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NOTES

HUMAN IMPACT ASSESSMENT ON THE SICILIAN AGROECOSYSTEMS THROUGH THE EVALUATION OF MELLIFEROUS AREAS

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ABSTRACT – Human activity has influenced and profoundly changed the territory of Sicily. The increase of urban and suburban areas, transport infrastructure and the changes in land cover use, have led to a fragmentation of the landscape and consequently, of areas of nectariferous importance. Honey is one of the products most tied to and influenced by the land composition since it derives its main features from the environment, vegetation and flora of the areas in which the bees move. The goal of this work is to built a map of the melliferous areas present in Sicily and then to chart and assess the state of fragmentation and disturbance of areas of apiarian interest, caused by the presence of urban infrastructure and road networks, so as to better define future planning guidelines for the protection and management of the environment for the preservation of honeybees and of beekeeping activities.

KEYWORDS: HUMAN IMPACT, GIS, FRAGMENTATION, URBAN INTERFERENCE, NECTARIFEROUS RESOURCES, MELISSOPALYNOLOGY

INTRODUCTION

Human activities have profoundly modified the territory of Sicily with the effect that both the native vegetation and agroecosystems are now subsumed into a complex artificial system. One of the effects caused by human pressure is landscape fragmentation (Di Giulio et al., 2009; Fischer & Lindenmayer, 2007) leading to the reduction of habitat in time and space and the separation into small areas that may become isolated from each other. Consequent to the fragmentation of these ecosystems are a significant loss of biodiversity (Brooks et al., 2002; Fahring, 2003, Hoffmeister et al., 2005), a strong alteration in plant richness and composition and a substantial breaking up of nectariferous areas.

Sicily was a territory characterized by high floristic and vegetation diversity thanks to the presence of several endemic species and interesting vegetation communities that represented important melliferous resources for the production of different honey types. Recently, the increasing urbanization has led to substantial fragmentation of the landscape and a considerable reduction of the areas traditionally used for the production of honey. Moreover, the impoverishment of nectariferous resources, due to the reduction or disappearance especially of those areas with a strong tradition of beekeeping, is reflected in both qualitative and quantitative production of various types of honey.

Several studies have been carried out to evaluate habitat fragmentation through the application of landscape metrics (Collinge, 1996; Hargis et al., 1998; Plieninger, 2006; Aparicio, 2008; Geri et al., 2010); however, few studies have been performed to evaluate current and potential honeybee pastures (Miori & Matteotti, 2007; Amiri & Mohamed Shariff, 2012). To our knowledge, there are no existing studies assessing the state of fragmentation as it is today. Buonanno & Aronne (2004) analyzed the distribution of honey plants and their blooming periods using GIS spatial

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analysis, Bernardinelli et al. (2005) showed a preliminary GIS application in the "Valli del Natisone" to manage relevant information for beekeepers concerning the location of apiaries, nectariferous and environmental resources; Bertolo et al. (2003) used GIS for mapping the hives. Serrano et al. (2008) created GIS application for the management of honey produced in Sierra Morena, Filis et al. (2003), developed an integrated geographical expert database system for the beekeeping.

The aim of this work is to analyse the presence and quality of the nectariferous areas and their fragmentation in the Sicilian territory as a result of human activity, in particular the effects produced by the dissection of the territory linked to the road network. Geographic information systems (GIS) has long been used for suitability mapping and land use analysis (Noor et al., 2008) and thanks to these applications it is considered one of the most important system for spatial planning and management (Collins et al., 2001; Malczewski, 2004).

This study is part of the project carried out under the national program MIPAF (2008-2010), implementing the CEE guideline 1234/2007 (ex Reg. CE 797/04) "*Azioni dirette a migliorare la produzione e commercializzazione del miele*", azione C - sottoazione C1: *Mappatura delle aree nettarifere*.

Materials and methods

The study area comprises the whole of Sicily, including the smaller Aeolian and Egadi islands. The region is characterized by very different soil types and topography, making it suitable for a wide variety of agroecosystem and land-use. A database was designed to accommodate different data: Sicilian flora, vegetation data following the phytosociological method of Zurich-Montpellier school (Braun-Blanquet, 1964), melliferous plants (for nectar and/or pollen), apiarian interest of melliferous plants (Fascetti and Spicciarelli, 2001; Simonetti et al., 1989; Ricciardelli D'albore & Persano Oddo 1978; Ricciardelli D'albore, 1998; Ricciardelli D'albore & Intoppa, 2000), geographical features, land cover use and kinds of crop type. (Persano Oddo et al., 2002; Amiri & Arzani, 2010; Amiri et al., 2011). The analysis of the vegetation has been integrated by performing several field surveys between 2008-2010 to describe the existing plant communities.

