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DIVERSITY OF FLOWER-RICH HABITATS AS A PERSISTENT SOURCE OF HEALTHY DIET FOR HONEY BEES

Ildiko ARANY
MTA Centre for Ecological Research, KlebelsbergTihany, Hungary. and Szent István University, Doctoral School of Environmental Sciences, Gödöllő, Hungary
arany.ildiko@okologia.mta.hu

Agnes VARI
MTA Centre for Ecological Research, Tihany, Hungary.
vari.agnes@okologia.mta.hu

Reka ASZALOS
MTA Centre for Ecological Research, Tihany, Hungary
aszalos.reka@okologia.mta.hu

Katalin KELEMEN
Milvus Group Association, Targu Mures, Romania
katalin.kelemen@milvus.ro

Marton Attila KELEMEN
Milvus Group Association, Targu Mures, Romania.
kelemenam@gmail.com

Gabor BONE
Milvus Group Association, Targu Mures, Romania.
gabor.bone@milvus.ro

Eszter LELLEI-KOVACZ
MTA Centre for Ecological Research, Tihany, Hungary.
lellei-kovacs.eszter@okologia.mta.hu

Balint CZUSZ
MTA Centre for Ecological Research, Tihany, Hungary.
czucz.balint@okologia.mta.hu

Abstract

The ecosystem service 'honey provision' was mapped in two regional case studies in Hungary and Romania. The process followed the participatory approach, aiming to build the knowledge of local experts into locally adapted simple rule-based matrix models. Several types of forests, agricultural land and grasslands were considered valuable sources of pollen and nectar for honeybees. At the landscape level it was not only the single habitat types but also the diversity of them is what was found to best sustain the bee colony throughout the growing season. Natural status of ecosystems support flower richness and thus create benefits for nature conservation and apiculture alike. On the other hand, some invasive plant species with bad conservation reputation are also appreciated by beekeepers, which can create potential conflicts between the two sectors. Regional ecosystem service maps can assist cross-sectoral discussion, help harmonize land management and serve as tool for conflict resolution.

***Keywords**: Human geography, geoinformation science, interdisciplinary studies, demography, landscape ecology, ecosystem services*

1. INTRODUCTION

For the last 50 years, traditional low intensity agricultural landscapes have undergone considerable change in Central and Eastern Europe (CEE) (Kovács-Hostyánszki et al., 2016; Hartel et al., 2014, Ribeiro & Šmid Hribar, 2019), which affects beekeeping in several ways. The expansion of large scale homogenous croplands with mass-flowering crops and woodland plantations of nectar producing trees (in the Carpathian basin especially black locust (Robinia pseudoacacia)) has resulted in ample floral food resources available for short time periods, which enables beekeepers to produce large quantities of honey for the natinal and EU market. In contrary to the declining tendencies of beekeeping in several Western European countries, this sector has undergone considerable growth in Hungary and Romania, and now these two countries are amomg the top five honey exporters in he EU (EC 2013). In the recent 10 years in Hungary, annually 30-50% of the marketed honey have originated from black locust, while another 10-30% from oilseed rape and sunflower. At the same time, diversity of agricultural crops, habitats and wild flowers have declined, causing shortage of foragable flowers in the gap periods between mass flowering seasons (Clough et al, 2014; Stoate et al., 2009). This is reflected by the fact that the share of the multifloral honey, which used to be dominant in the past, has declined to 10-20% in Hungary (Zilahy, 2012). The relatively monotonous - and thus suboptimal - diet, together with an increased exposure to pesticides has brought forth higher vulnerability for parasites and pathogens in bees (Decourtye et al., 2011; Goulson et al, 2015). The capacity of a landscape for supplying a certain ES usually depends on several different factors, which can be grabbed by spatial models specifically designed for the purpose (Burkhard & Maes, 2017). The process of ES model development for the mapping of honey production capacity is presented on the example of two regional case studies from Hungary and Romania. Both assessments were performed between 2014 and 2017 within the framework of ES assessment projects (OpenNESS project funded under EU FP7, see Dick et al. 2018 and Niraj-MAES project co-funded by the EEA Grant and the Romanian government, see Czúcz et al, 2018) and took place in rural areas under nature protection, with agriculture and forestry being the dominant land use types. Both projects aimed at comprehensive assessments identifying, assessing and mapping all major ES. In this paper we pick one ES (honey provision) from both projects, describe the development of ES maps and attempt to interpret and compare their outcomes. One of our guiding principles in both studies has been the participatory approach (Davies & Dwyer, 2008), meaning that we worked with local experts, and they were not only ’data providers’ but actively took part in the model development and the synthesis of results. This allowed us to reflect their knowledge about the capacities, opportunities and obstacles of the landscape for honey provision. Another key principle of the research has been the ES cascade concept (Potschin and Haines-Young, 2011) that we followed for interpreting and measuring the flow of services from nature towards society. Along these principles we planned a transdisciplinary research process that allowed the approaches of natural and social sciences to complement each other. By combining two case studies in the analysis we aimed to identify general values, challenges and potential solutions offered by rural landscapes in CEE for honey provision. Main goals of this paper are the following: (1) describe the models developed for mapping honey provision capacity in both regions, (2) identify key components of the long-term sustainability of beekeeping in CEE and (3) identify potential land use conflicts related to apiculture and suggest potential steps towards their solution.

