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Cooperating across borders in the Mediterranean

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REGIONE AUTONOMA DELLA SARDEGNA

LIVINGAGRO

SECOND B2B EVENT
Multifunctional Olive Systems

CATALOGUE OF INNOVATIONS

A COLLECTION OF INNOVATIONS

FOR THE SECOND B2B EVENT IN LEBANON

ON MULTIFUNCTIONAL OLIVE SYSTEMS

WP 2 OUTPUT 2.8 - ACTIVITY 2.8.1

LIVINGAGRO

Cross Border Living Laboratories for Agroforestry

ENI CBC Med Programme 2014 – 2020, first call for standard projects
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Project Summary

"LIVINGAGRO – Cross Border Living Laboratories for Agroforestry" is a project funded under the ENI CBC Med Programme 2014–2020, first call for standard projects, and refers to thematic objective A.2 "Support to education, research, technological development and innovation," priority A.2.1 "Technological transfer and commercialization of research results."

With a total budget of 3.3 million euros and a 2.9 million EU contribution through the ENI CBC Med Programme, the LIVINGAGRO project involves 6 organizations from 4 different countries (Italy, Greece, Lebanon and Jordan) and addresses the challenge of knowledge and technological transfer in Mediterranean agriculture and forestry systems for achieving and sharing good practices aimed at sustainable production, protecting biodiversity, enhancing transfer of innovation and increasing profitability for territories and main actors as well as stakeholders involved. Using an open innovation-oriented approach for co-creating economic and social values and interactions between supply and demand, eliminating geographical and cultural barriers, two Living Laboratories are being established focusing on multifunctional olive systems (LL 1) and grazed woodlands (LL 2).

Expected results

- ✓ Creation of two Laboratories (Living Labs) on the themes of multifunctional olive systems and grazed woodlands whose activation phases include the localization and identification of relevant stakeholders;
- ✓ Establishment of "Living Labs" through specific agreements between public and private entities;
- ✓ Development of the dedicated ICT platform;
- ✓ Creation of a public-private community which shall launch pilot actions aimed at experimentation;
- ✓ Signing of at least 4 research agreements between universities and research centers in collaboration with the economic operators of the project's partner countries;
- ✓ Organization of 20 field visits by research institutions to assess and identify companies' innovation needs;
- ✓ Cooperation between at least 8 companies and research organizations for the development of innovative activities and services;
- ✓ Activation of 6 courses related to the creation of innovative companies / startups;
- ✓ Creation of 10 corporate-scientific brokerage events in Jordan (4 B2B events), Lebanon (4 B2B events) and Crete (2 B2B events);
- ✓ Analysis and development of 10 new products / services for the agroforestry sector;
- ✓ Activation of 20 technology transfer and intellectual property brokerage services for companies, universities, research institutes and the general public.

Partnership

Beneficiary (LP):

Regional Forest Agency for Land and Environment of Sardinia (Fo.Re.S.T.A.S.), Italy

Partners (PPs):

PP 1: Italian National Research Council, Department of Biology, Agriculture and Food Science (CNR), Italy

PP 2: National Agricultural Research Center (NARC), Jordan

PP 3: Lebanese Agricultural Research Institute (LARI), Lebanon

PP 4: Mediterranean Agronomic Institute of Chania (MAICH), Greece

PP 5: ATM Consulting S.a.s. (ATM), Italy

Associated Partners (APs):

AP1: Autonomous Region of Sardinia, Dept. of Environment Defense

AP2: Autonomous Region of Sardinia, Dept. of Agriculture and Agro-pastoral Reform

AP3: Coldiretti Sardinia

AP4: Regional Association of Sardinian Breeders

AP5: The Lebanese University (Faculty of Agronomy, Beirut)

Project Duration

September 2019 – August 2023 (48 months)

INTRODUCTION

USING THE CATALOGUE

We want both senior and less experienced readers to be able to engage with the innovations featured here in order to assess whether these innovations are relevant to the local or global challenges facing them. The catalogue therefore assumes a certain level of understanding of olive growing, olive oil production, and livestock farming, but includes highly technical and scientific terms and notions only where this is essential for a basic understanding of the innovation. This is not a technical manual, but a catalogue intended to provide an overview of some of the innovations that may be useful to those involved with multifunctional olive systems in order to help bring together stakeholders and innovators who may be able to collaborate to solve common problems. Contact information is provided in order to facilitate networking.

ABOUT INNOVATIONS

The European Commission (EC) defines innovation in agriculture and forestry as "'a new idea that proves successful in practice.' In other words, the introduction of something new (or renewed, a novel change) which turns into an economic, social or environmental benefit for rural practice." It may be "technological, non-technological, organisational or social, and based on new or traditional practices. A new idea can be a new product, practice, service, production process or a new way of organising things, etc. Such a new idea turns into an innovation only if it is widely adopted and proves its usefulness in practice." LIVINGAGRO has gathered a wide range of innovations in this catalogue which project members believe will prove useful for those who work with multifunctional olive systems.

In 2015, European Commissioner Carlos Moedas established three central policy goals for EU research and innovation: open innovation, open science and open to the world. Open innovation, according to the European Commission, means "opening up the innovation process to people with experience in fields other than academia and science. By including more people in the innovation process, knowledge will circulate more freely." The LIVINGAGRO team invited numerous stakeholders to share their concerns about needs for innovation related to multifunctional olive systems then attempted to identify innovations related to those concerns, including innovations coming from nonscientists outside academia.

