Precision Agriculture's Economic Benefits in Greece: An Exploratory Statistical Analysis

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1 Introduction

World population is expected to be around ten billion people in 2050, while the climate change situation does not allow to increase arable lands [1]. So, a new challenge rises. More people must be fed, therefore there will be a demand to increase global food production while retaining quantity of arable lands steady. Then modern farmers have to focus on how to effectively utilize arable land they use.

The purpose of this study is finding how Greek districts are bundled on crop type (arable drops, horticulture, permanent crops), arable land size, improved agricultural field actions/processes (irrigation, fertilization and pesticide use, plant disease prevention, harvesting, sowing, ploughing, agricultural vehicle use) and specific economic benefits (reduced resource spending, increased labor productivity, improved use of commodities and equipment, increased product quantity and quality, increased income, improved environment protection). This grouping would make it possible to have a wide view of Greece's agriculture sector and see how improved agricultural processes benefit farmers.

To achieve the goals that have been set, an exploratory study took place on almost all districts of Greece. This research could be the start of a series of studies, focusing on agricultural economics in Greece. It could also be a useful farmers' guide. Every farmer has specific investing restrictions on improving agricultural processes due to limited budget. Consequently, every farmer could choose an optimized solution in terms of the agricultural processes she/he should focus, to improve farm sustainability.

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To improve agricultural actions, Precision Agriculture (PA) practices and related technologies are the timeliest way providing also a sustainable solution to agricultural development. PA could be defined as

> "a whole-farm management approach using information technology, satellite positioning (GNSS) data, remote sensing, and proximal data gathering. These technologies have the goal of optimizing returns on inputs whilst potentially reducing environmental impacts" [2].

As a concept, PA emerged around 1990, when Global Positioning System (GPS) and sensor technologies were made widely available at civil economy, while important advances took place in soil sampling, statistics, and computing power [3, 4]. Sensors started to be placed on agricultural equipment to measure specific yield and soil properties, aiming at maximizing outputs and reducing inputs [5, 6].

Till the appearance of PA, a farm field was considered as a uniform entity. The decisions a farmer made considering various agricultural actions, applied on the whole field [7]. PA offers a new perspective on agricultural fields' management. Therefore a farm field is divided to management zones (MZ), which are areas with similar characteristics under a specific criterion or a set of criteria [8–10]. Based on this approach, a farmer can differentiate decisions regarding a field by optimizing inputs on each individual MZ.

2 Literature Review

PA technologies are categorized into data acquisition, data analysis and evaluation, and precision application technologies [11]. The literature of this chapter will focus on precision application technologies, which are the most directly affecting agricultural actions and there are references to Unmanned Aerial Vehicles (UAV) and weather stations, which are some of the most trending equipment these times. It is interesting to see PA's application in practice, through the presented literature and seek benefits that come out as a result.

One of the most important PA technologies is the variable rate application (VR). It is based on the MZ philosophy and its application varies depending on the agricultural process that takes place on the field. There are two VR methods. The first one is called "map-based" and is based on (off-line) historical data. Information are extracted from a GIS so as to control a set of farm processes to optimize inputs. The second one is called "sensor-based". In this method sensors are used to detect soil properties and (on-line) adjust inputs [3]. VR is distinguished into the variable rate nutrient application (VRNA), the variable rate irrigation (VRI), the variable rate pesticide application (VRPA) and the variable rate planting/seeding (VRP/VRS).

Extended fertilizer use harms environment, damages soil quality and pollutes water. Optimized fertilizer use can achieve a considerable chemicals use reduction [6]. VRNA helps farmers optimize fertilizer application by measuring crop nutrient status and adjusting fertilizer rate accordingly [12]. Consequently, yield quantity can be increased, and crop quality can be improved. Therefore, economic gain is increased and, in parallel, agricultural activities are less hazardous for the environment [13]. A study on apples in Greece applied homogeneous and variable rate fertilization on orchard [14]. The results showed significant nitrogen inputs reduction on VRNA case. Yield quantity was a little smaller, but the farmer's profit increased, and the quality of apples improved. The same comparison was conducted by another research team in Italy during 2005–2008 [7]. The results showed that it is possible to identify the N ideal fertilization rate so as to maximize yield production and economic profit while affect the environment as least as possible. In summary, VRNA's applications of Nitrogen (N) are considered profitable by 72% of studies in corn and 20% in wheat. Respective applications on Phosphorus (P) and Potassium (K) are profitable by 60% of studies in corn [15].

