OLEA Framework for non refined olive oil traceability and quality assurance

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Abstract. This paper proposes a framework for the monitoring of olive oil production chain (OLEA management system). The deployment of the system initiates at the olive tree fields, where NFC technology is used as part of OLEA system capability for both pesticides and fertilizers control, fungicides use and olive oil traceability. Additionally, OLEA system uses sensors for the procurement of quantitative and qualitative olive oil characteristics at the extraction industrial process. Such characteristics are pertained to the depth of olive cluster geographical location as initial system's kick off and up to the identifiable tree point when the OLEA system will fully deploy. The paper presents also OLEA technical characteristics as well as the structure of its integrated database and middle-ware communication protocol, which will positively affect Greek olive oil industry product marketing and exports. Furthermore, an ongoing case study of the OLEA system used for olive oil quality monitoring and traceability purposes is presented.

Keywords: *Olea europaea*, olive oil management system, olive oil monitoring and traceability system, NFC technology, web applications, IoT applications and protocols, data mining algorithms.

1 Introduction

Olive oil is a natural fruit juice with excellent nutritional characteristics. It is a typical source food of the Mediterranean diet which has been associated with a low incidence of cardiovascular diseases, neurological disorders, breast and colon cancers, as well as with antioxidant properties. Moreover, an increase of interest in olive oil as a healthy food has been observed lately in areas other than the Mediterranean countries mainly because of its fatty acid composition and content of other functional food components, such as polyphenols (Vekiari et al., 2010).

Greece is the world's third largest olive oil producer after Spain and Italy, according to industry sources. More than 80 percent of the Greek annual production

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of olive oil is extra virgin oil, while 90% of the Greek olive oil is exported to the EU (Bettini and Sloop, 2014; Mylonas, 2015). 80% of Greece's olive oil production is located at the areas of Crete, Peloponnese and West Greece. Most olive mills in Greece are small sized and less technologically advanced than those in Spain thus leading to higher milling costs. Similar milling conditions occur in Italy, however, despite the small productivity potential, production is closely integrated with the olive farming stage (ICT monitoring processes), as well as the distribution stage (ICT marketing processes). Such controlled monitoring processes allowed Italy to overcome problems of the disseminated structure of olive oil partnerships and to brand exceptional olive oil products that meet exportation requirements.

In Greece, both the fragmented and technologically outdated coalitions' mechanisms regarding standardization and product quality control increases further the risks from improperly to not at all disposability of premium quality olive oil (Mylonas, 2015). According to the 2015 World's reports for the 10 best olive oil brands (WBOOR, 2015), Greek Messenia's branded "Lia" oil is placed at the 9th position bellow two Italian, Spanish and US brands. While US produces only 2% of olive oil worldwide (84% is Europe), managed to pertain the biggest number of unique olive oil brands in the global market (after Spain), due to its production monitoring and marketing infrastructure.

Olive oil organic cultivation is the form of agriculture that relies on techniques such as crop rotation, green manure, olive compost and biological pest control to maintain soil productivity and control pests on an olive oil field. Organic cultivation excludes or strictly limits the use of artificial fertilizers, pesticides (which include herbicides, insecticides and fungicides), plant growth regulators such as hormones, livestock antibiotics, food additives, and genetically modified organisms (Camarsa et al., 2010; Ehaliotis et al., 2011). In the latest years there are only a small number of farmers in Greece that are modifying their cultivation types to organic production following LIFE EU directives, and the whole cultivation policy remains unchanged due to the lack of both contemporary cultivation methods and educational-training as well as the strict state frameworks and cultivation monitoring methodologies.

In Greece, olive pressing companies, coalitions and partnerships are more than 400 in total. The pressing systems still preferably used are the traditional grindstone removing processes. A few more contemporary olive mills located in the areas of Peloponnese use the two phase decanter centrifugation method for the olive extraction. Other methods such as the three phase decanter, sinolea method or cold extraction methods are not at all used (Niaounakis and Halvadakis, 2006). Contemporary decanter systems reduce oil leakage from the traditionally milling process up to 15-20%. Since two phase mode virgin oils had high oxidative stability and better organoleptic characteristics (no correlation between their stability and phenolic concentration as appeared in the 3 phase process), ends up that the two phase machines are the ideal extraction equipment for producing olive oil of more quantity and comparative quality to that of the old fashioned grindstone milling process (Niaounakis and Halvadakis, 2006).

