
**A NEW ERA FOR SUSTAINABLE FARMING SYSTEMS FOR GREECE, BASED ON
CONVERGENCE OF SMART FARMING, AGRICULTURAL ROBOTICS AND
GEOSPATIAL TECHNOLOGIES**

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ABSTRACT

Safety and quality of agricultural products with better management and conservation of natural resources has become a significant issue worldwide and it constantly raises awareness in Greece, especially within the last decade. Latest advancements of the evolving agricultural sector towards applications of Precision Agriculture and Smart/Digital Farming and the “greening” of the agriculture based on the latest directives of Common Agricultural Policy (CAP) of the European Union (EU) for the current and the upcoming period (>2022) and the Green Deal , constitute a rigid framework of promising future opportunities and transformations. Additionally, new and emerging cultivation practices, like soilless farming (e.g., Hydroponics, Aquaponics, Aeroponics, vertical agriculture) and intensive, Integrated Agriculture and minimum tillage cropping systems, constitute high-tech solutions of production in Greece. However, as they require significant agrochemical inputs, high energy consumption vehicles and expensive infrastructures, they keep on polluting and exhausting the natural resources. An alternative, sustainable solution, based in latest technological advancements, is urgently needed. In this chapter, an approach is presented for the convergence of Smart Farming, Agricultural Robotics with Geospatial Technologies, providing solutions of their efficient collaboration towards farming practices. Focus will be given to the accumulated promises and opportunities which arise and they may constitute a new, innovative, and sustainable model of agriculture for Greece.

Keywords: Agricultural Robotics, Geographic Information Systems (GIS), Sustainability, Geospatial Technologies, Artificial Intelligence, Smart Farming, Sustainable Development Goals.

1. INTRODUCTION

Since the advent of agriculture around 10.000 years ago [1], farming practices continue, even today, to evolve and differentiate in multiple levels in time, as well as in local, regional, national and international scale (Figure 1). Such differences may be related to quite different reasons, such as the current needs of the society, or the applications of implemented cultivation practices (e.g., plowing with tractors instead of animals). Also, the resulting externalities (e.g., income from yields) of the cultivations, or the capacity of pioneers/researchers through time to approach

alternative perspectives for the agricultural sector and advance the efficiency and contribution to productivity of used equipment, constitute a framework of continuous evolutions. Such evolutions can occur because of the application of new operational strategies, policies and directives of national and international organizations (e.g., Food and Agriculture Organization (FAO), European Commission (EC), United States Department of Agriculture (USDA), etc.), or because of the innovations that are developed for several other, different reasons by disruptive, large scale events (for example, the World War II and the development of chemical substances for weapons, were supported by intense Research and Development (R&D) framework [2]).

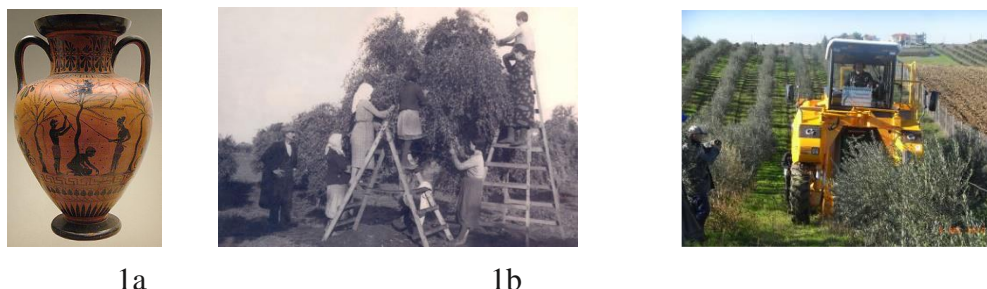


Figure 1 (1a, 1b & 1c). 1a. An ancient Greek amphora showing humans harvesting olives in ancient Greece [3]. 1b. Handpicking of olives in 1930s in Greece [4]. 1c. Modern mechanical harvesting of olives in Greece [5]

The annual worth of \$3,503 trillion dollars for 2019 of global, value added services in agriculture [6], forces further the extended use of non-physical inputs to agricultural production systems, based mainly on more efficient, agrochemical fertilizers/pesticides’ use with the help of new technologies, on new genetic improvements of plants through agricultural biotechnology [7] and on the use of heavy, energy consumption vehicles. Such framework results globally in severe negative effects to natural resources (Figure 2) and agroenvironmental linkages, such as: continuous accumulated pollution risks of water sources, continuous degradation of biodiversity and of ecosystems, environmental desertification of fertile soil and increased natural hazards’ impact from coasts, up to the mountains, which also have significant impact to the climate and to humans’ health [9].

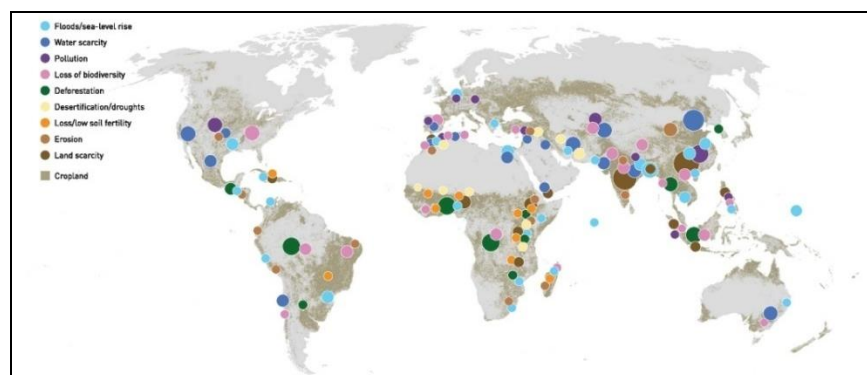


Figure 2. Map overview of risks associated with main agricultural production systems [8]

