Original Article

INTEGRATION OF NDVI IMAGERY AND CROP COVERAGE REGISTRATION SYSTEM FOR APIARY SCHEDULE

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Received: 06 September 2019; accepted: 05 March 2020

Abstract

Beekeepers need to establish migratory apiaries to benefit from pollen and nectar source plants as in order to increase honey yield. Thus, following the flowering seasons of honey source plants has vital importance when deciding the route of migration. In this study, MODIS imagery was used to generate weekly NDVI data between 1st April to 31st August 2018, when beekeeping activities start and end in the study area. Although MODIS images have high temporal resolution, low spatial resolution (250 meters) makes them insufficient when deciding the crop types and plants. While detecting plants in natural plant areas requires high spatial resolution NDVI, Crop Coverage Registration System (CCRS) parcel-based crop coverage records can enrich the NDVI data without increasing spatial resolution in agricultural lands. Thus, the CCRS data were integrated with NDVI images for migratory beekeeping in agricultural areas as an innovation. To generate both high temporal and spatial resolution, NDVI and CCRS data were integrated together with a beekeeping suitability map to generate the apiary schedule. The results were verified with 176 existing apiary locations and production dates retrieved from field studies which revealed the existence of three seasons in the study area as early and late apiaries (in natural plant areas) and apiaries in agricultural lands. Accuracy analysis showed that 82% of the apiaries intersected with suitable locations and that apiaries in agricultural areas were detected five days earlier than in field studies and obtained more accurately than natural plant apiaries.

Keywords: Apiary Schedule, Geographical Information Systems, Multi Criteria Decision Analysis, Site Suitability Analysis

INTRODUCTION

Beekeeping activities contribute to rural economic development thanks to bee products and the pollination of about 33% of crop species (Estoque & Murayama, 2010, 2011; Damián, 2016). Due to this importance, unaccounted income is gained with increased of agricultural crop yield (Oldroyd & Nanork, 2009; Maris et al., 2008). Increasing the honey yield from beehives requires predicting and detecting the suitable floral resources and suitable apiary locations within an apiary schedule concept. Normalized Difference Vegetation Index (NDVI) images are the most commonly used data sources to detect zones covered by plants and can be used to determine apiary locations (Jarlan et al., 2008; Landmann et al., 2015; Adgaba et al., 2017). There are several sources to generate NDVI data, including NASA Moderate Resolution Imaging Spectroradiometer (MODIS), the NOAA Advanced Very High Resolution Radiometer (AVHRR) and the Copernicus Sentinel-2 satellite systems. NDVI usage for monitoring landscape changes have been studied by Myneni et al. (1997), Zhou et al. (2001), Heumann et al. (2007), Karlsen et al. (2008) and Lange et al. (2017). In this context, the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation index is a frequently used NDVI source in phenology studies (Beck et al., 2006; Fontana et al., 2008; Bian et al., 2010; Schmidt et al., 2012; Ahmad, 2013; Eckert et al., 2015; Arundel et al., 2016). However, detecting pollen-nectar sources and the ecological distribution of plants to determine the location of apiaries is a complex process without any field studies. Differentiating honey bee plants is difficult within the temporal vegetation phenology concept due to the spatial and temporal resolutions of the NDVI images.

Although the recent studies are performed t for different purposes, the main problems about NDVI data sources are the same (Arundel et al., 2016). The temporal and spatial resolutions of the satellite systems are the main phenomena when determining the NDVI sources. While MODIS and AHVRR have low spatial resolution (250 meters and 1 km, respectively), these satellites have very high temporal resolution (daily). Low spatial resolution is revealed in mixed pixels, such as forest and grassland borders, and in agricultural lands near forests (Arundel et al., 2016). This problem can be solved through the use of Sentinel-2 images with their high spatial resolution (10-20 meters). However, especially for apiaries, flowering schedule determination requires high temporal resolution due to the short-lived plants and fast-growing agricultural crops. This disadvantage is avoidable through the usage of local spatial datasets or field studies to enrich NDVI data.

In this context, the Crop Coverage Registration System (CCRS) includes all parcels and related crop information for every year and is used in this study to specify the crops on which honey bees can be located. The CCRS was established in 2005 by the Republic of Turkey Ministry of Agriculture and Forestry for monitoring crops and regulation of agricultural incentives. In addition to this, its aim is monitoring the crops in all stages from cultivation to end-user. The CCRS is a spatial database based on parcels, and a large number of attribute data are related to the parcels which are actively used. Irrigation, fertilization and pesticide information are included in addition to crop data, and the records are updated each year. Turkey has a high amount of migratory beekeeping activity, so a knowledge of the crop texture before

Table 1.

Recent studies on beekeeping suitability and criteria

Criteria	Recent Studies
Elevation	Maris et al., (2008); Estaque & Murayama, (2010); Amiri & Shariff, (2012); Camargo et al., (2014); Zoccali et al., (2017);
Land use	Estaque & Murayama, (2010); Amiri & Shariff, (2012); Abou-Shaara et al., (2013); Camargo et al., (2014); Femandez et al., (2016); Zoccali et al., (2017);
Water Resources	Maris et al., (2008); Estaque & Murayama, (2010); Amiri & Shariff, (2012); Abou-Shaara et al., (2013); Camargo et al., (2014); Femandez et al., (2016); Zoccali et al., (2017);
Road Network	Maris et al. (2008); Estaque & Murayama (2010); Amiri & Shariff, (2012); Femandez et al., (2016); Zoccali et al., (2017)
Temperature	Amiri & Shariff, (2012); Abou-Shaara et al., (2013); Camargo et al., (2014); Zoccali et al., (2017)
Humidity	Abou-Shaara et al., (2013); (Camargo et al., 2014)
Precipitation	Amiri & Shariff, (2012); Camargo et al., (2014); Femandez et al., (2016);
Nectar and Pollen Class	Maris et al., (2008)
Summer Crops	Abou-Shaara et al., (2013)
Solar Radiation	Femandez et al., (2016)
Electromagnetic Radiation	Femandez et al., (2016)

the beekeeping season is of vital importance to predict and increase the honey yield and to guide the migratory beekeepers as to where to locate their apiaries.
Moreover, crop information gives valuable information about the flowering schedule of a region. Although the CCRS includes crop planting and harvesting dates, these data are not recorded accurately through land observation but are enough to predict the flowering schedule with the integration of NDVI data for apiaries. The integration of high temporal resolution NDVI imagery and CCRS records can generate a useful infrastructure for the apiary schedule. The growth of the plants can be specified through NDVI images and crop types through CCRS records which refer to the honey production date interval. This time interval will be mentioned as the apiary establishment duration, which starts from locating hives in a location and ends when moving to another location.
At this point, the beekeeping suitability concept can be integrated into both NDVI and CCRS data to limit the apiary establishment to only suitable areas. This approach enables both the generation of apiary establishment only in suitable areas and the exclusion of green areas which are unsuitable for beekeeping. The suitable areas can be defined via Multi-Criteria Decision Analysis (MCDA), since a large number of criteria affect beekeeping activities. In the MCDA concept, the Analytical Hierarchy Process (AHP), one of the most commonly applied methods, determines the importance of each criterion among the factors that determine suitability (Saaty, 1977; 1980; 1994; 2001; Saaty & Vargas, 1991). The AHP includes the calculations used to determine the best solutions for the specified problem among multiple alternatives (Arentze & Timmermans, 2000) and determines the weights with a pairwise comparison matrix in which the importance of all criteria is compared (Chen et al., 2010). There are quite a few studies on the beekeeping suitability analysis concept which use MCDA techniques. Those that include criteria for beekeeping suitability are given in Tab. 1.
Aspect, slope, elevation, flora, water resources, roads, settlements, precipitation, buildings, railroads, power lines and natural disaster areas have been included in previous studies as criteria to generate beekeeping suitability maps. The resultant maps were then overlapped with NDVI and CCRS integration to generate apiary schedules. The novelty of this study is the integration of suitable apiary locations, NDVI imagery and CCRS records instead of using only NDVI imagery as in recent studies. The main aim of this study is to generate an apiary schedule to be able to determine honey production dates within the beekeeping suitability concept and to detect the seasons of the study area in both natural plant areas and agricultural lands. The resultant maps guide both beekeepers and authorized institutions in monitoring and managing beekeeping activities and establishing a conceptual model for an apiary schedule and migration route determination.

