



Monitoring Pistachio Orchards

REMOTE SENSING IMAGE ANALYSIS, GIS, AND ICT FOR PRECISION FARMING

Project name:

VET Demonstration Partnership for Pistachio Farm in Armenia:
Geospatial Approach

Project acronym: VETfarm

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Course Description

Remote Sensing Image Analysis, GIS, and ICT for Precision Farming

VETfarm Project

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1. Executive summary

The course is designed for vocational training in the application of geospatial technology within the VETfarm project, an Erasmus+ capacity building initiative. The project focuses on integrating Remote Sensing (RS), Geographic Information Systems (GIS), and Information and Communication Technologies (ICT) to enhance precision farming techniques, specifically for pistachio orchards in Armenia. It details the development and application of Management Zones (MZ) to optimise resource allocation. It introduces the "Precision Farming Platform" (PFP), a movable sensor-based system designed for automated data collection and analysis. The course emphasises practical skills development, cost-effectiveness, and knowledge dissemination to enhance sustainable agricultural practices in the region.

The main objectives are:

- Build capacities to use integrated remote sensing and GIS data, and interpret them for pistachio orchards/trees monitoring;
- RS data analysis and modelling for Precision Farming (PF).
- Enriching EO data through IoT sensor networks, with a particular focus on pistachio crop conditions monitoring (tree height, canopy volume, pest, weed, etc.).
- Monitoring pistachio orchard (soil, trees) and processes (user/location/time-specific).
- Selection of algorithms, parameters, and visualisation for crop monitoring and assessment, including uncertainty analysis. With correctly validated algorithms and parameters, the use of agricultural inputs, such as water, can be optimised in a spatially variable manner using homogeneous production zones, known as Management Zones (MZ).
- The course will cover practical exercises on how to use cloud-based services/tools for crop monitoring, removing the complexity of processing large volumes of satellite data.
- The target audience includes vocational students, instructors, professionals, and technicians within the VETfarm Network, with a direct connection to a demonstration setup in Armenia.

- Executives?

- To be updated

2. Introduction

This course is designed to provide vocational training in Remote Sensing Image Analysis, specifically for Precision Farming. It is part of the VETfarm project, an Erasmus+ Capacity Building initiative aimed at establishing a "Demonstration Partnership for Pistachio Farming in Armenia: A Geospatial Approach." The course builds upon the Remote Sensing and GIS courses created within the

VETfarm project framework, which serve as prerequisites. It emphasises the development of both theoretical knowledge and practical skills.

The primary objective of the VETfarm project is to build capacities in using integrated remote sensing and Geographic Information System (GIS) data for monitoring pistachio orchards and applying precision farming techniques.

The course focuses on using integrated remote sensing and GIS data to monitor pistachio orchards, including tree health, soil conditions, and water needs. Students will learn to analyse satellite imagery, integrate data from IoT sensors, and apply cloud-based tools to apply Management Zones (MZs) for optimised agricultural inputs, to improve efficiency and sustainability in farming practices.

The course focuses on building capacity to utilise integrated remote sensing (RS) and Geographic Information System (GIS) data for precision farming, with a specific focus on **monitoring pistachio orchards and trees**. It emphasises the analysis, modelling, and enrichment of Earth Observation (EO) data through IoT sensor networks to optimise agricultural inputs and monitor crop conditions.

A significant emphasis in this integrated course is on Knowledge Management in Pistachio Orchards. This course is dedicated to disseminating knowledge and promoting collaborative learning. It introduces participants to incorporating movable sensor platforms and digital tools in managing pistachio knowledge through RS and geoinformation systems. A key distinguishing characteristic of this course is its direct connection to the demonstration setup in Armenia. Participants will have the opportunity to manage a pistachio farm, thereby gaining practical and interactive training locally.

These courses will be linked to the equipment, staff and students training, and internship programs developed within the VETfarm project, promoting practical applications and collaboration. After identifying the context and updated needs of growers—considering relevant factors such as pests and management practices—the course will develop infrastructure, knowledge, and digital tools. These will evaluate the impact of pistachio farm management practices on tree/fruit growth and health using Mobile Labs. This closed-loop measurement, model updating, and action require skilled personnel.

Management Zones (MZ) for Precision Farming: A Remote Sensing Approach

Concept: MZs are defined as "homogeneous production zones" within a field or orchard, identified based on similar characteristics like "yield-limiting factors."

Delineation: The course covers "delineating management zones (MZ) in pistachio fields using Sentinel-2 satellite data, aiming to optimise management practices." This involves analysing satellite and GIS data to identify specific regions with homogeneous characteristics, typically categorising them into "High yield," "Medium yield," and "Low yield" zones.

The generation of MZ is based on the WI tools and methods in information extraction from satellite data (see previous RS and GIS courses). For this, special attention is given to free, open-source systems for viewing, interpreting, and generating MZ.

Sampling Strategy: MZs are crucial for guiding sampling efforts. "Samples should always be taken from homogeneous areas or segments (MZ) to ensure reliable statistical results." A general guideline suggests dividing fields into three segments and taking at least three samples from each, totalling nine samples.

Application: MZs enable "spatially variable application of inputs," such as water and sampling efforts, leading to more efficient resource allocation and reduced waste.

Note:

- Management zones in the context of an orchard are defined in three dimensions plus time (3D+Time). These zones are influenced by the "resolution" of the "actor machines." To establish homogeneous regions, quad tree and voxel tree software can be employed. However, since trees are arranged on a planting grid, it is necessary to adapt the segmentation criteria from a "continuous" model to a grid-based approach.