2. METHODS

2.1 Study areas

Covering 830 square kilometres between the Danube and the Tisza rivers in the Great Plain of Hungary, the Kiskunság case study area (hereinafter referred to as KISK) is a natural forest-steppe mosaic of deciduous forests and dry sandy areas with wet meadows and salty lakes (Figure 1). It is a lowland between 80-140 m a.s.l., with annual precipitation no more than 500-550 mm, and annual mean temperature of about 10.5 degrees Celsius. The area is largely transformed by agriculture and the drainage of inland waters in the mid-20th century. Beekeeping is an increasingly important source of income in the area which has led to growing number of bee colonies during recent decades (Kecskés & Kulcsár, 2002).

The Niraj – Tarnava Mica region lies at the foot of the Eastern Carpathians in Romania, in the drainage basin of the Niraj and Tarnava-Mica rivers in South-East Transylvania. The study area (hereinafter referred to as NITM) of 910 square kilometres is on the altitude between 301 m and 1080 m a.s.l., with annual precipitation of around 700–1200 mm, and annual mean temperature of about 8,5 degrees Celsius. It is characterized by a mosaic of deciduous and coniferous forests, meadows, pastures and arable land, with ample natural and semi-natural habitats due to the still-alive traditional practices in particularly the management of grasslands and orchards (Figure 2). Here too, the number of beekeepers and hives have increased since Romania's EU accession (Glavan, 2014) because agricultural subsidies became available. There are a few settlements with remarkable apiculture such as Ghindari, Eremitu, Gănești, Bălăușeri.

Figure 1. Forest-steppe with dry sandy grassland in Kiskunság. (photo by György Kröel-Dulay)

Figure 2. Mosaic of forests, grasslands and orchards in the Niraj and Tarnava-Mica region. (photo by Milvus Group)

2.2 ES model development

Honey is a provisioning ES recognized by the CICES 5.1 classification system (Haines-Young & Potschin, 2018) under the category of 'Animals reared to provide nutrition' (category code 1.1.3.1). We defined the ES honey provision as the potential of the ecosystem to supply nectar and pollen for honeybees and so contribute to honey production. Locally specific 'rule-based matrix models' (Jacobs et al., 2015; Czúcz et al., 2018) were developed in both areas in an iterative process which incorporated the intuitive knowledge of the local experts in a transparent way, in the form of dedicated workshops and additional consultations. Our experts hold vast field experience in beekeeping on the particular areas, having managed their own colonies for decades. In addition to being beekeepers themselves, most of the experts were representatives of beekeeper organizations and relevant professional institutions. In the KISK case we worked with five representatives of two local beekeepers associations and one representative of the regional office of the National Food Authority (responsible for animal health). In the NITM case two of our four experts were leaders of the two local beekeepers associations.

The model development followed 4 main steps: (1) customize feasible ecosystem typology and create an ecosystem type map, (2) create a simple matrix model by assigning values to the ecosystem types, (3) identify additional spatial variables relevant for the ES and (4) integrate the additional variables into the ecosystem service model in the form of rules. Below we describe the methods used by each step.

2.2.1 Customize feasible ecosystem typology and create an ecosystem type map.

The key input data layers in both models were maps classifying the study areas according to fundamental functional units or ecosystem types (ET) (see e.g. Maes et al., 2014). ETs are, in our understanding, locally adapted land use or land cover categories that can reflect the relevant differences of ES provision in the particular landscape. The ET categories were identified in a 2-step process. Firstly we drafted an initial list of ETs based on previous experiences. This list was further refined after consultations with the permanent decision support bodies of local stakeholder experts in both projects (Case study Advisory Board in KISK, see Dick et al, 2018; and Stakeholder Advisory Board in NITM, see Czúcz et al., 2018).

In both cases we worked with basic spatial units ('pixels') of 100 x 100 m, and to each pixel we assigned the dominant ET. In case of KISK, the ET map was generated from a detailed regional vegetation map based on field mapping (Csecserits et al. 2016) while in NITM it was based on land cover data derived from satellite pictures (Google Satellite and Google Streets and Terrain layers from the 'open layers' plug-in of the QGIS programme (Quantum Gis 2.10.1. Pisa; QGIS 2016)) and land-use maps from a former Natura 2000 management plan and official forest administration data for some of the forestry districts. The maps were created with ArcGIS version 10.2 (ESRI 2011) in case of KISK and QGIS in case of NITM. We applied the EOV coordinate reference system (the national CRS for Hungary) in KISK and the Dealul Piscului 1970/Stereo70 (the national CRS for Romania) in NITM. More details of the ET map of NITM region are published by Czúcz et al. (2018).

