https://doi.org/10.17221/467/2020-AGRICECON

Moving toward the north? The spatial shift of olive groves in Italy

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Citation: Gambella F., Bianchini L., Cecchini M., Egidi G., Ferrara A., Salvati L., Colantoni A., Morea D. (2021): Moving toward the north? The spatial shift of olive groves in Italy. Agric. Econ. – Czech, 67: 129–135.

Abstract: Southern Europe is becoming a hotspot for climate change. Appropriate mechanisation is necessary for reducing soil compacting in such contexts. The olive tree distribution – a typical Mediterranean crop – showed a well-defined latitude gradient with progressive decline moving towards the north. Climate change, however, has supposed to cause a significant shift towards the north in the geographical range of olive trees. Our study analyses the spatial distribution of the olive tree area in Italy, a region within the species' ecological range apart from the Northern region, which is now becoming progressively specialised in this crop because of local warming. Results indicate that olive cultivated area increased in Northern Italy, especially in flat districts and upland areas, while decreasing (more or less rapidly) in central and southern Italy because of land abandonment.

Keywords: agriculture; climate variations; landscape; mechanisation; Northern Italy; socio-economic system

Climate change is a pivotal issue with socio-economic, cultural, and political implications (Conacher and Sala 1998; Sivakumar 2007; Helldén and Tottrup 2008). Rising temperatures and declining rainfalls lead to frequent and severe drought, soil aridity, and water shortage in affluent countries and emerging economies with negative consequences, e.g. in the agricultural sector (Sivakumar 2007). When associated with land mismanagement, climate regimes drive land-use transformations impacting vegetation cover and soil quality (Maracchi et al. 2005; Moriondo et al. 2006; Lorent et al. 2008; Romm 2011). Given the millenary anthropogenic pressure characterising the Mediterranean region (Antrop 2000, 2004; Garcia Latorre et al. 2001; Symeonakis et al. 2007), sustainable land management should assess long-term and short-term climate dynamics (Tanrivermis 2003; Solecki and Oliveri 2004; Briassoulis 2008; Helldén and Tottrup 2008).

Evidence for climate change across the Mediterranean region includes significant variations in air temperature and rainfall (e.g. rising occurrence of seasonal events) and the increasing probability of extreme events (Garcia Latorre et al. 2001; Brunetti et al. 2002; Olesen and Bindi 2002). However, relatively few studies investigated these processes' possible role in land-use change at various spatio-temporal scales (Smiraglia et al. 2016; Colantoni et al. 2017). In this perspective, this article aims to evaluate recent changes in the geographical distribution of a typical Mediterranean crop as a possible response to climate variations (Smiraglia et al. 2016). The olive tree is considered a traditional element of Mediterranean landscapes (King

https://doi.org/10.17221/467/2020-AGRICECON

et al. 1997). Braudel (1985) used the geographical range of this species to define the Mediterranean region's boundaries. This crop represents the most widespread land-use across the whole Mediterranean (Makhzoumi 1997; Loumou and Giourga 2003; Gomez et al. 2009). In such contexts, olive harvesting mechanisation systems are necessary to reduce the production costs and to improve the quality of the olives and subsequently of the oil and reducing the soil compacting, using e.g. precision farming tools (Amirante et al. 2012; Gambella et al. 2013; Colantoni et al. 2017).

Moreover, the use of prototype tractors designed for olive crops and reducing the impact on the soil increases the safety levels of the operator. This study assumes the Northern Mediterranean range of the olive tree migrating progressively towards the north as a response to climate warming (Moriondo et al. 2008). We tested this hypothesis for Italy, a Southern European country with marked climate disparities between a continental regime in northern regions and a semi-arid, Mediterranean regime in southern regions, during three recent decades using statistical data and an extensive literature review and updating a preliminary report covering a shorter time interval (Colantoni et al. 2013). The Italian land was taken as an example of land-use and climate change that could impact the whole Mediterranean region in the coming future.

