambous, K., Abate, D. and Faka, M., 2018. Quantifying the effectiveness of mountain terraces on soil erosion protection with sediment traps and dry-stone wall laser scans. *Catena*, 171, pp.251-264. DOI: <https://doi.org/10.1016/j.catena.2018.07.017>

Camera, C., Gentile, M., Djuma, H., Zoumides, C., Keleshis, C., Papageorgiou, A., Constantinides, C., Leonidou, A., Faka, M. and Bruggeman, A. (2024). Setting Up an Infinite Slope Stability Analysis on a High-Resolution DEM (0.21× 0.21 m2) of a Mechanically Terraced Slope in Cyprus. In: Çiner, A., et al. *Recent Research on Sedimentology, Stratigraphy, Paleontology, Geochemistry, Volcanology, Tectonics, and Petroleum Geology*. MedGU 2022. *Advances in Science, Technology & Innovation*. Springer, Cham. DOI: [https://doi.org/10.1007/978-3-031-48758-3\\_76](https://doi.org/10.1007/978-3-031-48758-3_76)

Djuma, H., Bruggeman, A., Zissimos, A., Christoforou, I., Eliades, M. and Zoumides, C. (2020). The effect of agricultural abandonment and mountain terrace degradation on soil organic carbon in a Mediterranean landscape. *Catena*, 195, p.104741. DOI: <https://doi.org/10.1016/j.catena.2020.104741>

Djuma, H., Bruggeman, A., Camera, C. and Zoumides, C. (2017). Combining qualitative and quantitative methods for soil erosion assessments: an application in a sloping Mediterranean watershed, Cyprus. *Land Degradation & Development*, 28(1), pp.243-254. DOI: <https://doi.org/10.1002/ldr.2571>

Zoumides, C., Bruggeman, A., Giannakis, E., and Kyriakou, N. (2022). A future for mountain terraces: experiences from Mediterranean wineries. *Mountain Research and Development*, 42(3):R35-R49. DOI: <https://doi.org/10.1659/MRD-JOURNAL-D-21-00031.1>

Zoumides, C., Bruggeman, A., Giannakis, E., Camera, C., Djuma, H., Eliades, M. and Charalambous, K. (2017). Community - Based Rehabilitation of Mountain Terraces in Cyprus. *Land Degradation & Development*, 28(1), pp. 95-105. DOI: <https://doi.org/10.1002/ldr.2586>

*Tradition meets the future: Conservation agriculture for healthy soils and healthy livelihoods*

## 2.6. Tradition meets the future: Conservation agriculture for healthy soils and healthy livelihoods



**Case:** Zaer, Morocco

### Restoration action category:

improved ground/ vegetation cover, minimal soil disturbance

### Measures included:

- Soil surface treatment
- Change of management: no-till

### Description of technology

Morocco's current climatic conditions significantly impact the management of water resources and soil fertility in agriculture, posing challenges for lands that are degraded or at risk of degradation. In response, the Green Generation 2020-2030 national agricultural program emphasises the expansion of direct seeding techniques. This approach aims to enhance soil conservation, improve water efficiency, and support sustainable agricultural practices amidst increasing environmental pressures.

### Main purposes:

- prevent or reduce land degradation;
- restore/rehabilitate land (reverse land degradation) (soil, water, vegetation)

## Agriculture in a changing climate

In Morocco's Mediterranean coastal zone, farmers are likely to face more frequent heatwaves, reduced rainfall, and prolonged dry periods. These climatic changes, paired with rapid population growth and land fragmentation, could reduce agricultural

viability and exacerbate rural poverty. Future projections highlight the need for soil conservation, water harvesting, and the revival of agro-silvopastoral systems to build long-term resilience and retain youth in rural areas.



Field which has not been tilled and were plant residue is left as a ground cover.

| Climate   |  |
|---|--|
| <b>Annual rainfall</b>  | < 250 mm<br>251 – 500 mm<br>Unstable precipitation   |
| <b>Reference meteorological station</b>   | INRA's station   |
| <b>Agro-climatic zone</b>   | The climate is semi-arid, with a Mediterranean-type rainfall regime that is characterised by a dry summer and a rainy winter. The average rainfall over 40 years was 394 mm, with a maximum of 665 mm and a minimum of 181 mm. |
| Topography  |  |
| <b>Slopes on average</b>  | moderate (6-10%)   |
| <b>Landforms</b>  | plateau / plains   |
| <b>Altitudinal zone</b>   | 101 - 500 m asl  |
| <b>The technology is specifically applied in</b>  | concave situations (depression – conversion of water flow)   |
| Soils   |  |
| <b>Soil depth on average</b>  | moderately deep (51-80 cm)<br>deep (81-120 cm)   |
| <b>Soil texture (topsoil)</b>   | fine/ heavy (clay)   |
| <b>Topsoil organic matter</b>   | medium (1-3%)  |
| <b>Soil texture (&gt; 20 cm below surface)</b>  | fine/ heavy (clay)   |
| Further information   |  |
| Soils in the region are generally low in organic matter and have varying levels of essential nutrients like nitrogen, phosphorus and potassium. The soil of Merchouch experimental station is a vertisol with possible external drainage, hydromorphic (Aque Chromoxerert). |  |
| Water   |  |
| <b>Availability of surface water</b>  | poor / none<br>The region relies on rainfed agriculture.   |
| <b>Water quality (untreated)</b>  | for agricultural use only  |
| <b>Water quality refers to</b>  | both ground and surface water  |
| Biodiversity  |  |
| <b>Species diversity</b>  | medium   |
| <b>Habitat diversity</b>  | medium   |
| Further information   |  |
| The direct seeding strategic plan integrates habitat preservation, agricultural productivity, and resource sustainability, fostering long-term soil conservation and resilience.  |  |