2.2.2 Create a simple matrix model by assigning values to the ecosystem types.

The model is based on the conceptual framework 'ES cascade' (Haines-Young & Potschin, 2010), where ES are understood as a flow from nature to society. This 'ES flow' is split into four distinct 'stations': (1) the extent and condition of ecosystems, (2) the capacity of ecosystems to provide a certain ES in a sustainable way, (3) the actually used amount of ES and (4) the benefits generated for humans by the ES. Honey provision was assessed at the second level of the ES cascade, meaning that potential supply (capacities) were estimated regardless of the actually produced amounts of honey.

The first step to assess honey provision capacity was to estimate the 'typical' honey provisioning capacities of the ecosystem types, which was done by panels of experts (beekeepers). Linking the ecosystem types directly to ES capacity scores constitutes the 'ES matrix' modelling approach (Burkhard et al., 2010; Jacobs et al, 2015) which derives the ES supply directly from a categorical map (e.g. land use and land cover types) with a limited number of 'ecosystem types' (ET) using a simple 'lookup table'. Experts were asked to fill in the matrix in consensus (Campagne & Roche, 2018): estimate the relative capacities of the ET categories on an ordinal scale (scores ranging between 1-10), where the lowest score means the lowest capacity within the study area, while the highest score is an ideal Robinia forest in the Carpathian basin (based on descriptions by Nyárády 1958 and Halmágyi & Keresztesi, 1991).

2.2.3 Identify relevant additional spatial variables relevant for the ES.

The 'matrix' of the expert scores already enables us to create a simple ES capacity map by substituting the ET types with their scores. However, this simple approach might fail to capture relevant aspects of the experts' understanding about what influences the capacities for the studied ES. In this case the matrix model might miss relevant relationships between specific environmental, biotic or management variables ('factors') and the local nectar provisioning capacity of the habitats that the beekeepers are empirically well aware of. Experts were asked to list potentially relevant variables. As a next step, they ranked them according to priority, selected the 2-5 most relevant factors, and discussed how much they influenced the nectar provisioning capacity of the various ecosystem types. Experts were also asked to judge whether the ET categories reflected the relevant differences of honey provision in the particular landscape, and the cases where they suggested further splitting of the ET categories were also taken into account as rules (see below) relying on the specific factor they used to explain the split.

2.2.4 Integrate the additional variables into the ecosystem service model in the form of rules.

In order to incorporate the selected additional environmental variables into the ES models, rules had to be identified along which these variables modify the ET scores. The general way for this is to identify categories or value ranges of a certain variable and define rules for each category. The rules are simple, additive or multiplicative formulas, which modify the 'matrix score' of the ET of each concerned cell. After this, the main task was to find the suitable data sources for the selected variables. Given the important constraints of data availability and the differences in area cover, resolution and age of existing databases, these steps were done in an iterative process. If there were questions (e.g. multiple data options) the experts were consulted again. In some cases the experts themselves suggested suitable databases. After rules had been designed and applied on the ET scores, local experts were consulted again to validate and, if necessary, refine the so generated final relative honey capacity values by sampling concrete localites and overviewing the draft ES map. The refined rules became final subjects of data manipulations and mapping.

All input layers were converted to raster files on the same 100 x 100 m grid. Data manipulations were performed in ArcGIS (ESRI 2011) and QGIS (QGIS 2016). The final maps were calculated in R with add-on packages sp (Pebesma & Bivand 2005), rgdal (Bivand et al., 2016), and raster (Hijmans, 2016). QUICKScan (Verweij et al, 2016), a GIS environment specifically designed to support participatory ES assessment processes, was also used for quick interactive visualization during the workshops with the experts.

Some of the management related variables mentioned by the experts could not be incorporated in our models, because there were no available data for them. Nevertheless, if these factors were regarded relevant for contributing to the honey provision capacity either in a negative or positive way, they were recorded too, with the aim of compiling recommendations for a more optimal and sustainable use of the areas for beekeeping.

3. RESULTS

3.1 ET categories

We identified 17 ET in the KISK site and 13 ET in the NITM site. Corresponding ecosystem type maps of the two areas are shown in Figure 3.

