Future global distributions of *Arachis hypogaea* under different climate change scenarios.

Astrid van den Burg s1664735

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Introduction

The peanut, *Arachis hypogaea* is a legume crop that is naturally distributed in the tropics and the subtropics. After aboveground pollination, the peanut pods develop underground, a growth form better known as geocarpy. This makes the peanut as a plant not that great of a distributional species, and it is mostly being dispersed by animals. The species is highly cultivated for general consumption and the production of oil, resulting in it diverging from its natural relatives and having a wider distribution. It occupies traits such as the capability to sustain extreme droughts and heat. [1] The peanut is a tetraploid (2n = 4x = 40) which is caused by the dispersion limitation that *Arachis hypogaea* has. [2]

With the use of species distribution modeling, a prediction will be made for habitat suitability in the present and future using bioclimatic factors that are predicted based on RCP scenarios.

This brings up the research question; What is the influence of climate change on the suitable habitat of *Arachis hypogaea*? It is expected that under the influence of climate change, with a global temperature increase, the species *Arachis hypogaea* will have a wider geographical space available.

Methodology and results

Species distribution modeling is done in several steps, first, the species occurrence data is downloaded from the GBIF database, the occurrence data is put onto a map and non-valid data is removed. After this, the environmental data is downloaded from Worldclim and version 1.4 is used for the different climate change scenarios used. A model was made using Maxent and the model performance is checked. Finally, species distribution model projections are made for different climate scenarios.

Occurrence data

The map in Figure 1 shows that the *Arachis hypogaea* species currently has a widespread distribution and can be found in tropical, subtropical and even in temperate regions in Europe, North America and Asia. Due to the amount of data that is available, there seems to be no to little spatial bias. The fact that the *Arachis hypogaea* is a cultivated plant species, can clarify the distribution rates in America and other more temperature regions contradictory with the expected ecological expected occurrence which are tropic to subtropic regions. Some edits were done on the occurrence data, data points were found in the ocean and single points where found in the north of Norway and in England, after some consideration, these data points were removed.

