Article

A morphometry map and a new method for honey bee morphometric analysis by using the ArcGIS

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Abstract

The morphometric analysis of honey bees has a substantial importance for honey bee subspecies characterization and discrimination while the ArcGIS is a geographical program for data analysis. In the present research, the combination between the morphometric data and the spatial analysis options of the ArcGIS was done and subsequently tested in creating a morphometry map for honey bees from some regions in Egypt as well as for the discrimination between two honey bee subspecies. Therefore, I present a model for creating the morphometry maps and a new method for the morphometric analysis by the transformation of the morphometric data to raster data layers. The obtained results showed that the created morphometry map classified the regions successfully according to the morphological character means. The morphometric analysis was successfully performed by using trend analysis and raster difference range. The analysis of the morphometric data as raster layers showed high sensitivity for the differences between subspecies and regions. The presented model and the method are effective and can be applied for the discrimination between subspecies, regions and colonies as well as can be used with other insects.

Keywords honey bees; ArcGIS; morphometrics; map.

1 Introduction

Morphomteric of insects and in particular honey bees, *Apis mellifera* L., is a developing technique. This technique has been developed from the use of body characteristics or standard morphometrics (e.g. Ruttner et al., 1978; Buco et al., 1987 and Rinderer et al., 1993) to the use of coordinates of the wing venation characters (Cartesian coordinate) or geometric morphometrics (Tofilski, 2008 and Çakmak et al., 2011). Due to the importance of the standard and geometric analyses many studies have been performed worldwide on honey bees, and the morphometric analysis methods were reviewed intensively by Bouga et al. (2011) while wing

venation characters were reviewed by Abou-Shaara (2013). The morphometric analysis methods either geometric or standard have been used separately or as integrated methods for subspecies discrimination (Tofilski, 2004; Meixner et al., 2007; Francoy et al., 2008; Abou-Shaara and Al-Ghamdi, 2012), and regional classification or cluster analysis (Marghitas et al., 2008; Adl et al.,2007; Shaibi et al., 2009; Güler et al., 2010) as well as for other purposes including; testing of races purity (Radloff et al., 2003; Miladenovic et al., 2011), the prediction of colonies productive characteristics (Edriss et al., 2002 and Mostajeran et al., 2006) and to monitor the changes within honey bee population over time (Abou-Shaara et al., 2012) beside other reasons.

On the other side, the geographical information system (GIS) has been employed for performing some investigations on apiculture; including the identification of rangeland suitability for honey bee colonies (Amiri et al., 2011; Amiri and Shariff, 2012) and for creating suitability maps for beekeeping and plants availability for honey bees (Coulson et al., 2005; Estoque and Murayama, 2010; Abou-Shaara et al., 2013). This program deals specifically with geographical data to solve some geographical problems or to predict the suitability of geographical resources to specific activity beside other purposes. Thus, this program has a lot of statistical and data presentation options. Unfortunately, the combination between the morphometric data and ArcGIS has not been done so far. Therefore, here I present a model for creating morphometry maps and a method for morphometric analysis either geometric or standard by using the ArcGIS. The model was used for creating a morphometry map for seven regions in Egypt. Also, the discrimination between two subspecies (Carniolan and Yemeni honey bees) by using standard and geometric morphometric was performed.

