

# Workshop MathAIEOapp

Wednesday, 5 July 2023 - Friday, 7 July 2023

Dipartimento di Scienze del Suolo, della Pianta e degli Alimenti



## Book of Abstracts



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## Litter detection from Super-Resolved Remote Sensing data

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“The REACT project (Crowdsourcing, Copernicus, and Hyperspectral Satellite Data for Marine Plastic Litter Detection, Quantification, and Tracking) aimed to develop a proof-of-concept for remote sensing of marine plastic litter. The project utilized image fusion techniques with multispectral (i.e., Sentinel-2, WorldView 2/3) and hyperspectral (i.e., PRISMA) satellite data, combined with in situ data collection, employing two different approaches: one based on spectral signature unmixing (SSU) and the other on machine learning (ML) methodologies.

The primary objectives of the project were to assess the detection capabilities of current and future remote sensing tools for plastic litter, understand the impact of atmospheric and illumination conditions on the spectral properties of marine plastics, develop adaptive indices insensitive to biases induced by sunglint, explore data fusion methods to increase the detectability of marine plastic litter and investigate SSU and ML algorithms for plastic litter detection. The project aimed to generate abundance maps and probability maps of marine plastic litter, representing the fraction and probability of plastic presence in each pixel.

The key user of the REACT project was the Environmental Prevention and Protection Agency of the Puglia Region in Italy, which is responsible for monitoring marine litter in compliance with European legislation.

Controlled experiments were conducted, utilizing 12 floating plastic targets of varying sizes and materials. Spectroradiometer measurements were taken during these experiments, and the targets were placed both offshore and onshore during satellite data collection campaigns in Mytilini and Geras Gulf, on the Greek island of Lesbos.

In the project, different methods of pansharpening hyperspectral (HS) images were evaluated, with component substitution methods yielding the best results. By fusing Sentinel-2 (S2) and WorldView (WV) images using the CNMF method, the capability of S2 imagery to detect marine plastic targets was enhanced. The endmember spectra of plastic materials showed high abundance values, while water endmembers exhibited low abundance values. SSU applied on HS detected offshore plastic targets, with certain limitations due to spectral inseparability between plastic targets and swallow waters. Land and swallow water pixels were masked, and SSU and pansharpening effectively detected floating plastic accumulations.

The study proposed three plastic indexes based on radiance differences in the VNIR region to discriminate plastic targets from water. These indexes were successfully applied to the pan-sharpened image, resulting in the detection of offshore plastic targets.

A combination of unsupervised (K-Means) and supervised (Light Gradient Boosting Model) methodologies was employed for ML-based detection. Despite the limited dataset, ML algorithms showed promising results in detecting floating objects offshore, reducing false positives and improving accuracy with increased training data.

Two probability maps were produced based on available data: one from pan-sharpened PRISMA data using supervised and unsupervised methods and the other from the fusion of S2 and WV data using the K-means method. These probability maps provided valuable information for monitoring plans, determining optimal monitoring station locations, and modelling dispersion.

However, the spatial resolutions achieved through image fusion were insufficient to detect common litter accumulations onshore, indicating the need for further studies in this area.

In conclusion, the REACT project successfully developed a methodology for remote sensing of marine plastic litter, utilizing image fusion techniques, SSU, and ML algorithms. Abundance maps and

probability maps were generated, providing valuable insights for monitoring, evaluation, and modelling purposes. Further research is required to enhance onshore detection capabilities and refine the methodologies employed in the project.”

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## Point clouds based studies for Forests' Monitoring

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TBA

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## An effective approach for automatic river features extraction using high-resolution UAV imagery

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The effects of climate change are causing an increase in the frequency and extent of natural disasters. Because of their morphological characteristics, rivers can cause major flooding events. Indeed, they can be subjected to variations in discharge in response to heavy rainfall and riverbank failures. Among the emerging methodologies that address the monitoring of river flooding, those that include the combination of Unmanned Aerial Vehicle (UAV) and photogrammetric techniques (i.e., Structure from Motion-SfM) ensure the high-frequency acquisition of high-resolution spatial data over wide areas and so the generation of orthomosaics, useful for automatic feature extraction. Trainable Weka Segmentation (TWS) is an automatic feature extraction open-source tool. It was developed to primarily fulfill supervised classification purposes of biological microscope images, but its usefulness has been demonstrated in several image pipelines. At the same time, there is a significant lack of published studies on the applicability of TWS with the identification of a universal and efficient combination of machine learning classifiers and segmentation approach, in particular with respect to classifying UAV images of riverine environments. In this perspective, we present a study comparing the accuracy of nine combinations, classifier plus image segmentation filter, using TWS, also with respect to human photo-interpretation, in order to identify an effective supervised approach for automatic river features extraction from UAV multi-temporal orthomosaics. The results, which are very close to human interpretation, indicate that the proposed approach could prove to be a valuable tool to support and improve the hydro-geomorphological and flooding hazard assessments in riverine environments.