3. Precision Farming: Geospatial Technologies for Pistachio Orchards

The goal is to integrate geospatial technologies for precision farming. The central theme of the course is the integrated application of Remote Sensing (RS), Geographic Information Systems (GIS), and Information and Communication Technologies (ICT) for optimising agricultural practices, specifically in pistachio farming. The course aims to "Build capacities to use integrated remote sensing and GIS data, and interpret them for Pistachio orchards/trees monitoring." This integration enables a data-driven approach to agriculture, shifting away from traditional, uniform treatments.

Focus on pistachio crop monitoring and management: While the principles are broadly applicable to precision farming, the course has a specific emphasis on monitoring pistachio crop conditions. This includes "canopy volume, weed, pest, etc.," and "Monitoring pistachio orchard (soil, trees) and

processes (user/location/time-specific)." This specialised focus ensures practical relevance for the VETfarm project in Armenia.

Optimisation of agricultural inputs through management zones (MZ): A key objective is the development and utilisation of MZ. With correctly validated algorithms and parameters, the use of agricultural resources, such as water and sampling, can be optimised in a spatially variable manner using homogeneous production zones, known as Management Zones (MZ). Satellite and GIS data are instrumental in identifying these zones, leading to more efficient resource allocation and reduced waste.

Leveraging cloud-based services and EO data: The course emphasises practical application through the use of cloud-based services/tools for crop monitoring (e.g., WI tools). This approach aims to simplify the process by "removing the complexity of processing large volumes of satellite data." Students will learn to work with "near-real-time EO data," including Sentinel-2 data.

Data enrichment with IoT sensor networks: To enhance the accuracy of monitoring, the course incorporates the use of IoT sensor networks. Enriching EO data through IoT sensor networks, with a particular focus on pistachio crop conditions monitoring and integration of MZ and climate data. This highlights the importance of a multi-source data approach for comprehensive insights.

Practical skills and decision support: The course is designed to be highly practical, with a significant portion dedicated to laboratory hours and exercises. Intended learning outcomes include the ability to "Understand a user-defined location (RoI) and pistachio health issues and then provide a selection of images for RoI for further image analysis." Furthermore, the course focuses on "Computer-assisted information extraction from remotely sensed data for decision support, including case studies based on the needs of the Under Sun (Case Studies to identify pest and water deficiency or surplus, and weed infestations)."

Cost-Effectiveness: A significant benefit highlighted is the "cost-effective basis" of using Remote Sensing Image Analysis in a GIS environment for Precision Farming. This implies that the technologies and methods taught can lead to economic advantages for farmers.

4. Integrating RS&GIS for Precision Agriculture Solutions

This section emphasises monitoring pistachio trees, preparing case studies for training, and acquiring fieldwork data, with an emphasis on skill development.

In the next section, the challenges within the pistachio industry, mission planning, the definition of pest and weed problems in pistachio orchards, data

acquisition, including the use of remote sensing and drone data, as well as digital tools for monitoring, detecting, classifying pistachios, creating management zones, and pest detection, will be discussed.

4.1 Pest management: *Agonoscena pistaciae* (Pistachio Psyllid)

Significance: The pistachio psyllid, *Agonoscena pistaciae*, is identified as a "serious pest" causing "significant foliar damage due to its sap-sucking nymphs that secrete wax and honeydew," ultimately impairing photosynthesis and reducing nut yield and quality. It is one of the most economically significant pests in pistachio orchards.

Detection Challenges: Measuring psyllid density remotely requires detecting "subtle changes in leaf reflectance or chlorophyll content caused by psyllium infestation" using high-resolution cameras or RGB/multispectral sensors on drones or movable platforms.

- Multi-stage Detection Strategy: MZ Creation: First, MZs are created using Sentinel-2 data to identify "weak areas in the orchard" where pest issues are likely.
- Leaf-level Detection (Nymph/Egg Stage): "In each MZ, a chassis cage will be constructed with cameras for digital control of the pest on leaves (compound leaves) from different directions... for the identification (detection and classification) of the pest." This involves counting individuals on leaf surfaces.
- Adult Stage Monitoring: A method will be developed to "monitor and determine the population change of the adult stage of the pest in the orchard to inform further action by farm managers (such as chemical control)."

Sensor Considerations: Practical considerations for sensors, including autofocus, close-range focus, wired/wireless connectivity, ruggedness, accuracy, affordability, and digital communication for remote data access. Note challenges with motion blur and stray light. Sample images of psyllids on leaves are provided, noting the ability to identify pests visually and with bounding box overlays from Matlab-developed code.

AI Integration: "Edge cameras with AI - AI-driven LoRaWAN pests detector using RGB AI Sensor via App" are proposed for fast image analysis and automated pest detection.

Pest Models and Spray Timing: "Pest models are customised to individual orchards, allowing for fine-tuned sprays for maximum impact and potentially reducing the number of treatments." These models, combined with climate information (e.g., degree-day modelling), provide "accurate and reliable risk levels sooner, making spray scheduling and logistics management easier."

As a result, this section showcases the precision agriculture solutions for fruit trees using IoT sensors, machine learning, and big data analytics. Key case studies include insect pest management through movable platforms and sensors, ..., plant stress monitoring to optimise irrigation. The VETfarm partners emphasise hands-off setup, installation and maintenance of sensor solutions for pistachio growers.

The pistachio growers in the established VETfarm network need to measure the density of psyllium or similar pests and diseases in the pistachio orchards using remote sensing technology to achieve accurate measurements.

Measuring Psyllium Density in Pista Fields Using Remote Sensing

Psyllium, a pest, can significantly impact pistachio yields. Can monitoring psyllium density via remote sensing be achieved with high-resolution cameras mounted on a stick or RGB/multispectral sensors on a drone? We need to detect subtle changes in leaf reflectance or chlorophyll content caused by psyllium infestation.

A literature review on the accuracy achieved based on the resolution of the sensors and the method used, if any, is presented below.

