EGYPTIAN ACADEMIC JOURNAL OF

BIOLOGICAL SCIENCES

ENTOMOLOGY

A

ISSN
1687-8809

WWW.EAJBS.EG.NET

Vol. 17 No. 4 (2024)

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 17(4) pp.69-81 (2024)*
DOI: **10.21608/EAJBSA.2024.393959**

Egypt. Acad. J. Biolog. Sci., 17(4):69-81 (2024)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/

The Possible Spread of The Small Hive Beetles, *Aethina tumida*, from Sudan and South Sudan to North Africa and the Arabian Peninsula under Different Environmental Conditions

Mohamed S. Younis[1*]; Hossam F. Abou-Shaara[2] and Tofaha A. Hassan[2]

[1]Bee Research Department, Plant Protection Research Institute, Agricultural Research Center, Cairo, Egypt.

[2]Department of Plant Protection, Faculty of Agriculture, Damanhour University, Damanhour, 22516, Egypt.

*E-mail: ms_younis@yahoo.com; hossam.farag@agr.dmu.edu.eg; tofaha.hassan@agr.dmu.edu.eg

ARTICLE INFO

Article History
Received:27/10/2024
Accepted:30/11/2024
Available:4/12/2024

Keywords:
Maxent, model, GIS, apiculture, SHBs.

ABSTRACT

The small hive beetles (SHBs), a serious pest to honey bee colonies, occur in Sudan/South Sudan. The objective of the present study was to investigate the possible spread of the SHBs from Soudan/South Sudan to the other Arabian countries during four time periods: present conditions, 2030, 2050, and 2070. The possible spread of the SHBs was modeled using Maxent software. The distribution maps were generated using specific datasets. The distribution maps were compared to identify the suitability of the Arabian countries for SHBs. The Geographical Information System (GIS) was used to compare the maps through the four time periods. The distribution maps showed that Sudan and South Sudan are the most suitable regions for SHBs under current conditions. Some areas especially in the Gulf countries were classified as suitable/more suitable for SHBs under future conditions. The movement of SHBs from Sudan towards the north to invade Egypt and then to other countries in north Africa or the Levant was not expected from the model maps. This can help explain the absence of this pest in Egypt thus far. The trade of bee equipment between Sudan/South Sudan to the other Arabian countries is suggested to cause the accidental introduction of these beetles to other Arabian countries.

INTRODUCTION

The Arabian world contains countries in Asia (the Arabian Peninsula) and Africa. Beekeeping is practiced widely in the Arabian countries (Al-Ghamdi *et al*., 2016). Small hive beetles, *Aethina tumida* Murray or SHBs were detected only in Sudan/South Sudan (El-Niweiri *et al*., 2008; Neumann *et al*., 2016) among the Arabian countries. These beetles belong to Family: Nitidulidae and can cause serious problem to honey bee, *Apis mellifera*, colonies. Basically, these beetles are endemic to Sub-Saharan Africa (Mostafa and Williams, 2000; Neumann and Elzen, 2004; Rasolofoarivao *et al*., 2013) but they have a good ability to invade new areas outside the endemic regions such as the USA and Australia (Hood, 2000; Neumann and Elzen, 2004). So these beetles have a high invasion and adaptation ability to new environments. Therefore, the ability of SHBs to invade other Arabian countries from Sudan/South Sudan is tested in this study under current and near future conditions.

The environment in the Arabian countries includes desert, temperate, coastal, and rainfall regions. Previous studies highlighted the high ability of SHBs to infest bee colonies under wide environmental conditions (Neumann and Elzen, 2004; Neumann *et al*., 2016). In 1998, these beetles caused high damages (about 3 million dollars) in a tropical state (Florida) in the USA (Ellis *et al*., 2002). SHBs can invade bee colonies causing damages to honey bee larvae, pupae and stored food. Additionally, these beetles fly from location to another which accelerates their prevalence in the infected areas. Also, these beetles can transfer diseases from bee colony to another (Eyer *et al*., 2009; Schäfer *et al*., 2010; De Graaf *et al*., 2013) causing many problems to infected colonies. Notably, there are no problems caused by these beetles to bee colonies with African bee subspecies in the endemic countries (Neumann and Elzen, 2004; Neumann and Härtel, 2004). In fact, honey bee subspecies in the Arabian countries are *Apis mellifera syriaca*, *Apis mellifera jemenitca*, and *Apis mellifera intermissa*. These subspecies have been exposed to hybridization with other bee subspecies from Europe such as the hybridization between the Egyptian bees, *Apis mellifera lamarckii*, and European bee subspecies (Page *et al*., 1981; Sheppard *et al*., 2001; Abou-Shaara and Ahmed, 2015). Also, trading of bee packages is a common practice between some Arabian countries such as Egypt and Gulf countries (Al-Ghamdi and Nuru, 2013; Al-Ghamdi *et al*., 2016). In general, bee subspecies in the Arabian countries are different than those from the endemic range of the SHBs. So, the invasion of SHBs to new Arabian countries can cause serious problems to bee colonies. This highlights the importance of this study to investigate the potential spread of SHBs in the Arabian countries.

Understanding the future spread of an organism in specific geographical regions can be achieved using modeling studies (Hosni *et al*., 2020; Jamal *et al*., 2021). The distribution models depend on using specific software such as geographical information system (Abou-Shaara, 2019; Hosni et al., 2020) and MaxEnt (Wei *et al*., 2018; Hosni *et al*., 2020; Phillips *et al*., 2020; Jamal *et al*., 2021). The modeling using this software depends on using bioclimatic variables (Phillips, 2017; Phillips *et al*., 2020) to obtain the distribution maps. Indeed, future conditions are predicted suing climate models (e.g. Yukimoto *et al*., 2019). So, datasets are on temperature and relative humidity are available for current and future conditions (Hijmans *et al*., 2005). Such factors are important to honey bees and their pests as well (Yoruk and Sahinler, 2013; Le Conte and Navajas, 2008; Abou-Shaara, 2016; Abou-Shaara *et al*., 2017). Therefore, the aim of this study was to specify the suitable areas in the Arabian countries for the spread of the SHBs from Sudan/South Sudan during different time periods.

MATERIALS AND METHODS

1. Records of SHBs:

In this study, occurrence records from Sudan and South Sudan were considered. The data were collected based on the previous publications (El-Niweiri *et al*., 2008; Neumann *et al*., 2016; Jamal *et al*., 2021) and from the Global Biological Information Facility (GBIF.org download 2020. https://doi.org/10.15468/dl.usdg47).