2. MATERIALS AND METHODS

2.1 Contemporary issues of Agriculture and Sustainability

2.1.1. Agroenvironmental Pressures, Geospatial Technologies and Sustainability

In recent years, several scientific fields around Agriculture have tried to combat these pressures. These fields are related with Sustainable Development, as it is defined by the famous final report of the UN's "Brundtland Commission" as, "*the development that meets the needs of the present without compromising the ability of future generations to meet their own needs and ways of production*" [10]. In order to tackle accumulated pressures related with climate change issues and negative impacts of forms of conventional/intensive agricultural practices within the agricultural sector and beyond, scientists have succeeded in enabling Geospatial Technologies to approach more efficiently such challenges, such as, the SERVIR initiative (Figure 3) [11]. Under this initiative, the Evaporative Stress Index (ESI) was developed as a global geospatial dataset which reveals regions of drought where vegetation is stressed due to lack of water, capturing early signals of drought without using observed rainfall data. This is very important for the end-user related with agricultural issues, especially in developing regions and other parts of the world, where there is lack of sufficient ground-based observations of rainfall, as such information is difficult to be observed and captured before it can be monitored through decreases in vegetation's health or "greenness".

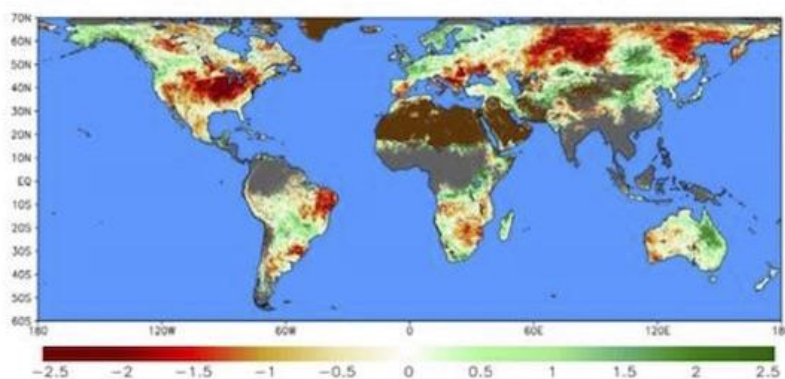


Figure 3. Global geospatial dataset for agriculture which reveals the regions of drought where vegetation is stressed due to lack of water, under the SERVIR joint initiative [11] provided by National Aeronautics and Space Administration (NASA) and United States Agency for International Development (USAID).

The Climate Change issue has become one of the major challenges that our planet is facing in the 21st century and continuously adds considerable stress to our societies, to the environment and to our operational, daily activities. The overall framework is currently – and in the future – concerning agroenvironmental and socioeconomic sectors worldwide. As a result, UN has established with the 2030 Agenda in September 2015 the 17 Sustainable Development Goals (SDGs) (Figure 4), [12], otherwise known as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity. As a continuation of this initiative, there was a distinctive translation of UN 2030 Agenda towards regional, sub-regional and national levels within the borders of the Mediterranean Region. Greece and other Mediterranean

countries, has adopted in February 2016 the revised Mediterranean Strategy for Sustainable Development 2016-2025 [13].

2.1.2. Sectors of Agriculture

Several alternatives have been developed as a means to establish sustainability in agriculture and, as a result, different sectors of agriculture have been defined and introduced the later decades. Therefore, we have three major sectors [14]:

- i) **Natural Agriculture**, where nature is free from every human interference with five major principles: no tilling, no fertilizing, no pesticides, no herbicide, no lopping.
- ii) **Conventional** (also known as **Classic, Scientific, Contemporary, Chemical**) **Agriculture**. It is based upon intensive processes of yielding and automation of cultivation, use of chemicals, lack of biodiversity, use of large energy amounts, etc., aiming maximum results.
- iii) **Sustainable Agriculture** which includes **Organic** (or **Biologic**, or **Ecologic**) that has no agrochemical inputs and **Integrated Agriculture** (including **Precision Agriculture**) which approves, under ecological thinking, the use of chemicals, intensive production, reduced biodiversity, use of products derived from genetic engineering, etc.

From the above mentioned Sustainable Agricultural alternatives, Organic Agriculture (OA), and potential extensions of it, can be considered as being the more focused operational sector targeting towards sustainability's objectives and practices. Under this perspective, OA can provide significant benefits for the yield, for the environment, for the circular economy and for the healthier nourishment of consumers too, raising for these reasons increased awareness worldwide, as well as in Greece.

2.1.3. Organic Agriculture in Greece and Geospatial Technologies

Greece is spreading around 132,000 square kilometers (Km²) south the Balkan Peninsula. Rural areas consist of more than 85% of its territory and the total agricultural area is about 4 million hectares. Natural environment of Greece is enriched by a large variety of macro and micro-environmental regions; it is surrounding from the three sides by the sea (Figure 4) working as a natural protecting shield; it has continuing changes in the landscape of the country affecting, through history, the development of implemented cultivation methods.