MATERIAL AND METHODS

Study Area

The study was carried out in Turkey's province of Konya (38,873 km^2) including its thirty-one districts (Fig. 1). The study area is located between latitudes 36°41'59.6" and 39°16'03.6", and longitudes 31°14'18.0" and 34°25'37.3". The altitude of the city is 1020 meters above sea level and the area has high mountains over 3000 meters. Because the topography of

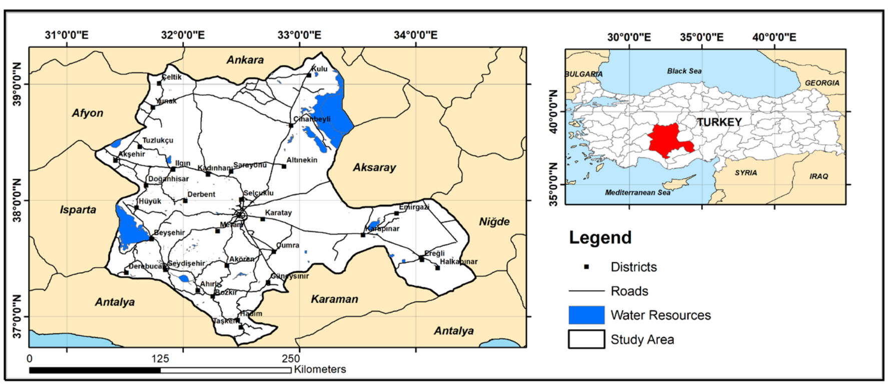

Fig. 1. The boundaries of the study area (Konya province).

Konya includes both high mountains and plains with valuable agricultural lands, it provides a good conceptual model for an apiary schedule. Additionally, Konya has the largest agricultural lands in Turkey where much agricultural activity is conducted, and natural plant and agricultural apiary activities which enhance apiary schedule application can be determined. The study area is one of the largest mono-floral honey regions in Turkey and this characteristic enables a more accurate apiary schedule to be made.

Methodology

Generating apiary schedule maps requires including suitable locations for beekeeping, NDVI images, CCRS records, criteria specification and verification of apiary schedule stages. The implementation model of the study is shown in Fig. 2.

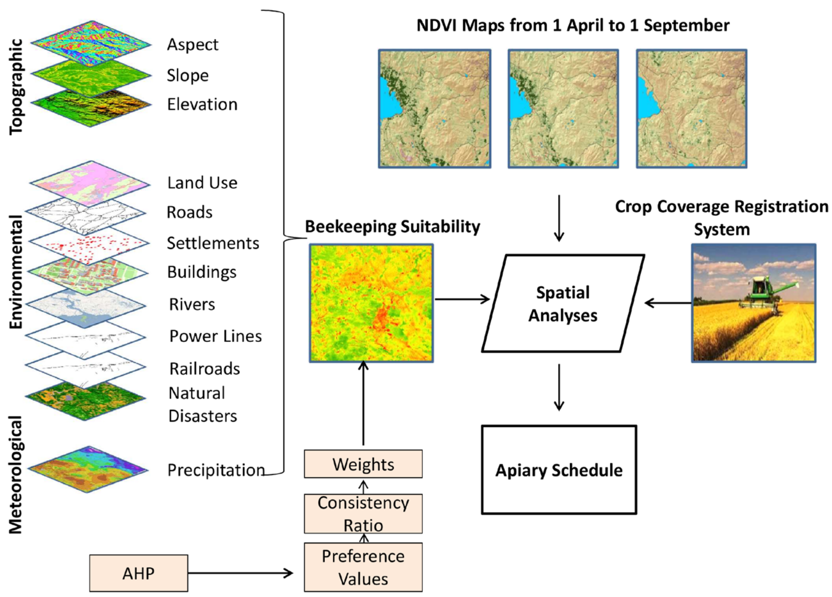

Fig. 2. The implementation model of the apiary schedule.

Datasets of the Model

Generating apiary schedules requires NDVI maps and CCRS records along with criteria maps for beekeeping suitability analysis. In total, fifteen NDVI maps were derived from MODIS images. NDVI calculation has a simple formula that uses near-infrared radiation and visible radiation (Eq. 1). The results range between +1 and -1, where values close to zero refer to non-vegetated areas (Hall et al., 2002).

$$\mathrm{NDVI} = \frac{(\mathrm{NIR-Red})}{(\mathrm{NIR+Red})} \quad (1)$$

The MODIS images were retrieved over a 10-day period and the NDVI data (Fig. 3) were generated by using ArcGIS 10.5 software.

In addition, parcel-based CCRS records were retrieved for the study area to generate a crop type map. For the purpose of defining the boundaries of the apiary schedule, the beekeeping suitability areas are used to determine suitability for apiaries and date interval. This is because every green area in the NDVI images might not refer to suitable locations and similar to this, every non-planted area might not refer to unsuitable locations, such as agricultural areas for foraging, and excluding unsuitable locations from the apiary schedule provides a more detailed and precise schedule map.

The criteria used to generate beekeeping suitability maps were specified by considering the beekeeping requirements in the field of topographic, climatic and environmental perspectives and twelve criteria were specified and included in the suitability analyses.

Topographic Criteria

Elevation, aspect and slope criteria were included in the suitability analysis according to previous studies by Maris et al. (2008); Estoque & Murayama (2010); Amiri & Shariff (2012); Abou-Shaara et al. (2013); Camargo et al. (2014); Fernandez et al. (2016) and Zoccali et al. (2017). Slope and aspect data were derived from ASTER GDEM elevation data at thirty -meter resolution via spatial analyst tools in ArcGIS 10.5 software.