2 Materials and Methods

2.1 The morphometry map by using the ArcGIS

To create the morphometry map using the ArcGIS 10, the available published means by Kaschef (1959) and Abou-Shaara et al. (2012) for some morphological characters (fore wing length, fore wing width, cuibital index, tongue length, basetarsus length and basetarsus width) belong to different 7 regions in Egypt as shown in Fig. 1 were arranged and prepared as shapefile layers. The created layers were subsequently converted into raster layers and were classified into three equal ranges described as low, moderate and high, as shown in Table 1. The classified rasters were then combined and the morphometry map was created. The steps of the used model are shown in Fig. 2. The presented model is similar to a model used by Abou-Shaara et al. (2013) for creating a suitability map for beekeeping under harsh environmental conditions.
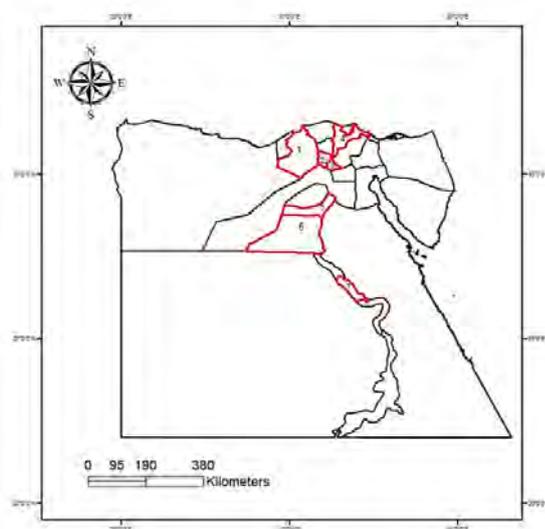
Fig. 1 The incorporated regions into the analysis; 1: El-Behera, 2: El-Monofeya, 3: Al-Kaliobeya, 4: Al-Dakahlia, 5: Beni-Suef, 6: El-Minya and 7: Sohag.

To test the significance between the classified regions, the Anselin Local Moran's I statistic according to the z-scores and *p*-values was employed at a significance level of 0.05.

Table 1 The classified range for raster layers.

Characters	Values range	Degree
Fore wing length (mm)	8.326667 - 8.12	Low
	8.533333 - 8.326667	Moderate
	8.74 - 8.533333	High
Fore wing width (mm)	2.8 - 2.72	Low
	2.88 - 2.8	Moderate
	2.96 - 2.88	High
Cubital index	2.706667 - 2.59	Low
	2.823333 - 2.706667	Moderate
	2.94 - 2.823333	High
Tongue length (mm)	5.58 - 5.41	Low
	5.75 - 5.58	Moderate
	5.92 - 5.75	High
Tibia length (mm)	2.91 - 2.82	Low
	3 - 2.91	Moderate
	3.09 - 3	High
Basetarsus length (mm)	2.173333 - 2.13	Low
	2.216667 - 2.173333	Moderate
	2.26 - 2.216667	High
Basetarsus width (mm)	1.093333 - 1.08	Low
	1.106667 - 1.093333	Moderate
	1.12 - 1.106667	High
Number of hooks	21.04 - 20.299999	Low
	21.78 - 21.04	Moderate
	22.52 - 21.78	High

2.2 The morphometric analysis by using the ArcGIS

Samples of two honey bee subspecies (Yemeni and Carniolan) honey bees were collected from colonies managed at the Bee Research Unit, KSU apiary (thirty bees per each subspecies). The fore wings were subsequently separated and scanned by using high resolution HP scanner at1200 dpi. The coordinates (x,y) of 18 standard fore wing points (see, Abou-Shaara and Al-Ghamdi, 2012) were determined by using imageJ 1.46 program for geometric morphometric analysis, and the inner wing length and width were measured for the standard morphometric analysis by using ScanPhoto method according to Abou-Shaara et al. (2011). The ArcGIS program was employed for performing the morphometric analysis and the two subspecies were compared based on trend analysis and dissimilarity range.
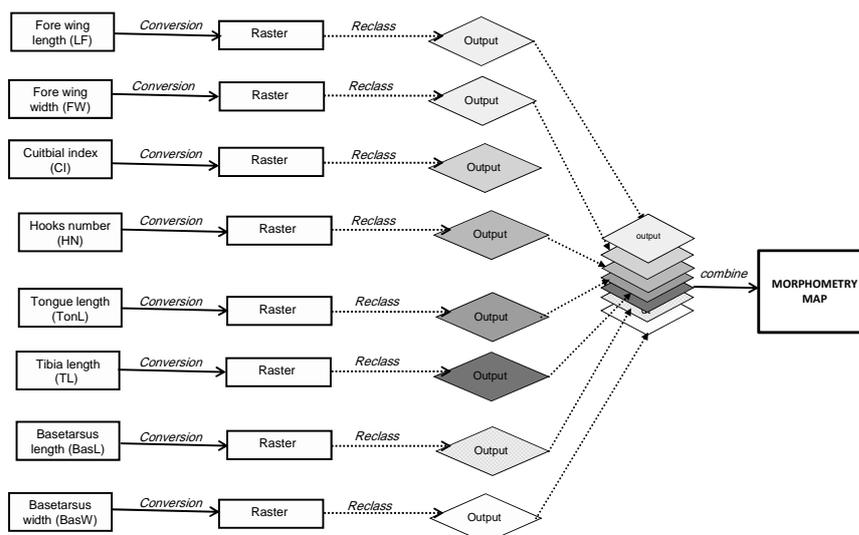
Fig. 2 Steps for creating the morphometry map by using the ArcGIS.