The different data were incorporate into the GIS and used to generate a number of different thematic maps.

All the maps, digitized and handled with ArcGIS 9.2. GIS system. The contribution of GIS was considered not only as a method for data gathering but also as a tool for visualizing a composite overlay map.

The different types of habitat identified by the legend of Carta Natura 2000, an EU wide network of nature protection areas established under the 1992 (43/92//EEC), are grouped in macro-categories on the basis of their ecological and vegetational affinity. We obtained overall 23 types of apiarian pasture. First of all, a digitized georeferenced map at a scale of 1:10.000 containing the CTR (Regional Technical Map) of Catania, Siracusa, Ragusa, Messina, Caltanissetta, Enna, Palermo, Trapani, Agrigento was built up. Next, the types of pasture previously typified, have been redefined and inserted in the map to built up the map of Apiarian Pastures (layer 1) at a scale of 1:10.000 for all Sicilian provinces through interpretation and photo-restitution of an orthophotomap (IT 2000 and ATA 2007-2008), and extensive ground survey.

Afterwards, an apiarian evaluation index was given, comprising five classes: 0=Null; 1=Occasional; 2=Limited; 3=Good; 4=Excellent (Persano Oddo et al., 2003; Piazza et al., 2005, Carini et al., 2001, Amiri & Mohamed Shariff, 2012), to the different honeybee pastures types identified, in order to generate the Apiarian Interest map at a scale of 1:10.000 (layer 2). In particular it should be highlighted that the null value index also includes the artificial and urban areas. Through the index we were able to provide a measure of the availability and of the polleniferous and nectariferous resources in the plant communities observed. The index includes higher/lower attractiveness of the plant species (Fascetti & Spicciarelli 2001; Simonetti et al., 1989) and their abundance/dominance in the plant communities (according to Braun-Blanquet,1964).

Finally, Urban Interference map (layer 3) and Fragmentation map (layer 4) were generated at a scale of 1:10.000. The shape file of road networks of the Sicilian provinces was used and a buffer of 500 m was created, taking into account this range as the average value of the disturbance caused by anthropogenic pollution on bee communities (Di Giulio, 2009).

The map of the Urban Interference, at a scale of 1:10.000 was built up by overlaying the map of Apiarian Interest, with those of road networks. The Urban interference map show the disturbance caused by transport infrastructure and urban areas on honeybee pastures.

The map of Fragmentation at a scale of 1:10.000 was made by subtracting the thematic layer of the Urban Interference map from the map of Apiarian Interest map.

Results

We identified 23 types of apiarian pasture (Table 1) and among these, several have high interest for beekeeping such

the phrygana and *Citrus* orchards, for example. Furthermore, the data obtained show (Table 2) that a large part of the Sicilian territory has Good and Excellent apiarian interest and therefore a high suitability for beekeeping.

Table 1. Distribution of the twenty-three types of apiarian pasture, and their apiarian interest in Sicily.

Types of apiarian pasture	Apiarian Interest	Surface of provinces (ha)			
		Catania	Siracusa	Ragusa	Messina
Etna volcanic communities and lapilli fields	Null	15855.15	-	-	546.98
Rocky slopes	Limited	23.52	264.99	1.41	370.33
Coastal habitat	Null	367.96	791.75	533.96	1096.88
Inland water bodies and marshes	Null	2508.95	1913.14	330.43	183.52
Sclerophyllous woodland	Occasional	6512.53	5809.32	1631.39	-
Phrygane	Excellent	575.01	4731.16	1730.76	495.62
Matorral	Good	22196.95	4690.62	1042.80	66608.76
Coniferous (*Pinus halepensis*) woodland	Good	-	155.70	100.65	-
Permanent water courses	Occasional	2729.83	1474.62	501.07	6206.59
Grassland and agriculturally-improved pastures	Good	34895.97	41793.66	13365.21	58763.88
Coniferous and broadleaved plantations	Limited	23.95	2074.97	200.56	8625.21
Coniferous reforestation	Null	6532.48	-	4567.23	-
Deciduous broadleaved plantations	Limited	17441.39	1254.07	294.63	56728.23
Eucalyptus plantations	Excellent	4675.78	47.72	232.73	298.68
Ceratonia siliqua woodland	Excellent	-	879.94	27998.51	-
Citrus orchards	Excellent	52065.29	38761.85	4111.99	10474.22
Fruit orchards	Good	10307.67	32.05	3428.23	2208.94
Olea europaea groves	Occasional	8503.68	11103.73	11251.64	38228.86
Vineyards	Limited	6117.81	71.85	2972.28	13716.89
Arable land and Intensive mixed/ unmixed crops	Good	140460.23	83473.44	80075.57	42135.13
Castanea sativa plantations	Excellent	3350.85	-	-	4779.89
Robinia plantations	Excellent	-	11.88	-	225.82
Urban areas	Null	20131.87	10835.02	7068.09	12637.20