Despite the immersive problems of monitoring and marketing olive oil products in Greece, the future of Greek olive oil economy seems promising due to the globally increased demands for the product. These demands are expected to grow by a 40-50% more than the 2015 Greek exports until 2020 (210,000 tons – 2015)

(International Olive council World, 2012; European Commission Agricultural Market Briefs, 2012). The increasing export activity of olive oil products offers great economic profits to a large number of people who are involved in the respective supply chain. Even if reports from Greek authorities are non optimistic in respect to the increase of Greek oil production, due to gradual reduction of EU CAP subsidies and scattered small scale production, the use of ICT production monitoring and traceability technologies shall increase product exportation which is already of high quality standards (European Commission Agricultural Market Briefs, 2012).

Focusing on Greece, the main olive varieties cultivated for drupes and oil are the following: (Niaounakis and Halvadakis, 2006; European Commission Agricultural Market Briefs, 2012) (a) *Koroneiki*: It represents 60% of Greece's production, its seed weight is 0.3-1gr and height 12-15mm. (b) *Athinolia*: an olive variety that produces low acidity oil, has 2.2-2.9gr seed weight and height of 7.5-25mm. (c) *Tsounati (Mastolia, Mouratolia)* (15% of Greece's production): variety giving high oil quantity with seed weight of 1.2gr and height of 10-16mm. (d) *Kalamon-Chalkidikis (ChondroElia)*: (1-2% of Greece's production) used mainly as table or paste oils. (e) *Manaki (Lianolia, Koutsourelia)*: (10% of Greece's production), high altitude variety of medium oil characteristics (acidity and oil quantity).

This paper presents a new olive oil monitoring and management framework called OLEA. The OLEA framework is consisted of the following hierarchical steps: 1. olive trees traceability and cultivation monitoring, 2. olive oil extraction sensory monitoring and 3 olive oil management.

The proposed OLEA framework and framework test-bed system implementation serves a two-fold monitoring purpose: a) It will maintain regional olive tree cultivation process information. Such information can be proven valuable and be used in several statistical analyses and cultivation findings for the years to come. b) It shall preserve regional olive oil characteristics. Such information is useful for the quality assurance of promoted products as well as branding of new products.

The remainder of this paper organization is as follows: Section 2 provides related work of existing olive oil quality monitoring systems. Section 3, outlines the proposed OLEA methodology and OLEA system high level architecture, while section 4 focuses on an OLEA algorithm case study. Finally, section 5 concludes this paper.

2 Olive Oil Monitoring Systems

In recent years, olive oil monitoring has been performed with the use of offline sample analysis. However, offline sampling needs costly instruments, such as accurate electrical balances, microscopes, automatic particle counters, and human processes of long measure time, which precludes early diagnosis of oil system failures and prevention.

Focusing on commodity work automation, Gao et al. (2004) proposed a multiple sensor system. Multiple integrated sensors could characterize the oil situation better than a single sensor. With multiple sensors systems, reliability reflects the capability of the sensor that could identify the oil system accurately. Oil characteristics can be measured online by single-function sensors. The oil measurement system is made up of three parts: Multiple sensors for temperature, pressure, moisture and viscosity; Signal acquisition channels with signal amplification, a diverter switch for analog signals and an A/D converter; and finally the analysis and processing unit made up of computer (industrial computer).

Towards that direction, Taouil et al. (2008) proposed a video supervision system used for quality monitoring in olive oil conditioning line. Oil monitoring system can be used for achieving high production rates that cannot be done by human workers easily.

