Original Scientific paper
10.7251/AGRENG2302117H
UDC 63:912(450)

THE LANDSCAPE CONTEXT AFFECTS THE ECOLOGICAL VALUE OF AN ORGANIC FARM IN AN ITALIAN INNER AREA

Claudia Fiorella HUAMANÍ CAHUAS[1,3]*, Maria Carla DE FRANCESCO[1], Marco DI CRISTOFARO[2], Stefano MARINO[2], Luigi MASTRONARDI[1], Angela STANISCI[1]

[1]Department of Biosciences and Territory, University of Molise, Termoli, Italy.
[2]Department of Agriculture, Food and Environment, University of Molise, Campobasso, Italy.
[3]Department for Innovation in Biological, Agro-Food and Forest Systems, University of Tuscia, Viterbo, Italy.
*Corresponding author: claudia.huamani@unitus.it; c.huamanicahuas@studenti.unimol.it

ABSTRACT

The general aim is to assess the landscape diversity and the ecological value of a multifunctional and diversified farm in an Italian inner area. The study was carried out in the context of the national DEMETRA research project, aimed at developing and implementing integrated and multifunctional agricultural production systems with a high degree of diversification and sustainability. For landscape context analysis, detailed land cover maps were produced and the composition and spatial configuration of the agricultural and natural landscape were quantified and evaluated. Moreover, using the i-Tree canopy software for rural areas, three ecosystem services were estimated. The results revealed a great diversity of land cover and use types, a small to medium size of the cultivated plots, and frequent contacts of cultivated areas with forest and semi-natural areas. This rural landscape supported the provision of numerous ecosystem services that resulted in a positive buffer effect for the quality of air, water and soil, ensuring great annual carbon sequestration, atmospheric pollution reduction, and consistently avoided runoff. Results highlighted the high ecological value of organic and multifunctional farms in inner areas and their contribution to face the environmental and food production challenges driven by global change.

Keywords: *landscape ecology, organic farming, landscape diversity, land use, ecosystem services.*

INTRODUCTION

Organic farming, characterized by a reduced environmental impact, has positive effects on soil quality, nutrient recycling, water resource management, biodiversity and other ecosystem services (Ciccarese & Silli, 2015; Abbott & Manning, 2015; Maitra *et al.*, 2020). A healthy agro-silvo-pastoral landscape can also absorb air pollutants, purify water, recharge aquifers, regulate the hydrological cycle, and provide recreational spaces and opportunities for psychological well-being (Scolozzi *et al.*, 2012). Multifunctional organic farms can therefore offer not only qualitatively and quantitatively better, resilient, and sustainable agricultural productions assuring many benefits to the community. In this context the scientific community has a key role on supporting farmers wishing to introduce agro-ecological innovations in both: implementing new approaches and on quantifying the related ecosystem services aiding their inclusion in the local and global green-market.

European inner areas host several ecological and multifunctional farms that maintain traditional landscapes and sustainable agriculture (Agnoletti *et al.*, 2019; Sivini & Vitale, 2023), and in Italy a good example of such landscapes are in the Abruzzo region (de Rooij, 2005; Grandi & Triantafyllidis, 2010). Abruzzo is an Italian region with high levels of biodiversity and is characterized by considerable ecological and environmental values (Bagnaia *et al.*, 2011). The high biodiversity value of the region is underlined by the large proportion of protected areas (37.2% of the region surface; both terrestrial and marine), the wide 58 Natura 2000 Sites and three National Parks (MASE, 2022a).

Abruzzo landscapes are characterized by wooded and semi-natural areas, in which deciduous forests, natural pastures and grasslands prevail (Pirone & Frattaroli, 2011). The utilized agricultural area (UAA) represents the 3.3% of the national agricultural lands (415,000 ha; Istat, 2022), and it includes the 2.4% of the organic farming in Italy (50,696 ha; CREA, 2021).

The study aims to give evidence of the positive effects of diversified ecological farms on ensuring highly functional (Goded *et al.*, 2019; Rotchés-Ribalta *et al.*, 2023), and heterogeneous landscapes (Brandt, 2003; Fahrig *et al.*, 2011; Stein-Bachinger *et al.*, 2022; Mannaf *et al.*, 2022) in the Abruzzo inner area (Central Italy). We specifically analyzed the landscape context of the VerdeBios farm present in an inner area where landscape is currently threatened by homogenization, mainly due to socio-economic dynamics linked to land abandonment of inland areas of the Apennines (Keenleyside *et al.*, 2010; Amodio, 2022), and whose presence over time may aid to contrast these threats. This article reports the results of an analysis on the landscape context diversity and the relative ecological value of the VerdeBios farm as well as the quantification of some ecosystem services. The target farm is characterized by a significant multifunctionality (agricultural production, zootechnics, pork processing, marketing in its own store, management of land for civic use, sale to solidarity purchasing groups).

MATERIAL AND METHODS

This study was born within the DEMETRA project (Ideation and validation of multifunctional and diversified production systems based on the integration between plant and animal production in the marginal areas of central-southern Italy), carried out by the BioCult Center of the University of Molise and funded by the MIPAAF competitive call referred to in DM 27/09/2018 n. 67374 (2020-2023).

It involves 5 farms that practice organic farming located in Abruzzo and Molise: Bio fattoria Licineto, Celenza sul Trigno (CH); Mancini Michelina Farm, San Salvo (CH); Opera Società Agricola Biodinamica di Vaira, Petacciato (CB); Terre del Seminario, Larino (CB); "VerdeBios", Celenza sul Trigno (CH).

