Saudi Journal of Biological Sciences 24 (2017) 1038–1044

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Determining spatio-temporal distribution of bee forage species of Al-Baha region based on ground inventorying supported with GIS applications and Remote Sensed Satellite Image analysis

Nuru Adgaba [a,*], Ahmed Alghamdi [a], Rachid Sammoud [b], Awraris Shenkute [a], Yilma Tadesse [a], Mahammad J. Ansari [a], Deepak Sharma [a], Colleen Hepburn [c]

[a] Engineer Bagshan Chair for Bee Research, Department of Plant Protection, College of Food and Agricultural Science, King Saud University, P O Box: 1460, Riyadh 11451, Saudi Arabia
[b] College of Computer and Information Sciences, King Saud University, Saudi Arabia
[c] Department of Zoology, Rhodes University, South Africa

ARTICLE INFO

Article history:
Received 26 March 2016
Revised 5 December 2016
Accepted 1 January 2017
Available online 24 January 2017

Keywords:
Bee forage
Plant inventory
GIS
Satellite image
Flowering period
Saudi Arabia

ABSTRACT

In arid zones, the shortage of bee forage is critical and usually compels beekeepers to move their colonies in search of better forages. Identifying and mapping the spatiotemporal distribution of the bee forages over given area is important for better management of bee colonies. In this study honey bee plants in the target areas were inventoried following, ground inventory work supported with GIS applications. The study was conducted on 85 large plots of 50 × 50 m each. At each plot, data on species name, height, base diameter, crown height, crown diameter has been taken for each plant with their respective geographical positions. The data were stored, and processed using Trimble GPS supported with ArcGIS10 software program. The data were used to estimate the relative frequency, density, abundance and species diversity, species important value index and apicultural value of the species. In addition, Remotely Sensed Satellite Image of the area was obtained and processed using Hopfield Artificial Neural Network techniques. During the study, 182 species from 49 plant families were identified as bee forages of the target area. From the total number of species; shrubs, herbs and trees were accounting for 61%, 27.67%, and 11.53% respectively. Of which *Ziziphus spina-christi*, *Acacia tortilis*, *Acacia origina*, *Acacia asak*, *Lavandula dentata*, and *Hypoestes forskaolii* were the major nectar source plants of the area in their degree of importance. The average vegetation cover values of the study areas were low (<30%) with low Shannon's species diversity indices (H′) of 0.5–1.52 for different sites. Based on the eco-climatological factors and the variations in their flowering period, these major bee forage species were found to form eight distinct spatiotemporal categories which allow beekeepers to migrate their colonies to exploit the resources at different seasons and place. The Remote Sensed Satellite Image analysis confirmed the spatial distribution of the bee forage resources as determined by the ground inventory work. An integrated approach, combining the ground inventory work with GIS and satellite image processing techniques could be an important tool for characterizing and mapping the available bee forage resources leading to their efficient and sustainable utilization.

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1. Introduction

The Kingdom of Saudi Arabia extends over two million km^2 land area. Despite its arid climatic conditions, the country consists of diverse ecologies and floras in which more than two thousands of plant species have been recorded (Collenette, 1999; Chaudhary, 2001). As a result, beekeeping is practiced in many areas of the country and it is one of the important income generating activities for rural communities. Despite the presence of diverse number of bee plants, seasonal shortage of bee forage is critical. These conditions force many beekeepers to move their

* Corresponding author.
E-mail addresses: nuruadgaba@gmail.com, nurmohammed@ksu.edu.sa (N. Adgaba), mjavedansari@gmail.com (M.J. Ansari), colleen@ivorymacs.co.za (C. Hepburn).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjbs.2017.01.009
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colonies from place to place (averagely 5 times/year) following the availability of bee forage in different ecologies and seasons (Nuru et al., 2014). This often led to overcrowding of large numbers of bee colonies in a few areas, causing intense competition for bee forage and the subsequent declines of productivity of colonies (Khanbash, 2001; Al-Ghamdi, 2007). However, the type of honey bee plants, their relative abundance, spatial distribution, phenology and their relative values for bees and honey production were not studied and documented.

Honey bee floral resources vary in ecological distribution and in periods of availability according to their flowering times (Chemas and Rico-Gray, 1991). It is therefore, very important to differentiate honey bee plants from the total plants, to map their spatial and temporal distributions and determine their relative values to bees and honey production for every geographical region. Such types of information are important to categorize bee forage plants as useful for colony population build-up and honey production (Partap, 1997).

To identify and inventory honey bee plants; different approaches such as palynological analysis of honey samples, direct observation of foraging bees and analysis of pollen loads and pollen stores in the nest have been used (Amoko, 1997; Hepburn and Jacot-Guillarmod, 1991; Hepbun and Radloff, 1995; Admasu, 2003; Abou-Shaara, 2015a,b). However, these methods only give a general idea as to which plant species the honey bee foragers collected pollen from, and not other co-existing plant species which may flower concurrently and from which resources are also readily available. In recent years, another approach is that of above ground vegetation biomass assessments have been used to estimate the bee forage potentiality of an area. The most common techniques are estimations from field measurements which involve representative sampling following the protocols such as by Kent and Coker (1992), Peichl and Arain (2006), Wulder et al. (2008), or direct measurements like those of Suganuma et al. (2006).

