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Expectations about the Potential Impacts of Climate Change on Honey Bee Colonies in Egypt

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Abstract

There are enormous challenges for managed honey bee, Apis mellifera, colonies in the world. Climate change is expected to be the major threat for honey bees in the future. Climate change can impact honey bee colonies negatively and/or positively. Unfortunately, few studies have been done on impacts of climate change on beekeeping. In this research, the possible changes in temperature and some bioclimatic factors in Egypt during near future 2070 were investigated using available datasets. Geographical information system (GIS) was used to perform the study. Potential impacts of climate change on honey bee colonies were then expected using visual comparison technique. It is expected that thermal stress on honey bee colonies in Egypt will be the major problem for beekeepers especially during summer. No major changes are expected to happen in the other bioclimatic factors including precipitation. Beekeepers are advised to harvest honey from their colonies earlier than current time. Some honey bee diseases and pests are not expected to be a great challenge in the near future. For future challenges, studies towards obtaining heat tolerant bees are very essential. Developing suitable methods for protecting honey bee colonies from thermal stress during summer are required.

Key words: Apis mellifera, Visual comparison, Ecology, Apiculture, GIS

INTRODUCTION

Climate is very important for honey bee, *Apis mellifera*, colonies' activity and productivity due to its impacts on honey bees and their diseases as well as the floral environment (Le Conte and Navajas, 2008). Currently, climate change is considered as the main future threat (Yoruk and Sahinler, 2013) due to its consequences on all living organisms including plants and their pollinators (Rader *et al*., 2013). However, few studies have been done on the impacts of climate change on honey bees, and the review article by Reddy *et al*. (2012) has shown that. The impacts of climate change are expected to influence, for example, plants and bee distribution (Le Conte and Navajas, 2008), flowering time of plants (Fitter and Fitter 2002; Scaven and Rafferty, 2013; Yoruk and Sahinler, 2013) and the interaction between plants and their pollinators (Hegland *et al*., 2009; Scaven and Rafferty, 2013). A possible decrease by about 14.5% in plants pollination by honey bee colonies is expected to happen (Rader *et al*., 2013). Thus, understanding impacts of climate change on honey bee colonies will help in preparing early solutions for possible future challenges.

Different tools have been employed to study impacts of stress factors (e.g. weather, land cover, food resources ... etc) on honey bee colonies and Geographical Information System (GIS) is one of them. GIS has been applied in apiculture for various objectives including for example; identification of land cover impacts on apiculture over time

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(Abou-Shaara, 2013a), identification of suitable locations for apiaries (Estoque and Murayama, 2010; Abou-Shaara *et al*., 2013a), investigating suitable wintering sites (Abou-Shaara, 2013b) or plants suitability (Coulson *et al*., 2005) for honey bee colonies, and for recommending potential regions for using modified beehives under harsh environmental conditions of summer (Abou-Shaara *et al*., 2013b). GIS can also be used in classifying lands according to their climatic conditions as done by Amiri *et al*. (2011); Amiri and Shariff (2012) and Abou-Shaara (2013b) during their investigations. Hence, GIS can be used to monitor climate change using suitable datasets of current and future conditions. The objective of the study is to understand potential impacts of climate change on managed honey bee colonies in Egypt using GIS in combination with suitable datasets.

MATERIALS AND METHODS

Study location

All Egyptian governorates were considered in this study. Egypt located between longitudes of 25° and 35°E, and latitudes of 22° and 32°N with total area of about one million square kilometers, and consists of 27 governorates (Fig. 1).

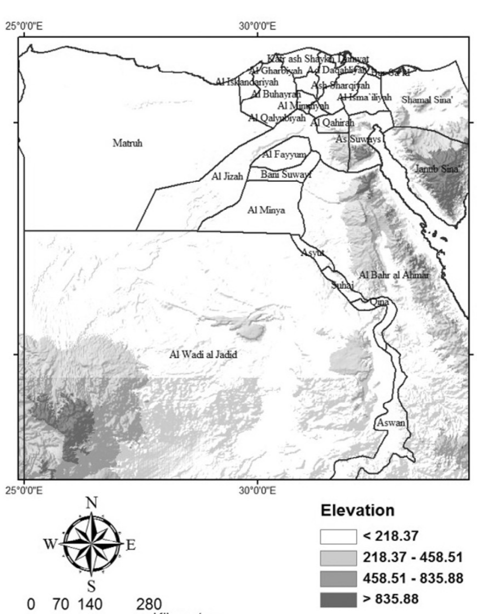

Fig. 1. Governorates of Egypt.