4.1.1 A review on the biology, ecology, and management of *Agonoscena pistaciae*

It has been determined that there are more than 100 harmful insect species in pistachio fields in Iran, and 20 of them cause economic damage and produce a 50% loss of product (Davatchi, 1958).

The VETfarm team in Armenia reported in 2025 that there are some harmful insect species in the study area in the Armavir region, and *Agonoscena pistaciae* is one of them. **Topics for discussion during the training workshop in Yerevan should focus on identifying the most economically significant ones.**

Agonoscena pistaciae Burckhardt & Lauterer (Hemiptera: Psyllidae), commonly referred to as the pistachio psyllid, is a serious pest of *Pistacia vera* L. (Sapindalis: Anacardiaceae) throughout the Middle East and Mediterranean basin. This pest was first reported by Keriokhin (1946) from both domesticated pistachio (*P. vera*) and wild pistachio (*Pistacia mutica*) in Iran (Takaloozadeh, 2008). Known for its rapid population growth and multiple generations per year, this pest causes significant foliar damage due to its sap-sucking nymphs that secrete wax and honeydew. These excretions contribute to the development of black sooty mold, thereby impairing photosynthesis and reducing nut yield and quality. Because of its economic importance, sustainable management approaches are necessary, and these must combine a deep understanding of the insect's biology, routine field

monitoring, and the application of modern technologies such as remote sensing.

The attached PDF file contains a review of the biology, ecology, and management of *Agonoscena pistaciae*.

Link: tbd

Link: Relevant academic papers, industry reports, and publications reviewed.

Pest development and control require nonlinear system models (population growth, simulations, etc.). How can we control a population (not eradicate it) to get reasonable harvests?

4.2 Requirement analysis for skills development

In this section, a practical infrastructure and sensor design and platforms for quality data acquisition on *Psyllidae* will be discussed. This will be used to determine the population development of *Agonoscena pistaciae* through field studies, sampling of the adult stage, the nymph and egg stage of the pest through remote sensing techniques.

First, Management Zones (MZ) will be created in a pistachio orchard using the Sentinel-2 satellite data, using the WI tools discussed above. This part of the course deals with the techniques and applications of generating MZ. MZs are defined as sub-units of farm fields with a relatively homogeneous combination of yield-limiting factors. Each zone can be managed with a different but specific single-rate management practice to maximise the efficiency of farm inputs in the context of precision agriculture. Based on the pistachio farm management inquiries discussed above, phenological information and climate information (drought) are vital factors in MZ delineation. In this context, MZ applications are:

- Identify MZ with low expected yield (weak areas in the orchard) in confirmation with the farm manager. Detect patches of productive and unproductive trees and their variations.
- identify sample sick and low-fertile trees in weak MZ together with the farmer manager and local experts (Expert knowledge),
- How accurately can the trees be compared with high and low-load (yield) (fertile and low-fertile trees) using Mobile Labs?

In this part, we generate MZ based on the open-source Sentinel-2 satellite data for variable-rate applications.

As discussed above, the generated MZ will help identify where representative yield/pest samples should be taken. A general guideline is to divide fields of

interest into three segments, with at least three samples taken from each segment. This results in a total of 9 samples (3 x 3), unless the differences between the regions or zones are not statistically significant.

Second, in each MZ, a chassis cage will be constructed with cameras for digital control of the pest on leaves (compound leaves) from different directions under the chassis during the pistachio growth stage. This stage is for the identification (detection and classification) of the pest. Additionally, the lifespan of *Agonoscena pistaciae* at different temperatures and growth stages will be considered. In this stage, the pest counting (observed significant differences in terms of colour and size) and their distribution will be done in each chassis cage. The counts of the egg and nymph stages of the pest will be made by counting the individuals on the lower and upper surfaces of the compound leaves.

Third, a method will be developed to monitor and determine the population change of the adult stage of the pest in the orchard to inform further action by farm managers (such as chemical control), as well as post-action monitoring and impact assessment.

Feasibility of use in the field, manual phase:

How to reach the leaves?

- Most likely to be affected at the top, we can start with a manually controlled telescopic "selfie" type stick or pole.
- Wear goggles as a monitor for guiding the 'camera'?
- Movable portal system with all your sensors, including RGB camera with (low/high) resolution, focused at a short distance, position, look angle, plant ID, date + time stamp. There is also a problem with stray light that can be overcome. The low resolution may be an advantage for cameras or camera boards with GPU edge computing. These could do fast image analysis. The required spatial references, GPS, magnetic field, and pressure can be added as HAT boards. We can make a preliminary table with pros and cons. The weight factors are up for discussion.
- The cost-benefit for the pest detections, based on the need of the UNDER SUN company and network!
- The mechanical phase could be implemented as a self-balancing mobile selfie stick.
- The positioning problem relative to moving leaves could be solved by taking video bursts followed by algorithmic selection of suitable data [experimental].
- 3D plant models
- Edge cameras with AI - AI-driven LoRaWAN pests detector using RGB AI Sensor via App

Requirements and considerations:

Using different sensors and devices, we want to monitor real-time data on soil, pistachio, and pest, and environmental indicators, meteorological information, and more, providing accurate references for pistachio production and environmental monitoring. In this way, the VETfarm team can help support the pistachio industry achieve practical and affordable solutions.

Practical considerations for leaf and canopy level sensors, along with the requirements for easy installation on a movable platform system, data collection, and sharing the data:

- Pan & Tilt (PTZ),
- Autofocus, and
- Effective focus at very close range (less than 5 inches / ~12 cm),
- Wired or wireless
- Rugged close-up pest monitoring
- Accuracy, reliability, ease of use, and installation convenience.
- Affordable costs
- Easy way to power sensors
- Digital communication and data transmission (remote access to data on the cloud), and management (data loggers!).
- Can we connect these sensors to a network to create an IoT sensor network?
- Training and technical support for the installation, maintenance, and operation of these sensors for ANAU and UNDER SUN.
- What is the warranty for these sensors?
- Waterproof and weatherproof features
- Triggering it from a smartphone as an alternative to drones.

