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MULTI-CRITERIA APPROACH FOR LAND SUITABILITY ASSESSMENT OF HOP CULTIVATION IN ITALY

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ABSTRACT

Land suitability assessment is an efficient method used to give indication about a sustainable land use planning. A decision support system based on multi-criteria analysis was used to evaluate land suitability for hop cultivation in four regions of Central and Southern Italy (Abruzzo, Basilicata, Latium and Molise). Seven environmental parameters (altitude, average minimum temperature between November and February, average maximum summer temperature, spring rainfall, summer rainfall, organic carbon content, and environmental sensitive area index) were considered to generate the suitability index. The analysis revealed that Abruzzo and Latium are more suitable for hop cultivation than Basilicata and Molise: only 7% municipalities for Latium and 11 % for Abruzzo were unsuitable for this cultivation. On the other hand, more than 50 % of Basilicata and 33 % of Molise resulted not suitable. Results provided an effective tool to evaluate physical land suitability and, consequently, to choose the adoption of a proper management and farming systems, which could allow the hop cultivation even in not potentially suitable areas.

Keywords: hop, land suitability assessment, multi-criteria evaluation

1. INTRODUCTION

Hop (*Humulus lupulus* L.) is an herbaceous perennial plant, belonging to the Cannabaceae family that remains productive past 20 years of maturity. It is most likely native to China, but hops are now grown in many moist temperate areas at latitudes from 35 to 55 degrees in both the northern and southern hemispheres up to 1,000-1,200 metres in elevation (Mahaffee and Pethybridge, 2009; Eby, 2011). This includes the Pacific Northwest of the USA, European countries such as Germany, Poland, Czech Republic, Slovenia, and China, the Southeast Australian and New Zealand markets (Carbone et al., 2017). These latitudes allow having long seasonal day lengths necessary to ensure good vegetative growth and canopy development, and to produce adequate inflorescence (or cone) yields.

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The hop plant consists of a perennial rootstock ("crown") of rhizomes below ground, annual climbing bines above ground, which provide the canopy and photosynthetic capacity to support flowering, and flowers. Hop plant is dioecious, which means that male and female flowers grow on separate plants. The female flower cones contain the commercial value of the plant because they are commonly used as raw material in the brewing process. In fact, cones contain the lupulin glands that produce important phytochemical compounds (α- and β-acids, essential oils, and polyphenols) which contribute to determine the bitterness, flavour, aroma, and antimicrobial properties of beer (Benitez et al., 1997). They are also used for medicinal purposes as sedatives, tonics and for soothing and calming effects on the body and minds (Zanoli and Zavatti, 2008; Olsovska et al., 2016). On the contrary, male plants are generally used by breeders to hybridise and develop new varieties.

Over the last years, the global hop demand has strongly increased in part to the rising popularity of craft beer. According to an annual report from German-based hop trader the Barth-Haas Group (The Barth report 2017/18), at the end of 2017, hop acreage increased 58,739 ha and 118,401,000 tons of hops were produced. This phenomenon has also affected Italy, mainly due to consumers' increasing interest in craft-style beers made from local microbreweries. The number of craft breweries in Italy has increased, from about 40 in 2005 to around 1,400 at the end of 2018 (Amoriello, 2019). Unlike traditional breweries, small-scale breweries have become a big hit with consumers owing to their local flair, variety of style offerings and ingredients quality, different in terms of tastes and flavours. One way to enhance the traditional style of craft beer is to remain rooted in tradition, using raw materials (barley and hops) from local territory. As a result, new opportunities are opening up in the cultivation and processing of hops in Italy. In fact, although hops are largely imported from Germany, United Kingdom, Belgium, and USA (Carbone et al., 2017), several farmers have begun cultivating international hop varieties in different Italian regions. According a survey conducted within a national research project, named LUPPOLO.IT, the current Italian hop-growing area is estimated to be more than 56 hectares at the end of 2018 and it will significantly increase in the near future (Amoriello, 2019).

