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A STUDY OF SPATIAL VARIABILITY IN A CHESTNUT ORCHARD (*Castanea sativa*) FOR PRECISION AGRICULTURE PURPOSES

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ABSTRACT
The aim of this study is to study the variability of apparent electrical conductivity, quantity, and quality characteristics in a chestnut farm. The experiment took place in a chestnut orchard located in Agia, Larissa, Greece during the 2022 – 2023 growing season (April 2023 – October 2023), and specifically from the stage of tree dormancy to the stage of harvesting. All cultivation treatments were performed uniformly according to the farmer's protocols. Soil data and chestnut samples were taken and evaluated to measure the above-mentioned variables (apparent electrical conductivity, quantity, and quality characteristics). The results showed that there was no significant correlation between apparent electrical conductivity and chestnut quality or quantity. They also showed obvious correlation between quantity and quality of chestnuts (high mass means plenty of chestnuts and vice versa).

INTRODUCTION
Chestnut (*Castanea sativa*) is an arboreal crop which is a source of income for many farmers in Europe and Greece (Bozoglu et al., 2019), especially in mountainous, impoverished areas. It grows in fields that are often unsuitable for others crops due to the morphology of the soil and because it requires an altitude of at least 250m above sea level to grow. In short, it utilizes fields that are unsuitable for other crops and economically unviable to exploit.

As is the case for many other crops of Greece and the Mediterranean in general, irrigation is one of the main limiting factors in productivity. The fact that this is most required in the summer months, when water is scarce, makes it necessary to find the optimal irrigation protocol. If we also consider the climate crisis which makes water even more valuable and that now the producers, in Greece at least, extract the necessary water from greater and greater depths, resulting in an increase of the production cost due to the energy use of the pumps, then we realize the urgency of the situation.

A first step towards its improvement is the more rational irrigation and use of water, which will reduce the cost. Especially in chestnut, the impact will be greater since, as mentioned above, the crop is a source of income in poor, mountainous areas. In addition to the financial benefits, however, we also have environmental ones such as the maintenance of underground aquifers, the limitation of the intrusion of brackish water on land, the saving of fresh water, etc.

Something else that can also be done is the application of precision agriculture methods. Rational, sustainable resource management and study of the variability of the fields, can significantly help with the inflow resources in agriculture. Irrigation water is one such resource. Introducing this method little by little, it would mean the acquisition of another tool that will help to make agricultural products more competitive, and thus more sustainable.

MATERIALS AND METHODS

On Friday, 28th of April 2023 (**2023-04-28**), the gathering of apparent electrical conductivity data took place, using the **EM38 – Mk. 2** sensor by **Geomatrix Earth Science Ltd.** It was gathered by covering the field's area on foot, to not have any magnetic interference by metal objects and surfaces (tractor components, wheels, car components etc.) that could lead to false/ disrupted data. Magnetism was a concern because of the way the **EM38 – Mk. 2** works. This device consists of two (2) dipoles - coils that are separated from each other (0.5 – 1) cm. One, the transmitter, creates an electromagnetic field and the other, the receiver, receives and measures the corresponding field generated by the incoming to ground electric current. We thus have measurements at soil depth (0.75 – 1.5) m. (Geomatrix Earth Science Ltd.) (Schneider et al., 2014 p. 373 – 378) (Schneider, 2023).