The work focuses on the VerdeBios farm, that is located in Celenza sul Trigno village in the province of Chieti, Abruzzo, at about 646 m a.s.l., in an environment naturally favorable to organic crops, being characterized by a meso-mediterranean climate and a landscape with widespread high naturalness (Fig. 1). It has an extension of 42.45 ha and is composed of 85 cadastral parcels. Most of the farm plots are occupied by natural pastures and meadows, olive groves and arable land and deciduous forests, and sheep and pigs are raised there. The wooded areas consist mainly of *Quercus pubescens* with the presence of *Quercus cerris* and other tree species such as *Acer campestre*, *Fraxinus ornus*, *Sorbus domestica*, *Juglans regia* and *Ulmus minor*. In the undergrowth there are *Juniperus oxycedrus*, *Spartium junceum*, *Rubus ulmifolius*, *Cornus sanguinea*, *Euonymus europaeus*, and *Prunus spinosa*. In the warmer and steeper slopes Mediterranean scrub and ilex groves dominate.

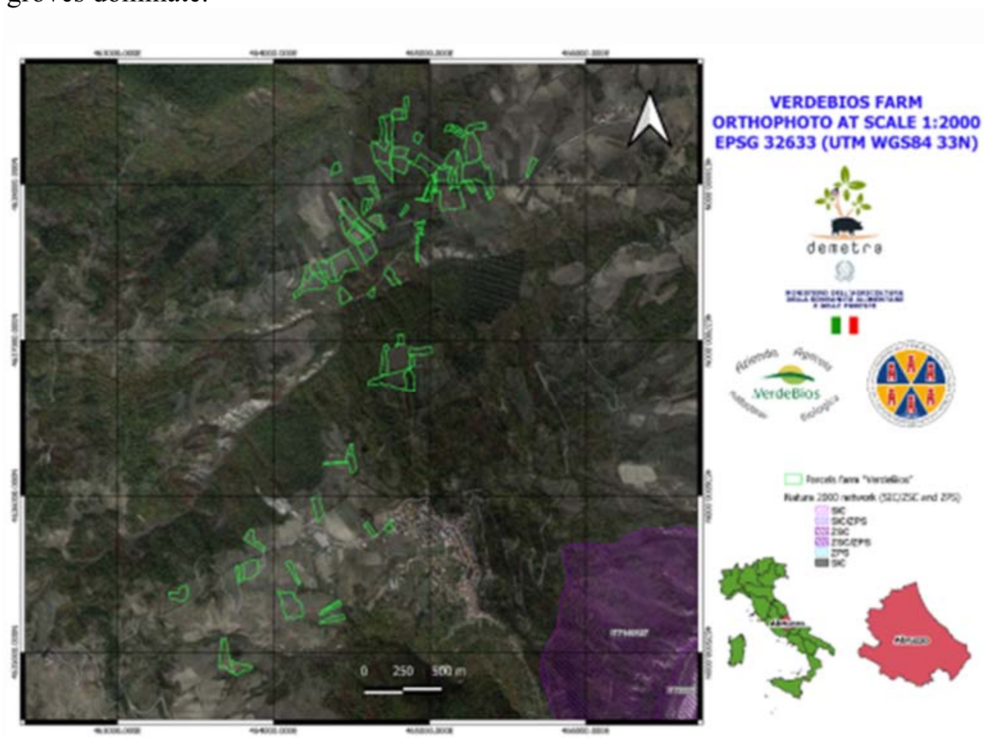

Fig. 1. Study area.

In order to investigate the landscape characteristics of the area, a map of the land use and cover of the VerdeBios farm parcels and the surrounding landscape was realized, considering a buffer zone of about 100 meters away from the farmland.

The cartography was carried out following the hierarchical scheme of the Corine Land Cover project at the third level of detail (ISPRA, 2018). Land use and land cover polygons were delineated and classified in a GIS environment (QGIS version 3.16) following a manual photointerpretation procedure of Google Earth digital orthophotos (year 2017) at a scale of 1:2,000 and assuming a minimum mapping unit (MMU) of 1,000 m^2 (< 0.1 ha). As ancillary cartographic information, the Regional Technical Map of the Abruzzo Region at a scale of 1:10,000 (Abruzzo Region, 2022), cadastral maps provided by the Italian Revenue Agency as a WMS service, and the Natura 2000 Network map (MASE, 2022b) were used. Validation of photo-interpretation was carried out through field checks.

Subsequently, to quantify and evaluate the composition and spatial configuration of the agricultural and natural landscape of the farm and the surrounding areas, ecological landscape indicators and diversity indices were applied (Kymberly, 2019; Huamaní Cahuas *et al.*, 2023).

Analysis was performed at the class and landscape level using Fragstats software (McGarigal *et al.*, 2012). The following metrics were calculated (Ferrari & Pezzi, 2013):

- Area of each land cover class in hectares (CA);
- Percentage of landscape (PLAND) of each cover class;
- Edge Density (ED) equals all edges in the landscape in relation to the landscape area and is an indicator of mosaic heterogeneity;
- Number of patches (NP) is the number of polygons of a given land cover or class;
- Shannon index and richness of patches that express landscape diversity in terms of richness of land cover classes and relative abundance (diversity index).

While, the percentage of land use and cover of the farm's contiguous areas (within 100 m of the farmland) was calculated using the following formula:

$$Pi = \frac{\sum_{j=1}^{n} a_{ij}}{A} * 100$$

Where: Pi is the proportion of the landscape occupied by category i; aij is the area in m^2 of category ij; and A is the total area of the landscape.