Current temperatures

Thermal maps for maximum temperatures were created for winter, spring, summer and fall by ArcGIS 10 using the available datasets on Worldclimate.com (each season was represented by one representative month as: February for winter, May for spring, August for summer and October for fall). These maps represent temperature means from 1950 till 2000 in °C units at 30 seconds spatial resolutions.

Future temperatures

Maps for expected future maximum temperatures during 2070 (mean for 2061 to 2080) for the four seasons were created by ArcGIS 10 using datasets available from global climate models of Beijing Climate Center_Climate System Model (BCC_CSM1.1) using Representative Concentration Pathways 45 (rcp45). The datasets either for current or future conditions were opened by ArcGIS 10 and then were classified into 2 or 3 classes based on data range and to facility map comparisons. Easily compared colors were used for each class, and then obtained maps were compared to identify the expected future changes. Minimum temperatures for current and future conditions obtained from the previously mentioned sources were presented in table to minimize figure numbers.

Bioclimatic factors

Some bioclimatic factors were compared for current and future conditions; namely precipitation (mm), annual mean temperature (°C), mean diurnal range °C (as difference between mean of monthly maximum temperature and monthly minimum temperature) and maximum temperature of the warmest month (°C). Bioclimatic factors for current conditions were obtained from available layers on World climate website while for future conditions were obtained from BCC_CSM1.1. For each bioclimatic factor, only the overall mean was presented except for precipitation where mean of each season was presented and that due to the available data. Climate change in the future was expected by comparing current conditions with future ones. Then, the potential impacts of climate change on managed honey bee colonies in Egypt were expected and discussed.

RESULTS AND DISCUSSION

Current and future temperatures

The expected increase of temperature during spring is about 1 to 3.9°C with maximum temperature of 47.2°C (Fig. 2). It could be said that all governorates will be impacted by such increase in temperature, especially some parts of Al-Minya, Bani Swaife and Al Fayoum (Fig. 3). Spring temperature will be similar to current summer temperature presented in Fig. 4. In the future, preparing apiaries for summer (summer procedures) should be done earlier during April to protect colonies from elevated temperature. During spring, the main honey plant is citrus and it is expected that flowering of citrus will happen earlier during March instead of April as happen currently. This expectation for earlier flowering time is in line with that of Yoruk and Sahinler (2013) and with the findings of Fitter and Fitter (2002). On the contrary with the expectation of Reddy *et al*. (2012), they expected a delay in plant flowering. It is most likely that plant flowering under elevated temperature will be earlier. Also, each of nectar quality and quantity will be impacted passively due to being plants under heat stress. Somewhat similar expectation regarding nectar was presented by Le Conte and Navajas (2008) and Scaven and Rafferty (2013).

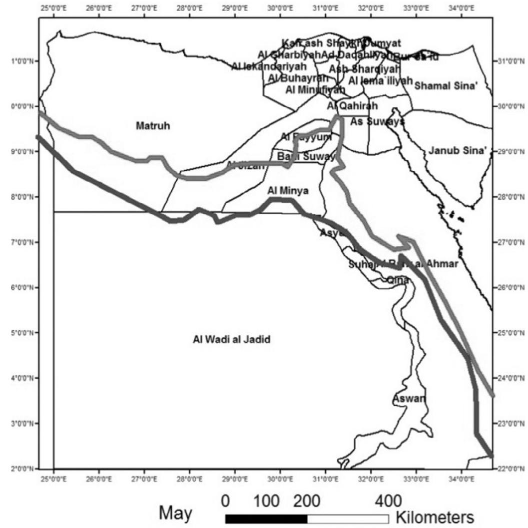

Fig. 3. The region with the highest increase in temperature during May represented by the area between red and blue line.

