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Remote Sensing As A Tool For Conservation: Honey bees, Forage And Distribution

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Abstract

Employing remote sensing techniques, researchers and conservationists can gain valuable insights into the complex interplay between land use changes, vegetation dynamics, and pollination services, ultimately contributing to the conservation and sustainable management of these vital ecosystems. Indicators play a crucial role in assessing the efficacy of conservation strategies, particularly when it comes to averting habitat degradation. The suitability of habitats for these bees is strongly influenced by ecological parameters compared to social and economic parameters.vIn the context of beekeeping, habitat suitability is a critical consideration, considering the ecological environment and land suitability for feed sources. Geographic Information Systems (GIS) play a important role in developing models for land suitability evaluation.

Keywords: Honey bees, remote sensing, GIS, Biodiversity Introduction

The significance of honeybee keeping lies in its production of honey, a natural product derived from flower nectar or plant secretions collected, transformed, and stored by bees. Honey and geopropolis from bees exhibit various health benefits, including antioxidant, antimicrobial, anti-inflammatory, wound healing, and anticancer properties. Beyond these individual benefits, honeybees play a crucial role in ecology, contributing to ecosystem equilibrium and well-being. Beekeeping success is dependent on ensuring a stable supply of bee forage, typically abundant in forests. Bee forage plants, cultivated for their nectar and pollen, form the primary feed source for honeybees. Remote sensing data, categorized by spatial, temporal, and spectral resolution, as well as data sources, provides ecologists with a powerful means of identifying individual organisms, particularly plants, and assessing the impact of anthropogenic activities on natural areas. Utilizing satellite image time series, threats like the anthropogenic modification of natural areas and the density of structures can be recorded. In a conservation context, remote sensing aids in assessing the success of Conservation and Beekeeping (CBC) efforts at limiting development. High-resolution satellite imagery, with a resolution of less than 1 meter, allows for manual analysis to measure land-use change rates, including structure density (huts, buildings, penstocks, livestock enclosures) and land modification (clearing, cultivation, settlement, and livestock production). These indicators are crucial for evaluating the effectiveness of conservation strategies, especially in terms of preventing habitat degradation.

Ecological Importance of Honeybees

The ecological importance of honeybees encompasses several key aspects, such as pollination services, biodiversity support, Stability of food web, seed dispersal, ecosystem resilience, human agriculture, habitat, forest conservation etc. these are explained below.

Pollination Services: Honeybees are efficient pollinators crucial for the reproduction of numerous flowering plants, supporting the production of fruits, seeds, and overall plant reproductive success. This process is vital for biodiversity and agricultural yields.
Biodiversity Support: Through active pollination, honeybees enhance plant diversity, providing a foundation for a healthy ecosystem that sustains various animal species.
Food Web Stability: The interdependence of plants, honeybees, and other organisms creates a stable food web. Disruptions to honeybee populations could affect multiple levels of the food chain.
Seed Dispersal: Honeybees unintentionally aid in seed dispersal as they collect pollen and nectar, contributing to the colonization of different areas by plant species.
Ecosystem Resilience: By contributing to the health and vitality of plant populations, honeybees enhance the overall resilience of ecosystems, making them more resistant to diseases and adaptable to environmental changes.
Human Agriculture: Many crops essential to human diets rely heavily on honeybee pollination. The decline in honeybee populations could have far-reaching implications for global food production, affecting both natural ecosystems and human livelihoods.
Habitat: Honeybees construct intricate hives that serve as homes for millions of other insects and animals, contributing to the creation of diverse habitats within ecosystems.
Forest Conservation: Sustainable beekeeping practices not only provide economic incentives for communities but also contribute to the health and preservation of forest ecosystems through pollination services.
In the face of anthropogenic threats such as habitat loss, pesticide use, and the spread of pathogens, honeybees have become a model organism for studying how environmental disturbances impact the provisioning of ecosystem services. Their decline could have cascading effects on both insect and plant biodiversity. Conservationists commonly use Very High Resolution (VHR), Quickbird, and WorldView-2 imageries to monitor and study these crucial ecosystems.