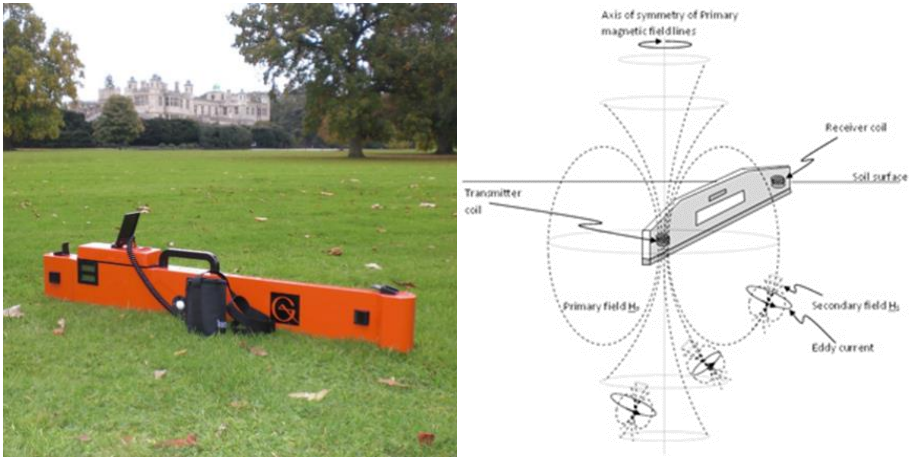

Figure 1. Left: The EM38 - Mk. 2 conductivity sensor. Right: The Physics principle used in the operation of the sensor.

Why was it important to know though? Because apparent electrical conductivity is defined as the ability of a solution (irrigation water and soil) to allow the flow of electricity through its mass, and it helps to:

1. Finding soil texture
2. Forecast Production
3. Target soil sampling
4. Gather information on the nutritional needs of plants.

(Liakos, 2013)

From Tuesday, 10th of October 2023 (**2023-10-10**) to Tuesday, 31st of October 2023 (**2023-10-31**), harvesting was done. A total of four harvests were made in the studied section, as not all the chestnuts were ready to be harvested at the same time. The harvests were conducted the following dates:

1. Tuesday, 10th of October 2023 (**2023-10-10**)
2. Friday, 13th of October 2023 (**2023-10-13**)
3. Sunday, 15th of October 2023 (**2023-10-15**)
4. Saturday, 21st of October 2023 (**2023-10-21**)

The harvests were done manually. That is because, during the study's course, a torrential storm, named **Daniel** impacted the area (Monday, 4th of September 2023 (**2023-09-04**) – Tuesday, 12th of September 2023 (**2023-09-12**)) (NASA Earth Observatory, 2023). This resulted in the terrain becoming too uneven and unsuitable for fragile harvesting equipment. Because of this, no mechanized harvesting could take place, so manual labor was used.

Figure 2. Left: Manual harvesting of chestnuts. Right: Automated chestnut harvester, making the ushering of chestnut farming into the new mechanized era of agriculture possible.

The workers collected the chestnuts from the ground and placed them in containers. Using a method which is analyzed below, it was calculated that on average, a full container weighed **24.76 kg**. Taking advantage of this, containers were left in the field where and when they were filled. Then with the help of the **My GPS Coordinates ver. 5.21 (296)** application, the number and the geographical coordinates of the containers were documented. That way, the most productive and least productive parts of the field could be known. Production data was recorded as follows:

Initially, certain containers full of chestnuts were weighed individually, one container per time that is. Then the container weight was subtracted from the gross so that net could be calculated **(Gross Weight = Net Weight – Container Weight**). Then the average net weights were calculated (**Average Net Weight = Sum of Net Weights / Total Containers**). Average full container mass was calculated at 24.76kg. So, a half-full container had a mass of: (**24.76 / 2 = 12.38 kg**)

That covered the quantity aspect of the experiment. To map the quality characteristics of the chestnuts, seventeen (17) chestnut samples were taken from the recorded full crates. The collection was done randomly, for unbiased results. Each sample had ten (10) chestnuts, for sample size uniformity, factor control and calculation ease. The quality characteristics evaluated in this work are:

1. Weight
2. Size
3. Percentage of cracked/ split nuts.

Initially each sample (10 nuts) was weighed on a digital precision scale to measure the total mass of the sample. Then, cracked/ split nuts were then separated from the rest, which were measured and weighed separately to calculate the mass of cracked/ split produce. After, the uncracked chestnuts were placed into a professional chestnut size sorter, which sorts all produce into one of these five (5) categories, depending on piece size, based on which the sale price of the chestnuts is determined (descending order):

1. Lux
2. Extra
3. A
4. B
5. C

Figure 3. A professional chestnut size sorter.

Then, each size sorted category was weighed separately in the precision scale again and the measurements were documented. That gave the following data:

1. Lux mass
2. Extra mass
3. A mass
4. B mass
5. C mass

After gathering and collecting the data, it then had to be visualized and mapped (Geographic Information Systems, GIS). So, the **ArcMap ver. 10.8.1** software by **ESRI** was used. Transferring data from excel files to it, easily, quickly, and efficiently, the electrical conductivity and harvest data could be viewed on simple and easy-to-read maps. **Quantile** classification method which divides the data equally into each classified class. The number of classes varied between three (3) and six (6), depending on the level of variability.