Since the official establishment of Organic Agriculture framework according to the Regulation 2092/91 of the European Union (former European Economic Community-EEC), a lot of things have changed in Greece. For example, the obligation of trade of certified organic products with a label, which officially certifies the organic process of production, as well as the authenticity of the licensed (by the government) organizational body which monitors and controls all inputs and outputs of the organic crop. This Regulation has been amended on several occasions, such as in 1999 when the Council extended its scope to cover organic livestock production with Regulation No. 1804/99, as well as in 2007 with Regulation No. 834/2007, and further (such as, Regulation No. 889/2008, No. 392/2013 and No. 2273/2017 [17], setting out the principles, aims and overarching rules of organic production and defining how organic products were to be labeled [18].

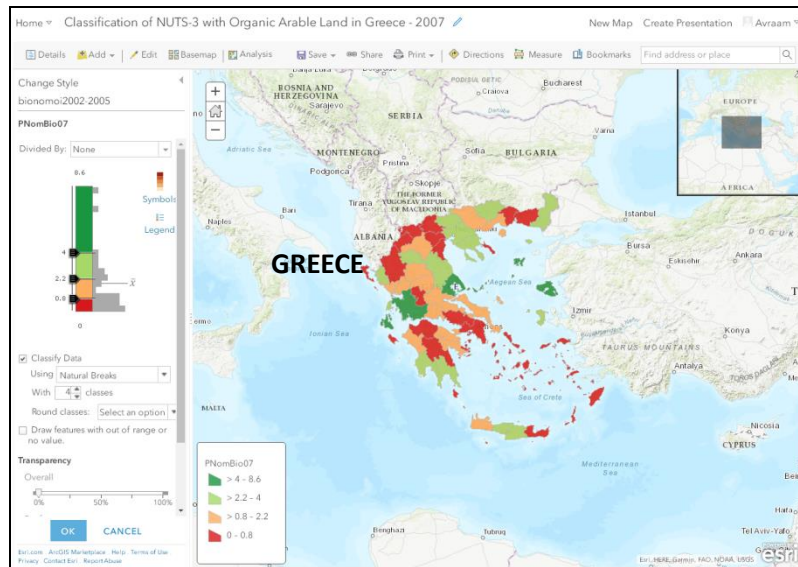


Figure 4. Thematic map of the NUTS-3 (Nomenclature of Territorial Units for Statistics) regions of Greece, showing 4 levels of the percentage (%) of the arable organic area of each prefecture in relation to the overall organic arable land in 2007. The classified map was created with the open source Web-GIS portal of ArcGIS Online [15], of ESRI (Map generated by personal research of the authors. Data sources: Greek Ministry of Rural Development and Food [16]).

In order to define the term of “Organic Agriculture” long standing organizations which are internationally approved determine the overall framework of proper understanding its meaning and status. As a result, OA as an alternative approach of agriculture is difficult to set under terms because it is not static. It evolves according to the scientific results from research projects that respond to its principles [19]:

- It uses biological methods for confrontation of insects, diseases, weeds.
- It aims on best soil fertility based in natural processes.
- It uses methods of “closed circle” production where the wastes from former cultivations or other recyclable influx are not thrown away, but they are incorporated, through recycling procedures, back in the cultivation (embedment of manure, leaves, compost mixtures, etc.)
- It can obtain the critical balance between human/food/nature, enabling the promotion of sustainable development.
- It avoids heavy machinery because of damages of soil’s connectivity and of soil’s microorganisms which are used in OA to enrich soil’s elements.
- It avoids the use of chemicals.
- It avoids using supplemental in animal nourishing.
- Comparing with conventional agriculture, OA needs about 20% more working hands, getting yield reduction by 10-30%, achieving higher prices in organized marketing infrastructures by 15-20%.

- It needs 3-5 years to transit a conventional cultivated field to a biologic farming system following the restrictions of Council Regulation (EEC) No 2092/91.
- It implements crop rotation and co-cultivation of plants.
- It underlies in inspections from authorities approved by the Greek ministry of Agriculture.

All these prerequisites constitute a rather unfriendly framework of economic uncertainties for the potential biofarmer in Greece. Additionally, there are certain weaknesses as regards the sound and integrative design of all-inclusive strategy to promote OA in Greece, in times of economic crisis. This situation can be seen by Figure 5, which depicts the unsteady period after the start of Greek economic crisis in 2009-2010, showing the fluctuation of the number of biofarmers applying OA practices, as well as the fluctuation of the area of their organic plots at the same period.

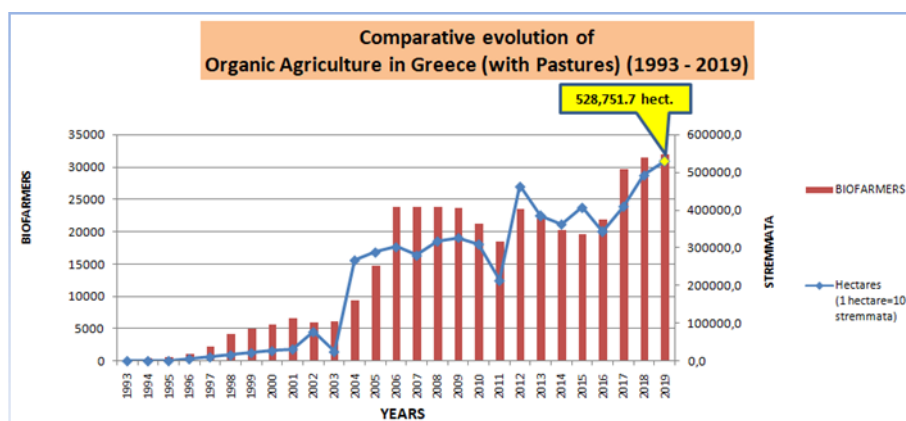


Figure 5. Fluctuation of the number of biofarmers applying OA practices, as well as the fluctuation of the area of their organic plots during the period 1993 – 2019. (Graph generated by personal research of the authors. Data sources: Greek Ministry of Rural Development and Food [16])