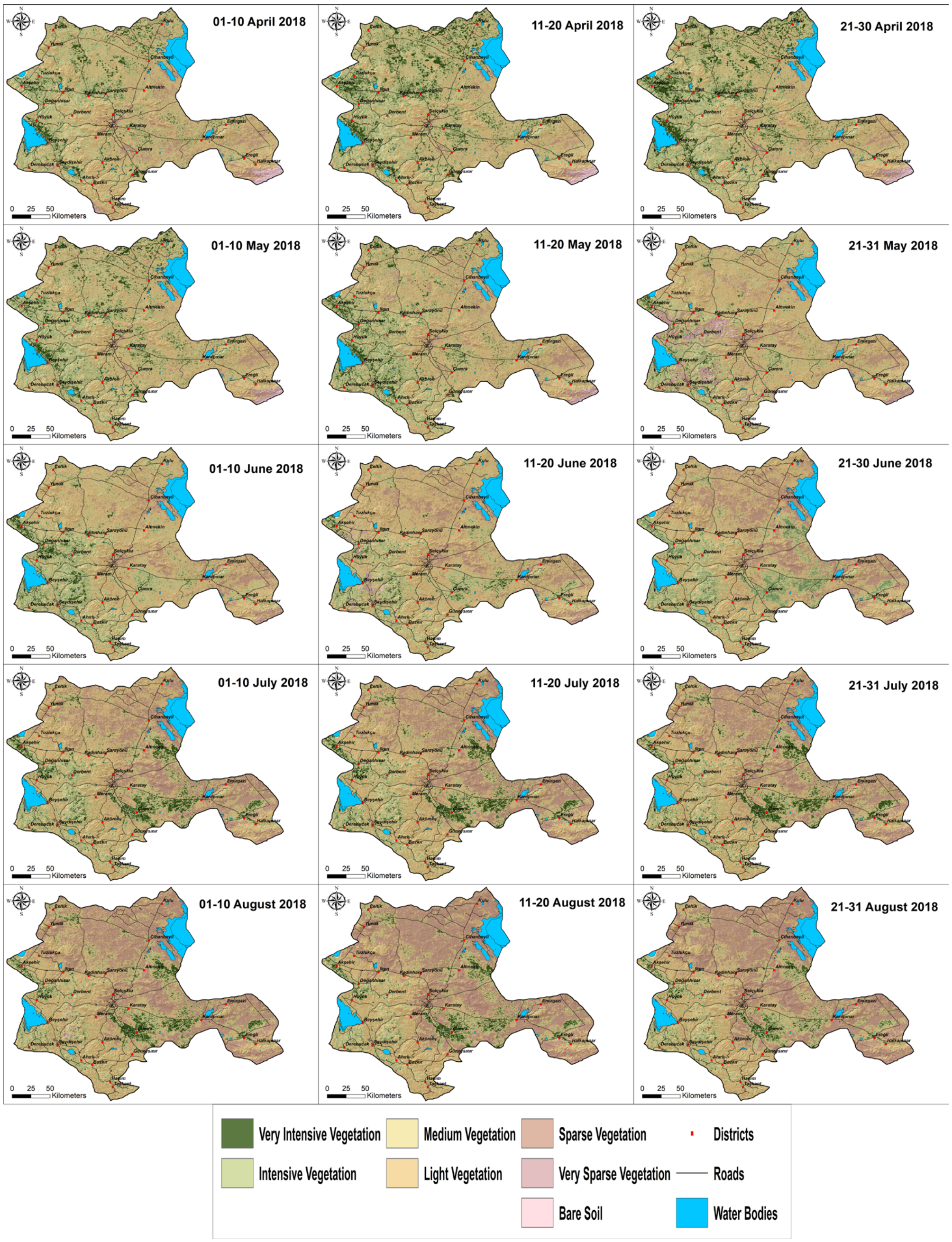

Fig. 3. NDVI images from 1st April to 31st August.

Climatic Criteria

Precipitation was included in the suitability analysis according to Amiri & Shariff (2012), Camargo et al. (2014) and Fernandez et al. (2016) due to the importance of this parameter for beekeeping. The precipitation rate is expected to be between 1275 and 1800 mm annual rainfall to ensure optimal beekeeping (FAO, 1976; Maris et al., 2008). The precipitation data were retrieved from the database of the Turkish State Meteorological Service Institute observation stations. In total, the precipitation data of ten observation stations were used and the precipitation map was generated through density analysis in ArcGIS 10.5 software.

Physical Environmental Criteria

Physical environmental factors such as roads, railways, buildings, settlements and power lines indirectly affect beekeeping activities. Locations close to these zones have disadvantages for beekeeping, as human-related pollution, air and noise pollution, greenhouse gases, exhaust emissions and intensive traffic flow negatively affect both flora and beekeeping activities. Thus, these criteria were included in the suitability analysis to consider and avoid the negative effects of artificial structures. The criteria data were retrieved from the Open Street Database in vector format and converted to buffer zones to determine the effect zones via spatial analyst tools in ArcGIS 10.5 software.

Water resources are also important for supplying water to apiaries and for the richness of flora. The study area has 2127 square-meter water resources and can provide clean water for apiaries. Natural disasters indicate the locations that are a threat to apiaries. Areas with a high potential for floods, sinkholes and landslides were included in this criterion to avoid loss of or damage to apiaries. The natural disaster data were retrieved from the Ministry of the Interior's Disaster and Emergency Management Presidency in vector format and converted to buffer zones in ArcGIS 10.5 software.

The Bee Flora Criteria

The flora criterion is of vital importance for beekeeping activities. The flora are the decisive factor of pollen resources and define the productivity and yield. This criterion also includes the agricultural lands because most of the migratory apiaries are located in agricultural lands for clover, sunflower and sainfoin. Urban settlements and industrial areas were not included to avoid the disadvantages and adverse effects of urbanization on honey production. The flora map was derived from CORINE 2018 land cover data and classified according to the land use type considering beekeeping requirements. Because biodiversity and flower data are unavailable for the study area, land use map classifications were used in this study.

Analytical Hierarchy Process (AHP) and Beekeeping Suitability Map

The Analytic Hierarchy Process (AHP), proposed by Saaty (1977; 1980), is a complex decision-making tool that considers the importance of each criterion. For this purpose, the AHP establishes an importance scale from 1 to 9 (1=Equal, 3=Moderate, 5=Strong, 7=Very Strong, 9=Extreme). The AHP is based on a normalized matrix and calculates weights with an average sum of the normalized matrix. Moreover, the AHP provides a consistency rate concept to

Table 2.

Beekeeping suitability pairwise matrix

Criteria	AS	EL	SL	FL	DtW	DtR	DtS	DtP	DtB	DtRI	PR	ND	Weight
AS	1	2	2,7	0,3	1,1	4	4	2,5	2,5	4	3	3	**0,129**
EL		1	1,1	0,2	0,5	2	2	1,1	1,1	2	1,5	1,5	**0,063**
SL			1	0,2	0,3	1,2	1,2	1	1	1,2	1,1	1,2	**0,048**
FL				1	3,5	9	9	8	8	8	7	8	**0,339**
DtW					1	4	4,2	3	3	4,2	3	2,8	**0,133**
DtR						1	1	0,8	0,8	1	0,9	0,8	**0,036**
DtS							1	0,8	0,8	1	0,9	0,7	**0,035**
DtP								1	1	1,6	1,1	1,2	**0,048**
DtB									1	1,4	1,1	1,1	**0,047**
DtRI										1	0,9	0,7	**0,035**
PR											1	0,8	**0,042**
ND												1	**0,045**
							(CR=0,081)		Total	1.0000			

(**AS:** Aspect, **EL**: Elevation, **SL:** Slope, **FL:** Flora, **DtW:** Distance to Waters, **DtR:** Distance to Roads, **DtP:** Distance to Powerlines, **DtB:** Distance to Buildings, **DtRI**: Distance to Railways, **PR**: Precipitation, **ND:** Natural Disasters) be able to calculate the consistency of overall weights and priorities (Saaty, 1994). Finally, the consistency ratio (CR) is calculated, which should be less than 0.1 to prove that the weights and priorities are consistent (Saaty & Vargas, 1991). The AHP method was used to generate the final suitability map for beekeeping in the study area.

Beekeeping suitability map generation requires determining the weights of each criterion via the AHP method with a comparison matrix. The importance of each criterion and preference values were specified considering previous studies in literature and the decisions of thirty expert beekeepers located in the study area. The preference values are given to the criteria considering the importance (from 1 to 9) of each criterion compared to another. The comparison matrix and preference values are given in Tab. 2.

