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Cooperating across borders in the Mediterranean

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REGIONE AUTÒNOMA DE SARDIGNA
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LIVINGAGRO

CATALOGUE OF INNOVATIONS

A COLLECTION OF INNOVATIONS FOR MULTIFUNCTIONAL OLIVE SYSTEMS AND GRAZED WOODLANDS

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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Dissemination Level	PU[1]

[1] PU = Public document; PP = Partnership document

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 will be established focusing on olive multifunctional system (LL 1) and grazed woodlands (LL 2).

Expected results

- ✓ Creation of two Laboratories (Living Labs) on the themes of multi-functional 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 6 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 agro-forestry 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 – September 2022 (36 months)

CONTENTS

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 olive multifunctional systems and grazed woodlands, 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 olive multifunctional systems or grazed woodlands.

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 olive multifunctional systems and grazed woodlands, 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 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, the MAICH 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: Intercropping 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, 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).

Innovation 1: Intercropping of olive trees and legumes

- **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.

- **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 two 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.

- **Find out more**
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  Hellenic Mediterranean University
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Innovation 2: 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 variety as a pollinator) 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 variety avocado trees in specific places.

- **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 at harvest time, the second in early summer. There must also be two 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.

- **Find out more**
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SECTION 2: Precision Agriculture

As the need to feed a growing world population using sustainable, environmentally friendly methods becomes increasingly apparent, more and more farmers are acknowledging the potential usefulness of precision agriculture, which is also known as smart farming and intelligent agriculture. These phrases are sometimes used interchangeably to refer to the utilization of information and communication technologies to minimize farmers' input while maximizing their output. For example, data gathered remotely using sensors on farms can be used to help farmers determine what a farm needs, thereby avoiding excessive application of fertilizers, water, or pesticides, while producing a greater quantity and better quality crops at a lower cost. Proponents argue that the environment, farmers, and consumers all benefit from the increased efficiency and decreased waste.

Innovation 3: NEUROPUBLIC's gaiasense smart farming system -- smart farming services for irrigation, fertilization, and crop protection

Image 1: A gaiasense agrometeorological station in an olive grove (by NEUROPUBLIC)

- **Background**

In 2016, Yanni's Olive Grove in Chalkidiki, northern Greece became the first Greek olive oil company to apply a smart farming program for olive tree cultivation in a pilot project supervised by GAIA EPICHEIREIN and NEUROPUBLIC in collaboration with Perrotis College Krinos Olive Center of the American Farm School. Very pleased with the result, Yanni's Olive Grove has continued to cooperate with gaiasense. Now the gaiasense smart farming system has also evolved to support a wide variety of crops in different parts of Greece and abroad.

- **Keywords**

smart farming, intelligent agriculture, precision agriculture, gaiasense, olive cultivation, olive growing, olive tree sensors, olive grove

- **Methodology**

The pilot program consisted of four distinct smart farming services for fertilization, irrigation, crop protection, and advice on cultivation practices. The services were offered through an online platform which used data from agrometeorological stations and leaf sensors in the olive groves, as well as satellite images of the olive groves, field measurements, observations, and soil/plant tissue sample analyses. The data were processed and used in specialized scientific models related to the fertilization, irrigation, and protection of the olive trees. The final outcome was smart farming advice that the olive growers could apply to their groves.

- **Specifications**

The gaiasense smart farming system is adapted to the particular soil and microclimatic conditions of a given area in order to ensure maximum efficiency. Gaiasense also supports numerous other crops, such as grapes, peaches, cotton, potatoes, and tobacco. The gaiasense mobile app is now available to make smart farming even more accessible and affordable even to smallholder farmers, omitting the need for investments in technological infrastructure and tools.

- **Impact**
  The pilot program's main objective was to minimize the production costs in the olive oil and table olive production processes, and to improve the quality and quantity of the final product. The result was a decrease in cultivation costs by over 35%, reduced irrigation water use, and better plant disease and pest management, with excellent product quality and quantity. By optimizing inputs, the gaiasense smart farming system has also achieved a significant cost reduction for other crops, including grapes, cotton, and peaches. With more than 65 installations and more than 300 telemetric stations covering about 30 crops and more than 70.000 hectares of fields in 6 countries, gaiasense has already had a significant impact on the digitization of the agricultural sector.

- **Filled gaps**
  The smart farming services of gaiasense significantly contribute to improved product quality, cost reduction, plant health, and the targeted, efficient use of natural resources (e.g. water) and agrochemicals (fertilizers, pesticides etc.). Reducing the environmental footprint of agriculture, these services help make olive production sustainable both environmentally and financially.

- **Limitations**
  Although the agrometeorological stations of gaiasense are energy autonomous and transmit data through a cellular network (meaning no need for a power source or internet connection for that), a stable internet connection and cellular network are still required to use the gaiasense services. In the case of damage due to extreme weather, the agrometeorological stations could require service or an upgrade. Individuals unaccustomed to using modern technology may find smart farming challenging initially, but gaiasense is easy to use and understandable, requiring no special skills. Support and guidance are always available through gaiasense, and to exploit the system's full potential, farmers can also work with an agricultural advisor who can adjust the advice if needed and guide them in its application to their groves or fields.