Colonies inspection and honey harvest beside other tasks should be done earlier.

An increase about 3.1 to 3.9°C is expected to occur during summer with maximum temperatures from 40.3 to 50.9°C cover mainly Upper Egypt (Fig. 4). Outside the colonies, honey bee workers will not be able to bear high temperature for long period of time. Abou-Shaara *et al*. (2012) found honey bee races are contrastive in their

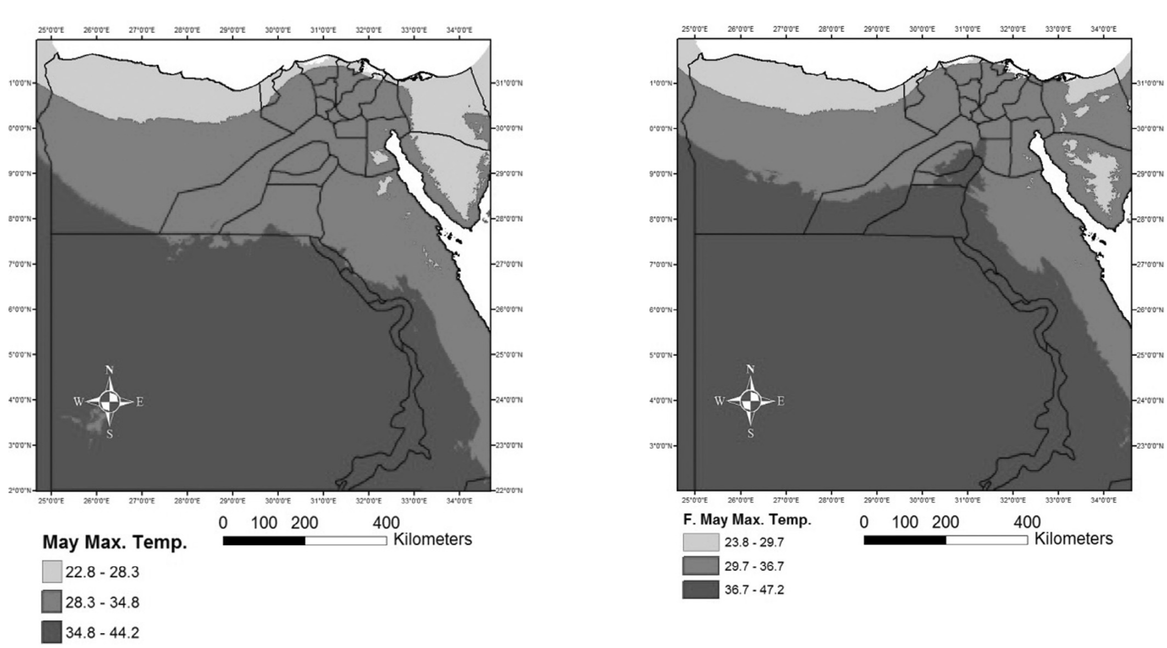

Fig. 2. Current (left) and future (right) maximum temperature for May (spring).