Irrigation is one of the most critical actions on agriculture, since the invention of agriculture. Its optimization can lead to substantial water saving [6]. VRI (Variable Rate Irrigation) achieves micro-irrigation across the farm according to every MZ's requirements [13]. It increases crop yield, water efficiency, while it maintains soil temperature and might result in less pesticide use. By testing the application on corn, the results indicated higher yield output and improved water efficiency [16]. The HydroSence project studied the VRI on cotton in Greece. The results showed 5–34% savings in water consumption, while yield output increased from 18 to 31% [13]. VRI was also tested on New Zealand on a maize farm. MZs were created based on electrical conductivity and soil water availability. The results showed water savings of around 26.3% [17].

VRPA can reduce the quantity of pesticide use. Reduced pesticide use improves the final quality of agricultural products [13]. Water and ground contamination is also reduced and the biodiversity is less affected than with conventional pesticide use. So there are several environmental benefits [18]. In a study on maize-based cropping systems within Europe, it was evaluated that VRPA can result in net profit in about 3–4 years [19].

VRP/VRS is a technology also based on the MZ philosophy on which farmers can selectively plant/seed depending to soil potential. The main benefit is increased yield quantity [13, 20, 21].

Another important aspect of farming is vehicle use in agriculture. PA also applies on this action. There are two matters that PA can improve on an agricultural vehicle, namely navigation and route optimization. A possible solution for improved navigation comes through the Multi Global Navigation Satellite System (GNSS) precise point positioning (PPP) which provides high accuracy positioning, with higher flexibility and potentially lower capital and running costs [22]. Route optimization is possible by use of real–time extend GNSS which optimize farmers' routes by avoiding missed-area and overlaps in area coverage operations [23].

Vehicle use optimization technologies can be used during seeding, tillage, planting, weeding, harvesting and autonomous vehicles enabling [13]. The use of machine guidance on corn and soybean crops on Kentucky resulted to 2.4% cost savings in seeding, 2.2% in fertilizing, and 10.4% in planting operations [24]. It can also reduce working hours by 6.04% and fuel consumption by 6.32% [25]. A study in Alabama demonstrated that the average net returns could be calculated between

83 and 612 € ha^{-1} [26]. Machine guidance has also a positive effect on fertilizer and pesticide costs by reducing them 3–5% [27].

Control traffic farming (CTF) is a system which optimizes driving patterns, operations and input applications. This system was implemented in Denmark on cereal farms, in areas where the arable land was greater than 300 ha. Its application resulted in fuel cost reduction by 25–27%. Application of CTF in Australia successfully cut machinery cost by 75%, while crop yields rose in different levels depending on crop [13, 27].

Precision physical weeding (PPW) technology offers optimized herbicide application and weed control according to observed weed density without damaging crops [12]. Its function is based on a continuous ground-based image analysis system that locates crop row on the field. It benefits the environment due to reduced pesticide and fuel consumption, and also due to the fact that a tractor using a weeding implement will tackle with lower draught forces in comparison with the mainstream methods [13, 28].

UAV is defined as a device which can be remotely controlled. There have been various UAVs classifications. A first one is based on aerodynamic features. A second one on autonomy level. A third one is based on physical characteristics (size, weight). Finally, a fourth one is based on power source [29].

UAV utilizes optimal sensors and uses various cameras to capture Red Green Blue (RGB) images which are useful to extract the Normalized Vegetation Index (NDVI) [4, 30]. NDVI values can provide useful data regarding crop disease, water stress, pest infestations, nutrient deficiencies, and other relevant conditions affecting crop productivity. UAVs can be applied on harvesting, spraying and yield estimation, weed detection, disease outbreaks, and insect infestations prediction [29, 31–33]. There had been plenty UAV applications. One of them took place in a vineyard in Spain. An UAV collected data via thermal sensors, which were used to extract information about the vineyard water status [29]. Another application took place on sweet potatoes, grapes asparagus and sugar crops in Peru. A UAV equipped with optical sensors was used to calculate the NDVI [29]. The results showed that the targeted use of pesticides results in pesticide quantity, economic expenses and ecological impact reduction. As a result, health crop status can be successfully estimated and plant diseases can be prevented. A similar application took place in a pomegranate orchard in Greece. The researchers concluded that UAVs are useful for supporting irrigation systems, accompanying maintenance systems and discriminating MZs [29].

A weather station is a system which is used to collect a series of data to monitor field weather. It can record gust speed, wind speed, leaf wetness, soil moisture, Photosynthetically Active Radiation (PAR), soil temperature, air pressure, air temperature, rain, relative humidity, dew point, solar radiation and electrical conductivity. A weather station is a prerequisite for applications such as control irrigation and diseases forecasting [15, 34, 35].

