

Modelling predicted global habitat suitability for *Apis Mellifera* (Honey bee) in 2050 under the RCP 4.5 scenario

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Introduction

Apis Mellifera is an eusocial hymenoptera insect species within the bee clade. It constructs colonial nests from wax, in which it produces and stores honey and rears offspring. Due to its ecological role as pollinators and production of honey, the species is of crucial economic, agricultural and ecological importance.

Progenitors of the *Apis* genus are believed to originate from South-East Asia, but the species *Apis Mellifera* most probably separated from their ancestral lineage in the Middle East around 6 million years ago (Engel 1999; Wallberg and Webster 2012).

Humans have been using honey bees' unique characteristics as pollinators for millennia and have helped spread the species across the globe. The Americas, which has no historic records of *Apis* presence, have now been fully colonised following European exploration of the continents. This is reflected in the GBIF data of the species; the database contains over 110.000 georeferenced records on all continents except Antarctica (GBIF.org).

Methods

Honey bee populations thrive in a wide range of habitats, but their distribution is limited by two important factors. The first is extreme cold. Honey bees do not go into dormant stage during winter like other insects, nor are they tolerant to freezing (Oxley&Oldroyd 2009). Although colonies have the capacity to survive cold winters by actively controlling the temperature in the hive and keeping the core at around 35°C, sub-zero temperatures can kill an individual honey bee in less than an hour. Additionally, bees rarely fly at air temperatures below 10°C, meaning they cannot forage during cold months (Heinrich 1996). Therefore I hypothesized that long winters and extreme cold periods would be a good variable to explain high latitude limits of honey bee habitats. I selected Bio6, which indicates the minimum temperature of the coldest month as a variable.

Secondly, honey bees need sufficient food sources, which are provided by flowering plants. I hypothesized that very arid regions are not suitable habitat for flowering plants and consequently, neither to honey bees. Therefore I selected Bio12 (annual precipitation) as the second variable for my model.

To estimate future habitat suitability for the species, occurrence data from GBIF was combined with climatic data from WorldClim in MAXENT. Bio12 and Bio6 indicators were used from the RCP 4.5 greenhouse gas concentration scenario from the MIROC5 climate model was selected to estimate climatic circumstances in 2050. Maxent settings were as illustrated in Figure 1.

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Figure 1: MAXENT settings

Model output

Figure 2 shows the output of the model generated by MAXENT, visualised by R. A big habitat shift does not appear to be likely under the chosen variables.

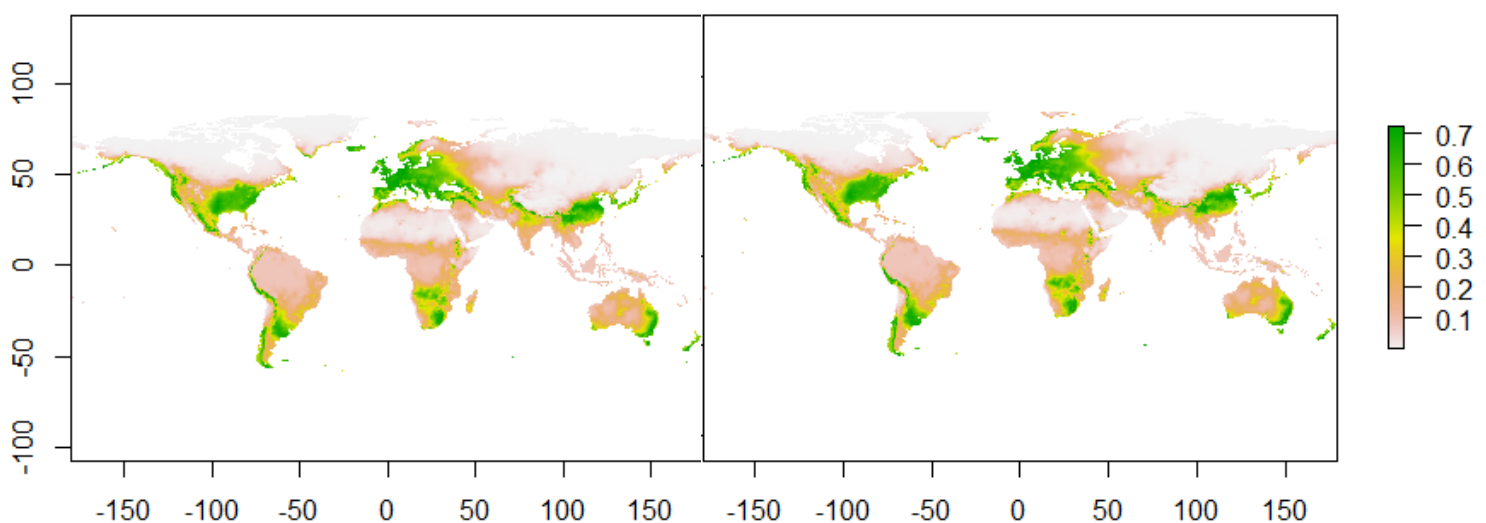
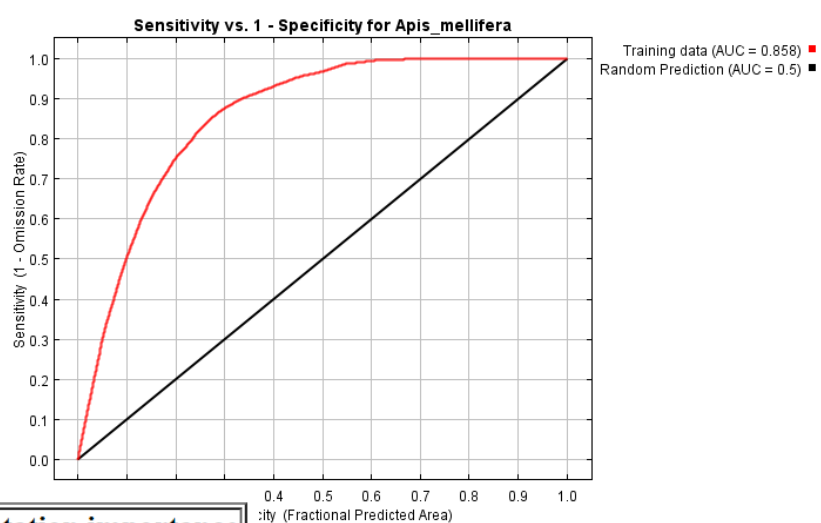