Open science, according to the EC, "focuses on spreading knowledge as soon as it is available using digital and collaborative technology." Along with LIVINGAGRO's ICT platform, website, Facebook page, B2B meetings, and other outreach efforts, this catalogue represents an effort to spread knowledge about innovations to the people who need them as soon as possible after project members identify the innovations. Open to the world "means promoting international cooperation in the research community," and LIVINGAGRO involves direct collaboration among four countries in the Mediterranean region, both in and beyond the European Union: Italy, Greece, Jordan, and Lebanon.

HOW WE CREATED THE CATALOGUE

Having identified potentially useful innovations, the partners of LIVINGAGRO suggested a template for innovators to complete. This included assessing the stage of readiness of a potential innovation, as well as which type of challenges it addresses. Taking into consideration the needs expressed by stakeholders, LARI's research team and technical team reviewed the information provided. Following this review, we went back to the innovators to address questions and fill in gaps, then incorporated the responses into the innovation descriptions.

SECTION 1: Olive Tree and Olive Oil Authentication

Whether determined through visually observable characteristics (phenotype), genes (genotype), or chemical analysis, olive variety and olive oil grade identification can be useful to nearly everyone who works with olives or olive oil, from producers and millers to researchers and consumers. Consumers and those who serve them, for example, are increasingly interested in learning about the exact type and origin of products, including the types of trees their olive products come from. Seeking high quality and anxious to avoid fraud, many prefer authentic, certified products.

Innovation 1: DNA-based diagnostic test to authenticate the varietal origin of olive oil

- **Background**

  Very rich in health benefits, olive oil has been a major part of the Mediterranean diet for millennia. Thanks to growing awareness of its nutritional value and flavor, as well as the globalization of food markets, olive oil is now widely distributed around the world. Unfortunately, its higher prices compared to vegetable oils make it especially disposed to fraudulent practices. This leads to concern about the quality and origin of olive oil. A variety of factors make it challenging to ascertain an oil's identity, since such variables as the climate, environment, agricultural practices, fruit ripeness, and extraction methods all affect the oil, in addition to the olive variety. We offer a new solution: a DNA-based diagnostic test for olive oil that conclusively identifies the variety of olives used to make premium monovarietal extra virgin olive oil.

- **Keywords**

  olive oil authentication, olive oil testing, olive oil analysis, monovarietal olive oil, olive oil authenticity, traceability control, olive oil traceability, monovarietal olive oil validation, SSR-HRM

- **Methodology**

  In a laboratory, DNA is extracted from a sample of olive oil and analyzed. A novel analytical technique for olive oil authentication and traceability control is used: high-resolution melting (HRM) DNA analysis with a real-time polymerase chain reaction (PCR). Molecular markers are used to distinguish monovarietal olive oils. This is a closed-tube approach involving a single reaction in the lab, which provides such advantages as speed, low cost, simplicity, sensitivity, and reliability. (See Find Out More below for scientific articles that provide details about this method.) The graph below is an HRM difference plot that shows three different melting profiles, one for each olive variety, allowing them to be conclusively distinguished from each other (Image 4):

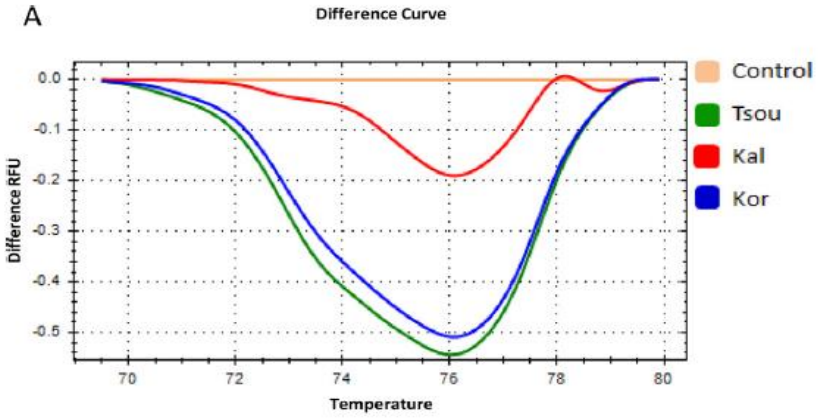

Image 1: a graph illustrating the difference between several olive oil varieties (by Panagiotis Kalaitzis)

- **Specifications**
  Specific molecular markers have to be selected and tested to discriminate and authenticate particular olive varieties. Therefore, a database of these markers is required to ensure reliable discrimination and validation. Such a database has been developed at the Mediterranean Agronomic Institute of Chania. Using this database, cultivar-specific diagnostic kits will be prepared to provide the appropriate markers for identification. A kit can be created to identify one olive variety or a number of different varieties.

- **Impact**
  There is great concern about the authenticity and traceability of high quality monovarietal extra virgin olive oil (EVOO) on the part of both consumers concerned about the authenticity of their high-priced EVOO and the people working in the olive oil sector who strive to make that EVOO and get it to consumers. Since a major part of authentication efforts concentrates on the identification of the varietal origin of an EVOO, this accurate innovation can be used to provide a certification likely to increase a product's appeal and price.

- **Filled gaps**
  DNA-based approaches are more accurate than analytical chemistry methodologies for olive oil varietal authentication due to their sensitivity, specificity, and reliability. DNA-based methods are preferable because they are not affected by the environment or conditions, and they require no statistical analysis. Once a sample is extracted, the test will have very high accuracy regarding the olive variety.

