Olive Tree in Emilia Romagna Region: an Ancient Crop, a New Environmental and Cultural Economic Resource

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Abstract

The National Research Council Institute of Biometeorology of Bologna (IBIMET-CNR) carried out a study aimed to the safeguard of autochthonous cultivars, through the census of secular olive tree plants, belonging to varieties at extinction risk or located in sites with historical or landscape add value in the Province of Bologna (North Italy) with particular attention to phytometric characters, sanitary status of the plants and the relation with their location characteristics. The presence of ancient plants in a specific site may indicate the absence of limiting factors for olive trees development. Considering the environmental factor values of these locations, a classification of the territory in classes of suitability for the cultivation was defined, with the support of a Geographic Information System (GIS). Ancient olive trees data were also collected and catalogued in an internet site (http://olivisecolari.ibimet.cnr.it) where it is possible to reach a virtual journey through studied olive trees. All plants are supplied with a phytometric card and a visualization on a map providing the exact location. The GIS elaboration of the environmental factors considered for the definition of the suitable lands for olive trees cultivation, identified 3556 ha as suitable, of which 972 ha highly suitable belonging to class I, where olive trees cultivation could be profitable because of suitable land morphology and the possibility of a good mechanization due to low field slopes.

Key-words: biometric index, landscape, GIS, *Olea europaea*, land suitability.

Introduction

Olive cultivation in Emilia-Romagna region is mainly concentrated in the three provinces located in the south-eastern part of the region: Rimini, Forlì-Cesena and Ravenna. Nevertheless in the last years olive cultivation have also found a suitable microclimate in the hilly area of the north-eastern part of the region. In fact, new olive orchards were also established in the western hilly zones (Emilia). Bologna represents one of the Emilia provinces where many ancient olive trees are still present. These secular plants are often found near ancient estates, fortresses, or by the cloister of the several churches which characterise Bologna province. Bologna boasts the presence of the only olive plant recognized monumental (L.R. n. 2, 1977, art. 6) in Emilia-Romagna region, characterized by 19 trunks.

As the interest for the olive cultivation is increasing and the number of new orchards on a small scale is growing, it becomes important to use autochthonous genotypes that were present in the past. The rational planning of a reintroduction of olive plants represents a great regional occasion for both landscape and economical development. Moreover the use of local selected autochthonous genotypes guarantees the production of oils characterized by elevated chemical and sensory standards (Rotondi et al., 2006; Rotondi and Lapucci, 2010).

The aim of this study was to investigate on the relationship between ancient olive trees

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phytometric parameters and pedo-climatic factors of their location, while defining location for new potential orchard implants. Species presence or abundance may readily reflect some measures of the character of the habitat within which they are found, in this case they are often identified as bioindicators (Stork and Samways, 1995). Under this view, the definition of the suitable pedo-climatic conditions for new cultivations may start from the characterization of environmental factors of ancient olive trees locations. Several advanced procedures and methodologies are available, applied to produce potential distribution maps of plant and animals, like DOMAIN (Carpenter et al., 1993) or Maxent (Phillips et al., 2006), mainly used by ecologists, but requiring several data about the environment and with important statistic efforts. For our purposes it may be enough to consider some environmental characteristics, defining thresholds based on values of ancient olive trees locations integrated with some simple agronomic observations. All considered environmental characteristics have been managed in a GIS project (Geographical Information System), giving the possibility to relate and analyse all environmental characteristics useful for this purpose.

The produced map it can be considered a first approximation that gives an idea of the extension of suitable lands for new olive orchards, representing anyway an important tool to support planners in making decisions.

Code	PAR 01	
Genotype	GRAPPUDA	
Location	CASALFIUMANESE	
Landscape	EXTRAURBAN	
Coordinates GPS	44° 18,053 N	11° 36,848 E
Altitude (m a.s.l.)	149	
Trunk	Monocormic	
Number of trunks	1	
Height (cm)	675	
Average diameter of canopy (cm)	628	
Density of canopy	High	
Circumference of trunk at 130 cm from ground (cm)	Trunk 1 Trunk 2 Trunk 3 Trunk 4 Trunk 5 Trunk 6	145
Height of first branch (cm)	Trunk 1 Trunk 2 Trunk 3 Trunk 4 Trunk 5 Trunk 6	150
Diameter of stump (cm)	170	
Canopy attitude	Spreading	
Canopy vigour	Good	
Pruning interventions	Regular	
Phytosanitary conditions	Good	

Figure 1. Example of phytometric card.