- **Next steps/potential extension**
  Winner of a Green Award as a technological tool for sustainable food production in Greece and abroad, the smart farming services of gaiasense that Yanni's Olive Grove used are now available to any farmer for a small annual fee, with no need for expensive investments in technological infrastructure. They are already being used by several cooperatives in Greece, as well as being tested abroad in such countries as Spain, Portugal, Poland, Ukraine, and Cyprus. Just launched, the gaiasense mobile app is now ready to make smart farming even more accessible and affordable to smallholder farmers.

- **Find out more**
  Website: https://www.neuropublic.gr/en/services/ and www.gaiasense.gr/en
  Phone: +30 210 4101010
  Email: info@neuropublic.gr / info@gaiasense.gr

Innovation 4: gaiasense1 mobile app for smart farming

- **Background**
  Widely acknowledged as an innovation at the European level, the gaiasense smart farming system of NEUROPUBLIC has been on the market for several years, used both in Greece and abroad. NEUROPUBLIC's gaiasense mobile app was developed more recently in order to meet farmers' needs for a low-cost but still highly reliable tool that would allow them to reap some of the benefits of smart farming and join the digital farming era without investing in expensive technological equipment, infrastructure, etc.

- **Keywords**
  gaiasense, smart farming, gaiasense app, gaiasense1, digital farming, precision agriculture

- **Methodology**
  The gaiasense mobile app was designed and developed using the technological and scientific infrastructure of the original gaiasense innovation, with thousands of specialized sensors and hundreds of stations designed and developed by NEUROPUBLIC in Greece. In the form of a mobile app, it provides farmers with a wealth of information about their farms, their crops, and much more.

- **Specifications**
  The gaiasense mobile app is available for Android and iOS smartphones through the Play Store and App Store respectively. Through a simple user interface, gaiasense1 provides a detailed weather forecast at the parcel level, early warnings for extreme weather phenomena, optimal time slots within the next three days for spraying pesticides, satellite images of each parcel that help determine the state of plants' health, information about water indicators, the progress of growth factors like growth degree days, warnings for risk of infection / infestation by diseases and pests, and much more.

- **Impact**
  The mobile app of gaiasense was only recently launched; however, it has already received positive feedback through user testimonials, reviews, and comments. Like the original gaiasense innovation, the mobile app is expected to help farmers minimize their production costs and water use, better manage plant diseases and pests, and improve the quality and quantity of their final products.

- **Filled Gaps**
  Gaiasense1 aims to become a valuable tool for farmers that would like to reap the benefits of smart farming in an easy, affordable way. It was designed for Greek farmers who need to make data-informed decisions without investing in expensive technological tools. Like the original gaiasense, gaiasense1 uses a holistic approach, with various types of data acquired from various sources, including the gaiasense telemetric agrometeorological stations, satellites, and field agronomists, in order to provide useful, accurate information to farmers.

- **Limitations**
  The gaiasense mobile app works on Android and iPhone mobile phones and requires an active internet connection (WiFi or mobile data). At the moment, the mobile app is only available in Greek, as it addresses the needs of Greek farmers.

- **Next steps/potential extension**
  Gaiasense1 is the first service offered through a mobile app. In the near future, gaiasense2 will be launched, providing all the offerings of gaiasense1, plus irrigation advice, crop protection advice, fertilization recommendations, soil sampling and analyses, and the option to customize the fields in the app, among other things. While gaiasense1 offers a wealth of information, gaiasense2 will also provide advisory features.

- **Find out more**
  Website: https://www.gaiasense.gr/app (in Greek)
  Phone (support): 216 200 2400
  Email (support): gaiasense@neuropublic.gr

Innovation 5: Zen Irriware precision irrigation system

- **Background**
  In a dry climate such as the Mediterranean region, irrigation is necessary in olive groves with an average annual rainfall of less than 400 mm, in intensive olive groves, and in poor soils. Agriculture is by far the largest consumer of fresh water, accounting for at least 70% of fresh water withdrawals from rivers, lakes and aquifers – more than 90% in some developing countries. It is extremely helpful to conserve as much water as possible in irrigation, since that will result in significant water savings overall.

- **Keywords**
  Precision irrigation, precision agriculture, irrigation software, intelligent agriculture, intelligent agriculture databases, saving water, water conservation, irrigation

- **Methodology**
  Zen Irriware uses the following information, which is entered into a database:
  1. an area's meteorological data
  2. soil characteristics (from a geoinformatics system of soil data or soil analysis)
  3. details about the crop (tree age, planting distances, etc.)
  4. the quality and availability of water in the area (including the application of deficit irrigation)
  5. the irrigation method
  6. the soil cover

  Taking into account the information mentioned above, Zen Irriware calculates the frequency and quantity of irrigation that a grove actually needs, sharing the result with the farmer by SMS or email to the producer's mobile phone, or directly controlling an electrovalve for complete automation of irrigation.

- **Specifications**
  All the producer needs is a mobile phone to receive the messages about irrigation of the grove. This is a simple, user-friendly innovation designed for the average producer.