2.3 The geometric morphometric analysis

The means were calculated for each point for all bee samples, then the means were normalized to be from (0 to 1). The data were arranged in three main columns (1: for Points, 2: for x and 3: for y). Then, the dataset files were saved as Tab delimited. The dataset files were opened in the ArcMap of the ArcGIS, then the display x,y option was used for displaying the points. The points of the two subspecies are shown in Fig. 3.

The data trend was firstly analyzed (Fig. 4) by using the trend option from spatial analyst tools menu (the output cell size was 0.00001522236 for the two subspecies). The data trend was analyzed for two reasons; 1) to transfer the datasets into raster layers, 2) to discriminate visually between the two subspecies. The statistics for the two subspecies including (Min, Max, Mean, S.D., Covariance matrix and correlation) were then calculated (Fig. 5) by using brand collection statistics option. Finally, the Yemeni honey bees trend raster layer was subtracted from the Carniolan honey bees trend raster layer to identify the raster difference range by using minus option (Fig. 6).
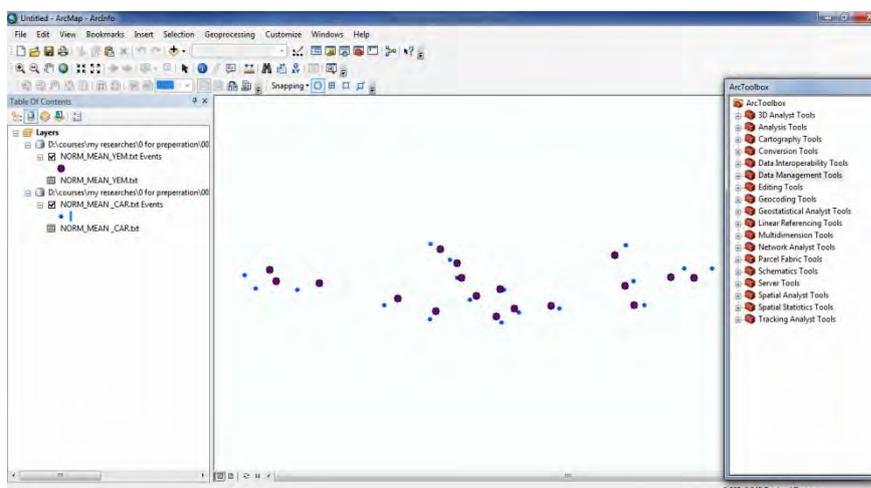
Fig. 3 Points of Yemeni and Carniolan honey bee wings.
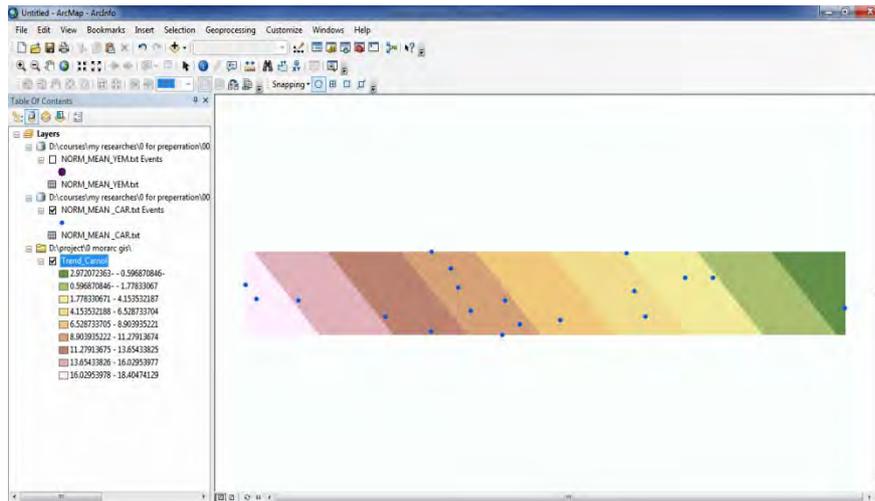
Fig. 4 The trend analysis for Carniolan honey bee wings.
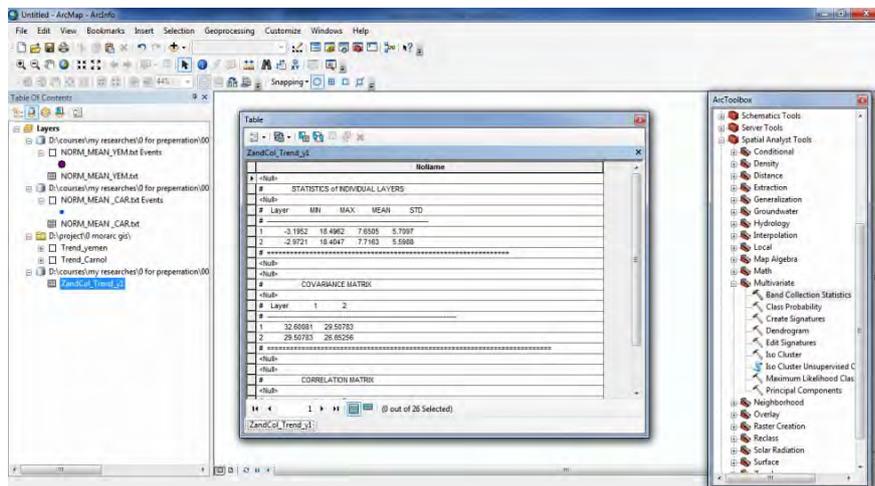
Fig. 5 The statistics output table.
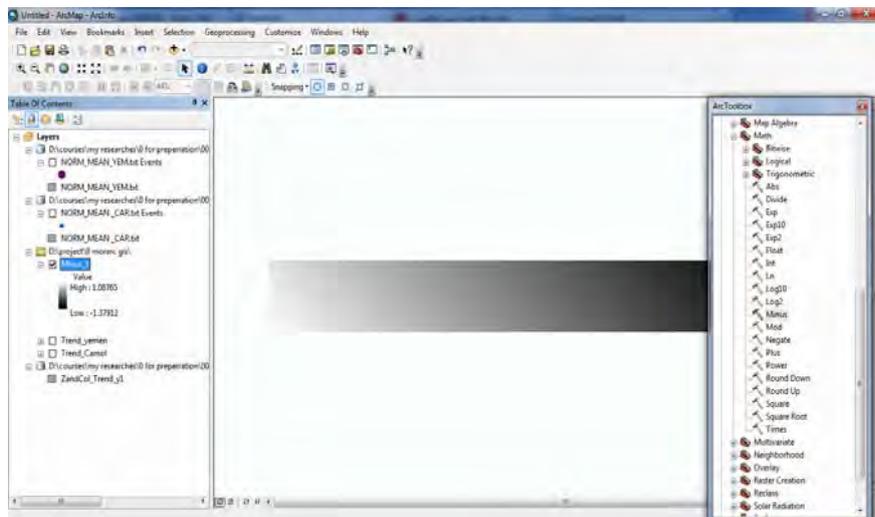
Fig. 6 The minus range appears in the left list. The difference ranged from -1.38 to 1.09 (The value of zero means the absence of differences).

2.4 The standard morphometrics analysis

The aforementioned steps were used with the inner wing length and width, considering inner wing length as (x) and inner wing width as (y) and wings as (points). Each of trend analysis, statistics and raster difference range were calculated for the two subspecies.