4.3 Preliminary results

Mobil Labs in Orchards: Enhance traditional farm management by incorporating cutting-edge innovative technologies and mechanisation. Introduce concepts like measurement and control, AI, precision agroforestry practices, sensor-based monitoring, and data analytics to optimise input and address challenges such as pest infestation and water scarcity. In this course, we will explore the design and setup of mobile labs. The labs include portable sensors that can be used on a farm to connect with the local community. Using present-day technology, such as combining Remote Sensing, IoT, AI, and geoinformation, it is possible to monitor the growth and development of plants with economic and environmental significance.

Equipment Procurement Strategy: Conduct a comprehensive market analysis to identify cost-effective sensor selection and integration systems, including soil and plant sensors, platform and pole-mounted sensors and cameras for monitoring pests and diseases. Additionally, establish a laboratory for testing and developing customised technological solutions. Implement Mobile Labs for testing and experimentation, using IoT-enabled systems to detect stress factors such as insect infestations, diseases, and water deficiencies. This approach aims to monitor early signs of disease outbreaks, facilitating proactive and targeted interventions.

Sample psyllid images:

Below is a figure displaying seven RGB images taken in the field for the pest detection challenge.





Figure X: The size, colour, and distribution of *Agonoscena pistaciae* and their droppings on leaves as a result of feeding adults and nymphs(acquired visual images using a cell phone).



Figure XX: Overlay bounding boxes after running a Matlab-developed code over seven raw RGB images, giving an overview of RGB + bounding boxes. Image seven is shown for easier discussion.

It is up to the users to decide whether this version is sufficient, given the other challenges in data acquisition.

From an academic/teaching point of view, we suggest:

- For skill training, this could be good enough, quick/short development time, no tuning of methods and parameters after initial human intelligence-based development.
- academic/course materials on knowledge-based image analysis/publication. We could add a search for an optimum confusion matrix result. Optimum is to be defined by a user.

Practically:

- The present manually acquired data has to be stored in a GIS-type data structure with position, look angle, plant ID, date + time stamp. Keywords to retrieve raw and processed data.
- Data acquisition with any camera (RGB sensor, iPhone, borehole inspection, etc.) has an unsolved problem of keeping leaves still relative to the camera to avoid motion blur (investigate tolerances).

Start with a manual + "selfie stick" type of extension to sample high leaves. How does the pest population density increase with Z or with outward growing "wave"? If available, experiment with, for example, a cherry picker or a small crane. Drones give extra turbulent leaf movement!

Quality data acquisition of leaf damage due to possible virus infection, etc., should be the first step for the data analysis part to make sense.

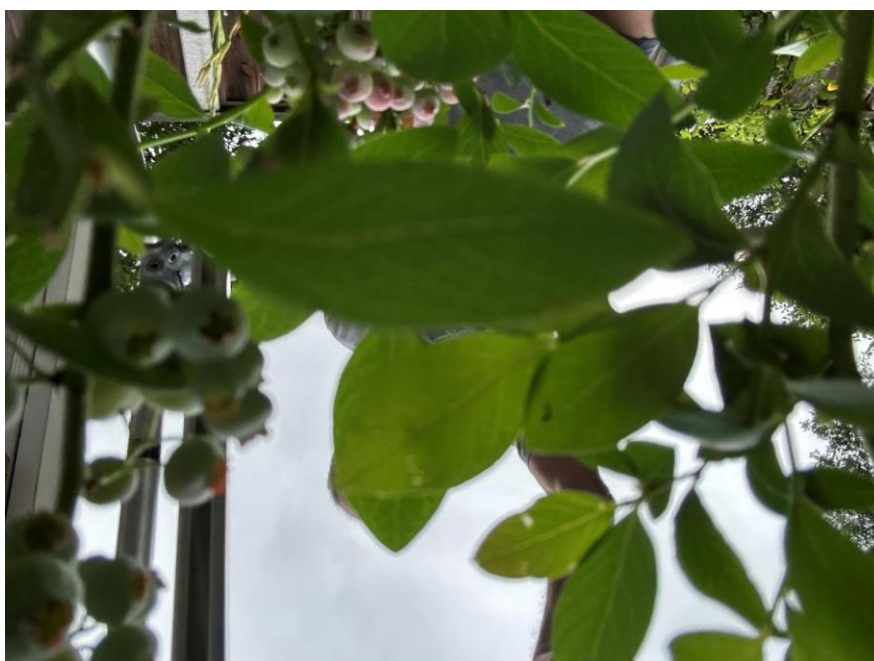
What is the priority and the next priority?

Still to do: configure the sensors, such as an RGB camera or an endoscope camera, for portable/field use.

Review the data acquisition process and the resulting images.

Showcase typical acquired images per sensor and challenges.

For example, the below figure, when displayed at 100%, shows an iPhone picture that clearly shows a problem with the autofocus and a preference for a considerable object distance. But if we fix the focus, it will provide 4x better linear resolution than the borehole/endoscope camera.





The borehole camera has a much lower resolution, but the focus at short distances is better.

There is also a problem with stray light that may be overcome.

The low resolution may be an advantage for cameras or camera boards with GPU edge computing. These could do fast image analysis.

The required spatial references, GPS, magnetic field, and pressure can be added as HAT boards.

We can make a preliminary table with pros and cons. The weight factors are up for discussion.