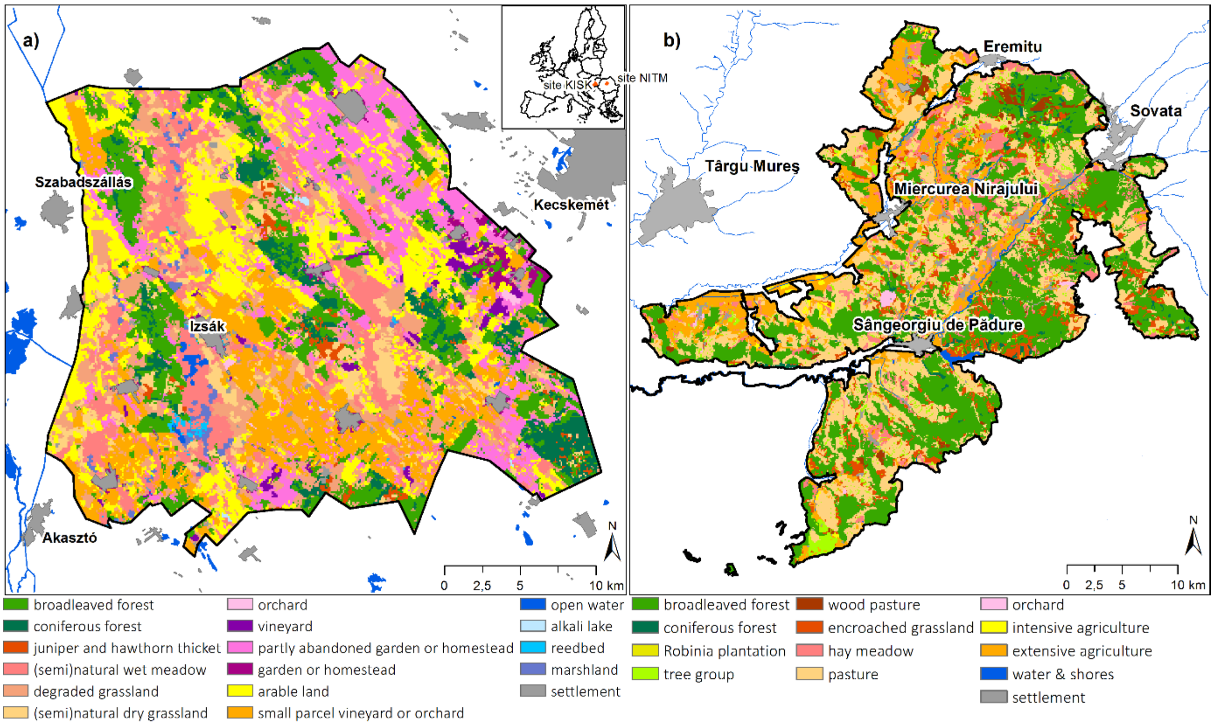

Figure 3. Ecosystem type maps of the KISK (left) and the NITM (right) study areas.

3.2 Scores

Relative capacity values were assigned to each ET categories as scores ranging 1-10. In the NITM case, plantations of Robinia pseudoacacia were scored highest among the ET categories. Robinia stands were followed by orchards, tree groups, encroached grasslands and hay meadows. In the KISK case, the highest scores were given to wet meadows and degraded grasslands, and slightly lower scores were given to many further ET: Juniper and hawthorn thicket, close to nature dry grasslands, orchards, marshland, gardens and homesteads and partly abandoned gardens and homesteads. It is important to mention that at this point of the process we had no ET category specifically for Robinia forests in the KISK site, despite that this tree is the most important resource for beekeepers there. Areas of Robinia therefore were invisible at the level of ET scores but became outstanding as soon as specific rule was determined for them (see next chapter 'Additional variables and rules'). Scores were quite different between the two case studies considering settlements and areas of non-wooded agriculture. While in NITM neither settlements nor arable lands were scored high, in KISK a special form of settlement – the so called homesteads – were appreciated by the experts. In NITM, the lowest scores were given to intensive agricultural land while extensive, small parcel agricultural areas were somewhat higher valued. In KISK, a similar differentiation was made between vineyards, showing a higher value for small parcel areas with mosaic structure. Arable lands were scored according to the actual crop (see next chapter 'Additional variables and rules'). Table 1 shows ET categories of the 2 areas with their share (percentage) of the area and relative scores as well as their classification in MAES classes (Maes et al., 2013).

Table 1. Ecosystem types of the study sites, their area share (percentage) and relative value (scores) of honey provisioning capacity.

MAES class (Maes et al. 2013)	Kiskunság site (KISK)			Niraj - Tarnava Mica site (NITM)		
		share	score	Ecosystem type	share	score
woodland and forest	broadleaved forests	14.2%	3	broadleaved forests	35.6%	3
				Robinia plantations	0.1%	8
				tree groups	3.8%	6
	coniferous forest	4.9%	1	coniferous forests	1.3%	2
	--			wooded pastures	1.6%	4
heathland and shrub	juniper and hawthorn thickets	1.0%	4	--		
	--			encroached grassland	7.6%	6
grassland	(semi)natural wet meadows	10.9%	5	hay meadows	6.9%	6
	degraded grasslands	14.2%	5	pastures	26.7%	4
	(semi)natural dry grassland	6.7%	4			
cropland	orchards	0.2%	4	orchards	0.4%	6
	vineyards	1.0%	1			
	small parcel vineyards and orchards	12.6%	3	extensive arable fields	12.7%	3
	arable fields	15.6%	1.6*	intensive arable fields	0.5%	2
wetland	marshlands	0.9%	4			
	reedbeds	0.3%	1			
rivers and lakes	open water bodies	0.3%	2	water bodies (incl. shores)	1.1%	3
	alkali lakes	0.1%	3	--		
urban	settlements	0.8%	3	settlements	1.7%	3
	gardens and homesteads	2.7%	4			
	partly abandoned gardens and homesteads	13.4%	4	--		