The CR of the comparison matrix was calculated as 0.081, which means that the weight calculation is consistent. Due to the high importance of the criteria of flora and distance to water resources, the weights were calculated as 34% and 13%. After weight calculation, the Beekeeping Suitability (BS) map was generated by the contribution of each criterion with its weight. The BS was calculated with the following equation:

Integration of NDVI and CCRS Records

In the CCRS records, all the parcels with sunflower crops were exported as a new layer. These parcels were then intersected with all NDVI images and merged. The result data included both planted areas outside agricultural lands and sunflower-harvested agricultural lands. A sample result of the NDVI and CCRS record map for 1st - 10th August is given in Fig. 4.

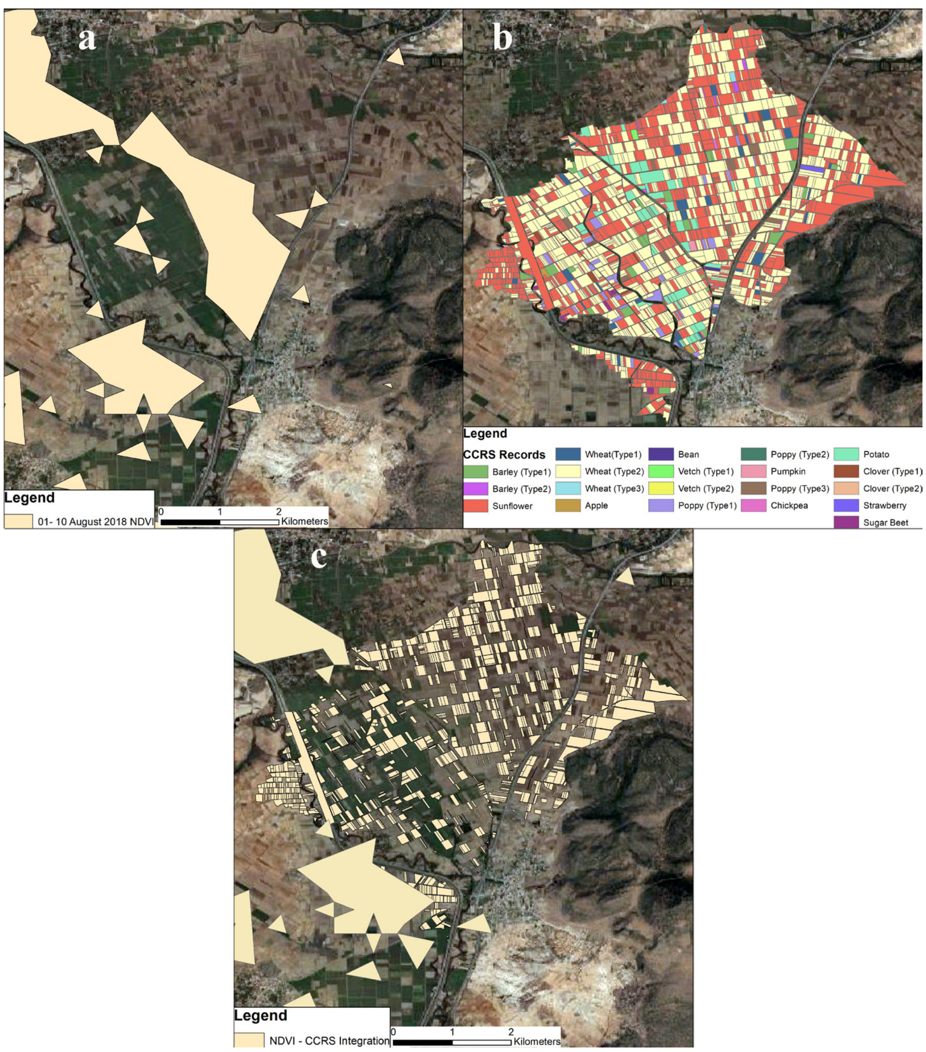

Fig. 4. a-) 01-10 August 2018 NDVI Imagery b-) CCRS crop type map c-) Integration of CCRS and NDVI data (Apiary Schedule).

Field Studies

Field studies included both specifying apiary location coordinates and apiary establishment dates, which refer to the beginning (when they are located) and end (when they are left) of the apiaries to verify both the suitability and apiary schedule. In total, 176 apiary location coordinates were collected and apiary production dates were recorded. Considering the apiary production dates, three clusters were detected, which refer to the three different seasons. The dates revealed that eighty of the apiaries were located in natural plant areas and ninety-six of the apiaries were located in agricultural lands. Moreover,

Table 3.

Field study results for a sample 5 of 176 apiaries

Apiary Name	Latitude	Longitude	Hive Count	Location	Begin Date	End Date	Honey Type
A1	32,86913	38,338409	50	Hüyük	3 April	10 May	Highland
A25	33,084416	38,181350	30	Gevrekli	5 April	16 May	Highland
A52	33,058012	38,308402	100	Karapınar	11 July	27 August	Sunflower
...	...	...	...	...	...	...	...
A102	32,88018	38,177285	15	Altınekin	9 July	23 August	Sunflower
A148	32,677932	38,339811	35	Bozkır	8 May	13 June	Highland

in natural plant areas, the existence of two seasons was revealed with forty-five apiaries in early season and thirty-five apiaries in late season. The average beginning and end of the apiaries were calculated for each cluster. The records of five apiaries as a random sample out of 176 apiaries are given in Tab. 3. The dates retrieved from the field studies also represent the flowering dates, when the beekeepers locate their apiaries.

Verification of the Results

The apiary schedule are verified by comparing the flowering season retrieved from field studies and the existing apiary locations. Existing apiary locations are accepted as suitable because the beekeepers have decided on the locations after a long period of experience.

The apiary schedule is verified with zonal statistics by determining the vegetation index which honey bees each within a three-kilometre buffer zone. Although the forage area gives valuable information about the suitability and reliability of the apiary schedule, it is also the most appropriate data to prove the schedule's accuracy. Thus, three-kilometre buffer zones were determined for each of the 176 apiary locations, and zonal statistics were calculated to determine the total vegetation availability within all honey season dates for each buffer zone. Every pixel of the resultant NDVI maps was counted and summarized with a mean value to compare each buffer zone to another. The results for three apiary schedule zones were evaluated by comparing forage zone statistics and date intervals retrieved from the field studies. The mean values were converted to the 1-to-9 scale in which 9 represented the most intensive planted forage zones and 1 the non-planted forage zones (Fig. 5).

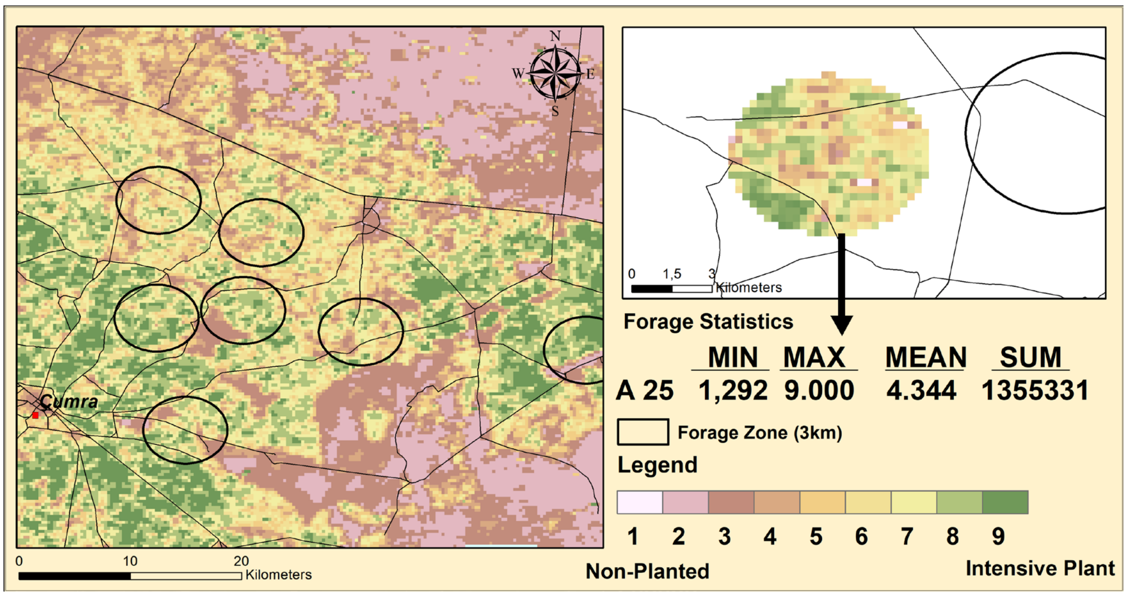

Fig. 5. Zonal statistics of forage zones.