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## Real-Time On-Board Detection by Using SAR-Based Machine Learning Techniques

**Author:** Khalid Tijani<sup>None</sup>

“This study introduces a new method for monitoring oil spills and ships using Synthetic Aperture Radar (SAR) raw data and deep learning techniques. The proposed approach involves several key

steps: pre-processing (including focusing, filtering, and land-sea mask), semantic segmentation, and classification using a deep convolutional neural network (DCNN) model. Real-time processing based on FFT ensures rapid response times.

For training the DCNN model, three datasets were combined: CleanSeaNet, TenGeoP-SARwv, and GAP\_OilSpill\_DB. The first two datasets are publicly available, while the authors created the third dataset by integrating documented case studies from news articles and cases identified in the sea area near the port of Brindisi, validated by expert GAP operators.

Data augmentation techniques were employed to enhance the model's performance by generating additional training data. The DCNN model utilizes DeepLab v3+ based on ResNet-18 architecture and is trained on a large SAR image dataset that includes various types of oil spills, look-alikes, novelty objects, and ships.

The proposed system is optimized for on-board satellite processing, ensuring real-time responses. Images are transmitted to the ground segment only when events of interest occur, such as the detection of novelty objects or potential oil spills involving nearby ships.

The study demonstrates that this approach offers a promising solution for real-time monitoring of oil spills, ships, and novelty objects using satellite SAR raw data. The integration of deep learning and data augmentation techniques significantly enhances detection accuracy and speed, leading to improved environmental management and oil spill response. Furthermore, this approach can be applied to diverse SAR datasets and has the potential for integration with existing oil spill response systems.

#### Acknowledgments

This work was carried out in the framework of the APP4AD project ("Advanced Payload data Processing for Autonomy & Decision", Bando ASI "Tecnologie Abilitanti Trasversali", Codice Unico di Progetto F95F21000020005), funded by the Italian Space Agency (ASI). ERS, ENVISAT and Sentinel-1 data are provided by the European Space Agency (ESA)."

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## Machine Learning Techniques For Automatic Detection Of Xylella Fastidiosa In Vhr Hyperspectral And Thermal Data

**Author:** Annarita D'Addabbo<sup>None</sup>

"Xylella fastidiosa (Xf) is a plant pathogen affecting 679 plant species worldwide. In the last years, it has been identified as the bacterium causing a devastating disease on olive trees in the Apulia Region (Italy), with a great impact on the landscape and on the agricultural yields, as well as significant economic losses.

The detection of infected trees and their eradication are the only effective means to stop the Xf spread. Nowadays, the diagnostic checks are made by the quantitative real time-Polymerase-Chain-Reaction (qPCR) using leaves or twigs sampled from trees in order to detect the presence of bacterial DNA. These procedures are complex, time consuming and expensive, moreover often ineffective because early detection of infected trees (also still asymptomatic ones) ought to be made on short temporal and large spatial scales in order to reduce the infection risk for the surrounding plants, which is currently hardly feasible through ground campaigns.

For these reasons, the use of hyperspectral and thermal data, remotely acquired by sensors mounted on airplane or Unmanned Aerial Vehicle (UAV) platforms has been recently assessed. Remotely sensed data have been demonstrated to be an effective tool for the early detection of Xf infection in several case studies. Operational applications require statistically well-founded methodologies to extract useful information from the data, in order to automatically classify healthy and Xf affected trees.

We present some results from the processing of data obtained in the framework of the Remote Early Detection of Xylella (REDox) project, funded by the Italian Business and Made in Italy Ministry (MISE)."

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## Models for the spread and control of invasive species

**Author:** Fasma Diele<sup>None</sup>

This presentation highlights the practical implementation of mathematical tools that have been essential to our ongoing activities at the National Biodiversity Future Centre. We specifically showcase their application within a protected area situated in Southern Italy, which holds significant importance as both a site within the Natura 2000 network and a key site within the National Biodiversity Future Centre. Our primary objective is to effectively address a range of challenges, with a particular emphasis on controlling the spread of dangerous species. We demonstrate the utilization of three distinct yet complementary approaches: (i) a qualitative analysis based on dynamical systems and bifurcation theory, (ii) the implementation of Z-control, an error-based neural dynamic approach, and (iii) the application of optimal control theory. The insights and findings obtained from our previous study conducted in this protected area greatly contribute to the ongoing activities at the National Biodiversity Future Centre.