* average - arable lands are scored according to their crop share

3.3 Additional variables and rules

In the NITM case five variables were identified to be relevant: elevation, grazing intensity, soil fertility, habitat naturalness and landscape diversity. All variables were defined to modify the ET scores according to additive rules: either adding or deducting 0,5 or 1 score point, depending on the status of the variable. In case of elevation a positive adjustment was defined for areas above the altitude of 500 m a.s.l. Negative adjustments were proposed for medium and high grazing intensity. Grazing intensity was calculated from statistical data of livestock unit numbers at community and municipality administration level, which was projected to the size of grazing areas of each commune area. The other 3 rules contained both positive and negative adjustments depending on the value of the selected variables. Soil types that occur in the area (according to Florea & Parichi, 1978) were ranked according to their fertility based on a soil science dictionary (Füleky & Jakab, 2004) and personal consultation of its author. Soils assigned high fertility ranks (upper tertile of the rank list) increased, while soils of low fertility (lower tertile of the list) decreased the ET score. Further two variables (naturalness and landscape diversity) were 'imported' from the ecosystem condition assessment components of the Niraj-MAES project (Czúcz et al., 2018). Similar to soil fertility, for both variables negative adjustments were set for the lower, while positive ones for the upper tertile of their range.

In the KISK case two variables were regarded critical: Robinia pseudoacacia mixture ratios of (coniferous and broadleaved) forests and crop portfolio of arable lands. In the case of Robinia, 4 ranges of mixture ratios were defined by the experts. For this data we used an atlas of bee pasture published for Hungary that focuses on Robinia occurences in forests (Fritsch, 2012). Robinia mixture ratios were categorized into ranges. Range categories above 5% progressively increased the scores until the ratio range 30-60%. Scores of forests with more than 60% Robinia share received high score but slightly lower than the 30-60% category. In the case of arable lands, crop shares were identified for each cell covered with the ET type ‘arable land’. The crop shares were derived from the CAPRI database (Kempen et al, 2005), which assigns an estimated (modelled) crop portfolio to relatively homogeneous areas (called Homogeneous Soil Mapping Units, HSMU) defined over an 1 km × 1 km regular grid. Similar to ETs, scores were given to the 11 crop types that occur in the area and the category ‘fallow land’ as well, which received higher score than any crop. Both some major crops (sunflower and oilseed rape) and some minor crops (dry pulses, flowers and fodder) were considered valuable, while the frequently sown cereals and maize got very low scores. For each HSMU unit we calculated an average score based on its estimated crop portfolio. Then, each 100x100 m grid cell of our ET map inherited the score of the HSMU with which it overlapped. Besides, the amount of pesticide use and the timing of stubble ploughing on arable lands as well as the timing of mowing on hay meadows were suggested as important in the KISK site. Due to lack of data these variables were recorded but not built into the model.

Table 2 shows the components of rules in both sites as well as their data sources and processing. Table 3 shows CAPRI crop types of the KISK site with relative scores and mean share within the study site. Figure 4 show the result maps of honey provisioning capacities of the two areas.

Table 2. Relevant variables for honey provision in the study sites, components of the rules determined for the variables, steps of data processing and sources of data.

case study	Components of the rules				Data sources and processing		
	ecosystem type	factor	decision space	effect	data	processing steps	source
NITM	all	elevation	elevation >= 500m < 500m	score <- score+0.5 no change	SRTM 30m dataset	resampling to grid	https://earthexplorer.usgs.gov
NITM	inrensive and extensive arable fields	soil fertility	low medium high	score <- score-0.5 no change score <- score+0.5	Soil Map of Romania	expert scoring for soil fertility	https://esdac.jrc.ec.europa.eu European Soil Data Centre, Florea & Parichi 1978.
NITM	pastures, wooded pastures	grazing intensity	grazing > 4 LU/ha 2-4 LU/ha <2 LU/ha	score <- score-1 score <- score-0.5 no change	number of cattle and sheep	calculating average grazing livestock densities	community & municipality administrations
NITM	all	landscape diversity	low medium high	score <- score-0.5 no change score <- score+0.5	ET map	Shannon diversity in moving windows	own data
NITM	all	habitat naturalness	low medium high	score <- score-0.5 no change score <- score+0.5	N2000 species monitoring	species distribution modelling	own data
KISK	broadleaved & coniferous forests	black locust (Robinia) cover	Robinia < 5% 5-30% 30-60% >60%	no change score <- score+1 score <- 6 score <- 5	forest inventories	resampling to grid	Fritsch 2012
KISK	arable fields	crop shares	values were calculated based on local crop share data from the CAPRI database		CAPRI database	expert scoring of crops, averaging over HSMUs	http://afoludata.jrc.ec.europa.eu/group/capri-spatial-hsmu-database Kempen et al. 2005

Table 3. Crop types of the KISK site according to the CAPRI database, with relative scores and mean share within the study site.