RESULTS

Suitability map for beekeeping in the study area

The results indicated that 10.8% and 42.5% of the study areas were determined as highly suitable and suitable, respectively, for beekeeping activities. A large percentage of the highly suitable areas included agricultural lands. Approximately 60% of the suitability specified was accounted for by the high weight values of the flora, distance to water resources and aspect. The beekeeping suitability map of the study area is shown in Fig. 6.

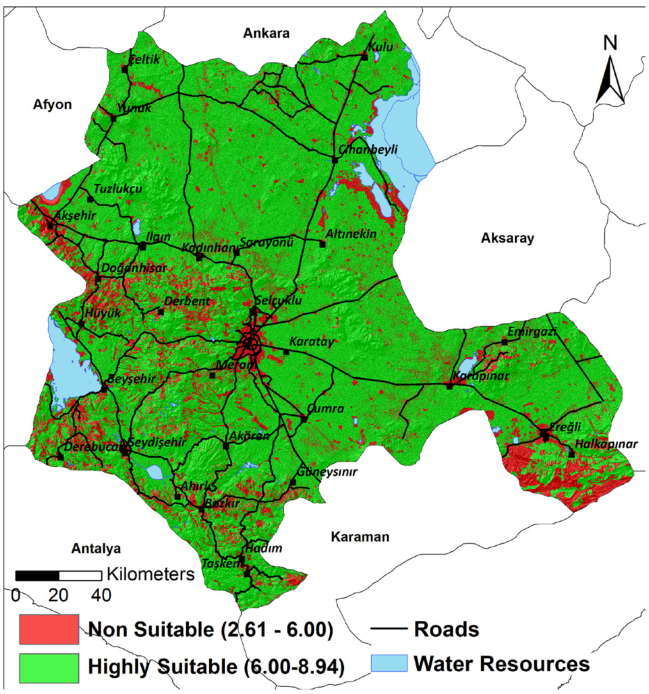

Fig. 6. Beekeeping suitability map.

Apiary schedule map for the active season

All the NDVI and CCRS combination maps were intersected with the suitability map, and non-suitable areas were excluded from the apiary schedule. Thus, the generated apiary schedule maps refer to the suitable and high-intensive planted crop lands which can be used for beekeeping activities (Fig. 7).

The apiary schedule map revealed the presence of two main zones which vary distinctly by seasons. The first season is for natural floral areas and the second season is for agricultural crop areas. The first season, the earliest season of the study area, starts on 1st April and ends on 10th May and covers the vicinity of Lake Beyşehir in the west of the study area due to the warmer climate of the region. Lake Eğirdir, which is not included in the study area but is quite close to Lake Beyşehir, also affects the warmer climate and early season of the region. The region has a large number of natural floral areas and large moors located between lakes and mountains.

The latest season of the study area starts on 1st July and ends on 30th August and covers the agricultural lands and represents the sunflower honey production in the southeast of the study area and south of Salt Lake. This region has the largest sunflower cultivation and most valuable agricultural lands in the study area and includes migratory apiary locations. The topography of the region is in the form of a plain and has very intensive agricultural activities.

According to the field studies, the average dates revealed that ninety-six of the apiary locations were located in agricultural lands for sunflower and eighty in natural floral areas (Tab. 4).

On the other hand, eighty apiary locations were clustered in two groups as early and late seasons, of which forty-five apiaries were located in early-season regions and thirty-five in late season

Table 4.

Average season start and end dates retrieved from field studies

	Region	Average Start Date	Average End Date	Apiaries
Early Season Apiaries	Beyşehir, Seydişehir, Bozkır	6 April	12 May	**45**
Late Season Apiaries	Hadim, Taşkent	3 May	27 May	**35**
Apiaries at Agricultural Lands	Çumra, Karapınar, Altınekin	8 June	24 August	**96**

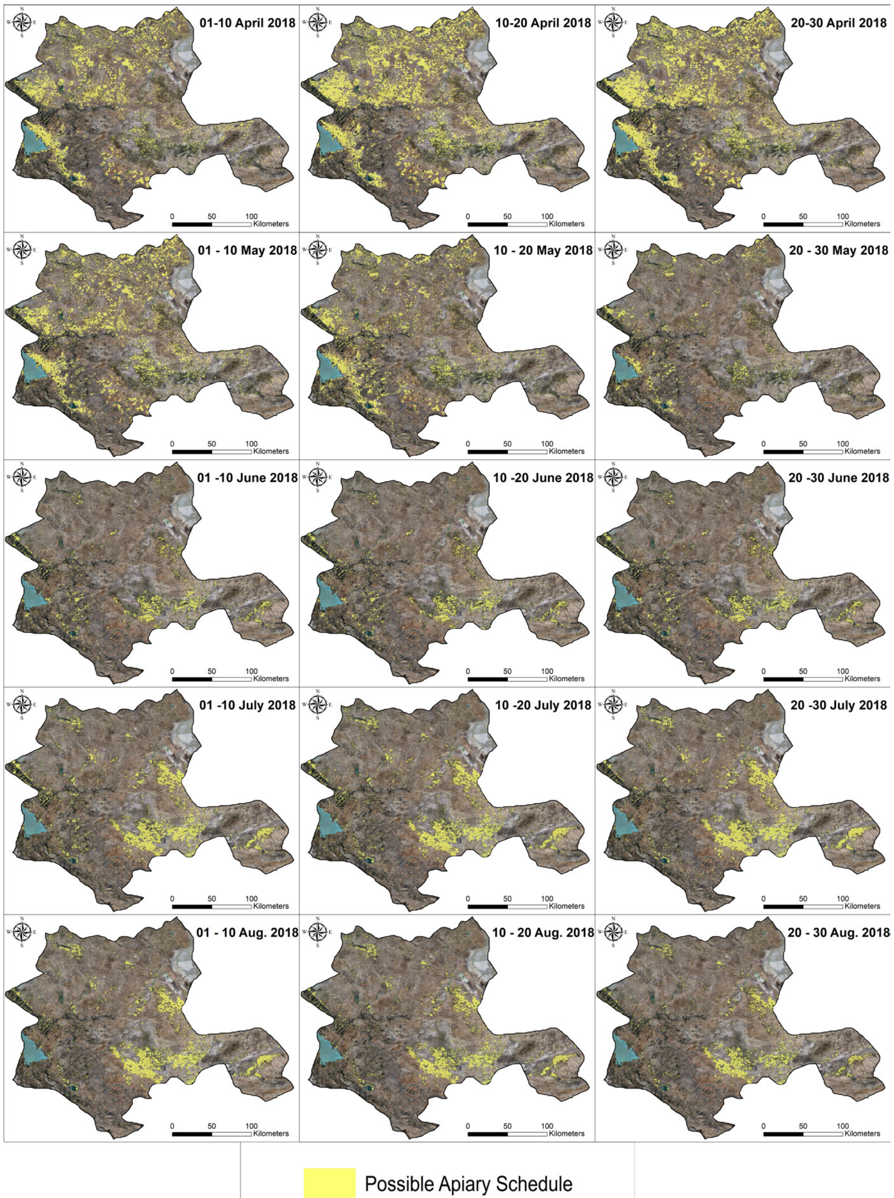

Fig. 7. Determined apiary schedules from 1st April to 31st August.

regions. The apiary locations according to the groups are given in Fig. 8.

