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OLIVE YIELDS FORECASTS AND OIL PRICE TRENDS IN MEDITERRANEAN AREAS: A COMPREHENSIVE ANALYSIS OF THE LAST TWO DECADES

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SUMMARY

The main objective of this research was to utilize pollen monitoring methodology to predict olive yields in three Mediterranean olive cultivation areas (Spain, Italy and Tunisia) and their relationships with the olive oil price dynamics. Moreover, olive yield and olive oil production compared with olive oil price trends in the last two decades was evaluated. The statistical analyses confirmed that biological parameters such as the pollen emission, the pollen season start (Pss), the full flowering (Ff) date or the pollen season length (Psl) showed positive correlation values with productive parameters, especially the Pollen Index (Pi). However, the difficulty to define clear relationships with oil price for optimizing the marketing strategies can be due to the olive sector European policy and to the complex international olive oil market situation. The occurrence of unharvested trees was increased and the reduction in agricultural operations as well as non-harvesting could become more widespread above all in traditional extensive systems.

INTRODUCTION

Olives are one of the most extensively cultivated fruit crops in the world, being the 95% of the total area under olive crop concentrated in the Mediterranean region (Barranco *et al.*, 2008). Over the centuries, olive trees have played an important role in rural development as one of the major sources of income and employment in this area (Loumou and Giourga, 2003). The olives fruit production is mainly used for olive oil extraction and the rest for table olives. The globally use of these products contributes to socio-economic and cultural development of the olive-growing regions. The traditional agricultural practices for Mediterranean olive groves are based on a low density of trees, with two or three trunks each, weed control by tillage and chemical treatment (Saavedra and Pastor, 2002). Although in recent years, the planting density has increased and irrigation has been introduced in many areas, tillage still is one of

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the most generalized practices in the olive grove. However, no-tillage practices reveal several benefits regarding to tillage, including increased yield (Saavedra and Pastor, 2002).

Early and effective crop forecasting is essential for optimizing both technical and human resources for harvesting and also for planning olive oil marketing and commercial distribution globally. Access to crop estimates helps to ensure better planning of the activities connected with production (optimization of labour, cultural practices, crop health care, etc.), marketing (stock management, activation of strategies, packing and distribution, etc.), and monitoring of movements in price markets, with the overall aim of making for a transparent sector. The concurrent underlying objectives are to create databanks housing agronomic, physiological and other data helping to provide a better insight into the performance mechanisms of the species during the delicate stage of flowering (Fornaciari *et al.*, 2005).

Fruit production crops have been forecasted by several agro-meteorological methods (CGMS-Crop Growth Monitoring System) (Bouman *et al.*, 1996), time trends (Palm, 1995) or base to satellite measurements (Bastiaanssen and Ali, 2003; Fei *et al.*, 2012). However, today the most widely used method for yield estimation is by visual observation prior to collect crop. Recent studies have shown better results in anemophilous species by modelling airborne pollen as an index of floral intensity and as a good bio-indicator of the future yields (Aguilera and Ruiz-Valenzuela, 2014; García-Mozo *et al.*, 2012; Orlandi *et al.*, 2010). In wind pollinated species, the annual airborne pollen has been demonstrated as a good indicator for both flowering intensity and plant behaviour during reproductive phenological stages (Aguilera and Ruiz-Valenzuela, 2009; Galán *et al.*, 2004, 2008; Orlandi *et al.*, 2012, 2013; Oteros *et al.*, 2013a, 2013b). Moreover, pollen emission data, which are widely used as a well-proven tool for indirect evaluation of the flowering period, they reveal interesting phenological information in terms of flowering timing (Aguilera *et al.*, 2015; Galán *et al.*, 2008).