- **Limitation**
  DNA-based approaches cannot provide any information about the geographical origin of monovarietal olive oils from similar cultivars. In some cases, it is not possible to extract DNA from a specific olive oil sample, and a fresher sample will be required. Quantitative assessment still remains a challenge.

- **Next steps/potential extension**
  A diagnostic test is being developed that can be used in various labs; in the future, any lab will be able to buy a test kit. Work is also progressing toward a kit that will detect adulteration with cheaper vegetable oils. Additional development will continue after an expression of interest from an investor.

- **Find out more**

Elsa Chedid, Myrto Rizou, Panagiotis Kalaitzis (2020) Application of High Resolution Melting combined with DNA-based markers for quantitative analysis of olive oil authenticity and adulteration. Food Chemistry: X, 100082.

Ganopoulos, I., Bazakos, C., Madesis, P., Kalaitzis, P., Tsaftaris, A. (2013) Barcode-DNA High Resolution Melting (Bar-HRM) analysis as a novel close-tubed and accurate tool for olive oil forensic use. J. Sc. Food and Agr. 93(9): 2281-2286.

Kalaitzis, P., Zein, E. (2016) Olive oil authentication, traceability and adulteration detection using DNA-based approaches. Lipid Technology 28 (10-11): 173-176, November 2016, DOI: 10.1002/lite. 201600048.

Spaniolas, S., Bazakos, C., Ntourou, T., Bihmidine, S., Georgousakis, A., Kalaitzis, P. (2008) Use of λ DNA as a marker to assess DNA stability in olive oil during storage. Eur. Food Res. Techno. 227: 175-179.

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Innovation 2: VAC-HS-SPME laboratory technique to characterize the aroma profile of olive oil for quality and authenticity assessment

- **Background**

Olive oil's sensory qualities are connected to a complex aroma profile which depends on several parameters: the olive variety, geographical origin, fruit ripeness, processing practices, and storage. For years, researchers have been striving to understand more about which chemical compounds (volatile organic compounds) create the aromas of different samples of olive oil. Such an understanding can help in the assessment of olive oil quality and authenticity. Since 1990, a sample preparation technique called headspace solid-phase microextraction (HS-SPME) has been used to analyze the volatile and semi-volatile compounds of olive oil and other foods for this purpose. A less explored, improved version of this technique called vacuum-assisted HS-SPME (Vac-HS SPME) applies reduced pressure conditions during sampling. Professor Eleftheria Psillakis and her team introduced this method in 2012, and since then it has been used with great success with various types of samples, most recently with olive oil.

- **Keywords**

Olive oil quality assessment, olive oil authenticity assessment, olive oil aroma, volatile compounds of foods, solid-phase microextraction, vacuum-assisted headspace solid-phase microextraction, low sampling pressure.

- **Methodology**

Olive oil samples are processed in a chemistry lab and analyzed on a gas chromatograph and a mass spectrometer. The compounds detected in each sample are listed. The Vac-HS-SPME procedure preserves the simplicity of the older HS-SPME process; the only extra step required is that of air-evacuating the sample container before or after introducing the sample, which takes less than one minute.

- **Specifications**

The most widely-applied sampling technique, HS-SPME, works best at temperatures ranging from room temperature to 80 degrees Celsius, with sampling times generally shortened when higher temperatures are applied. However, olive oil degradation is accelerated if the samples are heated, and extended sampling times lead to other complications. Vac-HS-SPME sampling has the potential to overcome these analytical challenges, as it can yield higher extraction efficiencies at mild sampling temperatures.

- **Impact**

The Vac-HS-SPME procedure enables discrimination between the different commercial categories of olive oil (virgin, extra-virgin and lampante oil) by characterizing the aroma profile of oil samples quickly and efficiently at lower temperatures than an older technique. This method can offer lab technicians an efficient, accurate new way to authenticate olive oil grades for consumers, olive oil producers, olive oil companies, and others in the olive oil sector who are concerned about avoiding fraudulent products.

- **Filled gaps**
  Vac-HS-SPME is very efficient and sensitive, with shorter sampling times compared to regular HS SPME, as well as high performance at milder temperatures, thus preserving the sample's volatile profile and avoiding possible decomposition, reactions, or artifacts formation. It can be applied to a wide range of olive oil varieties.

- **Limitations**
  Custom-made stainless-steel caps must be requested from the Laboratory of Aquatic Chemistry, and a specific type of vials and a vacuum pump are required. However, once these are procured, the Vac-HS-SPME procedure can be quickly performed at any chemistry lab without expensive equipment. Chemistry alone cannot identify an olive oil grade, according to EU law: "Tasting panels approved by EU countries must verify organoleptic characteristics of virgin olive oils."