3 Results

3.1 The morphometry map by using the ArcGIS

The created morphometry map showed the highest means for the analyzed characters were to four regions (El-Behera, Al-Kaliobeya, Al-Dakahlia and Beni-Suef). The moderated means were found in one region (El-Minya) while the lowest means were found in two regions (El-Monofeya and Sohag) as shown in Fig.7. The spatial statistical analysis by using Anselin Local Moran's I statistic showed the absences of the significant differences for six regions while one region only (Al-Dakahlia) was differed significantly than the others as shown in Fig. 8.
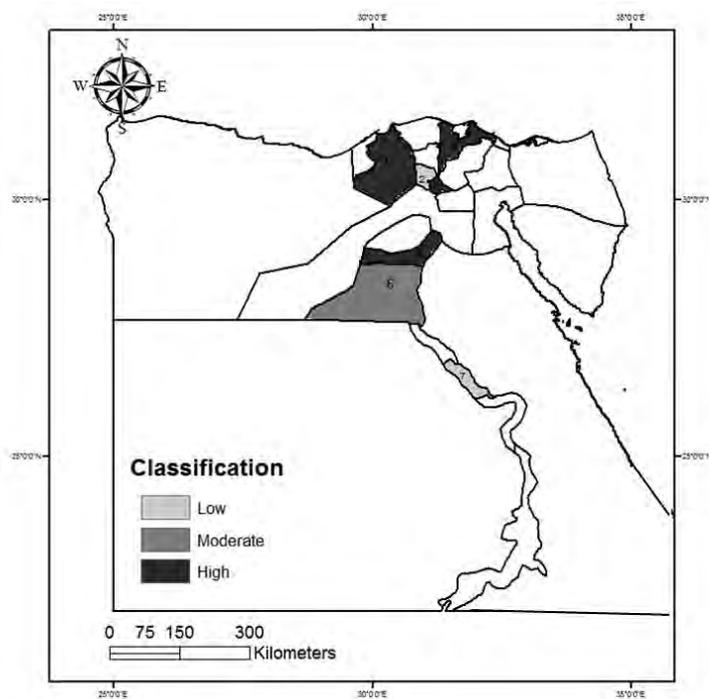
Fig. 7 The morphometry map for honey bees of different regions.
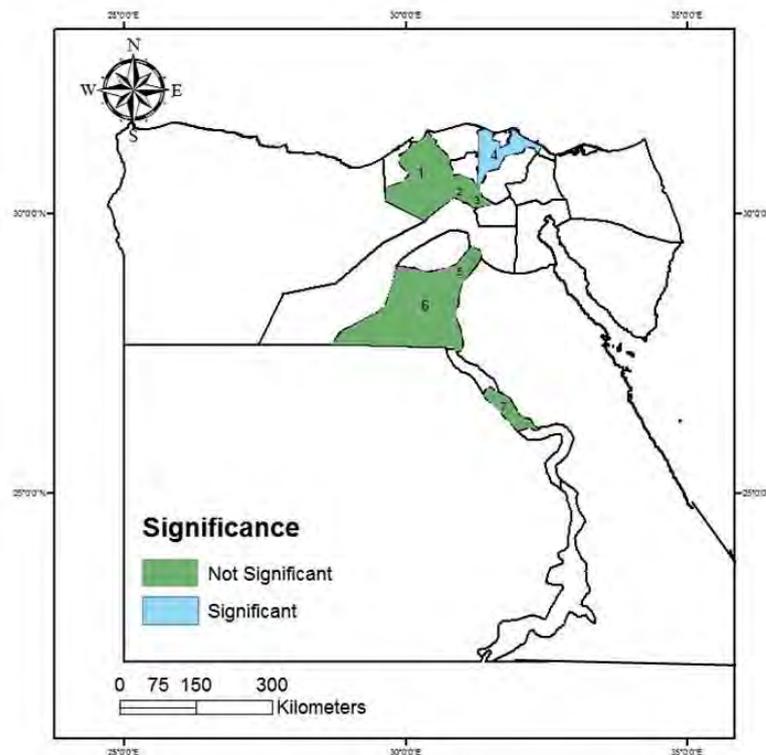
Fig. 8 The output of the spatial statistical analysis.