To collect and download geographic coordinates and data as mentioned above, the **My GPS Coordinates ver. 5.21 (296)** android smartphone app by **Android Apps & Tools** was used. A photo was being taken through the smartphone's camera. Then the application showed the exact coordinates in text on the photo. The app utilizes data provided by G.N.S.S. (Global Navigation Satellite System):

1. WGS84
2. G.P.S. (Global Positioning System)

Figure 4. Left and Right: How the application was used and showed the recorded data.

For the statistical analysis required, the **Statistical Product & Service Solutions** (**SPSS)** software by **IBM** was used. All numerical and qualitative factors were entered into it, giving back in turn all the data needed for safe and unbiased results.

RESULTS AND DISCUSSIONS

All the above-mentioned procedures and handlings gave the following results. In *Figure 5*, the spatial variability of apparent electrical conductivity and the total harvest mass can be seen. In blue-scale, electroconductivity can be seen, while in brown-scale, quantity of harvest. It can be observed that there seems to be no significant correlation between the two variables, at least at first sight. It is noteworthy that elevation increases the further south we go. Noting that, no correlation between elevation and the rest of the variables can be discerned.

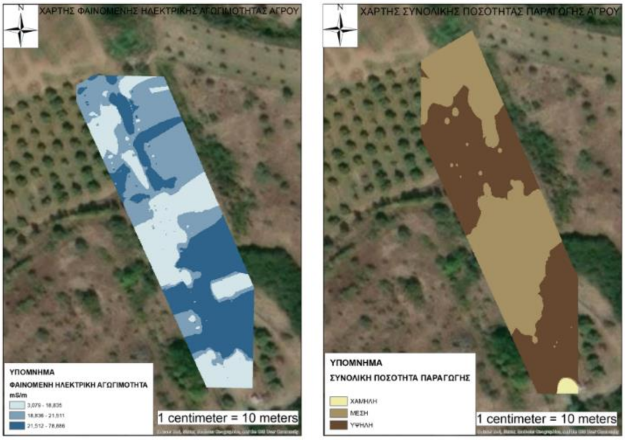

Figure 5. Left: Apparent electrical conductivity data displayed upon the surface of the field. The darker the hue, the higher the recorded value Right: Chestnut produce quantity data displayed upon the surface of the field. Hue tone works as in the left figure.

In the two following maps, the total sample mass and the spatial variability of the field can be seen and compared. The dots represent the location of the samples and the dots' size the weight of the samples. The larger the dots, the greater the weight. No safe and reliable conclusion can be derived from the maps alone.

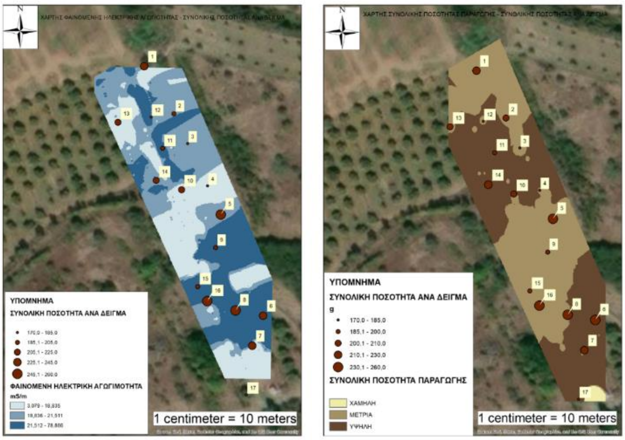

Figure 6. Left and Right: Total sample mass displayed upon the maps of *Figure 5.* The larger the dots, the higher the mass. Hue tone works as in *Figure 5.*

Lastly, the maps below show how each sample's size category varies within the field. No correlation between chestnut size and electroconductivity of the soil can be noticed.

