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Abstract	As an initial step in more extensive research into the links between biological and cultural diversity in present-day Italy, we reviewed Biocultural Diversity studies that explore the relationship between biological and cultural patterns of diversity to determine whether any direct causal relationships or common drivers could be inferred. We found no significant attempts to quantitatively measure biocultural diversity in the country as a whole. Italy shows a high number of mutual interactions, but common drivers and patterns between biological and cultural diversity were not evident. This could be either a problem of quantification due perhaps to an inherent incommensurability between the two dimensions, or different causative patterns that drive biological and cultural diversity.

Keywords (separated by '-')	Biocultural diversity - Linguistic diversity - Ethnic minorities - Land use - Traditional ecological knowledge - Italy
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RESEARCH

Biocultural Diversity in Italy

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Abstract

As an initial step in more extensive research into the links between biological and cultural diversity in present-day Italy, we reviewed Biocultural Diversity studies that explore the relationship between biological and cultural patterns of diversity to determine whether any direct causal relationships or common drivers could be inferred. We found no significant attempts to quantitatively measure biocultural diversity in the country as a whole. Italy shows a high number of mutual interactions, but common drivers and patterns between biological and cultural diversity were not evident. This could be either a problem of quantification due perhaps to an inherent incommensurability between the two dimensions, or different causative patterns that drive biological and cultural diversity.

Keywords Biocultural diversity · Linguistic diversity · Ethnic minorities · Land use · Traditional ecological knowledge · Italy

Introduction

Interactions between humans and their environment are multifaceted, and it can be argued that ecosystems and the human cultures inhabiting them influence and shape each other (Rozzi, 1999). It is well known that biodiversity "hotspots," such as the Amazon basin, Central Africa, or Southeast Asia also demonstrate exceptionally high degrees of cultural diversity (Gorenflo et al., 2012; Maffi, 2005). The deep interconnectedness of biological and cultural diversity and the notion of an "inextricable link" between the two has given rise to the concept of "Biocultural Diversity" (ISE, 1988; Posey, 1999).[1] Undoubtedly, an area's climate, landscape, and natural environment can profoundly impact the cultural values, norms, livelihoods, knowledge, and languages of its inhabitants (Berkes, 2008; Milton, 1998). On the other hand, human activities over the past 12,000 years have had a wide range of opposing consequences on their environment, from creation of novel ecological niches and new ecosystems to mass extinctions and overall reduction in biodiversity (Ellis, 2021; Stephens et al., 2019).

The concept of Biocultural Diversity to promote the recognition of the relationship between human cultures and biodiversity and their simultaneous preservation has gained increasing popularity (Bridgewater & Rotherham, 2019). The core problem in biocultural diversity studies, however, remains that while biological diversity can be studied quantitatively, culture is largely qualitative and therefore not easily subject to measurements (Patsiurko et al., 2012; Posey,

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[1] Literature pertaining to the alternative usage of the term "biocultural" in anthropology (see Bridgewater & Rotherham, 2019; Franco, 2022; Wiley & Cullin, 2016) and psychology (see Alexander, 1990; Massimini & Delle Fave, 2000; Riva et al., 2004) are excluded from this review.

1999; Seele et al., 2019). Indices proposed to assess biocultural diversity take into account only a few cultural proxies that are relatively easy to quantify but are hardly related to the material aspects of cultural diversity (e.g., language, religion, or ethnicity; Loh & Harmon, 2005). Naturally, such indices perform best where these particular proxies are at their highest diversity, but fail in nations that are relatively homogenous in terms of language and/or religion and yet demonstrate remarkable biological and cultural diversity due to other drivers (e.g., history, geography, geomorphology, climate, etc.).

To date, majority of the studies on biocultural diversity around the world have been focused on Indigenous and local populations and their relationship with their local environments, which are usually situated in global biodiversity hotspots. To test whether parallels between biological and cultural diversity can also be empirically assessed in industrialized nations, where direct links between human communities and their local natural environment have weakened over the last few centuries, we investigated this phenomenon in Italy, a European country with high levels of biological diversity and human cultural manifestations (Anagnostou et al., 2022; CBD, 2023). We focused on the following questions:

1. How the interaction between biological and cultural dimensions develops in the modern era;
2. Does cultural diversity drive and enhance biological diversity, or vice versa, and is there any bi-directional interaction between the two?
3. Can the present state of biocultural diversity be formally assessed in Italy?
4. What are the features of current biocultural projects in Italy?