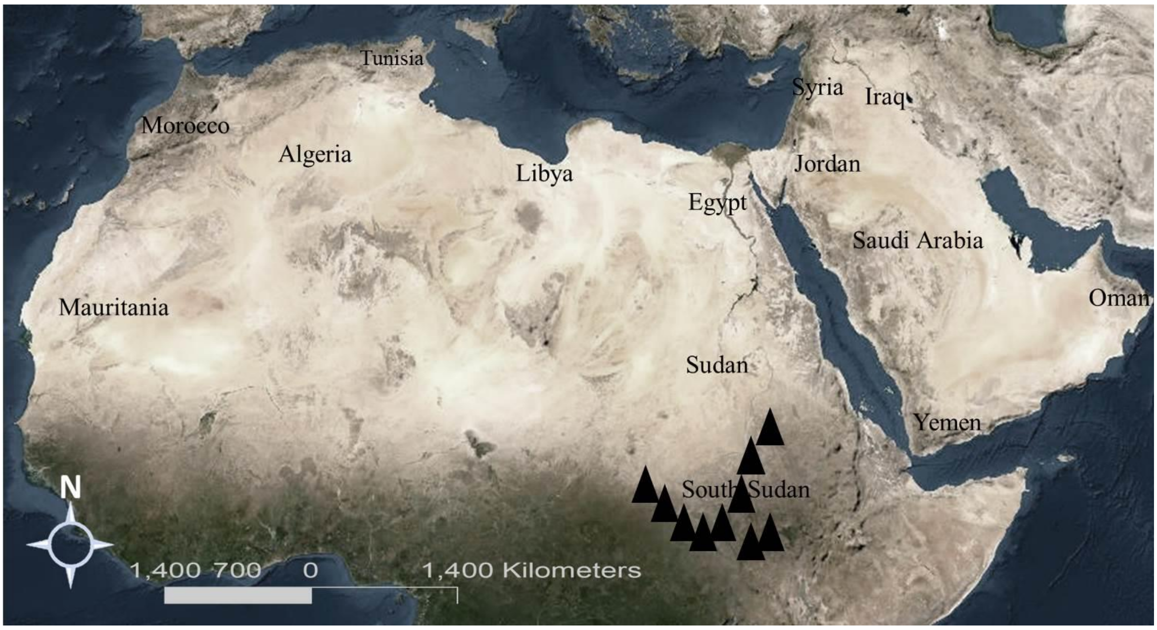

Fig. 1: The locations (black triangles) of small hive beetles in Sudan and South Sudan.

2. Bioclimatic Variables:

Specific variables with spatial resolution about 5 km^2 (**Table 1**) from WorldClim v2.1 (worldclim.org, January 2020) were used in the present study to establish the distribution maps for the SHBs in the Arabian countries. These variables were selected based on previous publication by Jamal *et al*. (2021). Four time periods were considered: current conditions (1970 to 2000), near future during 2030 (average from 2021-2040), future during 2050 (average from 2041–2060) and future during 2070 (average from 2061-2080). Future variables were from the Meteorological Research Institute Earth System Model Version 2.0 (MRI-ESM2.0) at the Shared Socio-economic Pathways (SSPs). More information about this climatic model is available in Yukimoto *et al*. (2019).

Table 1: The variables used in the model to generate the thermal maps.

Number	Environmental variable	Abbreviation
1	Maximum temperature of the warmest month	MTWM
2	Minimum temperature of the coldest month	MTCM
3	Mean temperature of the warmest quarter	MTWQ
4	Mean temperature of the coldest quarter	MTCQ
5	Annual mean temperature	AMT
6	Mean diurnal range	MDR

3. Data Analysis:

The maps for current conditions, 2030, 2050 and 2070 were established using Maxent v 3.4.1 (Phillips *et al*., 2020) with specific settings (**Table 2**). The maps were reclassified into four classes using the ArcGIS 10.5: Very low (0-0.01), Low (0.01-1), Moderate (1-10), Suitable (10-20) and More Suitable (20-100) (Jamal *et al*., 2021). The contribution of the selected variables in the model is presented in **Table 3**. The GIS was also used to establish separated maps for the moderate, suitable and more suitable areas for the SHBs during the four time periods.

Table 2: The settings used in Maxent to obtain the model maps.

Settings	Parameter
Records	23 presence records used for training, 7 for testing.
Background and presence points	10023 points used to determine the Maxent distribution
Linear/quadratic/product	0.385
Categorical	0.250
Threshold	1.770
Hinge	0.500
Output format	Cumulative

Table 3: Contribution percentage of each variable in the model.

Variable	Percentages
Mean temperature of the coldest quarter (MTCQ)	77.8
Minimum temperature of the coldest month (MTCM)	10.5
Maximum temperature of the warmest month (MTWM)	4.3
Mean diurnal range (MDR)	3.1
Mean temperature of the warmest quarter (MTWQ)	2.9
Annual mean temperature (AMT)	1.4

4. Performance Evaluation:

The area under curve (AUC) was used to evaluate the used model to obtain the distribution maps. Two analyses were incorporated into the calculation of the AUC: the receiver operating characteristic (ROC) for test/training data, and jackknife tests for the used variables.

RESULTS AND DISCUSSION

1. Performance Evaluation:

The area under the curve (AUC) calculated from the receiver operating characteristic (**Fig. 2)** was 0.979 for training data and 0.982±0.006 for test data calculated as in DeLong *et al*. (1988). The AUC for the used variables ranged from 0.50 (MTWQ) to 0.97 (MTCQ) (T**able 4)**. The values were generally more than 0.61 except for MTWQ.