Convergence of OA with Digital Technologies may provide new opportunities for biofarmers, as well as all people, private enterprises and organizations (national and international) that are related with this sustainable way of production. Input of information for members who participate, or are related with the OA sector, affects a variety of activities, such as the quantity and quality of products, the efficient management of cultivated methods, the economics of the organic agricultural holding and ultimately, the consumer of this product. At the same time, other “non-economic values” are greatly affected by the increase and sound ways of sustainable production in OA, against the increase and extended use of agrochemical pesticides, insecticides and fertilizers. Such values are the endangered species of wildlife (e.g., Brown Bear, *Ursus arctos L.*), the biodiversity, the rivers and lakes and, the cultural heritage of a specific region which is connected with the sustainable methods of production.

The proportion of OA of the EU member states, was either steady or increasing, when Greece had fluctuations of the same entities (Figure 6).

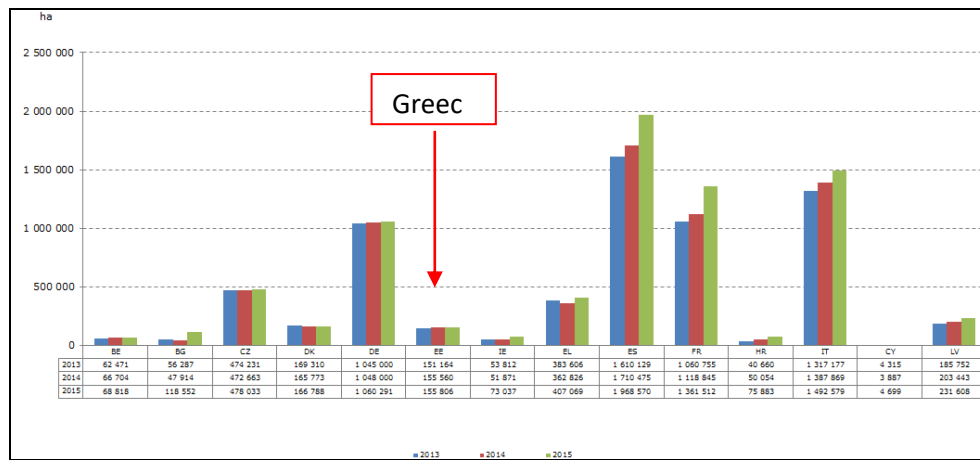


Figure 6. Organic area (certified organic + in conversion) in the Member States in 2013, 2014 and 2015 [20]

In order to have a better assessment of this unstable situation for the sustainable development and evolution of Organic Agriculture in Greece’s peninsula, we have to take into consideration some important factors:

- i. The organic cultivated area in Greece has been reduced significantly by ¼ (-25.9%) during the period 2012-2016 [21].
- ii. The average plot area per biofarmer for the total OA in Greece is 15.66 ha, but this includes also the permanent organic pastures. According to EUROSTAT [22], the total organic arable land in Greece, at the end of 2016, without any permanent grasslands was 102,166 ha, with an average plot area per farmer equal to 4.67 ha. .
- iii. The use of Information and Communication Technologies (ICT) and Internet of Things (IoT) and Agricultural Robotics (AR) is highly underestimated in OA, as they are considered expensive and not easy to be applied. This is important and enhanced by the small size of organic plots, which cannot support expensive equipment and uses (like Variable Rate Technologies – VRT) because of their cost.
- iv. There is a significant gap of development and economically support frameworks by the Greek governments to the farmers in the last decades to use such utilities. Latest approaches by the European Union and the EIP-AGRI initiative [23] is considered as a framework of better perspectives towards development of Smart Technologies for OA. However, now we’re in a turning point of new activities.
- v. There is a significant gap of promoting such learning curricula by educational organizations to Greek agronomists and biofarmers. Significant effort is provided the last years by the School of Professional Education of adults’ education at the American Farm School of Thessaloniki, through the course of "Contemporary Agricultural Practices" with experiential activities for adults through seminars [24].

- vi. At the same time, there is lack of such technological skills by biofarmers (and from farmers of other agricultural sectors too), as well as of the comprehension of the importance of their use in the overall management activities of their plot. For example, only a small percentage (7.7%) of people related with the agricultural sector were using mobile phones to access to information or services about the agricultural sector back in 2003 [25]. However, a later study [26] has shown that it is likely that the dominant motivation of farmers to use ICT is growing and it has professional characteristics and needs of their application.
- vii. There is significant lack of connecting and exploiting Geospatial Technologies (GTs) with OA. GTs such as Geographic Information Systems (GIS), Remote Sensing, Global Positioning Systems (GPS), Unmanned Aerial Vehicles/Systems (UAVs/UAS), Web-GIS platforms with free data and satellite images (Figure 7) at national and international level are continuously developing.



Figure 7. Classification image of NDVI (Normalized Differential Vegetation Index) from the satellite SENTINEL-2, showing the vigorous vegetation of the case study area (Olive grove of Perrotis College of American Farm School Campus (red square in drive map on the left, bottom corner) with NDVI= 0.503 on the spot, through EOS (LandViewer portal). This image can be downloaded and it is free of charge (up to 10 downloads per day are allowed by EOS) [27].