We conducted an exhaustive literature search using relevant online databases (e.g., Web of Science, Google Scholar, etc.) with subsequent bibliography mining. We retrieved existing literature from diverse disciplines focused either on biocultural diversity or on the intersection of biological and cultural diversity in Europe and/or Italy. We divided the literature in two broad categories: a) Cases where biodiversity is shown to enhance cultural diversity (the former as a driver of the latter); and b) Cases where human cultural activities have modified the selective pressures and shaped the local biodiversity and ecosystems.[2]

We first describe the literature on linguistic and genetic diversity in Italy (question 1) followed by the review of the biocultural landscapes in Italy in order to understand how Biodiversity could be a driver of cultural diversity or vice versa (question 2). We then combine all the data to address the possibility for a formal assessment of Biocultural Diversity in the country (question 3). Finally, we analyze the characteristics of biocultural projects in Italy (question 4).

Human Linguistic and Genetic Diversity in Italy

Language is a key component of human culture (Honkola et al., 2018; Maffi, 2005; Skutnabb-Kangas & Harmon, 2017) not simply as a means of communication but as a historical repository for a people's relationship with the land, the living natural web, and for entire worldviews. It has been argued that languages are transmitted through processes similar to genes, and a positive correlation exists between major language and genetic groupings (Barbieri et al., 2022; Cavalli Sforza & Menozzi, 1994). Although the linguistic richness of European countries cannot be compared to certain areas of the planet recognised as cultural hotspots (see Skutnabb-Kangas & Harmon, 2017), the linguistic diversity observed in Italy has been enriched by influences from Eastern, Central, and Western Europe, so much so that it is greater than that of other continental countries with comparable population size and geographical extent, both in terms of languages spoken and probability of randomly extracting two individuals of different mother tongues (Anagnostou et al., 2022). This pattern, mirrored by significant differences in ancestry as a result of migration, admixture, and isolation have generated in Italy the largest degree of population structure detected to date in Europe (Anagnostou et al., 2022; Destro Bisol et al., 2008; Raveane et al., 2019; Sazzini et al., 2020). An important role is played in this regard by linguistic minorities of German, Occitan, Provençal and Slavic derivation in the north, Croatian in the centre, and Greek and Albanian in the south and on the islands, most of whom are safeguarded by the Italian Constitution.[3] Numerous studies have been conducted in these communities (e.g., Bellia & Pieroni, 2015; Di Tizio et al., 2012; Mattalia et al., 2013; Mattalia et al., 2020a, b; Nebel et al., 2006; Pieroni & Cattero, 2019; Pieroni & Quave, 2005; Sarno et al., 2017; 2021b). Among them are the Arbëreshë, descendants of Albanians who emigrated in several flows from the fifteenth to the eighteenth centuries to diverse central and southern

[2] Definitions of terms used in this study are given elsewhere; e.g., *Biodiversity* (CBD, 1992, 2016); *Culture* (Brey, 2007); *Cultural Diversity* (Pretty et al., 2009; UNESCO, 2001); *Biocultural diversity* (Bridgewater & Rotherham, 2019; Díaz et al., 2015; Maffi, 2007, 2018; Posey, 1999).

[3] "*... la Repubblica tutela la lingua e la cultura delle popolazioni albanesi, catalane, germaniche, greche, slovene e croate e di quelle parlanti il francese, il franco-provenzale, il friulano, il ladino, l'occitano e il sardo*" (Gazzetta Ufficiale della Repubblica Italiana, 1999).

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Italian inland areas (Dessart, 1982; Tagarelli et al., 2005). Studies on the Arbëresh demonstrate the prolonged intercultural exchange between a local culture (South Italian) and an 'imported' one (Albanian). This exchange has involved not only language, but also many other aspects of social life, such as ethnobotanical knowledge (Pieroni, 2003; Pieroni et al., 2002a, b).