Honeybees Species

Globally, bees, with approximately 20,000 species falling under the Apidae family of the Hymenoptera order, play a crucial role in environmental health by facilitating the pollination of plant species in both natural ecosystems and agricultural crops. This has a direct impact on the yields of fruits and seeds, with bees responsible for pollinating around 73% of cultivated plants, leading to a potential increase of up to 50% in seed and fruit production.
The Apidae family comprises several tribes, including Apini, Bombini, Euglossini, Meliponini, Xylocopini, and other lesser-known tribes. Highly eusocial bee taxa, such as the European honeybee (Apis mellifera Linnaeus) and stingless bees (Meliponini), are integral to this family. Stingless bees, particularly prevalent in the tropics and subtropics, are considered highly eusocial and play a vital role in ecosystems from the American tropics to sub-Saharan Africa and the Indo-Australian regions.
Meliponini, a tribe of stingless bees, demonstrates diverse distribution across various ecosystems, including rainforests, cloud forests, and arid lands, spanning altitudes from sea level to 4000 meters in the Andes. Their continental distribution underscores their ecological importance as pollinators of native wild plants and crops. The presence of Scaptotrigona af. depilis in forage is noted as a potential indicator of environmental pesticide contamination. Additionally, various bee species, including Halictus ligatus, Halictus poeyi, Hylaeus affinis, Hylaeus modestus, Lasioglossum, Ceratina, Nomada, Sphecodes, Melissodes, Agapostemon, Augochlora, Bombus bimaculatus, Lasioglossum fatiggi, Hylaeus annulatus, and Apis melliferaillinoisensis, contribute to the diverse array of pollinators.

Factors affecting suitability of Honeybees

Concerning the ecological aspects of honeybees, the suitability of habitats for these bees is strongly influenced by ecological parameters compared to social and economic parameters. Temperature and rainfall criteria hold significant weight, followed by altitude and distance from rivers. Temperature, in particular, affects the fertility of bee queens and the foraging activity of bees, with low temperatures and high rainfall inhibiting their food-searching activities. Weather conditions directly impact the productivity of bee colonies. (Abou-shaara et al., 2013, Abou-shaara, 2013)
Nesting patterns of stingless bee species are adversely affected by human-induced disturbances and habitat fragmentation. Human activities such as habitat loss, conversion to intensive agriculture, agrochemical pollution, competition for resources, and the introduction of exotic species pose threats to bee survival and compromise their crucial role in providing ecosystem services. Pesticides, widely used in conventional

agriculture, exert sublethal effects on wild bees, affecting adults and larvae physiologically, morphologically, and behaviorally, ultimately diminishing their fitness and contributing to the overall threat of extinction.
The ecological conservation of honeybees is of paramount importance, and remote sensing emerges as a valuable tool in this endeavor. Remote sensing, encompassing the acquisition, processing, and interpretation of data obtained through radiometric sensors, proves indispensable in monitoring and managing honeybee habitats. While satellites and aircraft-based sensors are widely utilized, ground-based sensors and telemetry are increasingly contributing to the scientific understanding of ecosystems.

Remote sensing as a tool for conserving honeybee – Some case studies

To ensure the precision of remote sensing imagery in characterizing ground features, sensitivity analyses are conducted, evaluating the sensors' ability to capture specific features of interest. This meticulous approach involves a comprehensive inventory of structures and land modifications across CBC management zones, contributing to a thorough evaluation of management effectiveness.
In the context of beekeeping, habitat suitability is a critical consideration, considering the ecological environment and land suitability for feed sources. Geographic Information Systems (GIS) play a crucial role in developing models for land suitability evaluation. GIS, defined as computer systems integrating hardware, software, and georeferenced data, facilitates the collection, storage, management, processing, analysis, and visualization of both spatial and non-spatial information. GIS data, linked to Earth's surface through geographic or projected coordinate systems, provide valuable insights for beekeepers to enhance apiary management decisions. The use of GIS in beekeeping problem-solving is well-established, demonstrating its versatility in addressing various challenges in the field.
To employ remote sensing methods for conserving honeybees, several techniques and tools can be utilized:
Harmonic Radar for Tagging and Tracking:
Harmonic radar, capable of identifying the frequency of a diode, can be employed for tagging and tracking animals, including medium-sized bees like honeybees (Apis mellifera). Lightweight tags enable the monitoring of honeybee behavior, helping researchers understand resource-seeking patterns, communication of resource locations, and navigation during flight.
LiDAR for Off-site Monitoring:
LiDAR (Light Detection and Ranging) serves as an effective off-site monitoring method to measure bee location and dwell time, particularly over potential mine sites. The continuous-wave diode laser in LiDAR can detect the unique wing-beat of bees, enabling the assessment of bee density over time and space.
Establishment of Biological Corridors:
Governments can play a crucial role in preventing the extinction of native pollinators, such as stingless bees, by initiating initiatives to establish biological corridors. These corridors can mitigate the joint effects of habitat loss and climate change, helping conserve ecosystems crucial for pollinator survival.
GIS for Habitat Connectivity and Urban Gardens:
Geographic Information Systems (GIS) can aid in assessing and promoting habitat connectivity by protecting conserved areas and restoring disturbed areas. GIS is instrumental in analyzing the attractiveness of crops and plants for pollination, contributing to decision-making at the local level regarding the development of beekeeping and agriculture. Promoting urban gardens can offer additional food resources for bee species in urban areas.
Heat Maps for Decision-Making:
GIS and data processing tools like Microsoft Excel can be employed to create thematic heat maps based on various indicators such as Relative Attractiveness Index (RAI), Relative Dependence Index (RDI), and Relative Priority Index (RPI). These heat maps provide localized insights, aiding in more accurate decision-making at the local level regarding beekeeping and agricultural development.
Satellite Images for Identifying Potential Locations:
Geographical Information Systems (GIS) and Landsat satellite images can be utilized to identify potential locations for propolis production, a valuable product produced by bees.
The Geographic Information System (GIS) has been effectively utilized in apiculture to assess and categorize regions based on their suitability for honeybees, among other applications. In a specific context, GIS was employed to identify regions requiring the use of modified beehives for honeybee maintenance during the summer season. This process involved the creation of three distinct maps, each classified into five classes according to specific data ranges and laboratory experiment results:
Thermal Map:

This map classified regions into five classes based on maximum temperatures recorded during the summer season. The classification provided insights into the thermal conditions experienced by different geographic areas, helping identify variations in temperature ranges.

Drought Conditions Map:

This map categorized regions into five degrees of drought conditions, utilizing a combination of factors such as relative humidity, precipitation, and water resources. The classification aimed to capture the severity of drought conditions, providing a comprehensive understanding of the water-related challenges faced by different regions.

Overall Map for Temperatures and Drought Conditions:

A combined map was generated by integrating the information from the thermal map and drought conditions map. This overall map, also classified into five classes, offered a holistic perspective on the harshness of regions, considering both elevated temperatures and drought conditions.

By employing GIS in this manner, the study aimed to pinpoint the most challenging regions characterized by high temperatures and severe drought conditions. This geospatial analysis allowed for a nuanced understanding of the environmental factors influencing honeybee habitats, enabling targeted and informed decisions on the use of modified beehives to support beekeeping activities in the identified regions. Overall, GIS proved instrumental in assessing the suitability of different geographical areas for honeybees and optimizing apicultural practices to ensure the well-being of bee colonies.

Remote sensing is a rapidly developing science that spans many disciplines. The number of related tools has grown in both quantity and quality, and as the technology matures, these tools are also becoming more affordable and accessible. Remotely sensed data can be categorized based on spatial, temporal, and spectral resolution and data sources

For decades, ecologists have employed remotely sensed data to identify individual organisms or groups of individuals, especially plant.

Using a satellite image time series, we recorded threat-based development – anthropogenic modification of natural areas and the density of structures.

We used manual analysis of VHR satellite imagery (less than 1 m in resolution) to assess CBC success at limiting development, as measured by the land-use change rates for structure density (huts, buildings and penstocks; livestock enclosures) and land modification (clearing and significant degradation of the natural land cover for cultivation, settlement and livestock production). The indicators represent the vast majority of human activity in the landscape that could degrade wildlife habitat. To determine suitable remote sensing imagery, a sensitivity analysis was conducted in order to evaluate sensor ability to precisely characterize ground features of interest (Boyle et al. 2017).

The approach required a full and accurate inventory of the structures and land modification extents across the CBC management zones in order to evaluate management effectiveness. To determine suitable remote sensing imagery, we conducted a sensitivity analysis in order to evaluate sensor ability to precisely characterize ground features of interest (Boyle et al. 2019)

Beekeeping need to consider the habitat's suitability, based on its ecological environment as well as land suitability for the feed source. Geographic information systems (GIS) have the ability to develop a model in the framework of land suitability evaluation (Elsheikh et al. 2013). Data provided by GIS can be widely used by beekeepers to improve apiary management decisions. This is confirmed by various cases of using GIS to solve various problems in beekeeping.

Geographical Information Systems (GIS) are computer systems based on hardware, software, and georeferenced data that can be used to collect, store, manage, process, analyze, and visualize both spatial and non-spatial information representing real-world geographic phenomena (Burrough and McDonnell, 1998; Neteler and Mitasova, 2008). Georeferenced data refers to any data that are linked to a location on the Earth's surface through the use of a geographic or projected coordinate system. GIS data are digital objects which represent real-world entities (Longley et al., 1999) and are defined by: their geometric properties (spatial location), their attributes (characteristics associated with each object), and their topology (definition of how entities are related to others in space) (Burrough and McDonnell, 1998).