- **Find out more**
  Eleftheria Psillakis. Vacuum-assisted headspace solid-phase microextraction: A tutorial review, Analytica Chimica Acta, 986 (2017), 12-24. https://doi.org/10.1016/j.aca.2017.06.033
  Steven Mascrez, Elefteria Psillakis, Giorgia Purcaro. A multifaceted investigation on the effect of vacuum on the headspace solid-phase microextraction of extra-virgin olive oil, Analytica Chimica Acta, 1103 (2020),106-114. https://doi.org/10.1016/j.aca.2019.12.053

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SECTION 2: Re-Using Traditional Practices in Agroforestry

In agroforestry, trees or shrubs are grown in or around pastureland and/or agricultural crops. Silvopastoralism, a type of agroforestry that combines livestock grazing and trees, was and still is a traditional land use system in many areas. For example, in Xeromero, Aetoloakarnania in western Greece, livestock breeders have used the valonia oak forest for grazing as well as collecting acorn cups from the oaks for use in the tanning industry. Agrosilvopastoralism is another kind of agroforestry where livestock is introduced in the field after the completion of the annual crop. On the island of Kea in the Aegean Sea, farmers used to grow cereals and legumes between trees for both human consumption and as feed for the animals. Greek olive farmers have also traditionally grown annual crops for the market or for grazing animals among their trees—or simply allowed livestock to graze on wild plants in the groves. Lately, there has been a gradual abandonment of this kind of combined land use, with a preference for monoculture, such as olive trees grown alone.

However, using forests and olive groves for multiple purposes has many benefits. For example, it ensures a steady and enhanced economic return every year, with a reduced risk of losses due to weather conditions or other types of hazards. Agroforestry can also increase biodiversity, reduce the impact of pests, enrich soil nutrient content, reduce erosion, improve carbon sequestration, and help reduce the risk and severity of forest fires. For these reasons, a return to productive old ways can become a useful innovation that allows farmers and livestock breeders to both increase their incomes from the production of high quality products, and help preserve valuable forest lands and olive groves using sustainable practices.

Innovation 3: Olive tree, wild asparagus and free-range chicken polyculture

- **Background**

  Olive trees used to be cultivated with other crops and grazing animals on the same land. Crop specialization led to the abandonment of such polycultures in most cases, resulting in olive monocultures with frequent soil tillage but no cover crops or manure application. This caused decreased soil fertility and increased erosion, especially on sloping terrain. To prevent further damage, temporary or permanent green mulching is now often adopted. If a green cover must be maintained, why not use something that can produce additional income? Wild asparagus (Asparagus acutifolius) is a naturally occurring perennial vegetable that grows well in the moderate shade under olive trees. Its spears have been consumed from time immemorial, but the plant is not usually cultivated. However, its cultivation in an olive orchard provides an opportunity to increase income and productivity. Moreover, chickens in the same orchard can further increase farmers' income, as well as taking care of weeds the asparagus makes it difficult to eradicate otherwise.

- **Keywords**

  Olive trees, olive growing, olive production, wild asparagus, asparagus, free-range chickens, polyculture, agroforestry, life cycle assessment, environmental impact, weed management, fertilization, meat, poultry

- **Methodology**

  Asparagus plants can be cultivated along the tree rows, leaving the alley free for the movement of machinery. They can also be cultivated between the rows, but this may limit the type of equipment that can be used in the orchard. The presence of asparagus plants makes weed control in the olive orchard more difficult. However, livestock can provide good weed management, as well as fertilization. Large animals are mostly incompatible, so smaller animals should be preferred. Free range chickens represent one good solution: they do not harm the asparagus plants or the olive trees. (They can destroy olive suckers when they first emerge and are tender: this is an added bonus.) Two cycles of 1000 meat chickens per hectare (ha) can be raised in the olive orchard: one in the spring, before and/or after the asparagus harvest (but not during the harvest), and one in the autumn (the two seasons when weeds grow and need control). During the summer and winter months, weeds do not grow significantly due to drought and cold respectively, at least in Mediterranean-temperate climates, so no control is needed. This gives the orchard a break from grazing pressure and provides enough time for natural sanitation, thus avoiding a concentration of parasites. In other climates, the period for the cycles can be adjusted based on when there is greater need for weed control.

- **Specifications**

  Wild asparagus is perennial; once established, it does not required soil tilling, which helps prevent erosion. Asparagus plants can be transplanted in spring or autumn along the tree rows at 2.5-3 plants per meter of row (4-5 thousand plants/ha). If cultivated also in the alleys, rows should be at least one meter apart (20-25 thousand plants/ha), or farther apart if appropriate for the machinery used in the orchard. Young plants should be irrigated during the first year, either regularly or when necessary. Afterwards, they should be able to cope with natural rainfall as well as the olive trees. If the trees are irrigated, the same (drip) irrigation system can be used for both the trees and the asparagus, optimizing the investment. Manure or fertilization with other organic materials is highly advisable for the asparagus plants and will benefit the trees as well. Wild asparagus plants become productive after about 2-4 years from transplanting, and the yield for well-cultivated plants is around 50-100 grams/plant, thus about 200-500 kg/ha with plants along tree rows or 1000-2000 kg/ha with plants also in the alleys.

Meat chickens should be allowed to range from the age of three weeks until they are ready for the market (about three months later for the slow-growing breeds that are more suitable for free-range systems). Good fencing against predators is usually necessary. A guard dog can also be very effective against predators. Two cycles of 1000 chickens/ha will provide complete weeding and fertilization for the orchard. Despite grazing, chickens will consume almost as much feed as they would without grazing, but meat quality and animal welfare will be increased while cultivation costs (for weeding and fertilization) will be reduced.

- **Impact**
  A life cycle analysis has shown the great environmental benefits of this polyculture, demonstrating that by providing natural weeding and fertilization services, the chickens very significantly reduce the environmental impact of olive cultivation. Economic analyses are being carried out, but it is already clear that this polyculture increases overall yield per unit area by producing more crops on the same land. Thus it should provide more income than the separate cultivations.