However, hops require specific pedo-climatic conditions and plants cannot grow everywhere. Unfortunately, despite the high adaptability of the plant to different environmental conditions, no research has been directed toward the suitability assessment for hop cultivation in Italy, although the farmers strongly demand on it. At this regard, the aim of this study was to develop a methodology using decision support tools, such as the multi-criteria evaluation (MCE), to model and map the current suitability for hops cultivation. This study focused on four regions of central and southern Italy.

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2. MATERIALS AND METHODS

2.1 Study area

The study was carried out in four Italian regions (Fig. 1): Latium (latitude 41°13’ to 42°50’ N, longitude 11°27′ to 13°57′ E), Abruzzo (latitude 41°43’ to 42°54’ N, longitude 13°02′ to 14°47′ E) and Molise (latitude 41°23’ to 42°04’ N, longitude 13°57′ to 15°08′ E) are located in Central Italy with a land area of 17.232 km^2, 10.794 km^2 and 4.461 km^2, respectively, whereas Basilicata (latitude 39°56’ to 41°08’ N, longitude 15°21′ to 16°51′ E) is located in the southern part of Italy with a land area of 9.995 km^2. Because of its geographical position, Central and Southern Italy is characterized by a variety of climate regimes ranging from the Mediterranean dry climate to wet continental regimes.

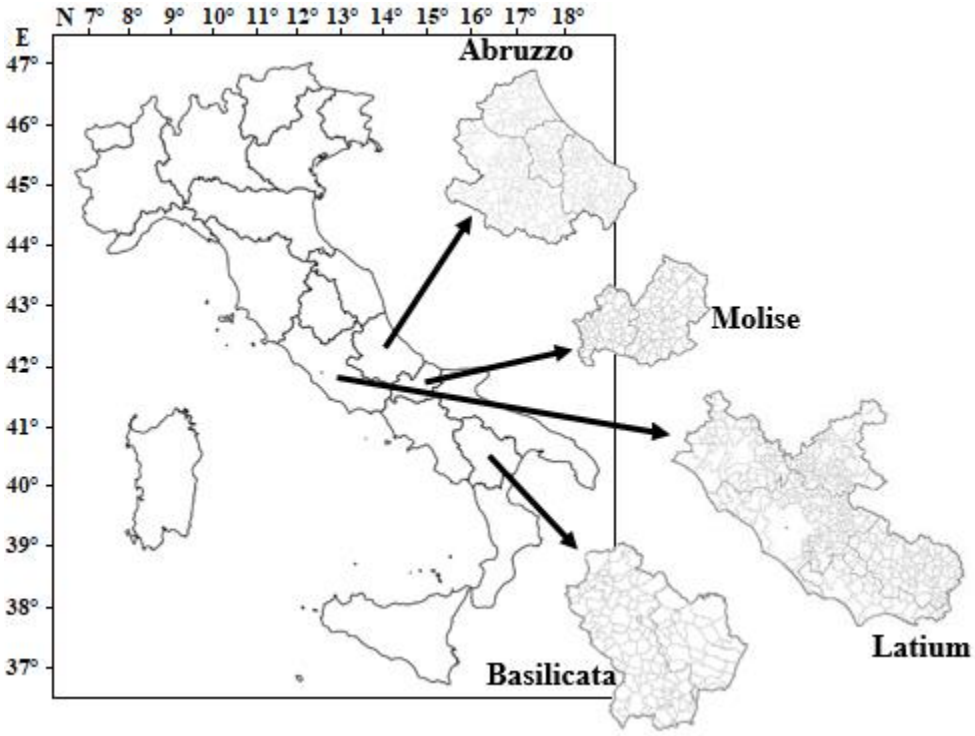

Fig. 1: Location of the four study regions (Abruzzo, Latium, Molise and Basilicata).