STUDY AREA

Italy (301 330 km^2) is partitioned into three main geographical regions (north, centre, and south), twenty administrative regions, more than one hundred provinces, and almost 8 100 municipalities (Gigliarano and Chelli 2016). The Italian National Institute of Statistics (ISTAT) defined three elevation belts to delineate land morphology, settlement patterns, and agriculture: lowlands (up to 100 m at sea level), uplands (between 100 m and 600 m at sea level) and mountain areas (Ciommi et al. 2017a). The Italian land was further partitioned into five elevation classes (Figure 1) considering the sea's closenees. When using annual agricultural statistics, the spatial intersect of provinces and elevation classes (287 agricultural districts) was adopted in this study. It provides the most disaggregated analysis' unit in Italy (Chelli et al. 2016; Ciommi et al. 2017b, 2018).

METHODOLOGY

Shifts towards the north in the spatial distribution of the olive tree were studied in Northern Italy, a cold and wet area represents the northern limit of the species (Figure 1). Two data sources of official statistics were adopted to verify the expansion of olive groves in Northern Italy: *i*) agricultural censuses carried out every ten years (last census: 2010; ISTAT) producing data on cultivated land and number of active farms at regional and sub-regional scale, and *ii*) the annual survey of land prices (between 1992 and 2018) undertaken by the Italian National Institute of Agricultural Economics (INEA), providing data on crop surfaces at the agricultural district scale. Both official sources include extensive (and comparable) information on cultivated olive area.

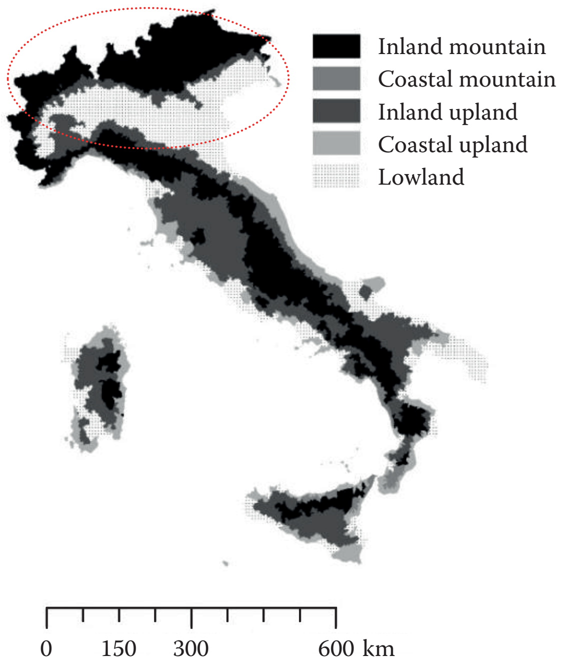

Figure 1. The five elevation belts in Italy

The red dotted line (circle) indicates Northern Italy
Source: Eurostat (2020)

Olive cultivated land at country level and in the three geographical regions (north, centre, and south) was calculated at four years (1992, 2000, 2009, 2018). The number of farms with olive cultivation and the invested olive surface in 2000 and 2010 were calculated in seven administrative regions of Northern Italy (Valle d'Aosta, Piemonte, Lombardia, Trento, Bolzano, Friuli Venezia Giulia, Emilia-Romagna). Per cent change in the number of farms and cultivated land were mapped to graphically illustrate the northern shift in the spatial distribution of olive groves in Italy. A specific focus on Emilia-Romagna, an administrative region in North-Eastern Italy with the highest share of olive cultivated area in total landscape, allowed a refined

https://doi.org/10.17221/467/2020-AGRICECON

analysis of long-term trends in olive cultivation at the northern range limits using data collected in the agricultural censuses of 1982, 1990, 2000, and 2010. Three indicators were adopted in this analysis: *i*) per cent share of farms with olive cultivation in total farms, *ii*) olive cultivated land in total agricultural area and *iii*) average olive cultivated area (ha) per farm.

As far as the analysis of climate regimes, the dataset used in this study contains month precipitation and temperature time series from reference meteorological networks including the Italian Air Force, the National Hydrological Service, and the National Agrometeorological Service, for a total of nearly 3 000 gauging stations covering the whole investigated area. The daily estimated evapotranspiration (ET_0; mm/day), was computed using the Penman-Monteith approach. To describe long-term climate variations, we calculated the average rainfall and the aridity index (*AI*) defined as:

$$AI = P/ET_0 \quad (1)$$

where: AI – aridity index; ET_0 – the reference evapotranspiration; P – the annual rainfalls.