- **Filled gaps**
  Polycultures are often more productive and better for the environment than monocultures, but only when the right combinations of crops are used. Wild asparagus appears to be a good understory crop in olive groves. However, intercropping complicates weeding and fertilization management. Using free-range chickens to do both jobs is a natural, cost-effective solution which also provides additional yield from the same land. Free-range animals need shelter against the weather. Olive trees provide such shelter, improving grazing time and range, as well as animal well-being. To summarize: the combination of olive trees, wild asparagus, and free-range chickens can benefit the olive grove and the livestock as well as increasing farmers' income.

- **Limitations**
  It may not always be convenient to diversify production on a small scale, especially for livestock operations. Fencing is usually necessary and costly. Slow-growing chicken breeds are better grazers, but they have low feed conversion efficiency, so their meat has higher production costs and a greater environmental impact. For effective weeding and fertilization, grazing should be uniform. This requires moving the chicken housing often and/or managing the animals to encourage uniform grazing. Otherwise there will be overgrazing and soil compaction and pollution in some areas, and insufficient weed control and fertilization in other areas.

- **Next steps/potential extension**
  Selection for breeds that combine sufficient grazing abilities with greater feed efficiency is desirable. Chickens might positively interfere with the olive fly cycle, destroying maggots in the soil, as well as possibly controlling asparagus beetles or olive weevil, but more research is needed in these areas. More work could also be done to promote the marketing of sustainable agroforestry products, so they could bring farmers even better prices. It would be useful to explore ways for farmers to work together to create the economies of scale necessary to get the greatest benefit from this agroforestry system.

- **Find out more**
  Presentation: https://www.youtube.com/watch?v=4ZWm4v95I_I
  Leaflet: https://www.agforward.eu/documents/leaflets/19_Olive_asparagus_innovation_leaflet.pdf
  Video (in Italian): https://www.youtube.com/watch?v=ALw73WwUr2o
  Free manual (in Italian):
  https://www.researchgate.net/publication/282653171_Manuale_per_la_coltivazione_consociata_Olivo_Asparago_selvatico_Pollo_rustico

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SECTION 3: Intercropping and Preparing for Climate Change in Olive Groves

Traditionally, olive groves in Greece have included plants such as legumes, cereals, herbs, vegetables, walnuts, grapevines, and truffles. Such a combination of two crops grown at once on a plot of land is known as intercropping. When it includes trees and an annual crop, it is also a type of agroforestry. The traditional agroforestry practice of intercropping offers many benefits over a monoculture--benefits for the soil, the farm, the broader environment, and (as a result) the farmer. Recommending that olive farmers consider innovating by adapting new, improved versions of traditional agroforestry practices, numerous scientists now provide specific advice to help farmers achieve the greatest possible benefits.

Intercropping increases olive groves' sustainability by adding to their biodiversity and stabilizing the soil, thus reducing trees' vulnerability to pests, diseases, and climatic stresses. The greater diversity in plant life enables a larger variety of organisms in the soil, as well as more beneficial insects, pollinators, and birds. With intercropping, the soil benefits from increased porosity, improved drainage, less erosion, and decreased nitrogen and phosphorus leaching, which means fewer valuable minerals lost and less pollution of groundwater and surface water. Fewer pesticides and nitrogen fertilizers are required, and olive trees tend to be healthier, which benefits the planet and the farmer. In addition to saving money on pesticides and fertilizer, farmers may also benefit financially both by producing higher quality olives and by harvesting a second crop. They can either sell this product (as in the case of the recently popular avocados) or use it as a natural soil enricher or an animal feed (as with legumes).

One of the most important crops for the Mediterranean region, the olive tree will be subject to increasingly harsh abiotic stresses due to climate change in the coming years. Abiotic stress comes from environmental conditions that can harm plants and reduce their growth and yield, such as extreme temperatures, soil salinity, and drought. (Biotic stress, on the other hand, is caused by living things such as insects, weeds, bacteria, viruses, or fungi.) Shifting cultivation zones, depletion of organic matter, desertification, degradation of water resources, and other challenges make it imperative to prepare for the future, for example by intercropping and by using trees that can resist the effects of climate change.

Innovation 4: Intercropping of olive trees and vetch

- **Background**

Traditionally, olive groves were co-cultivated with cereals and legumes in Greece. This type of land use lost favor for a time, but today the co-cultivation of olives with other useful plants has regained the old interest, since it offers many advantages to farmers and the environment with minimal cost and effort.

- **Keywords**

Olive growing, olive cultivation, olive trees, nitrogen-fixing plants, natural fertilization, Koroneiki, legumes, vetch, intercropping, agroforestry, co-cultivation, allelopathy, erosion, biodiversity

- **Methodology**
  After the olive harvest, from late December to mid-January, a legume is sown, preferably vetch, in the area under the crown of the tree, leaving only the base of the trunk clean. For this, approximately 300 grams of seeds are required for each tree. If there are weeds, they should be removed before sowing using a brush cutter, unless the weeds are Oxalis pes-caprae (African wood-sorrel, Bermuda buttercup), a common beneficial weed which may be left in the grove when vetch is planted. The vetch grows during the rainy season. At the end of March, when it blooms, the vetch should be cut near the soil level with a brush cutter. The cuttings can be left to decompose where they fall, or they can be incorporated into the soil. If there are branches left over after tree pruning, the branches and cuttings can be shredded together before incorporation into the soil (or shredded and left on the soil surface as mulch). In each case, the cuttings will help enrich the soil.