## The pilot area in the Zaër region: A profile

Morocco's agricultural sector relies heavily on its 9.2 million hectares of arable land, with around 65 percent dedicated to cereal cultivation. However, a growing population, limited availability of arable land, and soil degradation are placing increasing pressure on the country's food systems. Intensive agricultural practices, especially conventional tillage, have led to problems such as soil erosion, water and soil pollution, and desertification. Additionally, climate change further worsens these issues by reducing the availability of rainwater in arid and semi-arid regions.

The Zaër region, with its plateau landscape and irrigation from the Bouregreg River and its tributary, the Grou River, is well suited for cereal and food legume production. At the same time, the region's sloped topography is particularly vulnerable to drought and soil erosion, making effective soil and water conservation practices essential.

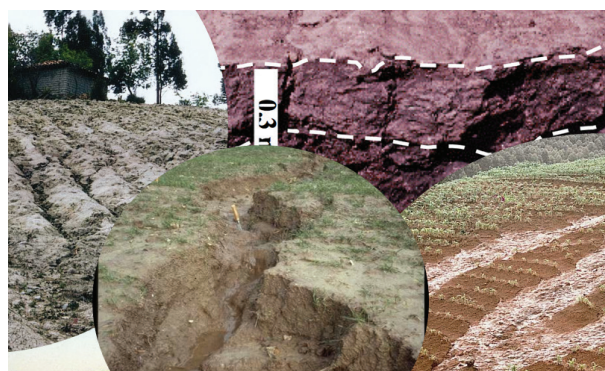
Conservation Agriculture is pivotal in mitigating the effects of extreme events such as drought and heat stresses. Research demonstrates that Conservation Agriculture can increase and stabilise food production for Morocco's growing population. Accordingly, it is a key component of Morocco's national agricultural strategies, such as the "Generation Green 2020-2030" strategy, which aims to promote direct seeding on one million hectares by 2030.

Conservation Agriculture is based on three key principles:

- (1) maximising crop diversity (crop rotation with diversified crop species),
- (2) minimising soil disturbance (no-till systems with direct seeding),
- (3) and keeping soil cover through crop residue management (e.g., using straw as mulch)).

To facilitate the implementation of Conservation Agriculture, the National Institute of Agronomic Research in Morocco (INRA) developed a No-Till Technology system, combining direct seeding with crop residue management.

Conservation agriculture: Implementation steps  
At the core of the No-Till Technology is a specialised no-till drill that simultaneously seeds and fertilises annual crops. This machine carefully cuts through existing crop residues, opens a 20 cm wide slot, places the seeds and N/P fertilisers, and reseals the soil to ensure optimal seed-soil contact. Row spacing can be adjusted to suit different crops – 20 cm for wheat and barley, and 40 cm for lentils and chickpeas. By avoiding ploughing, harrowing, and other aggressive tillage methods, soil disturbance is minimised, protecting its natural structure. In fact, minimising disturbance and maintaining a protective mulch cover mimics natural processes, creating healthier, more resilient, and productive agricultural systems.



Signs of soil degradation in the Zaër region

Common rotations in the region, such as leguminous crops (lentils, chickpeas) with cereals (soft wheat, durum wheat), are readily integrated into Conservation Agriculture systems.

Other wheat crop rotations include barley and fodder species, with fallow periods. Rather than tillage, farmers are using special herbicides to control weeds, allowing for an 18-month fallow period (a 'chemical fallow') following two crop cycles. Fallowing is essential for water conservation in this semi-arid area.