P and ET_0 are expressed in the same measurement unit (mm/day) and are reported as annual averages. The *AI* ranges between 0 and ∞: higher values indicate wetter conditions. The average annual rainfall and *AI* values were produced separately for Northern, Central and Southern Italy along with four time intervals (1951–1980, 1961–1990, 1971–2000, 1981–2010).

RESULTS

Average annual rainfalls decreased more rapidly in Northern Italy than elsewhere in Italy from 1.020 mm in 1951–1980 to 870 mm (–150 mm) between 1981 and 2010. Rainfalls decreased by 0.56% per year in Northern Italy compared with 0.54% and 0.39%, respectively observed in Central and Southern Italy (Table 1). The largest decline in precipitation was observed in the most recent years. The aridity index showed a similar pattern decreasing by 0.68% per year in Northern Italy compared with 0.60% and 0.46%, respectively, recorded in Central and Southern Italy. The aridity index was 1.42 in 1951–1980 and reduced to 1.15 in 1981–2010, converging to the average value observed in Central Italy between 1951 and 1980.

Olive cultivations expanded in Northern Italy in respect of the other parts of Italy. In 1992 olive crop was found in 54 agricultural districts of Northern Italy (out of 107 total districts), become 78 in 2000, 80 in 2009 and 81 in 2018. Therefore, their increase was +49% over the whole period (1992–2018). This growth rate was the highest observed in Italy (compared with 4% and 19% recorded respectively in Central and Southern Italy over the same time interval) and indicated a diffused expansion of olive crop, especially in the Po plain's lowland districts (Table 2). The olive crop's surface area was relatively low (0.20% in total investigated area) in Northern Italy while increasing by nearly 1% during 1992–2018, which is a particularly high value for a traditionally non-suitable crop (Figure 2). Notably, olive crop surface decreased by 0.9% in both Central and Southern Italy during the same period.

During the last inter-census period (2000–2010), the number of farms with olive cultivations in non-Mediterranean, Northern Italian regions increased rapidly, especially in Piedmont (+391 farms) and Friuli-Venezia-Giulia (+256 farms) despite the cumulated number of farms decreased significantly throughout Northern Italy (Table 3). Farms with olive cultivations increased from 2.5% to 3.4% in Lombardy and from 3.5% to 5.0% in Trento province. Olive groves increased even more evidently in Emilia-Romagna (+1.017 ha), covering 0.23% of the total regional area in 2000 and 0.35%

Table 1. Climate indicators by time interval and macro-region in Italy

Area	1951–1980	1961–1990	1971–2000	1981–2010
Average annual rainfall (mm/day)				
North	1 019	975	919	865
Centre	974	927	856	833
South	735	711	665	658
Average annual aridity index				
North	1.42	1.37	1.27	1.16
Centre	1.11	1.06	0.98	0.93
South	0.72	0.70	0.65	0.63

Source: Crea (2020)