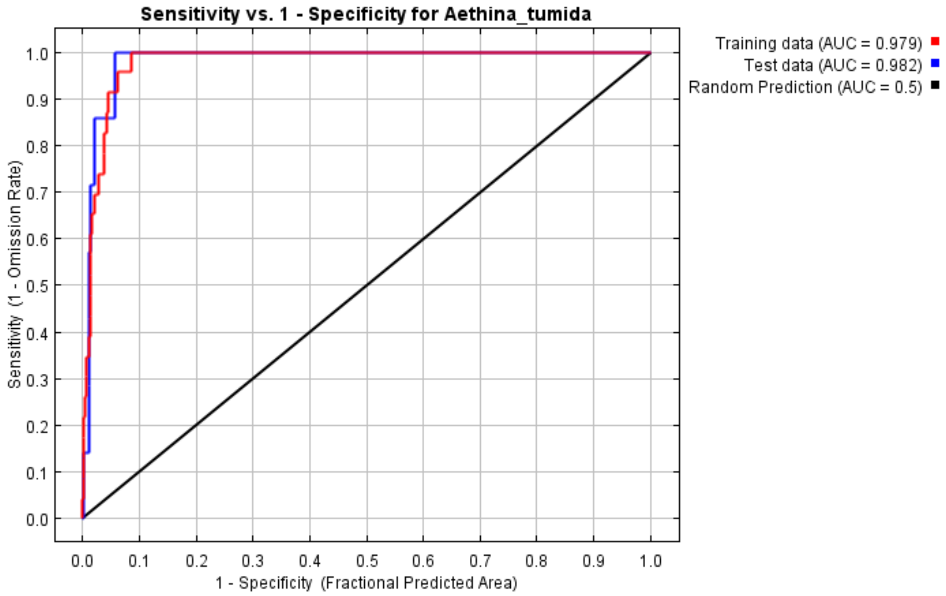

Fig.2: The receiver operating characteristic (ROC) curve for training/test data used in the model maps.

Table 4: Area under the curve (AUC) for the used variables in the model from the jackknife test.

Variable	AUC
Mean temperature of the coldest quarter (MTCQ)	0.97
Minimum temperature of the coldest month (MTCM)	0.92
Annual mean temperature (AMT)	0.85
Maximum temperature of the warmest month (MTWM)	0.63
Mean diurnal range (MDR)	0.61
Mean temperature of the warmest quarter (MTWQ)	0.50

2. Current Conditions:

The spread of SHBs in the Arabian counties under current conditions is shown in **Figure 3.** Sudan/South Sudan represented the main suitable regions for SHBs. Some parts of southwest Saudi Arabia and Yemen had some more suitable locations for the occurrence of SHBs. The areas with moderate suitability for the occurrence of SHBs are mainly located in the west of Africa, Sudan/South Sudan, some areas of Saudi Arabia, Yemen, Oman and Emirates. The border between Egypt/Sudan had some moderate areas for SHBs. All the other areas in the Arabian countries were considered as with very low/low suitability for SHBs.The very low suitability was concentrated in the Levant and some parts in North Africa.

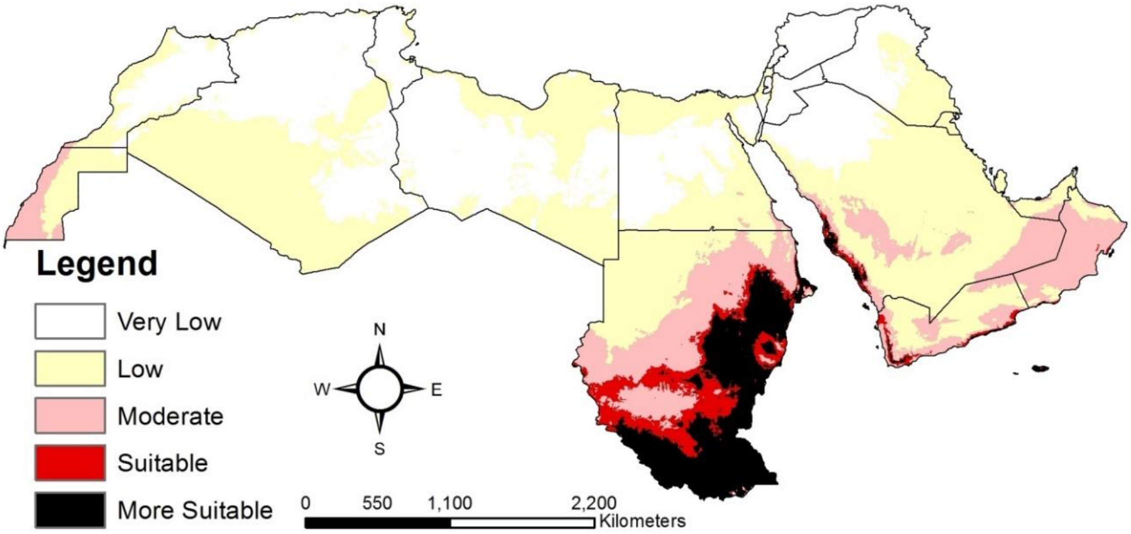

Fig. 3: The potential spread of the small hive beetles in the Arabian countries under current environmental conditions.

3. Potential Spread Under Future Conditions:

The situation of suitability degree for SHBs slightly changed during 2030 than current conditions (**Fig. 4**). Some suitable areas appeared in Oman and the border between Saudi Arabia/Oman. The areas with moderate suitability for SHBs increased in Yemen and Saudi Arabia, South Egypt, and some areas in Algeria. All the other regions were similar to current conditions and were classified as very low/low suitable for SHBS. So, limited spread of SHBs is expected to occur during 2030 than current conditions in the Arabian countries.

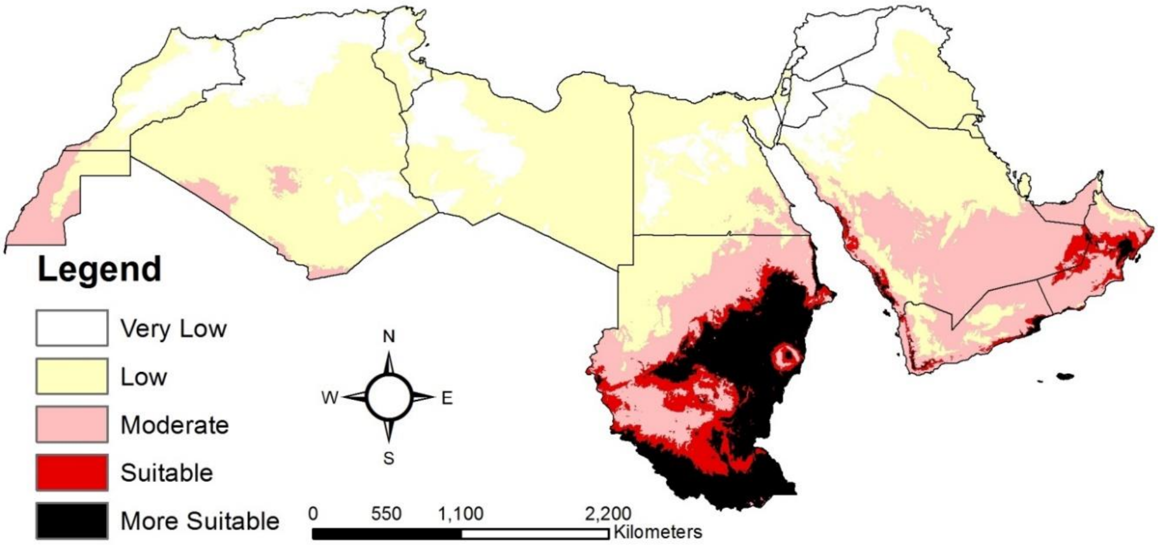

Fig. 4: The potential spread of the small hive beetles in the Arabian countries during the near future (2030).