The no-till drill ensures minimal soil disturbance and precise phosphate fertilisation. Residue management varies depending on the site, ranging from low residue maintenance (stubble with controlled grazing) to medium surface cover (stubble/straw maintenance, forage crops with exclusion of grazing). Key outcomes include reduced erosion and evaporation, improved water retention, lower runoff, and enhanced infiltration. While herbicides are used for weed control, they can be reduced over time, focusing on environmental sustainability. Maintaining crop residues in the fields increases soil organic matter, enhances carbon stored, and boosts nutrient levels, potentially reducing the need for inorganic fertilisers.

| Activity  | Timing (season)               |
|---|-------------------------------|
| <b>1. Stubble maintenance (no grazing, only partial straw removal)</b>  | After harvest / annually      |
| <b>2. Direct seeding + fertiliser (N/P) banding using no-till drill</b> | Early November annually       |
| <b>3. Chemical weed control</b>   | Dec/Jan annually              |
| <b>4. Nitrogen fertilisation</b>  | March annually                |
| <b>5. Harvest</b>   | May, after 6 months/ annually |
| <b>6. 18-month fallow period (with herbicide application if needed)</b> |                               |

Implementing No-Till Technology effectively requires a few key resources:

- Regular monitoring with farmers to ensure sustainable adoption.
- Delimitation tools, such as GPS, for precise land management.
- Rapid soil and crop analysis equipment to assess productivity.
- Adapted direct seeding equipment tailored to local farming needs.
- Training provided by institutions like INRA, ICARDA, and agricultural offices.

A significant challenge is balancing the need for crop residues as soil cover with the needs of livestock. Integrating direct seeding systems with livestock requires careful planning and targeted strategies.

## Benefits

Adoption in regions like Zaër demonstrates significant economic advantages, with cost savings of 90-120 Euros per hectare and profit margin increases exceeding 55 percent. Long-term studies confirm that Conservation Agriculture can maintain and improve crop yields, providing greater stability for farmers. Enhanced soil biological activity ensures long-term soil fertility and health, supported by research linking no-till practices to increased soil carbon sequestration. Direct seeding offers operational advantages including enhanced work efficiency, reduced labour costs, and lower fuel consumption through minimised tillage. Farmers consistently report reduced costs, improved yields, and effective soil conservation.

Environmentally, direct seeding promotes efficient water use, increases infiltration, reduces water loss, and mitigates erosion. Maintaining soil cover protects against rainfall impact and fosters pest-resistant crop varieties.

To maximise these benefits, it is essential to:

1. Keep soils covered with residues during planting and seeding to ensure sufficient soil moisture
2. Use appropriate equipment and inputs to maintain soil quality and prevent erosion
3. Control biomass removal and manage grazing to promote soil health

Conservation Agriculture represents a vital, sustainable approach to agriculture, enhancing the resilience of Moroccan farming systems in a changing climate. Continued focus on integrated crop and pest management is crucial to fully leverage these benefits. Supporting the wider adoption through ongoing research and the Department of Agriculture's Roadmap will ensure long-term success for both farmers and the environment, promoting sustainable and climate-resilient agricultural practices across Morocco. Reduction of machinery passes and diligent residue management ensure higher yields, lower costs, and the conservation of precious water resources.

## Contact

Dr. Rachid Mrabet & Dr. Rachid Moussadek  
(INRA Rabat, Morocco)  
rachid.mrabet@inra.ma  
rachid.moussadek@inra.ma

## Further information

Mrabet, R., H. Bahri, O. Zaghouane, H. Chiekh M'hamed, S. R. M. El-Areed & M. M. Abou El-Enin. 2022. Chapter 6: Adoption and spread of Conservation Agriculture in North Africa. In: Kassam, A. (ed). *Advances in Conservation Agriculture. Volume 3: Adoption and Spread*. Burleigh Dodds, Cambridge, UK. ISBN: 978-1786764751.

Moussadek, R., Laghrou, M., Kadiri, K., & Mrabet, R. (2024). Conservation agriculture in Morocco: review and analysis for the resilience of the cereal system on 1 million hectares by 2030. *African and Mediterranean Agricultural Journal - Al Awamia*, (143), 263–279.  
<https://doi.org/10.34874/IMIST.PRSM/afirmed-i143.48378>

Moussadek, R., Laghrou, M., Mrabet, R. & Van Ranst, E. (2023). Crop Yields under Climate Variability and No-Tillage System in Dry Areas of Morocco. *Ecological Engineering & Environmental Technology*. 24(1):221-232.  
<https://doi.org/10.12912/27197050/155024>

Moussadek, R., Laghrou M., Mrabet, R., Thami Alami I. & Mekkaoui, M. (2023). Mid and long term effects of Conservation Agriculture on soil organic matter, physical properties and biological activity in rainfed Mediterranean Soils. In: Basch et al. (eds.). 2023.

*Book of Extended Abstracts of the 8th World Congress on Conservation Agriculture*. Bern (Switzerland), June 21-25, 2021.

European Conservation Agriculture Federation (ECAAF). Brussels, Belgium. Pp:133-139.