Method suggested using Remote sensing to conserve honeybees

Harmonic radar, which identifies the frequency of a diode, can be used for tagging and tracking of animals (Galbraith et al., 2015). Tags can be light enough for use with medium-sized bees such as honeybees (Apis mellifera). This has contributed to the understanding of how honeybees seek out resources, communicate resource locations, and navigate flight

LiDAR has been used as an effective off-site monitoring method to measure bee location and dwell time over potential mines. LiDAR can be used to detect bee density over time and space and, using a continuous-wave diode laser, can detect the unique wing-beat of the bees. (Shaw et al., 2005, Hoffman et al., 2007)
In order to prevent the extinction of native pollinators such as the stingless bees, governments need to develop initiatives to establish biological corridors. Such actions could be crucial to conserving ecosystems that provide services by buffering the joint effects of habitat loss and climate change. According to different studies, protecting conserved areas and restoring disturbed areas could improve habitat connectivity and safeguard ecosystem services, which could facilitate the dispersal and establishment of wild bees during distribution shifts (Giannini et al. 2015). Promoting urban gardens could be an option to offer food resources for species that inhabit urban areas. an analysis of examples of the use of GIS in beekeeping was carried out to assess the current situation. In the future, this information could be used to identify potentially important areas for the development of GIS-based software solutions to meet the needs of beekeeping. The possibilities of GIS are especially important for the development of precision beekeeping, within which a combination of various digital solutions such as the Internet of Things and remote monitoring of bee colonies is possible (Sharma et al., 2018). Ultimately, these solutions can be widely used by beekeepers in decision making, planning their activities and supervision of the bee colonies (Komasilova et al., 2020). In this way, it is possible to improve the efficiency of the use of available resources for beekeeping, as well as contribute to the development and success of agriculture (Hadjur et al., 2022).
The study was conducted in the Pella regional unit in Northern Greece, which includes several municipalities and about 89 municipal communities. The authors used a large amount of data, including the attractiveness of crops and plants for pollination, Weighted (IDW) interpolation method. Microsoft Excel was also used for data processing. As a result, three heat maps were developed, each of which displays a specific indicator (RAI, RDI and RPI). According to the conclusions of the authors, the results displayed on the maps differ at the local level, as they depend on many parameters, in particular, on the land cover. land cover data, and honey bee pollination services. During the analysis of information and spatial data, the authors introduced three indicators: Relative Attractiveness Index (RAI), Relative Dependence Index (RDI), and Relative Priority Index (RPI). Based on these indicators, the corresponding thematic heat maps were developed.

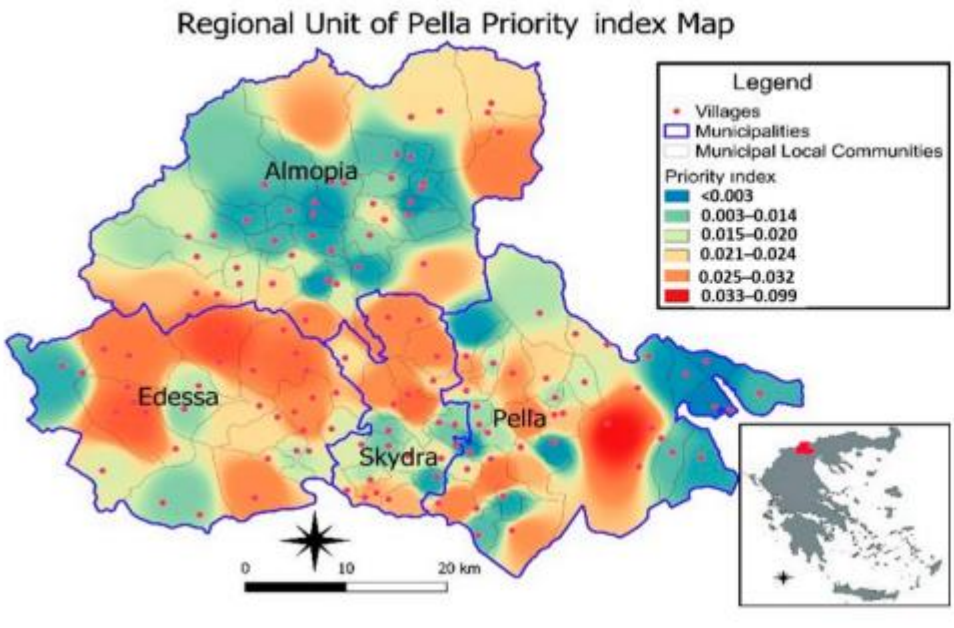

Figure 1 Relative priority map (Source: Marnasidis et al., 2021)