Abruzzo stretches from Apennine Mountains (the highest peak is at 2.913 m) to the Adriatic Sea. The climate of coastal areas is characterized by a Mediterranean climate with hot dry summers and mild and rainy winters; whereas the mountainous areas have a wet continental regime. The average annual temperature is 12.8 ℃ and average annual precipitation is approximately 800 mm. The amount of precipitation generally increases with elevation.

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Being Molise bordered to Abruzzo to the north and its geography similar to Abruzzo, the climate is close to those of Abruzzo. The average annual temperature is 13.7 ℃ and average annual precipitation is approximately 715 mm.

Latium is manly characterized by flat areas and small mountainous areas only in the most eastern and southern districts. The climate is Mediterranean with hot dry summers and mild winters in the Tyrrhenian coastal zones; the inland areas are rainier especially in the winter and spring period. The average annual temperature is 14.8 ℃ and average annual precipitation is approximately 840 mm.

At last, about 50 % of Basilicata areas is covered by mountains. The remaining areas are hilly which decline to coastal plains on the Ionian Sea at South-East and on the Tyrrhenian Sea at South-West. The climate is Mediterranean along the coastal zones and continental in those mountainous. The average annual temperature is 14.1 ℃ and average annual precipitation is approximately 710 mm.

2.2 Agronomic characteristics of hop plant

Hop plant can grow in a wide variety of climates, including semiarid, maritime, humid continental, and sub-tropical regions, with different cultivars being more adapted to different climatic conditions. Besides, the plant requires winter temperatures below 5-6 ℃ for 1 to 2 months, assured only at latitudes above 35 degrees, to avoid a weak and erratic spring growth, negatively influencing the uniformity of flowering, yield and cone maturity (Williams et al., 1961). Furthermore, hop crowns are able to survive temperatures of –25℃ or lower when insulated by snow or soil (Beatson et al., 2009). Then, hop plants enjoy 120 frost free days and hot summer days, but temperatures must not exceed 35-40 ℃ because high temperatures and droughts can cause the cones to fall (Biendl et al., 2014). Hops require a large amount of water during the growing seasons to optimize yield and quality. In the northern hemisphere, sufficient rainfall consists of almost 100 mm/m^2 each month (Biendl et al., 2014), for a total of 700-800 mm of water required from spring until shortly before harvest (Beatson et al., 2009; Turner et al., 2011). In growing areas with moderate or irregular distribution of rainfall, an appropriate management of irrigation systems are essential for maintaining adequate soil moisture (Trnka et al., 2008; Hlavinka et al., 2009).

For the northern hemisphere, the growing season goes from March to the end of summer, depending on cultivar and climate conditions (Biendl et al., 2014). Hops emerge in early spring and grow to a height of 5 – 7 meters on poles or under a trellis system (Eby, 2011). Flowering starts in late June or early July. The cones mature for picking between August and September.

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Hops grow successfully on many soil types from light sandy soils to clay (Dodds, 2017), but optimum soil conditions are nutrient-rich, light, deep sandy or gravelly, well-drained loams, well supplied with moisture, but free of waterlogging. Soil pH is also a very important parameter because it can significantly affect plant nutrient availability. Hops prefer soils with a pH range of 6.0 to 6.5; however, they also grow on soils with pH from 4.8 to 8.0. In the case of overly acidic or basic soils, it is necessary to adjust them before planting, to avoid elemental deficiencies or toxicity (Biendl et al., 2014). It is necessary to clarify that plant response to such best pedo-climatic indication is partly determined by genetics. It means that some hop genotypes will best adapt and produce commercially where others might not.