El Mekkaoui, A., Moussadek, R., Mrabet, R., Douaik, A., El Haddadi, R., Bouhlal, O., Elomari, M., Ganoudi, M., Zouahri, A. & Chakiri, S. (2023). Effects of Tillage Systems on the Physical Properties of Soils in a Semi-Arid Region of Morocco. *Agriculture* 2023, 13, 683.  
<https://doi.org/10.3390/agriculture13030683>.

Bamouh, A., Azizi, I. & Srour, M. (2020). Productivity, profitability and farmer's adoption potential of direct seeding of lentils in Zaer region (Morocco). *Mor. J. Agri. Sci.* 1(4): 181-185.

Laamouri, A. & Khattabi, A. (2025). Estimating the Economic Cost of Land Degradation and Desertification in Morocco. *Land* 14, 837.  
<https://doi.org/10.3390/land14040837>

## 2.7. Diverse yields: Agroforestry to protect soils and livelihoods



**Case:** Crete, Greece

### Restoration action category:

improved ground/ vegetation cover, minimal soil disturbance

Restoration action category: natural and semi-natural forest management, agroforestry, pastoralism and grazing land management

### Measures included:

- Tree and shrub cover
- Walls, barriers, palisades, fences

### Description of technology

*Ceratonia siliqua* (carob) is established in grazing areas, transitioning the land into agro-pastoral systems after successful establishment. This restoration action enhances ecosystem health by stabilising soil, increasing biodiversity, offering fire resistance and market diversification

### Main purposes:

- Improve production
- Prevent, reduce land degradation; restore/rehabilitate land

## Agriculture in a changing climate

Crete is expected to see rising average temperatures, more frequent droughts, and declining rainfall, particularly during critical growing periods. These conditions will place pressure on water resources and contribute to soil degradation and wildfire risk. Demographic decline in rural areas and economic

concentration in tourism will also affect farming communities. Strengthening agroforestry systems and improving water efficiency will be essential for climate-smart land use on the island.





Kostas Karatzis



| Climate  |  |
|--|--|
| Annual rainfall  | 251-500 mm                                     |
| Average annual temperature                                   | 17°C to 20°C                                   |
| Reference meteorological station                             | Neve Yaa'r meteorological station              |
| Agro-climatic zone   | sub-humid                                      |
| Topography   |  |
| Landforms  | plateau/ plains                                |
| Altitudinal zone   | 501-1,000                                      |
| Soils  |  |
| Soil depth on average  | moderately deep (51-80 cm)<br>deep (81-120 cm) |
| Soil texture (topsoil)                                       | medium (loamy, silty)                          |
| Topsoil organic matter                                       | medium (1-3%)                                  |
| Soil texture (> 20 cm below surface)                         | medium (loamy, silty)<br>fine/ heavy (clay)    |
| Water supply for the land on which the technology is applied | roomfed  |
| Groundwater table  | > 50 m   |
| Availability of surface water                                | medium (e.g. not available year-round)         |
| Water quality (untreated)                                    | for agricultural use only                      |
| Water quality refers to                                      | surface water                                  |
| Biodiversity   |  |
| Species diversity  | high   |
| Habitat diversity  | high   |

## The pilot area in Heraklion: A profile

In the past, the European Common Agriculture Policy supported an adequate income for farmers on Crete through structural policies, contributing to regional economic development, particularly in less favoured areas. However, these very subsidies also accelerated the agricultural intensification and specialisation, which in turn led to increasing degradation of agricultural soils. Production became export-oriented and homogenised, resulting in the loss of the island's self-sufficiency in products such as cereals, fruits, and vegetables. The rising market value of animal products further incentivised free-range livestock farming. Statistical figures for some of the mountainous communities show an increase of the total number of sheep and goats by over 200 percent between 1980 and 1990. The ecological impact of the introduction of domestic grazers on native species on Mediterranean islands since prehistoric times has been well documented.

Since the 1950s, large-scale migration from rural to urban areas took place, while the rural land was over-exploited by the few remaining farmers. Today, the rural population continues to decline, even though Crete's total population, especially around Heraklion, has grown significantly over the past four decades, increasing the pressure to convert agricultural land into residential or industrial areas.

In the Melidochori Area, the effects of overgrazing are particularly evident, disrupting the agricultural system and limiting its potential. The region has a sub-humid climate, with an average annual rainfall of 690 mm and average temperatures of 17.5°C. For about seven months each year, temperatures range from 5°C to 18°C, contributing to a subtropical climate.

### In practice: The example of Kostas Karatzis

Kostas Karatzis co-owns Karatzis Estate, a 50-hectare silvopastoral farm in Melidochori. Since 1995, he and his team have planted over 10,000 trees, including broadleaf, carob, mulberry, pine, cypress, and others like walnut and fig. This chin land use has revitalised degraded land affected by drought and overgrazing, turning it into a thriving ecosystem, rich in biodiversity.