This study was carried out within the context of innovation. Innovation is an important aspect of economic development [36].

> "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" [37].

It can be classified as product, process, organizational and marketing innovation [37]. PA can definitely be regarded as a way to innovate. As the presented literature has already demonstrated, PA improves agricultural processes. Hence, PA technologies are regarded as process innovations.

> "A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software" [37].

3 Research Methodology

3.1 Data Collection

Aiming to investigate the range of innovation diffusion on agriculture in Greece and see the differentiation of Greek districts, a research was conducted among farmers in Greece. So as to successfully represent the agricultural population, Greece was divided to districts, according to the Association of Greek Regions (EN.P.E) [38] and there were certain answer goals on each district according to the farmers' population which is online published by Hellenic Statistical Authority [39]. A questionnaire was chosen as the data collection method and the percentage sampling was selected as the sampling method. The research was conducted specifically on Greece mainland and Crete district.

The questionnaire was created as a Google form. It included 16 questions, where each question represents a variable. The initial thought regarding the questions was to include directly PA technologies as variables. However, Greek farmers are generally low educated and not informed about PA [40]. Thus, on a second thought it was decided that PA technologies would be indirectly implied by variables which express actions, e.g. actions that a farmer performs on farm soil, so as to make the questions' content simpler.

Most questions were divided in two categories. The first one refers to actions that take place on a field (irrigation, fertilization and pesticide use, plant disease prevention, harvesting, sowing, ploughing, agricultural vehicle use) and the second one refers to the economic benefits that a farmer could have by improving farm actions, reduced resource spending, increased labor productivity, improved use of commodities and equipment, increased product quantity and quality, increased income, improved environment protection. Every question category followed a specific formulation based on the Community Innovation Survey (CIS) questionnaire, which is used by Eurostat about innovation at industry and services sectors every 3 years (European Commission, 2018). The question formulations are presented below:

- Did you introduce new or improved processes of "variable_name" during the last 3 years?
- Did you have "variable_name" during the last economic year in comparison with 3 years ago?

The possible answers for these question formulations were "yes" or "no".

There were also three other questions. The first one regarded the Greek district in which each respondent resided. The possible answers were the districts of Eastern Macedonia and Thrace, Central Macedonia, Western Macedonia, Epirus, Thessaly, Western Greece, Central Greece, Peloponnese and Crete. The second one concerned the crop category. Based on HELSTAT's categorization there are three main crop categories [41]:

- Arable crops (wheat, legumes, industry plants, aromatic plants, fodder plants, melons, potatoes)
- Horticulture
- Permanent crops (vineyards, orchards, citrus, fruit trees, dry fruits, olive groves)

The third one referred to the number of hectares each farmer cultivates. This question had four possible answers. The first category included farmers cultivating up to 8 hectares, the second one from 8 to 20 hectares, the third one from 20 to 40 hectares and the last one regarded arable land above 40 hectares. There are studies that do not regard professional farmers, those who utilize less than 8 hectares [42]. But it is regarded interesting to search if this farmers' category differentiates among other farmers.

All questions on the Google form questionnaire were chosen as closed, to make them as simple and less time-consuming as possible and mandatory so as to avoid missing values. Missing values is a serious issue for nominal data, hence it had to be avoided. An exception was made for the crop type question, in contingency that a farmer might cultivate multiple crop types. On the questionnaire beginning, a brief description of the survey purpose was mentioned and contact details where included in case of further clarifications needed. It was also stated that answers were completely anonymous. Before the process innovation questions a brief description of innovation and process innovation definition was quoted.

The answer collection strategy was the indirect connection with farmers via people, who have regular communication and trust them. Such people are agricultural consultants, agricultural cooperatives, agronomy shop owners, and accountants. These middlemen could carry forward an email in which the research description, contact details and the questionnaire link on Google forms were included. On special occasions a printed form of the questionnaire was used and, in a few cases, farmers called back asking to answer the questionnaire as a phone call interview. The research started on July 2019 and ended on December of the same year.