2.3 Data and variables

According to the agronomic characteristics mentioned above, some environmental physical parameters (including climate, landscape and soil) were chosen to build a potential land suitability index (SI) for hop cultivation. To guarantee the representativeness of hop plant characteristics and homogeneity of available data at municipality level, the following one constraint and six parameters were considered: altitude, average minimum temperature between November and February, average maximum summer temperature, spring rainfall, summer rainfall, organic carbon content in the first 30 cm of soil, environmental sensitive area index. The climatic data (1981-2010) were obtained from the Italian Atlas of Climate and Climate Change (Esposito et al., 2015) and from meteorological stations, while the data of environmental sensitive area index (ESAI) and of the organic carbon content (0-30 cm) from ISPRA (2016). The composite ESAI index is a geometric mean of several indicators related to the soil (bedrock, texture, depth and slope), to the climate (aridity index defined by the ratio between average annual precipitation and average annual potential evapotranspiration) and to the vegetation (protection from erosion, resistance to aridity, vegetation cover and fire risk) (ISPRA, 2016).

2.4 Multi-criteria evaluation and land suitability assessment

The land suitability assessment (LSA) of hop cultivation in Italy was carried out following the FAO guidelines approach for land evaluation (FAO, 1976). It is a useful method to quantify the convergence of land characteristics, based on climate, landscape and soil properties, with crop requirements. LSA is classified in orders and classes. The orders are divided into suitable (S) and not suitable (N). Then, the “suitable” order is further divided into three classes, which reflect degrees of decreasing suitability: highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) classes.

The suitability is performed using a fuzzy multiple criteria evaluation (Corona et al., 2008). In MCE, all environmental input factors are transformed into scores, ranging from 0 (no member)

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to 1 (member), by fuzzy membership functions, and aggregated through a decision rule to generate the suitability index (SI). Fuzzy membership functions for each parameter were drawn in figure 2. The Weighted linear combination (WLC) was the aggregation rule used in this study. The weight factor was established according to the degree of importance of environmental characteristics on hop plant performance. Then, the suitability index is obtained by multiplying the weight matrix with membership values matrix and possible constraints, as follows:

$$SI = \sum_{i=1}^{n} w_i x_i \prod_j c_j$$

where n = number of factors; w_i = weight of factor i, x_i = membership grade for factor i; c_j = environmental constraints in Boolean form (0/1). In this study the only considered constraint was the altitude.

At last, the suitability index at municipality level was efficiently represented by suitability maps for the four considered regions.

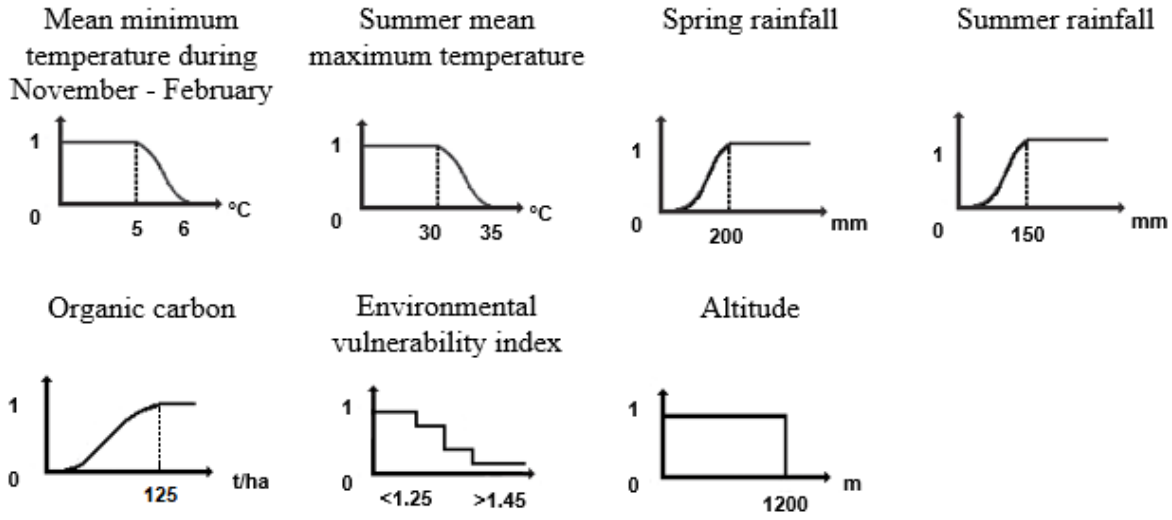

Fig. 2: Fuzzy membership functions for each considered environmental parameters.