3.2 The morphometric analysis by using the ArcGIS

3.2.1 The geometric morphometric analysis

The trend analysis showed differences in points distribution and points range (Fig. 9). The trend range of Carniolan honey bees was from 0.59 to18.40 while for Yemeni honey bees was from 0.78 to 18.49.
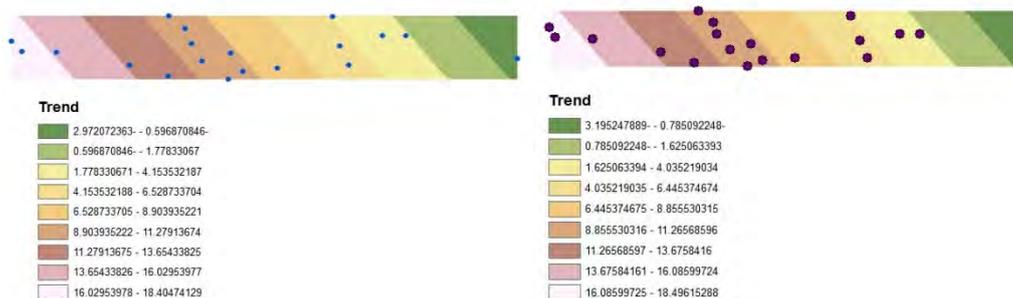
Fig. 9 Trend analysis for Carniolan honey bees (left) and Yemeni honey bees (right)

The raster datasets mean ± SD was 7.65 ± 5.70 for Yemeni honey bees and 7.71 ± 5.60 for Carniolan honey bees. The covariance matrix was 29.50%. The difference between raster layers for the two subspecies ranged from -1.38 to 1.09.

3.2.2 The standard morphometric analysis
For inner wing length and width the trend analysis showed differences between the two subspecies (Fig. 10) the trend range was from 10.15 to 19.16 for Carniolan honey bees and from 13.93 to 17.12 for Yemeni honey bees.
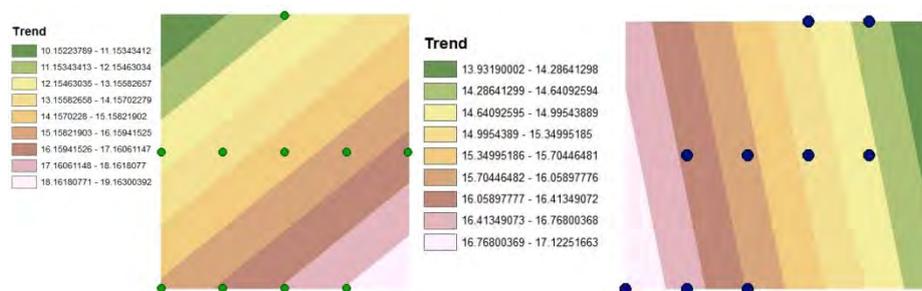
Fig. 10 Trend analysis for Carniolan (left) and Yemeni (right) honey bees.

The mean ± SD was 15.53 ± 0.79 for raster datasets of Yemeni honey bees and 14.65 ± 1.87 for Carniolan honey bees. The covariance matrix was 2.29 %. The difference range between raster layers for the two subspecies ranged from -4.66 to 5.12.

4 Discussion
The morphometry map seperated the regions according to morpohological character means into three categories; low, moderate and high. By evaluating the input datasets the same results were obtained. Therefore, the used model in creating the morphometry map succeeded in regional classification according to the morphological character means. As found by Abou-Shaara et al. (2013) a similar model succeeded in the classification of different regions according to the suitability for beekeeping under harsh conditions of low relative humidity and elevated temperature. The absence of the significant differences between all the regions except one, can be explained by the low differences between the means. An increasing in the character means were noticed toward the northern regions of Egypt than the southern regions, that may be due to the high hybridization degree between honey bee colonies at the north than the south due to the highest beekeeping activity in the north of Egypt. Also, may be the migratory beekeeping in these regions has impacted the morphological characters. Accordingly, it has been reported that the migratory beekeeping can form differences within populations (Arias et al., 2006; Marghitas et al., 2008).

The differences between the two subspecies were detected by using geometric and standard morphometrics, however, standard morphometric analysis showed higher differences between the two subspecies than the geometric morphometrics. The differences between the raster layers for the two subspecies as shown in Fig. 11 showed high variations between the two subspecies especially for inner wing length and width. This result is in line with the previous findings by Abou-Shaara and Al-Ghamdi (2012), they found high significant differences between inner wing length and width while centroid size, matrix correlation and transformation grids showed relatively few differences between the two subspecies. Typically, the difference between the means of the two subspecies for inner wing length was 0.41 mm and for inner wing width was 0.15 mm. Moreover, the difference between the two subspecies in their wing coordinates centroid size was about 0.0025 (Abou-Shaara and Al-Ghamdi, 2012). Thus, the transformation of the morphological data into raster layers followed by the