Taking into account product quality control as a major factor of quality assurance, Mailer and Beckingham propose a sensory (organoleptic) system for testing. Sensory quality is the most important test to ensure the oil is acceptable for consumption (Mailer and Beckingham, 2006). The organic parts of olive oil tested are: Aroma, flavour, pungency and bitterness.

According to the IOC standards, extra virgin olive oil, for example, should not have any sensory defects and should have some fruitiness. That means that the definition of the sensory quality control shall include far more attributes than the ones proposed by Mailer and Beckingham. Moreover, in order to achieve significant quality standards, it is both required to develop the capability to preserve sensory quality consistently as well as to have a reasonably good knowledge of regional olive oil varieties attributes. Primarily, this would be an augmented knowledge and ability to detect product defects and faults. At a more advanced level it could provide the ability to identify oil for specific markets and the capability to blend oils to meet customer specifications.

Kiama et al. (2004) proposed a low-cost RFID - based palm monitoring system. Passive RFID tags are used in the plantation field to uniquely identify each palm oil tree and their Fresh Fruit Bunches (FFB) production is collected and monitored by scanning the passive RFID tags using high frequency RFID scanners. This technology aims to convert the harvest data into digital information which can be processed and analyzed by PMS system and presented as informative outputs such as dynamic charts. This system has only one level of access, top management users (GIS Managers and Administrative Managers), as it mainly deals with crucial and sensitive information. The overall system is made up of three main components namely RFID system, Central PMS and the GIS system.

3 Proposed Methodology and Architecture of the OLEA System

Authors propose an olive oil monitoring and quality assurance methodology called OLEA framework, supported by a test-bed system called OLEA system. OLEA system methodology includes the OLEA clustering algorithm and the steps that the OLEA system implements, while OLEA system architecture is presented in Fig.1 Below are the OLEA system technical implementation details according to framework steps.

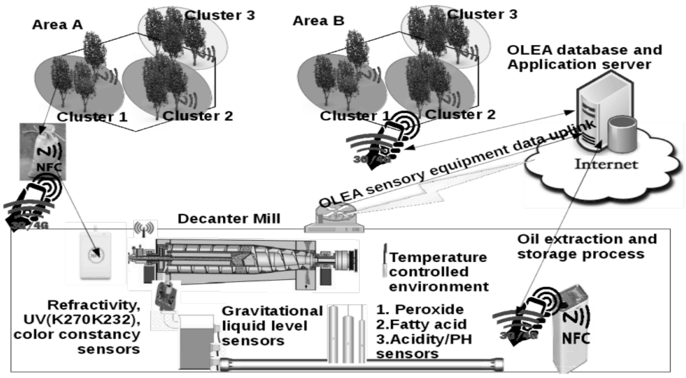

Fig. 1. OLEA High level system architecture

The authors of this article propose the utilization of the OLEA framework for the process of olive oil quality evaluation, traceability and branding. The proposed framework includes the following methodology steps:

1. Traceability step: OLEA product traceability regions are divided into two distinctive layers:

Layer 1: The olive field spatial geographical location GIS system maintained by either a local prefecture or the nationwide OPEKEPE (Greece EU CAP funding organization)(OPEKEPE, 2017). Each field location is divided into smaller polygon areas (see Fig. 1) that pertain similar microclimate characteristics (Theodosiou et al., 2012).

Layer 2: Olive tree traceability, presented in Fig. 1 as rounded areas of tree clusters. Such traceability is achieved with the use of passive NFC tags placed on every tree each farmer claims for OPEKEPE funding. Apart from ID traces these tags are also capable of recording yearly fertilization, pesticide activities (date of appliance, type of medicine used, agriculturist approval for biological or non biological cultivation) following an NDEF message formulation similar to the one presented by Kontogiannis et al for the purpose of NDEF NFC tagging for the sheep industry (Kontogiannis et al, 2016). From 2015 and on, the use of pesticides requires agriculturist prescription and farmer certification, thus the recording of olive trees can be performed in a more organised way (Minister of Agriculture, 2015).