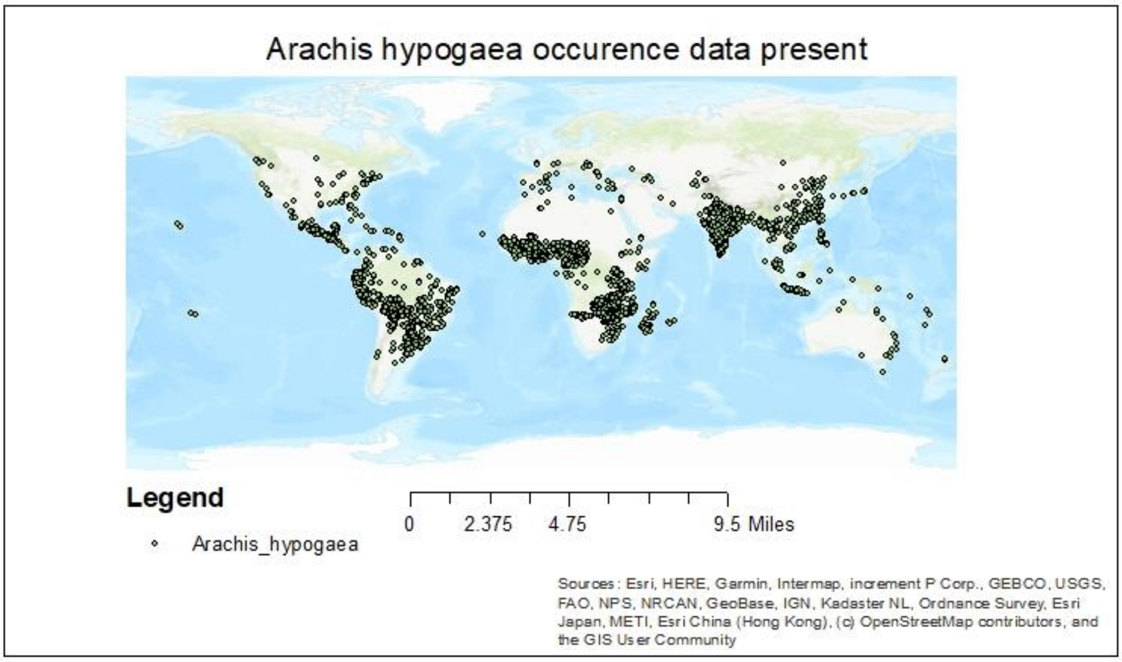

Figure 1. Map of the present *Arachis hypogaea* occurrence data obtained from GBIF.

Environmental data

For the species distribution modeling the following bioclimatic variables are chosen bio02, bio04, bio08, bio14, bio15, bio16 and bio19 (see Table 1).

Table 1. Bioclimatic variables used in species distribution modeling of *Arachis hypogaea*.

Bioclimatic variables	
BIO02	Mean Diurnal Range (Mean of monthly (max temp – min temp))
BIO04	Temperature Seasonality (standard deviation *100)
BIO08	Mean Temperature of Wettest Quarter
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO19	Precipitation of Coldest Quarter

A correlation table is made with all the different bioclimatic variables with the use of the occurrence data, the bioclimatic variables that have a high correlation with each other are not needed since they are telling the same information. Among the bioclimatic variables when there was a correlation with each other, one was chosen based on the assumption that *Arachis hypogaea* is a subtropic to tropical plant in favor of wet and warm conditions. This resulted in a total of 7 bioclimatic variables, which all have a lower correlation than 0.7.

In Rstudio a vif() test resulted in the following VIF table (see Table 2). As shown in the figure the VIF values are all low, meaning that the bioclimatic variables were chosen to represent the influence for climate change the best for the *Arachis hypogaea* species.

Table 2. Table of the bioclimatic variables and the corresponding VIF values.

	Variables	VIF
1	Bio02	1.746574
2	Bio04	1.910918
3	Bio08	1.769690
4	Bio14	2.482299
5	Bio15	2.062777
6	Bio16	2.427098
7	Bio19	2.412446

Model settings

For the model settings in Maxent the handout Exercise: Model your chosen species' habitat suitability under present and future climate conditions was used. This includes the given output of the Jackknife and the response curves. The number of replicates used in Maxent to train the model is set to 5.

Model output

A model was made with the use of MAXENT resulting in an AUC of 0.816. This can be considered as a good model, see figure 2.

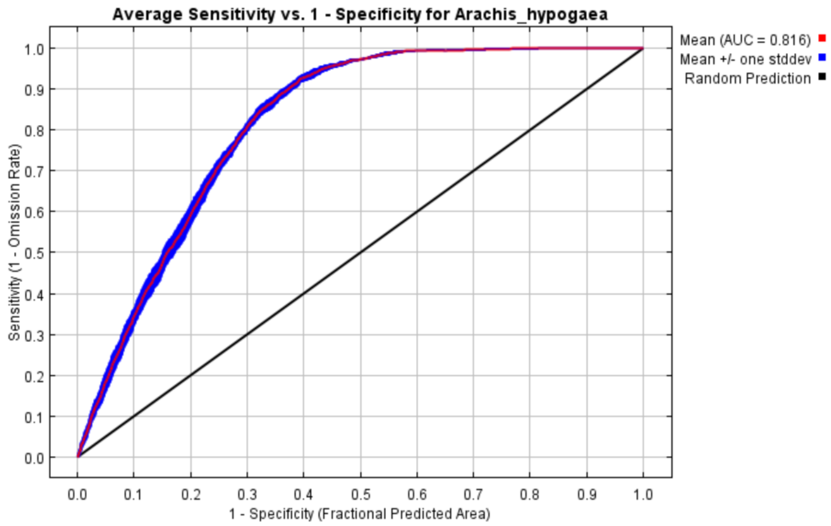

Figure 2. Graph of average sensitivity versus specificity for *Arachis hypogaea*.