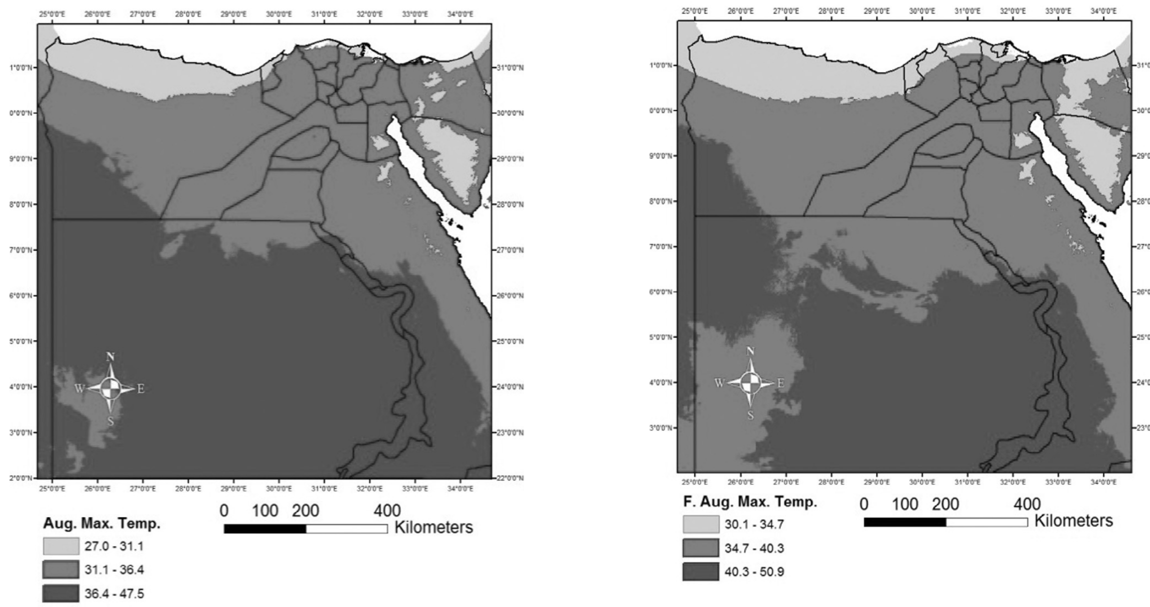

Fig. 4. Current (left) and future (right) maximum temperature for August (summer).

thermal tolerance ability and exposing honey bee workers in vitro to 45°C and 75% RH killed the bees within 24 hours. Individual bees can face elevated temperature through stress proteins (Hranitz *et al*., 2009) but not for a long period of time. Foraging activity could be impacted passively by elevated temperature of 43°Cor more as reviewed by Abou-Shaara (2014). Forager bees would change their foraging strategy to avoid foraging at extreme hot periods.

Inside colonies, honey bee workers will be able to regulate their internal temperature through some tasks including: fanning behaviour, evaporative cooling, or heat shielding (unemployed bees absorb excess heat to protect brood as shown by Starks and Gilley, 1999). More colony losses are expected to be happened during the summer season as currently happen in some hot regions (e.g. central

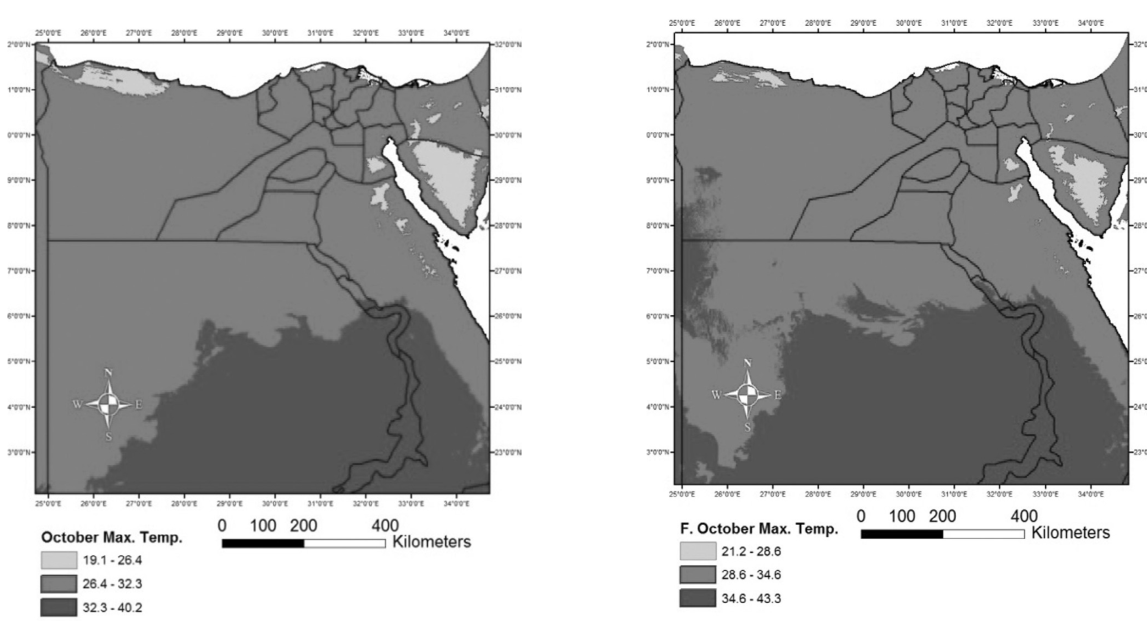

Fig. 5. Current (left) and future (right) maximum temperature for October (fall).