These results will guide us to plan for an optimum setup and chassis or moveable portal.

4.4 Mobil Labs and Precision Farming Platform (PFP)

Design and setup 'Precision Farming Platform (PFP)'

Concept: "Mobile Labs" and a "Precision Farming Platform (PFP)" are introduced as practical, portable systems for on-farm data collection and experimentation. These "incorporate cutting-edge innovative technologies and mechanisation" including "measurement and control, AI, precision agroforestry practices, sensor-based monitoring, and data analytics."

Design and Functionality: A multi-functional chassis, developed by AgriWatch and adaptable for pistachio trees, serves as the PFP. It can integrate various sensors (RGB, multispectral, depth cameras, infrared radiometers) for detailed crop monitoring, including pest detection.

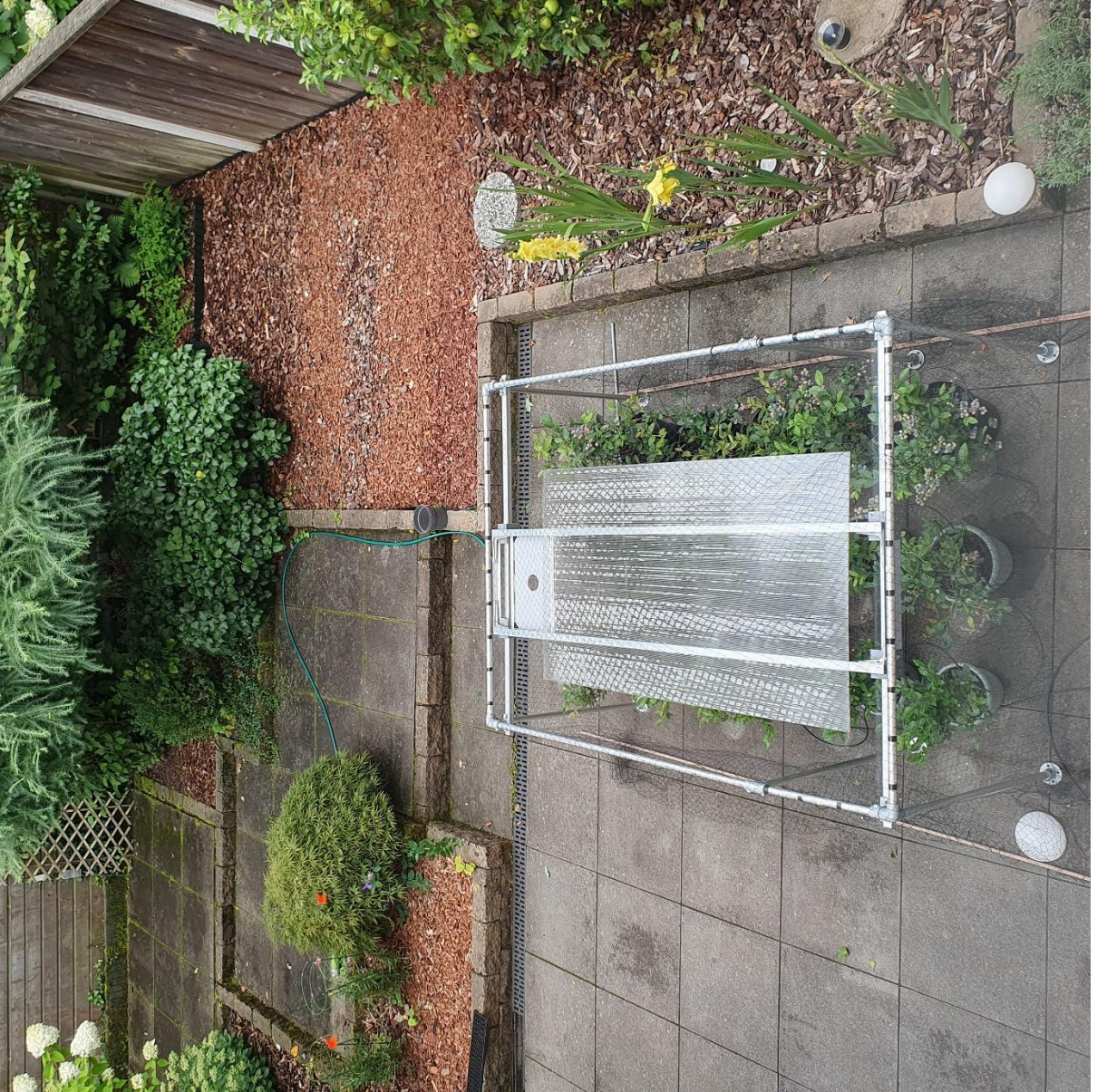
Advantages: The PFP enables "standardised sampling" (e.g., 3m x 3m grid) within MZs, allowing for manageable data collection and comparison of health metrics across the farm. It also facilitates the evaluation of "impact of farm management practices, specifically pest management and pesticide application, on plant growth and health under controlled conditions."

Assessing the health and conditions of fruit trees is crucial for maintaining plant/fruit quality and yield. However, measuring health across the entire farm and considering all relevant factors presents a significant workload using ground sampling, especially when considering the manual inspection involved (for checking the pest infestation). To streamline this process, a standard sampling measure of, e.g., 3 meters by 3 meters, has been proposed by AgriWatch using the delineated MZ by **WI tools** using Sentinel-2 multitemporal data and can be improved using drone images. This standardised sampling allows for practical and manageable (considering labour requirements) sample data collection, facilitating the comparison of health metrics across the farm without the exhaustive effort required for a comprehensive analysis of all sections.

A movable sensor platform was developed in the Netherlands at AgriWatch for this sampling, within blueberry plants, to demonstrate the necessary hardware resources and practicality. This chassis cage with a movable sensor platform is referred to as the 'Precision Farming Platform (PFP)'. This platform can easily be adapted for pistachio trees in the UNDER SUN farm.