The restored landscape now supports improved grazing through nuanced soil stability, enables new business opportunities through the production of new crops like carob, and serves as a model of sustainable land management for the local community. Though Kosta's financial resources are similar to those of his peers, his practical knowledge and strong engagement in community projects make him a local leader and role model.

### Agroforestry: Implementation steps

A stand of *Ceratonia siliqua* (carob trees) is planted

in grazing areas, typically in a six-metre grid. Initial structural measures are required, mostly related to preparing slopes and soil for sapling planting and establishing irrigation infrastructure. A protective fence must be maintained for the first 10 years to prevent livestock from damaging young trees. During the first three years, the two-year-old saplings are actively managed. This includes watering, fertilisation and replacement of dead or weak trees. Once established, intensive irrigation is no longer needed and grazing can resume with minimal restrictions.

The main drawback of this technology is a temporary reduction in livestock and other crop yields during the first decade of application until trees are mature.

### Benefits

Silvopastoral systems offer significant environmental and economic benefits to land users, especially for grazing systems. They do not only combat land degradation but also promote soil health and local biodiversity. In particular, carob trees provide:

- Fodder from carob pods and cuttings for livestock
- Shade during hot summer months
- Increase in soil stability, organic matter content and water retention

The economic benefits extend beyond grazing. Carob can be utilised to create alternative income sources, such as carob honey and flour, serving as a viable business diversification strategy for farmers. Their moisture-rich trunks also make carob trees resistant to wildfires.

Aside from agricultural benefits, silvopastoral practices maintain high habitat quality for local wildlife, including birds and bees, enriching biodiversity. Native to the Mediterranean, *Ceratonia siliqua* blends well into the rugged agro-pastoral landscapes of the Mediterranean islands. The enhanced natural beauty of the landscape, coupled with ties to Cretan traditions, enrich the community's cultural and aesthetic values and make the area more attractive for agritourism and recreational activities.

## 2.8. Improving soils and biodiversity with food forests



**Case:** Bethlehem of Galilee, Israel

### Restoration action category:

Agroforestry

### Measures included:

- Change in land use type
- Change in management: Permaculture
- Layout according to natural and human environment

### Description of technology

A food forest embodies a restorative approach to land management, transforming degraded landscapes by utilising naturally occurring ground cover to preserve soil health and biodiversity while producing food. Established on previously degraded sites, such as the one initiated in 2017, food forests also serve as multifunctional spaces that provide diverse socio-cultural, environmental, and economic benefits.

### Main purposes

- prevent, reduce land degradation; restore/rehabilitate land
- preserve/ improve biodiversity
- mitigate climate change and its impacts

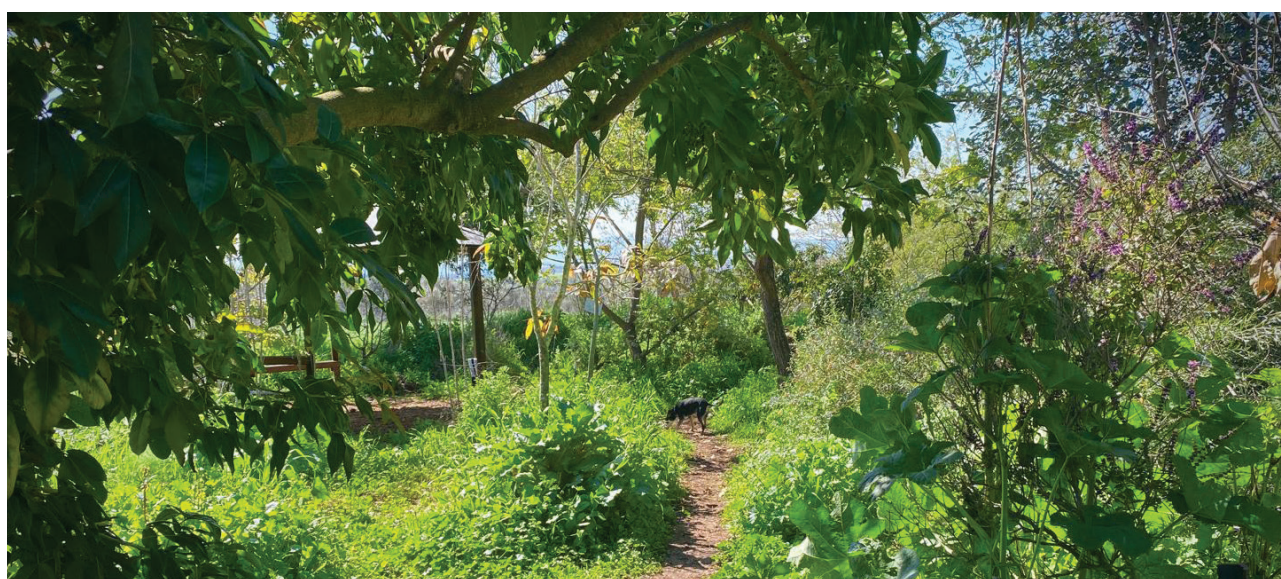
### Main benefits

- Sustainable food production
- Community strengthening and local resilience
- Biodiversity and ecosystem resilience
- Soil restoration and improvement
- Carbon sequestration and climate regulation