Numerous studies confirmed the importance of airborne pollen and weather requirement during the months successive to the olive flowering for olive yield forecasting (Aguilera and Ruiz-Valenzuela, 2014; Fornaciari *et al.*, 2002; Galán *et al.*, 2004, 2008; García-Mozo *et al.*, 2012; Orlandi *et al.*, 2014a; Oteros *et al.*, 2014). These models offer more precise forecasts but delay the statistical modelization till the end of summer or during autumn, depending on the site (Galán *et al.*, 2008; Oteros *et al.*, 2014). From a commercial point of view, each month of advance in the yield forecasting (even with a minor but sufficient level of confidence) may represent a precious information from which take advantage in comparison to other competitors in the market. On the other hand, it is also important to take into account the difficulty to count with different meteorological parameters in several Mediterranean cultivation areas.

In the present study, olive yield forecasting models have been analysed and evaluated for three of the main world producing countries: Spain, Italy and Tunisia. These models have been elaborated to test the statistical level of confidence immediately at the end of olive flowering periods (May, June) utilizing only biological data as predictive

Table 1. Selected monitoring areas in Spain (Sp), Italy (It) and Tunisia (Tu).

Growth area	Coordinates	Altitude (m a.s.l.)	Rainfall (mm) annual mean	Temperature (°C) annual mean
Jaen (Sp)	37°48′N, 03°48′W	568	488	17.1
Cordoba (Sp)	37°50′N, 04°45′W	123	603	18.4
Perugia (It)	43°06′N, 12°23′E	450	817	14.4
Benevento (It)	41°07′N, 14°50′E	152	846	16.3
Avellino (It)	40°55′N, 14°47′E	29	788	14.6
Salerno (It)	40°37′N, 14°52′E	29	889	15.1
Lecce (It)	39°49′N, 18°21′E	48	441	16.3
Trapani (It)	37°40′N, 12°46′E	7	448	19.4
Menzel (Tu)	35°25′N, 09°50′E	160	280	21.1
Chaal (Tu)	34°34′N, 10°19′E	97	212	20.1

variables. These countries count with an airborne pollen database from decades based on a standardized protocol in the frame of a network, offering quantitative and phenological data about the biological phenomenon.

The main objective of this research is to propose aerobiological models to predict olive crop size in the Mediterranean area, using olive crop production as dependent variable and airborne pollen parameters (intensity and timing) as independent variables for evaluating the real forecasting efficiency of the biological variables.

The second objective is to analyse the effective relationships between olive yields in the principal Mediterranean olive cultivation areas and the relative olive oil price dynamics, evaluating the influence of olive fruit production levels respect the oil price determination. If robust correlation could be established between forecasting olive yields and oil price, the same oil commodity market dynamics could be evaluated with some months of advance permitting to assume competitive commercial decisions. Generally, the precedent cited investigations on the olive yield forecasting not were interested to olive oil price formation limiting their interest to the relationships between biological variables and successive fruit formation.

MATERIALS AND METHODS

The present study derived from a previous multiregional experience on aerobiological investigations realized in some olive airborne pollen monitoring areas widely distributed throughout three Mediterranean countries (Spain, Italy and Tunisia). For each of them, the average values of olive airborne pollen in different sites were considered: from 1992, in Spanish sites, from 1993, in Tunisian areas and from 1999, in Italian representative olive groves (Oteros *et al.*, 2014). The monitoring areas selected for this research were those that, in the study mentioned above, showed the best correlation results regarding the olive crop production (Table 1). The data series recorded in these areas (until the year 2012) were analysed in-depth.

The biological parameter considered in this study was the olive pollen captured in the atmosphere during the olive flowering period, using aerobiological monitoring.

Pollen emission data for the olive trees were collected continuously by using Hirst type volumetric pollen traps (Hirst, 1952) located in the more representative olive crop areas of Spain and Italy. In Tunisia, the airborne pollen monitoring was realized both with Hirst type pollen traps and with Cour sampler (Cour, 1974) in the last years, while till 2008, only this last sampler was utilized and the related results were downscaled to estimate continuous data (Orlandi *et al.*, 2014b). For sampling, analysis and data management, it has been followed the minimum recommendations proposed by the European Aeroallergen Network (Galán *et al.*, 2014).