- **Impact**
  1. Optimizes use of irrigation water, thus conserving water
  2. Minimizes environmental risks (e.g. nitrate pollution)
  3. Reduces the cost of production (by reducing inputs)
  4. Minimizes soil leaching
  5. Reduces root system suffocation conditions
  6. Reduces the likelihood of damage from impending extreme weather (heatwave, frost)

- **Filled gaps**
  The irrigation of olive groves is generally done without scientific guidance or full consideration of the grove's actual needs, resulting in water waste. Because oversupply does not have a direct impact on trees, farmers feel safer if they provide more water than necessary, especially when its price is low. In the end, up to 35% of this water is lost, since only 65% is used by the trees. In times of drought and in dry areas, this water loss can have serious consequences. Zen Irriware can help avoid this.

- **Limitations**
  Soil analysis is required. So far used only in Greece.

- **Next steps/potential extension**
  Expansion to other countries in the Mediterranean basin.

- **Find out more**
  https://zenagropc.com/en/precision-irrigation/
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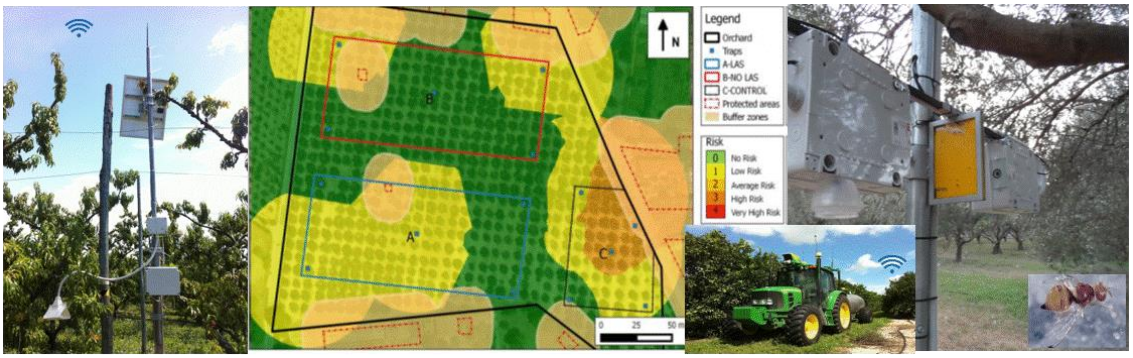
Innovation 6: FruitFlyNet-ii automated monitoring and control system against the olive fly and Mediterranean fruit fly

- **Background**
  Environmentally friendly, effective control of pests for olive, peach and citrus crops is of great socio-economic importance in the Mediterranean region. Countless farmers suffer significant crop damage and financial loss due to inadequate pest control.

- **Keywords**
  olive fruit fly, olive fly, Mediterranean fruit fly, medfly, *Bactrocera oleae*, *Ceratitis capitata,* Mediterranean region, pest control, olive groves, citrus orchards, peach orchards, integrated pest management, location aware system

- **Methodology**
  Part of an ENI-CBCMed project, FruitFlyNet-ii is an integrated electronic control system for olive, citrus and peach orchards. The project is expected to develop a complete package of innovative solutions that will include automated data collection and electronic services, all adapted to deal with each type of insect and the specifics of each farm.



FruitFlyNet-ii: Commercializing a Location Aware System of environmentally effective e-monitoring and ground spraying control solutions for Olive and Med fruit fly pests based on Living Labs innovations and startups enforcement.

Image 2 (by the FruitFlyNet-ii team)

- **Specifications**
  The integrated system will include
  a) design, construction and optimization of electronic insect traps (e-traps)
  b) installation and operation of a wireless network of sensors and data transfer (images and meteorological data)
  c) development of a geographical database
  d) development of decision making systems for spraying
  e) creation of real-time sprayer guidance systems
  f) spray traceability systems and evaluation of their accuracy and effectiveness

- **Impact**
  The project expects to offer environmentally effective pest control, meaning improved phytosanitary treatment, by extension increasing crop quality and quantity.

- **Filled gaps**
  FruitFlyNet-ii meets a need for sustainable, environmentally-friendly pest control that can improve product quality and quantity by integrating the following for the first time: automatic real-time field data acquisition, an innovative e-trap, spraying, e-guidance, and traceability.

- **Limitation**
  Not currently designed for control of other types of pests or plant diseases.

- **Next steps/potential extension**
  An earlier FruitFlyNet project introduced and tested a Location Aware System (LAS) that appeared very promising in small-scale testing. The FruitFlyNet-ii project aims to develop a complete package solution so farmers can e-monitor the olive fruit fly and medfly pests. Two prototypes are planned: the OliveFlyNet and the MedFlyNet, each with an e-trap and a set of e-services. The LAS prototypes will be optimized by the inputs of living labs. Patents and commercialization are the expected results.

- **Find out more**
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Innovation 7: MyOliveGroveCoach multi-spectral sensing for the predictive management of Verticillium wilt in olive groves

- **Background**
  Caused by a soil-borne fungus, Verticillium wilt can cause olive trees to completely dry up, sometimes killing them. It is difficult to control, so early detection, before symptoms are even visible to the human eye and before the fungus has spread widely to neighboring trees, can be particularly helpful. Remote sensing is a new technology that enables this early detection, and drones equipped with multispectral cameras can provide affordable, easy-to-use monitoring of olive groves.