Of particular interest are case studies investigating the correlation between "linguistic islands" in Italy and their genetic characteristics. Research in the eastern Alps (Lessinia, Sauris, Sappada, and Timau) (Capocasa et al., 2013), western Alps (Walser and Romance minorities in the Upper Lys Valley) (Boattini et al., 2011), among the Ladin- and Germanic speaking Cimbri in Trentino (Boattini et al., 2021; Coia et al., 2012), and among the Alghero and Carloforte in Sardinia (Maxia et al., 2007; Moral et al., 1994; Robledo et al., 2012) all show remarkable genetic structures shaped by a combination of a founder event and continued isolation even from culturally-related neighbouring populations, with ethnicity playing an important role in increasing endogamy and inbreeding rates related to consanguinity and other cultural factors. In this respect, surnames are shown to be clearly structured according to regional geographic patterns particularly in southern Italy and Sicily (Boattini et al., 2018), but not in Trentino (Coia et al., 2012).

A similar pattern of limited genetic diversity, high frequency of specific haplogroups, and an outlier position within the Italian genetic space is reported among the Commons in northern Italy. These are peculiar institutions of medieval origins whose key feature is not a minority language, but a tight relationship between population and territory, mediated by the collective property of shared resources (Sarno et al., 2021a).

Some congruence has been noted between the geographic ethno-linguistic repartition of human communities with the genetic clusters of economically important plants (i.e., walnut and chestnut) across the range of these species in Eurasia, suggesting that phenomena such as isolation by distance, landscape heterogeneity, and cultural boundaries may simultaneously promote human language diversification and differentiation of plant species across the same geographic region (Pollegioni et al., 2020).

Biocultural Dynamics in Italy

The term *Biocultural Landscape* refers to a complex set of cultural assets that represent the combined work of nature and humans (Merola, 2021; UNESCO, 2019) that is theoretically related to *Cultural Landscape*[4] and *Biocultural Refugia.*[5] Some studies in Italy have focused on specific biocultural landscapes and their importance in preservation of environmental resources, agro-ecosystems functionality, landscape diversity and traditional and cultural memory; e.g., the traditional landscapes of fruit trees and vines (Barbera & Biasi, 2011), olive trees in Apulia (Mohamad et al., 2013), cork oaks in Sardinia (Vogiatzakis et al., 2005), or the silvopastoral systems with carob trees in Sicily (Venturi et al., 2021). A wider assessment of Italian biocultural landscapes has been carried out led by the institution of the National Register of Historical Rural Landscapes[6] (Agnoletti, 2010, 2013).

A new direction in biocultural diversity studies that has impacted research in Italy has been spearheaded by the independent *Intergovernmental Platform on Biodiversity and Ecosystem Services* (IPBES) (https://www.ipbes.org), established in 2010 with the aim to strengthen the science–policy interface for the conservation of biodiversity and sustainable development. IPBES alone is responsible for popularizing terms such as *Ecosystem Services,*[7] which includes *provisioning services* (e.g., food and water), *regulating services* (e.g., regulation of floods, drought, land degradation, and disease), *supporting services* (e.g., soil formation and nutrient cycling), and *cultural services*[8] (e.g., recreational, spiritual, religious, and other non-material benefits) (MA, 2003). Another term coined by IPBES that is increasingly gaining popularity is *Nature's Contributions to People* (NCP)[9] (Pascual et al., 2017; originally *Nature's benefits to people*, Díaz et al., 2015). Studies on distribution of NCPs have explored potential priority areas for conservation in Europe, including in Italy, that will co-benefit both nature and people (O'Conner et al., 2021) and have demonstrated a substantial global overlap between areas that provide the majority of NCPs ("*critical natural assets*") with hotspots

4FL01 4FL02 4FL03 [4] Defined as geographic areas in which the relationships between human activity and the environment have created ecological, socio-economic, and cultural patterns and feedback mechanisms that govern the presence, distribution, and abundance of species assemblages (Farina, 2000; Taylor & Lennon, 2011).