Crop type	CAPRI code	score	mean share
Vegetables, flowers			
Tomatoes	TOMA	2	0.3%
Other fresh vegetables (red pepper)	OVEG	1	4.2%
Floriculture	FLOW	3	0.1%
Cereals			
Common wheat	SWHE	1	17.9%
Durum wheat	DWHE	1	1.3%
Barley	BARL	1	8.7%
Rye	RYEM	1	7.9%
Oats	OATS	1	1.6%
Maize	LMAIZ	1	24.3%
Rice	PARI	1	0.2%
Other cereals	OCER	1	4.4%
Root crops			
Potatoes	POTA	1	0.3%
Sugar beet	SUGB	1	0.6%
Oilseeds and industrial			
Sunflower	SUNF	3	2.9%
Rape and turnip rape	LRAPE	3	1.4%
Soya	SOYA	2	0.5%
Fibre and oleaginous crops	LTEXT	1	0.7%
Tobacco	TOBA	1	0.2%
Other non permanent industrial crops	OIND	2	0.4%
Other annual crops			
Dry pulses	PULS	3	0.8%
Fodder other on arable land	OFAR	3	8.4%
Other crops	OCRO	1	4.8%
Fallow land	LFALL	5	8.1%

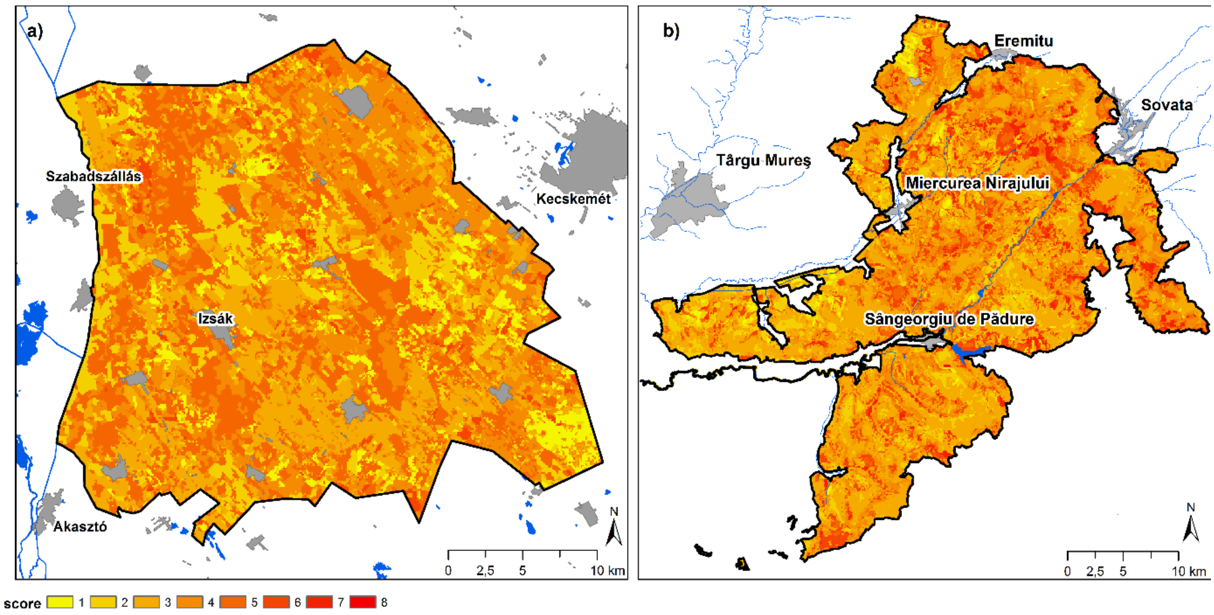

Figure 4. Maps of honey provisioning capacity of the KISK (left) and the NITM (right) study sites.

4. DISCUSSION

While changes of the socio-political system in the 1990's resulted in a temporary tendency of agricultural extensification (due to land abandonment and decreased chemical use) in several CEE countries, this tendency was reversed after the EU accession, when intensification in land management and infrastructural development was enabled by the Common Agricultural Policy (Emmerson et al, 2016). This, overall, lead to the accelerated disappearance of extensive farming practices and the decrease of farmland biodiversity, which was the case in Hungary and Romania as well (Mihók et al., 2017; Mikulcak et al, 2013). This was a tendency at large, however, some remote regions were less affected and traditional agricultural ecosystems more or less survived the last 30 years, making these areas relicts of an exceptionally high rural biodiversity (Kovács-Hostyánszki et al, 2016). Both of our case studies are such areas. Being a national park since 1975, its protected status helped preserving this diversity in the KISK case, while rural biodiversity and traditional land use were reasons for assigning Natura 2000 status for the NITM area in 2009 (Manolache, 2017). Besides their conservation values, their diversity in terms of ETs provide considerable nectar provisioning capacities for the regional apiculturists, making beekeeping an important component of the local economies. There are a number of beekeepers in both areas with remarkable expertise, knowledge and field-based experience about the components of an 'ideal bee pasture'. The involvement of these experts enables to capture complex nature-society relationships in the form of simple, but (locally) relevant models in order to assess the ES of honey provisioning. A possible tool for such involvement is the rule-based matrix method. For some of the rules a similar result could have been achieved by splitting some of the ecosystem types into 'subtypes' (e.g. 'highly grazed grasslands' vs. 'grasslands with low grazing intensity'). Nevertheless, as the honey capacity mapping was nested into a broader ES assessment project in both cases, there was little room to iteratively adjust the set of ecosystem type categories for each single ES being mapped. Furthermore, the rule-based approach offers a highly flexible, transparent general framework for integrating spatial information into the ES models based on local expert knowledge, which is still relatively easy to understand for non-experts (Czúcz et al., 2018). All this makes it suitable for an iterative participatory model building process. Comparing two resulting models can highlight specific differences and, at the same time, the features relevant for the particular ES in general, too. Below we synthesise the results of participatory mapping based on the ET scores, rules and narratives given by the local experts. We aim to highlight similar and different patterns between the two areas and draw general consequences of honey provisioning capacity in rural CEE regions.