Such platforms are enriched and enhanced with advanced operational services, constituting a framework of increased provision of (geo)spatial and non-spatial information and perspectives of Big Data analytics with additional interdisciplinary, operational potentials to end-users. With support by geospatial analysts, more efficient strategies and policies can be approached and designed through web-based Geoinformatics applications.

- viii. There was a significant gap of a truly, all-inclusive, strategic approach for OA under a framework of economic crisis in Greece since 2010. For that issue, there was a focus towards economic policies that often create divergence, rather than contributing to achieving sustainable development.
- ix. Significant digital advancements and initiatives have just recently started to take place in Greece towards the “Digital Transformation of the Agricultural Sector”. On the

16th March 2018, there was an official announcement by the government as regards the establishment of the new “Digital Strategy in Agriculture”. Among other parts of this announcement, important are the following: the establishment of the “Agro-Internet of Things” and of the “Rural Broadband” in Greece, the establishment of 6,500 earth stations with “smart sensors” that will collect valuable data (such as temperature, moisture, soil data, atmospheric data and more), open to everyone. It is estimated that 450.000 farmers will be benefited at the beginning by reducing by 30-45% the cost of production; 1,500,000 hectares of the 20 most exported Greek cultivations will be included in the project. It is considered the first national infrastructure in terms of Smart Farming in the European Union [28].

For better understanding the spatial classification of organic plots in regions of Greece (NUTS-2) and potential needs and constraints that exist around Greece. Mavridis (2007) applied spatio-temporal analytics and modelling of the dissemination of organic plots’ area, but without appreciation by the governmental authorities (Figure 8), or other related societies.

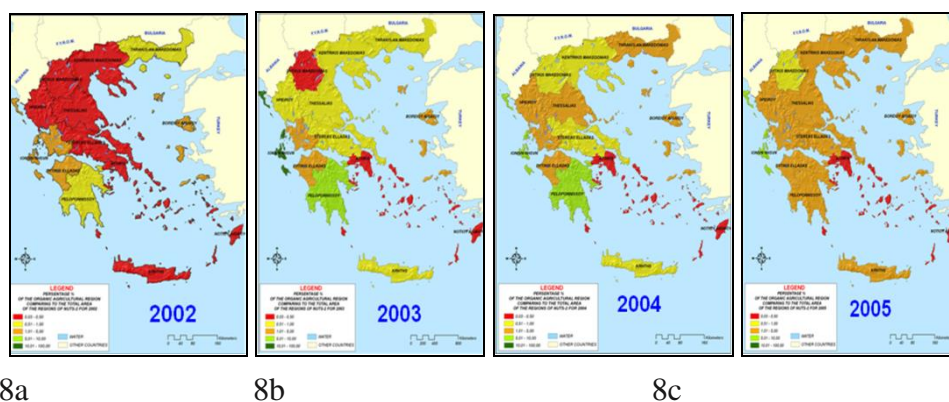


Figure 8 (a, b, c, & d). Spatiotemporal evolution of the proportion (%) of organic cultivated area (organic arable land + grasslands) in Greece compared with the overall area of the surrounding NUTS-2 region for 2002-2005 [29]

Geospatial and other related technologies based on sensors and other equipment and facilities, which digitally capture objects and their actual condition in the real world, are having the potential of further development and growth in the future. As a result, their exploitation towards objectives of OA should be considered a supportive tool for further development worldwide, as well as in Greece too. This is very important, not only for the capture of visible and existing entities of the real world, but also, because this new era of technological advancements will provide frameworks to enable new services, generating massive amounts of data analytics. Therefore, all new operational entities – such as Agricultural Robotics - that could support and cooperate with such technologies, will be the digital, intelligent Trojan Horse of the future which it will enable the leveraging of spatial and non-spatial data to perceive, approach, analyze, cooperate, compute, present, learn from, design and shape new horizons of the future world.

Digital technologies such as smartphones, tablets, in-field sensors, drones and satellites, provide a range of farming solutions such as improved crop yields and animal performance, efficiency of process inputs and labour reduction, which can increase profitability. However, the convergence of Agricultural Robotics with Sustainable Agriculture may provide even more unprecedented benefits, beyond the agroenvironmental framework

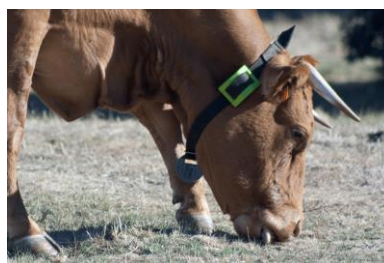
3. ISSUES OF DIGITAL REVOLUTION AND SUSTAINABLE FARMING SYSTEMS

3.1 Perspectives of Digital Exploitation in Agriculture

Digitization of agricultural activities in plant and animal production can improve in many ways the working conditions for farmers, while reducing the environmental impact of agricultural practices and provide important information to the consumer. These technologies can offer significant benefits on aspects of remote measurement of soil conditions, on provision of better water/irrigation management and crop monitoring in PA. In Precision Livestock Farming (PLF) (Figure 9) in terms of OA, they can provide significant benefits for better nourishment of animals, better health by monitoring heat stress and their activity in the field through GPS and better quality and quantity of milk and meat.



9a



9b

Figure 9 (a & b). (9a) DigitAnimal enterprise can select and analyze data throughout the day, when the cows are ready for insemination. (9b) Satellite monitoring in real time for the daily activities of the cows mounted GPS sensor [30].