For the assessment of ecosystem services we adopted i-Tree software (USDA, 2021). The tools available in i-Tree assist technicians, private companies, and government organizations by quantifying the ecosystem services provided by rural and urban landscapes (Olivatto & Barduchi Barbin, 2017; Nowak *et al.*, 2018). The procedure taken as a guide was: Area delimitation -> Surface covers definition -> Surveying -> Report production (Olivatto & Barduchi Barbin, 2017). The analysis was performed through the i-Tree Canopy tool for rural areas, which consisted of uploading a shapefile of the VerdeBios plots on the online platform, then proceeded to perform a random sampling, placing 750 survey points (Olivatto, 2019; Selim *et al.*, 2023), detailing for each point to which surface cover corresponded (i.e., trees or not trees). We focused on climate regulation, air quality regulation, runoff mitigation/local temperature regulation.

RESULTS AND DISCUSSION

A total of 22 land cover classes were identified according to the Corine Land Cover legend at the third level of detail, identified by photo interpretation and field checks. Of these, 9 types fall in agricultural areas, 6 in artificial surfaces, 5 in forest and semi-natural areas and 2 in water bodies (Fig. 2).

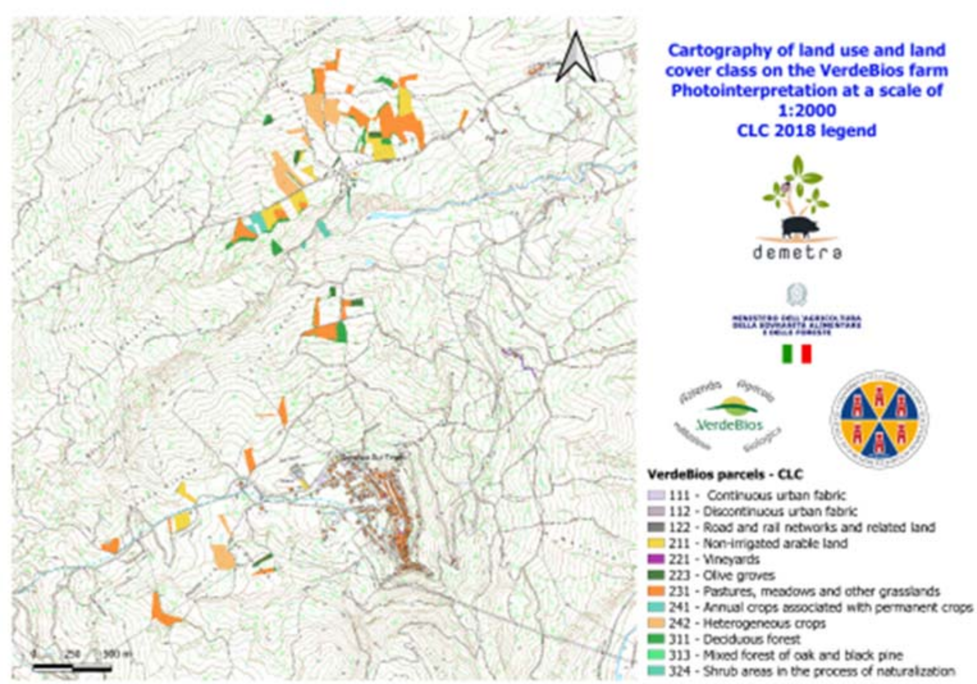

Fig. 2. Land cover map of the "VerdeBios" farm at the third level of Corine Land Cover legend.

There is a clear predominance of "Pastures, meadows and other grasslands" (class 231) covering 17.20 ha and representing 40.56% of the total study area, followed by "Heterogeneous crops" (class 242) with 9.05 ha (21.34%), "Non-irrigated arable land" (class 211) with 7.40 ha (17.46%) and "Oak and Cerro forest" (class 311) with 3.99 ha (9.40%). The Edge Density indicates that class 231 has a ratio of 98.46 m/ha, followed by class 311 with 62.61 m/ha, class 211 with 58.84 m/ha and class 223 with 39.26 m/ha. Regarding the average polygon size, the highest average value is class 242 with 0.82 ha, followed by class 241 with 0.51 ha, class 231 with 0.37 ha and class 211 with 0.35 ha.

A map considering a buffer area of 100 meters away from the cadastral parcels of the farm was made to know the composition of the land cover types in contact with the VerdeBios farm's estate (Fig. 3). The target farm is surrounded by almost 70% of other agricultural areas, but it is also in contact with forest and semi-natural areas (29%) and a very small number of artificial areas (4%).

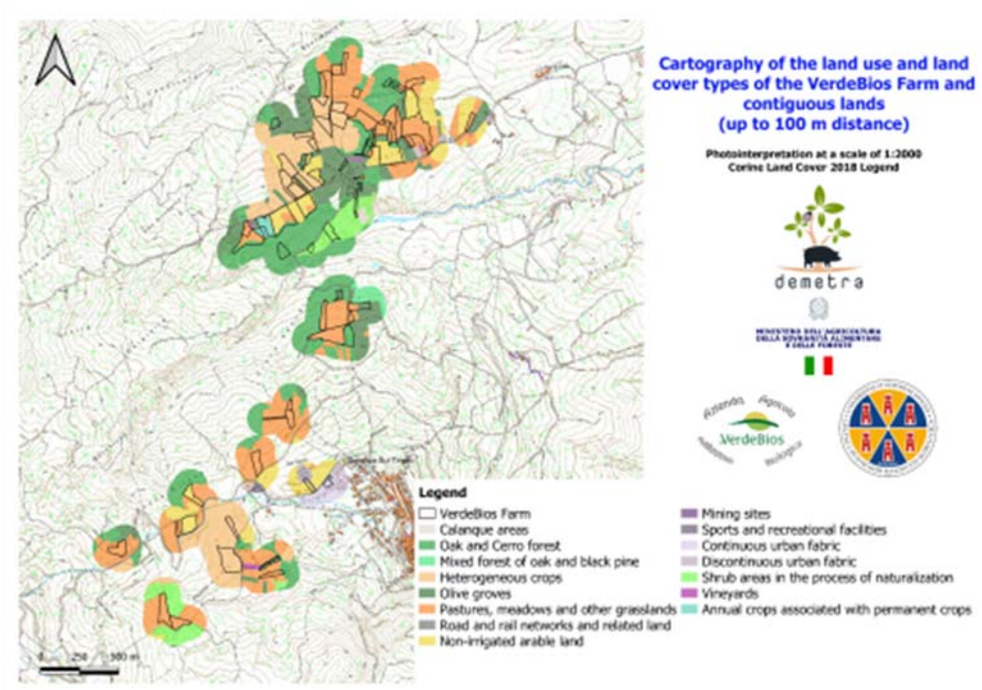

Fig. 3. Land cover classes (Third level of Corine Land Cover legend) occuring in the “VerdeBios” farm and contiguous areas (buffer of 100 meters).