2. Olive oil sensory monitoring step: The OLEA system includes sensory-based equipment (shown at Fig. 1) installed at the oil presses, for the measurement process of the olive oil quantity and the quality clustering based on metrics. Due to its special purpose and function, this could be nationally patented as well.

3. Olive oil Management step:

Logging and reporting: The OLEA database shall record olive oil production quantity and quality attributes connected to cultivation characteristics of tree cluster areas. The database shall also provide information for tree clusters regarding quantities produced, their quality, and market prices. Such information attained nation-wide could be proven very helpful for the development of the oil industry and therefore stimulation of the national economy.

Olive oil clustering algorithm: The proposed OLEA clustering algorithm of olive fields is based on the following attributes:

1. Olive oil field location characteristics based on the OLEA Traceability step. That is, location characteristics acquired by: Protected Designation of Origin (PDO), the Protected Geographical Indication (PGI) or Protected Origin Production names or Protected origin names of Highest Quality – OPAP.
2. Olive oil micro-climate area characteristics, agriculturist yearly reports of cultivation type as recorded by the NFC tags.
3. Olive oil quantity and quality characteristics of olive oil recorded extraction by the sensory system

The OLEA clustering algorithm is outlined in Figure 1. The per-variety OLEA clustering process offers the capability to brand new products based on quality reports and cultivation conditions as well as pertain accurate quantity availability for marketing purposes, no matter how scattered the production and cultivation areas are.

The methodology is performed as follows:

First, a set of metric qualitative measures of the extracted olive oil characteristics is evaluated per tree field. This filtering and evaluation process can be performed separately from the clustering process and the evaluated metrics data are stored back at the OLEA database.

The second step of the OLEA algorithm includes a per olive tree field sector identification based on OPEKEPEs' spatial data and registration validity of the sector stored at the OPEKEPEs' database of recorded olive tree fields.

After successful validation, the microclimate separation process initiates where each field area is bounded to a specific microclimate area polygon accordingly (Fig. 1, areas A, B) (Zinas et al., 2013). Upon first layer cultivation area separation, a field clustering process is undertaken for each area. That is, clusters of trees of a tree area with maximum space of 10000 sq. m. Such areas are uniquely identified with the use of an NFC tag, that keeps track of data regarding cultivation process, pesticides used, and adjustment dates. Olive tree field NFC recorded metrics are the following:

C1] NFC maintained metrics with the use of OLEA mobile phone application: Metrics associated with the tree farming process, cultivation and harvesting such as:

1. Fertilization indexes and metrics (Kgr of biological or chemical fertilization/Ha - quantity (gr) of borium, nitrogen, phosphorus, potassium and iron per tree per year, etc.), 2.Soil fertilization periods and soil minerals composition from the last recorded chemical analysis (B and other minerals like N, P, K and iron), 3. Pesticide periodicity and chemical composition metrics and indexes (chemical sprayed (%ww, %wv)/Kg over 1000 sq. m multiplied by the number of cultivation years (1 cultivation year equals to 6 months) operations), 4. Olive trees age and average distance, 5. Certified biological cultivation or not.

For each cultivation tree-cluster location and microclimate, measures are kept at the OLEA database and set/updated by the farmer's mobile application or OLEA web GUI. More specifically the microclimate measurements and predictions are automatically updated with the use of agents at the Wunderground service (Wunderground API, 2014).