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## Control, stability and its applications

**Author:** Mohammad Akil<sup>None</sup>

Control theory is a field of engineering and mathematics that deals with the analysis and design of systems with the ability to control or regulate their behavior. It provides a framework for understanding how to manipulate the inputs to a system in order to achieve desired outputs or responses.

The primary goal of control theory is to develop mathematical models and techniques that enable the design of control systems to achieve specific objectives. These control systems can be found in a wide range of applications, including aerospace, robotics, manufacturing, power systems, automotive, and many others.

At its core, control theory involves studying the dynamics of a system, which refers to how the system responds to various inputs over time. A system can be described using mathematical models such as differential equations, transfer functions, or state-space representations. These models capture the relationship between the system's inputs, outputs, and internal states.

Control theory encompasses several fundamental concepts and techniques. Here are a few key elements: Feedback, Controllers, Stability and Performance, Control Design Methods, System Identification.

In this talk, we give a simple introduction on control theory and more precisely on the stability of physical system governing by the PDE.

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## Predators As A Possible Strategy For Controlling A Xylella Fastidiosa Epidemic - Part I

**Author:** Vincenzo Capasso<sup>None</sup>

"In Southern Italy there has been an ongoing Olive Quick Decline Syndrome (OQDS) outbreak, due to the bacterium Xylella fastidiosa, which has caused a dramatic impact from both socio-economic and environmental points of view.

Current agronomic practices are mainly based on uprooting the sick olive trees and their surrounding ones, with later installment of olive cultivars more



resistant to the bacterium infection. Unfortunately, both of these practices are having an undesirable impact on the environment and on the economy.

In recent papers *Zelus renardii* (Hemiptera, Reduviidae) has been identified as a predator of *P. spumarius* for a possible control of a *Xylella* epidemic.

Here, by generalizing previous models of ours, a spatially structured mathematical model has been proposed to include the predator *Zelus renardii* in the dynamics of a *Xylella* epidemic.

The fact that *Z. renardii* has been reported to be a generalist predator implies the choice of an Holling type III functional response of predation in the mathematical model. As a consequence, it has been shown that the introduction of *Z. renardii* as a predator of *P. spumarius* is not an efficient control strategy to eradicate

a *Xylella* epidemic. Instead, a specialist predator or of a parasitoid, whenever identified, would lead to the eventual eradication of a *Xylella* epidemic; as a matter of fact, in this case the appropriate choice for the predation functional response would be an Holling type II.

In either cases it has been confirmed, as from our previous results, that a significant reduction of the weed biomass can lead to the eradication of the vector population, hence of a *Xylella* epidemic, independently of the presence of predators.

A relevant contribution of our approach consists of a suitable restriction of measures of intervention (control) only to a subregion of the whole habitat of interest ("Think globally, act locally").

All of the above has been illustrated by a set of computational experiments, within a variety of different possible parameter scenarios."

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## Bistability of a mathematical model for the control of an olive tree disease

**Author:** Iulia Martina Bulai<sup>None</sup>

"In this talk I will present a plant epidemic model accounting for interactions between some beneficial phyllosphere organisms and a phytopathogen fungus by means of a four dimensional Ordinary Differential Equation (ODE) system. The system possesses five equilibria that are suitably analyzed for feasibility and stability. Numerical simulations show potentially interesting bistable behavior, exhibited by three different pairs of equilibria, as well as persistent oscillations in some cases [1]. All three pairs of bistable equilibrium points, for the four dimensional model, have been analyzed by approximating the basins of stability, plus the bistable case for the three dimensional model where the beneficial phyllosphere organisms is not yet inserted in the olive system [2]. Knowing more about the bistable dynamics of the system allows the possible assessment of human intervention for control of the disease.

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[2] I. M. Bulai, M. Salvia. Approximation of basins of attraction for bistable dynamical system for olive disease control. To appear in Applied Numerical Mathematics, 2023.

Joint work with: P. Baptista, T. Gomes, M. Salvia and E. Venturino"

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## Optimal spatiotemporal resource allocation for the control of *Ailanthus altissima* in Alta Murgia National Park

**Author:** Angela Martiradonna<sup>None</sup>

“Invasive alien species (IAS) are non-native organisms that are introduced, intentionally or unintentionally, into ecosystems outside their natural range and have negative impacts on the environment, economy, or human health. These species can disrupt natural ecosystems, outcompete native species for resources, alter ecological processes, and cause economic and social harm.