Materials and methods

Ancient plants were identified considering trees older than 100 years, interesting characters related to the variety, landscape values, as location inside abbeys, fortresses, natural parks, archaeological sites, or recognized as monumental trees in many municipalities in the province of Bologna. Each ancient tree was censed and characterized by photographical documentation and phytometric description for each plant, while recording geographical coordinates. Phytometric description was composed by 7 biometric parameters (number and circumference of each trunk, height of the tree, maximum diameter of the canopy, first branch height, canopy density, maximum diameter of the stump) and 6 descriptive parameters (location, landscape characteristics, structure and vigour of canopy, pruning interventions, and general phytosanitary conditions). Measures of circumference have been taken for each trunk at a 1.30 m above the ground level, a tape measure has been used to determine the height of the first branch insertion point and stump maximum diameter. Measures of maximum diameter of the canopy and height of the plant have been obtained using a telescopic measuring rod. Structure and vigour of the canopy and pruning interventions have been defined after direct observations of the trees, while in order to classify plants considering phytosanitary conditions have been examined principal diseases caused by insects (*Bactrocera oleae*, *Prays oleae*, *Otiorrhinchus Cribricollis, Saissetia oleae*), by fungus (*Cicliconium oleaginum, Verticillium dhalie*) and

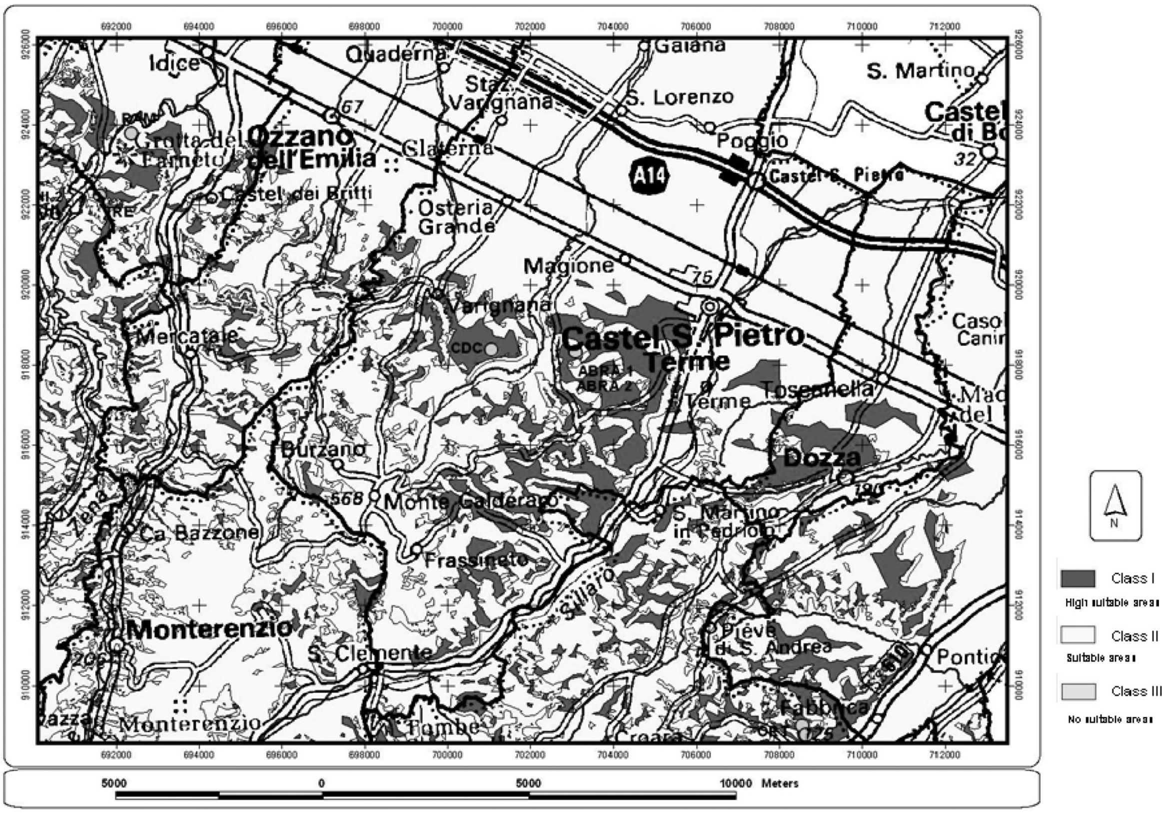

Figure 2. Suitability map for olive trees cultivation (zoom to Castel San Pietro Terme Municipality).

by bacteria (*Pseudomonas savastanoi*). For each olive tree a biometric form was compiled (Fig. 1). All data have been statistically treated using the program SAS version 9.1.3. (SAS Institute Inc.; Cary, NC USA).

Plants have been subdivided in two categories, a first composed by easily recognizable varieties and a second with uncertain genetic identity. Subsequently leaves of unknown olive varieties were collected and submitted to biomolecular analysis using SSR techniques (Simple Sequence Repeat), according to Ganino et al. (2008). Ancient trees locations indicate where pedo-climatic conditions are not limiting for the plant growth, thus secular olive trees were considered as bio-indicator in defining optimal range values of environmental factors when searching for new trees orchard locations. Ancient olive trees have been