Table 1. (Continued)

Types of apiarian pasture	Apiarian Interest	Surface of provinces (ha)				
		Enna	Caltanisetta	Palermo	Trapani	Agrigento
Etna volcanic communities and lapilli fields	Null	-	-	-	-	-
Rocky slopes	Limited	64.44	151.18	2443.55	282.09	425.79
Coastal habitat	Null	1.62	331.94	498.33	1618.35	1102.11
Inland water bodies and marshes	Null	1743.67	611.10	1956.79	2234.31	1653.87
Sclerophyllous woodland	Occasional	1005.47	564.91	13081.31	2447.38	1245.25
Phrygane	Excellent	444.46	1466.95	1911.46	2423.00	4945.89
Matorral	Good	7522.01	1030.56	32901.95	8484.75	5421.74
Coniferous (*Pinus halepensis*) woodland	Good	-	-	-	-	-
Permanent water courses	Occasional	3625.65	3697.33	7632.32	1919.82	3984.06
Grassland and agriculturally-improved pastures	Good	56521.01	29652.74	107856.81	32415.23	52580.55
Coniferous and broadleaved plantations	Limited	213.29	1913.16	14473.78	4759.78	11071.06
Coniferous reforestation	Null	5056.25	4.10	916.40	380.43	213.66
Deciduous broadleaved plantations	Limited	4836.47	92.71	17666.46	8759.69	3532.97
Eucalyptus plantations	Excellent	11722.66	12447.05	2471.14	1707.63	3410.64
Ceratonia siliqua woodland	Excellent	-	-	-	-	-
Citrus orchards	Excellent	6424.92	568.56	10264.04	1585.64	4656.20
Fruit orchards	Good	2806.26	6310.17	4930.69	714.80	9387.06
Olea europaea groves	Occasional	14087.61	9667.50	64025.71	21371.31	34848.30
Vineyards	Limited	896.15	7907.48	18963.39	80053.50	38290.50
Arable land and Intensive mixed/ unmixed crops	Good	135373.60	130539.06	226681.70	89698.85	140262.82
Castanea sativa plantations	Excellent	-	-	107.92	-	-
Robinia plantations	Excellent	-	-	-	-	-
Urban areas	Null	4167.76	5874.30	20548.52	17321.14	17943.19

-, absence of apiarian pasture

Table 2. Distribution of apiarian interest in percentage in Sicily.

Apiarian Interest	Sicilian provinces								
	Catania	Siracusa	Ragusa	Messina	Enna	Caltanissetta	Palermo	Trapani	Agrigento
Null	12.78%	6.44%	7.74%	4.46%	4.28%	3.21%	4.35%	7.75%	6.24%
Limited	6.64%	1.74%	2.15%	24.49%	2.34%	4.73%	9.75%	33.74%	15.92%
Occasional	4.99%	8.75%	8.29%	13.70%	7.30%	6.54%	15.43%	9.25%	11.96%
Good	58.51%	61.92%	60.71%	52.33%	78.84%	78.72%	67.79%	47.20%	61.99%
Excellent	17.08%	21.14%	21.11%	5.02%	7.25%	6.80%	2.69%	2.05%	3.88%

Analysis of Urban interference map (Figure 1) and Fragmentation map (Figure 2) shows how Catania and Messina provinces have the greatest degree of fragmentation of nectariferous areas arising from the urban road network which also represents a barrier for a number of animal species, and it is the cause of mortality for the bees in collisions with vehicles (Di Giulio, 2009). In these areas the agroecosystems are mainly *Citrus* groves and chestnut woods that have excellent apiarian interest; 17.08% of the territory of Catania has Excellent apiarian interest, 58.51% Good; Messina has only 5.02% of Excellent apiarian interest and 52.33% Good apiarian interest.