In the context of the Alta Murgia National Park, *Ailanthus altissima* has been recognized as an IAS, posing challenges to the park’s native ecosystems and biodiversity. The park management and conservation efforts focus on addressing the spread and control of *A. altissima* within its boundaries.

In this work, we implemented a spatiotemporal model to address the spread and control of *A. altissima* in the Alta Murgia National Park. The objective of the model is to find the the most effective resource allocation strategy for the eradication of the plant, while considering the budget constraints associated with the control program. Remote sensing data and expert knowledge were utilized to estimate the initial distribution of the species and its habitat suitability. These inputs were derived from a land cover map of the study area, generated using very high-resolution satellite images. As a result, we developed the web service COINS (Control of INvasive Species), a decision support tool to be integrated into IAS management, which was ported to Virtual Research Environments.

This is a joint work with: Christopher M. Baker, Palma Blonda, Francesca Casella, Fasma Diele, Carmela Marangi, Francesco Montomoli, Nicholas Pepper, Cristiano Tamborrino and Cristina Tarantino.

Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of ItalianMinistry of University and Research funded by the European Union – NextGenerationEU; Award Number: Project code CN 00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the ItalianMinistry of University and Research, CUP B83C22002930006, Project title “National Biodiversity Future Center –NBFC

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Marangi, C., Martiradonna, A. and Ragni, S. Optimal resource allocation for spatiotemporal control of invasive species. *Appl. Math. Comput.* 439, 127614 (2023).

Baker, C. M., Diele, F., Marangi, C., Martiradonna, A. and Ragni, S. Optimal spatiotemporal effort allocation for invasive species removal incorporating a removal handling time and budget. *Nat. Resour. Model.* 31, e12190 (2018).”

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## On-off intermittency in a host-parasitoid model with a deterministic chaotic driver

**Author:** Angela Monti<sup>None</sup>

“In this talk we focus on a 2D discrete host-parasitoid model to investigate the onset of on-off intermittency when we consider the environmental variability as a deterministic chaotic driving process [1] instead of a stochastic one [2, 3]. To do that, we will vary in time the grazing parameter according to an evolution law that can exhibit chaotic behavior. This leads to a coupled non linear discrete 3D dynamical system, that is found to display a complex phenomenology and on-off intermittency in a narrow region of the parameter space. The deterministic framework allows to relate more directly the onset of the on-off intermittency to the dynamical properties of some attractors of the system.

This is a joint work with D. Lacitignola (Università di Cassino e del Lazio Meridionale) and F. Diele (IAC-CNR).

#### Acknowledgements.

Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of Italian Ministry of University and Research

funded by the European Union –NextGenerationEU; Award Number: Project code CN 00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP B83C22002930006, Project title “National Biodiversity Future Center - NBFC”.

Funder: POR PUGLIA 2014/2020 - AZIONE 6.5 - 6.5.A (D.G.R. 150/2020 E D.D. n.108 del 06.08.2020), Project title “Monitoraggio di habitat e specie nel sito Murgia Alta”.

[1] Lacitignola D., Diele F., Monti A., On-off intermittency in a host-parasitoid model with a deterministic chaotic driver (in preparation).

[2] Vissio G., Provenzale A., On-off intermittency and irruptions in host-parasitoid dynamics, *Journal of Theoretical Biology* 546, 111174 (2022).

[3] Monti A., Diele F., Marangi C., Provenzale A., The onset of intermittency in the Beddington-Free-Lawton model (in preparation)”

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## Welcome

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## Introduction to the 1st morning session

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## Deep Learning for Soil Mapping

**Author:** Paolo Napoletano<sup>1</sup>

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In this talk, I will discuss the most recent research activities carried out in our laboratory regarding digital soil mapping and more specifically the estimation of soil parameters from remote measurements using machine and deep learning techniques. The limitations and future challenges of digital soil mapping will be discussed

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## Modelling the Xylella transmission, building up an effective IPM strategy

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Modellizzare la trasmissione della Xylella, costruire una strategia IPM efficace

Il *Philaenus spumarius* L. (Hemiptera Aphrophoridae) regola l'invasione di *Xylella fastidiosa* pauca ST53 (Xf), infettando piante in Italia. La conseguente malattia OQDS (Olive Quick Decline Syndrome) ha decimato gli olivi in Puglia. I sintomi dell'OQDS, che si manifestano in ritardo rispetto all'infezione, costringono ad una gestione non ideale dell'invasione. Inoltre, gli alberi infetti sono serbatoi del patogeno e sostengono i cicli annuali di invasione di Xf, attraverso l'acquisizione e la diffusione da parte di vettori residenti.