Multi-Functional Chassis:

The multi-functional chassis design can be adapted for various applications in monitoring fruit trees and pistachios. The design platform aims to provide cost-effective, data-driven solutions for sustainable pistachio farming, leveraging cloud-based tools, IoT sensor networks, and mobile lab setups for real-time monitoring and decision support.









Anti-bird net: Cover for fruit trees to protect from birds

Updated chassis frame with wheels, used in conjunction with a depth camera. Data requires MATLAB for reading and processing.





In conclusion, the ongoing assessment of pistachio health and conditions and the testing of chemical application methods are critical steps toward improving farm management. The use of standardised sampling, combined with IoT remote sensing and imagery analysis and targeted pest identification, offers a practical and cost-effective approach to understanding and addressing the challenges faced on the farm. Continued monitoring and adaptation of these practices will be key to enhancing yield and ensuring the long-term sustainability of the pistachio orchard.

Additionally, the impact of farm management practices, specifically pest management and pesticide application, on plant growth and health can be evaluated using IoT sensor data on a movable platform under controlled conditions.

5. Best practices – Projects and Cameras

Educational and Community Engagement

Target Audience: The course is designed for "vocational students and interns, ANAU instructors, professionals, and technicians at UNDER SUN Company, along with stakeholders in the VETfarm Network."

Practical Training: A "key distinguishing characteristic of this course is its direct connection to the demonstration setup in Armenia. Participants will have the opportunity to manage a pistachio farm, thereby gaining practical and interactive training locally."

Skill Development: Emphasis is on "skills development, community engagement, and raising awareness and prepares individuals to tackle environmental and technological challenges in the region." Intended learning outcomes include understanding pistachio health issues and using remote sensing data for decision support.

Inclusive Innovation: The project promotes "Inclusive Innovation" by using "hardware and software for orchard digital solutions to drive innovation in agriculture." This includes developing and using "open-source digital farming tools, making technology more accessible to farmers."

Demonstration Farms: "Pistachio demonstration farms and Gardens" serve as "physical spaces where students can actively participate in growing food, learning about different crops, and understanding the agricultural cycle and challenges." They are crucial for "precision management demonstrations, raise awareness, and enable adaptation, testing, and application development."

Additionally, through this, students and professionals will be trained interactively to assess the impact of orchard management on pistachio health, leveraging technologies like AI, remote sensing, IoT, and geoinformation systems. This approach supports skills development, community engagement, and raising awareness and prepares individuals to tackle environmental and technological challenges in the region.

1. Enhancing Educational Institutions:

- Student and Professional Development:

Vocational agricultural projects offer students opportunities to learn about food production, sustainable farming practices, and the connection between agriculture and the environment.

- Company and Community Engagement:

These projects often involve partnerships with local communities and companies, providing access to fresh produce and educational programs, and creating increased employment opportunities.

- Pistachio demonstration farms and Gardens:

The primary purpose of these pilot setups is to facilitate precision management demonstrations, raise awareness, and enable adaptation, testing, and application development. These efforts will address potential

risks at all levels, including village schools, vocational education and training, and universities.

These are physical spaces where students can actively participate in growing food, learning about different crops, and understanding the agricultural cycle and challenges.

- Community Partnerships:

Many projects collaborate with local communities, schools, and organisations to provide educational resources and access to fresh produce.

- Research and Innovation:

Vocational farms and gardens can also serve as research sites for exploring sustainable farming methods, crop varieties, and pest management strategies.

- Educational Programs:

Workshops, internships, farm tours, and other educational programs are often offered to students, faculty, and the wider community.

2. Precision Agriculture:

Some projects incorporate precision agriculture techniques, using data and technology to optimise farming practices and resource management.

- Solutions:

The project, for instance, emphasises the development and use of open-source digital farming tools, making technology more accessible to farmers.

- Digital Farming Tools:

These tools can help farmers with tasks such as monitoring crop health, optimising irrigation, and managing pests.

3. Benefits and Outcomes:

- Cost-Effectiveness: The use of Remote Sensing Image Analysis in a GIS environment for Precision Farming is highlighted as a "cost-effective basis." Also, the significant economic and environmental benefits of implementing Precision Farming Solutions (PFS) include reduced spray treatments and optimised input use.

- Improved Yield and Quality: The overall aim is to "improve crop yield and grade" by providing insights into how fruit trees respond to various stressors (pests, water deficit), enabling more informed decisions.
- Automated Data Collection: The PFP enables "automated data collection ('hands-off, labour-free') using the platform system in pest management that automatically captures images and data of the pest, eliminating the need for manual inspection." This saves time and allows for scaling scouting efforts.
- Proactive Interventions: Mobile Labs and IoT systems aim to "monitor early signs of disease outbreaks, facilitating proactive and targeted interventions."

4. Challenges and Future Directions:

- Data Acquisition Quality: Challenges remain in ensuring "quality data acquisition" due to factors like motion blur (keeping leaves still relative to the camera) and stray light.
- Sensor Configuration: Ongoing work includes configuring sensors like RGB cameras and endoscope cameras for optimal portable/field use.
- Cost-Benefit Analysis: Future research and training should "include a cost-benefit analysis to evaluate the economic impact of implementing services or solutions, particularly in precision agriculture."
- Uncertainty Analysis: Highlights the need for "uncertainty analysis: The process of identifying and quantifying the uncertainties associated with model inputs, parameters, and outputs is crucial for assessing the reliability of predictions."

In essence, the course represent a movement towards integrating agriculture into vocational institutions, creating opportunities for practical learning, community engagement, and the advancement of sustainable farming practices.