Despite their merits in degree of accuracy and applicability for specific tree species, ground inventory work is highly time and labor intensive and difficult to cover large areas. Peichl and Arain (2007) showed the presence of a strong correlation between spectral information recorded by Remote Sensing of Satellite Images with that of vegetation conditions. In addition Sahoo et al. (2005) used satellite-derived images showing temporal vegetation phenology (green-up and brown-down) to monitor vegetation changes. Several vegetation indices particularly, NDVI reflectance images are most commonly utilized in vegetation analysis (Jarlan et al., 2008). Gould (2000) and Rocchini et al. (2007) have used Remote Sensed Satellite Images to map vegetation cover down to species-level.

However, satellite images in their raw form are not suitable to understand and interpret in a meaningful way and to use them for specific objectives. Therefore, it requires a suitable image segmentation process, which is partitioning of an image into non-overlapping, meaningful and homogenous regions based on their pixel properties (Sammouda et al., 2013). Pixel clustering is one of the effective and efficient techniques used to create homogenous image regions for image segmentation and its aim is to partition the desired clusters with high intra-class similarities (Felzenszwalb and Huttenlocher, 2004). In the satellite image segmentation, the application of the Hopfield Artificial Neural Network (HNN) clustering algorithm technique is reported to be useful to process the images in meaningful homogenous regions (Shi and Mallick, 2000).

Since different tree species become green-up as a result of flushing of leaves at different times, Remote Sensed Satellite Image processing of such changes, supported with GIS based ground inventory work, can be used to analyze the temporal and spatial distribution of bee forage species at different seasons. The aim the current work was to determine the spatiotemporal distribution of honey bee forages of the target areas through detail ground inventory work using GIS applications and supported with Remote Sensed Satellite Image processing techniques.

2. Materials and methods

2.1. Study area

The study was conducted in Al-Baha region, Saudi Arabia (Fig. 1). The region is characterized by diverse physiographic conditions which vary from lowland plains to highland plateaus with altitudinal range of 300–2400 m above sea level. The topography of the region is mainly undulated hills, mountains with strips of fertile valleys. The average relative humidity of the region ranges from 52 to 67%. The rainfall amount is relatively low and varies from 229 to 581 mm/annum. The mean temperature is 22.9 °C.

2.2. Ground inventory

The vegetation composition of the target areas was determined by taking 11 representative study sites (valleys). A total of 85 large sampling plots (50×50 m each) (total sampling area of 212,500 m^2) were covered. The sampling plots were taken following Kent and Coker (1992), Flombaum and Sala (2007) and Suganuma et al. (2006) protocols. Unlike the previous protocols, we used large sampling plots, because trees and shrubs found very scattered in the study area. For each plot all the necessary informa-

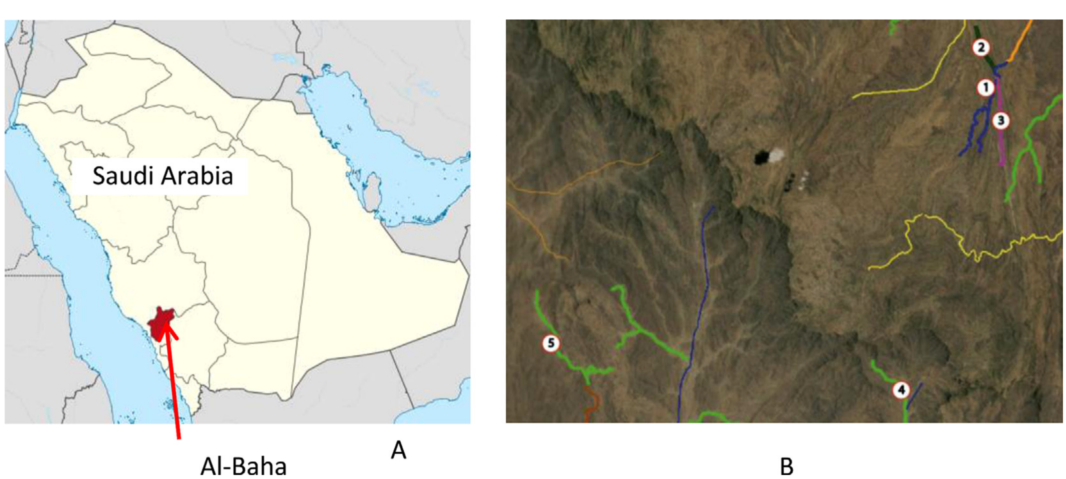

Fig. 1. Map of the studied areas: A = Saudi Arabia, (Al-Baha region); B = specific studied valleys (1 = Majma, 2 = Berha, 3 = Wable, 4 = Alkhatani, 5 = Neera).

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