I vettori causano danni più che proporzionali al loro numero, propagando il patogeno nel tempo e nello spazio più di una volta per vettore. La morte degli olivi, vanifica gli investimenti passati, esaspera i costi annuali di coltivazione e annienta i redditi futuri. Xf stermina le piante sensibili, ammettendo che non esiste alcuna cura per la malattia.

La soglia di azione per il controllo dei vettori è inaccettabilmente bassa nella pratica, dato che ogni vettore può infettare anche solo assaggiando una pianta alimentare suscettibile e moltiplicando gli atti di alimentazione nella finestra di vita degli adulti. Il nostro approccio suggerisce di controllare l'infezione 1 (la prima trasmissione che porta al processo infettivo su una pianta indenne), riuscendo a uccidere ogni vettore al momento della sua prima alimentazione su olivo. L'azione tenta di ridurre alla proporzionalità diretta ogni capacità di infezione del vettore. Una gestione efficace dell'infezione riesce ad eliminare i vettori che causerebbero le infezioni 2, 3...n con azioni di controllo meccanico, chimico o biologico, prima che i vettori 2, 3...n infettino.

L'efficacia del controllo dell'infezione dipende dalla morte del vettore alla prima alimentazione. Uccidendo lo stesso numero di vettori dopo che questi hanno effettuato le infezioni 2, 3... n su piante diverse, si ottiene un banale controllo dei vettori che è inefficace perché ogni vettore infligge plurime infezioni. Il controllo della trasmissione nelle aree infette può limitare in modo significativo l'invasione di *Xylella* nelle aree esenti dalla malattia e fermare l'invasione del patogeno.

Presto, una scarsa popolazione di vettori renderà rare le acquisizioni e le trasmissioni, portando all'isolamento del batterio nelle piante infette. La morte progressiva delle piante malate ridurrà la malattia a pochi focolai attivi, semplificandone la gestione.

Infine, l'olivo ospita una gilda di fitofagi che può minimizzare gli utili, anche compromettendo la qualità del prodotto. La modellizzazione di una strategia olistica di gestione dei parassiti dell'olivo garantirà una produzione integrata, limitando gli insetticidi agli interventi strettamente necessari e mirati. Le azioni di controllo devono considerare i fattori TARDIS (Time And Relative Dimension In Space, BBC®) per rendere la strategia efficace in tutti i contesti olivicoli.

**Keywords:** Antifragilità, IPM, CoDiRO, Organismi alieni, Invasivi, Quarantena.

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Modelling the Xylella transmission, building up an effective IPM strategy

*Philaenus spumarius* L. (Hemiptera Aphrophoridae) regulates the invasion of *Xylella fastidiosa* pauca ST53 (Xf), infecting plants in Italy. The resulting disease OQDS (Olive Quick Decline Syndrome) decimated olive trees in Apulia. The symptoms of OQDS, which appear later than the infection, force a less-than-ideal management of the invasion. Moreover, infected trees are reservoirs of the pathogen and sustain the annual invasion cycles of Xf through acquisition and spread by resident vectors.

Vectors cause damage more than proportional to their numbers, propagating the pathogen over time and space more than once per vector. The death of olive trees wipes out past investments, exacerbates annual cultivation costs and annihilates future income. Xf exterminates susceptible plants, admitting no cure for the disease exists.

The threshold of action for vector control is unacceptably low in practice, as any vector can infect even just by tasting a susceptible food plant and multiplying feeding acts in the adult life window. Our approach suggests controlling infection 1 (the first transmission leading to the infectious process on an uninfected plant) by killing each vector at its first feeding on an olive tree. The action attempts to reduce any vector infection capacity to direct proportionality. Effective infection management

eliminates vectors that would cause 2, 3... n infections by mechanical, chemical, or biological control actions before the vectors 2, 3... n infect.

The effectiveness of infection control depends on the death of the vector at first feeding. By killing the same number of vectors after they have carried out infections 2, 3... n on different plants, trivial vector control is achieved, which is ineffective because each vector inflicts multiple infections. Controlling transmission in infected areas can significantly limit the invasion of *Xylella* into disease-free areas and stop the pathogen's invasion.

Soon, a low vector population will make acquisition and transmission rare, leading to the isolation of the bacterium in infected plants. The progressive death of diseased plants will reduce the disease to a few active foci, simplifying its management.

Finally, the olive tree hosts a phytophagous guild that can minimise profits, even compromising product quality. Modelling a holistic pest management strategy for the olive tree will ensure integrated production, limiting insecticides to strictly necessary and targeted interventions. Control actions must consider TARDIS (Time And Relative Dimension In Space, BBC®) factors to make the strategy effective in all olive contexts.