5.1 Orchard Sensors and Methods

Based on different users and requirements in the pistachio sector, event detection, such as pests, frostbite, drought, and water stress, is required.

Cameras that can be used on a movable platform for monitoring crop growth, monitoring and studying phenological changes and early detection of disease outbreaks. For example:

- Wildlife cameras
- Crop Management Solutions for Pistachios – Semios
- Webcams
- Depth cameras
- TinyML
- Webvision 360

- Infrared Radiometers:
<https://www.apogeeinstruments.com/infraredradiometer/>
- Road traffic cameras for crop monitoring, such as Chinese Dahua network cameras (DH-IPC-HFW71242H-Z; Dahua Technology - dahuasecurity.com)
- StarDot NetCam (<https://phenocam.nau.edu/webcam/>).
- Radiometers can be used to measure plant canopy temperature for estimating plant water status.

6. Quiz

What is the primary objective of the VETfarm project regarding precision farming? The VETfarm project's primary objective is to build capacities in using integrated remote sensing and GIS data for monitoring pistachio orchards and applying precision farming techniques. It focuses on analysing satellite imagery, integrating IoT sensor data, and utilising cloud-based tools to optimise agricultural inputs through Management Zones.

What is the primary goal of Integrated Remote Sensing Image Analysis, GIS data and/or knowledge, and ICT for Precision Farming?

- The primary goal is to improve crop yield and grade. It achieves this through the integration of sensors, sensing, and expert knowledge available in GIS databases, including cadastre data, base maps, elevation datasets, soil datasets, and meteorological datasets.
- Integrates several key technologies. It utilises sensors and sensing to monitor daily insect counts, eliminating manual scouting and identifying "hot spots" of pest pressure. It also helps variable rate spraying and disruption, maximising protection. The system further incorporates site-specific pest data/information, correlating local conditions with sensor counts and weather patterns to predict pest pressure and fine-tune spray timings, potentially reducing the number of treatments.

What is the primary goal of the Insect Pest Management solution, and how does it aim to achieve this?

- The main objective is to enhance crop yield and quality. This is achieved through IoT sensors for pest counts, monitoring, and optimised spray timing tools, all tailored to specific pest behaviours.

Explain how the demonstration setup for the movable sensor platform works and its benefits for plant protection throughout the season.

- The platform integrates various technologies (IoT, AI, big data analytics) to create a "precision farming platform." Provide examples from insect pest management and plant stress monitoring.

Describe the key features and advantages of using 'Precision Farming Platform', such as a sensor for pest counts in pest management.

- Automated sensor for pest counts eliminates the need for subjective operators and manual checking, saving time and allowing farmers and farm managers to scale scouting efforts. They provide daily data of pest images and summaries, enabling detection, classification, and prioritisation of "hot spots" of high pest pressure from a cell phone or computer.
- Also, the economic and environmental benefits growers might experience by implementing Precision Farming Solutions (PFS) are significant. Reference specific features like automatic pest identification, spraying and disruption, reduced spray treatments, and impact assessment.
- Automated data collection ("hands-off, labour-free") using the platform system in pest management that automatically **captures images and data of the pest**, eliminating the need for manual inspection.

How do pest models and pest detection and classification help growers with spray timing and logistics? What else is needed?

- Pest models are customised to individual orchards, allowing for fine-tuned sprays for maximum impact and potentially reducing the number of treatments. Pest models and climate information, such as degree-day modelling and forecasting, provide accurate and reliable risk levels sooner, making spray scheduling and logistics management easier.

What factors contribute to the orchard's failure to yield uniform fruit of equivalent quality consistently? Can we pinpoint variations in pistachio production within a designated growing season and elucidate the underlying causes? To what extent can the trees/areas be effectively compared, for instance, between those with high and low yields or those classified as fertile versus low-fertility?

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Beyond insect pest management, what other pistachio challenges does the movable sensor platform help growers address? Name at least three.

- Beyond insect pest management, the platform helps farmers and farm managers address challenges, including identifying water deficiency or surplus and weed infestations.

- The course aims to monitor pistachio crop conditions, such as tree height, canopy volume, and weed presence, through EO/drone data enriched by IoT sensor networks. Other relevant pistachio orchard characteristics include tree health, soil conditions, and water and fertiliser needs.

How does the pistachio monitoring solution help optimise yield and fruit quality?

- Plant Monitoring solution optimises yield and fruit quality by providing insights into how fruit trees respond to pests or tree water deficit and available water. This allows growers to make more informed irrigation decisions to achieve desired yields while minimising input resources.

Who handles the installation, (remote) monitoring, and maintenance of the platform system, and why is this a benefit for growers?

- Professional experts and vocational students handle the installation, remote monitoring, and maintenance of the platform system. EU partners will support the technological aspects, making the system hands-off and labour-free for them.

Explain the concept of "Management Zones (MZ)" in the context of a precision farming platform (PFP) as described in the course.

- Management Zones (MZ) are homogenous areas within a pistachio field, identified using satellite and GIS data, and confirmed by farm managers. These zones (e.g., high, medium, low yield) allow for spatially variable application of agricultural inputs and targeted sampling, moving away from uniform treatments for improved efficiency.

How does the course address the complexity of processing large volumes of satellite data for crop monitoring?

- The course addresses this complexity by emphasising practical application through the use of cloud-based services/tools for crop monitoring, such as WI tools. This approach simplifies the process by removing the need for users to directly handle the intricate processing of vast amounts of satellite data.

Name three types of data sets, beyond satellite imagery, that are utilised in the GIS data and/or knowledge selection module.

- Beyond satellite data, the GIS data and/or knowledge selection module utilises 3D+Time GIS datasets and products. These include cadastre data, base maps, elevation datasets, soil datasets, and meteorological datasets.