- **Specifications**
  The whole process is simple, quick, and inexpensive. Irrigation is not necessary after sowing, because the rainfall at that time of year is generally sufficient for vetch to thrive.


Image 2 Vetch growing around olive trees (by Spiros Lionakis)

- **Impact**
  1. Increases the quality of the olives
  2. Saves money by reducing the need for chemical fertilizers
  3. Efficiently utilizes rainwater
  4. Enriches the soil with nitrogen (about 12-15 units / acre) and organic matter
  5. Improves the olive grove's microclimate
  6. Minimizes soil leaching and groundwater pollution
  7. Reduces root system suffocation
  8. Increases the porosity / drainage and aeration of the soil
  9. Hosts beneficial insect fauna
  10. Averts problems with weeds due to the rapid germination of the vetch and its allelopathic effect

- **Filled gaps**
  Vetch can store enough nitrogen in its root system to suffice for each olive tree for almost three years. This means farmers both save money by reducing their need for inorganic fertilizers, and reduce the amount of nitrogen leaching (which means the soil's nitrogen is washed away in surface water and underground water, so it pollutes the water and cannot be used by the plants).

- **Limitations**
  Adequate rainfall after sowing is essential for the successful germination of vetch; this is usually not a problem during the winter in Greece. If there are weeds other than Oxalis pes-caprae in the olive grove, they must be cut before sowing.

- **Next steps/potential extension**
  If desired, the vetch crop can also be harvested for use as animal feed. Co-cultivation with cereals such as barley, in addition to the vetch, can offer even more benefits. The vetch can climb on the cereals, and the cereals can be used as animal feed.

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Innovation 5: Olive tree-avocado intercropping

- **Background**
  Intercropping with a crop such as avocados can offer many benefits for both the environment and farmers, including a significant financial advantage, given the high selling price of avocados. While olive trees used to be co-cultivated with various other trees, this has become less common, leading to many negative effects for both the olive groves and the rest of the ecosystem. The most obvious example in Greece is a serious problem with the olive fly and the widespread use of pesticides to combat it. As a solution, farmers can once again introduce more biodiversity into the rural ecosystem, for example by planting avocado trees between widely-spaced olive trees. In addition to making it easier for the natural enemies of pests to thrive and help prevent pest outbreaks, this practice will significantly boost farmers' income.

- **Keywords**
  Olive tree, olive farming, Koroneiki, Hass avocado, Reed avocado, Lamb Hass avocado, avocados, intercropping, agroforestry, carbon storage, biennial bearing

- **Methodology**
  In an olive grove with Koroneiki variety olive trees planted 7*7 or more (that is, with at least 7 meters between each row, and at least 7 meters between each tree in a row), we plant avocado trees (Hass, Lamb Hass, or Reed variety, plus Bacon or Zutano variety to maximize the likelihood of pollination) half way between each pair of olive trees in a row to create a 3,5*7 planting system. We leave 7 meters free between rows for farm machinery, vehicles, and plenty of exposure to sunlight (since both types of trees need a lot of light). In order to maximize the likelihood of avocado pollination, we need to plant Bacon or Zutano variety avocado trees in specific places.


Image 3: Olive-avocado intercropping (by Lisa Radinovsky)

- **Specifications**
  Appropriate pruning is essential so all the plants receive adequate exposure to sunlight. There are two main pruning periods for all the plants, the first after harvest time, the second in late summer. There must also be two separate irrigation systems (one for each kind of tree), because these trees have different irrigation and fertilization needs.

- **Impact**
  This type of intercropping can increase farmers' income. It also benefits the environment, as it decreases erosion while enabling higher carbon storage. It creates a better microclimate and an improved habitat for many animals, birds, insects, etc., increasing biodiversity so that less pesticide is likely to be needed.

- **Filled gaps**
  By increasing overall fruit production, this sustainable type of intercropping can help compensate for olive farmers' low income due to climate change, biennial bearing, high production costs, and low olive and olive oil selling prices.

- **Limitations**
  A specialist should evaluate the grove's location, water, and soil to see if appropriate conditions exist for this type of intercropping to succeed. Additionally, there must be an adequate water supply. Pruning knowledge is essential, since shade affects the production of avocados and olives.

- **Next steps/potential extension**
  Intercropping with nitrogen fixing plants in addition to avocados is recommended in order to enrich the soil microbiome, increase its fertility (especially in terms of nitrogen), increase biodiversity, and lower costs. This could reverse soil degradation while producing higher quality fruits.

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Innovation 6: A tool to identify olive genotypes that are tolerant to salinity

- **Background**
  The olive is of great socioeconomic importance for many Mediterranean countries. Unfortunately, as climate change intensifies in the coming years, extended periods of drought will result in a water shortage for agriculture, especially during the summer. In that case, irrigation with high saline (salty) water might become the only way to irrigate olive orchards. However, salinity induces a significant decrease in olive trees' productivity. Some cultivars are more tolerant to salinity stress than others. Structural changes at the cellular level occur mainly in the sensitive cultivars, not in the more tolerant ones. These structural changes to the cortex cells can be observed in root cross sections. For this reason, a sampling of roots after several days of salinity treatment followed by a determination of structural changes in their cortex cells will provide a strong indication of the level of tolerance of an olive cultivar.