As reported in recent scientific publications (Hass *et al.*, 2018; ISPRA, 2020; Samways *et al.*, 2020; Sirami & Midler, 2021; Tscharntke *et al.*, 2021; Barão *et al.*, 2022), the heterogeneity of the agricultural landscape, the small to medium size of cultivated areas, the diversity of land cover and use, and the proximity to natural and semi-natural environments increases the abundance of pollinators and maintains a high ecosystem biodiversity.

In general, an agro-forest landscape with widespread naturalness, such as the landscape context of the VerdeBios farm, supports the provision of numerous ecosystem services, such as the reduction of insect pests and insect vectors of pathogens, natural biological control, water and soil quality, and has greater resilience to the effects of climate change (Martin *et al.*, 2019).

In addition, the high spatial heterogeneity of agroecosystems as those observed in the analyzed area may increase the opportunities for multiple species to spatially segregate and locally coexist in equilibrium, thereby contributing to the maintenance of high levels of biodiversity and thus overall ecosystem functioning (Rosenfield *et al.*, 2022).

In contrast, a farm practicing conventional, intensive agriculture with non-diversified production is characterized by a homogeneous and therefore poorly functional landscape (Ekroos e*t al.*, 2010; Karp *et al.*, 2012; Carrié *et al.*, 2021; Sánchez *et al.*, 2022). Moreover, intensive farms, in order to improve their cultivation practices and facilitate mechanization, eliminate certain landscape

elements that provide indispensable ecosystem services (Emmerson *et al.*, 2016; Ribeiro *et al.*, 2019). The farm reality studied is strongly alternative to the process being underway of intensification of agriculture and homogenization of the landscape for the maximization of individual productive ecosystem services (production of food, fodder and biofuels; Maitra *et al.*, 2020).
These processes take place at the expense of other important services such as the provision of clean water, the maintenance of biodiversity and the loss of local knowledge and the identity value of places (Ferrari *et al.*, 2019). The high quality of the natural and rural landscapes is also associated with a tourist attractiveness that is lost in landscapes where agriculture becomes intensive (Mastronardi *et al.*, 2017). Several European studies show that multifunctional natural and rural landscapes are perceived as hotspots of ecosystem services (Di Cristofaro *et al.*, 2020) and provide multiple benefits for the well-being of different categories of stakeholders both locally and in neighboring cities (Garcia-Martin *et al.*, 2017; Fagerholm *et al.*, 2019).
The quantification of these services is useful for assessing environmental sustainability, promoting the farm itself, and making known its contribution to combating global changes (Lynch *et al.*, 2021). In that frame, the biophysical and economic valuation of some important ecosystem services provided by the landscape of the VerdeBios farm were calculated (Table 1).

Table 1. Biophysical and economic valuation of some important ecosystem services provided by the trees present on the VerdeBios farmland.

Ecosystem services	Indicators	Biophysical evaluation	Economic evaluation
Climate regulation	CO_2 Sequestration	112.28 ton/year	5,250 €/year
	Carbon storage	604.97 ton/year	103,706 €/year
Air quality regulation	Removal of air pollutants (CO, NO_2, O_3, SO_2, $PM_{2,5}$, PM_{10})	759.88 kg/year	43 €/year
Mitigation of runoff	Runoff avoided	315,16 liters/y	N/A

These services have relevance in the mitigation and adaptation to climate change and the reduction of surface runoff (Bengtsson *et al.*, 2019; Morizet-Davis *et al.*, 2023).

Trees contribute to climate change mitigation, because of their natural metabolic processes, they sequester atmospheric carbon dioxide by storing it during growth (Lorenz & Lal, 2010; Mistry *et al.*, 2019). The annual gross carbon sequestration (amount of carbon absorbed by the tree stand in a year) by trees on the VerdeBios farm is 30.62 tC/year, which is equivalent to 5,250.00 €/year. Carbon storage refers to the net amount of carbon stored in trees; that is, it is the total carbon that the plant has been integrating throughout its life (Di Cosmo *et al*., 2022). The trees of the VerdeBios farm store almost 604.97 t C/year.