## Agriculture in a changing climate

Northern Israel is forecasted to experience rising temperatures and decreasing rainfall, contributing to water scarcity and heightened evaporation rates. These shifts are likely to stress irrigation systems and increase salinity risks. With urban

expansion and economic growth expected, land competition will intensify. For land users, integrating biodiversity-enhancing practices and efficient irrigation will be crucial to maintaining productivity and ecological health.



| Climate  |  |
|--|--|
| Annual rainfall  | 251-500 mm                                     |
| Average annual temperature                                   | 17°C to 20°C                                   |
| Reference meteorological station                             | Neve Yaa'r meteorological station              |
| Agro-climatic zone   | sub-humid                                      |
| Topography   |  |
| Slopes on average  | gentle (3-5%)                                  |
| Landforms  | plateau/ plains                                |
| Altitudinal zone   | 501-1,000                                      |
| Soils  |  |
| Soil depth on average  | moderately deep (51-80 cm)<br>deep (81-120 cm) |
| Soil texture (topsoil)                                       | medium (loamy, silty)                          |
| Topsoil organic matter                                       | medium (1-3%)                                  |
| Soil texture (> 20 cm below surface)                         | medium (loamy, silty)<br>fine/ heavy (clay)    |
| Water  |  |
| Water supply for the land on which the technology is applied | raomfed  |
| Groundwater table  | > 50 m   |
| Availability of surface water                                | medium (e.g. not available year-round)         |
| Water quality (untreated)                                    | for agricultural use only                      |
| Water quality refers to                                      | surface water                                  |
| Biodiversity   |  |
| Species diversity  | high   |
| Habitat diversity  | high   |



## The pilot area in Bethlehem of Galilee: A profile

Agriculture in Israel is a strongly developed, technology-oriented industry that produces both for domestic consumption as well as export. Since most Israelis, including the farmers, have served in the military, they are well trained in handling different technologies. Despite the presently increasing erosion of agricultural soils due to the intensive agriculture, the majority of farmers as well as the Ministry of Agriculture do not pay attention to soil health at the moment. The ministry's main focus is on research and farm support in the development and application of cutting-edge farm technologies. The lack of an explicit economic valuation of healthy soils, the short-term focus on profitability, the need for high productivity and a general lack of awareness for the various services that soils and biodiversity are providing are all reasons for the negligence of soil conservation practices in agriculture in Israel.

The food forest in Bethlehem of Galilee in Israel is a pioneering example of sustainable agricultural, drawing inspiration from the principles of permaculture and imitating services of natural forest ecosystems. Surrounded by hilly terrains in the Upper Galilee, the food forest integrates diverse edible plants, medicinal species, and ecological features like ponds and animal habitats. The food forest aims to revitalise degraded soils and enhance biodiversity, requiring minimal external inputs while developing self-sustaining ecosystems. Its design allows for versatility, making it suitable for various landscapes, whether as community spaces or educational hubs. Addressing local challenges such as water management and increasing ecological awareness, these projects play a crucial role in fostering sustainable livelihoods.

Over the last seven years, the owners carefully planned and worked to transform the wider landscape. This involved redesigning the topography, planting numerous trees, and introducing supporting plants. Their efforts required extensive planning and patience. Today, Bethlehem of Galilee food forest has evolved into an environmental and social business. Over 40 such projects have been established across both rural and urban areas in Israel, each contributing to a greener, more resilient environment. This plays a significant role in reversing land degradation and serves as an educational hub, promoting sustainable land and water management practices that benefit and improve the livelihoods of the local community in the long term.

### In practice: The example of Yuli and Nitzan Betzer

When Yuli and Nitzan Betzer moved back to Nitzan's hometown Bethlehem of Galilee in the Northern part of Israel, they wanted to create a project with a tangible environmental and social impact. They envisioned a place where nature and community flourished hand in hand.



Yuli and Nitzan Betzer, photo: Yuval Yanai, June 2023

The couple identified the potential in a degraded piece of land that once belonged to Nitzan's old family farm. They explored and experimented with various agricultural models ranging from low maintenance forest gardening to high maintenance regenerative agriculture. Ultimately, they decided to create a food forest based on permaculture principles, a balanced approach combining elements of agriculture with the natural ecosystem.

