NEW GEOMATICS TECHNIQUES FOR BEES MONITORING: THE BEEMS PROJECT

Vincenzo Di Pietra[1], Paolo Dabove[1]

[1]Department of Environment, Land, and Infrastructure Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, Turin, 10129, Italy

Correspondence to: Paolo Dabove[1] (paolo.dabove@polito.it)

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Abstract

Bees provide essential pollination services to natural ecosystems and agricultural crops. However, bee populations, both wild and farmed, are in decline around the world. To better manage and restore bee populations, long-term monitoring programs are needed. Direct monitoring of bees is expensive, time-consuming and requires a high level of expertise. Therefore, economic indicators for bee diversity and community composition are essential. The BEEMS Project, a project of Scientific and Technological Cooperation between Italy and Israel (Scientific Track 2019), aims to evaluate the cost-benefit ratio of new aerial Geomatics techniques compared to classical terrestrial methods to collect biotic and abiotic indicators of diversity bees and the composition of their communities. This work aims to present the project's progress, focusing on the Geomatics techniques applied to collect environmental data and produce spatial information useful for the work's progress.

Keywords: Geomatics, photogrammetry, bees, multi-temporal analyses.

INTRODUCTION

Pollination plays a key role in maintaining global human food supply (Klein et al. 2007) and the functional integrity of most terrestrial ecosystems (Ollerton et al. 2011). While crop pollination relies mainly on managed colonies of the domesticated honey bee (*Apis mellifera*), wild, unmanaged pollinators were found to be highly effective, often critical contributors to pollination services in natural and agricultural systems (Garibaldi et al. 2013). Among these wild pollinators, native bees are the most important pollinator group (Delaplane and Mayer 2000). Diverse bee communities usually provide more efficient and reliable pollination services than a single pollinator species (Blüthgen & Klein 2011) and are therefore of high conservation priority. The on-going global declines in both wild and managed pollinators raised the interest in native bee conservation and restoration and therefore in long-term monitoring programs. However, executing such monitoring programs is a major challenge, as they are labor-intensive, and require high expertise in the collection of bees and their subsequent taxonomic identification. To date, little has been done in developing efficient tools for monitoring bee communities.

The current prevailing approach for bee monitoring is site sampling oriented, time-consuming and labor-intensive upon collecting the required amount of data. Another approach is identifying, determining, and measuring which biotic and abiotic indicators of floral and nesting resources best reflect bee species diversity and community composition.

Recent advances in the field of remote sensing have allowed performing such measurements parallelly to classical ground methods. The use of Radar technology (Milanesio et al. 2020), UAVs, and image analysis can provide a wide-scale, fast, data-rich digital-platform for developing cost-effective bee monitoring programs. These tools have been widely used for many research activities, starting from subfluvial springs' investigations (Aicardi et al. 2017), thermal analyses (Banding et al. 2012), forestry applications (Aicardi et al. 2016) and hyperspectral measurements (Weinmann et al. 2018).

The BEEMS project, a project of Scientific and Technological Cooperation between Italy and Israel (Scientific Track 2019), aims to develop a technology-based approach for advanced bee community monitoring, coupling photogrammetric tools, based on RGB images, with thermal and multispectral data, to develop a multi-scale and multi-temporal platform for monitoring bees and possibly other insect groups. This contribution wants to enhance this study's progress, focusing the attention on the methodology and future steps.

METHODOLOGY AND CASE-STUDIES

With the aim to assess the biodiversity of the native bees Israelian environment, the Department of Entomology of the Faculty of Agriculture, Food and Environment of The Hebrew University of Jerusalem, has identified the most important indicators which affect the bees community composition. Among the many, some of them can be measured thanks to the geomatics techniques. In particular, the environmental spatial variability is represented by the ground cover from which is possible to obtain the Shannon-Weaver Index, an ecological index that takes into account the proportion of the cover ground. Moreover, what mainly affects the bees biodiversity is the presence of food, the nesting capability and the spatial variability of the area. These three aspects are reflected by the flower richness and abundance, the soil chemical characteristics and the ground cover.

From a Geomatics point of view, the BEEMS project proposes to collect these biotic and abiotic indicators, through the development of novel aerial remote sensing approaches, coupled with mapping techniques and image analysis. Machine learning algorithms will be applied to automatically extract the required indicators and compare them with those obtained, considering classical techniques.