[5] Defined as the physical places that not only shelter farm biodiversity, but also carry knowledge and experiences about practical management of how to produce food while stewarding biodiversity and ecosystem services (Barthel et al., 2013). 5FL01 5FL02 5FL03 5FL04

[6] The National Register can be accessed online. https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/17423 6FL01 6FL02

[7] Defined as the benefits people obtain from ecosystems (MA, 2003). 7FL01

[8] Defined as non-material benefits people obtain from ecosystems through cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism (MA, 2005; Reyes-García et al., 2015). 8FL01 8FL02 8FL03 8FL04 8FL05

[9] Ddefined as all the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life (Díaz et al., 2018). 9FL01 9FL02 9FL03 9FL04

for biological and cultural diversity (Chaplin-Kramer et al., 2022). In addition to this approach, increasing attention is being paid to the mutual interactions that connect peoples and their environments, so that, while NCPs focus mainly on the benefits that humans can derive from natural elements, *People's Contributions to Nature* draws attention to the central role that indigenous peoples and local communities and their long-term, low-impact activities play in shaping the ecological and biological interactions of the local environment (Ojeda et al., 2022; Reyes-García et al., 2014).

Biodiversity as a Driver of Cultural Diversity

The accumulated body of knowledge, practices, and beliefs of locals about their environment, variously termed *Traditional Ecological Knowledge* (TEK), *Local Environmental Knowledge* (LEK), *Indigenous knowledge* (IK), *ecoliteracy*, or simply *ecological knowledge*, is a key element in biocultural studies (Hernández-Morcillo et al., 2014; Nakashima et al., 2012; Pilgrim et al., 2008; von Glasenapp & Thornton, 2011; Zent & Zent, 2013). Among the main components of such ecological knowledge are ethnobotanical and ethnozoological aspects.

Ethnobotanical studies have highlighted the significant and crucial role of TEK, which encompasses a range of traditional land and resource management techniques (Anderson, 2005). The botanical biodiversity of a landscape is correlated with the richness of medicinal and culinary traditions of the local peoples and richness of their vocabulary. Italian local food products show an enormous amount of cultural diversity,[10] undoubtedly influenced by local elements of biodiversity (e.g., wild greens, mushrooms, berries, fish and other seafood etc). Another prominent example is cheese, where the organoleptic qualities and taste of milk for dairy products are heavily influenced by the species composition of grasses growing in local pastures (Carpino et al., 2004; Povolo et al., 2012).

The ethnobotanical literature in Italy is very rich; however, while the majority of studies investigate local traditions and practices in one or a few regions of Italy, nation-wide studies are rare. Summaries are given by Guarrera's encyclopedia of traditional and folk medicine in Italy (Guarrera, 2006), Ghirardini et al. (2007), who reported on wild food plant consumption in 21 local communities across the country, and Monari et al., (2022), who present a dataset of wild and cultivated plants traditionally used as medicinal remedies in Italy. Comparative studies between Italy and Bulgaria (Leporatti & Ivancheva, 2003) and Italy and Tunisia (Leporatti & Ghedira, 2009) show considerable convergence in therapeutic uses of many species, signaling shared heritage between Italy and other nations. Noteworthy is the database for Italian wild edible plants of Paura et al., (2021), in which 1103 taxa are documented to be used as alimurgic species, a significant contribution to the understanding of the wealth of uses of edible vascular plants throughout Italy.

Traditionally, ethnobotanical research has developed more in central-southern Italy than in the north (Guarrera, 2005; Guarrera & Lucia, 2007). Most regional ethnobotanical studies follow Guarrera (2006) in grouping traditional plant uses into discrete categories (e.g., medicinal, cosmetic, nutrition, religious, games, etc). In a series of relevant publications, Motti and colleagues have reviewed traditional herbal remedies across Italy used in pediatric health care (Motti et al., 2018), in women's health care (Motti et al., 2019), in managing anxiety and insomnia (Motti & deFalco, 2021), as herbs and spices (Motti, 2021), and in making alcoholic beverages (Motti et al., 2022).

Other examples of floristic diversity driving cultures include local economies based on the transformation or use of a specific tree or shrub found only in certain regions; e.g., broom makers in Tuscany and Abruzzo using *Erica scoparia* (Congedo, 2019) or *Sorghum* spp. (Serafini, 2011), wine barrel makers using *Abies alba* from (planted) forests in Casentino, Tuscany (Anonymous, 2021), *Ampelodesmos mauritanicus* and other fibre plants used in basket weaving in Mt. Aurunci Regional Park in Central Italy (Novellino, 2006), collection of resin from pine trees in Valvestino, Lombardy (GardaPost, 2021), or the historical "chestnut civilization" of the lower Alps and Apennines (Rao, 2013). In addition, diverse traditional plant nutraceuticals are used to improve animal health as well as the quality of milk and dairy products. Such ethnoveterinary practices have been documented in some regions of Italy, e.g., in central Lucania, Basilicata (Guarrera, 2006; Pieroni et al., 2004).