For all the monitoring areas, four aerobiological parameters were calculated: (i) the Pi, i.e., the sum of the daily pollen concentrations per m^{-3} of air during the whole pollen season; (ii) Pi during the pre-peak pollen season (Pi-pp), it is considered as the sum of the daily pollen counts from the start of the main pollen season to the day on which maximum count was recorded (peak pollination date); (iii) Pi during the aerobiological effective pollination period (Pi-epp), considered as the sum of the daily pollen concentrations of the four days preceding the peak pollination date (Orlandi *et al.*, 2005); (iv) daily pollen concentration recorded during the peak pollination day (Pp), expressed as pollen grains m^{-3} of air.

The Pss and length were defined on the base of daily pollen concentrations: Pss was defined as the first day on which at least one pollen grain m^{-3} was reached whenever five subsequent days contained one or more pollen grains m^{-3}; the Ff, defined as the day of maximum pollen concentration registered, and the Psl, number of days from the Pss to the last day on which one pollen grain m^{-3} was collected, when subsequent days had concentrations lower than this value.

Regarding the national olive cultivation data, both the annual country yield (ton) and olive oil production (ton) data were obtained from the databases of the 'International Olive Council (IOC)', while the national olive oil price data (in euro) were provided for the 'Food and Agriculture Organization Corporate Statistical Database (FAOSTAT)'. In particular, IOC is the only intergovernmental organization in the world to bring together olive oil and table olive producing and consuming stakeholders, while FAOSTAT website disseminates statistical data collected and maintained by the Food and Agriculture Organization (FAO).

To study the relationship between the national olive yield (ton), olive oil (ton) and the biological parameters recorded in the different olive cultivation areas (i.e., Pss, Ff, Psl and the different pollen emission variables), Spearman's non-parametric correlation test was performed. The average pollen counts for the different sites selected in each country were calculated to represent year by year the mean olive cultivation condition. National olive yields and olive oil productions recorded during the study period were also utilized to establish the more significant relationships between them (as dependent variables) and the biological parameters recorded months in advance to the final harvest using multiple regression analyses.

Finally, a trend analysis with Mann–Kendall test was realized for the yearly olive yield (ton), olive oil (ton) e olive oil price (euro kg^{-1}) of the three countries considering the study period as a whole. The trends were evaluated using the Z coefficient estimation for every variable considered. A positive Z-value shows the presence of

Table 2. Correlation coefficients between national olive yield and olive oil production with flowering timing and pollen emission means recorded in the selected monitoring areas.

	Spain		Italy		Tunisia	
	Yield	Oil	Yield	Oil	Yield	Oil
Yield		0.98*		0.74*		0.88*
Oil	0.98*		0.74*		0.88*	
Pss	− 0.03	− 0.01	0.77*	0.59	− 0.08	0.20
Ff	− 0.03	0.00	0.79*	0.50	0.16	0.42
Psl	− 0.07	− 0.08	0.02	− 0.14	− 0.01	0.00
Pi	0.82*	0.79*	0.69*	0.62	0.83*	0.87*
Pi-pp	0.55	0.51	0.62	0.52	0.76*	0.85*
Pi-epp	0.61	0.58	0.65	0.47	0.74*	0.82*
Pp	0.75*	0.73*	0.71*	0.56	0.68	0.75*

*Significance $p < 0.05$.
Pollen Index (Pi); Pollen Index during the pre-peak pollen season (Pi-pp); Pollen Index during the effective pollination periods (Pi-epp); Pollen season peak (Pp); Pollen season start (Pss); Full flowering (Ff); Pollen season length (Psl).

an increasing trend within a data series, while a negative Z-value shows a decreasing trend (Sirois, 1998). For the four tested levels of significance of the trends, the following symbols are used: $**$, a = 0.01 (highly significant); $*$, a = 0.05 (significant); and +, a = 0.1 (nearly significant). The statistical software NCSS 2007 was used for the correlation and regression analyses, and the Excel template MAKESENS version 1.0 (Salmi *et al.*, 2002) was used for the Mann–Kend all trend analysis.