In this work, the methodology used to perform ground cover classification and the preliminary results will be illustrated. The ground cover percentage was computed through a semiautomatic object-oriented (OBIA) supervised machine learning classification. At present, two measurement campaigns have already been carried out in two complementary study areas in central Israel, in February 2020. The two different environment sites located in Israel considered in this project are the Judean foothills, a shrublands/maquis ecosystem with vertisoil made as a mosaic of agricultural fields and planted pine forests (at SE of Tel Aviv), and the Alexander Stream National Park, a coastal sand ecosystem subject of restoration policies (at N of Tel Aviv). In these areas, six plots have been identified where the analyses have been performed. For the surveys, a DJI Matrice 200 UAV with a Slantrange 4P+ multispectral camera has been used. This camera has six channels integrated with an ambient illumination sensor (AIS), a LiDAR and a GNSS receiver for direct georeferencing and radiometric calibration of images. The advantages of using such sensors are to avoid using a calibration panel on the ground for the on-site image calibration while instead measuring simultaneously the incident and reflected sunlight for direct calibration. The specifications are reported in Table 1, while the in-flight set-up is showed in Fig. 1. During the two survey campaigns, about 20 flights were made, and around 150 GB of 2048 x 1536 pixels images have been acquired, with a mean ground sample distance (GSD) of about 2 cm. The information stored in the images is the RGB channels and the Red-W, the Red Edge and the Near InfraRed ones. A total of 27 Ground Control Points (GCPs) have been measured in both test sites with a multi-frequency, multi-constellation geodetic GNSS receiver in RTK mode.

Fig. 1. Instruments used during the survey's campaigns

Table 1. Technical specifications of the hardware used during the data acquisition.

Aircraft 	Max Takeoff Weight	6,14 Kg
	Max Payload	2,3 Kg
	Dimensions	Unfolded (with propellers): 887×880×378 mm
	Max Flight Time (Full payload)	13 min
Camera 	Focal length	0,016 m
	Frame Rate (Hz)	0.8
	Spatial Resolution (GSD @100 m AGL)	2.2 cm
	Spectral Channels	6
	Size, Vegetation Sensor	14.6 x 6.9 x 5.7 cm
	Weight	350g
Precision Navigation Module 	LIDAR Resolution	1 cm
	LIDAR Accuracy	< 10 cm
	GPS	GPS RTK enabled Dual L1

All the data processing phases have been performed exclusively through Geographic Free and Open Source Software (GFOSS), mainly using the QGIS software for spatial analysis and the creation of thematic maps, the libraries of the open-source project Orfeo Toolbox (OTB) for the segmentation and classification of very high-resolution images, and the development of ad-hoc machine learning techniques for the information extraction, useful for the project.

Effective use of features as input data for a classification procedure can improve classification accuracy. Thus, the classification dataset was enriched with derivative features, namely, spectral-, textural-, and statistical-based features. Table 2 reports the used measures for segmentation and classification. For each segments were computed the mean, the standard deviation, the median, the variance, the skewness and the kurtosis of spectral, histogram and textural features.

Table 2. Features selected for the classification input dataset. They were computed using ORFEO toolbox.

Category	Features
Spectral-based	Color Index
Statistical-based	Variance
	Mean
	Skewness
	Kurtosis
Elevation	Digital Elevation Model
Geometric	Extension (Number of Pixels)
	Flat
	Roundness
	Longness
	Perimeter

PRELIMINARY RESULTS

The photogrammetric processing results are several digital products that contain radiometric, texture, spectral, and spatial information. These products are:

- Three-dimensional dense point clouds (DPC);
- Digital Surface Models (DSM);
- Orthomosaic map;

All these products are georeferenced and defined in WGS84-UTM zone 36N. The results are summarized in Table 3 and 4 for Alexander Stream National Park and the Judean foothills.

Table 3. Summary of processing parameters and accuracy results of the Alexander Stream National Park site's digital products.