Siracusa and Ragusa have a lowest degree of fragmentation and insularisation of nectariferous areas and present interesting vegetation types including plant species of high apiarian interest, such as maquis and phrygana of rosemary and thyme. In fact, a large part of the territory of Siracusa and Ragusa presents a percentage of 61.92% and 60.71% Good apiarian interest and a percentage of 21.14% and 21.11% Excellent apiarian interest respectively. These are the highest values among all the Sicilian provinces.

The agricultural landscape of Caltanissetta and Enna is

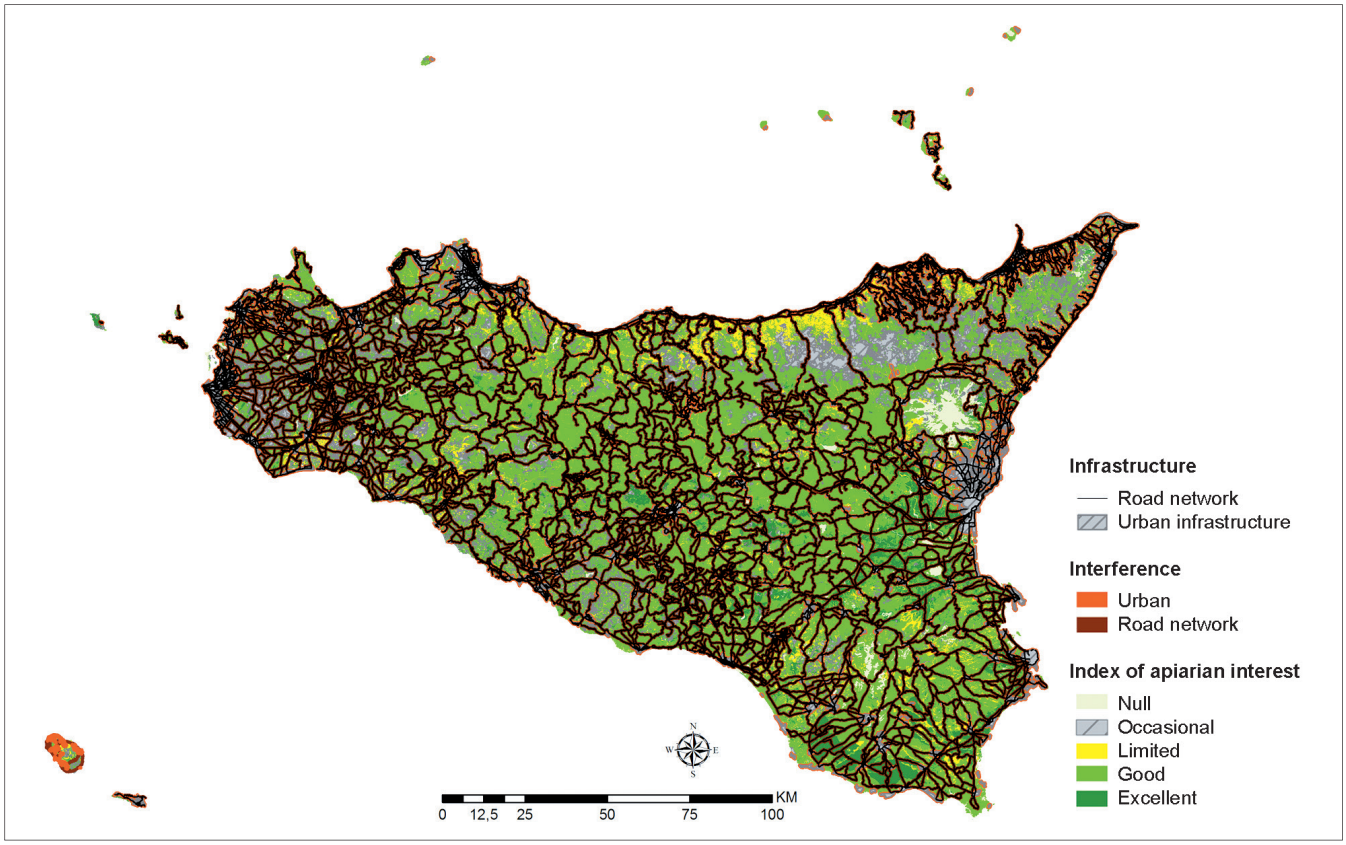

Figure 1. Pastures of Apiarian Interest: map of Urban Interference.