### Creating a food forest: Implementation steps

Creating a food forest begins with selecting a suitable location considering crucial factors such as soil quality, climate, and water availability. A thorough site assessment is essential to evaluate existing resources and limitations, including any major issues with degraded soil or water scarcity.



The team prepares the ground for the establishment of an ecological pond.

Once a suitable site is chosen, preparation becomes the next priority. This involves improving the soil through methods like working in compost or cover cropping to ensure it is nutrient-rich and fertile. Furthermore, implementing effective water management systems – such as swales for directing runoff or rainwater harvesting setups – sets the

foundation for a thriving micro ecosystem.

Choosing the right saplings and plants for a food forest - edible, medicinal, and ornamental species - requires careful consideration of their ecological compatibility and functions. Arranging the plants and designing the forest environment should mimic natural ecosystems and incorporate regenerative agriculture principles to create a balanced environment. This creative phase of development provides also an optimal stage to engage with the local community garnering support, fostering creative learning and ensuring long-term collaboration in the project. During the first three years, the primary focus should be on maintaining soil health, promoting biodiversity, and ensuring the survival of the planted species.

Additionally, they serve as educational and therapeutic spaces, strengthening community ties and local resilience. Besides the plentiful and diverse harvest, benefits include reducing the dependency on external resources, such as water, fertilisers, and energy, thanks to the ecosystem's self-sustaining nature. Additionally, permaculture systems including food forests create spaces for social engagement, recreation and education and fostering economic opportunities within local communities.

In the long term, food forests play a vital role in restoring degraded soils, improving water retention and enhancing biodiversity by creating stable, resilient ecosystems.



The couple regards the degraded soil in 2017 where the food forest will be established.

This involves regular watering, fertilising, and replacing any weak or struggling plants. To empower community members, educational programs on permaculture principles and maintenance techniques may be necessary.

Once established, the food forest will demand minimal intervention, as it will rely on self-sustaining processes. Ongoing maintenance will include routine observation, periodic pruning, monitoring plant health, and managing invasive species. Over time, the ecosystem will become more resilient to environmental challenges, such as droughts or pest invasions, while providing collective benefits to the community. Contextual factors, such as community needs, cultural practices, and available funding, should inform the design and implementation process. A context-sensitive approach allows food forest restoration actions to succeed across diverse environments, from rural to urban settings, enhancing local ecosystems while delivering long-term ecological and economic benefits.

### Benefits

The establishment of food forests provides a range of immediate and long-term benefits for both land users and the environment. For land users, food forests provide sustainable food production, medicinal plants, and economic opportunities through the sale of produce or ecotourism.

They contribute to carbon sequestration and climate regulation, offering significant ecological advantages.

Incorporating ponds, wildlife habitats, and diverse plant species enhances ecosystem functions, such as nutrient cycling, pollination, and habitat creation. These benefits align with sustainable agriculture and social well-being principles, positioning food forests as productive and restorative landscapes. Ultimately, food forests increase ecosystem resilience against challenges like droughts and pests while providing collective benefits to communities.

### Contact

Contact from the pilot area in Bethlehem of Galilee

Yuli Betzer:

E-mail: [yaaractivity@gmail.com](mailto:yaaractivity@gmail.com)

Phone number: +972-526901744

Contact from the research team:

Ghadir Zbedat:

E-mail: [Zbedat.g96@gmail.com](mailto:Zbedat.g96@gmail.com)

Prof. Anna Brook:

E-mail: [abrook@geo.haifa.ac.il](mailto:abrook@geo.haifa.ac.il)

*Further information*

<https://www.bethlehemfoodforest.com/>

### 3. Spreading the fruits of knowledge: Supporting informed land management with LanDS

LanDS is an online toolbox developed as part of the REACT4MED project, with input from researchers, local experts, and restoration practitioners across the Mediterranean. Its goal is to help scale up the successful land restoration actions that were tested in the Pilot Areas to other regions facing similar challenges.