RESULTS

The Spearman's correlation results for the national olive yield (ton), olive oil (ton) and the biological parameters are shown in Table 2. In each country, high correlation values have been obtained between yearly olive fruit and oil produced, even if some variability is manifested above all by Italian data. Flowering timing manifested high correlation only in Italy with significant positive values in relation to olive yields while in the other countries olive productions not appeared significantly related to the flower development periods.

Pi was highly correlated with the olive fruits and oil production of the three areas. Spain and Tunisia showed the highest correlations regarding yield and oil production, with r values higher than 0.80, in comparison with those obtained in Italy that evidenced values of 0.69 for olive yields and 0.62 for olive oil production (Table 2). Also the pollen season peak (Pp) manifested high correlation values in relation to yield and/or oil production in the three areas, showing r values higher than 0.70 in all the cases.

The highest average Pi value considering the whole study period was obtained in Spain (31,317 ± 12,772 grains of pollen), followed by Italy (13,136 ± 8,158 grains of pollen) and finally for Tunisia (12,128 ± 8,446 grains of pollen). In Spain and Tunisia, the maximum olive pollen levels were recorded in 2003, with Pi values of 70,888 and

Table 3. Multiple regression analysis with olive yield and olive oil as dependent variables.

		Dependent Variable	Independent Variable	Regression Coefficient b(i)	*t*-value	Prob Level
Spain		Olive Yield	Intercept	437909	0.633	0.5347
	R^2	0.7516	Pi	1009384	6.199	0.0000
	Adj R^2	0.7240	Prod *t*-1	0.2816	2.477	0.0234
		Olive Oil	Intercept	113738	0.715	0.4835
	R^2	0.6791	Pi	198750	5.311	0.0000
	Adj R^2	0.6434	Prod *t*-1	0.0481	1.842	0.0821
Italy		Olive Yield	Intercept	−4989491737	−2022	0.0707
	R^2	0.7409	Ff	55,615	3.221	0.0092
	Adj R^2	0.6891	Pi	21	2.187	0.0536
		Olive Oil	Intercept	−2129483611	−1797	0.1059
	R^2	0.6458	Pss	195215252	2.202	0.0552
	Adj R^2	0.5277	Pi	486369	2.411	0.0392
			Pp	−2327299	−2.121	0.0630
Tunisia		Olive Yield	Intercept	3662723225	4133	0.0006
	R^2	0.6884	Pi	381197	6.306	0.0000
	Adj R^2	0.6711				
		Olive Oil	Intercept	747787618	5309	0.0000
	R^2	0.7508	Pi	70761	7.364	0.0000
	Adj R^2	0.7369				

Pollen Index (Pi); Pollen season peak (Pp); Pollen season start (Pss); Full flowering (Ff); Olive yield of the prior year (Prod $t-1$).

27,517 grains of pollen respectively. In this year, one of the higher crop yield records was obtained for both areas, being of around 7,500,000 tonnes of fruit for Spain and 1,400,000 tonnes of fruit for Tunisia. In Italy, the maximum Pi value was recorded in 1999 (34,086 grains of pollen), year with a high crop yield of 3,765,000 tonnes of fruit.

On the base of these results, multiple regression analyses have been carried out for each country considering olive yields and oil productions as dependent variables and the most correlated flowering variables as independent ones (Table 3). In Spain, significant coefficients ($R^2 = 0.75$ and 0.68, respectively for olive yield and oil production) were obtained using Pi of the precedent year (t−1). In Italy, significant coefficient ($R^2 = 0.74$) was obtained for olive yields considering only Ff dates and Pi; while Start flowering dates, Peak pollination and Pi conducted to realize a lowest value ($R^2 = 0.65$) for olive oil production. In Tunisia, significant coefficients ($R^2 = 0.68$ and 0.75, respectively for olive yield and oil) have been obtained with Pi.