Zootherapy, the treatment of human ailments with remedies derived from animals or their products, is a neglected field of study compared to medicinal plant research despite its prevalence in traditional medical practices worldwide. One study identified 80 animal species used in a wide range of zootherapeutic remedies in Italy, Albania, Spain, and Nepal, representing four phyla (Annelida, Arthropoda, Chordata, Mollusca) (Quave et al., 2010).

It should be noted that these traditional preferences are prone to change over time. An example is the recent development of interest in wider consumption of edible mycorrhizal fungi in Sardinia, a society that has traditionally shunned using fungi as food, thanks to increasing contacts and influences from continental Italy, a strongly mycophilic country (Comandini et al., 2018; Pérez-Moreno et al., 2020).

[10] See, for example, *Presìdi in Italia*: https://www.fondazioneslowfood.com/it/nazioni-presidi/italia-it/

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Culture as a Driver of Biological Diversity

Human cultural activities in many cases have modified selective pressures and shaped local biodiversity and ecosystems. Land use change is the main direct cause of biodiversity loss, especially in large-scale agricultural and productive forestry operations. This factor alone drives an estimated 30% of biodiversity decline globally (IPBES, 2019; UN Environment 2019). In addition, depopulation and abandonment of traditional practices, especially in the mountainous areas, affect the land use and land cover inducing the modification of the landscape mosaic. The latter process facilitates secondary forest expansion, modifying the structure, floristic composition, stand density, and regeneration capacity of forests, thus changing the ecosystems' functionality and resilience (Chauchard et al., 2007; Vacchiano et al., 2017). These processes have sometimes been considered a form of "landscape degradation" (Marchetti et al., 2018; Palombo et al., 2013), however using this term for the return to natural processes to areas managed for centuries by humans is highly controversial.

Abandonment of arable land and pastures since the 1960s in Italy has resulted in an increase in forests and artificial areas and a decrease in croplands and pastures (Falcucci et al., 2007; Malandra et al., 2018). The loss of open habitats in favour of afforestation processes has led to decreased fragmentation and patchiness (Geri et al., 2010) and consequently a decrease in species connected to cultural landscapes (Amici et al., 2015) and an increase in species linked to natural habitats in different parts of peninsular Italy (Amici et al., 2013; Lelli et al., 2021). Changes in species composition have also been noted in the fauna, with forest birds, ungulates, and carnivores increasing, while typically Mediterranean species are decreasing (Falcucci et al., 2007). Studies in Italy have shown that cessation of traditional farming in depopulated areas results in spontaneous reforestation accompanied by simplification and homogenization of the original mosaic, with no intermediate fragmentation process (e.g., Bracchetti et al., 2012; Marchetti et al., 2018).

Various efforts have been undertaken to valorize biocultural heritage and combat abandonment of traditional landscapes, depopulation, and the consequent loss of knowledge, practices, and landscape features, e.g., in the area of Lake Trasimeno in Umbria (Marchesini & Parbuono, 2022), Garfagnana in northern Tuscany (Belletti et al., 2022), or the Italian Inner Areas in Molise (Trivisonno, 2022). These projects focus either on sustainable rural territorial development, or on preservation of particular aspects of rural lifestyles, e.g., craftsmanship of iron, terracotta, wood, and textiles etc., by the process of "re-peasantization" with the aim of recovering traditional knowledge from the past and combining it with creative innovations to accommodate new expectations and multifunctionality (Bindi, 2022a). Studies on biocultural values of traditional agricultural activities such as apiculture in Piedmont and Liguria (Hearn & Dossche, 2016) or preservation of local breeds of sheep in Basilicata (Sardaro & La Sala, 2021) also highlight the importance of combination of such historical practices with new innovative methods and allow further income to farmers and preserve their heritage.