Apiary schedule map for early season

Early season apiaries were clustered into three groups and located on plains. The average elevation of the apiaries varies from 1018 meters above sea level to 1046 meters, where the climatic and topographic conditions can be accepted as similar. The plant density values vary from minimum 2.0 to maximum 7.58 in the forage zone statistics. For the forage zone statistics, the maximum plant density started on 10th April and continued until the 10th May. For the field study results, the average start and end dates (red lines) were determined as 6th April and 12th May, which represents a good overlap (Fig. 9).

Apiary schedule map for late season

Late season apiaries were clustered into two groups and located mostly in mountainous areas. The average elevation of the apiaries varies between 1158 and 1346 meters, where climatic and topographic conditions are quite different compared to the other apiary locations. Due to the climatic conditions in higher elevations, the flowering seasons of the plants start later than in lower elevations. The difference in elevation leads to the constitution of a second season,

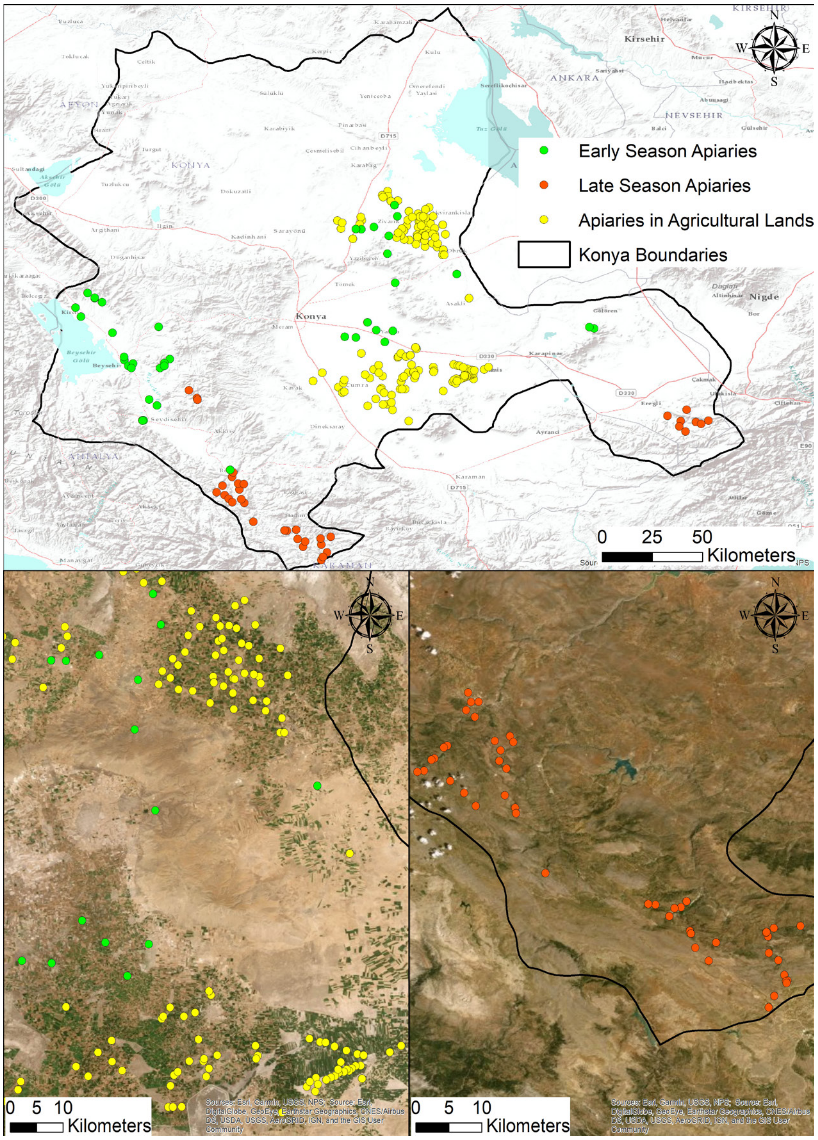

Fig. 8. Existing apiary locations and their clusters.

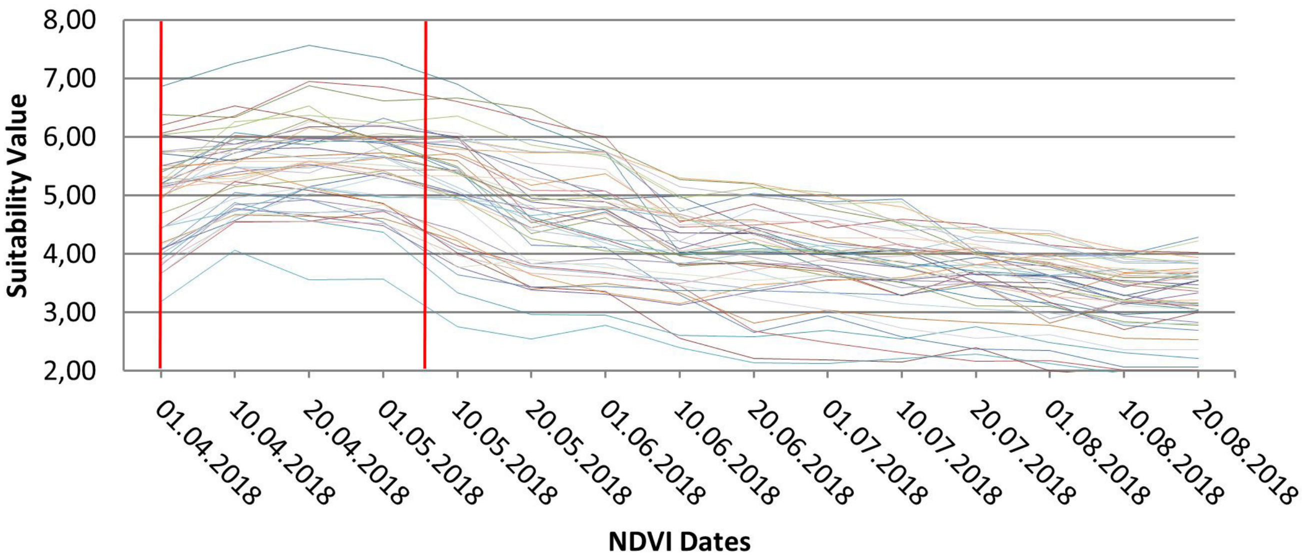

Fig. 9. NDVI graphics for early season apiaries.