In Figure 1, the actual and predicted values of annual olive yields are presented with the statistical percentage error for each country area. The charts evidence the good regression results using the variables that have shown better results after the correlation analysis, even if the percentage errors in some years (above all in Spain and Tunisia) are close to 30%. However, a more detailed analysis evidenced that forecasting errors higher than 5% were often recorded because actual olive yields manifested particular positive or negative peaks. So in these ‘exceptional’ years, too large under or over estimation of future fruits formation and not evaluation error of

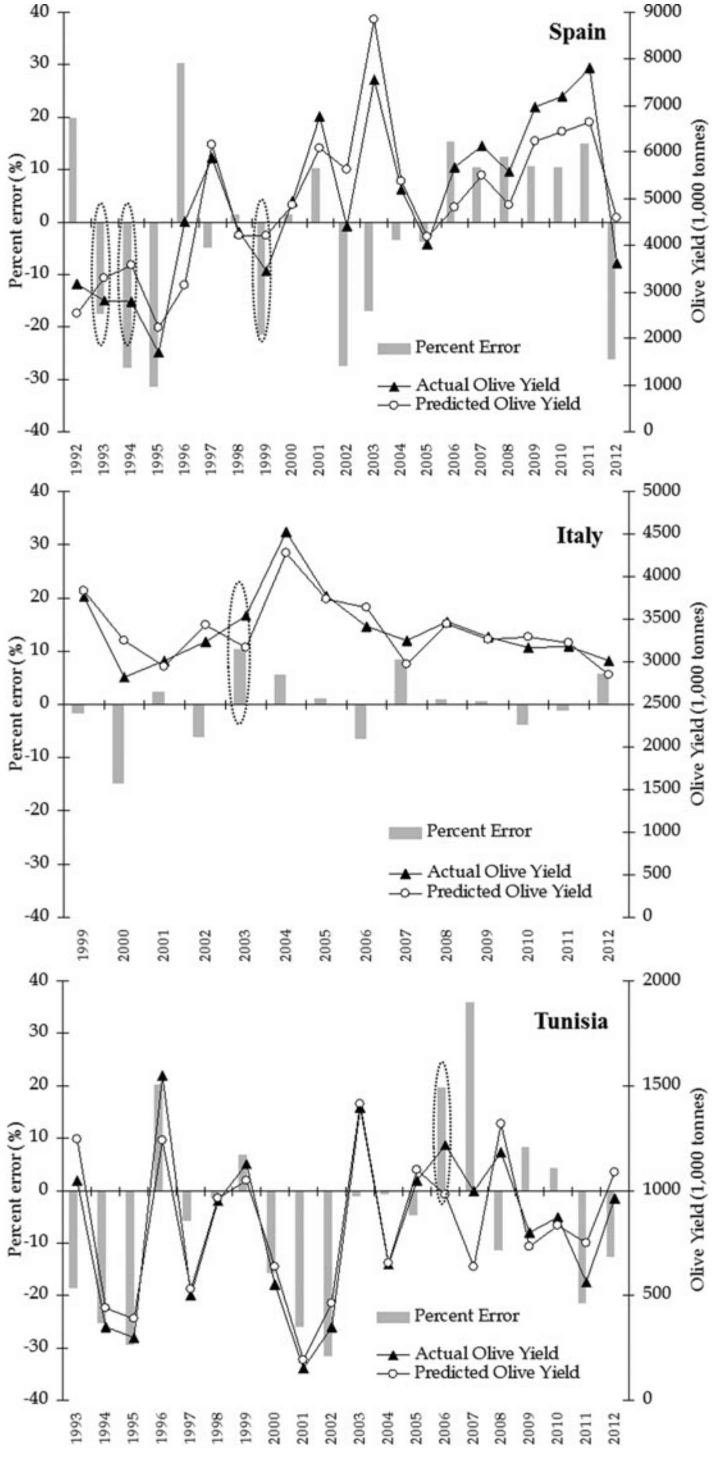

Figure 1. Actual and predicted olive yields (1,000 tonnes) in the three countries considered.

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the production increase or decrease in comparison to the precedent year (year by year variation) may be evident.