In the Alps, animal herding and grazing was historically linked to larch forests since they have a light canopy and allow for good grass growth in the understory. As a consequence, these forests were also shaped to be better grazing lands. Larch forests today remain a heavily modified ecosystem, a real cultural landscape, and a good example of bidirectional influence or self-reinforcing feedback between biological and cultural diversity (Garbarino et al., 2010; Motta & Lingua, 2005; Schulze et al., 2007).

Itinerant pastoralism (transhumance) is a form of extensive farming that is based on the continuous movement of flocks following the availability of grasslands for pasture along different and complementary ecosystems (Nori & De Marchi, 2015). This ancient practice is deeply rooted since the Roman Empire and has influenced settlements, routes, local landscapes, and sociocultural structures in Italy. Recent studies on transhumance in Southern Apennines (Troiano et al., 2021), Collina Po protected area in Piemonte (Genovese et al., 2022), Friuli (Lozej, 2022), and the Alms in South Tyrol/Alto Adige (Colombino & Powers, 2022) not only underline the importance of transhumance grazing as a valuable management tool to maintain high biological diversity in mountain pastures, but also highlight the latent conflicts in areas where traditional farming activities coexist with a renewed and multifunctional way of inhabiting the land. The "heritagization" and "touristization"[11] of transhumance in recent years, accompanied by controversial uses of pastures and proliferation of illegal permits, pose serious challenges to efforts to support pastoral activities, an unresolved area in European or Italian agricultural policies for this sector (Bindi, 2022b).

There is a growing recognition that Sacred Natural Sites (SNS)[12] form hotspots of biocultural diversity and significantly contribute to conservation in traditional non-western societies. Ritual pilgrimage to these sites in south Italy (e.g., Campania) is mostly linked to Christianity (Francescato & Talamo, 2012), although it is likely that many of the Italian SNS have been inherited by Catholicism

[11] E.g., "*Ecomuseum of Pastoralism*" in Pontebernardo, Cuneo, and the *Ecomuseum Itinerari Frentani*, Larino (Belligiano et al., 2021). See also studies in Veneto and Lombardy (Chang et al., 2010; Iseppi et al., 2015), in Amalfi coast (Merola, 2021), and in the area of Judicarie, Trento (Povinelli et al., 2022).

[12] Defined as areas of land or water having special spiritual significance for peoples and communities (Wild & McLeod, 2008).

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from earlier forms of religion, perhaps with animistic features, whose vestiges have been preserved in popular beliefs and festivities. Interestingly, the practices of different monastic orders have had different effects on forest composition and structure: While Franciscans preserved (and used) the "native" forests as a form of respect for the creation, the Benektin and Camaldulese orders planted and managed evergreen *Abies* trees as a symbol of eternity and spiritual aspiration (Redazione Toscana Oggi, 2015). The Camaldulese monks created the first forest management "law" of the world (*Codice Forestale Camaldolese* of 1520) and their abbey at Vallombrosa is the birthplace of Italian Forest Science Universities (Romano, 2010).

In Central Italy (Tuscany, Marche, Umbria, Lazio, Abruzzi, and Molise), a high proportion of sacred Catholic sites are located in natural areas. These SNS harbor higher richness of plant and lichen species and a more valuable species pool, and are also important for conserving stands of large trees and habitat heterogeneity across different land-cover types (Frascaroli, 2013; Frascaroli et al., 2016; Nascimbene et al., 2019). These patterns are related not only to pre-existing features, but also to traditional management. Ritual and processual interplays between humans and non-humans are shown to be essential for sustaining the resilience of these sites, and continuation of traditional management practices are crucial for conservation of SNS sites (Frascaroli, 2016; Frascaroli et al., 2016; Frascaroli & Verschuuren, 2016). In the Italian forest landscape where old-growth stands are practically absent, sacred forest sites may provide unique old-growth structures and buffer anthropogenic disturbances (Nascimbene et al., 2019).

Can Present Biocultural Diversity Be Formally Assessed in Italy?

In order to empirically assess the biocultural diversity of any given area, a scientific approach requires accurate measurement of the variables involved. Efforts to quantify biological or cultural diversity both rely heavily on selected proxies. Biodiversity is usually extrapolated from the known richness of one or a few groups of plants or animals in an area. This task however is much more complicated with respect to cultural diversity, as fewer quantifiable proxies exist in the cultural context.