The output of Maxent also results in response curves as can be seen in Figure 3. When looking at the response curves you see that the bioclimatic variables bio04, bio08 and bio16 are the most important. This is the temperature seasonality, the mean temperature of the wettest quarter and the precipitation in the wettest quarter. Which implies a high influence of rain on the growth of the peanut.

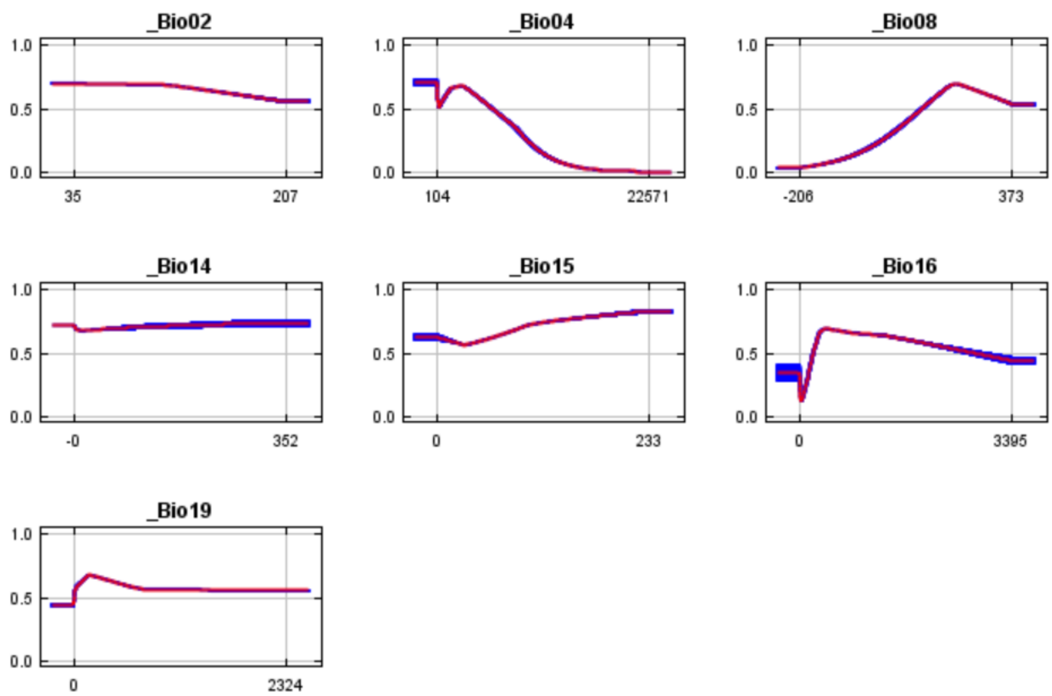

Figure 3. Response curves from the Maxent model output for the different bioclimatic variables.

There is not much visible change between the present and the future scenarios. When looking further into the comparison between scenario 8.5 and the present, you only see differences in the European regions turning into a less suitable environment. When looking at the Jackknife output the variable Bio04 is the most important, the temperature seasonality. This can be caused by the fact that the *Arachis hypogaea* is sensitive to cold temperatures. When looking at the maps, you can see a change in the modeled suitable future habitat in Europe and North America, which can be caused by the little occurrence data points that are currently in the south of Europe and the disputable occurrence data from the more Northern part of Europe (see Fig. 4 and 5).