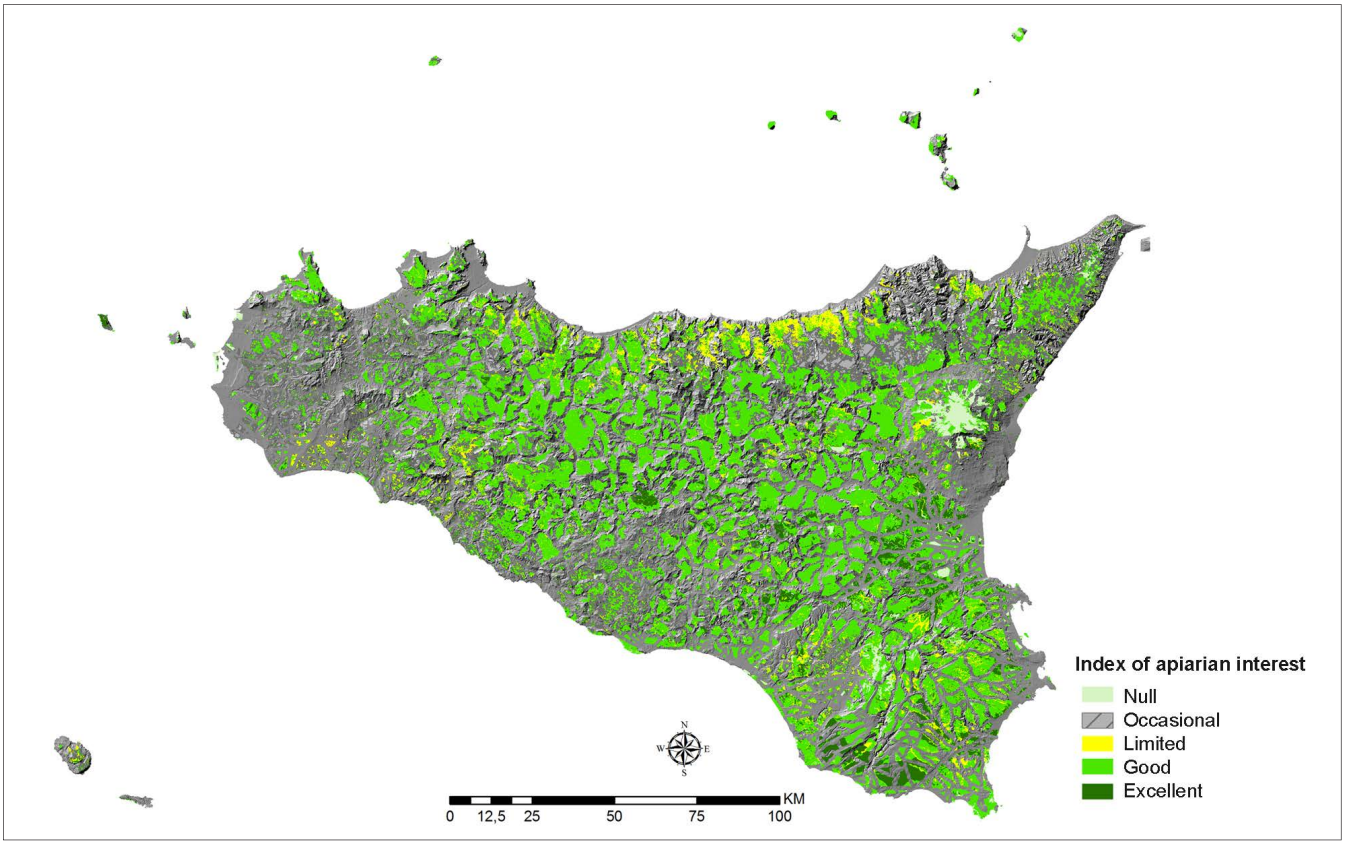

Figure 2. Pastures of Apiarian Interest: map of Fragmentation.

mainly characterized by widespread reforestation with *Eucalyptus* sp. and intensive arable farming, while natural habitats are reduced and degraded. Particularly widespread are homogeneous agricultural landscapes, often without connections to natural systems. The surfaces of these provinces have a percentage of 78.72% and 78.84% Good apiarian interest respectively. This fact is due to the wide spreads of arable lands, to the intensive mixed/unimixed crops, to the presence of grasslands and abandoned pastures. That's why the most of Umbellifere and multifloral honeys are produced in these areas

The provinces of Palermo, Agrigento and Trapani are the ones with the greatest number of areas of Limited and Occasional apiarian interest: the percentage are 9.75% and 15.43% for Palermo, 11.96% and 15.92% for Agrigento, 9.25% and 33.74% for Trapani.