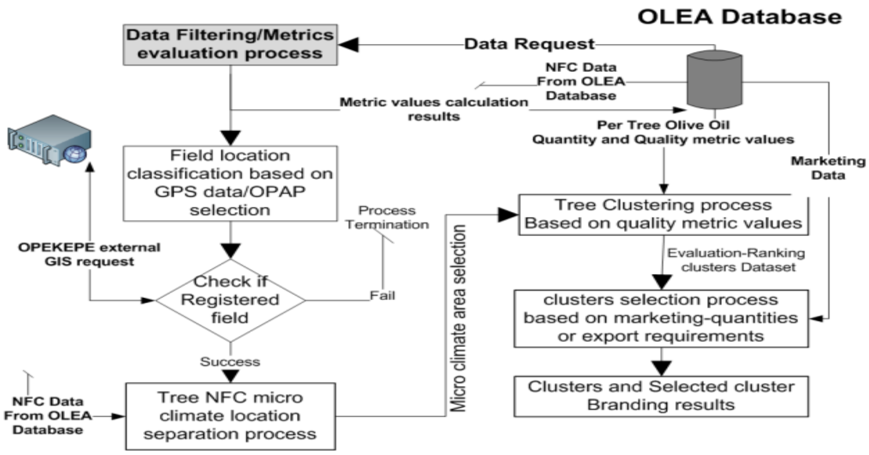

Fig. 2. OLEA clustering and branding algorithm

C2] Location and microclimate measures maintained by the farmer and OLEA application service agents:

1. Field altitude, 2. Field distance in Km from the sea, 3. Field solar monthly-average irradiance (W/sq. m), monthly sunlight average day recordings, flux-luminosity measurements etc, 4. Field soil moisture measurements, 5. Field monthly average rainfall measurements, 6. Yearly critical meteorological conditions recorded for occurring over the field (criticality and occurrence) such as hail or drought or frost. Daily microclimate area predictions.

For recording the extracted olive oil quantity and chemical consistency (quality attributes) per tree cluster, the proposed OLEA framework includes a multi-sensory equipment placed similarly to the ones proposed by Scarafia (Scarafia, 2011), in the olive fruit decanter equipment (see Fig. 1). This multi sensory equipment includes sensors such as: 1. Gravity liquid level sensors for monitoring produced oil quantities, 2. Refractivity UV sensors for K232, K270 measurements of UV absorbance, 3. Colour sensors for monitoring colour constancy, and 4. Peroxide, acidity sensors (see Fig. 1). These measurements are then uploaded in real-time to the OLEA application service. The capture attributes from this automatic sensory process are the following:

C3] Olive oil attributes identified by sensors measured during the milling process and uploaded to the OLEA application service:

1. Olive size (Number of olives per Kg – 230 up to 320 olives/Kg in Europe, this is set as large to brilliant size), 2.Peroxide value (meq O2/Kg), 3. %v/v Oleic acid and free fatty acid, 4.Omega-3/6 polysaturated acids-rancidity index, 5. UV absorbance (K232, K270, DeltaK), 6. Harvesting age (days/hours of harvesting passed), 7. Colour characteristics., 8. Organoleptic classification based on the median of any defect (Md) and median of fruity attributes (Mf) (tests based on human sensory perception).

Oxide rancidity protection, additives and refinement process metrics are not taken into account by authors, since refinement, if it occurs, is a process that follows the oil chemical characterization. Oil refinement is done by using chemicals that are harmful to humans. This means that the oil is treated with acid, or purified with an alkali, or bleached. It can also be neutralized, filtered or deodorized. This paper focuses only on virgin oils characterization with no intermediate refinement or additive process.

After NFC tree cluster tagging and metrics evaluation of each clustering area the clustering of areas into groups is performed based on previously mentioned metrics (see: C1, C2, C3). Metrics are interval continuous values and/or ordinal discrete values that can be treated as continuous. The clustering process that follows is performed on metrics that are preferably normalized over similar value scales.

Such clustering process is achieved using the of K-means algorithm. The process is initialized with n=3 clusters and is repeated by incrementing n, until metric requirements are satisfied by at least one of the generated clusters. Then, that cluster which satisfies metric requirements and has the highest total score, according to requirements is selected. That is, for all clusters, a total score value is calculated in order for clusters to get ranked according to market requirements. This total score value is the sum of all normalized qualitative metric values multiplied by a probability index called clustering or metric importance coefficient.

The selection process that follows selects the cluster of highest rank based on total score and continues top down selection, until quantity requirements are met or a cluster is reached where at least one metric value is bellow the requested value for that metric.