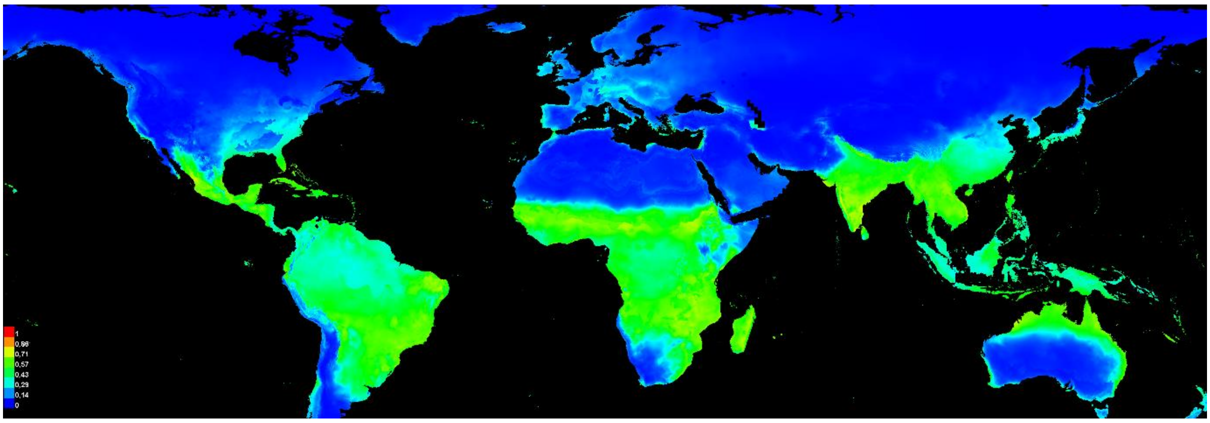

Figure 4 The present species occurrence.

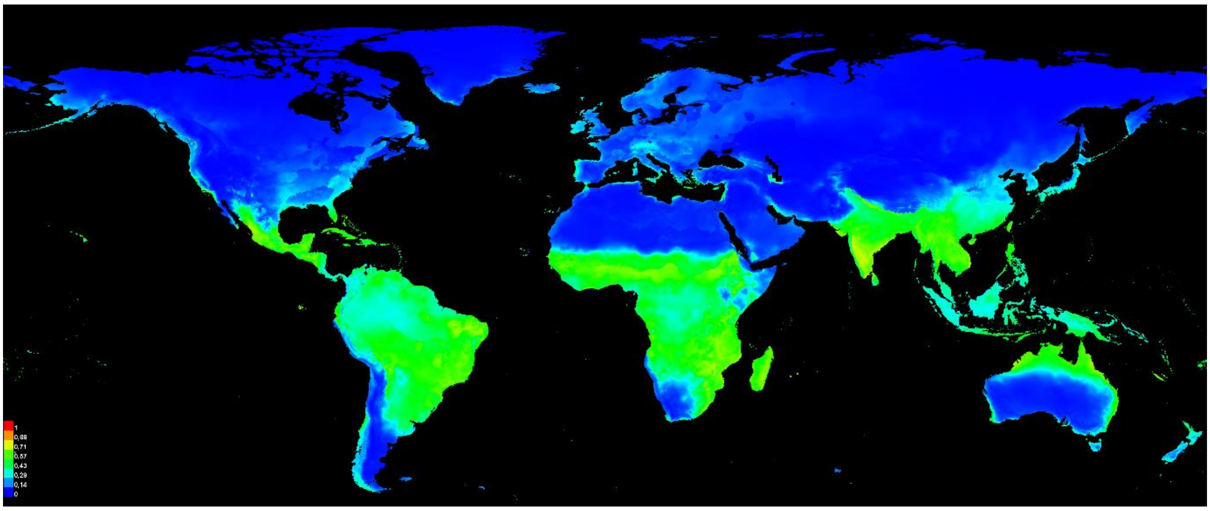

Figure 5. Future species occurrence under the RCP8.5 scenario.

SDM projections

Maps were made in ArcGIS of the species distribution modeling projections of the present climate data and of the RCP8.5 scenario, see Fig.6 and 7. There is no to a little negative change between the present suitable habitat and the RCP8.5 scenario. This can mostly be seen in central Africa and in the Amazon. Furthermore, suitable habitat is partly lost in America and in India. In South America and Africa, there seems to be no net increase or decrease, but a shift in the geographical available space. In North America, Europe and Eurasia, there is a loss in geographical available space. If there is newly available space it is hard for the peanut to reach the new locations, because of the limited dispersal possibilities of the species.