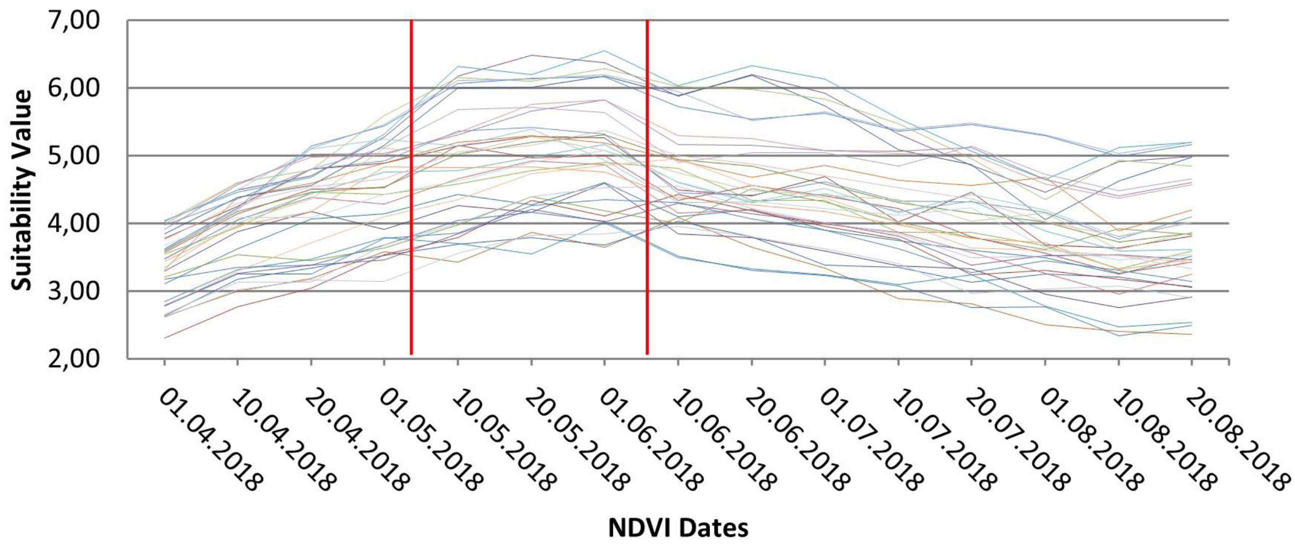

Fig. 10. NDVI graphics for late season apiaries.

which is an advantage for beekeepers. The plant density values vary from minimum 2.3 and maximum 6.4 in the forage zone statistics. An evaluation the forage zone statistics shows that the maximum flowering plant density started on 20th May and continued until 20th June (Fig. 10). The field study results show that the average start and end dates were determined as 10th May and 10th June, which represents a weaker overlap than for the early season.

Apiary schedule map for agricultural crops

In total, ninety-six apiaries were located in agricultural zones within two main clusters, fifty-two of them were located in the Çumra-Karapınar districts and thirty-eight in the Altınekin district. These regions have similar the topography and climatic conditions and the same agricultural crops. Plant density varies from minimum 2.1 to maximum 7.82 within the apiary schedule. The graphics revealed that the maximum plant density started on 1st July and started to decrease on 20th August. The field study results show that average start and end dates were determined as 8th July and 24th August. The plant density and apiary schedules are given in Fig. 11. The red lines represent the start and end times of the season which were retrieved from the field studies.

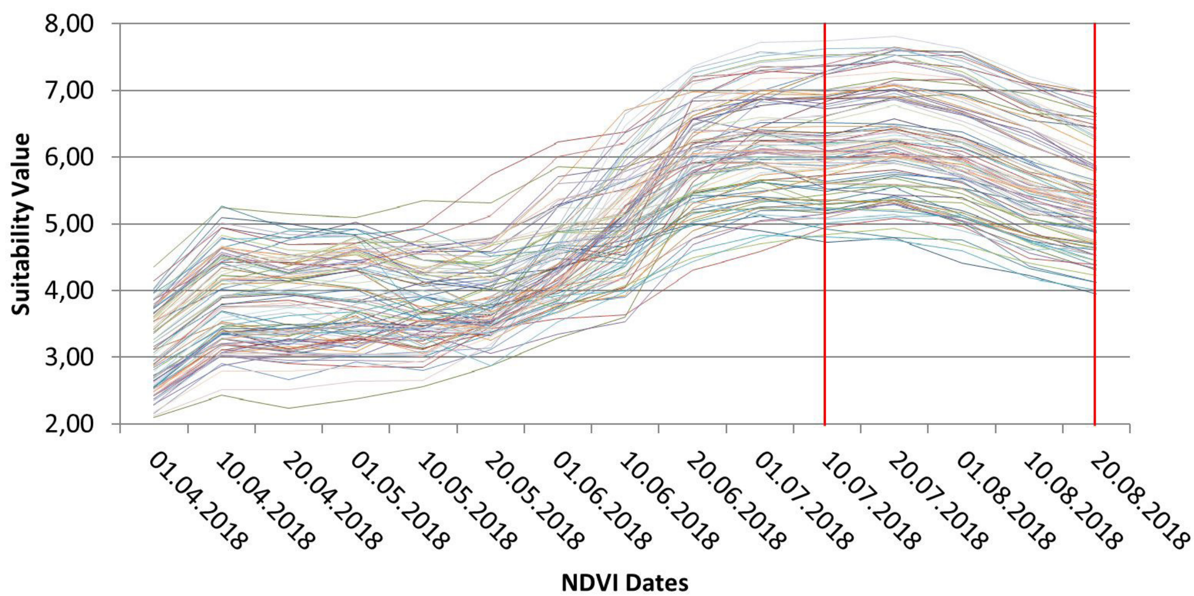

Fig. 11. NDVI graphics of apiaries in agricultural lands.

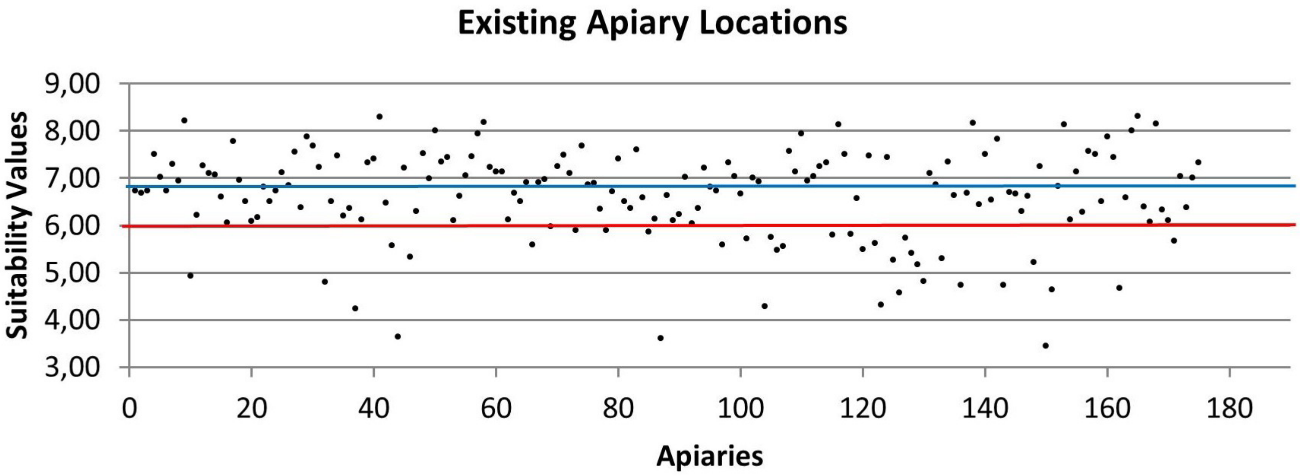

Fig. 12. Distribution of apiaries according to suitability values corresponding to their geographical locations, considering the value 6 as the suitability threshold (The blue line represents the average suitability value of 176 beekeeping locations).