The situation during 2050 showed some variations than 2030 (**Fig. 5**). Some more suitable areas appeared in Saudi Arabian/Oman border beside suitable areas. Some parts in Central of Saudi Arabia were classified as suitable/more suitable for SHBs. Areas with moderate, low and very low suitability for SHBs showed no huge changes than 2030.

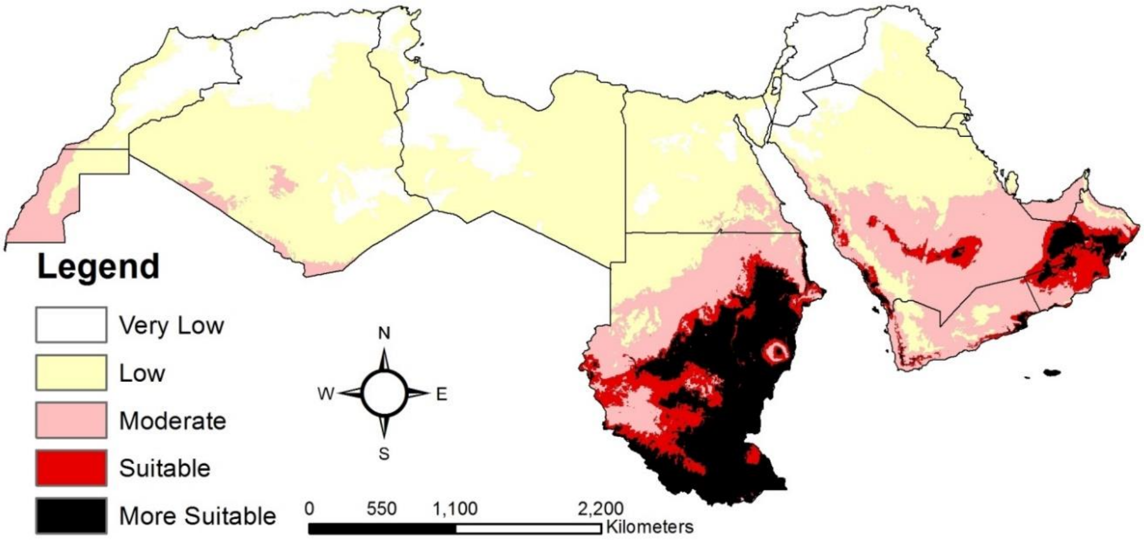

Fig. 5: The potential spread of the small hive beetles in the Arabian countries during the near future (2050).

The suitability for SHBs during 2070 is shown in **Figure 6.** The situation during 2070 changed than 2050 in some regions. The more suitable/suitable areas increased in Saudi Arabia and Oman. The moderate suitable areas increased in Algeria and West Africa. Some parts of Yemen that was classified as suitable for SHBs during 2050 were reclassified as moderate suitable during 2070. No huge changes in very low/ low suitability areas were observed than previous maps.

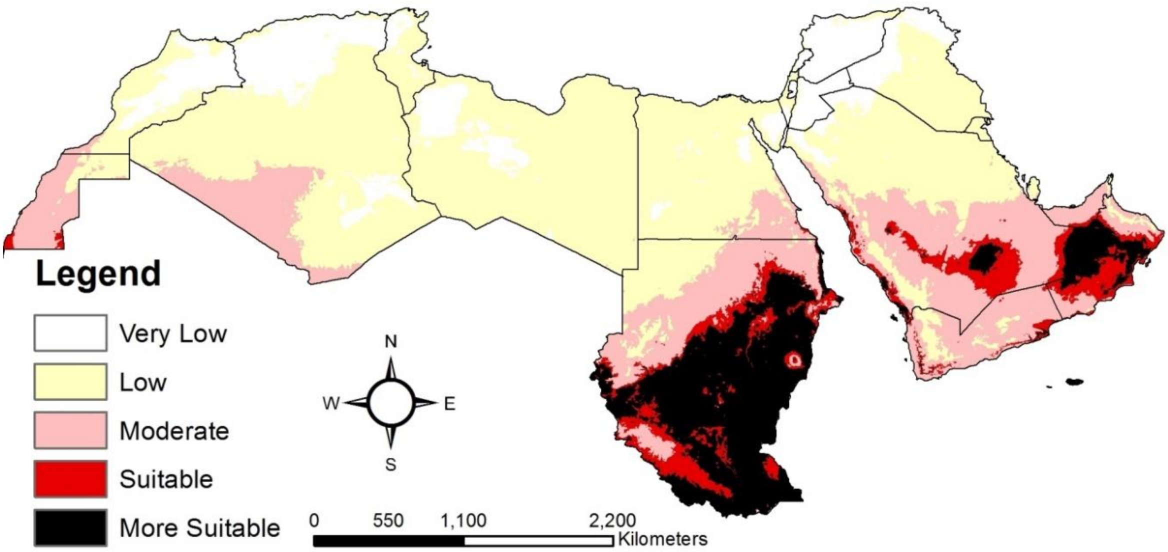

Fig. 6: The potential spread of the small hive beetles in the Arabian countries during the near future (2070).

4. Gradual Changes in The Suitability Classes:

The gradual changes in the moderate suitable areas for SHBs in the Arabian countries are shown in **Figure 7.** The map shows that the moderate suitable areas for SHBs under current conditions and up to 2070 are concentrated in South Egypt, Sudan/South Sudan, Central and Southern parts of the Arabian Peninsula, Southern parts of Algeria, and West Africa. The changes during 2030 than current conditions are concentrated mainly in South Egypt, North Sudan, Saudi Arabia, Algeria, and Western parts of Africa.