https://doi.org/10.17221/467/2020-AGRICECON

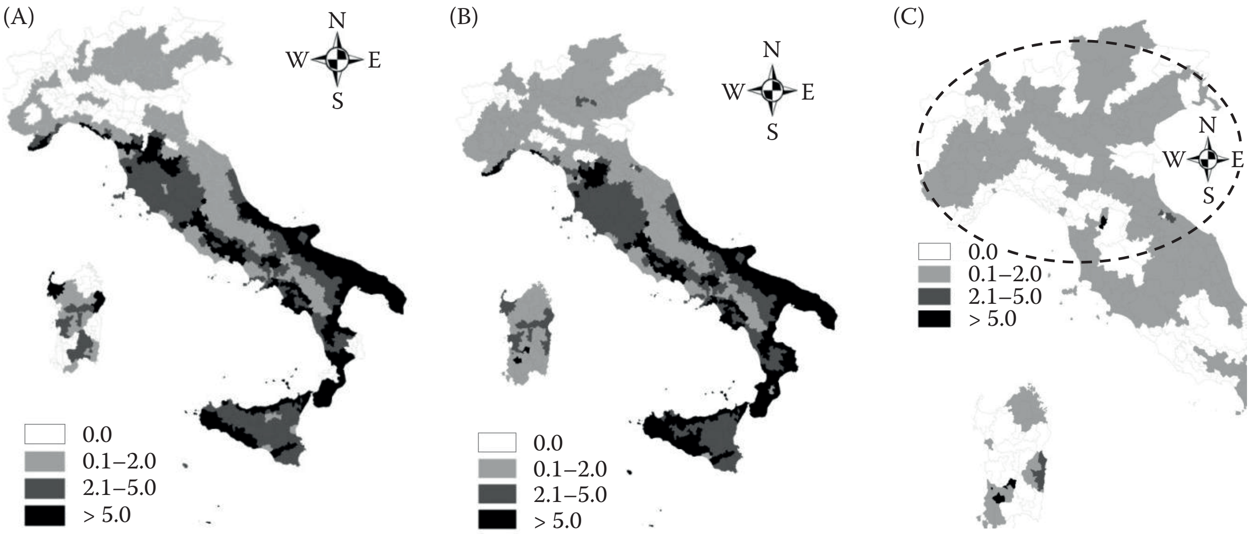

Figure 2. Percent surface area of cultivated olive tree on total district area by agricultural districts and year in Italy; (A) 1992 (%), (B) 2009 (%), (C) change over time (%), Northern Italy

Source: Sistan (2020)

in 2010. Considering aggregate data collected at the national censuses of agriculture from 1982 to 2010, a focus on Emilia-Romagna (the Northern Italian region with the highest percentage of the olive cultivated area) indicates that the percentage of farms with olive cultivation increased continuously from 1982 (2.0%)

Table 2. Olive tree cultivated area in Italy by year and geographical region

Region	1992		2000		2009		2018	
	N	%	*N*	%	*N*	%	*N*	%
North	54	0.18	78	0.19	80	0.19	81	0.20
Centre	53	3.47	55	3.68	55	3.44	55	3.39
South	103	6.65	123	6.80	123	6.59	123	6.47
Italy	210	3.46	256	3.57	258	3.43	259	3.31

N – number of agricultural districts; % – total surface area on total district area
Source: Sistan (2020)

Table 3. Farms practicing olive cultivation in seven northern Italian regions in 2000 and 2010

Region	Number of farms			% on total farms		Olive tree surface (ha)			% on total UAA	
	2010	2000	absolute change	2010	2000	2010	2000	absolute change	2010	2000
Piemonte	454	63	391	0.7	0.1	303	47	256	0.03	0.00
Valle d'Aosta	21	0	21	0.6	0.0	10	0	10	0.02	0.00
Lombardia	1 798	1 770	28	3.4	2.5	1 810	1 317	493	0.18	0.13
Bolzano	5	2	3	0.0	0.0	10	2	8	0.00	0.00
Trento	818	991	–173	5.0	3.5	366	361	5	0.27	0.25
Friuli Venezia Giulia	506	250	256	2.3	0.8	313	122	190	0.15	0.05
Emilia-Romagna	4 826	5 069	–243	6.7	4.8	3 661	2 644	1 017	0.35	0.23

UAA – utilized agricultural area; the data used are from 2010, because the agricultural censuses is carried out every ten years (last census: 2010; ISTAT)
Source: Eurostat (2020)