4.1 Forests and wooded habitats

Highest values were assigned to Robinia forests in both areas, confirming that black locust is an important resource for beekeeping in these countries. However, none of the areas belong to the best Robinia bee pasture sites of the Carpathian basin. In fact, neither sites fall are optimal for the tree in terms of temperature (NITM) or drought (KISK), which results in less than optimal flowering success. Besides, the tree has different status in the two sites. While in the NITM site both its availability and spontaneous spreading potential is limited (there are only a few, more or less homogenous plantations with no more than 0,1 percentage share of the study area), it is a very common species in the KISK site, where it occurs both in homogenous plantations and in mixed stands with other broadleaved (especially poplar) or coniferous (especially black pine) species. Having ample sources of propagules, black locust is an invasive species in the KISK area that causes concerns for nature conservation (Csecserits et al., 2016). Interestingly, in this landscape that amply offers forests of various Robinia densities, mixed forests with no more than 30-60% Robinia were more appreciated by the beekeepers than homogenous plantations. Argument was that mixed forests of this ratio can supply an amount of Robinia nectar similar to homogenous plantations, but at the same time they host richer shrub and herb layers offering alternative sources for bees at the same time. This is important because black locust trees in the KISK site are vulnerable to late spring frosts which, in some years, can freeze high percentage of their flowers. Forests that host several flowering species in the spring season (such as poplars (Populus spp.), ash (Fraxinus spp.), maple (Acer spp.) and hawthorn (Crataegus monogyna)) can offer alternative resources for that case. In general, diversity of species in a forest increases its resilience against extreme events (Larsen, 1995; Folke et al, 2004) and thus enables it to sustain its functions and services such as, in this case, provision of pollen and nectar in the spring.

Trees and woody scrubs outside forests are important resources due to their heterogeneity and multi-functionality (Porcel Rodriguez et al, 2015), and they offer valuable resources for bees, too. In the NITM site, the highly valued ET 'tree groups' often includes Salix willows along the river banks which, together with early flowering fruit trees of the ET 'orchards', offer pollen resources in the crucial early spring period to feed on after the winter. Similar was the reason behind the high score of encroached grasslands, which are former grasslands now dominated by shrubs such as Prunus spinosa, Crataegus monogyna and Rosa canina.

4.2 Grasslands

Considering grasslands we can highlight the wet and mesophilous hay meadows appreciated in both areas equally. Meadows in good condition can have outstanding floral richness that is not just offering pollen and nectar all through the growing season but holds high conservation value at the same time. Keeping a good ecological status of meadows is a shared goal of beekeepers and nature conservation in both areas. According to our results, management of grasslands can be very determinant for their bee pasture value. In the NITM site, grazed pastures were distinguished from mown meadows with lower scores. This difference was further amplified by a rule further reducing the scores of pastures based on the intensity of their management, i.e. the density of grazing livestock. This is confirmed by the argument that while grazing is part of the local traditional land use, current numbers of livestock (especially of sheep) go beyond the grasslands' carrying capacity. This can not only hinder plants from flowering but can also degrade the ecological condition of the grasslands, which is a shared concern for beekeeping and nature conservation alike.

Once abandoned, managed grasslands get encroached quickly by shrubs and trees in the NITM site, offering wooded bee pastures. Drier conditions in KISK, however, make natural succession slower, therefore there is a longer period for abandoned areas to stay open and vulnerable for the colonization of another invasive plant, the common milkweed (Asclepias syriaca) (Csecserits et al., 2016). This plant is in expansion in the area that causes serious conservation concerns, yet it supplies high amounts of nectar for a tasty honey, which is increasingly considered as valuable regional product. This value is reflected in the high score given to degraded grasslands in the KISK site.