- **Keywords**
  precision agriculture, intelligent agriculture, multi-spectral sensing, Verticillium wilt

- **Methodology**
  MyOliveGroveCoach uses sensors to capture information about foliage size, plant height, body diameter, and root system size using the light reflected from plants. More specifically, it uses multispectral imaging from unmanned aerial vehicles to develop an olive grove monitoring system based on the autonomous and automatic processing of the multispectral images using computer vision and machine learning techniques. In this way, it can detect some problems and diseases before they are serious enough to be visible to the human eye. The sensors can also monitor plant growth, helping to enable optimized input amount and timing (for fertilizer, irrigation water, etc.). Using innovative methods for image processing and analysis, as well as for fusing multispectral and spectrometer data, this innovative system allows the accurate and reliable characterization of olive trees.

- **Specifications**
  Scientists started by collecting healthy, dried out, and diseased olive leaves that were also identified by multispectral image analysis. They analyzed the leaves to calculate the spectral signature of a disease (that is, the wavelengths of light reflected by healthy vs. unhealthy leaves). Scientists then used novel machine learning and AI approaches to fuse the spectrometer and multispectral data and accurately classify the leaves. This enables end users to accurately and promptly characterize the state of olive trees based on the wavelength of light they reflect.

- **Impact**
  MyOliveGroveCoach offers an innovative, low-cost, rapid, and readily deployable solution for olive precision agriculture that can enable prompt management of problems and diseases by detecting them before they are visible to the human eye. Since it can help farmers and agronomists determine the amount and timing of pesticides, fertilizers, and irrigation water a grove requires, this innovation can help reduce production costs, reduce the groves' environmental footprint, and increase olive yields. In that way, it can aid in the optimization of olive farming practices, while improving their organization, standardization, and traceability.

- **Filled gaps**
  This innovation can help olive producers detect Verticillium wilt before visual inspections would reveal the problem. In that way, and by helping farmers determine when and how much input their groves require, it can also aid in improving the overall sustainability of the olive food system (in social, health, environmental, and economic terms). Its clear benefits may assist in accelerating the digital transformation of the olive sector and in increasing stakeholders' awareness of new technologies.

- **Limitations**
  Difficulties in the annotation process during the data collection campaigns and a lack of available data sources in scientific literature and from previous research projects.

- **Next steps/potential extension**
  Conduct additional controlled tests to ascertain accuracy of specific results, validate the developed solution for the detection of additional olive plant stress factors, and extend the applicability of the technology to other applications (such as detecting and quantifying frost in citrus) and diseases.

- **Find out more**

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SECTION 3: Machinery

Olive oil has been produced for millennia, and it is sometimes still extracted from olives using traditional millstones and presses. However, starting around the middle of the 20th century, advances in milling technology have been changing the olive oil industry, increasing quality and efficiency. Today most of the world's extra virgin olive oil is made in modern mills using efficient machinery that allows the oil to retain more of its aromas, flavor, and health benefits. Innovators continue to explore possibilities for improvements at the cleaning, crushing (grinding), mixing (malaxing), and separation (centrifugation) stages, sometimes adding new steps, such as depitting and skin removal, in an effort to produce more flavorful, healthier oil. They adapt old machines and invent new ones.

Innovation 8: New washing and drying system for olives in the mill

- **Background**

With climate change making the planet warmer, it is becoming harder to create good quality olive oil, because harvesting at a high temperature does not yield good olive oil--unless one lowers the olive temperature, as this simple machine does.

Image 3: part of the washing and drying system (by Panagiotis Kalaitzis)

- **Keywords**

olive washer, olive dryer, washing and drying system for olives, olive mill, olive oil production, olive milling

- **Methodology**

This invention enables millers to lower the temperature of harvested olives by 2 to 3 degrees Celsius while cleaning and drying olives.

- **Specifications**

The machine uses only clean UV-filtered water in an environmentally friendly small quantity, avoiding phenol loss and waste.

- **Impact**

At a lower temperature, olives tend to yield higher quality olive oil. Drying the olives so no water enters the depitter also helps to produce olive oil with more healthy phenols and aromas. The result is better oil that is likely to bring a higher price.

- **Filled gaps**

Addressing quality concerns, this system is unique in significantly lowering the olives' temperature as it washes and dries them. We are unaware of any other system that does all of this at once.

- **Next steps/potential extension**

This machine could easily be manufactured now if the inventor received adequate compensation.

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Innovation 9: Olive depitter/crusher adapted to remove most of the olive peel, contain no plastic or rubber parts, keep temperature stable, and more

- **Background**
  Normally, the friction in a crusher/depitter increases the temperature by 7 degrees Celsius as the olive paste is made, leading to reduced aromas in the oil. When olives are harvested very early, e.g. in September, more phenols are created in the malaxer if the olive peel has been removed. Machines in olive mills tend to include plastic and rubber parts, but since plastics contain phthalates, which cause reproductive problems and hormone disruption, many prefer to avoid food that has come into contact with plastic.