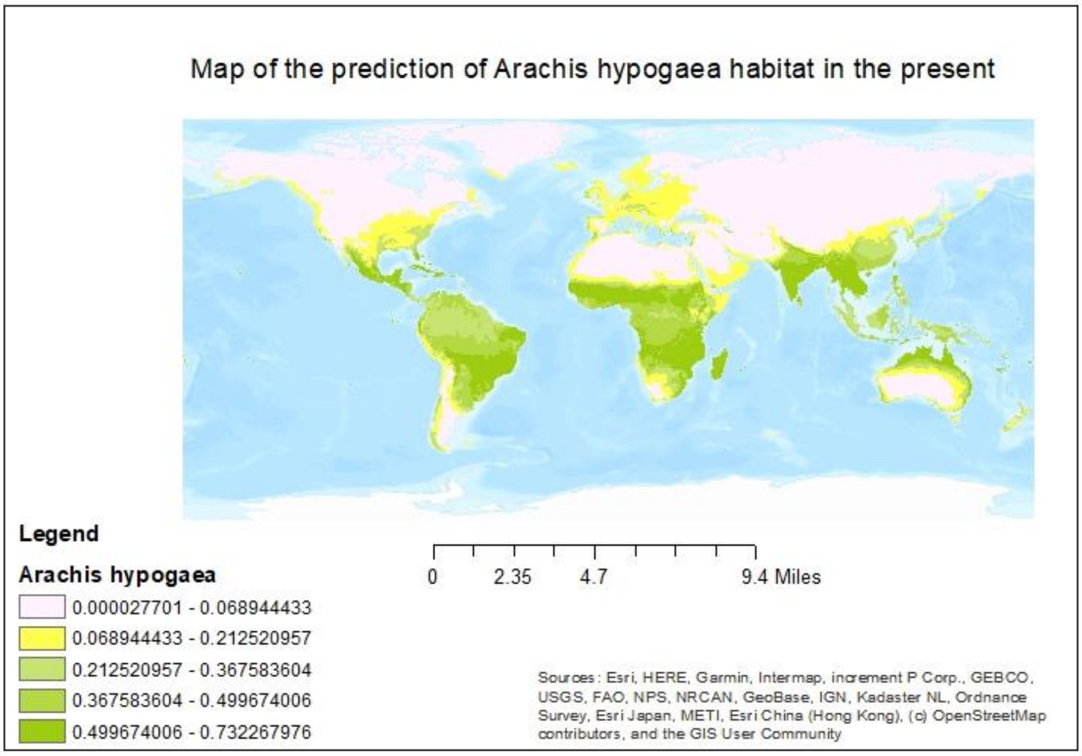

Figure 6. Map of the predicted suitable habitat of *Arachis hypogaea* with the present climate data. The green color implies an increase in suitability from light to dark green, yellow shows a decrease in habitat suitability and grey shows a remaining non-suitable environment.