Trees in rural landscape can help mitigate the impacts of climate change by regulating carbon sequestration and even reducing climate extremes (Vacek *et al.*, 2023; Ottaviano & Marchetti, 2023). Diversification of mixed production systems is of increasing interest as an adaptive approach to climate change, thus buffering risks to food production systems through increased livelihood resilience, food security and multiple ecosystem services (Baker *et al.*, 2023). For example, in agroforestry, trees can improve growing conditions for annual food crops by creating microclimatic effects (Morizet-Davis *et al.*, 2023). Moreover, trees help improve air quality by reducing air temperature and directly removing air pollutants from the air (Nowak, 2019). It is estimated that trees removed 759,88 kg/year of air pollutants (CO, NO_2, O_3, SO_2, $PM_{2,5}$, PM_{10}). Air in rural areas is of better quality than in many urban areas (Cvijanović *et al.*, 2017), and having a heterogeneous agricultural landscape can vitally help ecosystem processes in terms of air quality (Field & Parrott, 2017; Quandt *et al.*, 2023). The trees occurring in the VerdeBios farm contribute to the removal of pollutants such as carbon monoxide (CO), nitrogen oxide (NO_2), ozone (O_3), sulfate (SO_2) and particulate matter $PM_{2,5}$ and PM_{10}. The results show that trees contribute the most to the removal of O_3 (473,86 kg/y) from the atmosphere, secondly PM_{10} (187,99 kg/y) and thirdly NO_2 (53,16 kg/y). Air pollution is one of the main causes of respiratory diseases, so the elimination of polluting particles influences people's health (Manisalidis *et al.*, 2020). Moreover, elevated O_3 concentrations, coupled with climate change, could have negative effects on tree physiology (Takahashi *et al.*, 2020). Trees contribute to air purification, as a consequence of their functioning by helping to reduce the temperature of the surrounding air through transpiration; they facilitate the deposition of suspended pollutants on the plant surface (Nowak *et al*., 2014). Trees can store atmospheric pollutants in wood, in annual growth rings (Alterio *et al.*, 2020). The economic value associated with the removal of PM_{10} is significantly high due to its direct relationship with lung disease affectations.

Trees and shrubs are beneficial by reducing surface runoff as they intercept precipitation. Surface runoff is the hydrological process at the origin of phenomena such as soil erosion, river flooding and mudflows that can generate significant damage. Surface runoff is that amount of rainwater that, during and after a precipitation event, is not intercepted by vegetation (trees and shrubs) and reaches the ground (Lagadec *et al.*, 2016; Guo *et al.*, 2019).

The results obtained show that the trees on the VerdeBios farm help reduce runoff by up to 315,16 liters/year.

CONCLUSIONS

Multifunctionality and ecosystem services have gained increasing interest in policy, as evidenced by key documents related to the Common Agricultural Policy 2023-2026, the Green Deal and the Farm to Fork strategy, and Nature-Based Solutions.

The analysis of the composition and spatial heterogeneity of the landscape associated with the VerdeBios multifunctional organic farm showed a high diversity of land cover types, a small to medium size of cultivated parcels and frequent contact with forest and semi-natural areas and pastures, delivering high provision of ecosystem services.

Trees present on farms have positive impacts on the environment, such as climate regulation, air purification and runoff mitigation; however, there is still a notable gap in the existing literature.

In this context, agro-ecological policy promotes configurational heterogeneity in European agro-ecosystems to increase functional biodiversity and ecosystem services provision, and the multifunctional organic farms may contribute significantly to reach that EC targets.

ACKNOWLEDGEMENT

We thank Mr. Antonio Antenucci, owner of the VerdeBios farm, for his availability throughout all working phases. The research was funded by DEMETRA project – Centro BioCult University of Molise, MIPAAF competitive call referred to in DM 27/09/2018 n. 67374 (2020-2023).

REFERENCES

Abbott, L. K. & Manning, D. A. (2015). Soil health and related ecosystem services in organic agriculture. S*ustainable Agriculture Research*, *4*, 526-2016-37946.

Agnoletti, M., Emanueli, F., Corrieri, F., Venturi, M. & Santoro, A. (2019). Monitoraggio dei paesaggi rurali tradizionali. Il caso Italia. *Sostenibilità*, *11* (21), 6107. https://doi.org/10.3390/su11216107

Alterio, E., Cocozza, C., Chirici, G., Rizzi, A. & Sitzia, T. (2020). Preserving air pollution forest archives accessible through dendrochemistry. *Journal of Environmental Management*, 264, 110462. https://doi.org/10.1016/j.jenvman.2020.110462

Amodio, T. (2022). Territories at risk of abandonment in Italy and hypothesis of repopulation. *Belgeo. Revue belge de géographie*, 4. https://doi.org/10.4000/belgeo.57229

Bagnaia, R., Caruso. S., De Marco, P., Catonica, C., Canali, E., Cardillo, A., Croce, S., D'Errico, D., Desiderio, D., Labbrozzi, N., Laureti, L., Piciocco, C. & Tribuiani, P. (2011). Carta della natura della regione Abruzzo: Carta degli habitat alla scala 1:50.000. ISPRA

Baker, E., Kerr, R. B., Deryng, D., Farrell, A., Gurney-Smith, H. & Thornton, P. (2023). Mixed farming systems: potentials and barriers for climate change adaptation in food systems. *Current Opinion in Environmental Sustainability*, *62*, 101270. https://doi.org/10.1016/j.cosust.2023.101270

Barão, I., Queirós, J., Vale-Gonçalves, H., Paupério, J. & Pita, R. (2022). Landscape Characteristics Affecting Small Mammal Occurrence in Heterogeneous Olive Grove Agro-Ecosystems. *Conservation*, *2*(1), 51-68. doi: 10.3390/conservación2010005

Bengtsson, J., Bullock, J. M., Egoh, B., Everson, C., Everson, T., O'connor, T., O'Farrell, P. J., Smith, H. G. & Lindborg, R. (2019). Grasslands—more important for ecosystem services than you might think. *Ecosphere*, *10*(2), e02582. https://doi.org/10.1002/ecs2.2582

Brandt, J. (2003). Multifunctional landscapes–perspectives for the future. *Journal of Environmental Sciences*, *15*(2), 187-192.