- **Keywords**
  olive crusher, olive depitter, olive depitter/crusher, olive mill, olive milling, olive oil production, olive oil quality, olive oil health benefits, olive oil phenols

- **Methodology**
  There are five important innovations in this single machine, which was originally just a depitter/crusher, including the temperature stability, removal of the skin as well as the pits, and replacement of plastic and rubber with stainless steel. The machine can also be adapted to work for olives of different sizes. It can now remove 50% of the olive peel, which is enough to make a difference. There is no temperature increase as it works: this invention keeps the temperature in the crusher almost constant.

- **Specifications**
  The adapted version of this machine had all the plastic and rubber removed from the housing and replaced with stainless steel, as various changes were made; only the outside remains the same.

- **Impact**
  Stabilizing temperature, removing olive skin, and avoiding plastic yields higher quality, higher phenolic, healthier olive oil that should bring the producer a better price.

- **Filled gaps**
  This invention addresses problems faced by early harvesters and all olive oil producers who wish to create higher quality, healthier olive oil with a greater appeal for consumers, which generally translates into a higher price for the oil.

- **Limitation**
  This was designed for a medium-sized olive mill; a mechanic would need to figure out how this would work on a larger scale, in a larger mill.

- **Next steps/potential extension**
  The inventor would like to commercialize his inventions but needs financial assistance to do so. He would like to set up his own olive mill using his invented machines and get them patented to put on the market for medium-size producers who want to make EVOO that is both high phenolic and

organoleptically excellent. He has plans ready for several machines and could work with a mechanic to make them, given appropriate compensation.

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SECTION 4: Health Benefit Determination

In recent decades, scientific studies have offered convincing proof that olive oil, a key component of the famously healthy Mediterranean diet, can help prevent or combat a long list of diseases. There is evidence that extra virgin olive oil can help lower inflammation, triglycerides, blood pressure, and blood glucose levels. It can help fight off depression, skin cancer, strokes, osteoporosis, heart disease, breast cancer, type 2 diabetes, rheumatoid arthritis, Alzheimer's disease, hardening of the arteries, and atherosclerosis. Both the European Union and the US Food and Drug Administration (FDA) have officially acknowledged that olive oil can help control cholesterol levels when used to replace animal fat.

Study results increasingly show that many of the health benefits of olive oil come from its phenolic compounds (polyphenols), which have antimicrobial, antioxidant, and anti-inflammatory properties, meaning they help prevent many illnesses, and perhaps even cure some diseases. For example, olive oil phenols have killed cancer cells in test tubes, decreased inflammation as ibuprofen does, and inhibited tumor growth. In 2012 the European Food Safety Authority (EFSA) approved a health claim about olive oil that states, “olive oil polyphenols contribute to the protection of blood lipids from oxidative stress” (EU regulation 432/2012). This means they protect LDL cholesterol from oxidation, thus helping prevent heart attacks and strokes. However, the EFSA limited this claim to olive oils containing “at least 5mg of hydroxytyrosol and its derivatives (e.g. oleuropein complex and tyrosol) per 20mg of olive oil.” (This also includes oleacein and oleocanthal.) There are more of these polyphenols in some olive oils than others; many factors influence an olive oil’s phenolic content. Polyphenol levels must be tested to determine an olive oil’s eligibility for the official EU health claim.

Innovation 10: The Olive Predictor

- **Background**
  Since numerous consumers are willing to pay more for healthy products, many olive oil producers are interested in having their oil certified with the EU’s health claim. To do so, they must produce an olive oil high in certain phenolic compounds. Since harvest time can make a difference in whether they manage to do this, many harvest early. However, if they harvest too early, their yield will be very low. The Olive Predictor offers a solution to the dilemma of when to harvest: it enables producers to predict the healthy phenolic content and the amount of olive oil they will produce before harvesting their olives.

- **Keywords**
  olive oil health benefits, high phenolic olive oil, EU health claim, health claim for olive oil, extra virgin olive oil, olive oil polyphenols, Olive Predictor, Aristometro, oleocanthal, oleacein

- **Methodology**
  The device consists of a miniature mill that includes a mini grinding mill, a mini malaxer, and a centrifuge system capable of producing a sufficient quantity of oil from just 200 grams of fruit. The second part and the great innovation of the system is the Aristometro device, which is small enough to hold in one hand. With as little as 7 grams of oil, in just 15 minutes, this device can predict the oleocanthal and oleacein content of the oil to be produced, and therefore can determine whether the oil is likely to be eligible for the European health claim.

- **Specifications**
  The procedure involves very few olives, a low cost, and a short time for the production and testing of a small amount of olive oil.

- **Impact**
  The Olive Predictor enables producers to make the optimal choice about the harvest time to achieve the best ratio of quantity and quality, in terms of the content of the beneficial ingredients mentioned in the European health claim about olive oil's phenolic compounds – in this case, the oleocanthal and oleacein content. This can lead to a higher selling price for their olive oil.

- **Filled gaps**
  The Olive Predictor takes the guesswork out of the question of when to harvest olives in order to produce the healthiest possible oil, without completely sacrificing quantity.