Geographical information system (GIS) and Landsat satellite images were utilized to identify potential locations for propolis production.
The geographical information system (GIS) has been previously used in apiculture for classifying regions according to their suitability for honey bees as well as for other purposes. Therefore, the regions that require the use of modified beehives, generally, for keeping honey bees during the summer were identified using the GIS. Three maps classified into five classes based on data ranges and the results of the laboratory experiments were created; 1) thermal map classified into five classes using the maximum temperatures during the summer season. 2) drought conditions map classified into five degrees using the combination of relative humidity, precipitation and water resources. 3) overall map for temperatures and drought conditions classified into five

classes based on the previous two maps. The harshest regions with elevated temperatures and drought conditions were then identified. (Fig 2-6)

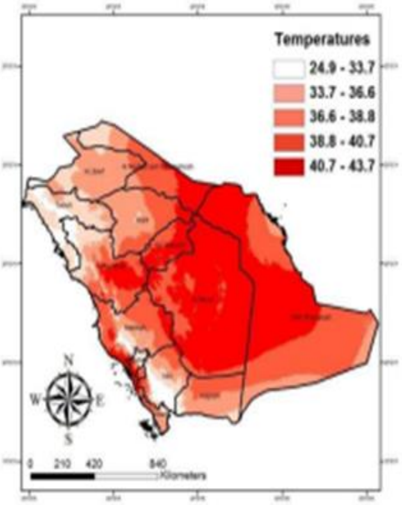

Figure 2 classifications according to maximum temperatures (Source: Abou – Shaara et al., 2013c)

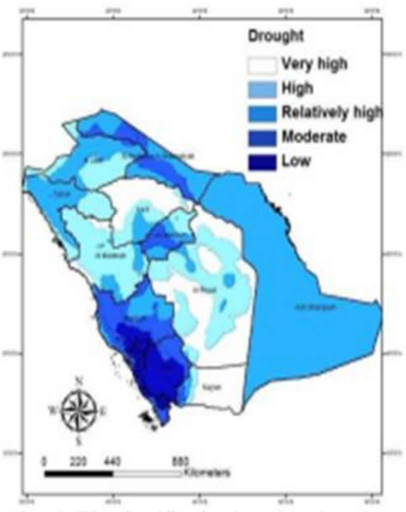

Fig. 3 The classification based on drought conditions (Source: Abou – Shaara et al., 2013c)

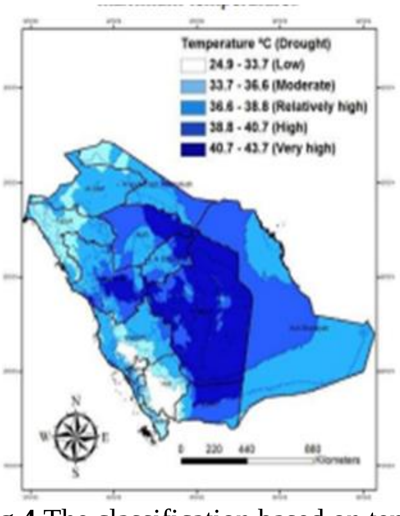

Fig.4 The classification based on temperatures and drought conditions (Source: Abou – Shaara et al., 2013c)

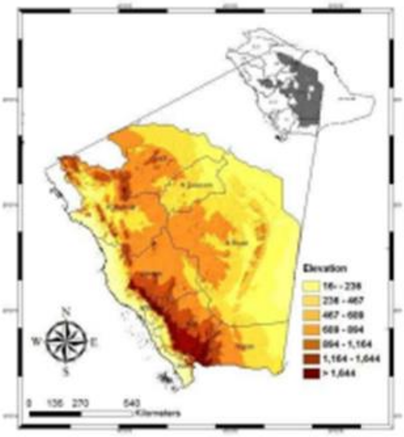

Fig. 6 The elevation of the harshest regions in comparison with the other regions (Source: Abou – Shaara et al., 2013c)

Conclusion

The integration of remote sensing technologies, GIS, and data analysis tools provides a comprehensive approach to conserve honeybees. These methods contribute to understanding bee behavior, assessing habitat connectivity, and making informed decisions at both local and regional levels for the sustainable management of bee populations and their ecosystems.

Conflicts of interest

None

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