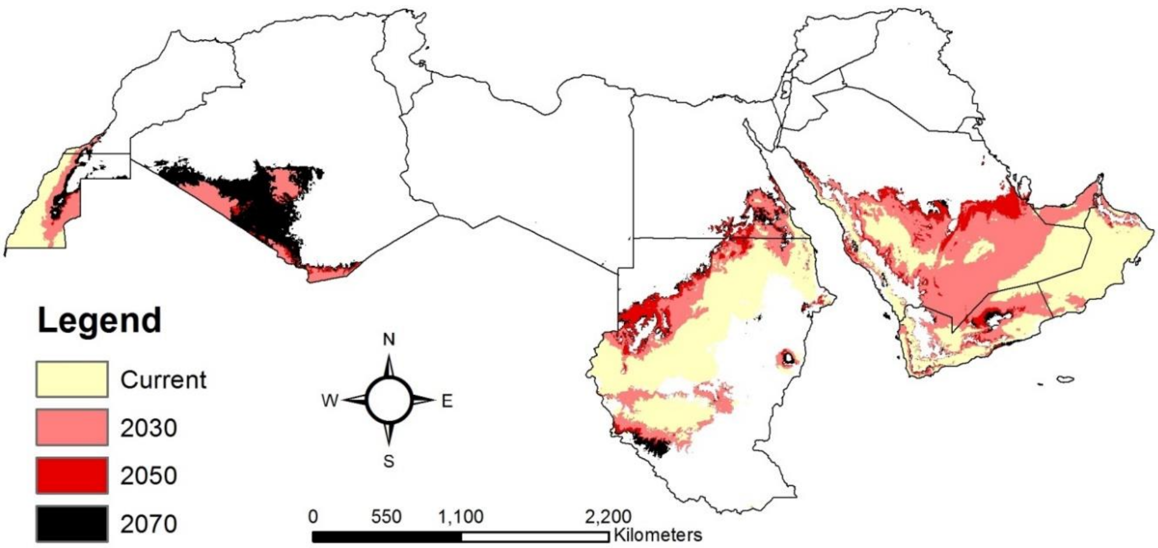

Fig. 7: The moderate suitable areas for the small hive beetles in the Arabian countries during four time periods: current conditions, 2030, 2050, and 2070.

The gradual changes in the suitable areas for SHBs in the Arabian countries are shown in **Figure 8.** This map clearly shows that the suitable areas outside Sudan/South Sudan during the next years will be in Saudi Arabia, Yemen, and Oman.

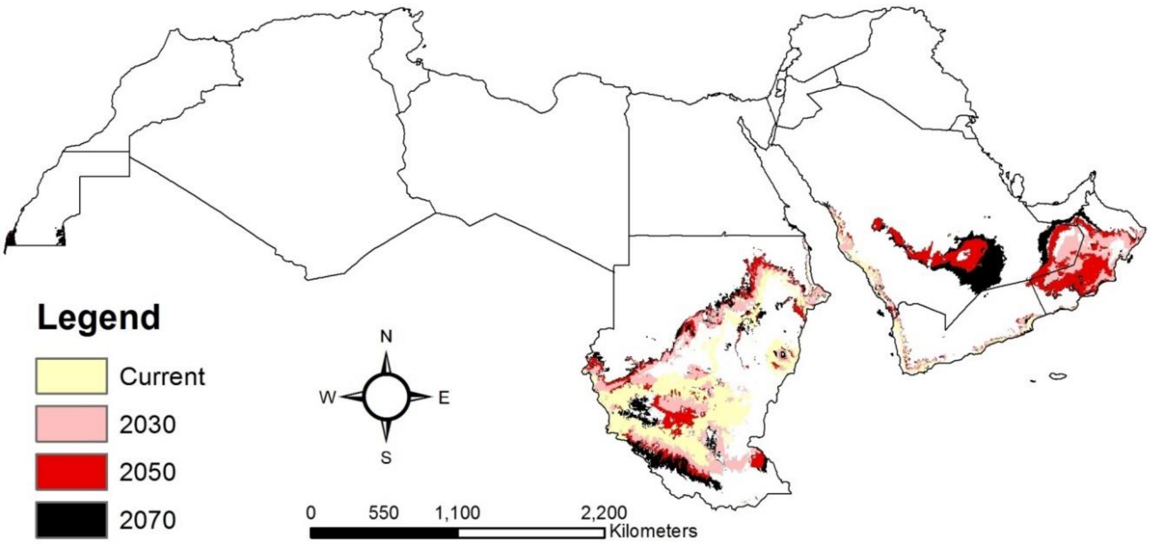

Fig. 8: The suitable areas for the small hive beetles in the Arabian countries during four time periods: current conditions, 2030, 2050, and 2070.

The map (**Fig. 9**) highlights the gradual changes in the more suitable areas for SHBs in the Arabian countries. It is clear that some parts in Saudi Arabia, Yemen and Oman will be the more suitable areas for SHBs outside Sudan/South Sudan. All the other regions in North Africa and the Levant did not show any more suitable areas for SHBs.

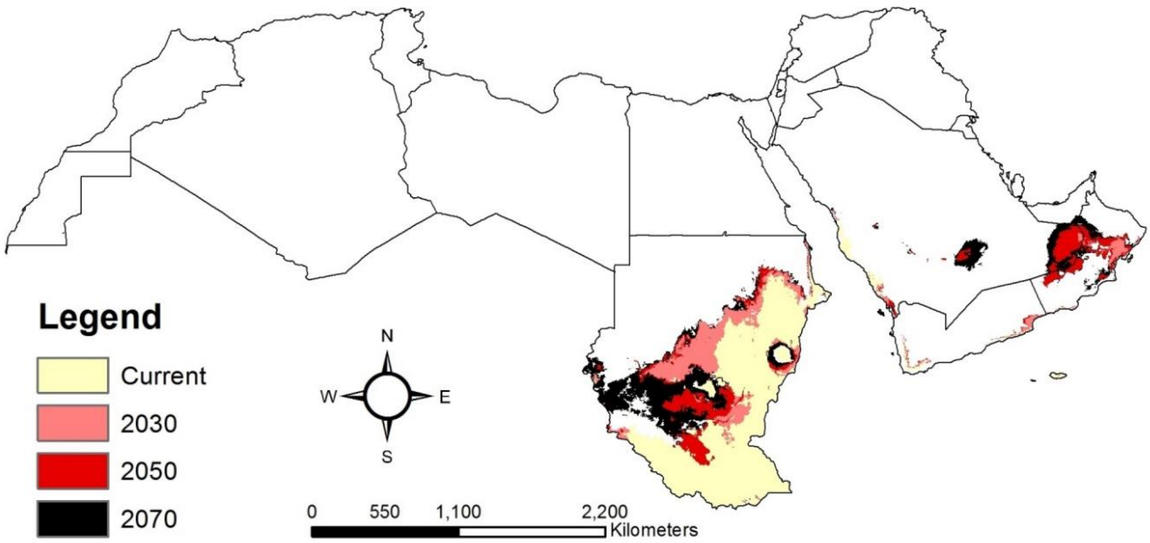

Fig. 9: The more suitable areas for the small hive beetles in the Arabian countries during four time periods: current conditions, 2030, 2050, and 2070.