Further exploitation of selected data (spatial and non-spatial) which can be provided in real-time and continuously transferred to a mainframe, can give to farmers/entrepreneurs better understanding of the variability of soil into their farm, or the development of crop patterns, or variations of animal's activity through the day, so as to promote practices of their welfare. Under such an integrated, operational framework, (bio)farmers can plan in advance more effectively their activities related with the farm and they can be more efficient. Smart Farming Technologies constitute an operational sector of increased capabilities and augmented synergies. Such technologies in agriculture include:

i) Satellite Monitoring, ii) Soil/Plant/Weather Sensors, iii) Mobile devices with specific application/s for the farm, iv) Smart Zone Seeding technologies, v) Autonomous - Modular Robotics, vi) Weather Modelling, vii) Smart Micro Irrigation, viii) Fertilizer Modelling, ix) “On-the-spot” and “On-the-fly” spraying systems, x) Internet of Things, xi) UAVs/UAS (Unmanned Aerial Vehicles/ Unmanned Aerial Systems)

Beyond this promising framework of technological facilities and innovative opportunities, new advancements in technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Agricultural Robotics (AR) and Big Data (BD), are providing new, multidisciplinary and interdisciplinary, potential perspectives. Their operational efficiency can drive and lead to unprecedented innovations in agriculture and beyond [31], which may be beneficial for the environment, for farmers, for consumers and for the creation of new operational frameworks and

synergies, such as the creation of alternatives of new types of business models in the overall agricultural sector and within other economic sectors too.

For all the reasons mentioned above like, the evolving period of the OA sector in Greece and the need to promote activities towards the Mediterranean Strategy for Sustainable Development 2016-2025, further consideration should be made: The potential overtaking of the Moore's Law within the next five to ten years promoting faster, smaller, cheaper and stronger devices and the beginning of the "Digital Strategy towards the Agricultural Sector" towards the establishment of new operational facilities in Greece, all participating actors and interested individuals, entrepreneurs and policy makers of the OA sector should comprehend that fact. Now is the time for Greece of convergence of operabilities towards i) Sustainable/Organic Agriculture, ii) GeoSpatial Technologies, iii) Agricultural Robotics and iv) Smart Farming (SOAGSTARS Farming) framework, as it is proposed by the authors.

In order to have a better understanding of the importance of this milestone, we have to comprehend that the establishment of a new, advanced and multi-operational framework of ICT with extended interlinkages with agriculture and Geospatial Technologies, has already started. This is even more important, especially if we consider the fact that we are currently at the dawn of the 4th Industrial Revolution [33], which makes our enrollment towards this perspective more crucial than ever before. Under this new industrial reformation of our daily lives which is under development, the establishment of the proposed framework towards a more sustainable, efficient, ubiquitous, agricultural sector, is further enhanced by its four pillars which are in an increasing trajectory, at national and international scale, providing complementary elements and enhanced services of one to the other.

3.2 Potential Examples of Convergence of Agricultural and Sustainable/Organic Agriculture within the SOAGSTARS Farming framework

As there are a lot of different fields that someone can explore and approach so as to embrace such solutions, the main scope and core of this chapter is following, in order to provide these examples to any interested individual from Greece, or from other countries.

European Union has recently developed the Digital Single Market strategy, establishing the initiative of "Digitising European Industry" [31]. Its objective is to ensure that "*any industry in Europe, big or small, wherever situated and in any sector can fully benefit from digital innovations to upgrade its products, improve its processes and adapt its business models to the digital change*". Based on the emerging applications developed under the SOAGSTARS Farming framework which are fully connected with the previous initiative, end-users of such frameworks should comprehend the importance of the following statement: *The new era of Digital Agriculture is mostly related with the exploitation of data (spatial and non-spatial) and the enabled technologies.*

These new technologies extract value from data, helping to improve productivity and capability of enhanced activities for the end-user within the field, as well as around it, and in other operational levels of the society under the framework 24/7/365 (which means, continuously and without stop of flow of data and services). *Being small as an enterprise, or farm, is not considered any more an excuse for being a late-adopter of such technologies. "Small" should mean "agile", not "slow in adoption"*.

Another important reminder is the fact that SOAGSTARS Farming framework is mainly related with the sustainability of Organic Agricultural Systems (OAS), therefore the operabilities of its technologies should be in line with the principles of OA. As a result, although practices of Precision Agriculture (PA) and Integrative Agriculture (IA) are considered beneficial for the sustainable development of crop cultivating practices through Variable Rate Technologies (VRTs) of agrochemicals, PA and IA should be excluded.

However, PA provides significant benefits to sustainability by:

- Examination and record of the variability per unit area (on-the-spot) of the farm in important soil properties that affect its productivity,
- Recording and mapping of the inherent "variability" of the soil-plant system,
- Focus on the creation of Management Zones,
- Support on the application of the appropriate input flows (avoiding excessive quantities of irrigation, seed, pesticides, fertilizers, etc.) per unit area (on-the-spot),
- Examination of the temporal behavior of the land system (soil-air-water interaction), with emphasis on its sustainability through collaborative processes,

Without compromising the significant contribution of Precision Agriculture towards sustainability efforts, the following paragraphs aim to approach and to focus on the advanced capacity that new, innovative, digital technologies can provide to Organic Agriculture and to the Agroenvironmental Resources in overall.