For example, let's assume an OLEA clustering process based on three qualitative metrics (m_1, m_2, m_3) and a market requirement for metric mean values of U1, U2 and U3. Then, based on market or export requirements, each metric value U1, U2, U3 is assigned with a statically set probability of importance p_i, $\sum_{i=1}^{l} pi = 1$, where l=3 is the number of metrics used (in our case three metrics). Then a market required score value based on probability of market importance is calculated according to Equation 1:

$$\mathrm{TS_M} = \sum_{i=1}^{l} p_i U_i \,, \quad \sum_{i=1}^{l} p_i = 1 \qquad (1)$$

where l=3 is the number of metrics used. Similarly, for each k-means cluster a total score metric value is calculated and compared to TS_M value as shown in Equation 2, where k is the cluster number, which the total score value corresponds to.

$$\mathrm{TS_k} = \sum_{i=1}^{l} p_i' M_i \qquad (2)$$

K-means algorithm is used for the creation of product clusters where on each cluster the mean metric values of M_1, M_2, M_3 and cluster total score are calculated, based on Equations 3 and 4, and then compared to the market required total score value:

$$\mathrm{TS_k} = p_k' M_k = \left(\frac{\frac{1}{n_k}\sum_{i=1}^{n_k} m_i}{\sum_{k=1}^{n}\frac{1}{n_k}\sum_{i=1}^{n_k} m_i}\right)\left(\frac{1}{n_k}\sum_{i=1}^{n_k} \mu_i\right) \qquad (3)$$

where n_k is the total cluster elements from the K-Means process, i are the number of tree fields in each cluster (i=1..n_k), and μ_i the qualitative metric value for each tree field id that belongs to a cluster. In depth, M_k is the mean metric value per cluster. Probability p_k' is expressed as the normalized M_k value and it expresses the cluster's metric value impact on the other clusters. If no probabilities are used for metric values, the Total score for cluster k is calculated based on Equation 4.

$$\mathrm{TS_k} = p_k' M_k \overset{p_k'=1}{=} \frac{1}{n_k}\sum_{i=1}^{n_k} m_i \qquad (4)$$

The K-means clustering process initially starts with k=n=3 (where n is the number of metric set as requirements). This leads to the creation of three clusters with mean cluster values M1, M2 and M3 accordingly per cluster (Equation 3) and a total score value per cluster (Equation 2).

If there is at least one cluster with $TS_k<TS_M$, then the cluster with the maximum olive oil quantity value that fulfils metric requirements is selected as appropriate (That is, the cluster with the max(TS_k), where $TS_k<TS_M$. If there is no cluster that fulfils the requirement, then the clustering K-means process is performed repeatedly increasing each time the number of clusters by one, until the market requirements for at least one cluster mean values is met (if metric vector values (m1,m2,m3) are less than (U1,U2,U3) vector values).

Based on total score, a clusters' ranking process is maintained and from that ranking process the high order clusters in rank, are denoted as of high exportation and branding value clusters (selection process) and are selected from top to bottom until quantity requirements are met.

4 OLEA clustering algorithm proof of concept

The case study experimentation in this work includes the Manaki Greek olive variety cultivation in the area of West Greece (fields at Preveza and Lefkada). In this study, a total area of 120 square meters of Manaki oil tree cultivation is divided into 1000 square meters production fields. Each field is identified by a unique NFC tag id that includes field's geographical location, fertilization methods used, altitude, etc. An average fields tree distance is about 6.5-7m away thus 25-30 olive trees are included in each field. The average NFC tagged sector fields production is about 1000-1200 Kgr/0.1 Ha.

All fields are situated at the two nearby microclimate areas of Preveza and Lefkada and the altitude variation between all is from 50 up to 250 meters. Two metrics were used in this study in order to verify the proposed methodology: The %v/v of Oleic Acidity and the total net weight of olive production per NFC tagged field block set to the size of 1000 sq. m. All such blocks were marked by NFC tags and square edge-bounded by GPS coordinates.

Table 1. k-means clusters, average quantity per cluster field in it and %v/v average acidity of per k-means cluster. Cluster 2 meets market acidity requirements and quantity requested.