Like every research has its difficulties and setbacks, so this research does. The main problem acquiring answers was that in Greece there is not an official database to include farmers' names and contact details. Also Greek farmers were considered e-illiterate due to their low education level [40]. As a first step there was an effort to directly connect with farmers having no results. A first try to deliver the questionnaire in printed form proved to not be a good option, as most of subjects left unanswered questions, which lead to missing values. A printed questionnaire form would not also be an option in terms of printing and transfer cost. In the cases where questionnaires were sent back in printed form, 50% of them had missing values on nominal variables, leading to their rejection from the final results. Furthermore, the direct connection with farmers, showed that they are distrustful and hesitant people. In 90% of phone calls, they refused to answer the questionnaire. So even if a database existed it might not be useful. Finally, Attica district is mostly an urban area and Greek islands focus their economy on fishery. Even though they do have a small agricultural population, they don't focus their regional economy on agriculture. Consequently, Attica, Ionian Islands, North Aegean and South Aegean districts were excluded from the research. By this way the research could be more focused and less time-consuming. Another issue of this study is the fact that PA is indirectly implied at the questionnaire. As a result, it is not certain, if an agricultural process is improved due to PA. Maybe other innovative practices were applied, but it is regarded that nowadays most innovative activities concern PA.

In order to answer our exploratory question, automatic clustering was used and specifically the agglomerative hierarchical clustering (HAC), or else called ascending hierarchical classification (CAH). On this method a criterion based on their distance is used, to join objects in pairs. The clustering algorithm is completed, when all the original objects are merged into one.

3.2 Data Analysis Process

A data differentiation could be between categorical and continuous data. There are statistical methods, which are most suitable for continuous data and others that are suitable for categorical data. But there are datasets in which both data types are included. In terms of clustering a mixed typed dataset is an important field of research interest. This matter is tackled by applying a strategy of using a combination of sequential dimension reduction and clustering [43–45].

CAH is a clustering method based on the criterion of inertia [46–49]. The criterion of inertia is also called the generalized criterion of Ward [50] and is particularly prevalent in applications of humanities and society [51].

The result of the Ascending Hierarchical Classification is a dendrogram, i.e. a diagram in the form of a tree, inclined or inverted, depending on the program used, on which the successive compounds of the elements are depicted. The closer to the top of the tree chart, the more general the teams are, and the closer to the base of the tree chart, the more specialized the teams are.

Let I_o be the total inertia of n objects (points) with respect to their center of gravity g. We consider a grouping of n objects into s groups $G_1, G_2, \ldots, G_s$,. Each G_i group has a g_i center of mass with mass $m_i$the sum of the masses of its objects. The inertia of the groups' center of gravity with respect to the center of gravity g is called the "order inertia" and is denoted by I_{Δ}.

$$I_{\Delta} = \sum_{i=1}^{s} mi\, d^2(g_i, g)$$

Since the center of gravity of the center of gravity is g, the order inertia measures the deviation of the groups' centers from g. The greater the extraclass inertia, the more distinct the groups are.

In each G_i group, the inner inertia is calculated, i.e. the inertia of its points with respect to the center of gravity g_i. Inner inertia measures the deviation of its points from its center of gravity, so the lower the inner inertia, the more compact the group is. The sum of the inner inertia of groups is called intraclass inertia (IE). Small intraclass inertia indicates compact groups. The Huygens theorem states that in each grouping the sum of extraclass and intraclass inertia remains constant. What is changing is the rate of extraclass and intraclass inertia. That is:

$$I_{o\lambda} = I_{\Delta} + I_{E}$$

It is worth noting that a group consisting of a single point has an inner inertia of zero as its center of gravity coincides with that point. Therefore, considering the initial state of the n objects as a trivial grouping of n groups with an element, there comes the realization, that the total inertia I_o is only intraclass inertia. Also considering the n objects as a group (final state), then its center of gravity coincides with g and therefore the extraclass inertia is equal to zero. In this case the total inertia I_o is only intraclass inertia [52].

When switching from a group s to the next s − 1 group grouping, two groups merge into one, while the s − 2 groups remain unchanged. What does not change from one grouping to another is the rates of intraclass and extraclass inertia, as their sum is constant.

Specifically, when switching from s groups to s − 1 groups, intraclass inertia increases and consequently the extraclass inertia decreases. That is, by limiting the number of groups, the groups become less compact and less distinct.

According to Ward's generalized criterion [49], "when switching from s-grouping to s − 1 grouping, we unite those groups so that the increase of intraclass inertia becomes minimal". It is proved that the increase of intraclass inertia while uniting groups G_i, G_j with mass m_i, m_j and centers g_i, g_j is:

$$\delta = \frac{mimj}{mi + mj} d^2(g_i, g)$$

where $d^2(g_i, g_j)$ is the distance of group centers G_i, G_j [53].