- **Limitation**
  The Olive Predictor does not measure all the oil's phenols; nor does it evaluate its taste or aroma. To use the Olive Predictor at this point, farmers must send freshly harvested olives to a lab at the University of Athens; the olives should be tested within 24 hours of the harvest for best results.

- **Next steps/potential extension**
  Including the innovative, patented Aristometro device to measure the oleocanthal content of olive oil—which is already available for general use--the Olive Predictor has so far been used only in the laboratory. However, the Olive Predictor is ready to bring to market, lacking only the required investors and collaborating company. The goal is to make it a compact instrument that is commercially available for use everywhere, even in olive groves.

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SECTION 5: 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. Researchers, growers, breeders, and conservationists want to know which olive cultivars are growing in which areas and conditions in order to assess biodiversity, consider how to prepare for climate change, and prepare to preserve genetic resources. Cultivar identification is also fundamental to overcoming confusion concerning varietal names, a common obstacle in current olive research. Innovative ways of identifying olive cultivars are especially useful for all of these reasons, and more.

Innovation 11: 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):

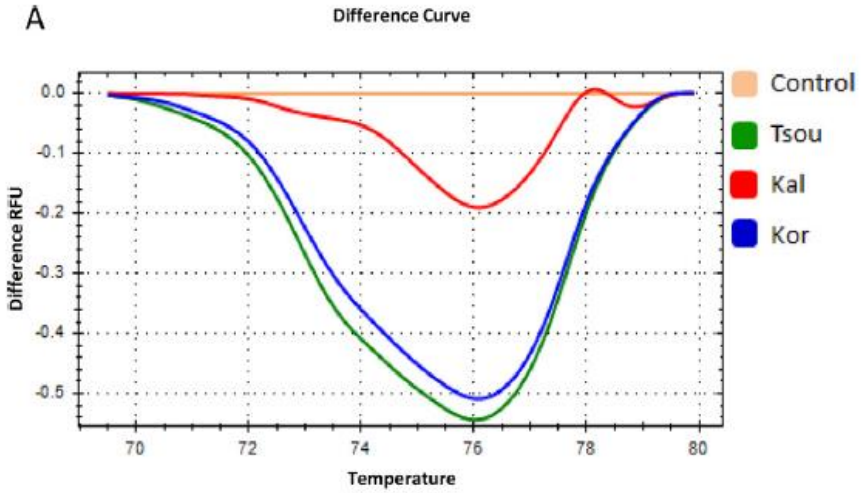

Image 4: a graph illustrating the difference between several olive oil varieties (by Panagiotis Kalaitzis)

- **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.

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  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 12: oliveID, an image-based tool to identify olive cultivars based on a numeric analysis of size, shape, and structure

- **Background**

  The morphological analysis of olive leaves, fruits and pits—the analysis of their size, shape, and structure--can be an efficient tool to help characterize and discriminate between cultivars, as well as establishing relationships among them. The olive cultivar identification tool described below is based on a simplified scheme that has been adopted by the International Union for the Protection of New Varieties of Plants (UPOV).

- **Keywords**

  olive cultivar identification, olive variety identification, morphological analysis, olive fruit, olive leaf, olive endocarp, types of olives, identifying olive variety

- **Methodology**

  To get started with this new automated methodology, the user takes a picture of an olive fruit, leaf or endocarp (pit). The raw image is transformed into a black and white picture. Our new tool uses that picture to quantify many shape related features of the fruit, leaf and endocarp based on strictly defined mathematical specifications, then provides accurate, objective numerical measurements corresponding to the leaf, fruit, or pit's form and structure. Finally, contemporary computer programming techniques and innovative automated algorithms classify the numerical measurements according to the database with the morphological characteristics of each olive cultivar that it is available at the Mediterranean Agronomic Institute of Chania, Greece.

- **Specifications**
  For best results, the fruit, leaves, and pits should be collected from a specific part of the tree at a particular stage of maturity. The pits should be separated from the pulp with a coarse fabric, then soaked in 10% bleach for 5 minutes. For the photos, samples should be placed on top of glass, with the camera fixed on a solid arm above it; a light-blue paperboard makes the best background. Adjustments must be made to transform the image into a black and white photo.

- **Impact**
  Feasible modern image-based methodologies to identify olive cultivars fast and accurately will be highly valuable for farmers, millers, buyers, authorities, and researchers, among others. In the food industry, for example, this new tool could facilitate the sorting of olive batches to obtain monovarietal olive oil at the mill and improve the accuracy of postharvest classification of olives according to such features as fruit surface size and condition for table olives or olive oil.

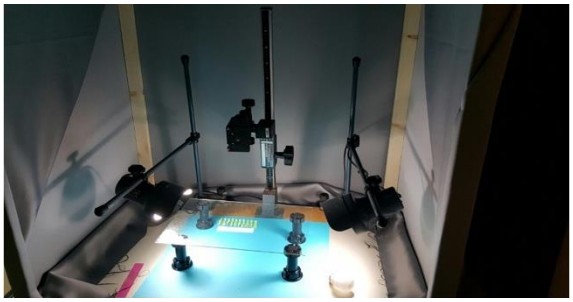

Image 5: olives prepared for photography (by Konstantinos Blazakis)

- **Filled gaps**
  People commonly identify olive cultivars based on the appearance of fruit, leaves, pits, and other parts of the plant. However, visual observations require experience and can be subjective, inconsistent, and inaccurate. This integrated automated tool will characterize and identify a large set of olive cultivars more accurately.