DISCUSSION

The high area under the curve indicates that the used model in the analysis had good performance (Mulieri and Patitucci, 2019; Jamal *et al*., 2021). The area under the curve for training/test data was high with few differences than 1. This indicates the good performance of the used model to expect the potential spread of SHBs in the Arabian countries. On the other side, most variables showed high area under the curve with values over 0.61.

The map for current conditions showed the limited spread of SHBs in Sudan/South Sudan. This is in line with the actual presence of SHBs in the Sudan/South Sudan among the Arabian countries (El-Niweiri *et al*., 2008; Neumann *et al*., 2016). SHBs have not been recorded in any other country either in North Africa or in the Levant and the Arabian Peninsula (Al-Ghamdi *et al*., 2016). SHBs do not exist in Egypt (the closet regions Sudan) according to previous studies (El-Niweiri *et al*., 2008; Hassan and Neumann, 2008; Neumann *et al*., 2016; Abou-Shaara *et al*., 2018). The model predicted that some parts of southwest Saudi Arabia and Yemen had some more suitable areas for SHBs. So, such areas expected to be the more suitable for the prevalence of SHBs in the Arabian Peninsula under current conditions in case of the invasion of SHBs to the Gulf countries. Indeed, the accidental introduction of SHBs from Sudan/South Sudan to the Gulf countries can occur through trade activities. Such activities were considered as a possible path for the prevalence of bee diseases/pests (Mutinelli, 2011; Gordon *et al*., 2014; Neumann *et al*., 2016).

The future maps during 2030, 2050 and 2070 clearly confirmed the high suitability of Sudan/South Sudan for SHBs. In addition to these endemic regions for SHBs, Saudi Arabia, Oman, and Yemen showed some areas with more suitable/suitable classification for these beetles. No regions in the Levant and North Africa showed more suitable/suitable areas for SHBs, suggesting the low ability of these beetles to invade and establish in these countries during the near future. The study by Jamal *et al*. (2021) were done on all Africa and Europe, and such study suggested the invasion of some parts of North Africa with SHBs. Mostly the source of these beetles are expected to be from other African countries but not from Sudan. The present study did not expect the movement of SHBs towards Egypt, except few areas in the border region between Egypt/Sudan.

Several areas in West Africa, South Egypt, and the Gulf Countries showed moderate suitability for SHBs. In fact, the direct movement of SHBs from Sudan towards Egypt and then towards the Arabian Peninsula or towards the West to invade Libya is not supported by the model maps under current and near future conditions. Also, vast areas in North Africa and the Levant were considered as with very low/low suitability for SHBs. This study suggested the less ability of SHBs to invade and to be established in the northern parts of the Arabian countries located in Africa and the Levant. The accidental introduction of SHBs from Sudan/South Sudan to other Arabian countries and mostly due to human activities in transportation of goods is expected to be the reason behind the spread of SHBs into new regions. In a similar way, accidental existence of SHBs in Portugal was recorded in a shipment of queens (Murilhas, 2004; Neumann and Ellis, 2008; Valério da Silva, 2014).

It seems that the environmental conditions especially in some areas of Saudi Arabia, Oman and Yemen are similar to those in Sudan/South Sudan. Such similarities especially the elevated temperature in the Gulf countries (Abou-Shaara *et al*., 2013) and Sudan/South Sudan can explain the presence of more suitable/suitable areas for SHBs in these specific countries. Basically, temperature has an important role in the development of these beetles (Neumann *et al*., 2001; Neumann and Elzen, 2004). Concerning beekeeping, honey bee colonies in the more suitable/suitable areas for SHBs are expected to suffer from these beetles in case of invasion and establishment. In fact, these beetles do not depend on bee colonies only as source of food but they can feed on various plant materials in a similar way to other Nitidulid beetles (Wolff *et al*., 2001; Ellis *et al*., 2002; Neumann *et al*., 2016; Abou-Shaara *et al*., 2018). In fact, there are natural biological control agents for these beetles (Muerrle *et al*., 2006; Cuthbertson *et al*., 2012; Abou-Shaara and Staron, 2019), and such agents need more studies especially in areas with risk of future invasions by SHBs.

Conclusion:

This study modeled the potential spread of small hive beetles in the Arabian countries from Sudan/South Sudan during current conditions and near future: 2030, 2050, and 2070. The model maps showed that the new regions that can be highly invaded by these beetles are located in the Arabian Peninsula especially Saudi Arabia, Yemen, and Oman. The invasion of these beetles to Egypt is not expected from the present model except the border areas between Egypt/Sudan. All Northern parts of the Arabian countries in Africa and the Levant are not anticipated to be invaded by these beetles. The study suggested the role of the exchange of bee equipment from Sudan/South Sudan to the other Arabian countries in the potential prevalence of these beetles to new regions. So, planned monitoring and control strategies should be done by the responsible authorities in Sudan/South Sudan to limit the spread of these beetles to other regions. Also, co-operation between the Arabian countries should be planned to follow up the status of this pest in the infected areas.

Declarations:

Ethical Approval: Not applicable.

Authors Contributions: Mohamed Younis (Conceptualization, Methodology, Writing – review & editing, submission for publication), Hossam Abou-Shaara (Conceptualization, Methodology, Data curation, Writing – review & editing), and Tofaha A. Hassan (Methodology, Writing – review & editing). All authors reviewed drafts of the article and approved the final draft.

Competing Interests: The authors declare that they have no competing interests.

Availability of Data and Materials: The data supporting the study are included in the manuscript.

Source of Funding: There is no funding source for this study.

Acknowledgements: Not applicable.

REFERENCES

Abou-Shaara, H.F., 2016. Expectations about the potential impacts of climate change on honey bee colonies in Egypt. *Journal of Apiculture,* 31, 157-164.

Abou-Shaara, H.F., 2019. Utilizing bioinformatics to detect genetic similarities between African honey bee subspecies. *Journal of Genetics,* 98, 96. https://doi. org/ 10. 1007/s12041-019-1145-7

Abou-Shaara, H. F., & Ahmed, M. E. (2015). Characterisation and tracking changes of morphological characteristics in honey bee, Apis mellifera, colonies. *Journal of Entomological and Acarological Research*, *47*(3), 103-108.