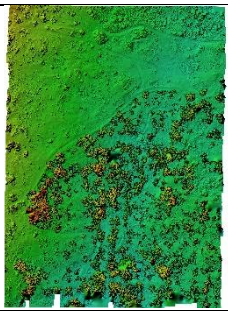
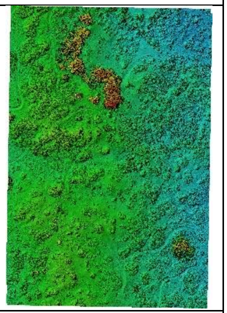
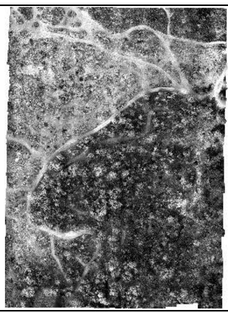
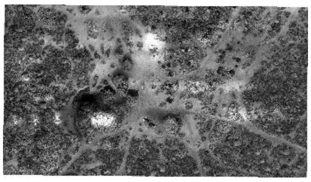
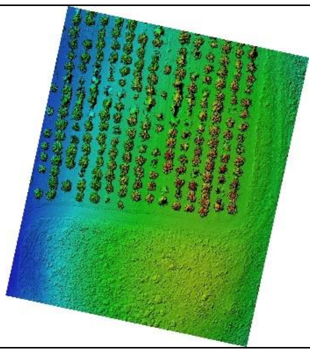
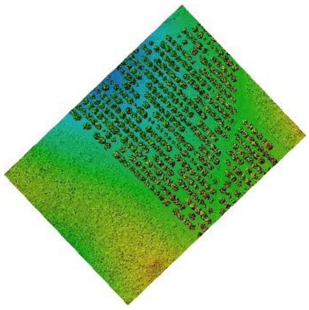
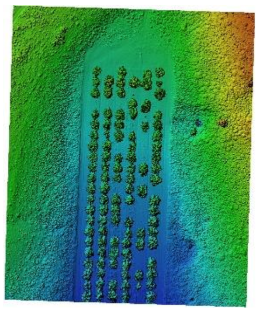
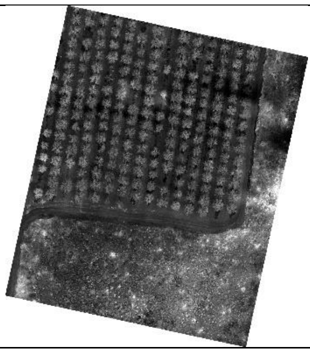
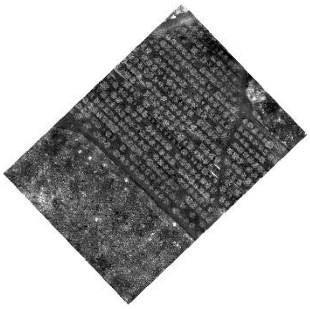
Digital Product	**Parameters**	Dataset 1	Dataset 3	Dataset 4
Aerial images	**number**	4.446	3.918	5.022
DPC	**point number**	171.888.569	130.377.749	170.992.083
	processing time	28 min	38 min	38 min
DSM	**map**			
	size	10,127x13,513	11,317x6,440	8,813x12,936
	dim pixel	2,57 cm/pix	2,86 cm/pix	2,75 cm/pix
	processing time	3 min	2 min	24min
Orthomosaic	**map**			
	band number	6	6	6
	size	19,870x27,002	22,623x12,87	17,569x25,85
	dim pixel	1,28 cm/pix	1,43 cm/px	1,38 cm/pix
	processing time	27 min	15 min	43 min

Table 4. Summary of processing parameters and accuracy results of the Judean foothills site's digital products.

The Judean foothills				
Digital Product	**Parameters**	**Dataset 1**	**Dataset 2)**	**Dataset 3**
Aerial images	**number**	1.450	6.846	4.722
DPC	**point number**	98.452.320	194.483.854	82.769.132
	processing time	37 min	3 hours	1 hours 40 min
DSM	**map**			

	size	9,595 x 10,824	13,979 x 13,852	7,042 x 8,467
	dim pixel	1,61 cm/pix	1,9 cm/px	2,01 xm/pix
	processing time	2 min	27 min	2 min
Orthomosaic				
	band number	6	6	6
	size	19,190 x 21,648	27,904 x 27,696	13,929 x 16,893
	dim pixel	0,08 cm/pix	0,09 cm/pix	1,01 cm/pix
	processing time	22 min	3 hours	115 min

From the photogrammetric process, it was possible to compute several spatial and spectral features, useful to data interpretation and classification. In particular, thanks to the six bands' combination, it was possible to compute vegetation, water content, and soil indices. Several indices already proposed in literature have been computed and used as features. These features allow to describe the characteristics of the area and to train a supervised classification model. In total, more than 20 indices have been computed. At this stage of the project, three classes describe the characteristics of the natural environment: bare soil, low vegetation and high vegetation. In the next steps, the classes will be extended to herbaceous plants, woody plants, dry herbaceous plants, rocks and stones. For each class, more than 300 objects as been identified to be used as training and testing. Random Forest classification (Breiman L., 2001) model was trained using the input dataset.

Figure 2 shows the result of the semiautomatic classification procedure and allows to visually notice the high resolution of the classification based on UAV imagery. These are the results obtained in a small portion of the Alexander Stream National Park, and more detailed results will be proposed in future update of the project. Table 5 shows the accuracy metrics of the classification procedure, in particular the F1-score, Precision and Recall values of each class. Finally, Table 6 reports the quantitative analysis of the classes in therm of Area and ground cover percentage. These values could be compared with the ones acquired by direct measurement on the ground.