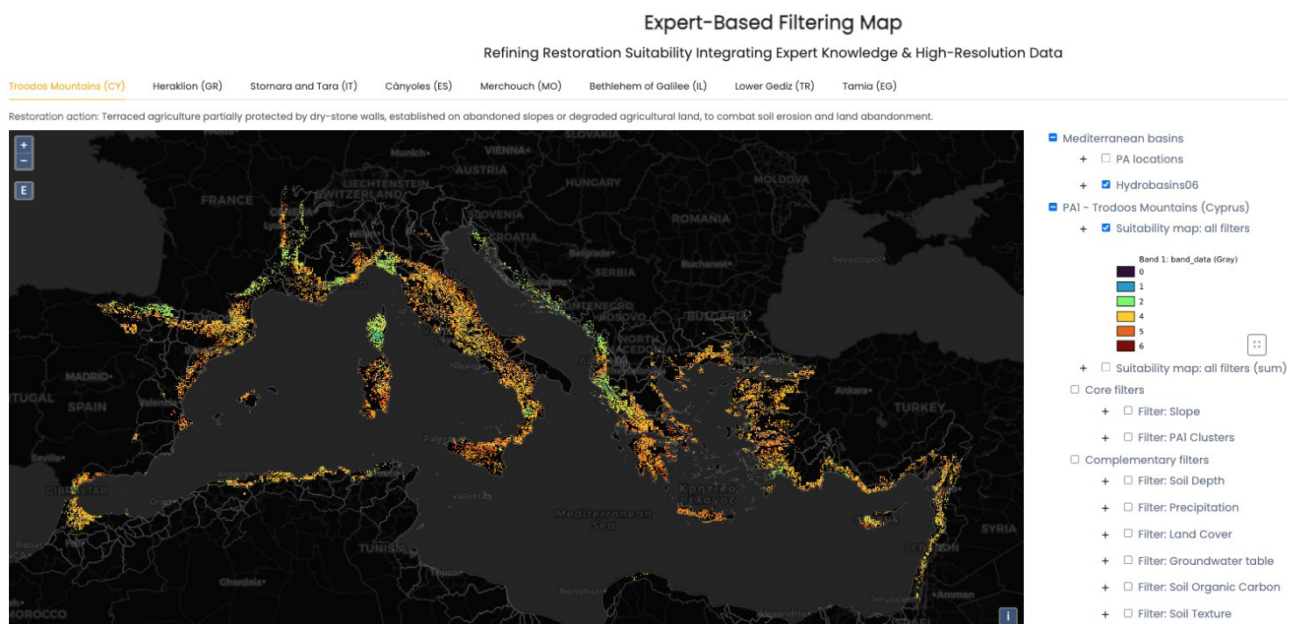
The platform is designed to support farm advisers, land managers, and policymakers. These users can access data and tools to assess land degradation risks, explore suitable restoration actions, and evaluate their potential impacts.

LanDS combines scientific data – such as soil, climate, and land use information – with on-the-ground experience from restoration projects. It offers maps and indicators to help identify which areas are most vulnerable to degradation and

where restoration is likely to be most effective. This helps decision-makers develop tailored, cost-effective strategies for sustainable land and water management.

An integrated monitoring tool within LanDS also allows users to upload local data and resources, enabling farm advisers and land managers to track the performance of the implemented restoration actions over time.

By bringing together local knowledge and broader environmental and socioeconomic information, LanDS supports context-sensitive, evidence-based decisions that are effective in the long term. The insights it offers can inform policies and strategies aimed at building more resilient and productive landscapes, ultimately benefiting farmers and rural communities across the Mediterranean.



Excerpt from the suitability map for potential upscaling and outscaling of terraced agriculture (restoration action in Cyprus) across the Mediterranean region, displayed in the “Expert-Based Filtering Map” of the LanDS dashboard. The interactive suitability map indicates areas in the Mediterranean where terraced agriculture could present a viable solution to restore agricultural soils. Based on climate, land, socioeconomic and local knowledge, the user can explore how suitable different areas are (from 0 = not suitable to 6 = highly suitable).



Suitability maps are available for all restoration actions tested in React4Med. To explore the LanDS toolbox and learn more, visit: <https://lands.soft-water.it>



### **Acknowledgments**

Project REACT4MED “Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean” is funded under Grant Agreement No. 2122 of PRIMA, the Partnership for Research and Innovation in the Mediterranean Area, a Programme supported by Horizon 2020, the European Union’s Framework Programme for Research and Innovation.

### **Special thanks to collaborators and stakeholders:**

**Victoras Finopoulos**, Marathasa Wines, Cyprus  
**Minas Mina**, Kyperounda Winery, Cyprus  
**Ektoras Tsiakkas**, Tsiakkas Winery, Cyprus  
**Apostolos Gregoriou**, Vlassides Winery, Cyprus  
**Panagiotis Dalias**, Agricultural Research Institute, Cyprus  
**Nikolina Kyriakou**, Department of Agriculture, Cyprus  
**Christos Theodorou**, ICOMOS-Cyprus, Cyprus  
**Antonia Theodosiou**, Environment Commissioner, Cyprus

### **Information on picture credits**

**Manuel Asensi**, Spain  
**Manel Asensi**, Spain  
**Pep Gimeno Botifarra**, Spain  
**Hilari Alonso**, Spain  
**Joan Moixino**, Spain  
**Pablo Calatayud**, Spain  
**Miguel Velázquez**, Spain  
**Paco Méndez**, Spain







Project REACT4MED “Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean” is funded under Grant Agreement No. 2122 of PRIMA, the Partnership for Research and Innovation in the Mediterranean Area, a Programme supported by Horizon 2020, the European Union’s Framework Programme for Research and Innovation.