In Spain during 1993, a forecasting percentage error higher than 5% was recorded (data included in circle in the charts). Moreover, in other two years (1994 and 1999) the real and predicted data were not accorded in the year by year olive yield variation. In Italy, during 2003, a percentage error higher than 5% was recorded, in concomitance with a decreasing predicted olive yield and a contemporary increase of the effective fruit production. Finally, in Tunisia, only in 2006, this prediction error was recorded.

Regarding the olive oil price, not so good results have been obtained due to probably other variables, such as complex market mechanisms that play an important role (Figure 2). In Spain, two clear significant increasing trends for both the olive yield and olive oil were detected. The last year of the series (2012) presented very low values for both the olive yield and oil productions data which resulted as an outlier. Nevertheless, the olive oil price not manifested particular tendencies during the entire period considered, remaining included in a range between 1.8 euro kg^{-1} and 3.8 euro kg^{-1}.

In the case of Italy, not significant trends were manifested by olive productions or by olive oil prices during the entire time period. The production levels were lower than in Spain but the oil price was higher, within the interval between 3 and 5 euro kg^{-1}.

Tunisia has shown an highly significant increasing trend for the oil price ($a = 0.01$), with two sub-series, the first from 1991 to 2001, when the prices have fluctuated between 0.90 and 1.4 euro kg^{-1}, and the second in the last decade, with prices between 1.5 and 2.5 euro kg^{-1}. Both olive yield and olive oil not evidenced any tendencies, manifesting high annual oscillations due to particular climate conditions of the areas of cultivation (uncertainty with rainfall) that determined the marked alternate bearing. Moreover, in Italy and Tunisia not clear correlations emerged between annual yields and the oil productions. Nevertheless, in Spain, three particular periods during the historical series can be identified. During the time period 1992–2001, the olive yield productions correlated significantly and negatively with the olive oil prices (r value -0.68; $p < 0.05$), while for the period 2009–2012, the olive oil prices correlated significantly and negatively with the olive yield (r value -0.76; $p < 0.05$) and the olive oil productions (r value -0.80; $p < 0.05$). However, in the intermediate period, from 2002 to 2008, not significant relationships were detected.

DISCUSSION AND CONCLUSIONS

Yield forecasting models have proven to be useful tools in the promotion of increased understanding of the mechanisms involved in crop system behaviours (Aguilera and Ruiz-Valenzuela, 2014; Orlandi *et al.*, 2012). The statistical evaluation confirmed that all the quantitative flowering variables generally showed positive correlation values with productive parameters, especially the Pi, evidencing the biological relationship between male gametes involved in fertilization processes, transported by pollen grains, and consequent fruit formation. In addition, the airborne pollen count provides indirect information on the number of available flowers, and consequently of ovaries