- **Keywords**
  Olea europaea, olive, olive trees, olive cultivars, salinity tolerance, drought, irrigation, salt water irrigation, salinity stress, root cross sections, cortex cells, structural changes, olive seedlings, climate change

- **Methodology**
  Several thousand seedlings representing olive germplasm will be exposed to NaCl (salinity) stress for several days. After a specific period of time, root samples will be collected from each seedling and will be used to prepare cross sections which will be stained to determine cortex cell size, diameter, shape and intercellular spaces. Immunostaining can also be applied to observe changes in protein levels which have been associated with olive tolerance under salt stress.

- **Specifications**
  The plants will be fertilized with a solution containing a high concentration of NaCl. After a specific time period, a part of their roots will be cut into thin sections by a microtome. After staining, their morphology will be observed under a microscope in order to determine cortex cell characteristics in comparison to root sections from olive seedlings grown under regular conditions using high quality irrigation water.

- **Impact**
  Climate change combined with irrigation with saline water will increase the demand for cultivars with a high tolerance for salinity. There is a pressing need to identify methods to screen olive germplasm for salinity tolerance in an efficient, simple, inexpensive, reliable way.

- **Filled gaps**
  To date, the response to salinity in olive trees has been identified either at the morphological level, which takes a long time due to a delay before visible symptoms appear, or at the level of quantification of elements such as sodium, potassium, and chlorine. However, neither of these approaches is well adapted for the high throughput studies required to identify genotypes tolerant to salinity. This method meets a need for a reliable, efficient, relatively simple way to determine the response of olive seedlings to salinity.

- **Limitations**
  The sectioning and handling of root samples requires equipment that is expensive, and the consumables involve considerable cost. There is a need for a laboratory to process the samples and determine structural changes under a microscope. This requires know-how and a high initial investment. Knowledge of microscopy and sample preparation are required.

- **Next steps/potential extension**
  The next steps involve screening a large number of cultivars that are tolerant of salinity, and a large number that are sensitive to salinity, in order to identify the most reliable changes in the root cortex cells under conditions of salinity. Another goal is to optimize the experimental methodology for optimum results in the shortest possible time. The aim is to introduce a new technique that can be used wherever the equipment and scientists are available.

- **Find out more**
  Response of prolyl 4 hydroxylases, Arabinogalactan proteins and pectins content under long salinity stress in four olive cultivars. Azariadis A., Vouligeas, F., Salameh, I., Kouhen, M., Rizou, M., Blazakis, K., Sotiriou, P., Ezzat, L., Mekkaoui, K., Krokida, A., Adamakis, I-D., Dandachi, F., Shalla, B., Kostelenos, G., Figgou, E., Giannoutsou, E., and Kalaitzis P. Under revision for Cells.

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SECTION 4: Recovery and conservation of ancient and traditional olive groves to save the environment and preserve their genetic heritage

Olive cultivation in the Mediterranean region dates back several millennia, having started approximately 6000 years ago. Since that time, the olive tree has been one of the most important fruit tree crops in the region, providing very famous and useful products for the Mediterranean diet, olives and olive oil.

The olive tree is a long-lived tree. A huge number of centennial olive trees in all the Mediterranean countries, including Lebanon, provide evidence of the strength and majesty of this tree. The olive genetic material in these groves constitutes a pool of very important genotypes with the ability to resist harsh agroclimatic conditions and maintain good production. As a source of trees that may be able to adapt to climate change, they must be protected for future use in olive breeding.

The majority of olive orchards in Lebanon are very old traditional plantations (more than 300 years), with very low productivity (less than 1000 kg per hectare) because they are neglected. Efforts to restore them can help farmers increase their profitability.

Innovation 7: Recovery of abandoned traditional olive orchards for multifunctional purposes

- **Background**
  Traditional olive systems persist in many hilly and mountainous areas in the Mediterranean. They are generally characterized by an irregular layout of very old trees with a large canopy and/or multiple trunks and superfluous primary branches. The canopy of the trees is usually not pruned frequently or well enough, if it is pruned at all, causing serious deterioration of the plant. These conditions, combined with reduced soil fertility, negatively affect fruit production, resulting in negligible production or extreme cases of alternate bearing, so that the olive orchards become unsustainable and are abandoned. However, innovative management strategies in the context of an agroforestry approach may help to recover the agro-ecological and economical sustainability of these orchards for multifunctional purposes.

- **Keywords**
  Olive, pruning, canopy recovery, soil management, agroforestry, intercropping, sustainability, olive groves, olive trees, olive orchards

- **Methodology**
  Correct techniques of rejuvenation pruning (for both the canopy and the root system) and soil management can be applied by farmers in order to promote the recovery of the vegetative-reproductive balance of olive trees and achieve their full fruit production potential. Rejuvenation pruning of the canopy can reduce the height of the trees, simplify the skeletal structure of the canopy and enable pruning and harvesting directly from the ground in a safer, faster way. The use of rippers in combination with the application of organic amendments to the soil can enhance the rejuvenation of the roots and speed up the canopy recovery. Depending on the specific conditions of the orchards, different approaches can be applied.

- **Specifications**
  Specific principles must be applied when rejuvenation pruning is used with olive trees. A vase-shaped canopy training system allows a good vegetative-reproductive balance. Pruning intensity, strategy and time should be adapted to the specific pedo-climatic condition.