https://doi.org/10.17221/467/2020-AGRICECON

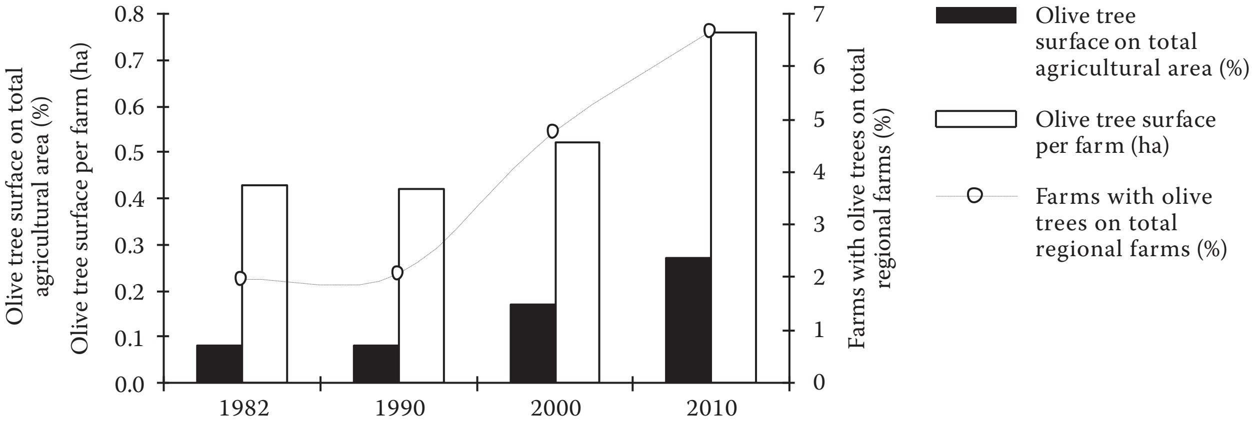

Figure 3. Long-term trends in farms practicing the olive cultivation in Emilia-Romagna by year

The data used are from 2010, because the agricultural censuses is carried out every ten years (last census: 2010; ISTAT)
Source: Authors' elaboration

to 2010 (6.6%). A similar trend was observed in the cultivated area (0.1% and 0.3% in total agricultural surface in 1982 and 2010, respectively). The olive cultivated area per farm increased from 0.43 ha in 1982 to 0.76 ha in 2010 (Figure 3).

DISCUSSION

Associating landscape transformations with climate change is certainly appropriate. But climate change is not the only actor behind the land-use change. Drought and aridity are certainly parts of a more fragile landscape: these are necessary conditions but not strictly sufficient. Interactions between the different agents that impact on landscape and bio-physical agents (as climate, aridity, global warming, water scarcity, fires, overgrazing, and more generally the increase in the overall anthropogenic pressure on the territory) are basic factors, along with the increase in population density, infrastructures, and land consumption. What is important when researching rural landscapes, is the intrinsic focus on the triggering forces and the economic, social, ecological consequences. Complex problems involving socio-economic and ecological issues justify the use of multi-disciplinary, geographical approaches (Slaymaker 2001; Fussel and Klein 2006; Brunori and Rossi 2007). With this perspective in mind, our study provides empirical evidence on the intrinsic shift towards the north in the olive tree's geographical range in Northern Italy, in parallel with intense climate variations toward aridity. Earlier studies have identified Northern Italy as a significant climate hotspot in Southern Europe regarding water shortage and climate aridity (Brunetti et al. 2002, 2004). As a crop typically adapted to poor soils and dry Mediterranean climate, the olive tree has been increasingly cultivated in dry marginal, upland and mountainous areas at the northern Italian range during 1982–2010. Olive's cultivation has also spread in fertile agriculturally-devoted lowland along the Po River, benefiting from the milder temperatures during winter and drier conditions during spring and summer, typical of Emilia-Romagna region, just to provide an example.

The continuous expansion of olive groves in Northern Italy is (directly or indirectly) associated with inherent climate variations observed in Italy. It can be regarded as a proxy of long-term soil aridity and severe drought episodes, in turn delineating a possible adaptation of farmers to climate change (Kelly and Adger 2000). Further efforts are needed to clarify the cost-benefits of introducing a rustic and low-income crop like olive tree in potentially fertile and high-value added land of Northern Italy. In these regards, it is worth mentioning how the olive's cultivated area per farm increases over time in Northern Italy in parallel with a significant decrease in the number of active farms and the total cultivated land. Assessing short-term trends in olive's cultivated area is also important in the light of the sustainable use of land capital. These transformations could have specific impacts (both positive and negative) on the socio-economic system and the environmental characteristics of the region (Briassoulis 2008), and should be monitored in-depth from both the ecological and social points of view (Smit 1994). The negative implications of this scenario could be reduced by applying sustainable land management strategies.

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Moreover, the non-negligible implications of such scenario concern several aspects of crop mechanisation. Different orographic conditions have a negative impact on use of machines in collection yards, making in some cases difficult or impossible to introduce intensive farming methods or super-intensive practices if not, indeed, access with self-propelled, shaker-interceptors machines or by assembling an agricultural tractor. In these cases the only possible form of mechanisation result that given by the mechanical shakers employed by operators on the ground, with inevitable increases in production costs and the intrinsic reduction of crop productivity. In order to reduce the impact on the soil and on the crops, the application of facilitating machines on tracked mini-trasponters, which distribute the weight of the machine evenly on the ground, is being evaluated.