3. RESULTS AND DISCUSSION

The potential suitability maps for hop cultivation are reported in figure 3, whereas the percentage of suitable municipalities for hop cultivation in the four study regions in table 1.

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Table 1: Percentage of suitable municipalities for hop cultivation in the four study areas: Latium, Abruzzo, Basilicata and Molise.

	Abruzzo	Molise	Lazio	Basilicata
Highly suitable (S1)	48	21	4	0
Moderately suitable (S2)	7	21	32	2
Marginally suitable (S3)	34	25	57	44
Not suitable (N)	11	33	7	54

The regions of Central Italy (Latium, Abruzzo and, to a lesser extent, Molise) resulted more suitable than Basilicata. Specifically, the Apennine areas showed high suitability for hop cultivation, whereas less suitability resulted for coastal areas, characterized by less favourable pedological and climatic conditions. Abruzzo showed high suitability in 48 % of the Municipalities, except for the areas whose altitude exceeded 1200 m. Even the Municipalities of the Lazio region were found to be suitable, although, compared to Abruzzo, most of them (57 %) showed low suitability. These areas are characterized by high maximum temperature (also more than 40 °C) and scarcity or absence of precipitation during summer. These unfavourable features also affect many coastal and southern areas of Molise. Basilicata seemed to have a lower (44 %) or no (54 %) suitability, especially in the eastern areas of the region characterized by a very high environmental sensitive area index.

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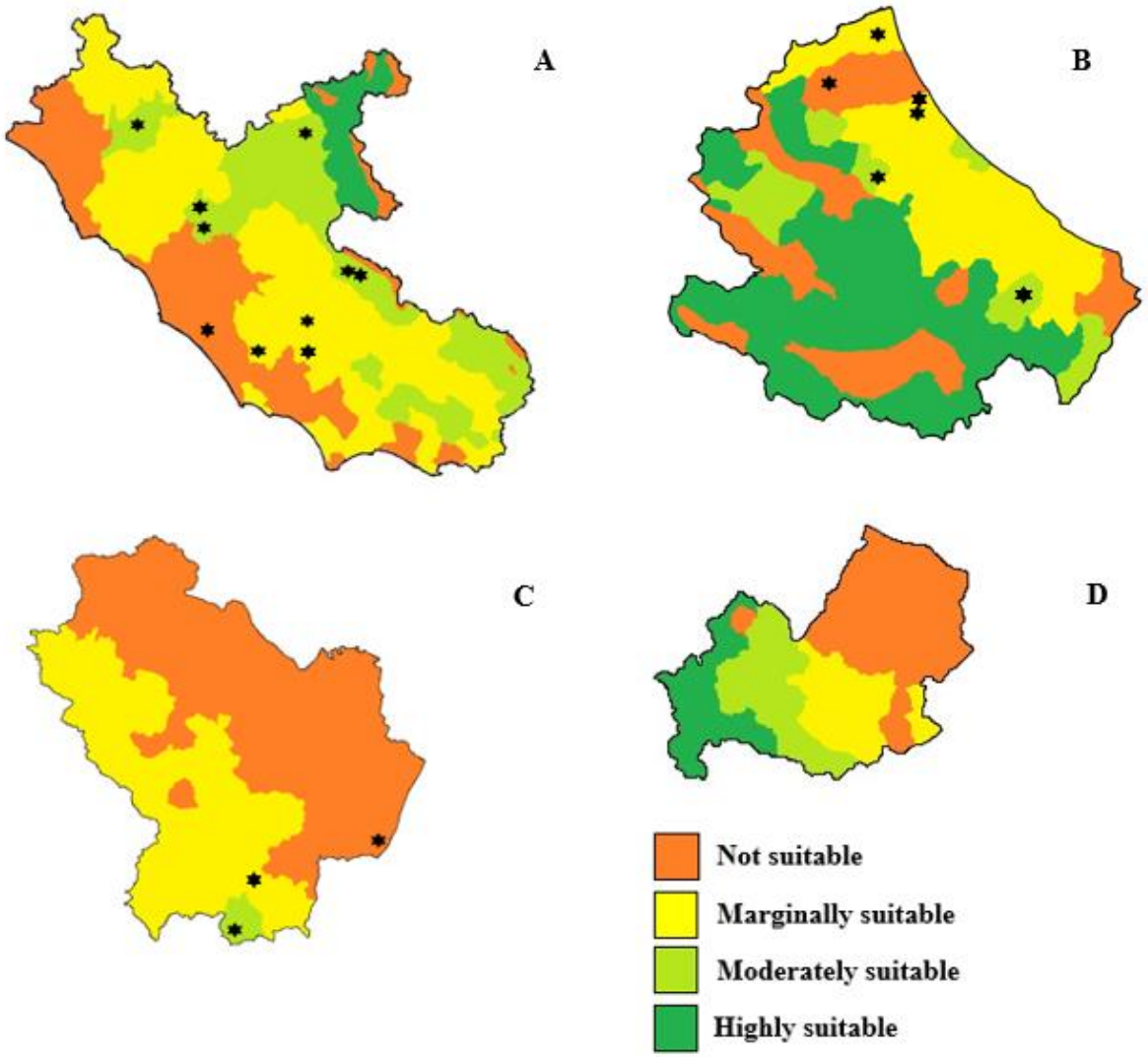