visualized on thematic maps in order to extract several pedo-climatic characteristics, like temperatures and rainfall trends and soil morphology characteristics, like altitude, soil aspect and slope. In building a map for the identification of new location for olive cultivation, one option, as a first step, is to select locations that are similar to those where secular trees are located. Rainfall was not considered a limiting factor for olive trees cultivation in Bologna, where annual requirements are largely satisfied (Licausi et al. 2008). About temperatures, it has been impossible to characterize the investigated area as historical data series are not available, anyway negative effects related to low temperatures or cool returns were avoided eliminating higher altitudes and valleys as suitable areas for cultivation. Again, some land use categories as protected areas or urban areas, erosion furrows areas where not considered. Using elevation information as digital isolines and points (the last mainly for flatter areas) with a resolution of 5 m and the spatial analyst tool of Arcview 3.2 (ESRI), a Digital Elevation Model (DEM) has been built. The DEM represents the continuous variation of over space reliefs produced by interpolating known elevation values from isolines and points.

Ones DEM is built, it is possible to produce continuous thematic maps of altitude, slope and terrain aspect and thus to derive the altitude (as m a.s.l.), the slope (as degree) and the aspect of the locations where secular trees have been found.

The slope is defined by a plane tangent to the surface as modelled by the DEM, identifying the maximum rate of change, from each DEM cell to its neighbours. The aspect derivation identifies the steepest down-slope direction from each cell to its neighbours in the DEM. The values of the output grid map represent the direction of the aspect, e.g. 0 is true North, a 90 degree aspect is to the East. Cells with 0 slope (flat areas) are assigned an aspect of -1. The eight cardinal directions correspond to the following range of degree values: North (from 0° to 22.5° and from 337.5° to 360°); Northeast (from 22.5° to 67.5°); East (from 67.5° to 112.5°); Southeast (from 112.5° to 157.5°); South (from 157.5° to 202.5°); Southwest (from 202.5° to 247.5°); West (from 247.5° to 292.5°); Northwest (from 292.5° to 337.5°). In particular the aspect and the altitude values of ancient olive trees locations where statistically compared with trees morphology, in order to understand about the landscape effect on tree developments.