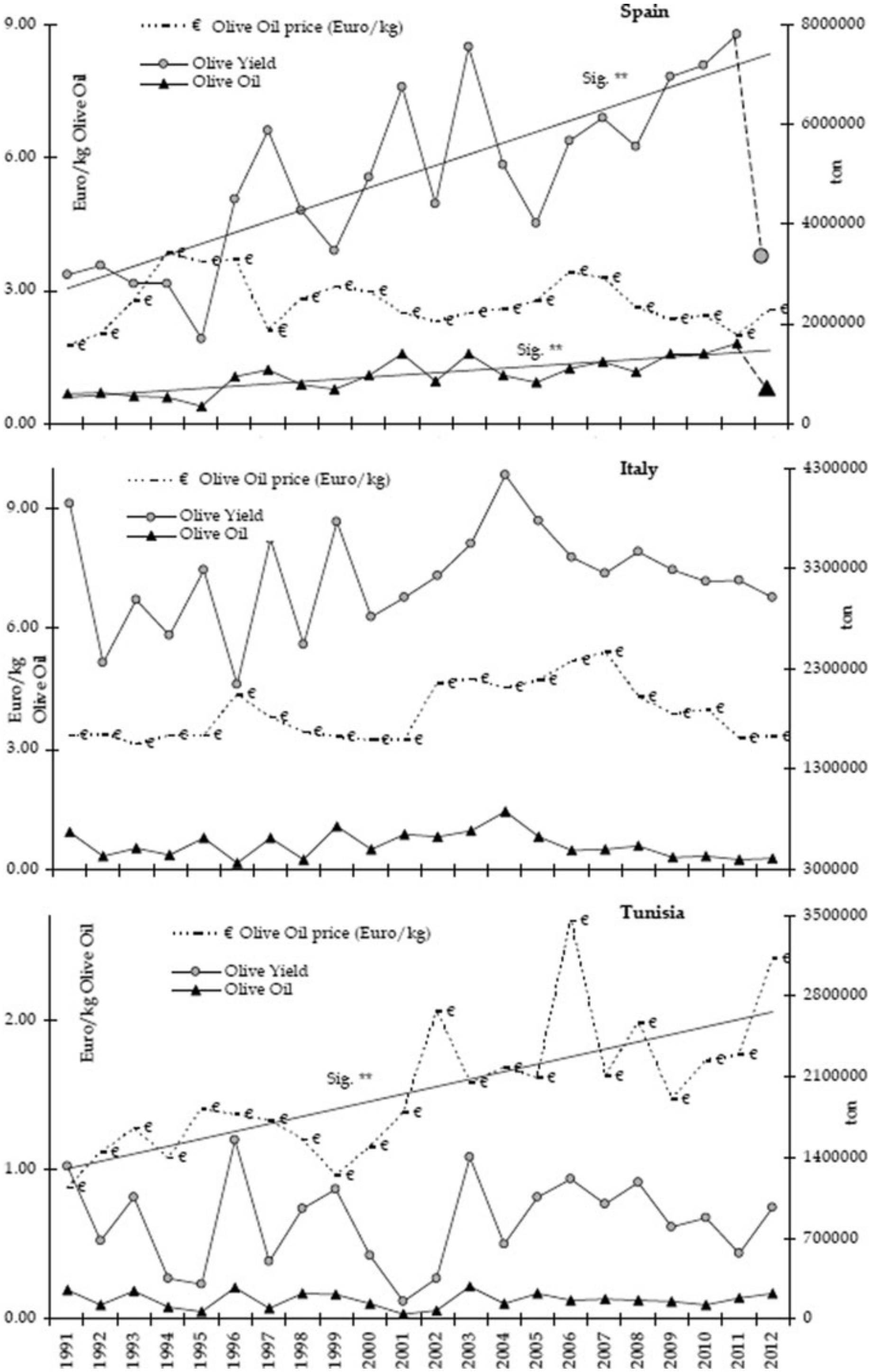

Figure 2. Temporal trends for olive yield (ton), olive oil production (ton) and olive oil price (euro kg^{-1}). Trend significance (Sig.): ∗∗, a = 0.01 (highly significant); ∗, a = 0.05 (significant); +, a = 0.1 (nearly significant).

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that would become fertilized for the successive fruit formation (Aguilera and Ruiz-Valenzuela, 2014; Galán *et al.*, 2008; Orlandi *et al.*, 2010). Nevertheless, it is important to consider that olive trees are influenced by several weather and agronomic conditions during both the pre-flowering period and the time period between flowering and harvest, such as water deficit, temperature extremes and phytopathological problems. These can have negative impact on fruit quantity and quality, and thus increase the interannual variability of the final fruit production (Galán *et al.*, 2008; Ribeiro *et al.*, 2008). In this way, and according to several authors, the conditions during the months prior the flowering period, such as water deficit, crop management techniques or plague, are reflected in the annual number of flowers and amount of pollen produced by olive trees (Orlandi *et al.*, 2010; Ribeiro *et al.*, 2008). Consequently, the Pi can be used to reflect these variations, to incorporate them indirectly into the yield forecasting models.

The high yield forecasting errors obtained for the predictions of some years were probably due to meteorological factors recorded after fruit formation period, especially during some years in North Africa where yearly rain variations can be decisive for the final harvest (Oteros *et al.*, 2014). Olive tree is a species characterized by alternate bearing in which the yearly 'on' (bearing years) or 'off' (non-bearing years) productions can be highly influenced by seasonality. The difficulty to define clear relationships between biological variables and olive oil price for optimizing the marketing strategies can be probably due to the olive sector European policy based on supports to the olive producers and to the unusual and complex international olive oil market price situation (EC-DGAGRI, 2012; GEIE Agrosynergie, 2009).