Cluster ID and symbol:	Average cluster tree field oil quantity (lt)	Average cluster oil acidity %v/v	Total Cluster oil quantity (lt)
C1(○)	2033	0.56	10166
C2(Δ)	1000	0.49	11000
C3(+)	1216	0.61	24322
C4(x)	769	0.59	12304
C5(◊)	661	0.55	32389
C6(∇)	861	0.56	16359

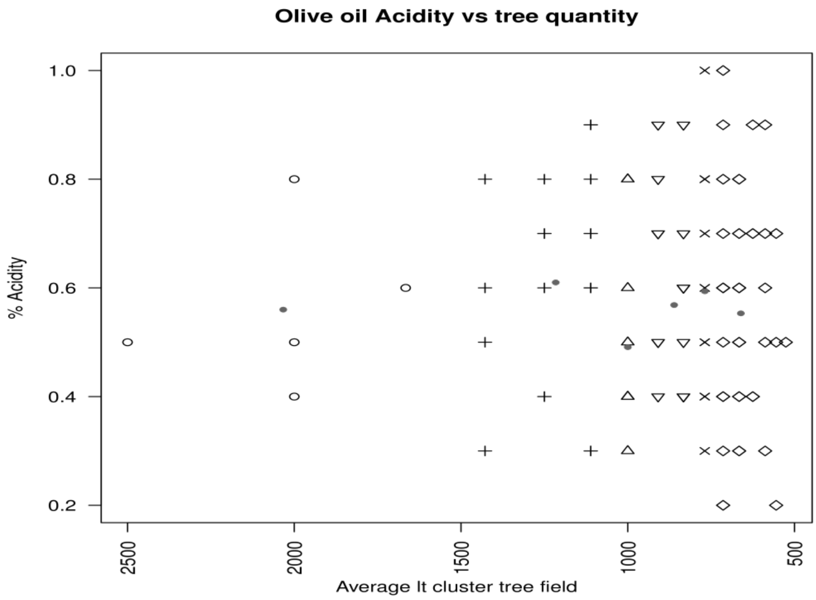

Fig. 3. Clusters returned from the OLEA algorithm. Cluster C2 is marked with the Δ symbol and is the OLEA algorithm selected cluster.

Based on the market olive oil need requests to the farmers' co-partnership, the EVOO (Extra Virgin Olive Oil) maximum acidity regulations and market requirements regarding olive oil acidity were set into maximum of 0.5% v/v and the market requested olive oil quantity is 7000 lt. For that purpose using our proposed OLEA methodology a k-means process was performed for the selection of the fields that produced olive oil less that the acidity threshold set. Table 1 shows the clusters where the requirement of acidity is met (cluster C2).

5 Conclusions

This paper presents a new framework called OLEA, for the process of olive oil attributes acquisition, traceability and management. OLEA methodology uses an NFC based olive tree clustering scheme that maintains cultivation and environmental attributes information stored in its database. This information is reinforced with qualitative olive product characteristics derived by the olive fruit milling process. The attributes recorded by OLEA are landscape similarity attributes; meteorological characteristics; agricultural field operations used and finally milled product quantity and product quality evaluation metrics.

Authors outline the system architecture based on the OLEA methodology. This system includes NFC tags for tree clusters identification and sensors for the process of product metric values measurement. OLEA system also includes an integrated application and database service where all measured NFC and sensor data are collected and then application level queries towards the database can be performed using web interface or mobile phone application interface.

Authors propose a new clustering algorithm, used for the process of maintaining uniform olive product characteristics as well as branding new products. This algorithms uses as input a customer's product requirements in terms of threshold values of the OLEA olive oil recorded attributes and delivers back to them a selection of the most appropriate clusters areas to harvest. To support their methodology, a case study scenario is presented, where the proposed clustering and selection algorithm is applied. From the case study results, it is clearly shown how the OLEA clustering algorithm can achieve the standardization of olive oil products quality as well as branding of new products based on market needs. Furthermore, the utilization of the proposed OLEA framework shall provide adequate olive oil attribute records with regional environmental and cultivation methodology as well as product branding and traceability.

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