- **Impact**
  The suggested procedures will allow farmers to recover the productivity of their traditional olive orchards. Once trees have recuperated, there will be a better vegetative-reproductive balance, and alternate bearing will be reduced. These procedures will also allow the soil to recover, so it can be used for grazing of the natural green cover or for intercropping, which could give farmers an additional source of income. Costs for the recovery of the olive orchard are largely covered by income from the non-shreddable rejuvenation pruning material (wood). Shreddable pruning material can be beneficially used to improve the organic matter content of the soil or as part of a grazing diet. Finally, the results of the suggested techniques will motivate farmers to preserve rather than abandon traditional olive orchards.

- **Filled gaps**
  The recovery of traditional olive orchards through rejuvenation pruning and the use of soil management techniques to improve biodiversity can help maintain the environment, prevent soil erosion and increase the overall resilience of the groves. The olive orchards can also become more multifunctional, providing differentiated and high-quality products such as other crops or grazing or touristic activities. The financial benefits deriving from different sources of income can motivate farmers to maintain olive orchards rather than abandoning them.

- **Limitation**
  Specific recovery plans should be studied for different pedo-climatic conditions. The time required for complete recovery depends on the farmers' ability to take the appropriate steps required to enhance vegetative growth (pest management, nutrition, irrigation, etc.).

- **Next steps / potential extension**
  Results of on-site experiments on traditional olive orchard recovery are available for a few pilot cases. Further studies are required to determine specific sustainable agronomic/economic intercropping/grazing combinations for olive orchards under different pedo-climatic and social conditions. Such results should be shared among farmers in different geographical areas, and local legislators should fund more similar projects and meetings to encourage the use of conservationist techniques in order to support local economies with a multifunctional approach.

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Innovation 8: Surveying and characterizing ancient olive trees in Lebanon to elaborate a conservation strategy

- **Background**
  Millennial and centennial olive trees with important historical, genetic and ornamental value are still growing across Lebanon. Many of these old trees are seriously threatened; only a few have been classified as monumental, ensuring that they will continue to remain an integral part of the traditional agrobiodiversity systems, mixed in with younger trees that have been planted in recent decades. These old trees might be unknown traditional cultivars that have not yet been characterized. Also, they may be linked to some of the current traditional cultivars and might represent early stages in the domestication processes of the olive tree in the country and in the Mediterranean region.

- **Keywords**
  Olea europaea L., ancient olive trees, olive trees, ancient trees, traditional olive varieties, Lebanon, olive tree characteristics, SSR markers, olive tree conservation, preservation of ancient olive trees

- **Methodology**
  A survey of ancient trees and a subsequent morphological analysis of their size, shape, and structure will provide information about the uniqueness of the trees. This will be combined with an analysis of their molecular markers (SSRs) to verify the genetic profile of the trees and assist in the development of a threat assessment report as well as a preservation strategy. This plan can be considered an innovative design for a new standard operational procedure that can be used to protect and take advantage of ancient olive trees in Lebanon.

Image 4: "Sister Olive Trees of Noah," Bcheale Village, North Lebanon (by Lamis Chalak)

- **Impact**
  SSR analysis has begun showing the link between some centennials and recently planted trees of traditional varieties for the first time in Lebanon. The characterization of the ancient Lebanese olive germplasm can help record and preserve the genetic heritage of Mediterranean olive trees, perhaps enabling the discovery of subspecies resistant to climate change or with other exciting potential. A survey of the trees can also help prepare for their preservation and inspire new agritourism and ecotourism ventures that could benefit rural communities.

- **Filled gaps**
  In addition to filling gaps in knowledge of the ancient trees, this project will assess and publicize serious threats to them, emphasizing the need to undertake conservation actions and the various benefits of such conservation.

- **Limitation**
  So far, this study has been focusing on a limited number of old trees in the country.

- **Next steps / potential extension**
  This study should be extended to other countries for a better understanding of the domestication of the olive tree in the Mediterranean region. Moreover, further isotopic analyses would help increase our understanding of the ability of these symbolic Mediterranean trees to survive over centuries in the face of various stresses.

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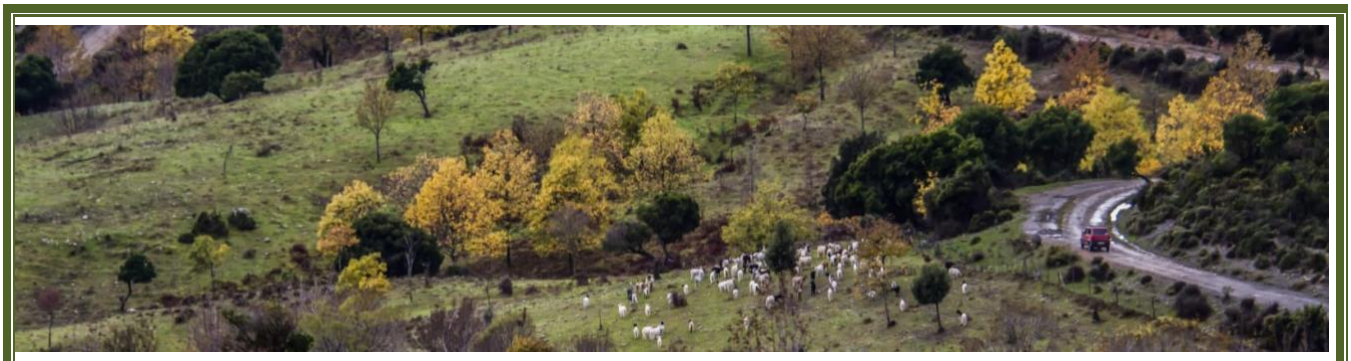

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