Carrié, R., Ekroos, J. & Smith, H. G. (2022). Turnover and nestedness drive plant diversity benefits of organic farming from local to landscape scales. *Ecological Applications*, *32*(4), e2576. https://doi.org/10.1002/eap.2576

Ciccarese, L. & Silli, V. (2015). Agricoltura biologica, una scelta giusta per l'ambiente, la sicurezza alimentare e la salute?. Energia, Ambiente e Innovazione. doi: 10.12910/EAI2015-060

CREA- Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – Centro di ricerca politiche e bioeconomia (2021). L'agricoltura italiana conta 2021. [online] URL: https://www.crea.gov.it/web/politiche-e-bioeconomia/-/agricoltura-italiana-conta Accessed on 03/01/2023.

Cvijanović, D., Matijašević-Obradović, J. & Škorić, S. (2017). The Impact of Air Quality conditioned by emission of poluttants to the development of rural tourism and potentials of rural areas. *Economics of Agriculture*, *64*(3), 871-885.

de Rooij, S. J. G. (2005). Multifunctional farming is revitalising rural life in Abruzzo. *COMPAS Magazine for endogenous development*, *9*, 30-33.

Di Cristofaro, M., Sallustio, L., Sitzia, T., Marchetti, M. & Lasserre, B. (2020). Landscape Preference for Trees Outside Forests along an Urban–Rural–Natural Gradient. *Forests,* 11, 728. https://doi.org/10.3390/f11070728

Di Cosmo, L., Gasparini, P. & Floris, A. (2022). Forest Carbon Stock. In: Gasparini, P., Di Cosmo, L., Floris, A., De Laurentis, D. (eds) Italian National Forest Inventory—Methods and Results of the Third Survey. Springer Tracts in Civil Engineering. *Springer, Cham.* https://doi.org/10.1007/978-3-030-98678-0_12

Ekroos, J., Heliölä, J. & Kuussaari, M. (2010). Homogenization of lepidopteran communities in intensively cultivated agricultural landscapes. *Journal of Applied Ecology*, *47*(2), 459-467. https://doi.org/10.1111/j.1365-2664.2009.01767.x

Emmerson, M., Morales, M. B., Oñate, J. J., Batary, P., Berendse, F., Liira, J. ... & Bengtsson, J. (2016). How agricultural intensification affects biodiversity and ecosystem services. In *Advances in ecological research*, *55*, 43-97. https://doi.org/10.1016/bs.aecr.2016.08.005

Fagerholm, N., Torralba, M., Moreno, G., Girardello, M., Herzog, F., Aviron, S., Burgess, P., Crous-Duran, J., Ferreiro-Domínguez, N., Graves, A., Hartel, T., Măcicăsan, V., Kay, S., Pantera, A., Varga, A. & Plieninger, T. (2019). Cross-site analysis of perceived ecosystem service benefits in multifunctional landscapes. *Global Environmental Change*, *56*, 134–147. doi: 10.1016/j.gloenvcha.2019.04.002

Fahrig, L., Baudry, J., Brotons, L., Burel, F. G., Crist, T. O., Fuller, R. J., Sirami, C, Siriwardena, G. M. & Martin, J. L. (2011). Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecology Letters*, *14*(2), 101-112. https://doi.org/10.1111/j.1461-0248.2010.01559.x

Ferrari, C. & Pezzi, G. (2013). L'Ecologia del paesaggio. Edizioni Il Mulino.

Ferrari, M. G., Bocci, E., Lepisto, E., Cavallero, P. & Rombai, L. (2019). Territories and Landscapes: place identity, quality of life and psychological well-being in rural areas. In: Bianco A., Conigliaro P., & Gnaldi M. (eds) Italian Studies on Quality of Life. Social Indicators Research Series, 77. Springer, Cham. doi: 10.1007/978-3-030-06022-0_19

Field, R. D. & Parrott, L. (2017). Multi-ecosystem services networks: A new perspective for assessing landscape connectivity and resilience. *Ecological Complexity*, *32*, 31-41. https://doi.org/10.1016/j.ecocom.2017.08.004

Garcia-Martin, M., Fagerholm, N., Bieling, C., Gounaridis, D., Kizos, T., Printsmann, A., Muller, M., Lieskovski, J. & Plieninger T. (2017). Participatory mapping of landscape values in a Pan-European perspective. *Landscape Ecology*, *32*(11), 2133–2150. doi: 10.1007/s10980-017-0531-x

Grandi, C. & Triantafyllidis, A. (2010). Organic Agriculture in Protected Areas the Italian Experience. *Natural Resources Management and Environment Department. Food and Agriculture Organization of the United Nations*.

Goded, S., Ekroos, J., Azcárate, J. G., Guitián, J. A. & Smith, H. G. (2019). Effects of organic farming on plant and butterfly functional diversity in mosaic landscapes. *Agriculture, Ecosystems & Environment*, *284*, 106600. https://doi.org/10.1016/j.agee.2019.106600

Guo, Y., Zhang, Y., Zhang, T., Wang, K., Ding, J. & Gao, H. (2019). Surface Runoff. In: Li, X., Vereecken, H. (eds) *Observation and Measurement of Ecohydrological Processes*. Ecohydrology, vol 2. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-48297-1_8

Hass, A. L., Kormann, U. G., Tscharntke, T., Clough, Y., Bosem-Baillod, A., Sirami, C., Fahrig, L., Martín, J-L., Baudry, J., Bertrand, C., Bosch, J., Brotons, L., Burel, F., Jorge, R., Giralt, D., Marcos-García, M. Á., Ricarte, A., Siriwardena, G. & Batáry P. (2018). Landscape configurational heterogeneity by small-scale agriculture, not crop diversity, maintains pollinators and plant reproduction in western Europe. *Proc. R. Soc. B*, *285*(1872), 20172242. doi: 10.1098/rspb.2017.2242

Huamaní Cahuas, C. F., de Francesco, M. C., Frate, L., Marino, S., Tozzi F. P. & Stanisci, A. (2023). La biodiversità e il valore ecologico del paesaggio agro-silvo-pastorale dell'azienda agricola biologica "Verdebios" di Celenza sul Trigno (CH). https://doi.org/10.5281/zenodo.7516738

Istituto Nazionale di Statistica-ISTAT (2022) [online] URL: https://www.istat.it/it/archivio/273753 Accessed on 26/07/2023.