Concerning latent changes in rural landscapes, like the olive groves' shift toward the north in Mediterranean countries, we need tools that allow us to study such processes synergistically over both space and time. We need to have data not only in the present, but also in the past. In this way, it will have the possibility of building short and medium term scenarios and forecasts. Remote sensing, geographical information systems and statistical applications allow us to make increasingly updated and precise landscape change maps. We also need qualitative research: historical images and photographs of landscapes are important to know the state of rural landscapes in the past, which can be compared with recent photographs to see any eventual process of soil degradation, vegetation and rural settlements on-site.

CONCLUSION

The use of the olive tree as a bio-climatic indicator has been progressively consolidated in environmental studies. Although the olive tree's spatial distribution in Europe was characterised by well-defined latitude gradient progressively reducing in density towards northern regions, evidence on a progressive shift towards the north in the geographical range of this crop has been increasingly documented. These results demonstrate how persistent climate variations associated with land mismanagement may drive changes in land-use impacting vegetation cover and land quality and even transforming (e.g. simplifying or fragmenting) traditional landscapes. Rural planning should cope with the feedback relationship between climate changes and land-use changes at various geographical scales. Landscape transformation can be more effectively governed by multi-level and multi-disciplinary policies incorporating short-term and long-term agronomic targets including mechanisation. In such a perspective, the investigated region may be considered as a laboratory of land-use/climate interactions representing an intrinsic challenge for sustainable land management.

REFERENCES

Amirante P., Tamborrino A., Leone A. (2012): Olive harvesting mechanization systems in high density orchards. Acta Horticulture, 949: 351–358.

Antrop M. (2000): Changing patterns in the urbanised countryside of Western Europe. Landscape Ecology, 15: 257–270.

Antrop M. (2004): Landscape change and the urbanisation process in Europe. Landscape and Urban Planning, 67: 9–26.

Braudel F. (1985): The Mediterranean (La Méditerrané). Paris, France, Flammarion: 1–223. (in French)

Briassoulis H. (2008): Land-use policy and planning, theorising, and modeling: Lost in translation, found in complexity. Environment and Planning B: Planning and Design, 35: 16–33.

Brunetti M., Buffoni L., Mangianti F., Augeri M., Nanni T. (2004): Temperature, precipitation and extreme events during the last century in Italy. Global and Planetary Change, 40: 141–149.

Brunetti M., Maugeri M., Nanni T., Navarra A. (2002): Droughts and extreme events in regional daily Italian precipitation series. International Journal of Climatology, 22: 543–558.

Brunori G., Rossi A. (2007): Differentiating countryside. Social representations and governance patterns in rural areas with high social density: The case of Chianti, Italy. Journal of Rural Studies, 23: 183–205.

Chelli F.M., Ciommi M., Emili A., Gigliarano C., Taralli S. (2016): Assessing the equitable and sustainable well-being of the Italian provinces. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 24: 39–62.

Ciommi M., Gentili A., Ermini B., Chelli F.M., Gallegati M. (2017a): Have your cake and eat it too: The well-being of the Italians (1861–2011). Social Indicators Research, 134: 473–509.

Ciommi M., Gigliarano C., Emili A., Taralli S., Chelli F.M. (2017b): A new class of composite indicators for measuring well-being at the local level: An application to the equitable and sustainable well-being (BES) of the Italian provinces. Ecological Indicators, 76: 281–296.

Ciommi M., Chelli F.M., Carlucci M., Salvati L. (2018): Urban growth and demographic dynamics in southern Europe:

https://doi.org/10.17221/467/2020-AGRICECON

Toward a new statistical approach to regional science. Sustainability, 10: 1–16.

Colantoni A., Di Bartolomei R., Perini L., Zitti M. (2013): The northern shift in the geographical distribution of the olive tree – A bioclimatic indicator? International Journal of Ecology and Development, 24: 1–11.

Colantoni A., Monarca D., Laurendi V., Villarini M., Gambella F., Cecchini M. (2017): Smart machines, remote sensing, precision farming, processes, mechatronic, materials and policies for safety and health aspects. Agriculture, 8: 1–256.

Conacher A.J., Sala M. (1998): Land Degradation in Mediterranean Environments of the World. Chichester, England, Wiley: 1–491.