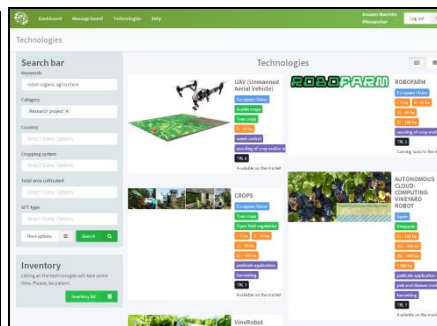
3.2.1 Smart Farming Sensors and Digital Farming Platforms

- **Smart-Akis project**

Smart-Akis project (Figure 10) [34] is an effort of European Network mainstreaming Smart Farming Technologies among the European farmer community, bridging the gap between practitioners and research on the identification and delivery of new Smart Farming solutions to fit the farmers’ needs. Although it is not clearly focused to organic farmers, its platform can provide significant solutions and propose specific technologies of different Technology Readiness Levels (TRLs) to any problems that biofarmers have to deal with under the framework of organic cultivation practices, based on principles of OA.



10a



10b

Figure 10 (a & b). 10a) The portal of Smart-Akis project (<https://www.smart-akis.com/>) on Smart Farming Technologies and, 10b) The Smart farming Platform with including Smart Technologies [34].

- **Smart Multi-Sensors**

As it is already mentioned (paragraph §3.1), Soil/Plant/Weather Sensors can provide synergies and complementarities to the biofarmer for better knowing the characteristics and indicators related with the farm practices and production. As these indexes are related with many different fields for the end-user/biofarmer, there is a need to enable different sensors for each different part of the cultivation method. For example, there is a need for a sensor for soil moisture, another one for temperature, another one for the quality and the fertility of the soil, etc. Such perspective is quite discouraging for the biofarmer in Greece and it is not easy to be adopted within the current situation of economic crisis.

An alternative is the use of multi-sensors that can provide such information on-the-fly, and it can be connected through Wi-Fi (Wireless Fidelity) networks, or/and through Bluetooth. Such multi-sensor is the “Parrot Flower Power (PFP)” (Figure 12) which can capture data in-the-field, in indoor and outdoor conditions. Such data are related with a) Air Temperature, b) Soil Moisture, c) Soil Electrical Conductivity and d) Sunlight (Figure 11a). It can be connected through a smartphone app available for Android and iOS mobile systems, and it can provide advices and alerts targeted at the specific crop through a database that includes more than 7,000 plant species. According to the characteristics of each plant, it can advice the end-user on aspects of irrigation of plants, of protection from extreme sunlight conditions, or of extreme cold conditions and of enrichment of the soil with sustainable fertilizers, which are approved by the EU Regulations. What’s more important is the fact that it gathers all these data and it provides them separately, or altogether through graphs for further analytical approaches (Figure 11b). It is working through a battery that stands for six (6) months, without any other potential impact to the farm. However, this device could be more efficient and targeted to the needs of the Greek biofarmers, as long as it could be connected through Wi-Fi networks and through Cloud services.



11a

11b

Figure 11 (a & b). 11a) The Parrot Flower Power device with its sensors and, 11b) The smartphone application that is connected with the plant’s database and it provides graphs and advices according to the specifications of each plant species through Bluetooth connection [35].

However, as the Wi-Fi networks (5G, 5G+ networks) are continuously evolving in capacity and speed of transferring data and providing advanced services to more end-users, such devices are considered to have weaknesses to their remote communication with the end-user and the absence of online, real time connection. This is more significant for sustainable, agro-environmental

management which depends on detailed and timely spatial and temporal knowledge of processes and factors that affect the physiological growth and development of the cultivation [36]. Alternative solutions towards wi-fi integration can be considered the “Spiio” [37] and the “Koubachi” [38] plant multisensors (Figure 13).



13a



13b

Figure 13 (a & b). 13a) The Spiio wi-fi Plant Sensor [37] and, 13b) The Koubachi wi-fi Plant Sensor [38]

3.2.2 Emerging Digital Technologies for Sustainable/Organic Purposes

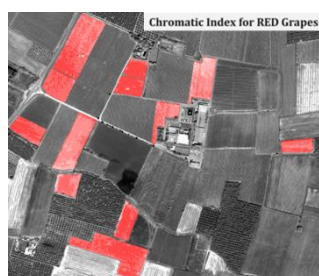
- *Agricultural Robotics and UAVs towards sustainable Knowledge*

The key areas that are related with Sustainable/Organic Agriculture require increased efforts by biofarmers, with heavy workloads which are mostly regulated by themselves, without the presence of technological innovations and heavy/energy consuming tractors. As a result, a lot of work in the farm is mainly provided throughout the day by the hands of biofarmers. In general, the quality of the farm is constantly managed and based on the farmers' senses, such as the eye monitoring of several characteristics of their plants, or by their continuous movement through their plants for better knowledge of the cultivating factors, changes and needs of their crops within the farm and of management zones of varied inputs, as well as in relation to the adjacent ecosystem (for example, the existence of proper micro-environments of predator-insects). However, farms are different in nature, in size and in anaglyph. In this occasion, UAVs can be considered significant tools for enhancement of such knowledge within the farm as well as, at the adjacent area with speed and efficiency (Figure 14).