- **Limitations**
  The decisions the user must make about which fruit, leaves, or pits to use and how to make adjustments to the image can introduce a subjective element into the process. Care in selection, photography, and adjustments may be challenging for some. Programming currently uses the MATLAB environment; more work will be required for the method to use open programming libraries as well.

- **Next steps/potential extension**
  The next step is the implementation of this innovation in a smartphone application that can be used by anyone anywhere, even in the olive grove. The plan is to drastically simplify both the process and the type of photography required.

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Innovation 13: 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 chromatographer 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 6: Preparation for Climate Change

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.

Innovation 14: Grafted olive trees resistant to the effects of climate change

- **Background**
  Some olive cultivars are far more tolerant of the types of abiotic stress caused by climate change than others. These cultivars will be used as rootstocks, and commercially popular olive varieties will be grafted onto them, creating new stress-tolerant cultivars.

- **Keywords**
  Olea europaea, olive trees, olive growing, olive cultivation, traditional olive cultivars, climate change, global warming, abiotic stress, grafting, rootstocks

- **Methodology**
  Several traditional varieties with higher tolerance to salinity and drought, including Lefkolia, Arvanitolia, and Leccino, are being used as rootstocks for grafting with commercial cultivars. Before grafting, genetic and morphological characterization is carried out, along with an evaluation of quality traits and abiotic stress tolerance. Older plants are evaluated physiologically for yield and oil quality.

- **Specifications**
  The evaluation of rootstock performance is under way and will be performed on commercially important varieties like Koroneiki, Kalamon, Throumbolia, and Tsounati.

- **Impact**
  Generating novel grafted cultivars with abiotic stress tolerance and possibly increased quality traits will expand the current cultivation zones in Greece and make olive production more resilient to future climate change. This will help reduce the pressure of climate change on the olive oil and table olive sectors, while offering products to the public that are similar to those they especially appreciate. In addition, the characterization and registration of rootstocks will provide a reliable source of information for numerous companies in Greece and abroad that are involved with olive products.

- **Filled gaps**
  This project will provide a wealth of new information about previously unknown cultivar-rootstock combinations, Greek olive cultivars that have not yet been genetically or physiologically characterized, and the combining ability of cultivars that have not been grafted together before.

- **Limitations**
  To date, the cultivars and rootstocks being used derive mainly from Greece, and not from the broader Mediterranean region; an expansion beyond Greek varieties would allow a more conclusive assessment. A limited number of geographical locations have been used as testing sites so far, particularly in northern Greece, where cultivation is expected to expand in the future.

- **Next steps/potential extension**
  The novel varieties and products created will be evaluated in terms of cultivation utility and nutritional quality, respectively. Investments will be welcome from both public and private parties, domestically and internationally. Future studies incorporating an even larger collection of varieties and cultivars from throughout the Mediterranean basin will expand the repertoire of cultivar-rootstock combinations on a much larger scale.

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SECTION 7: Re-Using Traditional Practices in Agroforestry

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 and on the island of Kea in the Aegean Sea, 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. In this way, they ensure a steady and enhanced economic return every year, irrespective of weather conditions or other types of hazards. Lately there has been a gradual abandonment of this kind of combined land use, with a tendency to cut down the old-growth oak trees and establish a monoculture of olive groves, which are expected to provide higher income with less work (compared to livestock grazing). Another problem the system faces is low natural regeneration of trees. In this context, a return to productive old ways can become a useful innovation that allows livestock breeders to both increase their incomes from the production of high quality products, and help preserve valuable forest lands.

Innovation 15: Thinning and pruning trees in silvopastoral systems

- **Background**
  Traditionally, Greek farmers used pruned branches from forests for many purposes. With such practices forbidden on public lands, this is no longer done very often, and forest maintenance has become a growing problem. However, an innovative return to this past procedure—at least on private land, for now—can offer numerous benefits.

- **Keywords**
  oak, silvopastoral system, grazing, regeneration, financial support, agroforestry

- **Methodology**
  On private farmland, farmers can prune the trees and use the pruned branches for many purposes. Small branches can be used as animal feed. Depending on their quality and size, larger branches can be used for fences and as firewood. There are indications that this procedure would not harm the tree but, on the contrary, will promote sprouting.

- **Specifications**
  Oak trees must be pruned in a specific way to avoid damaging tree vitality, following the advice of experts. The correct procedure creates a round form of the tree that is typically seen throughout Greece.