Figure 2: current habitat suitability (left) and future habitat suitability (right)

Figure 3 show model performance as Receiver Operator Curve (ROC). The Area Under the Curve (AUC) is 0.858, so the model is considered informative. It appears that Bio6 variable was a bigger contributor to the model than Bio12 (Figure 4). The minimum temperature of the coldest month (Bio6) indeed seems a good variable.



Variable	Percent contribution	Permutation importance
env_bio6	74.6	76.1
env_bio12	25.4	23.9

Figure 3, top: ROC and AUC

Figure 4, left: variable importance table

Responses to future scenario & biological interpretation

The model does not show major changes in predicted conditions for the distribution of *Apis Mellifera* as shown in figure 2. However, when future habitat suitability change is visualised, a pattern does seem to appear. Figure 5 shows habitat suitability in 2050, in which green areas show where suitable habitat is expected to grow, and red areas where it is expected to shrink. Yellow areas will remain the same. In North America, North Eastern Europe, Russia and small parts of China habitat shifts towards higher latitudes seem likely in several locations. This is probably due to rising temperatures in those areas (resulting in higher minimum winter temperatures). This means that bees, like several other species of insects, will be able to migrate and settle in more northern locations.

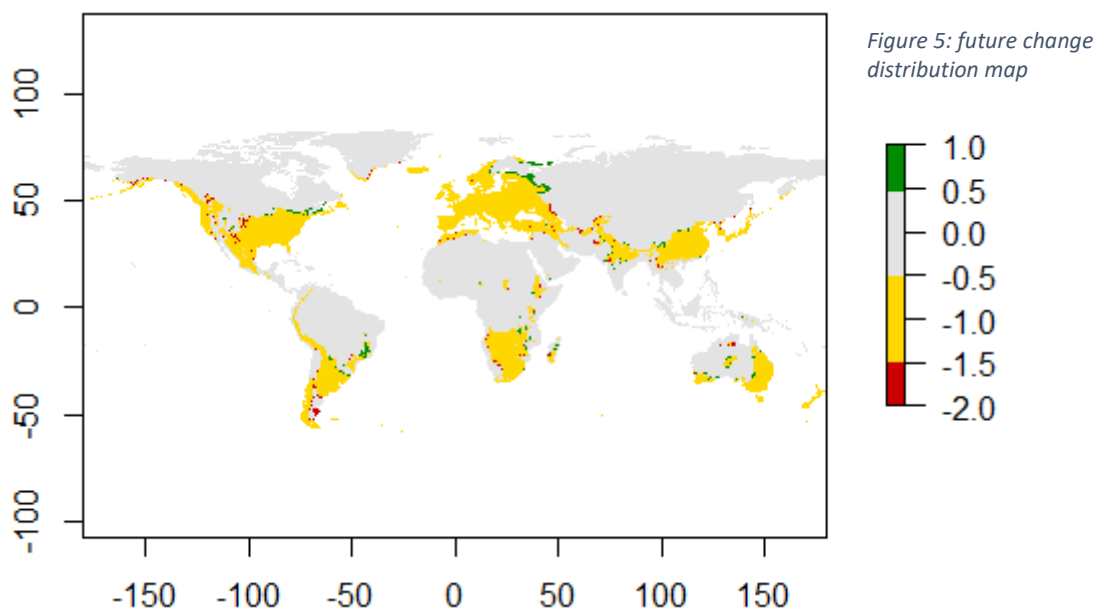


Figure 5 also shows several areas in which the model indicates loss of predicted suitable habitat. As annual precipitation was one of the variables used as inputs of the model, I consider desertification a possible cause of this predicted loss.

The model has several limitations. First, it only takes into account two climatic variables, thus leading to a very limited representation of future climatic change. Predicted habitat change may be informative on a global scale, but to estimate future range shifts of the species on a national or even local scale, much more climate data would be needed.

Secondly, the model totally disregards the instigator of enhanced climate change: humans. We do not only influence species distributions by changing climatic conditions, but by a much wider range of activities. Use of pesticides containing neonicotinoids have led to diminishing honey bee populations (Tsvetkov et al. 2017). Other types of pollution and factors like land use change can all potentially change habitat suitability. A model incorporating more variables like these would thus allow for more accurate and fine scale predictions.

References

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