The global *Index of Biocultural Diversity* (IBCD) proposed by Loh and Harmon (2005) is a measure of the average of biological (BD) and cultural (CD) diversities in an area (IBCD=BD + CD/2), where biological diversity is defined as the average of diversity of mammals and vascular plants (BD = MD + PT/2) and cultural diversity as the average of linguistic, religious, and ethnic diversity (CD = LD + RD + ED/3). Other indices attempt to quantify certain aspects of biocultural diversity, e.g., the *Cultural Food Significance Index* (CFSI) which aims to evaluate the cultural significance of wild edibles (Pieroni, 2001), or the *Dietary Species Richness* (DSR) as a measure of food biodiversity (Lachat et al., 2018). More sophisticated mathematical indices for biocultural complexity have been proposed by Reyes-Valdés and Kantartzi (2020), who present an information theory approach to biocultural complexity, by Reyes-García et al., (2023), who utilize the "*Culturally Important Species*" concept (CIS) to assess the biocultural status of specific components of nature that matter to people, and by Zent and Maffi (2009), who introduce *Vitality Index of Traditional Environmental Knowledge* (VITEK) as a measure for loss/retention of traditional environmental knowledge between generations (Zent & Maffi, 2009). Indices such as these generally do not take into account the fluid nature of culture and do not have the capacity to cater for historical change (Beinart, 2014). They rely on proxies (i.e., religion or languages) that favour zones of high indigenous and linguistic diversity and are not very informative in industrialized nations such as Italy, or are otherwise too data-demanding and time-consuming to calculate. Even though new studies often employ modern technologies and novel methodological approaches to collect and analyze data related to traditional landscapes and historical ecology (e.g., Ferrara & Wästfelt, 2021 in Sicily, or De Pasquale & Livia, 2022 in Vallecorsa, Lazio), in our review of literature we did not find any significant and focused attempts to quantitatively measure biocultural diversity in Italy.

Biocultural Projects in Italy

Over the past two decades, several national and international projects in Europe and Italy have explicitly or implicitly focused on biocultural diversity in Italy with various outcomes. Among these are: RUBIA (circum-Mediterranean ethno-botanical and ethnographic heritage in traditional technologies, tools, and uses of wild and neglected cultivated plants for food, medicine, textiles, dyeing, and handicrafts, 2003–2005) (Frank, 2011); the ECONET project "Sustainability using Ecological Networks" of the European Commission's Life Environment Programme (1999–2004), with over 1500 people involved in three countries (Italy, the UK, and the Netherlands), which was successful in raising awareness on the concept of ecological networks, supported its integration into farming, forestry, and land regeneration, and its incorporation into regional and local land use and management policies to overcome the problems of habitat loss, fragmentation, and species isolation (Pungetti, 2013); The Green Pilgrimage Network, launched in 2011 at Assisi (Umbria) by the Alliance of Religions and Conservation (ARC, https://www.arcworld.org), attempting to build a network of Sacred Sites to protect a valuable patrimony of natural, historical and architectural sites linked to Christianity

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(Francescato & Talamo, 2012); and BIOESSaNS (Biodiversity and ecosystem services in sacred natural sites), implemented since 2010 to address the nexus between SNS and biocultural diversity in Central Italy, with three distinct phases: (1) identification, categorization, and mapping of the SNS; (2) floristic assessment and comparison of a sample of thirty representative SNS as well as control non-sacred sites; and (3) interviews and participant observations at the same sample SNS (Frascaroli, 2013; Frascaroli et al., 2019; Frascaroli & Verschuuren, 2016; Zannini et al., 2021, 2022).

The Atlante Bioculturale Italiano is an Istituto Italiano di Antropologia project concerning the genetic and genomic diversity of Italian populations in relation to their cultural diversity using a systematic analysis of mitochondrial DNA and Y chromosome diversity in a large set of communities, including those subject to geo-cultural isolation factors. Their results show that the magnitude of genetic diversity among them is greater than that observed throughout the rest of the European continent, largely driven by the multitude of geographic and linguistic isolates across the country (Anagnostou et al., 2022; Capocasa et al., 2014).