- **Impact**
  This procedure enables farmers to save money on animal feed, fencing, and firewood and/or to earn extra income by selling pruned branches to be used in those ways. It is hypothesized that this pruning will also have a positive effect on acorn production. Moreover, this natural clearance will remove flammable biomass, thus reducing forest fire risk. At the same time, there are indications that it promotes resprouting of small branches. The semi-circular crown provides shelter for numerous birds and other fauna species, increasing biodiversity. By providing financial incentives for farmers to aid in forest preservation, the practice supports both farmers and the valuable agroforestry systems that are closely linked to the natural and cultural heritage of Greece, as well as the rural economy. Finally, it motivates farmers to preserve rather than remove old growth trees.

- **Filled gaps**
  Although agroforestry systems provide numerous high-quality products, mostly organic, including dairy, meat, honey, and herbs, livestock breeders and farmers are plagued by the low return they get for their products. Since tree pruning can benefit farmers financially, it can help solve both

financial problems and forest maintenance challenges. An awareness of such benefits could provide much-needed motivation for farmers to maintain old growth trees on their properties.

- **Limitation**
  For now, this procedure is only permitted on private property. This practice is not allowed on public lands nowadays, but it should be legalized and reintroduced as an incentive to local farmers to preserve these valuable ecosystems throughout the country.

- **Next steps/potential extension**
  This has been tested only in private silvopastoral systems. This could be tested further if funding became available. Another project is testing the use of soil covers to decrease soil moisture evaporation, decrease flammable biomass buildup, and enhance regeneration; this practice could be combined with pruning and thinning.

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Innovation 16: Clearing shrubs and sowing a mixture of grass and legumes in silvopastoral systems

- **Background**
  Farmers on the Aegean island of Kea used to sow a variety of intercrops between oak trees for many uses, including cereals for human consumption and as animal feed. During a recent stakeholders' meeting on the island, farmers expressed their willingness to investigate alternative ways of using valonia oak silvopastoral systems to enhance their income once again. One possibility that was discussed is the cultivation of promising forage grasses under valonia oak trees. To investigate the effect of oak trees' shade on grass development, a controlled experiment was established in a silvopastoral system with valonia oak trees in the southern part of the island. In this system, the valonia oak forest is used for both grazing and acorn cup collection.

- **Keywords**
  oak, agrosilvopastoral system, silvopastoral system, grazing, feed, financial support

- **Methodology**
  Clear the shrubs in a traditional oak agrosilvopastoral system, then sow a mixture of legumes and cereals there. It can be harvested or used for grazing at the end of the growing season.

- **Specifications**
  A variety of species can be used as intercrops between the trees, depending on the region.

- **Impact**
  Even if the shade cast by the trees limits the production beneath them, the overall production of forage is likely to increase, making this a money-saving plan, according to experiments in Greece and other countries. Another important positive effect of this procedure is that farmers remove flammable biomass when they clear the shrubs, thus reducing the risk of fire and helping to preserve the forest.

- **Filled gaps**
  This traditional approach, which was used in the past in all silvopastoral systems, encourages the preservation of silvopastoral systems by their final users, the farmers, by providing financial incentives for their preservation. This is important since these valuable agroforestry ecosystems are closely linked to Greece's natural and cultural heritage. They also provide numerous high-quality, mostly organic products, such as dairy, meat, honey, and herbs, thus contributing a great deal to the rural economy.

- **Limitation**
  The intercropping species must be chosen carefully by experts to ensure compatibility with local conditions and probably lower light availability.

- **Next steps/potential extension**
  To evaluate the possibility that agrosilvopastoral systems can provide multiple products while supporting local stakeholders, an experiment was established under the framework of the AGFORWARD project. This practice has also been tested in other countries. The results have been encouraging in all cases. Different seed mixtures could also be tried in different areas.

- **Find out more**
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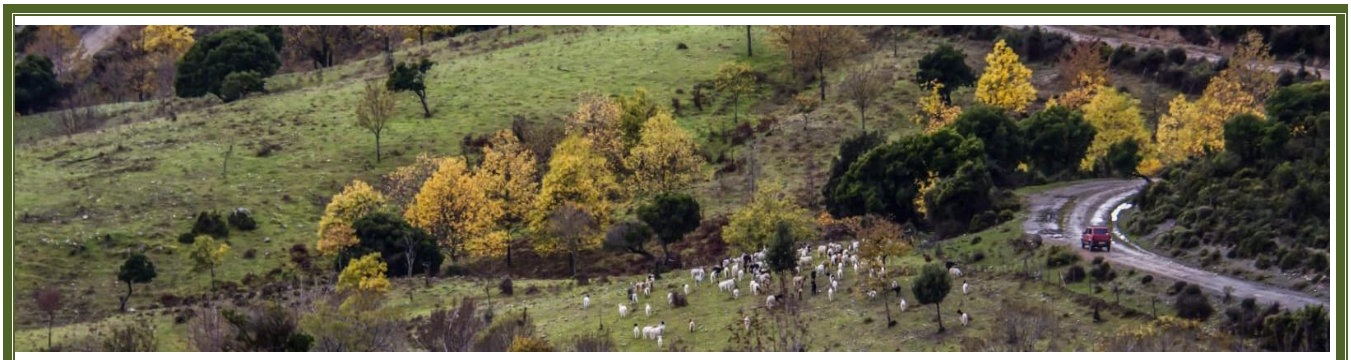

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