In particular,the province of Trapani has the highest degree of fragmentation and insularisation of nectariferous areas and the most intensive concentration of roads and urban areas of all the Sicilian provinces. Most of these areas are characterized by areas of occasional or no apiarian interest, a condition that affects both natural and agroecosystems. The landscape is mainly characterized by complex crops: fragmented and irregular patches, close to urban centres, where the presence of infrastructure, produces a high fragmentation of agricultural farms.

Discussion

Sicily, thanks to its diversity of the flora (Conti et al., 2005) and vegetation, but also for the presence and richness of its agricultural landscape, is an area with a high vocation for beekeeping. The mapping of the nectariferous areas showed the presence of both natural vegetation aspects (Brullo et al., 2002) and of agroecosystems of high apiarian interest (De Leonardis et al., 1994; Ferrauto et al., 1996; Tomaselli et al., 1999). However, most natural environments are quite fragmented in the territory because of strong anthropic impact and the larger surviving unspoilt areas are mainly confined to mountainous and inaccessible areas, such as the highlands of the Nebrodi, Madonie and Peloritani mountains chains.

Most of the region of Sicily is characterized by the presence of agroecosystems. Extensive arable and horticultural crops, chestnut woods, *Citrus* orchards, *Eucaliptus* plantations,

almond and carob tree orchards are particularly widespread and it is from these areas that the main productions of multifloral and unifloral honey derive. In addition to those traditional types of honey such as *Citrus*, *Eucalyptus*, *Castanea*, there are other less well known varieties which come from carob tree, medlar or almond orchards. However, the intense human activity we find today, has led to an elevated impoverishment and fragmentation of both natural ecosystems and of agroecosytems as can be clearly seen from the two maps.

Some of the principal human activities which have contributed in recent times to the continuous modification of the landscape are: growing urbanization, increase in transport and agricultural infrastructure, agricultural mechanization and the simplification of the agricultural landscape. Some measures introduced by the European Community have shown a lack of sensitivity to the preservation of land and the maintenance of biodiversity and have contributed to the further fragmentation of the landscape by favouring some crops to the disadvantage of others and leading to the planting, uprooting, sowing or even the abandonment of a number of crop types. In addition to this, it must be added the incentive to use some particular cultivars characterized by sterility which while being the most profitable from an economic standpoint, bring a variety of problems. Among these, there is a considerable erosion of the genetic agrarian makeup and from a melissopalynological point of view a considerable reduction of the pollen in honey. An example is the monofloral honey of *Citrus* in which the percentage of pollen of *Citrus* sp. pl. can also be <10% in the presence of sterile cultivars (Ricciardelli D'Albore, 1998), as has been found in Sicilian honey.

Other changes that occur in agroecosystems and that affect the quality and quantity of honey production over time should be mentioned: the expansion of areas under cultivation, the use of specific methods of cultivation, indiscriminate use of herbicides, expansion of homogeneous agricultural landscapes. These practices, especially widespread in Sicily, produce a reduction of natural habitats and of buffer belts, contributing to a greater fragmentation and insularisation of these agroecosystems. From the qualitative viewpoint these modifications may engender, generally, variations in the pollinic spectrum of honeys (presence and/or absence of specific pollen types , and/or changes in the pollinic frequency). The native vegetation plays a significant part in the composition of pollinic spectrum of honey and it is thanks to the presence of these wild species that it is possible to determine the botanical and geographical origin of honey.

From the quantitative viewpoint the reduction or disappearance of specific crops could lead to a reduction in the purity of those monofloral honeys, but also at times to a significant decrease or complete disappearance of those honeys.

Conclusions

The analysis of the fragmentation map has highlighted a high state of fragmentation of the nectariferous areas caused by the presence of intense urbanization as illustrated in map of Urban Interference. In fact, this map shows the disturbance caused by the presence of transport infrastructure and of urban and suburban areas within the natural ecosystems and agroecosystems used by bees.

The maps produced are useful not only to identify those areas that are particularly valuable for beekeeping but also to point out those most sensitive to fragmentation processes due to high urbanization of the territory and so to better define the future planning guidelines for the protection and management of environment.

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