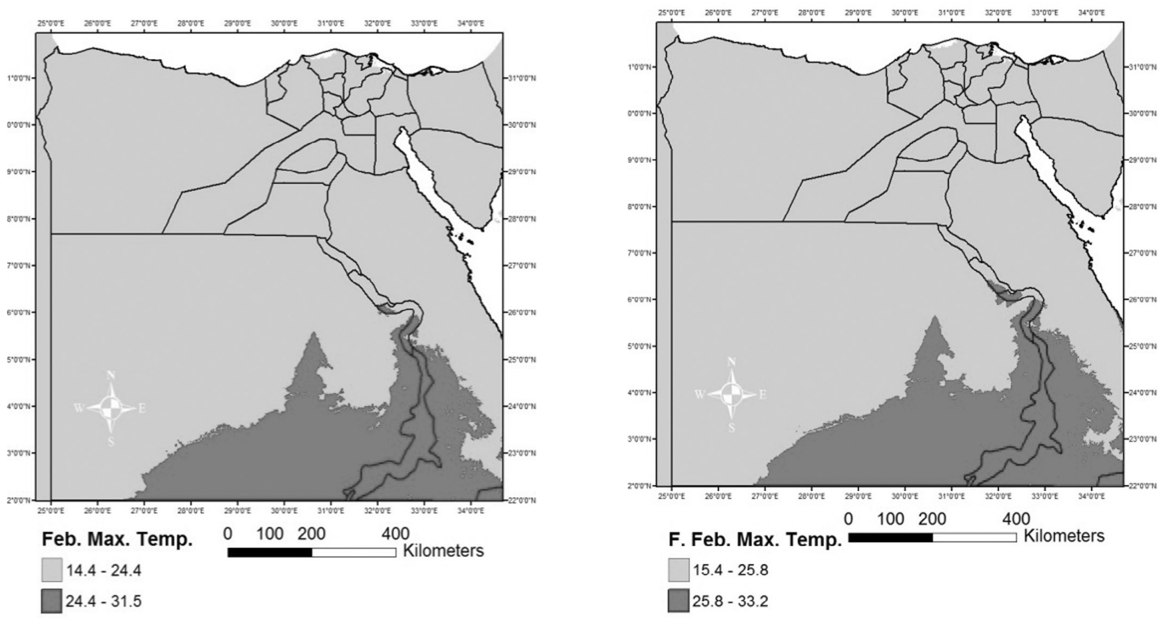

Fig. 6. Current (left) and future (right) maximum temperature for February (winter).

parts of Saudi Arabia as shown by Abou-Shaara *et al*., 2013c), because honey bee workers need more energy and efforts to be able to regulate their colonies temperature. Thus, protecting colonies from heat burdens is necessary to save workers energy and colonies performance. Providing the colonies with suitable modified beehives as done by Abou-Shaara *et al*. (2013c) could be considered as a suitable method. They found that modified beehives (provided with fans and humidity source) enhanced colonies performance (e.g. honey and pollen storing activity).

The main honey plant during this period is Egyptian clover (*Trifolium alexandrinum*), and it is expected that clover flowering period will be short and will happen earlier during late April instead of late May. As mentioned with Citrus, nectar quality and quantity of clover will be negatively impacted due to heat burdens on plants. Hive inspection, colonies feeding, honey harvest ... etc. should be rescheduled to fit with future changes. Honey bee workers were found to loss more body water under elevated temperature (Atmowidjojo *et al*., 1997; Abou-Shaara *et al*., 2012). Thus, beekeepers should take care of providing their colonies with extra sources of water. Providing honey bee colonies with more sugar feeding is expected to be done to save colonies' life especially from end of clover season till onset of cotton season in fall. The