calculation of the differences between the layers succeeded in detecting the differences between the input datasets, even if the differences are very low between the means.
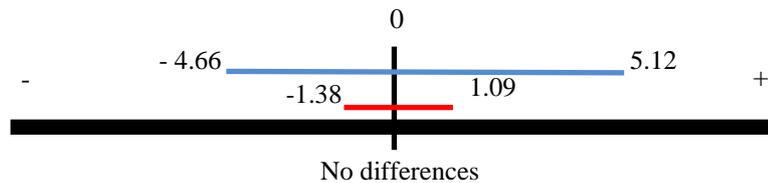
Fig. 11 Ratser difference range for wing point coordinates (red) and inner wing length and width (blue).

The presented method for morphometric analysis showed high sensitivity to minor differences between honey bee races. It worth to mention that the presented method can be used alone or in combination with other statistical methods. In standard morphometric and after characters measuring, the means are mostly measured followed by principal component analysis (PCA) by using factor analysis (Sheppard and Meixner, 2003 and Farhoud and Kence, 2005) and cluster analysis (e.g Shaibi et al., 2009). The main factors resulted from PCA can be subsequently prepared for trend analysis considering factor1 as (x) and factor 2 as (y). Also, the cluster means can be analyzed by the trend analysis. In case of geometric morphometric, after the calculation of centroid size and matrix correlation (e.g. Tofilski, 2008; Abou-Shaara and Al-Ghamdi, 2012) the trend analysis can be applied. Additionally, the comparison between regions and colonies can be performed by creating morphometry maps and by using the trend analysis.

5 Conclusion

The presented model for creating morphometry maps shows high accurateness in performing regional and statistical classification. Also, the morphometric analysis by using the ArcGIS is simple, effective and very sensitive for the detection of the differences between datasets. The transformation of the morphometric data into raster layers allows the use of the ArcGIS in performing the morphometric analysis which can be considered as a new trend in morphometric analysis using geographical softwares. This method also can be employed for the morphometric analysis of other insects.

References

Abou-Shaara HF. 2013. Wing Venation Characters of Honey Bees. Journal of Apiculture, 28(2): 79-86

Abou-Shaara HF, Al-Ghamdi AA. 2012. Studies on wings symmetry and honey bee races discrimination by using standard and geometric morphometrics. Biotechnology in Animal Husbandry, 28 (3): 575-584

Abou-Shaara HF, Al-Ghamdi AA, Mohamed AA. 2013. A Suitability Map for Keeping Honey Bees Under Harsh Environmental Conditions Using Geographical Information System. World Applied Sciences

Journal, 22(8): 1099 -1105

Abou-Shaara HF, Draz KA, Al-Aw M, et al. 2011. Simple method in measuring honey bee morphological characters. Proceedings of 42nd International Apicultural Congress–APIMONDIA in Buenos Aries (Argentina), Argentina

Abou-Shaara HF, Draz KA, Al-Aw MA, et al. 2012. Stability of honey bee morphological characters within open populations. Uludag Bee Journal, 12(1): 31-37

Adl MBF, Gencer HV, Firati C, et al. 2007. Morphometric characterization of Iranian (*Apis mellifera meda*), Central Anatolian (*Apis mellifera anatoliaca*) and Caucasian (*Apis mellifera caucasica*) honeybee populations. Journal of Apicultural Reseach, 46 (4): 225-231

Amiri F, Shariff ABM. 2012. Application of geographic information systems in landuse suitability evaluation for beekeeping: A case study of Vahregan watershed (Iran). African Journal of Agricultural Research, 7(1): 89-97

Amiri F, Shariff ABM, Arekhi S. 2011. An Approach for Rangeland Suitability Analysis to Apiculture Planning in Gharah Aghach Region, Isfahan-Iran. World Applied Sciences Journal, 12(7): 962-972

Arias MC, Rinderer TE, Sheppard WS. 2006. Further characterization of honey bees from the Iberian peninsula by allozyme, morphometric and mtDNA haplotype analyses. Journal of Apicultural Research, 45(4): 188-196