Crea (2020): Olive, Fruit and Citrus Crops. [Dataset]. Crea. Available at https://www.crea.gov.it/en/web/olivicoltura-frutticoltura-e-agrumicoltura (accessed Dec, 2020).

Eurostat (2020): Utilised Agricultural Area by Categories. [Dataset]. Eurostat. Available at https://ec.europa.eu/eurostat/web/products-datasets/-/tag00025 (accessed Dec, 2020).

Fussel H.M., Klein R.J.T. (2006): Climate change vulnerability assessments: An evolution of conceptual thinking. Climatic Change, 75: 301–329.

Gambella F., Paschino F., Bertetto A.M. (2013): Perspectives in the mechanisation of saffron (*crocus sativus l.*). International Journal of Mechanics and Control, 14: 3–8.

Garcia Latorre J., Garcia-Latorre J., Sanchez-Picon A. (2001): Dealing with aridity: Socio-economic structures and environmental changes in an arid Mediterranean region. Land Use Policy, 18: 53–64.

Gigliarano C., Chelli F.M. (2016): Measuring inter-temporal intragenerational mobility: An application to the Italian labour market. Quality and Quantity, 50: 89–102.

Gomez J.A., Alvarez S., Soriano M.A. (2009): Development of a soil degradation assessment tool for organic olive groves in southern Spain. Catena, 79: 9–17.

Helldén U., Tottrup C. (2008): Regional desertification: A global synthesis. Global and Planetary Change, 64: 169–176.

Kelly P.M., Adger W.N. (2000). Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change, 47: 325–352.

King R., Proudfoot L., Smith B. (1997): The Mediterranean: Environment and Society. London, Arnold: 1–315.

Lorent H., Evangelou C., Stellmes M., Hill J., Papanastasis V., Tsiourlis G., Roeder A., Lambin E.F. (2008): Land degradation and economic conditions of agricultural households in a marginal region of northern Greece. Global and Planetary Change, 64: 198–209.

Loumou A., Giourga C. (2003): Olive groves: The life and identity of the Mediterranean. Agricultural and Human Values, 20: 87–95.

Makhzoumi J.M. (1997): The changing role of rural landscapes: Olive and carob multi-use tree plantations in the semiarid Mediterranean. Landscape Urban Planning, 37: 115–122.

Maracchi G., Sirotenko O., Bindi M. (2005): Impacts of present and future climate variability on agriculture and forestry in the temperate regions: Europe. Climatic Change, 70: 117–135.

Moriondo M., Good P., Durao R., Bindi M., Giannakopoulos C., Corte-Real J. (2006): Potential impact of climate change on fire risk in the Mediterranean area. Climate Research, 31: 85–95.

Moriondo M., Stefanini F.M., Bindi M. (2008): Reproduction of olive tree habitat suitability for global change impact assessment. Ecological Modelling, 218: 95–109.

Olesen J.E., Bindi M. (2002): Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy, 16: 239–262.

Romm J. (2011): Desertification: The next dust bowl. Nature, 478: 450–451.

Sistan (2020): Geographical Database of the Annual Agricultural Survey of Italy. [Dataset]. Sistan. Available at https://www.sistan.it/index.php?id=72 (accessed Dec, 2020).

Sivakumar M.V.K. (2007): Interactions between climate and desertification. Agricultural and Forest Meteorology, 142: 143–155.

Slaymaker O. (2001): Why so much concern about climate change and so little attention to land use change. Canadian Geographer, 45: 71–78.

Smiraglia D., Ceccarelli T., Bajocco S., Salvati L., Perini L. (2016): Linking trajectories of land change, land degradation processes and ecosystem services. Environmental Research, 147: 590–600.

Smit B. (1994): Global change, climate and geography. Canadian Geographer, 38: 81–89.

Solecki W.D., Oliveri C. (2004): Downscaling climate change scenarios in an urban land use change model. Journal of Environmental Management, 72: 105–115.

Symeonakis E., Calvo-Cases A., Arnau-Rosalen E. (2007): Land use change and land degradation in southeastern Mediterranean Spain. Environmental Management, 40: 80–94.

Tanrivermis H. (2003): Agricultural land use change and sustainable use of land resources in the Mediterranean region of Turkey. Journal of Arid Environment, 54: 553–564.

Received: November 23, 2020
Accepted: February 17, 2021