ISPRA -Istituto Superiore per la Protezione e la Ricerca Ambientale (2018). Territorio. Processi e trasformazioni in Italia. ISPRA, 296/2018, Roma.

ISPRA- Istituto Superiore per la Protezione e la Ricerca Ambientale (2020). Il declino delle api e degli impollinatori. Quaderni Natura e Biodiversità n.12/2020. ISBN 978-88-448-1000-9, 43 p

Karp, D. S., Rominger, A. J., Zook, J., Ranganathan, J., Ehrlich, P. R. & Daily, G. C. (2012). Intensive agriculture erodes β-diversity at large scales. *Ecology letters*, *15*(9), 963-970. https://doi.org/10.1111/j.1461-0248.2012.01815.x

Keenleyside, C., Tucker, G. & McConville, A. (2010). Farmland Abandonment in the EU: an Assessment of Trends and Prospects. *Institute for European Environmental Policy: London, UK*, 1-98.

Kymberly, A. W. (2019). An introduction to landscape ecology. Foundations and Core Concepts. Oxford Scholarship. doi: 10.1093/oso/9780198838388.003.0001

Lynch, J., Cain, M. E., Frame, D. & Pierrehumbert, R. (2021). Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO_2-emitting sectors. Frontiers in Sustainable Food Systems, 4. doi: 10.3389/fsufs.2020.518039

Lagadec, L. R., Patrice, P., Braud, I., Chazelle, B., Moulin, L., Dehotin, J., Hauchard, E. & Breil, P. (2016). Description and evaluation of a surface runoff susceptibility mapping method. *Journal of Hydrology*, *541*, 495-509. https://doi.org/10.1016/j.jhydrol.2016.05.049

Lorenz, K. & Lal, R. (2010). The Natural Dynamic of Carbon in Forest Ecosystems. In: Carbon Sequestration in Forest Ecosystems. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-3266-9_2

Maitra, S., Shankar, T., Gaikwad, D. J., Palai, J. B. & Saga, L. (2020). Organic agriculture, ecosystem services and sustainability: A review. *International Journal of Modern Agriculture*, *9*(4), 370-378.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A. & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. *Frontiers in public health*, *8*, 14. https://doi.org/10.3389/fpubh.2020.00014

Mannaf, M., Zuo, A. & Wheeler, S. A. (2022). The spatial influences of organic farming and environmental heterogeneity on biodiversity in South Australian landscapes. *Journal of Environmental Management*, *324*, 116414. https://doi.org/10.1016/j.jenvman.2022.116414

Martin, E. A., Dainese, M., Clough, Y., Báldi, A., Bommarco, R., Gagic, V., Garratt, M. P. D., Holzschuh, A., Kleijn, D., Kovács-Hostyánszki, A., Marini, L., Potts, S. G., Smith, H. G., Al Hassan, D., Albrecht, M., Andersson, G. K. S., Asís, J. D., Aviron, S., Balzan, M. V., ... & Steffan-Dewenter, I. (2019). The interplay of landscape composition and configuration: new pathways to manage functional biodiversity and agroecosystem services across Europe. *Ecology Letters*, *22*(7), 1083-1094. doi: 10.1111/ele.13265

MASE – Ministero dell’Ambiente e della Sicurezza Energetica – 2022 a. [online] URL: https://www.mite.gov.it/pagina/sic-zsc-e-zps-italia. Accessed on 03/01/2023.

MASE - Ministero dell’Ambiente e della Sicurezza Energetica 2022 b, Geoportale Nazionale. [online] URL: http://www.pcn.minambiente.it/mattm/servizio-wms/ Accessed on 03/01/2023.

Mastronardi L., Giaccio V., Giannelli A. & Stanisci A. (2017). Methodological proposal about the role of landscape in the Tourism Development Process in Rural Areas: the case of Molise Region (Italy). *Europ. Countrys*, *2*, 245-262. doi: 10.1515/euco-2017-0015

McGarigal, K. & Cushman, S. A., Ene E. (2012). ‘‘FRAGSTATS v4: spatial pattern analysis program for categorical and continuous maps’’. Computer software program produced by the authors at the University of Massachusetts, Amherst.

Mistry, A. N., Ganta, U., Chakrabarty, J. & Dutta, S. (2019). A review on biological systems for CO_2 sequestration: organisms and their pathways. *Environmental Progress & Sustainable Energy*, *38*(1), 127-136. https://doi.org/10.1002/ep.12946

Morizet-Davis, J., Marting Vidaurre, N. A., Reinmuth, E., Rezaei-Chiyaneh, E., Schlecht, V., Schmidt, S., Singh, K., Vargas-Carpintero, R., Wagner, M. & von Cossel, M. (2023). Ecosystem Services at the Farm Level—Overview, Synergies, Trade-Offs, and Stakeholder Analysis. *Global Challenges,* 2200225. https://doi.org/10.1002/gch2.202200225

Nowak, D. J., Hirabayashi, S., Bodine, A. & Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, *193*, 119-129.

Nowak, D. J., Maco, S. & Binkley, M. (2018). i-Tree: Global Tools to Assess Tree Benefits and Risks to Improve Forest Management. *Arboricultural Consultant*, *51*(4), 10-13.

Nowak, D. J. (2019). The atmospheric system: Air quality and greenhouse gases. In: Hall, M., Balogh, S. (eds) *Understanding Urban Ecology*. Springer, Cham., 175-199. https://doi.org/10.1007/978-3-030-11259-2_8

Olivatto, T. F. & Barduchi Barbin, N. B. C. (2017). Using i-Tree Software to Estimate and Value Ecosystem Services. Case of study: Air pollutants removal in Portugal Park. *Brazilian Technology Symposium*. ISSN 2447-8326. V.1.