Fig. 3: Land suitability map for hop cultivation in the four study areas: Latium (A), Abruzzo (B), Basilicata (C) and Molise (D). The ongoing hop farms are reported with a star.

However, as shown by the comparison with the ongoing hop farms (some of these lying on not suitable areas), a precise field management and variety choice can allow a satisfactory hop production, in terms of yield and quality, even in potentially unsuitable areas. For example, in areas with high temperatures and low rainfall it is not recommended to plant German hop cultivars, rather cultivars of American origin are preferred. Moreover, in areas with soils with high pH, in addition to acting with appropriate fertilizations, it is possible to choose cultivars, such as Cascade or Chinook, more suitable for alkaline soils. On the contrary, in areas with

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acidic or naturally low in phosphorus soils it is necessary to incorporate amendments such as lime and superphosphate before planting (Dodds, 2017). At last, the scarcity of water can be managed using a drip irrigation system.

4. CONCLUSION

Within the LUPPOLO.IT project, a model to assess the suitability for potential hop cultivation in Italy was developed. The geographical location and the pedological and climatic conditions of Italy are generally favourable to the development of hop supply chain, as evidenced by the numerous ongoing hop farms. However, this development requires different strategies depending on many strongly interrelated environmental factors. In fact, new growers have to evaluate pedo-climatic features and to choose the appropriate varieties and management on their own site before undertaking any large-scale investment. The proposed model could be seen as a powerful tool for solving hop planning problems. It could help farmers who want to approach this cultivation, providing territorial information for planning systems for hop production and supporting them in selection of the most suitable site for the hop plant location and management.

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REFERENCES

[1] T. Amoriello, “Indagine sulla filiera brassicola: evoluzione e prospettive per lo sviluppo del settore”, in *Criticità e opportunità per lo sviluppo sostenibile di una filiera del luppolo italiano*, 2019, Roma, Italia, pp. 13-23 (ISBN 978-88-3385-011-5).

[2] Barth-Haas Group, “The Barth Report Hops 2017/2018”, 2018, Joh. Barth & Sohn GmbH & Co KG, Nuremberg.