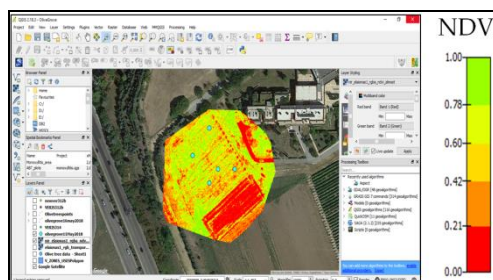
Such perspective can be achieved even by simple cameras mounted on a UAV used just for observation purposes. However, with more advanced cameras with higher resolution and operational capacity, additional benefits of geospatial knowledge can be provided with increased spatial accuracy that can be less than 1 cm, complementing on the knowledge derived from satellite image analysis with lower resolution as shown in Figure 7. The use of spraying drones has been researched in Perrotis College and a comparison study with ground and aerial systems, revealed the benefits of spraying UAVs [45].

In another approach, showing the importance of Agricultural Robotics in OA, we have to consider using the latest developed large tractors with latest sensors on it. However, they are not

possible to move properly in continuous changes of the Greek, rural landscape, which has moderate to high slopes (with an angle of more than 30°) of mountainous, or semi-mountainous areas where about 44% of agricultural holdings exist [40]. Also, they are quite heavy and they will cause significant consumption of fuels, as well as soil compaction with further negative consequences to the fertility of the soil, to the yield of the cultivation, or even increasing the potential of extensive flooding to the field.



14a



14b

Figure 14 (a & b). 14a) An area with different plots of vineyards scanned with Worldview-2 showing through density of red color, the spatial variability of Chromatic Index of red grapes [39] and, 14b) The olive grove of Figure 7, scanned by a UAV, presenting with the use the software Pix4D and QGIS v. 2.18 Las Palmas, the classification of NDVI within the plot, with greater accuracy than with EOS, LandViewer (Geospatial analysis was provided by the authors).

A digital response to that issue is the use of Autonomous Robots, such as “Bonirob”, developed by AMAZONEN-WERKE together with the Osnabrück University of Applied Sciences and other partners [41], providing from phenotyping, to precision spraying and penetrometer app. Also, the multi-purpose “SRFV-Small Robotic Farm Vehicle” from Queensland University of Technology, Australia which weighs 600 kgr [42] and, the “Weedy Robot” of Wageningen University developed with Agrotechnology and Food Innovations BV and the University of Hohenheim [43]. These are a representative subset of existing technology, although there are many other robots and projects that could have been mentioned. Besides their benefits, these robots are considered heavy (e.g., the “Weedy Robot” weighs 1250 kgr), and they have a fairly fixed physical appearance (Figure 15).



15a



15b



15c

Figure 15 (a, b and c). 15a) Bonirob, 15b) SRFV-Small Robotic Farm Vehicle, 15c) Weedy Robot.

For many cultivation practices heavy equipment are needed. The incorporation of AR with additional equipment and sensors, as well as other operational devices, is considered a positive

step towards supporting services to tackle these problems. As mentioned, in many occasions such robots are quite heavy, weighing more than 0.5-1 tn (e.g., the Weedy Robot).

- ***Agile - Modular Agricultural Robotics***

The transformation of the hardware and software of an Agricultural Robot based on the different needs of the end-user/biofarmer, is considered a significant advantage, especially under the increased different needs in the field (Figure 16).



Figure 16. Different examples of robots assembled from Thorvald II modules

This modularity has been provided as a pioneering approach by the Thorvald II robotic system [44], developed by the team of Prof. Pål Johan From, at the Norwegian University of Life Sciences. Thorvald II has some remarkable characteristics that make it able to stand out from other robotic systems, especially towards objectives of OA. Some of them are [44]:

- i) The robot is autonomous, light-weight and it has four-wheel drive and four-wheel steering. It also has four suspension modules which make it able to adapt to uneven surfaces and maintain good traction on all drive wheels in rough terrain.
- ii) Various robots may be constructed from the standard Thorvald II modules, e.g., robots of different size, or with four-wheel drive and four-wheel steering, differential drive robots, robots with or without suspension, etc.
- iii) The robot may be made stiff or flexible by adding or removing frame members.
- iv) With simple, custom frame components with standard modules, greater variation can be achieved according to the needs of the biofarmer.
- v) Different sensors/devices can connect to the module based on the farmers' needs.
- vi) By enabling GPS, LiDAR (Light Detection and Ranging) images, IMU (Inertial Measurement Unit) with a map, it navigates to prerecorded way-points in the field, avoiding obstacles, while caring heavy tools.
- vii) It can apply non-chemical methods through new technologies, such as by using UV-B (Ultra Violet-Black) light to combat mildew in strawberries, or apply research activities of plant phenomics and provide their phenotype characteristics.

4. CONCLUSIONS

Digital technologies have come a long way after their initial use in agriculture in Greece and they have a much longer way and contribution to follow in the future. New Smart Sensors can provide through significant advancements and dissemination of data in real-time supported by IoT applications and Wi-Fi networks. However, based on the current and future needs of Sustainable/Organic Agriculture, exceptional is the fact of the combination of light-weight Modular Agricultural Robotics and UAVs with Geospatial Technologies, cooperating with sensors and new, innovative, non-chemical technologies, like UV-B.

This new era of operational advancements and exploitation of digital technologies in terms of Sustainable/Organic Agriculture, can promote further the creation of new horizons of opportunities. As a result, new, innovative technological advancements will be further developed to tackle with accumulated, agroenvironmental pressures and climate change issues. Also, new business models will arise that will shape the future framework of the Greek society, promoting it as an active member of the planet which supports and advance further future objectives of sustainable production and living, aiming to a better quality of agricultural products and of life for the population of the whole planet.

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