Olivatto, T. F. (2019). Using i-Tree Canopy to Estimate and Value Ecosystem Services of Air Pollutant Removal. In: Iano, Y., Arthur, R., Saotome, O., Vieira Estrela, V., Loschi, H. (eds) *Proceedings of the 3rd Brazilian Technology Symposium*. BTSym 2017. Springer, Cham., pp 291–299. https://doi.org/10.1007/978-3-319-93112-8_30

Ottaviano, M. & Marchetti, M. (2023). Census and Dynamics of Trees Outside Forests in Central Italy: Changes, Net Balance and Implications on the Landscape. *Land*, *12*, 1013. https://doi.org/10.3390/land12051013

Pirone, G. & Frattaroli, A. (2011). Lineamenti della biodiversità vegetale in Abruzzo. Acta Italus Hortus, *1*, 9-12.

Quandt, A., Neufeldt, H. & Gorman, K. (2023). Climate change adaptation through agroforestry: Opportunities and gaps. *Current Opinion in Environmental Sustainability*, *60*, 101244. https://doi.org/10.1016/j.cosust.2022.101244

Regione Abruzzo 2022 - Servizio per l'Informazione Territoriale e la Telematica. [online] URL: http://geoportale.regione.abruzzo.it/Cartanet/catalogo/cartografia-di-sfondo-raster/copy_of_carta-tecnica-regionale-ediz.-2007-1 Accessed on 03/01/2023.

Ribeiro, J. C. T., Nunes-Freitas, A. F., Fidalgo, E. C. C. & Uzeda, M. C. (2019). Forest fragmentation and impacts of intensive agriculture: Responses from different tree functional groups. *Plos one*, *14*(8), e0212725. https://doi.org/10.1371/journal.pone.0212725

Rosenfield, M. F., Brown, L. M. & Anand, M. (2022). Increasing cover of natural areas at smaller scales can improve the provision of biodiversity and ecosystem services in agroecological mosaic landscapes. *Journal of environmental management*, *303*, 114248. doi: 10.1016/j.jenvman.2021.114248

Rotchés-Ribalta, R., Marull, J. & Pino, J. (2023). Organic farming increases functional diversity and ecosystem service provision of spontaneous vegetation in Mediterranean vineyards. *Ecological Indicators*, *147*, 110023. https://doi.org/10.1016/j.ecolind.2023.110023

Samways, M. J., Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Fukushima, C. S., Gaigher, R., Habel, J. C., Hallmann, C. A., Hill, M. J., Hochkirch, A., Kaila, L., Mackenzie, L. K., Maes, D., Mammola, S., Noriega, J. A., Orfinger, A. B., ... & Cardoso, P. (2020). Solutions for humanity on how to conserve insects. *Biological Conservation*, *242*, 108427. doi: 10.1016/j.biocon.2020.108427

Sánchez, A. C., Jones, S. K., Purvis, A., Estrada-Carmona, N. & De Palma, A. (2022). Landscape complexity and functional groups moderate the effect of diversified farming on biodiversity: A global meta-analysis. *Agriculture, Ecosystems & Environment*, *332*, 107933. https://doi.org/10.1016/j.agee.2022.107933.

Scolozzi, R., Morri, E. & Santolini R. (2012). Pianificare territori sostenibili e resilienti: la prospettiva dei servizi ecosistemici.

Selim, S., Dönmez, B. & Kilçik, A. (2023). Determination of the optimum number of sample points to classify land cover types and estimate the contribution of trees on ecosystem services using the I-Tree Canopy tool. *Integrated Environmental Assessment and Management*, *19*(3), 726-734. https://doi.org/10.1002/ieam.4704

Sirami, C. & Midler, E. (2021). Agricultural landscape heterogeneity, biodiversity and ecosystem services. Centre for studies and strategic foresight Analysis N.163. Ministry of Agriculture and Food, PARIS.

Sivini, S. & Vitale, A. (2023). Multifunctional and Agroecological Agriculture as Pathways of Generational Renewal in Italian Rural Areas. *Sustainability*, *15*(7), 5990. https://doi.org/10.3390/su15075990

Stein-Bachinger, K., Preißel, S., Kühne, S. & Reckling, M. (2022). More diverse but less intensive farming enhances biodiversity. *Trends in Ecology & Evolution*, *37*(5), 395-396 https://doi.org/10.1016/j.tree.2022.01.008

Takahashi, M., Feng, Z., Mikhailova, T. A., Kalugina, O. V., Shergina, O. V., Afanasieva, L. V., Heng, R. K. J., Majid, N. M. A. & Sase, H. (2020). Air pollution monitoring and tree and forest decline in East Asia: A review. *Science of The Total Environment*, *742*, 140288. https://doi.org/10.1016/j.scitotenv.2020.140288

Tscharntke, T., Grass, I., Wanger, T. C., Westphal, C. & Batáry, P. (2021). Beyond organic farming–harnessing biodiversity-friendly landscapes. *Trends in Ecology & Evolution*, *36*(10), 919-930. doi: 10.1016/j.tree.2021.06.010

United States Department of Agriculture – USDA Forest Service. (2021). I-Tree Eco User's Manual (v6.0). https://www.itreetools.org/documents/275/EcoV6_UsersManual.2021.09.22.pdf

Vacek, Z., Vacek, S. & Cukor, J. (2023). European forests under global climate change: Review of tree growth processes, crises and management strategies. *Journal of Environmental Management*, *332*, 117353. https://doi.org/10.1016/j.jenvman.2023.117353