Bouga M, Alaux C, Bienkowska M, et al. 2011. A review of methods for discrimination of honey bee populations as applied to European beekeeping. Journal of Apiculture Research, 50(1): 51-84

Buco SM, Rinderer TE, Sylvester HA, et al. 1987. Morphometric differences between South American Africanized and South African (*Apis mellifera scutellata*) honey bees. Apidologie, 18: 217-222

Çakmak I, Özkan A, Çakmak SS, et al. 2011. A preliminary study on discrimination of different infestation levels of parasite(*Varroa destructor*) by wing geometric morphometric analysis on honey bees. Uludag Bee Journal, 11(4): 118-123

Coulson RN, Pinto MA, Tchakerian MD, et al. 2005. Feral honey bees in pine forest landscapes of east Texas. Forest Ecology and Management, 215: 91-102

Edriss MA, Mostajeran M, Ebadi R. 2002. Correlation between honey yield and morphological traits of honey bee in Isfahan. Journal of Science and Technology of Agriculture and Natural Resources, 6(2): 91-103

Estoque RC, Murayama Y. 2010. Suitability analysis for beekeeping sites in La Union, Philippines, Using GIS and multi-criteria evaluation techniques. Journal of Applied Sciences Research, 5(3): 242-253

Farhoud HJ, Kence M. 2005. Morphometric and MtDNA analysis in honeybee populations (*Apis mellifera* L.) of north and northwest Iran. Proceedings of the Balkan Scientific Conference of Biology. 594-597, Plovdiv, Bulgaria

Francoy TM, Wittmann D, Drauschke M, et al. 2008. Identification of Africanized honey bees through wing morphometrics: two fast and efficient procedures. Apidologie, 39(5): 488-494

Güler A, Bek Y, Guven H. 2010. The Importance of Morphometric Geometry on Discrimination of Carniolan (*Apis mellifera carnica*) and Caucasian (*A. m. caucasica*) Honey Bee Subspecies and in Determining Their Relationship to Thrace Region Bee Genotype. Journal of the Kansas Entomological Society, 83(2): 154-162

Kaschef AH. 1959.The single strain of the Egyptian honeybee *Apis mellifica fasciata* Latr. Insectes Sociaux, 3: 243-257

Marghitas AL, Paniti-Teleky O, Dezmirean D, et al. 2008. Morphometric differences between honey bees (*Apis mellifera carpatica*) Populations from Transylvanian area, Zootehnie Si Biotehnologii, 41(2): 309-315

Meixner DM, Miroslaw W, Jerzy W, et al. 2007. *Apis mellifera mellifera* range in eastern Europe – morphometric variation and determination of its limits. Apidologie, 38: 1-7

Miladenovic M, Rados R, Stanisavljevic LZ, et al. 2011. Morphometric traits of the yellow honeybee (*Apis mellifera carnica*) from Vojvodina (Northern Serbia). Archives of Biological Sciences, 63(1):251-257

Mostajeran MA, Edriss MA, Basiri MR. 2006. Analysis of colony and morphological characters in honey bees (*Apis mellifera meda*), Pakistan Journal of Biological Science, 9(14): 2685-2688

Radloff SE, Hepburn R, Bagay LJ.2003. Quantitative analysis of intracolonial and intercolonial morphometric variance in honeybees, *Apis mellifera* and *Apis cerana*. Apidologie, 34(4): 339-351

Rinderer TE, Buco SM, Rubink WL, et al. 1993. Morphometric identification of Africanized and European honey bees using large reference populations. Apidologe, 24: 569-585

Ruttner F, Tassencouyt L, Louveaux J. 1978. Biometrical statistical analysis of the geographic variability of *Apis mellifera* L. Apidologie, 9: 363-381

Shaibi T, Fuchs S, Moritz RFA. 2009. Morphological study of Honeybees (*Apis mellifera*) from Libya. Apidologie, 40: 97–105

Sheppard WS, Meixner MD. 2003. *Apis mellifera pomonella*, a new honey bee subspecies from central Asia. Apidologie, 34: 367-369

Tofilski A. 2004. DrawWing, a program for numerical description of insect wings. Journal of Insect Science, 4: 17

Tofilski A. 2008. Using geometric morphometrics and standard morphometry to discriminate three honeybee subspecies. Apidologie, 39:558-563