Keywords: Antifragility, IPM, CoDiRO, Alien Organisms, Invasive, Quarantine.”

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## Detecting asymptomatic infections of olive quick decline syndrome using hyperspectral data analysis

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*Xylella fastidiosa* subspecies *pauca* (Xfp), a Gram-negative bacterium in the family Xanthomonadaceae ( $\gamma$ -proteobacteria), is one of the most dangerous plant pathogens worldwide. It colonizes the xylem of the host, and is transmitted by several xylem sap-feeding insect vectors (Homoptera, Auchenorrhyncha). Formerly restricted to the Americas, a very aggressive genotype, Xfp ST53, has been reported in Apulia as responsible for the Olive Quick Decline Syndrome (OQDS), a vascular disease causing the death of millions of young and centenarian olive trees. The monitoring of the infected area must be fast and reliable, thus, allowing an early diagnosis of the disease also when the symptoms are not yet visible. In fact, any delay would preclude the effectiveness of the mandatory phytosanitary measures to slow down the epidemic progression, thus, increasing the infection risk for the surrounding plants. The aim of this work was to assess whether the analysis of hyperspectral data, using different statistical methods, allow to select with sufficient accuracy, which plants to sample and test with qPCR, to save time and economic resources. Partial Least Square Regression (PLSR) and Canonical Discriminant Analysis (CDA) indicated that the most important bands were those related to the chlorophyll function, water, lignin content, as can also be seen from the wilting symptoms in plants infected by Xfp. The confusion matrix of CDA showed an overall accuracy of 0.67, but with a better capability to discriminate the infected plants. Finally, an unsupervised classification, using only spectral data, was able to discriminate the infected plants at a very early stage of infection. Then, testing by qPCR should be performed only on the plants predicted as infected from hyperspectral data, thus, saving time and financial resources.

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## Prevention and control of OQDS outbreaks caused by *Xylella* fas-

## tidiosa. Part II

**Author:** Vincenzo Capasso<sup>None</sup>

“In Southern Italy there has been an ongoing Olive Quick Decline Syndrome (OQDS) outbreak, due to the bacterium *Xylella fastidiosa*, which has caused a dramatic impact from both socio-economic and environmental points of view.

Current agronomic practices are mainly based on uprooting the sick olive trees and their surrounding ones, with later installment of olive cultivars more resistant to the bacterium infection. Unfortunately, both of these practices are having an undesirable impact on the environment and on the economy.

In recent papers *Zelus renardii* (Hemiptera, Reduviidae) has been identified as a predator of *P. spumarius* for a possible control of a *Xylella* epidemic.

Here, by generalizing previous models of ours, a spatially structured mathematical model has been proposed to include the predator *Zelus renardii* in the dynamics of a *Xylella* epidemic.

The fact that *Z. renardii* has been reported to be a generalist predator implies the choice of an Holling type III functional response of predation in the mathematical model. As a consequence, it has been shown that the introduction of *Z. renardii* as a predator of *P. spumarius* is not an efficient control strategy to eradicate

a *Xylella* epidemic. Instead, a specialist predator or of a parasitoid, whenever identified, would lead to the eventual eradication of a *Xylella* epidemic; as a matter of fact, in this case the appropriate choice for the predation functional response would be an Holling type II.

In either cases it has been confirmed, as from our previous results, that a significant reduction of the weed biomass can lead to the eradication of the vector population, hence of a *Xylella* epidemic, independently of the presence of predators.

A relevant contribution of our approach consists of a suitable restriction of measures of intervention (control) only to a subregion of the whole habitat of interest (“Think globally, act locally”).

All of the above has been illustrated by a set of computational experiments, within a variety of different possible parameter scenarios.”

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## Nanotechnology and Circular Plant Protection

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Nanotechnologies applied to agriculture represent a recent, innovative, and promising scientific approach able to satisfy the EU request in term of sustainability for different sectors. In the meantime, the European Green Deal respect to the reduction of waste as well as of agrochemicals request strong and green input strategies able to reach ambitious results within 2030. Circular economy concept represents a new and green alternative to deal with the challenges that the agricultural products instead a cost can become a resource. The traditional agriculture system, chemical-based, is going to miss these challenges and nanotechnology can be the answer to the failure of conventional methods by ensuring plant protection and food security in a sustainable way. Among the huge application of nanomaterials usable in crop protection, recent promising results were obtained studying the properties of Cellulose Nanocrystals (CNCs). CNCs can be obtained from agro-food lignocellulosic biomasses. All these approaches can be considered inside the Precision Agriculture 'tank' that, during the next years, will offer a great support to improve the ratio between agricultural output (food) and agricultural input (land, energy, water, agrochemicals, fertilizers, etc.). Recent results highlighted the possibility of using cropping wastes (pruning residues, shells, stem, etc.) to synthesize novel lignocellulosic nanocarriers, such as cellulose nanocrystals and lignin nanoparticles. Here, a selection of the agro-forestry chains has been described for their valorization, developing circular control strategies against crops pests, such as bacterial and fungal plant pathogens.

