Using Species Distribution Modelling (SDM) to predict future distribution of *Ipomoea batatas*.

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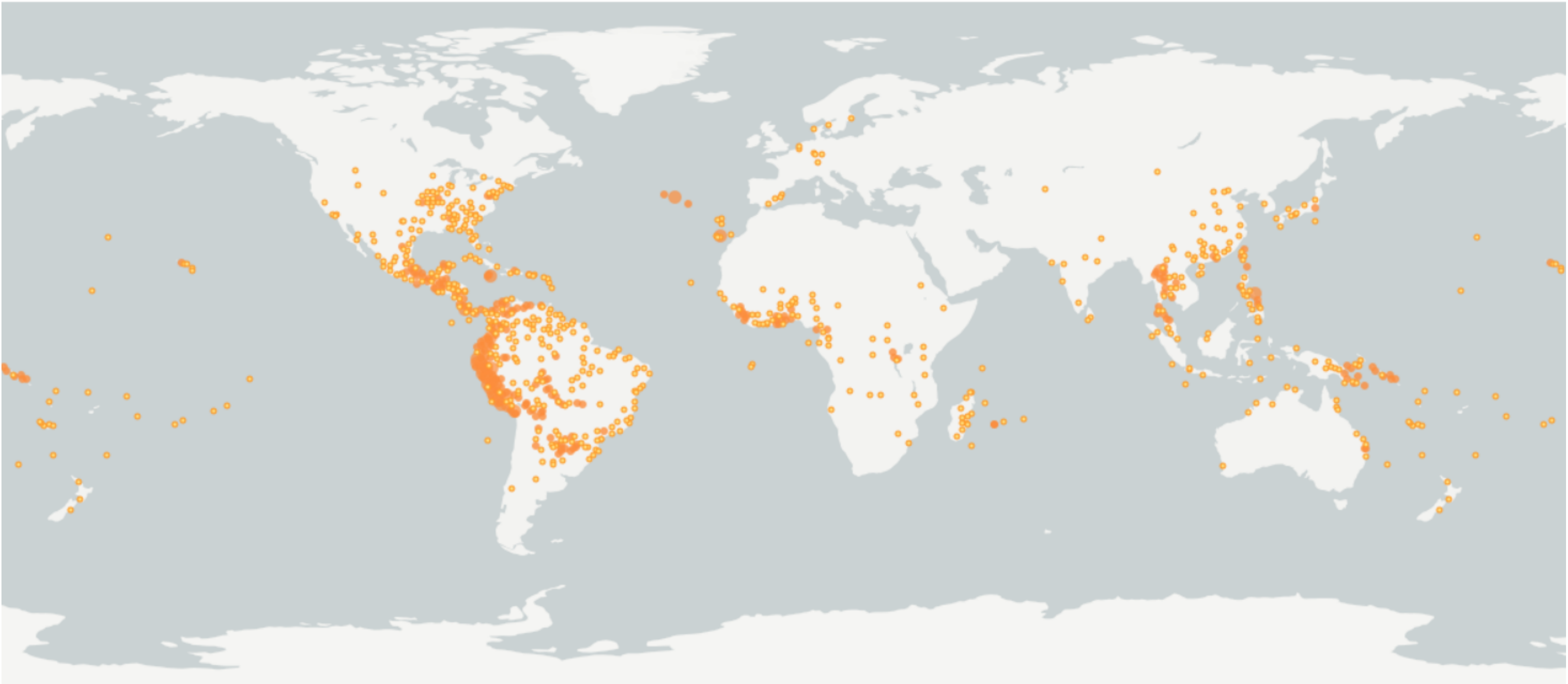