While the method proceeds, so as to record the most statistically significant variables, a statistical test was used based on which one is tested for group c and one answer is *j*, if the percentage of answer j is significantly higher in group *c* than the percentage of answer *j* in the whole sample (A) [54].

The process is evolving as in case of classical case studies. The null hypothesis H_0 states that the percentage of the answer *j* in group *c* is equal to the percentage of the answer *j* in the whole sample. The alternative H_0 is that the percentage of the answer *j* is greater in group c than the percentage of the answer j in the whole sample.

The statistical test used follows the standard normal distribution and at each value of this test corresponds a probability of *p*. The corresponding probability *p* is the probability of incorrectly rejecting the null hypothesis of the equality of the percentages of the answer in the group and the whole sample. The higher the percentage of response *j* in group *c*, the lower the corresponding probability and the higher the control value. The higher the control value, the higher the probability to reject the H_0 hypothesis.

It is noted that because a one-sided test is used following the normal distribution, the answers are statistically significant at a significance level of $p = 5\ \%$, if the value of the test is greater than 1.65. Consequently, for the interpretation of the groups, those answers with a probability below 5% or a control value greater than 1.65 can be implemented [55].

4 Results

In total, 1032 answers were collected. After the data collection process, the next step was to confirm that the collected answers successfully represent the population. As far as the geographical distribution of farmers concerned, the Table 1 demonstrates the results and the nationwide distribution of farmers in Greece by region. By comparing the columns named "Total Holdings (% of total population)" and "Questionnaire's answers per region (% of total answers)", the collected sample successfully represent the agricultural population of Greece.

On the arable lands use, based on ELSTAT's data 6976 hectares are used for arable crops, 256 hectares are used for horticulture and 4391 thousand hectares are used for permanent crops [41]. So, a percentage calculation can take place as it is demonstrated on Fig. 1.

As the question regarding this variable was multiple choice, from this variable three new dichotomous variables come up with the possible answers of "yes" or "no". The next pie chart (Fig. 2) shows off the distribution of agricultural land among farmers.

The results demonstrate that there is small diversification in terms of agricultural land size. The results are reasonable regarding the fact that extensive agricultural plains in Greece exist only in Thessaly and in Eastern Macedonia. The Fig. 3 demonstrates the positive answers on process innovations.

The most dominant innovation concerns fertilizer use, and the least observable innovation concerns ploughing. As permanent crops do not need ploughing and this crop type represents 54% of the answers, this is an expectable result. The Fig. 4

Table 1 Sample—population comparison

Region (DIS)	Coded name	Total holdings	Total holdings (% of total population)	Questionnaire's answers per region	Questionnaire's answers per region (% of total answers)
Eastern Macedonia and Thrace	DIS1	51,628	9	87	8
Central Macedonia	DIS2	96,482	17	163	16
Western Macedonia	DIS3	23,089	4	46	4
Epirus	DIS4	29,462	5	49	5
Thessaly	DIS5	60,323	10	126	12
Central Greece	DIS6	65,859	11	110	11
Western Greece	DIS7	80,502	14	133	13
Peloponnese	DIS8	88,410	15	158	15
Crete	DIS9	87,040	15	160	16
Summary		582,795	100	1032	100

Fig. 1 Crop type answers (% of total answers)

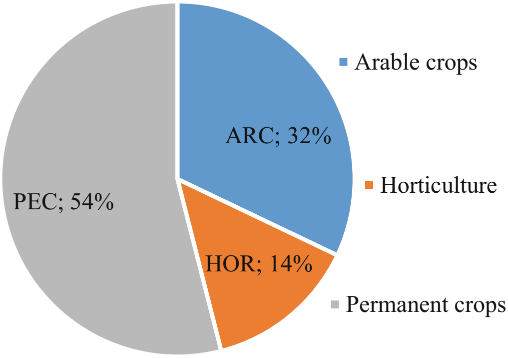
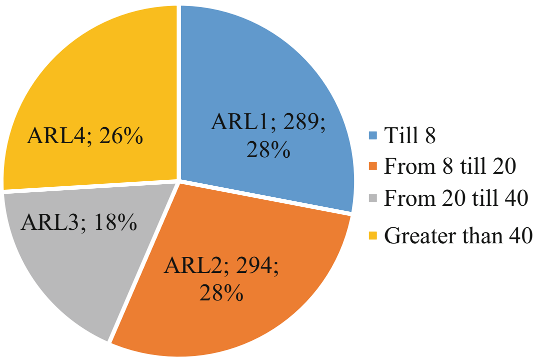


Fig. 2 Arable land answers in hectares (% of total answers)