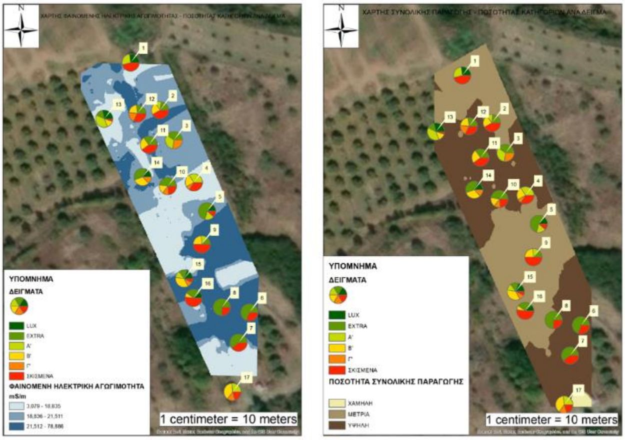

Figure 7. Left and Right: Chestnut qualitative data displayed upon the data of *Figure 5.* The greener the color, the larger the larger the chestnuts. The redder the color, the smaller the chestnuts. Absolute red shows cracked/ split nuts. Hue tone works as in *Figure 5.*

Maps can lead to unreliable, biased, and wrong assumptions regarding the significance of the correlation between all the above-mentioned variables. That is why statistical analysis is necessary, as it is directed and influenced by the data only, thus leading to true, reliable results, not always though. So, the following table can be seen.

Table 1.

The results of the statistical analysis of all the data made in SPSS software. Cells marked in green indicate obvious significant correlations and those in orange indicate non-obvious significant correlations.

VARIABLES (Pearson Correlation, 2-tailed)	Yield	Total Mass	Cracked Mass	Lux Mass	Extra Mass	A Mass	B Mass	C Mass	Electrical Conductivity
Yield	1,000	0,076	0,020	-0,239	0,240	-0,131	-0,122	-0,076	0,040
Total Mass	0,076	1,000	0,273	0,322	.725**	-0,324	-.611**	-.584*	0,209
Cracked Mass	0,020	0,273	1,000	-0,183	-0,010	-0,300	-0,243	-.624**	0,088
Lux Mass	-0,239	0,322	-0,183	1,000	-0,264	0,433	-0,034	-0,194	-0,031
Extra Mass	0,240	.725**	-0,010	-0,264	1,000	-.558*	-.585*	-0,224	0,231
A Mass	-0,131	-0,324	-0,300	0,433	-.558*	1,000	-0,076	0,065	-0,363
B Mass	-0,122	-.611**	-0,243	-0,034	-.585*	-0,076	1,000	0,275	0,099
C Mass	-0,076	-.584*	-.624**	-0,194	-0,224	0,065	0,275	1,000	-0,184
Electrical Conductivity	0,040	0,209	0,088	-0,031	0,231	-0,363	0,099	-0,184	1,000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

CONCLUSIONS

To summarize, the following were concluded by the study's end:

1. Harvesting machinery need to be more widely used and introduced further into the chestnut production process, since they eliminate the need of manual labor, thus reducing cost and almost eliminating the threat of labor shortage during peak demand.
2. Yield monitoring, the recording of harvest data that is, needs to be mechanized and modernized since, as it was shown above, it is still done manually.
3. There is no significant correlation between apparent electrical conductivity and all other variables (chestnut quantity/ yield, chestnut quality).
4. That, obviously, wherever large chestnuts are in abundance, smaller ones are rarer.
5. The more common smaller chestnuts are the less common cracked ones are.

ACKNOWLEDGEMENT

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REFERENCES

Bozoglu et al. (2019): "Developments in the Chestnut Market of Turkey" (KSÜ Tarım ve Doğa Derg 22(1): 19-25, 2019)

Geomatrix Earth Science Ltd. (2023): "EM38 – Mk. 2"

Liakos Vasileios (2013): "Application of New Technologies in the Management of Apple Orchards" (p. 26 – 30)

Schneider (2023): "The Potential Use of the EM38 for Soil Water Measurements"

Schneider et al. (2014): "Apparent Electrical Conductivity (ECa) as a Surrogate for Neutron Probe Counts to Measure Soil Moisture Content in Heavy Clay Soils (Vertosols)" (Soil Research, 52 p. 373 – 378) (University of New England, UNE)

NASA Earth Observatory (2023): "A Deluge in Greece" [Accessed on 2024-08-11]