Investigated areas have been classified in three classes of suitability for the cultivation: highly suitable areas, suitable areas and not suitable areas. Methodology is explained in details in Di Virgilio and Facini (2007). Briefly each suitability class contains a range values and thresholds for each environmental factor considered important for the identification of the suitability areas. Class I, highly suitable areas: in this class are included all the flat areas with a less than 8.53° slope (15 %), this last was considered as the threshold for the mechanization of the orchard, with field aspect ranging from South-East to South-West and with an altitude ranging from 100 m to 300 m a.s.l. Class II, suitable areas: includes flat areas till a slope of 28° (73%), that is the maximum observed slope among the ancient trees locations, with field aspect from East to West and with an altitude level ranging from 100 m to 400 m a.s.l. For this last class it has been assumed that the slope does not represent a limiting factor for the development of the olive tree, thus using as threshold the maximum value observed for ancient olive tree locations. Both aspects and altitude range has been increased respect to class I, anyway still remaining in the limits of ancient olive tree locations. Class III, non suitable areas: includes altitudes lower than 100 m because in the considered areas of investigation several well established orchards are cultivated on field under 100 m of altitude, while the flat areas may be problematic for water stagnation and low temperatures. Altitudes higher than 400 m may be characterized by inappropriate temperatures, as well as for fields directly exposed to North and river valleys, this last never considered as suitable. Ones defined range values and thresholds for each suitable class, using "map calculator" tool of ArcView 3.2, only areas satisfying defined ranges were selected simultaneously from each environmental factor map (Fig. 2).

Results and discussion

The study considered 30 ancient olive trees found in different municipalities of the Bologna district.

All catalogued trees were selected considering the age older than 100 years. Consequently all the studied plants were included in a growth phase named "senescence". According to Barone and Di Marco (2007), during this phase take place a gradual degenerative process of the structures, the ratio between dry matters of leaves and wood clearly reduces and the production of olives becomes inconstant and decreasing, with a reduction of the average dimensions of fruits (Loussert e Brousse, 1978).

Consequently the morphological, phytosanitary and productive evaluation of a secular plant, must be conducted considering that the actual structure of the tree is the result of the combined activity of environment and agronomical interventions.

Modifications occurred during the growth should have caused radical changes, not only to the morphological structure but also to the genetic factor; in case of plants obtained with grafting technique, after the plants death, the new suckers belong to the variety of the old understock. This explains the largest diffusion of plants used as understock, which are normally used for their attitude in terms of adaptation to

Table 1. Descriptive statistics of plants morphology and of land characters.

	N. of trunks	Tree height (m)	Canopy diameter (m)	Branch diameter (m)	Altitude (m a.s.l.)	Aspect (°)	Slope (°)
min	1.0	4.30	4.17	0.69	100	-1	0
max	19.0	10.00	11.72	4.64	369	257	28
mean	3.5	6.50	6.84	2.23	253	64	11
range	18.0	5.70	7.55	3.95	269	258	28
st error	0.6	0.27	0.34	0.17	14	12	2
SD	3.4	1.47	1.84	0.93	77	63	9

the ground, root development, instead of their productivity ability.

The research interested the province of Bologna, however the study will be extended to the other provinces of Emilia-Romagna. Results of SSR analysis and their comparison with the Italian SSR data-bank, allowed the varietal characterization of ancient olive trees. 25 genotypes did not belong to any known cultivar, while only 5 of the 30 analyzed plants belong to 3 known varieties, which are Orfana (typical cultivar largely diffused in Ravenna district), Leccino (widespread in the north-centre of Italy) and Grappuda (variety scarcely diffused, cultivated exclusively in Forli-Cesena district) (Ganino et al., 2008).

Considering biometric characters of the selected plants, as showed in table 1, resulted that the number of trunks of the 30 catalogued secular trees varies from 1 to 19 with an average of 3.5 trunks; in details, 8 monocormic plants were found, while the other polycormic plants presented a number of trunks that varied from 2 to 7, with except for one monumental accession characterized by 19 trunks. Polycormic secular trees can be considered as the result of an old traumatic event, which should have been caused by a climatic happening, as a sudden decrease of temperature, or by extreme agronomic chooses, the plants were cut from the base and new suckers were generated from it. Therefore the presence of a monocormic secular tree in a specific territory can be considered as clear evidence of the low temperature damage events.

The height of all catalogued trees was found in a range from 4.30 m to 10 m, with an average height of 6.50 meters. The diameter of the canopy has been found in a range from 4.17 m to 11.72 m, with an average of 6.84 m. The smallest stump catalogued, measured a diameter of 0.69 m while the largest stump catalogued showed a 4.64 m diameter (Tab. 1).