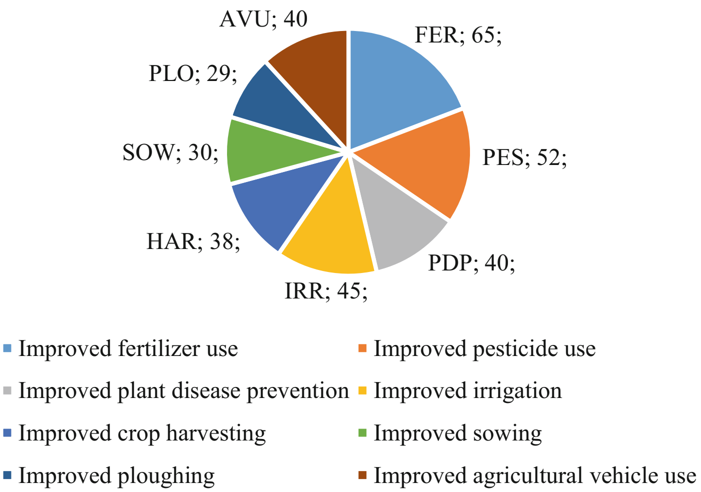


Fig. 3 Positive answers on process innovations (% of total answers)

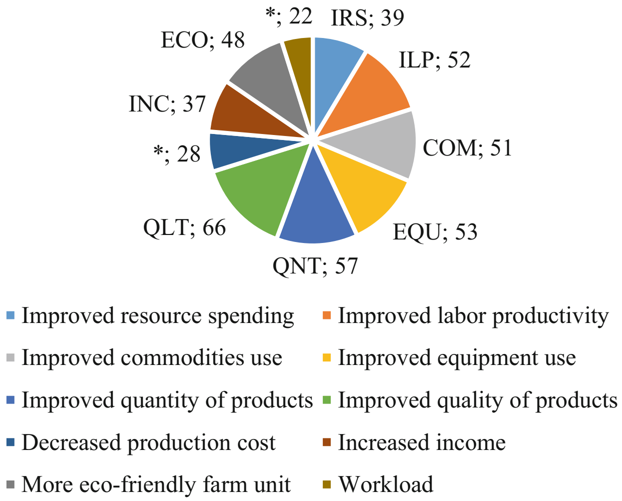


Fig. 4 Positive answers on economic benefits (% of total answers)

presents the percentage of farmers who have been benefited for each possible economic benefit.

The "decreased production cost" and the "workload" variables had one-sided answers as most farmers answered "no". So these characteristics would not be useful as variables and they were excluded from the data analysis. Most farmers regard, that they have improved their products' quality, while their workload remains at least the same.

Table 2 Nodes of CAH

N[a]	A[b]	B[c]	W[d]	δ[e]
10	1	3	0.12609	0.00066
11	4	9	0.20723	0.00087
12	6	7	0.23362	0.00122
13	2	5	0.28347	0.00216
14	11	8	0.35679	0.00272
15	10	13	0.40956	0.00405
16	14	12	0.59041	0.00646
17	15	16	1	0.0277

[a]Indicate the new nodes that are created immediately after the initial nodes—objects. Their numerical name refers to the order in which they were created
[b]The nodes in which this node is included (or in which it breaks) are displayed
[c]The nodes in which this node is included (or in which it breaks) are displayed
[d]This is the percentage of the node weight, i.e. the number of people that the node includes in percentage
[e]Records the increase in intraclass inertia in the creation of the new node (or the decrease in the order inactivity respectively)

The first statistical analysis' table shows the nodes of the Ascending Hierarchical Classification. It contains the created nodes together with some parameters, which are further analyzed (Table 2).

Therefore, as can be seen, a sharp increase of the intraclass inertia results in the level of the number 15 node, resulting in the creation of a classification with 3 groups. Next, we receive the result of CAH through the dendrogram that is presented schematically (Fig. 5).

According to the above diagram we have in the formation of three groups. The first group consists of node 15, including the districts of Eastern Macedonia and Thrace, Central Macedonia, Western Macedonia and Thessaly. The second group consists of node 14, including the districts of Epirus, Peloponnese and Crete. The third group consists of node 12, in which are included the districts of Western Greece and Central Greece.

Thus, all the characteristic answers for each group resulting from CAH emerge. These characteristic answers are recorded in Table 3. At next, the statistically significant variables are presented for each group in a decreasing order.

As regarding to the dichotomous variables encoding, the number "1" next to the encoded name means "yes" to the concerning question and the number "0" means "no" to the concerning question.