Abou-Shaara, H.F., Staron, M., 2019. Present and future perspectives of using biological control agents against pests of honey bees. *Egyptian Journal of Biological Pest Control, 29*,24. https://doi.org/10.1186/s41938-019-0126-8

Abou-Shaara, H.F., Ahmad, M.E., Háva, J., 2018. Note: recording of some beetles in honey bee colonies. *Cercetări Agronomice în Moldova,* 51, 85-90.

Abou-Shaara, H.F. ; A.A. Al-Ghamdi and A.A. Mohamed (2013). Honey bee colonies performance enhance by newly modified beehives. *Journal of Apicultural Science,* 57 (2): 45-57.

Abou-Shaara, H.F.; A. A. Owayss; Y. Y. Ibrahim and N. K. Basuny (2017). A review of impacts of temperature and relative humidity on various activities of honey bees. *Insectes Sociaux*, 64: 455-463.

Al-Ghamdi, A., & Nuru, A. (2013). Beekeeping in the Kingdom of Saudi Arabia opportunities and challenges. *Bee World*, *90*(3), 54-57.

Al-Ghamdi, A.A., Alsharhi, M.M., Abou-Shaara, H.F., 2016. Current status of beekeeping in the Arabian countries and urgent needs for its development inferred from a soci-economic analysis. *Asian Journal of Agricultural Research,* 10, 87-98, 10.3923/ajar.2016.87.98

Cuthbertson AGS, Mathers JJ, Blackburn LF, Powell ME, Marris G, Pietravalle S, Brown MA, Budge GE (2012) Screening commercially available entomopathogenic biocontrol agents for the control of Aethina tumida (Coleoptera: Nitidulidae) in the UK. *Insects,* 3:719726. https://doi.org/10.3390/insects3030719

De Graaf, D.C., Alippi, A.M., Antúnez, K., Aronstein, K.A., Budge, G., De Koker, D., De Smet, L., Dingman, D.W., Evans, J.D., Foster, L.J., Fünfhaus, A., Gonzalez, E.G., Gregorc, A., Human, H., Murray, K.D., Nguyen, K.B., Poppinga, L., Spivak, M., vanEngelsdorp, D., Wilkins, S., Genersch, E. 2013. Standard methods for American foulbrood research. *Journal of Apicultural Research,* 52, https://doi.org/ I10.3896/IBRA.1.52.1.11

DeLong, E. R., DeLong, D. M., & Clarke-Pearson, D. L. (1988). Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*, 837-845.

Ellis, J.D., Neumann, P., Hepburn, H.R., Elzen, P.J., 2002, Longevity and reproductive success of *Aethina tumida* (Coleoptera: Nitidulidae) fed different natural diets. *Journal of Economic Entomology,* 95, 902-907. https://doi.org/ https://doi.org/10.1093/jee/95.5.902

El-Niweiri, M.A., El-Sarrag, M.S., Neumann, P., 2008. Filling the Sudan gap: the northernmost natural distribution limit of small hive beetles. *Journal of Apicultural Research,* 47, 184-185. https://doi.org/ 10.3827/IBRA.1.47.3.02

Eyer, M., Chen, Y.P., Schäfer, M.O., Pettis, J.S., Neumann, P., 2009. Small hive beetle, *Aethina tumida*, as apotential biological vector of honeybee viruses. *Apidologie,* 40, 419-428. https://doi.org/ 10.1051/apido:2008051

Gordon, R., Bresolin-Schott, N., East, I.J., 2014. Nomadic beekeeper movements create the potential for wide-spread disease in the honeybee industry. *Australian Veterinary Journal,* 92, 283-290. https://doi.org/10.1111/avj.12198

Hassan, A.R., Neumann, P., 2008. A survey for the small hive beetle in Egypt. *Journal of Apicultural Research,* 47, 186-187. https://doi.org/ 10.3827/IBRA.1.47.3.03

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high-resolution interpolated climate surfaces for global land areas. *International Journal of Climatology, 25,* 1965–1978.

Hood, W.M., 2000. Overview of the small hive beetle *Aethina tumida* in North America. *Bee World,* 81,129–137. https://doi.org/ 10.1080/0005772X.2000.11099483

Hosni, E.M., Nasser, M.G., Al-Ashaal, S.A., Rady, M.H., Kenawy, M.A. 2020. Modeling current and future global distribution of *Chrysomya bezziana* under changing climate. *Scientific Reports,* 10: 4947. https://doi.org/10.1038/s41598-020-61962-8

Jamal, Z.A.; H. F. Abou-Shaara; S. Qamer; M. A. Alotaibi, K. A. Khan; M. F. Khan; M. A. Bashir; A. Hannan; S. N. AL-Kahtani; E. A. Taha; S. I. Anjum; M. Attaullah; G. Raza and M. J. Ansari (2021). Future expansion of small hive beetles, Aethina tumida, towards North Africa and South Europe based on temperature factors using maximum entropy algorithm. Journal of King Saud University Science, 33, https://doi.org/10.1016/ j.jksus. 2020.101242

Le Conte, Y., Navajas, M., 2008. Climate change: impact on honey bee populations and diseases. *Revue Scientifique et Technique,* 27, 499-510.

Mostafa, A.M., Williams, R.N., 2000. New record ofthe small hive beetle in Egypt and notes on its distribution and control. Bee World, 83, 99-108. https://doi.org/ /10.1080/0005772X.2002.11099549

Muerrle TM, Neumann P, Dames JF, Hepburn HR, Hill MP (2006) Susceptibility of adult *Aethina tumida* (Coleoptera: Nitidulidae) to entomopathogenic fungi. *Journal of Economic Entomology,* 99:1–6.

Mulieri, P.R., Patitucci, L.D., 2019. Using ecological niche models to describe the geographical distribution of the myiasis-causing *Cochliomyia hominivorax* (Diptera: Calliphoridae) in southern South America. *Parasitology Research*, 118, 1077-1086. https://doi.org/10.1007/s00436-019-06267-0.

Murilhas, A.M., 2004. *Aethina tumida* arrives in Portugal. Will it be eradicated? European *Bee Newsletter*, 2, 7-9.

Mutinelli F. (2011) The spread of pathogens through trade in honey bees and their products (including queen bees and semen): overview and recent developments, *Revue Scientifique et Technique*, 30, 257–271.