Verification of Apiary Schedule

The apiary locations and suitability values were examined to verify the suitability map, and the results showed that fourteen apiary locations intersected with low suitability and forty-two apiary locations intersected with highly suitable locations. Thus, 144 of the existing beekeeping areas intersected with suitability values higher than 6 and provided 82% intersection with existing apiary locations. The graphics of suitability values according to the existing apiary locations are given in Fig. 12., and the optimal production start suitability threshold value (6) for apiaries is emphasized with a red line. The blue line indicates the average suitability of all 176 existing apiary suitability values. The accuracy and intersection rates show that the suitability map can be used for both apiary schedules and locating apiaries.

As a result, all the field studies and determined apiary schedule dates are given together in Fig. 13. The most suitable results were obtained for apiaries in agricultural lands via integrated CCRS records with regard to the increased resolution of NDVI images in agricultural lands. For the evaluation of natural plant apiaries, the early season apiaries were determined one week later and one week earlier than the field study dates. This result is also related to the NDVI imagery resolution because sparse and small plants could not be specified with this resolution. The one-week date differences from the start and end are quite significant because plant intensities are the same before and after the season, which the NDVI resolution is not sufficient to detect. Similarly, late season apiaries were calculated two weeks later than in the field study results. This result indicates the

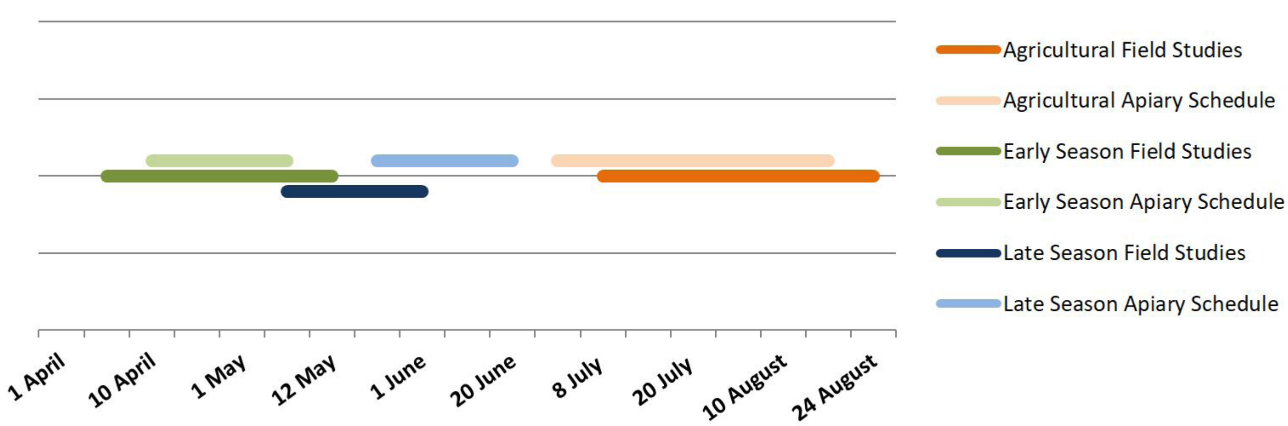

Fig. 13. Comparison of apiary schedule and field study dates.

difficulty of differentiating the forest cover and natural plants in mountainous areas. However, these difficulties can be overcome through the use of high spatial resolution NDVI imagery.

As seen in Fig. 8, some early season apiaries were detected inside agricultural lands, and upon examination they were revealed to be located in mountainous and natural floral areas surrounded by agricultural lands. The overlapping of these apiaries with the apiary schedule was generated between 10th April and 10th May. Late season apiaries were located in mountanious lands where climatic and topographic conditions were quite harsh.

Although early season apiaries in agricultural lands intersected more noticeably with the apiary schedule zones, the late season apiaries were not specified and did not intersect with the apiary schedule zones. One reason for this result is related to the resolution of the NDVI images. The late season apiaries were located on forested mountains with very small natural plants which NDVI resolution was not sufficient to detect. Another reason is that forests were excluded from the apiary schedule via the suitability map to distinguish the plant and forest covers. Thus, together with the resolution effect, these zones could not be determined in the apiary schedule. However, the resolution of the NDVI images was sufficient to detect the large moors and planted areas. Thus, early season apiaries were determined accurately because non-forest areas and large natural plant areas could be identified with NDVI imagery.

DISCUSSION

This study presented a conceptual model for predicting apiary migration zones via an apiary schedule map and a suitability analysis. The methodology used in this study reveals a most detailed and comprehensive approach for apiary migration which includes apiaries in both natural and agricultural lands. The diversity of the topography, the climatic conditions and the flora of the study area enriched the results and reliability of the apiary schedule which can be accepted as a conceptual model for all of Turkey. Although MODIS NDVI images are not sufficient to generate apiary schedules, integrating the CCRS records overcame this problem, albeit only in agricultural lands, by both increasing the resolution and identifying the crop type. The natural plant areas, however, still required high resolution NDVI data images to detect the schedule more accurately. A five-day difference between the determined apiary schedule and real apiary production dates is a good and reliable result for apiaries and can occur due to the climatic conditions of a season from year to year. In this context, the results should be evaluated based on the guiding role of the apiary schedule which points to the agricultural lands where beekeepers can locate. Moreover, the resultant apiary schedule provides a prediction of yield and total production estimations within a specified area. In addition to this, generating an apiary schedule not only provides possible areas but also generates a honey type map for a study area. Because the CCRS involves all crop information, the crop types can be separated and possible honey type areas can be easily detected. In this way, with the contribution of the suitability map, beekeepers were provided with a complete guide to with regard to honey type, honey yield, suitable areas and productivity scheduling. By using the CCRS records, the use of field studies can be decreased as much as possible compared to other studies. Previous studies have only included suitability map generation and validation, but this study is the first to introduce the apiary schedule-oriented suitability analysis. Moreover, the accuracy and reliability of the suitability map was increased in this study through the evaluation of the most detailed criteria used for site suitability for apiary locations from other research (Maris et al., 2008; Estoque & Murayama, 2010; Abou-Shaara et al., 2013; Camargo et al., 2014; Fernandez et al., 2016; Zoccali et al., 2017). Criteria for buildings, railroads and natural disaster zones were first used in addition to other criteria used in previous studies. Additional criteria such as meteorological conditions, wind directions, flowering, foraging area, and pesticide usage in agricultural lands were also included to increase the suitability. The unavailability of a temporal flora map and plant density information, which are important for bees particularly limited accurate decision making. Thus, especially a late season apiary schedule could be determined accurately in the case of local field studies for detecting plant density and flowering data. The contribution of these criteria will provide both more accurate suitability analyses and apiary schedules.

In different topographical, physical and climatic conditions, as in the study area, beekeeping activities are enhanced due to the probability of an increased honey season. Beekeepers can increase the honey yield by following the different seasons. At this point, this study reveals two main subjects for beekeepers to increase their honey yield. The results establish for beekeepers both a route where to migrate and the start and end dates of migration. Moreover, the beekeeping suitability concept reveals suitable areas which beekeepers had never located, and by establishing new apiaries new beekeeping areas are specified and the honey yield increased. Thus, because beekeepers will know when to migrate and where to locate, they may set their annual plan. By extending this conceptual model to Turkey, a large number of seasons will be revealed and general routes for beekeepers specified. The migration routes can also be verified via GPS systems through the monitoring of beekeeper movements during a year. Moreover, the possibility of over fifteen honey types in Turkey will allow beekeepers to harvest more honey types by setting their schedules according to the apiary schedule. By introducing both the suitability and apiary schedule concepts, the results of this study can constitute the infrastructure of National Apiary Management platforms.

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