[3] R. Beatson, S. Kenny, S. Pethybridge and D. Gent, “Hop production”, in W. Mahaffee et al. (ed.) *Compendium of hop diseases and pests*, 2009, The American Phytopathological Society, St. Paul, MN.

[4] J. L. Benitez, A. Forster, D. De Keukeleire, M. Moir, F.R. Sharpe, L. C. Verhagen and K. T. Westwood, “Hops and hop products”, 1997, Carl-Verlag, Germany.

[5] M. Biendl, B. Engelhard, A. Forster, A. Gahr, A. Lutz, W. Mitter, R. Schmidt, C. Schonberger, “Hops. Their cultivation, Composition and Usage”, 2014, Fachverlag Hans Carl GmbH, Nuremberg, Germany.

[6] K. Carbone, T. Amoriello, M. Pagano, G. Sperandio, A. Assirelli, S. Tarangioli and A.

Monteleone, "Prospettive interessanti per il luppolo italiano", *L'informatore agrario,* 2017, n. 20, p.49-51.

[7] P. Corona, R. Salvati, A. Barbati and G. Chirici, "Land Suitability for Short Rotation Coppices Assessed through Fuzzy Membership Functions", in *Patterns and Processes in Forest Landscapes*, 2008, pp. 191-211.

[8] K. Dodds, "Hops a guide for new growers", 2017, Development Officer Temperate Fruits, NSW DPI, Tumut. (ISBN 978 1 76058 007 0).

[9] S. Eby, "Hops, Humulus lupulus. An investigation of agricultural practices and how producers are linked with business networks and consumers", 2011, Nuffield Canada.

[10] S. Esposito, M. C. Beltrano, F. De Natale, E. Di Giuseppe, L. Iafrate, A. Libertà, B. Parisse and M. Scaglione, "Atlante italiano del clima e dei cambiamenti climatici", 2015, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per la climatologia e la meteorologia applicate all'agricoltura. Roma (ISBN 978-88-97081-80-7).

[11] P. Hlavinka, M. Trnka, D. Semeradova, M. Dubrovsky, Z. Zalud and M. Mozny, "Effect of drought on yield variability of key crops in Czech Republic", *Agric. For. Meteor*., 2009, n. 149, pp. 431-442.

[12] ISPRA, "Suolo e territorio", in *Annuario dei Dati Ambientali*, 2016, (ISBN 978-88-448-0796-2).

[13] W. Mahaffee and S. Pethybridge, "The genus Humulus", in W. Mahaffee et al. (ed.) *Compendium of hop diseases and pests*, 2009, The American Phytopathological Society, St. Paul, MN.

[14] J. Olsovska, V. Bostikova, M. Dusek, V. Jandovska, K. Bogdanova, P. Cermak, P. Bostik, A. Mikyska and M. Kolar, "*Humulus lupulus* L. (hops) – A valuable source of compounds with bioactive effects for future therapies", *Mil. Med. Sci. Lett*., 2016, n. 85(1), pp. 19-30.

[15] M. Trnka, J. Kyselý, M. Možný and M. Dubrovský, "Changes in central-European soil-moisture availability and circulation patterns in 1881-2005", *Int. J. Climatol*., 2008, n. 29, pp. 655-672.

[16] S.F. Turner, C.A. Benedict, H. Darby, L.A. Hoagland, P. Simonson, J.R. Sirrine and K.M. Murphy, "Challenges and Opportunities for Organic Hop Production in the United States", *Agronomy Journal*., 2011, n. 103(6), pp. 1645-1654.

[17] I.H. Williams, J.B. Roberts and J.R. Coley-Smith, "Studies of the dormant phase of the hop (Humulus lupulus L.) Annual report for 1960", 1961, Department of Hop Research, Wye College England, pp. 48–58.

[18] P. Zanoli and M. Zavatti, "Pharmacognostic and pharmacological profile of *Humulus lupulus* L.", *Journal of Ethnopharmacology*, 2008, n. 116, pp. 383-396.