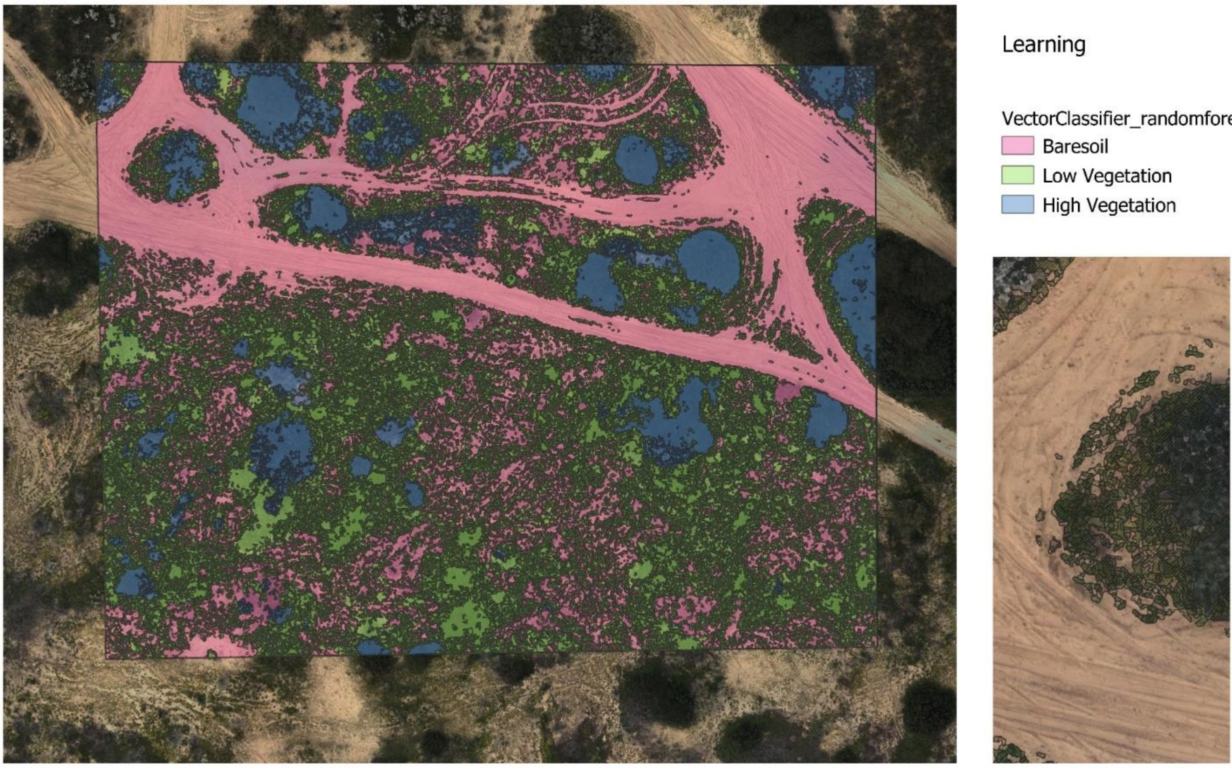


Fig. 2. Results of the ground cover classification with a detail.

Table 5. Accuracy metrics calculated on the random forest classification.

	Baresoil	High Vegetation	Low Vegetation
Precision	0.846	0.938	0.770
Recall	0.860	0.929	0.731
F-score	0.831	0.948	0.814

Table 6. Ground Cover computation.

Label	Pixel number	Area (m^2)	Ground Cover (%)
Baresoil	183630	1836.30	37.94
Low Vegetation	230936	2309.36	47.71
High Vegetation	58743	587.43	12.13

CONCLUSIONS

The BEEMS project wants to test new aerial Geomatics techniques compared to classical terrestrial methods to collect biotic and abiotic indicators of diversity bees and their communities' composition. This work has presented the project's progress, highlighting the new Geomatics techniques based on advanced photogrammetric tools, to develop a multi-scale and multi-temporal platform for monitoring bees. The next steps will be to apply a machine-learning algorithm to automatically extract the required indicators and compare them with those obtained, considering classical techniques. In particular, supervised and unsupervised classifications will be used, and different classification models to assess these case studies' performances. Local statistics, textural, morphological and geometrical features, radiometric indices and edges will be extracted from the DSM, DPC and orthophotos presented in this work, and used as a basis for class identification.

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