Table 1. Minimum temperatures of current and future conditions

Month	Current (°C)	Future (°C)
May	11.50-30.00	13.26-32.40
August	14.30-31.30	16.6-34.60
October	8.00-27.80	10.46-29.80
February	3.00-17.30	6.05-18.1

Table 2. The approximate value of some bioclimatic parameters

Parameter	Current (°C)	Future (°C)
Annual mean of temperature	32	34.1
Mean of diurnal range	21.4	22.1
Maximum temp. of warmest month	47	52

Table 3. Precipitation (mm) of current and future conditions

Parameter	Current	Future
May	0-16	0-26.5
August	0-23	0-30.2
October	0-17	0-21.5
February	0-36	0-47.9

time between each sugar feeding should be not more than 10 days because colonies will be under thermal stress.

During fall, an increase in temperature with approximately 2.1 to 3.1°C is expected to occur (Fig. 5). There are no much beekeeping activities during fall. Beekeepers usually do not harvest cotton honey because its low marketable value. Colonies feeding and diseases control are the main tasks during this period beside preparing the colonies for winter season. Honey bee colonies will need more sugar feeding. Diseases control should be done earlier during September. Preparing honey bee colonies for winter may be delayed till late December due to warm weather during winter.

An increase in temperature about 1 to 1.7°C is expected to occur for all Egyptian governorates during winter (Fig. 6). The warmer winter is good for honey bee colonies and foraging activity could not be impacted except during rainy time and cold days with temperature about 6.05°C (Table 1). Temperature below 10°C could negatively impact flight activity of honey bees (Abou-Shaara, 2014). Honey bee colonies will need protection from rain with few wintering procedures. Such increase in temperature may induce

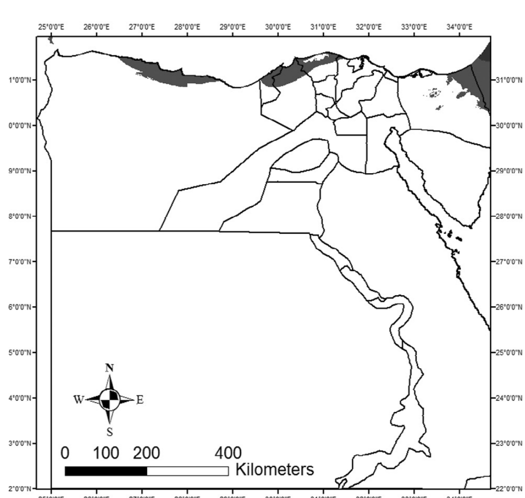

Fig. 7. Regions with high precipitation (from 18.41 to 47.90mm) during February.

flowering of plants during winter which may increase colonies activity and reduce required amount of sugar feeding to colonies.

Concerning minimum temperatures, an increase in temperatures will happen by about 1 to 3°C during all seasons (Table 1). The lowest temperature is 6.05°C during winter and the highest one is 34.60°C during summer in the future. In general, these temperatures are suitable for honey bee colonies. The risk of exposing honey bee colonies to cooling is not existed.

Future temperatures will be increased by about 1 to 3.9°C in Egypt by 2070. Accordingly, an increase in temperature about 1 to 3.5°C on the global level was predicted to happen by 2100 (Yoruk and Sahinler, 2013). Seasonal temperature has impacts on thermal behavior of honey bees (Grodzicki and Caputa, 2014), and thus protecting honey bees from heat stress is necessary. To save the life of their brood, honey bee workers tend to have a stable temperature within their colonies between 33 to 36°C (Petz *et al*., 2004) using different mechanisms either for increasing or decreasing internal temperature based on ambient temperature. Honey bees in the future will be smaller than the current ones as adaptation to thermal stress. This expectation is in line with Scaven and Rafferty (2013), and findings of Abou-Shaara *et al*. (2012) as they found that smaller bees have more thermal tolerance ability than larger ones. Basically honey bee races are dissimilar in their thermal tolerance ability. Honey bee workers can survive under elevated temperature conditions up to 49.1°C for Carniolan honey bees (Kafer *et al*., 2012) or up to 50.7°C for feral honey bees of Arizona region (Atmowidjojo *et al*., 1997). Yemeni (Abou-Shaara *et al*., 2012) and Italian (Kovac *et al*., 2014) honey bees showed higher thermal tolerance ability in comparison with Carniolan honey bees. Using suitable honey bee race to face future thermal challenge is necessary. Carniolan honey bees are common in Egypt, hence, developing heat tolerant Carniolan bees using selective breeding could be considered as suitable trend. Selecting smaller bees with good productivity during a selective breeding program is expected to lead to suitable bee race for beekeeping in the future. Alternatively, using Italian or hybrids of Italian with Carniolan honey bees is expected to be more suitable for future beekeeping in Egypt.