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## Introduction to the 2nd morning session

**Author:** Genni Fragnelli<sup>None</sup>

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## A mathematical model for spatial concentration of *Xylella fastidiosa*

**Author:** Giusi Vaira<sup>None</sup>

In this talk we present a mathematical model that can be applied to the study of spatial distribution and concentration of *Xylella fastidiosa*. From mathematical point of view we consider the stationary model in order to understand the influence of the barriers in the concentration of the bacterium.

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## An eco-epidemiological model of *Xylella fastidiosa* outbreaks

**Author:** Maria Grazia Naso<sup>None</sup>

In this talk, we analyse, from the mathematical and numerical point of view, an eco-epidemiological model describing the infection dynamics of *Xylella fastidiosa* outbreaks. An existence and uniqueness result is proved and some numerical results and simulations are presented.

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## Wildfire susceptibility estimation: an explainable artificial intelligence approach

**Author:** Roberto Cilli<sup>None</sup>

TBA

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## Machine learning techniques for predicting grapevine and olive water status through Sentinel 2 and PlanetScope multispectral imagery

**Author:** Alessandro Gaetano Vivaldi<sup>None</sup>

Anas Tallou, Vincenzo Giannico, Simone Garofalo, Salvatore Camposeo, Giuseppe Lopriore, Gaetano Alessandro Vivaldi

Abstract

Plant water status is an important factor that needs an accurate temporal and spatial assessment to maintain acceptable yield and quality standards in a changing climate. Integrating remote sensing

(RS) technology to estimate stem water potential (SWP,  $\Psi_{\text{stem}}$ ) can provide good alternatives to traditional in situ plant water status measurements. Hence, field measurements of  $\Psi_{\text{stem}}$  were taken during two consecutive growing seasons from an irrigated vineyard and olive orchard (Apulia region, Southern Italy) at the time of image acquisition. Multispectral reflectance data from PlanetScope and Sentinel II sensors, corresponding to different reflectance values of the grapevine and olive tree samples' spectral bands (PBs), were recorded at  $\Psi_{\text{stem}}$  measurements and used to calculate vegetation indices (VIs). Two machine learning (Random Forest and Support Vector Machine) and one Multiple Linear Regression technique (MLR), were used to develop the grapevine and olive SWP prediction model and test their accuracy, independently considering PBs and VIs as predictors. The aim was to develop a robust prediction model of plant water status for sustainable water management. Our results indicate that the use of the RS reflectance values of grapevine and olive trees to develop a  $\Psi_{\text{stem}}$  prediction model using a machine-learning technique can provide a reliable option for plant water status estimation.

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## Deep learning for Multimodal sensors fusion in remote sensing

**Author:** Paolo Napoletano<sup>1</sup>

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The talk will include the presentation of a multimodal remote sensing dataset collected in our laboratory and the presentation of the challenges and future prospects of using deep learning models in multimodal sensor fusion, paving the way for advances in remote sensing research and applications.

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## CNN crop classifications on multi-GPU architectures

**Author:** Andrea Miola<sup>None</sup>

Crop classification is a key aspect in the fight against climate change, since it helps farmers and agricultural organizations to monitor crop growth and health, predict yields, and manage resources more efficiently. In this talk we'll explore how Neural Networks and remote sensing data can be used to classify crops and why their popularity is seeing an unprecedented growth. We will also present results from High-Performance Computing (HPC) architectures equipped with different GPU accelerators, while highlighting the advantages of such systems in this kind of applications.