Regarding to the orographical structure of the studied area, ancient olive trees were found in a range of altitude from 100 m a.s.l. to 369 m a.s.l., with an average of 253 m a.s.l. Maximum observed slope was 28°, while olive trees in flat areas under 100 m a.s.l. was not observed. Olive trees seem to be able to survive also on steeply soil, but in any case, field with slope values higher than 15% (8.53°) are not suitable for a mechanized management of the orchard. Olive trees have been found on areas with prevalent aspect as from 0° to 257°, while olive trees were not present on fields exposed to North (Tab. 1).

In order to verify the effects of the environment on the morphology of the plants, some of the biometric measures were statistically compared with surface aspect and altitude.

Specifically the aspect has been defined as first limiting factor for the olive trees growth, owing to the cold droughts coming from north-east, which can cause sudden decreases of temperatures. As reference has been taken an event occurred in December 1996 in the eastern part of Emilia – Romagna region. As consequence of a depressionary minimum established between southern Italy and Greece, intense and very cold droughts came from eastern Europe. This situation, preceded from mild temperatures superior to normal, determined, between December 27 and 31, a fast decrease of minimum temperatures, until -12 °C, which persisted for four days, and reached the lowest between December 30 and 31 (Rotondi and Magli, 1998). That event was not an isolated happening, in fact analogous events took also place in 1907, 1929, 1956 e 1985 (Morettini, 1961; Jacoboni, 1985 and Fontanazza, 1989).

In order to evaluate the influence of aspect on olive trees growth, the locations of the 30 selected plants have been classified in two groups: the first group characterized with a field aspects

Table 2. Distribution of mono and polycormic ancient trees (as n and as % on total) respect to the field aspect classes. N-E represents aspect from North to East (from 0° to 90°) considered not suitable for trees cultivation, while E-N represents soils aspects form East to North (from 90° to 360°).

Fields aspect	E-N	N -E	TOT n of trees
n° of trees			
monocormic	6	2	8
polycormic	15	7	22
TOT on aspect	21	9	30
% of trees			
monocormic	20.00	6.67	26.67
polycormic	50.00	23.33	73.33
TOT on aspect	70	30	100

included between North and East, which are supposed to be directly exposed to the north-eastern cold draughts; the second group including the remaining plants locations.

As reported on Table 2, only 9 plants belong to the first group, moreover 7 plants of them showed a polycormic structure. The low presence (6.7%) of monocormic secular trees located in a North-East exposed area confirmed that north-eastern draughts should be considered as one of the first limits for olive trees growth in the province of Bologna.

The effect of altitude on plant morphology has been studied dividing selected plants in two groups, monocormic and polycormic. Inside each group plants were classified as function of the altitude of their locations. The most evident result is that no monocormic secular trees were found above 300 m a.s.l. (Tab. 3*)*. This result has been used to define the classes of suitability for olive trees cultivation, considering the altitude of 300 m as a superior limit for the olive growth in the province of Bologna.

The GIS elaboration of the environmental factors considered for the definition of the suitable lands for olive trees cultivation, identified 3556 ha as suitable, of which 972 ha highly suitable belonging to class I, where olive trees cultivation could be profitable because of suitable land morphology and the possibility of a good mechanization due to low field slopes. Figure 2 reports a particular of the suitable map with a zoom on Castel San Pietro Terme Municipality. Almost 10% of the investigated area did not show limiting factors for the development of the olive trees.

Municipality with the highest percentage of suitable area for cultivation resulted Sasso Marconi, while the one with the highest presence of highly suitable fields was Castel San Pietro Terme, with 160.07 ha (Tab. 4).

It has to be considered as inside each defined suitable area, several local unsuitable conditions inappropriate to the cultivation could be present (urban areas, woods, protected areas, wet areas, etc.), that could be considered when increasing the study resolution at Municipality or even at farm levels. Managing land information with a GIS gives the possibility to have dynamic maps, that means the possibility to change and improve the map reliability and increase details of visualising easily adding for example new factors as limiting for the cultivation. The map was produced at part of Bologna district scale and it wanted to give a general indication of potential areas basing on first determinant factors.