Another program, Globally Important Agricultural Heritage Systems (GIAHS) (2002-present), was established by the Food and Agriculture Organization (FAO) (https://www.fao.org/giahs) that included traditional lemon gardens and the terraced agricultural system on Amalfi coast, the olive groves of the slopes between Assisi and Spoleto, and Soave traditional vineyards (Pinheiro et al., 2022). The Italian Ministry of Agricultural, Food, and Forestry Policies conducted a survey in 2009–2010 that identified 123 areas across in Italy with an average size of 1300 ha in order to establish a national monitoring system for traditional rural landscapes, which led to the establishment of the Italian National Register of Historical Rural Landscapes that also serves as the Italian list for potential application to GIAHS. These landscapes are characterized by a long history of human occupation, the presence of traditional practices, typical foods, complex landscape mosaics and high biocultural diversity. The resilience of these systems was demonstrated when, despite climatic and socioeconomic pressures, a second survey five years later found no major changes between 2014 and 2019 (Agnoletti et al., 2019; Agnoletti & Santoro, 2022).

Discussion and Conclusion

Italy shows a high number of mutual interactions between humans and their ecosystems, but to date no common drivers and patterns between biological and cultural diversity have been identified. Among the factors underlying the remarkable diversity in modern Italian human populations, Anagnostou et al. (2022) list migration, isolation, and natural selection generated by the interplay of geography, environment, and culture. This maybe a good starting point; however, it only views Biocultural Diversity from the perspective of human genetics. Different causative patterns drive biological and cultural diversity, and the problem of quantification - due perhaps to an inherent incommensurability between the two dimensions - further impedes progress. Thus, a comprehensive analysis of biocultural diversity in Italy remains elusive.

To date, ethnobotanical studies in Italy have been the main sources of robust analysis of the interactions and links between plant biodiversity and cultural diversity. These studies show a remarkable diversity of biocultural links, most probably due to the diversity of Italian flora, but more specifically due to the cultural diversity that the country still hosts, possibly attributed to the interplay between geography and history. Proofs of these patterns can be found, for example, in the remarkable number of landraces of cultivated plants, or the huge diversities of local food products and cuisines, confirmed by over 200 ethnobotanical studies conducted on wild flora in the past 50 years. In particular, ethnobotanical studies specifically conducted among linguistic and religious communities in Italy have shown remarkable idiosyncratic and distinctive patterns of wild plant uses, although often mitigated by the usual phenomena (such as urbanization and globalization) that in the last decades have eroded TEK in industrialized nations and therefore possibly diluted biocultural differences. The erosion of TEK has been significant due to the lack of direct contact with nature while tending animals, agricultural fields, or home gardens, suggesting that there is a very urgent need for further in-depth studies on plant biocultural diversities in Italy and to document this knowledge before it is lost to future generations (Pyle, 1993; Quave et al., 2012; Soga & Gaston, 2016).

Given global urbanisation processes and the abandonment of many mountain and remote areas driven by contemporary socio-economic upheavals, the idea of preserving cultural landscapes as they were for many centuries seems impractical. In Italy and other industrialized nations, parts of traditional landscapes will inevitably return to nature in a process that is now defined as “rewilding” (Navarro & Pereira, 2012; Perino et al., 2019). This can be seen as a positive development in human-nature interactions, since it will contribute to biodiversity preservation (Genes et al., 2019; Nogués-Bravo et al., 2016). Nonetheless, there is an urgent need to develop a proper understanding of a potential new equilibrium in human-nature interactions, where the return of parts of the previously-traditional landscapes to nature leads to sustainability in nature-culture dynamics (Mikołajczak et al., 2022; Schulte to Bühne et al., 2022).

We also note that some areas of biocultural diversity seem to be severely under-studied in Italy, e.g., the impact of invasive, exotic, and alien species on biocultural diversity, or biocultural diversity with respect to marine environments.

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Collecting and analyzing in a quantitative way these and other relevant data will be fundamental in understanding and creating an index of Biocultural Diversity that can be combined with other quantitative indices.

In addition, in this review, we did not investigate the historical and anthropological aspects of biocultural diversity in Italy. A separate review on the latter topic might be interesting from a methodological point of view, as certain case studies may be applied to a modern context where variability in material culture and traditional habits can be measured while comparing it against biological variability and indices of human mobility and interconnectedness.

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