4.3 Agriculture

Agricultural crops are crucially important resources for modern apiculture in Central and East European countries. Despite this fact, intensively managed arable lands were scored low in the NITM area for two reasons. First, there is little sunflower and oilseed rape in the typical crop rotation, and second, these fields can hold risk of insecticide exposure of the bees (Van Bergen, 2013; Potts et al, 2016). Small parcel ploughlands were, however, scored somewhat higher, which was reasoned by their diverse supply of minor crops such as vegetables and culinary herbs. In the KISK site a different approach was used. It was not the intensity of management but the actual crops that defined the value of arable lands, highlighting areas of sunflower, oilseed rape and fodder (roughage). Interestingly, fallow lands were scored the highest, showing again that the diversity of wild flowers (especially annual weeds) was highly appreciated by the beekeepers. The benefits of wild plants on arable land are not restricted to beekeeping, as (like in forests) the diversity of species may guarantee resilience in agricultural landscapes (Tscharntke et al, 2005). Annual weeds were also the argument for highlighting stubbles as important floral resource for bees in late summer. However, stubbles can only be utilized by bees if there is enough time between crop harvest and stubble ploughing, so that weeds can develop into their flowering status. This rarely happens in Hungary, because early stubble ploughing is imposed by a government decree on the control of ragweed (Ambrosia elatior), a highly allergen invasive weed.

It is important to mention that it is not only honeybees benefiting from agricultural crops but also vice versa. As 75% of the world's leading food crops are partly or exclusively insect pollinated (Klein et al, 2007), there is growing attention at global level to the regulatory ES of pollination by wild bees as well as honeybees. This is especially relevant since this service is becoming increasingly critical in several parts of Europe and North America due to intensive agricultural technologies, climate change and the spread of invasive species (Clough et al., 2014; Stoate et al, 2009). The growing number of bee colonies in Romania and Hungary can, to some extent, counteract this negative tendency at the regional level, creating synergy between the sectors of apiculture and agriculture.

4.4 Settlements

Homesteads are loosely distributed traditional farms surrounded by gardens and agricultural areas, a typical form of settlement in the Great Plain of Hungary before the 1960s, with a tendency of abandonment in recent decades. Actively used and abandoned homesteads are equally valued bee pastures in the KISK site for their diverse offer of flower resources: domestic gardens and ornamental flowers as well as invasive weeds, the latter typical on abandoned homesteads (Pándi et al, 2014). In the NITM area isolated homesteads are rare as this type of homes had much less tradition in the region. Settlements were appreciated here too but only with a moderate score.

4.5 Ecosystem condition

Naturalness and diversity of habitats as well as soil fertility were reflected in the expert discussions in both areas, although they were incorporated in the model in a direct way only in the NITM case. There, high naturalness and habitat diversity were considered to be positively affecting the honey provisioning capacity of all habitats. Soil fertility was a factor considered only for arable fields, also in a positive direction. As the rules were additive, certain areas of tree groups, orchards, hay meadows or encroached grasslands in natural status and diverse landscape could approximate the value of Robinia plantations, showing a clear and straightforward positive relation between ecosystem condition and honey provisioning capacity. In the KISK area, however, there was a contradictory relationship between the two. While most natural or semi-natural ETs were scored high, some degraded habitats were also appreciated due to the occurence of black locust and common milkweed. This ambiguity can be resolved, however, if we take into consideration the high variety of habitats within the area and the mosaic structure of the landscape, which is an advantage for beekeeping. In other words, it is not only some specially highlighted habitats or species, but the rich menu of several, more or less equally valuable resources available within short distance that makes this area a good bee pasture. This assumption is confirmed by the relatively even distribution of ET scores in KISK.

5. CONCLUSIONS

Although a few mass flowering plants provide large part of the honey yield, diversity of floral resources is necessary to sustain persistent source of forage for the bee colony in the long term. The most essential of such resources are the presence and diversity of habitats rich in minor crops and wild flowers that help bridging bottleneck periods between mass flowering seasons, an aspect especially crutial for stationary colonies. Rural areas that can still provide these resources are more and more appreciated by beekeepers as they counteract the growing tendency of monotonous bee diet, and thus strengthen the resilience of the bee colony against parasites and pathogens (Requier et al, 2015). At the same time, by providing stable feeding and – in case of wild bees – nesting site for bees, these areas provide the valuable service of crop pollination.

Proper management of habitats is important to preserve their capacity to produce nectar and pollen. This protects honey bees and wild bees alike, and it is supported by several international and EU policies (Potts et al, 2016). Careful planning and timing of potentially harmful interventions, especially the application of pesticides is necessary. Cooperation between beekeepers, farmers, foresters and nature conservation managers is also necessary in order to optimize the benefits derived from the production of food, fodder, timber and honey, and to ensure favourable conservation status of habitats at the same time. Good ecosystem condition and high biodiversity are basically shared goals between nature conservation and apiculture, yet a few particular species of bad conservation reputation are judged fundamentally differently, creating a potential source of conflict. As also concluded by Mukwada (2018), it is important to enhance discussion between sectors of nature conservation and land use about the management of invasive species on protected areas. ES maps highlighting the value of certain locations can inform such conciliation and cross-sectoral discussion, help harmonize land management and through that, they may even serve as tool for conflict resolution between sectors.

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