When a variable exists in more than one group then it is included in the group that is most important (e.g. HOR1 will be included in group 12 and not in group 14). In this way, groups are maintained with distinct (different) characteristics compared to the rest ones. According to the Table 3, the most important variables of group 12 (and in addition in order of importance) are HOR1, ILP1, INC1, HAR1, PLO1, AVU1, and QLT1. Respectively, the most important variables of group 14 are

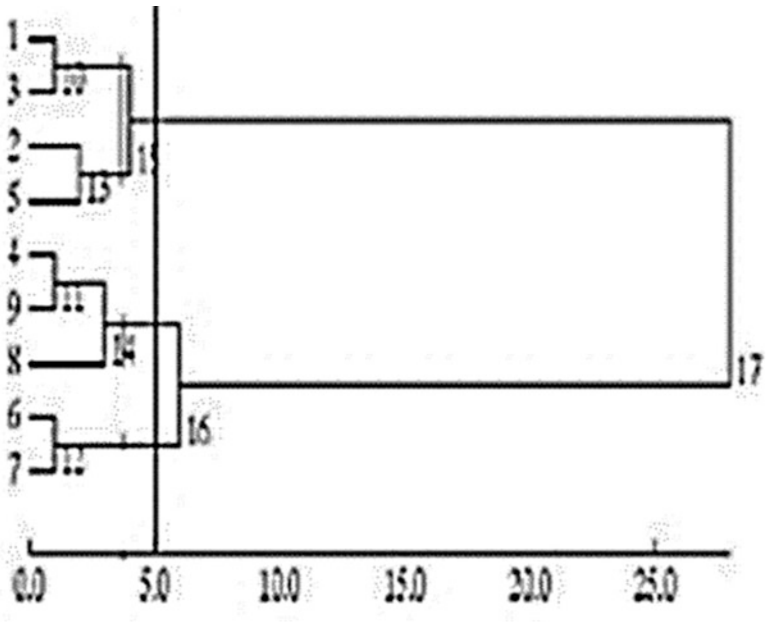


Fig. 5 Dendrogram of CAH

Table 3 Description of the most statistically significant variables of groups 12, 14, 15 in terms of significance p = 5%

Coded name	12	Coded name	14	Coded name	15
HOR1	5.3	ARC0	12.4	ARC1	13.9
ILP1	2.7	ARL1	9.5	ARL4	10.4
INC1	2.4	PEC1	7.7	PEC0	9.4
PES0	2.3	SOW0	4.3	SOW1	4.6
HAR1	2.2	ARL2	4.08	FER0	3.3
PLO1	2.2	FER1	3.5	WAT0	3.3
AVU1	2.1	IRR1	3.0	ARL3	2.6
IRR1	1.7	HOR1	2.7	AVU0	2.5
QLT1	1.7	AVU0	2.2	HAR0	2.5
ARC0		HAR1	2.1	HOR0	2.4
ARC1		ARC1		PDP1	2.1
Coded name	12	Coded name	14	Coded name	15
HOR0		HOR0		ILP0	2.0
PEC0		PEC0		QLT0	2.0

ARC0, ARL1, PEC1, SOW0, ARL2, FER1, and IRR1. The most important variables of group 15 are ARC1, ARL4, PEC0, SOW1, FER0, IRR0, ARL3, HAR0, HOR0, PDP1, ILP0, and QLT0.

5 Discussion

There are quite interesting findings regarding the results. With respect to the crop type most of the respondents cultivate permanent crops. This result can be explained by the fact that 44% of the sample operate in Western Greece, Peloponnese and Crete. These regions' climate favor permanent crops, so this fact justifies the results.

In terms of arable land, there are no recent data about arable land distribution. In addition, big agricultural plains exist only in Eastern Thessaly and Eastern Macedonia. This fact means that most farmers have not the possibility to own vast agricultural land. There is also the fact that many farmers' land is scattered through an area. In each case the results demonstrated that there are small differences between each category on this variable.

The majority of farmers are innovative in fertilizer and pesticide use. Harvesting, sowing and ploughing are processes that take place on arable crops. As arable crops represent 32% of the total sample, this justifies that the innovation percentage on these processes is low. Furthermore, an agricultural vehicle is most useful for a minimum size of arable land. Hence, in relative comparison the 40% of innovative farmers is a good innovation percentage. The rest process innovation percentages indicate that farmers in Greece keep improving their work, either the innovation refers to an improved existing method, or the implementation of a new one.