Neumann, P., Ellis, J.D., 2008. The small hive beetle (*Aethina tumida* Murray, Coleoptera: Nitidulidae): distribution, biology and control of an invasive species. *Journal of Apicultural Research*, 47, 180-183. https://doi.org/ 10.1080/00218839. 2008. 11101453

Neumann, P., Elzen, P.J., 2004. The biology of the small hive beetle (*Aethina tumida*, Coleoptera: Nitidulidae): Gaps in our knowledge of an invasive species. *Apidologie, 35*, 229-247. https://doi.org/10.1051/apido:2004010

Neumann, P., Härtel, S., 2004. Removal of small hive beetle (*Aethina tumida* Murray) eggs and larvae by African honeybee colonies (*Apis mellifera scutellata* Lepeletier). *Apidologie*, 35, 31-36. https://doi.org/10.1051/apido:2003058

Neumann, P., Pettis, J.S., Schäfer, M.O., 2016. Quo vadis *Aethina tumida*? Biology and control of small hive beetles. *Apidologie*, 47, 427-466. https://doi.org/ 10.1007/s13592-016-0426-x

Neumann, P., Pirk, C.W.W., Hepburn, H.R., Elzen, P.J., Baxter, J.R., 2001. Laboratory rearing of smallhive beetles *Aethina tumida* (Coleoptera: Nitidul-idae). *Journal of Apicultural Research,* 40: 111-112. https://doi.org/ 10.1080/00218839. 2001. 11101059

Page, R.E., Ibrahim, M.M. and Laidlaw, H.H. 1981. The history of modern beekeeping in Egypt. *Gleanings in Bee Culture*, **109**:24-26.

Phillips SJ (2017) A Brief Tutorial on Maxent. Available from url: http://biodiversityinformatics.amnh.org/open_source/maxent/

Phillips, S.J., Dudík, M., Schapire, R.E., 2020. Maxent software for modeling species niches and distributions (Version 3.4.1). Available from url: http:// biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 2020-3-20.

Rasolofoarivao, H., Clemencet, J., Ravaomanarivo, L.H.R., Razafindrazaka, D., Reynaud, B., Delatte, H., 2013. Spread and strain determination of *Varroa destructor* (Acari: Varroidae) in Madagascar since its first report in 2010. *Experimental and Applied Acarology*, 60, 521-530. https://doi.org/ 10.1007/s10493-013-9658-x

Schäfer, M.O., Ritter, W., Pettis, J.S., Neumann, P., 2010. Small hive beetles, *Aethina tumida*, are vectors of *Paenibacillus larvae*. *Apidologie*, 41, 14-20. https://doi.org/ 10.1051/apido/2009037

Sheppard, W.S., Shoukry, A. and Kamel, S. 2001. The Nile honey bee- The bee of ancient Egypt in modern times. *American Bee Journal*, 141(4):260-263.

Valério da Silva, M.J., 2014. The first report of *Aethina tumida* in the European Union, Portugal 2004. *Bee World*, 91, 90-91. https://doi.org/ 10.1080/0005772X. 2014. 11417619

Wei, B., Wang, R., Hou, K., Wang, X., Wu, W., 2018. Predicting the current and future cultivation regions of *Carthamus tinctorius* L. using MaxEnt model under climate change in China. *Global Ecology and Conservation*, 16, 1-11. https://doi. org/10. 1016/j.gecco.2018.e00477

Wolff, M., Uribe, A., Ortiz, A., Duque, P., 2001. A preliminary study of forensic entomology in Medellin, Colombia. *Forensic Science International*, 120, 53-59. https://doi.org/10.1016/S0379-0738(01)00422-4

Yoruk, A., Sahinler, N., 2013. Potential effects of global warming on the honey bee. Uludag *Bee Journal*, 13, 79-87.

Yukimoto, S., Kawai, H., Koshiro, T., Oshima, N., Yoshida, K., Urakawa, S., Tsujino, H.; Deushi, M.; Tanaka, T.; Hosaka, M.; Yabu, S.; Yoshimura, H.; Shindo, E.; Mizuta, R.; Obata, A.; Adachi, Y. & Ishii, M. (2019). The Meteorological Research Institute Earth System Model version 2.0, MRI-ESM2. 0: Description and basic evaluation of the physical component. *Journal of the Meteorological Society of Japan. Ser. II.* 97 (5): 931-965.

ARABIC SUMMARY

الإنتشار المحتمل لخنفساء الخلية الصغرى *Aethina tumida*, من السودان وجنوب السودان نحو شمال أفريقيا والجزيرة العربية تحت ظروف بيئية مختلفة

محمد سمير يونس[1] ; حسام فرج أبوشعرة[2] ; تفاحة عبد المنعم حسن[2]
[1]: قسم بحوث النحل, معهد بحوث وقاية النبات , مركز البحوث الزراعية , القاهرة , مصر.
[2]: قسم وقاية النبات, كلية الزراعة, جامعة دمنهور, دمنهور, 22516، مصر.

تعد خنفساء الخلية الصغرى من الأفات الخطيرة التى تصيب طوائف نحل العسل وتتواجد بمناطق فى السودان وجنوب السودان. وتهدف هذة الدراسة للتعرف على مدى إمكانية إنتشار هذة الأفة من مناطق تواجدها بالسودان وجنوب السودان نحو الدول العربية الأخرى خلال أربع فترات زمنية: الظروف الحالية، 2030، 2050، و 2070. تم إستخدام النمذجة البيئية بواسطة برنامج Maxent لإتمام هذة الدراسة والحصول على خرائط الإنتشار. وقد تم مقارنة خرائط الإنتشار للتعرف على المناطق الملائمة لإنتشار هذة الأفة بالدول العربية بواسطة نظم المعلومات الجغرافية (GIS). وقد أظهرت خرائط الإنتشار أن السودان وجنوب السودان هم أكثر الدول ملائمة تحت الظروف الحالية. ولكن بعض المناطق بدول الخليج تم تصنيفيها ضمن المناطق الأكثر ملائمة لهذة الأفة تحت الظروف البيئية المستقبلية. ولم يتوقع التحليل إمكانية إنتشار هذة الأفة من السودان لتغزو مصر ولتمتد لمناطق أخرى فى شمال أفريقيا وبلاد الشام. وهذا يفسر سبب غياب هذة الافة فى مصر حتى الأن. ويبدو أن التجارة وخاصة المتعلقة بأدوات تربية النحل من السودان وجنوب السودان نحو الدول العربية الأخرى ربما تساهم بشكل غير مباشر فى إدخال هذة الأفة وهو أمر يحتاج توخى الحذر.

الكلمات المفتاحية: تربية نحل العسل, خنفساء الخلية الصغرى , نمذجة ,GIS.