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## Drone-Tech: a new AI approach for smart cities illegal waste contrast

**Author:** Raffaele Laforteza<sup>None</sup>

Illegal waste disposal, especially in southern Italy, has become one of the most critical violations of the waste management laws and contributes to the social alarm raised by waste and ecological crimes. Illegal waste disposal threatens public safety and health, the environment, and the economy, with scenarios that range from small dumps created by citizens to vast landfills of toxic materials



collected and buried in dangerous places and also as a cause for wildfires. Specifically, illegal trafficking of human waste has recently become one of the most lucrative activities of organised crime. Often, criminal organisations set waste on fire to eliminate evidence of hazardous materials, releasing highly toxic fumes (e.g., dioxin) that put public health at risk or even reducing farming capabilities of the affected areas. Unauthorized landfills often lack the proper waste treatment leading to the release of leachate, which pollutes the ground water table, other water sources and causes long-term damage, e.g., by increasing cancer incidence. The early detection and continuous monitoring of illegal waste disposal is therefore crucial to prevent and alleviate their impact and the cost of the waste treatment. The goal of the DRONE-TECH project is to develop an innovative and ready-to-use tool for detecting and monitoring illegal waste dumping sites across large urban and peri-urban areas and in compliance with law enforcement and regulations. The project incorporates artificial intelligence (AI) techniques (i.e., deep learning, led by UNIBA) into an innovative module for automatic change detection (provided by Sightec) of imagery provided by drones (operated and managed by Highlander) and based on an integral collaboration of end-users (Municipality of Bari, Local Police, fire brigades, other agencies and regulators operating in, or affected by, the field of waste management) to create an ultimate system for the detection and monitoring of illegal dumping sites and support the management of surveillance activities of waste accumulation over time across large urban and peri-urban areas.

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## Introduction to the 3rd morning session

**Author:** Anna Maria Stellacci<sup>None</sup>

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## Introduction to the 1st afternoon session

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## Introduction 2nd afternoon session

**Author:** Dora Salvatore<sup>None</sup>

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## Salinity Properties Retrieval from Sentinel-2 Satellite Data and Machine Learning Algorithms.

**Author:** Nada Mzid<sup>None</sup>

The accurate monitoring of soil salinization plays a key role in the ecological security and sustainable agricultural development of semiarid regions. The objective of this study was to achieve the best estimation of electrical conductivity variables from salt-affected soils in a south Mediterranean region using Sentinel-2 multispectral imagery. In order to realize this goal, a test was carried out using

electrical conductivity (EC) data collected in central Tunisia. Soil electrical conductivity and leaf electrical conductivity were measured in an olive orchard over two growing seasons and under three irrigation treatments. Firstly, selected spectral salinity, chlorophyll, water, and vegetation indices were tested over the experimental area to estimate both soil and leaf EC using Sentinel-2 imagery on the Google Earth Engine platform. Subsequently, estimation models of soil and leaf EC were calibrated by employing machine learning (ML) techniques using 12 spectral bands of Sentinel-2 images. The prediction accuracy of the EC estimation was assessed by using k-fold cross-validation and computing statistical metrics. The results of the study revealed that machine learning algorithms, together with multispectral data, could advance the mapping and monitoring of soil and leaf electrical conductivity.

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## **The Tebaka project: a remote sensing platform for precision farming**

**Author:** Ester Pantaleo<sup>None</sup>

TBA

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## **Institutional greetengs**

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## **Fruit detection by collaborative robots and machine learning methods. A case study on pomegranate**

**Author:** Simone Pascuzzi<sup>None</sup>

The challenges, costs and complexities of agricultural work require the development and adoption of alternative techniques. In this context, collaborative robots can represent a key factor for the development of agriculture. These are autonomous equipment developed to perform different tasks, make decisions and act in real time without human intervention. Furthermore, robots are also very useful for the sustainable management of the territory, as they guarantee the acquisition of information useful for limiting inputs and the related environmental pollution. Collaborative robots can be equipped with visual sensors for acquiring data which, when properly processed, can be of support to farm management, such as fruit counting or crop growth and health monitoring, etc. A home-built crawler robot equipped with low performance camera (Intel RealSense D435) was used to capture images in a pomegranate orchard. These images have been then processed by a deep learning segmentation framework for separating the fruits (pomegranates) from the surrounding areas. The multi-stage transfer learning technique has been used. At first, a pre-trained network (DeepLabv3+) has been tuned to pomegranate images acquired under controlled conditions and then progressively enhanced to segment the images in the field. In particular, the images of fruits arranged on a horizontal surface with a neutral background were acquired under both natural and controlled lighting conditions. Images with uniform illumination were labelled based on colour thresholds in the RGB space followed by morphological operations and used to transfer learning from the pre-trained architecture. The improved network has been later applied to produce accurate labels for images captured in the presence of shadows. These labels were used to retrain the network, which has been finally applied to segment the images captured by the robot in the pomegranate orchard. The results obtained from this procedure have pointed out that, despite the low quality of the field images, the segmentation of these images has been efficient with high values of the adopted metrics. In particular, the F1-score of 86.42% and IoU (Intersection of Union) of 97.94% has been achieved.