On economic benefits the quantity of produced agricultural products is regarded as improved by 66% of the sample. Indeed, Greece's climate favors agriculture. In addition, as Greece has not such vast agricultural land like United States of America, Ukraine or Australia, Greece cannot produce the amount of agricultural products like these countries. As a result, a focus on improved quality of products is suggested as the most suitable strategy for farmers in Greece. In general farmers have answered that they had half of the suggested economic benefits during the last 3 years. Nevertheless only 37% of the sample has increased their income. This fact may be a matter of further research. An interesting finding is the fact that almost half of farmers are ecologically aware, as 48% of them declared that their agricultural activities are more eco-friendly than 3 years ago. Finally, production cost and workload are two matters that most farmers are not benefited. The percentage of positive answers was so low, that these characteristics had low quality as variables, so they were excluded from the data analysis.

The cluster analysis was conducted on a Burt table in which the nine regions of Greece were the table's row and the rest of the variables as the columns. The analysis highlighted three distinct clusters. The differences between these clusters included differences on climate, crop type, size of arable land, but also differences on innovation and economic benefits. The differences on innovation and economic benefits differenced not only on kind but also in numbers.

6 Conclusions

This research aimed to seek agricultural innovation across Greece, along with the resulting economic benefits. In particular, the ultimate goal was to cluster Greek regions on crop type, size of arable land, process innovations, and economic benefits. To fulfill this purpose an e-questionnaire was created, directed to farmers on mainland Greece and Crete. Based on data provided by Hellenic Statistical Authority, there were specific region answer goals, in order to represent the agricultural population of Greece. Because it was not possible to directly communicate with farmers, people who are professionally linked with farmers were asked to forward the questionnaire. At the end of the research 1032 answers were collected and ascending hierarchical classification was applied to process the data.

The first important extracted information is that the clusters are composed of districts which each one is next to each other. This fact indicates climate similarities. By this way, a map of agricultural innovation is created, and the Greek territory is divided in three groups.

The first group consists of farmers in Eastern Macedonia and Thrace, Central Macedonia, Western Macedonia and Thessaly. This group is primarily characterized by arable crops, arable land greater than 40 hectares and not permanent crops. The category "arable land greater than 40" is a legit outcome in this group due to the fact that in Eastern Macedonia and Thessaly, the largest agricultural plains in Greece exist. This group is also characterized by no horticulture crops, improved sowing, improved plant disease prevention, but, on the other hand, not improved fertilizer use, irrigation, harvesting and not improved labor productivity and quality of final products. Although the second series of characteristics is less important than the first ones, it could be concluded that despite the fact that innovations, such as VRP/VRS and UAV, are implied, there are no positive economic outcomes, despite the advantage of having the largest arable land in Greece.

The second group consists of farmers in Epirus, Peloponnese, and Crete. This group is heavily characterized by no arable crops, arable lands below 20 hectares and permanent crops. A few less intense characteristics include improved fertilizer use and irrigation, but not improved sowing. Permanent crops and small arable land prevail in this group. Few innovations (e.g. VRNA, and VRI) have been implemented during the last 3 years, however, with no positive economic benefits.

The third group is consisted of farmers in Western and Central Greece. This group is strongly labeled by horticulture. A series of less important variables that define this group are improved harvesting, ploughing, and agricultural machinery use. Thus, improved labor productivity, increased income and quality of final products are also variables that are included in this group. In terms of PA, MG, and UAV implementation, this group is the only one that has economic benefits in comparison to the others.

In the Community Innovation Survey questionnaire, a business is regarded as innovative if it uses at least one innovation during the last 3 years. Based on this definition, Greek agriculture is innovative, but there are still no economic outcomes. In the previous clustering although every group included innovations on agricultural processes, only the last one included also economic benefits. The main difference between groups is the crop type and the number of innovative processes. The first two groups are characterized by arable and permanent crops accordingly and two innovation types on each one of them. The prevailing crops in the last group are horticulture crops and three innovation types take place. Therefore, farmers in Western and Central Greece are the most benefited.

In conclusion, horticulture crops are regarded more productive than the others and it is indicated that a minimum number of innovations is required for economic benefits to come up. Horticulture requires less arable land than other crop types and plants in greenhouses are safe from sudden weather effects which is the most serious farmers' concern. Moreover, it is interesting to note that arable land used in agriculture consists only of the 2% of total utilized arable land use in Greece [41]. Further research could study farmers' profiling, searching for characteristics that define innovative behavior like demographics or entrepreneurial mindset. Horticulture crops might also attract academic community's interest.

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