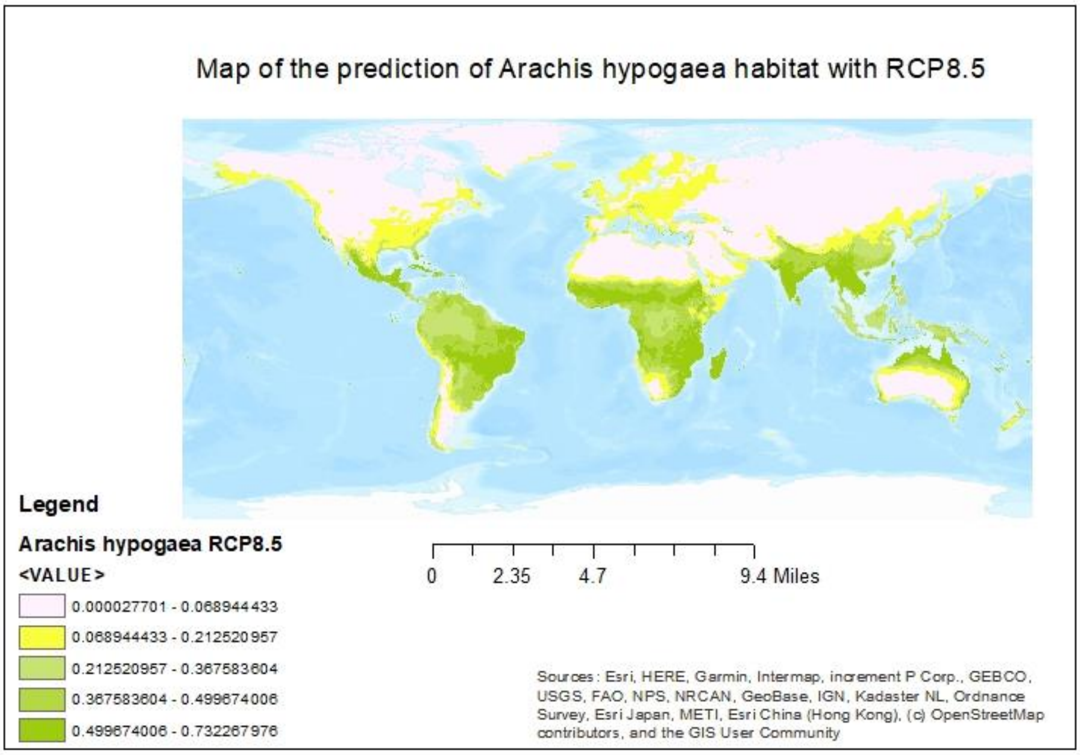

Figure 7. Map of the predicted suitable habitat of *Arachis hypogaea* according to the RCP8.5 scenario. The green color implies an increase in suitability from light to dark green, yellow shows a decrease in habitat suitability and grey shows a remaining non-suitable environment.

Discussion and conclusion

The different climate change scenarios that were performed did not show much difference from the present suitable habitat for *Arachis hypogaea*, resulting in doing the analysis only on the present species distribution model and the model for the most extreme scenario RCP8.5.

The bioclimatic variables that have the highest influence on the model are bio04, bio08 and bio16, which are the temperature seasonality, the mean temperature of the wettest quarter and the precipitation in the wettest quarter. Showing that these factors are the most important for the growth of the *Arachis hypogaea* as their predicted suitable habitat is highly influenced by them.

In the present map (Fig. 6), it is seen that there already is a high amount of decrease of available habitat space, this can be due to the many occurrence data points found in Europe and North America, which is mostly caused by the cultivation of peanuts and not by natural distribution. When taking cultivated peanuts out of consideration, the peanut is not in great danger, nor will its distribution increase due to climate change when comparing the present suitable habitat with the RCP8.5 scenario. It is not expected that there is an increase in the distribution of *Arachis hypogaea* since its dispersion possibilities are limited despite the temperature increase that should be favorable for the peanut. However, more regions will be available for peanut cultivation.

For future research, it would be recommended to remove occurrence data that is probably from or nearby cultivated areas. This can give a clearer distribution pattern and can predict future natural distribution better.

Literature

1. Akram, N. A., Shafiq, F. & Ashraf, M. Peanut (*Arachis hypogaea* L.): A Prospective Legume Crop to Offer Multiple Health Benefits Under Changing Climate. *Compr. Rev. Food Sci. Food Saf.* **17**, 1325–1338 (2018).

2. Moretzsohn, M. C. *et al.* A study of the relationships of cultivated peanut (Arachis hypogaea) and its most closely related wild species using intron sequences and microsatellite markers. doi:10.1093/aob/mcs237.

3. GBIF database. *Arachis hypogaea* data obtained on December 2 https://www.gbif.org/occurrence/search?q=arachis%20hypogaea

4. Worldclim database. Climate data for present and future with different scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5 version 1.4. 5 minutes. https://www.worldclim.org/version1