Table 3. Distribution of mono and polycormic ancient trees (as n and as % on total) respect to altitude classes.

Classes of altitude	100 - 198 (m a.s.l.)	199 - 255 (m a.s.l.)	256 - 300 (m a.s.l.)	> 300 (m a.s.l.)	TOT of n° trees
n° of trees					
monocormic	2	1	5	0	8
polycormic (2 - 3)	3	2	1	2	8
polycormic (> 4)	3	4	2	5	14
TOT on altitude	8	7	8	7	30
% of trees					
monocormic	7	3	17	0	27
polycormic (2 - 3)	10	7	3	7	27
polycormic (> 4)	10	38	13	7	17
TOT on altitude	27	23	27	23	100

Table 4. Extension of suitable areas, belonging to class I and class II, for each municipality.

Municipaity	Class I (ha)	Class II (ha)	Tot (ha)	% suitable areas (Class I + II)
Sasso Marconi	108.72	315.53	424.25	23.67
Castello di Serravalle	57.41	99.29	156.69	21.53
Pianoro	108.70	309.20	417.91	20.99
Marzabotto	31.70	216.33	248.02	17.91
Monteveglio	34.90	69.15	104.05	17.19
Casalfiumanese	87.51	167.22	254.73	16.72
Fontanelice	13.35	98.48	111.83	16.45
Monte S. Pietro	61.06	146.19	207.25	14.93
Borgo Tossignano	22.37	45.85	68.22	12.59
Casalecchio di Reno	15.39	24.42	39.81	12.33
Monterenzio	20.66	216.53	237.20	12.11
Vergato	13.45	101.62	115.06	10.33
Castel S. Pietro Terme	160.07	107.23	267.30	9.69
Monzuno	11.16	99.64	110.80	9.17
Dozza	31.72	9.32	41.04	9.12
Grizzana	14.19	113.24	127.43	8.86
Castel del Rio	4.59	79.12	83.71	8.57
S. Lazzaro di Savena	40.14	30.52	70.66	8.51
Ozzano	29.61	70.49	100.11	8.32
Loiano	0.89	46.63	47.52	4.88
Imola	100.15	68.08	168.23	4.42
Gaggio Montano	0.54	45.08	45.62	4.18
Savigno	3.41	34.83	38.24	3.75
Castel di Casio	-	21.52	21.52	2.45
Castiglione dei Pepoli	-	11.90	11.90	0.97
S. Benedetto Val di Sam	-	11.70	11.70	0.94
Porretta Terme	-	5.81	5.81	0.92
Camugnano	-	15.67	15.67	0.87
Castel d'Aiano	-	3.40	3.40	0.40
Granaglione	-	0.45	0.45	0.06
Monghidoro	-	0.40	0.40	0.04
Lizzano in Belvedere	-	0.01	0.01	0.00

Conclusion

The choice to protect autochthonous cultivars and their reintroduction with new orchards in the hilly zones of Bologna, allows to valorize final productions and to improve the relationship between olive oil and territory. These interventions mean also to contribute in terms of landscape protection and improvement of the geological structure of the hilly areas, which otherwise will run towards serious events of soil erosion.

This study demonstrates the correlation between secular olive trees and their locations, characterized by similar values of aspect and altitude. Thus these values can be considered as optimal for the olive growth in Bologna and therefore used as a drive for a sustainable spreading of olive trees cultivation.

On the base of the relation among monocormic trees presence against surface morphology, specifically for Bologna province, the northeastern draughts resulted as one of the first limits for olive trees growth, while 300 m soil altitude as a superior limit for olive growth. Almost 10% of the investigated area did not show limiting factors for the development of the olive trees, resulting in a good potential for olive trees development for this area.

The produced suitable map, despite the fact that give an indication of potential areas for olive trees cultivation basing just on first determinant factors, represents an important planning tool easily implementable as a part of a GIS project.

This research interested the province of Bologna, however the study will be extended to the other provinces of Emilia-Romagna, where olive trees cultivation is widely diffused.

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