Describe two ways the "Precision Farming Platform (PFP)" helps growers with pest management beyond simply counting pests.

- The PFP aids pest management by providing daily data on pest images and summaries, enabling detection, classification, and prioritisation of "hot spots" for targeted intervention. It also facilitates the development of site-specific pest models that allow for fine-tuned sprays, potentially reducing the number of treatments and overall input costs.

What are "Mobile Labs" in the context of the VETfarm project, and what is their purpose?

- Mobile Labs are portable sensor setups designed to enhance traditional farm management by incorporating innovative technologies. Their purpose is to enable local data collection and connection with the community, allowing for testing and experimentation using IoT-enabled systems to detect stress factors like insect infestations, diseases, and water deficiencies directly on the farm.

List three practical considerations for leaf and canopy level sensors that need to be installed on a movable platform system.

- Practical considerations for leaf and canopy level sensors include features like Pan & Tilt (PTZ), Autofocus, and practical focus at very close range (less than 5 inches). Other important factors are whether they are wired or wireless, ruggedness for close-up monitoring, affordability, and ease of power and data transmission.

How does the VETfarm project intend to make digital farming tools more accessible to farmers?

- The VETfarm project emphasises the development and use of open-source digital farming tools. This approach aims to reduce barriers to entry for farmers, making the technology more affordable and readily available for tasks such as crop health monitoring, irrigation optimisation, and pest management.

Who is responsible for the installation, monitoring, and maintenance of the VETfarm platform system, and what benefit does this provide to growers?

- Professional experts and vocational students handle the installation, remote monitoring, and maintenance of the platform system, with support from EU partners for technological aspects. This arrangement makes the system "hands-off and labour-free" for growers, allowing them to focus on farming operations rather than complex technical management.

7. Glossary of Key Terms

Integrated Technologies: The course centralises "the integrated application of Remote Sensing (RS), Geographic Information Systems (GIS), and Information and Communication Technologies (ICT) for optimising agricultural practices, specifically in pistachio farming." This aims for a "data-driven approach to agriculture, shifting away from traditional, uniform treatments."

Pistachio Crop Monitoring: A specific focus is on "monitoring pistachio crop conditions. This includes 'canopy volume, weed, pest, etc,' and 'Monitoring pistachio orchard (soil, trees) and processes (user/location/time-specific)."

Optimised Resource Management: The VETfarm project aims to enhance efficiency and sustainability by optimising agricultural inputs (e.g., water, fertilisers, pesticides) through the identification and application of Management Zones (MZs) and by integrating IoT sensor networks within these zones.

Automated sensor-based pest detection: Devices used in pest management that automatically capture images and data of pests, eliminating the need for manual inspection.

Demonstration platform installation: a service where the VETfarm team handles and showcases the complete setup, installation, monitoring, and maintenance of their systems, reducing the burden on growers.

Insect Pest Management: Strategies and tools used to control or reduce insect populations that negatively impact crop yield and quality.

Internet-of-Things (IoT): A network of physical objects ("things") embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet.

***Agonoscena pistaciae*:** A specific insect pest, commonly referred to as the pistachio psyllid, is a serious pest of *Pistacia vera* L. (Sapindalis: Anacardiaceae) throughout the Middle East and Mediterranean basin.

Pest pressure alerts: Notifications sent to farmers and farm managers (via phone, App, etc.) when pest activity or environmental conditions reach a pre-set threshold, indicating high risk to pistachio plants.

Plant stress monitoring: The process of continuously tracking physiological indicators of crops to assess their response to environmental conditions, particularly water availability.

Precision Farming Platform (PFP): An agricultural management concept based on observing, measuring, controlling, and responding to inter- and intra-field variability in crops, using geospatial technology to make informed decisions. PFP is designed for farmers of tree fruit. It provides essential tools to

manage pressing issues in fruit production, such as insect and disease pressure, water management, and weather challenges. The core problem it solves is providing actionable data and insights to help farmers make informed, sustainable decisions, improve crop yields, and respond to pressures like rising input costs.

Site-specific pest models: Pest development models that are customised to the unique conditions and data from a specific orchard or farm, rather than relying on generalised regional data.

Management Zones (MZ): Homogeneous production zones within a field or orchard, identified based on similar soil characteristics, crop performance, or other relevant factors, using satellite data, allowing for spatially variable application of inputs.

Region of Interest (RoI): A user-defined area within an image or dataset that is specifically targeted for analysis or processing.

Uncertainty analysis: The process of identifying and quantifying the uncertainties associated with model inputs, parameters, and outputs is crucial for assessing the reliability of predictions.

Cost-Benefit Analysis: Future research and vocational training should include a cost-benefit analysis to evaluate the economic impact of implementing services or solutions, particularly in precision agriculture. This would help farmers understand the financial advantages of adopting these precision agriculture techniques.

8. Basic literature

Rokhafrouz M, Latifi H, Abkar AA, Wojciechowski T, Czechlowski M, Naieni AS, Maghsoudi Y, Niedbała G. Simplified and Hybrid Remote Sensing-Based Delineation of Management Zones for Nitrogen Variable Rate Application in Wheat. *Agriculture*. 2021; 11(11):1104.

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Davatchi, G. A. 1958. Sur Quelques insectes Nuisibles Au Pistachier En Iran. *Revue de Pathologie Vegatale et Entomologie Agricole de France*. Tome XXXVII. No 1 Paris; 166 pp.

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- The PDF file containing a review of the biology, ecology, and management of *Agonoscena pistaciae* ... tbd
- Link: Relevant academic papers, industry reports, and publications reviewed.

WI references tbd ...

ANAU references tbd ...

- Naira pistachio paper ...

UNDER SUN references tbd