The olive sector analysis of the studied countries clearly evidenced the great efforts of Spanish producers, with olive yields increased since half 90', and contemporary the difficulties in Italy and Tunisia, especially during the last study period (2004–2012). Moreover, the price analysis also showed the alignment of Tunisians olive oil prices to the Spanish ones since 2002 but a substantial constancy within two different ranges, one for Spanish and Tunisian olive oils (between 2 and 3 euro kg^{-1}) and the other between 3 and 5 euro kg^{-1} for the Italian olive oil.

In addition, the Spanish olive overproduction recorded from 2006 to 2011 led to a positive supply shock that has weighed heavily on prices in Spain and Italy since 2007, with a consequent steady reduction. This reduction in prices probably had an impact in the Italian olive yields inducing cultivation abandonment for not harvest convenience.

Without a political financial support to olive farmers, as occurred in past in Europe, make the market be the major driving force for producers when making their choices. Generally, in the longer term (due to the perennial nature of the olive groves), the effects should be a diminution in the olive grove areas and an increase of production in the more competitive zones (i.e., plains with irrigation).

However, if the market conditions remain poor as in the last years (since 2009, when the price of olive oil was very low) the occurrence of unharvested trees and the reduction in agricultural operations could be increased, as well as non-harvesting, or in the extreme cases abandonment of production altogether, can become more widespread. The systems most sensitive to the risk of abandonment are most likely to be the traditional extensive systems.

In the marginal lands, the growing systems are often traditional and extensive, and their positive environmental, social and cultural features are widely recognized (landscape formation, control of soil erosion, maintenance of biodiversity, fire control, maintenance of activity, socio-economic development of rural areas) (Loumou and Giourga, 2003). However, some of these olive groves are threatened with abandonment or conversion, mainly because of low yields, steep slopes which restrict the possibilities of mechanisation, small farm size and difficult access to the market.

Nevertheless, abandonment may be limited due to specific factors. Olives are sometimes grown without regard for the economic results (e.g., due to a strong cultural attachment or for home consumption). Moreover, quality is the main competitive advantage in respect to other vegetable oils produced at much lower cost. Producer groups must to express a genuine link with the specific geographical area, taking advantage of this strong marketing tool to promote quality linked to origin.

As regards the olive oil market, the price reduction trend was stopped in 2012 when a strong production 'off' was recorded in Spain (nevertheless, it was forecasted thanks to the biological variables) which determined an impulsive tendency inversion with a price increase of about 30% in comparison to the precedent year value (Sánchez-Martínez *et al.*, 2008).

The olive yield forecasting model, also in terms of predicting the behaviour of prices, indicating some months in advance those years that may be particularly productive ('on' production) or those which will be characterized by 'off' production in different areas of study, can be used to manage the international olive oil market from the summer prior the harvest. In this sense, it could be hypothesized for example the expansion of the harvest operations of marginal olive groves in which the same harvest may be convenient only in years when higher price can be reached ('off' year) and not in 'on' olive yield years when harvest could be focused only in intensive olive groves, where the agronomic operations are cheapest.

These useful indications have even more value considering the existence of a significant negative pollen correlation both between Spain and Tunisia (excluding 2003 when in both areas massive pollen emissions were recorded) that between Spain and Italy. This negative correlation, if properly evaluated, could indicate the high and low production years for the main production areas in a perspective of olive oil market integrate management at a Mediterranean level.

Finally, it is also important to take into consideration that price seems to be the most determinant criterion for the vegetable oil consumption, despite that, if consumers are persuaded of a product's superior quality characteristics, they prefer it (Siskosa *et al.,* 2001). In this sense the customers have to be convinced that it is not possible to have an extra virgin olive oil with its unique characteristics to the price of other vegetable oils unless you get off to strange compromises with the world oil industry.

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