Bioclimatic factors

Presented bioclimatic factors in Table 2 confirm the increase of temperature during future. The maximum temperature of the warmest month during 2070 will be increased by about 5°C. During all seasons, precipitation will be increased by about 4 to 11mm than current conditions as shown in Table 3. However, still future precipitation is not high because it will be ranged only from 0 to 47.9mm. The highest precipitation is existed during winter and mainly on coastal regions as shown in Fig. 7. The relatively low increase of precipitation is not expected to mitigate the high thermal stress on plants and honey bees. May be such increase of precipitation encourages the growth of some plants especially at desert regions but these plants should have the ability to face thermal stress. It could be said that precipitation changes will not have great impact on honey bee colonies or honey production especially since the high precipitation occurs in small regions of Egypt.

Concerning pests of honey bee colonies including hornets, bee wolfs and yellowjackets, the thermal stress will impact biology and ecology of them. Honey bees can tolerate elevated temperature than Yellowjackets as mean of critical thermal maxima was 49.1 and 44.9 for bees and Yellowjackets, respectively (Kafer *et al*., 2012). Also, Japanese honey bees can kill Asian hornets using heating behavior (Sugahara *et al*., 2012). Therefore, current honey bee pests will be impacted negatively by elevated temperature. Being future temperatures suitable for honey bee enemies (Yoruk and Sahinler, 2013) is not expected to happen. May be honey bee pests will develop their own mechanisms for facing elevated temperature or likely other species of bee enemies will replace current ones. It is expected that honey bee pests will appear earlier than their normal time and may be their developmental time will be reduced due to temperature increase. These pests may be changed their normal nesting behavior and they will select more cool and shaded places.

Varroa mite population will be impacted negatively by temperature increase. Elevated temperature has negative impact on Varroa, colonies treatment with temperature of 40°C for 48 hours is suitable for removing Varroa mite from caged bees (Harbo, 2000). Thus, Varroa mite will not be a dangerous threat in the future for beekeeping and reduction in number of infested colonies with Varroa mite could occur. In hot countries (e.g. Saudi Arabia), Varroa mite is not widely existed in honey bee colonies especially in central regions (Abou-Shaara *et al*., 2013c). However, Varroa control should be done when necessary. Other diseases will be also negatively impacted by elevated temperature including sensitive pathogen to heat (*Ascosphaera apis*), honey bee workers are able to kill this pathogen by generating heat or as it was called brood comb fever (Starks *et al*., 2000). For other bacterial, viral or fungal diseases, it is expected that no major changes will happen to them. Basically there are no much problems currently happen from these diseases to honey bee colonies in Egypt.

CONCLUSION

Thermal stress will be the main challenge for managed honey bee colonies in the future. Methods for protecting honey bee colonies from elevated temperatures especially during summer need to be investigated. Biology of honey bee colonies, queen rearing and suitable periods for queens mating need to be reassessed in the future to understand impacts of climate change on these parameters. Studies on ecology and distribution of honey bee diseases and pests will be required to identify in detail the impacts of climate change on them. Beekeeping practices need to be rescheduled to fit with future changes. To save honey production in the future, studies towards obtaining honey plants with high ability to tolerate thermal stress and with high nectar quality and quantity are advisable to be started from now. Developing suitable methods (e.g. modified beehives) for protecting honey bee colonies from thermal stress during summer are required. Also, starting in developing heat tolerant bees either by selective breeding (selecting smaller bees with good productivity) or by the hybridization with other races (e.g. Carniolan with Italian bees) is very essential to be done to face thermal challenge.

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