Contents

Introduction

Over the past decades, the impact of climate change has become more clear, or as stated by the AR5 report on climate change by the IPCC; "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems." [1]. These impacts of climate change include agricultural production, changing suitable areas for crops to grow and subsequently impacting global economics [2]. This report will focus on the impact of climate change on habitat suitability in the sweet potato (*Ipomoea batatas*). Sweet potatoes are a great source of beta-carotene, which can be converted into vitamin A by the body. The sweet potato is perennial, requires a warm climate, is extremely heat tolerant, but does not tolerate frost [3]. One of the advantages of the sweet potato as a crop is the few natural enemies it has, which results in pesticides rarely being needed [4]. In order to research the effects of climate change on the suitable habitat of the sweet potato, this report will use Species Distribution Modelling (SDM) as a tool to predict future suitable habitat ranges worldwide. An SDM is a numerical tool that combines species observations, like occurrence or abundance, with environmental estimates [5]. Using SDM, this report will aim to answer the following research question: How will climate change influence global distribution of the sweet potato (*Ipomoea batatas*)? We hypothesize that, using RCP 4.5 as a model for future climate conditions, suitable habitat around the equator will be lost, while suitable habitat in temperate regions will be gained. Climate change will cause increases in temperature and drought around the equator, leading to loss in suitable habitat, while it will also cause an increase in temperature in the temperate regions, which decreases the chance of frost, a climate condition the sweet potato cannot tolerate.

Methodology

Workflow

This report will follow a rather straightforward process, depicted in figure 1 below.

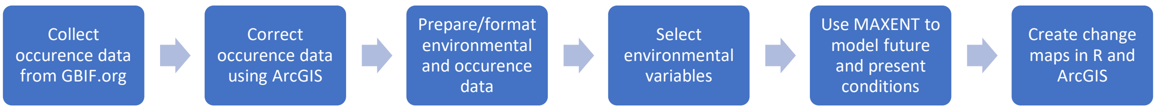

Figure 1 Workflow of the report.

Occurrence data

The global occurrence data of the sweet potato was gathered from GBIF.org, a free and open access point to biodiversity data. Data was only taken from records which included locations. As seen in figure 2 below, the general distribution of the sweet potato is global and most concentrated around the equator, while also spreading up to 40 degrees in latitude. The species is not found any further north or south, probably due to its intolerance against frost and preference for a warm climate. Unfortunately, no corrections were done on the data taken from GBIF, since I was unable to attend the second ArcGIS practical. This might effect the outcome of our model and should be taken into account.

*Figure 2 Global distribution of the sweet potato (*Ipomoea batatas*), taken from GBIF.org*

Environmental data

While choosing the environmental variables for the model, I tried to include the characteristics of the species. In total, I chose 5 variables; Bio01 (annual mean temperature) as the sweet potato is described to prefer warm climates. Bio04 (Temperature seasonality) as this would include the preferred stable climate and reflect the intolerance to frost somewhat. Bio12 (Annual precipitation) as sweet potato is described to require certain amounts of precipitation, especially during its flowering stage. Bio14 (Precipitation of driest month) as sweet potato is does not like dry periods. Bio15 (Precipitation seasonality) because the sweet potato prefers a rather constant level of precipitation [3]. Table 1 below shows the results of the autocorrelation test performed in R.

	Bio01	**Bio04**	**Bio12**	**Bio14**	**Bio15**
Bio01	1	-0.8309	0.315102	0.046492	0.297163
Bio04	-0.8309	1	-0.52727	-0.22189	-0.14771
Bio12	0.315102	-0.52727	1	0.706004	-0.23263
Bio14	0.046492	-0.22189	0.706004	1	-0.53518
Bio15	0.297163	-0.14771	-0.23263	-0.53518	1

Table 1 Autocorrelation table, yellow numbers are values below the threshold of -0.7 while red numbers are values above the threshold of 0.7

The results from the multicollinearity test performed in R can be found in table 2 below.

Variables	VIF
Bio01	3.690120
Bio04	4.347030
Bio12	2.877280
Bio14	2.834328
Bio15	1.662315

Table 2 Multicollinearity test results

Model output

The AUC of the model is 0.810, as can be seen in figure 3 below. The ROC has a standard deviation of 0.003.

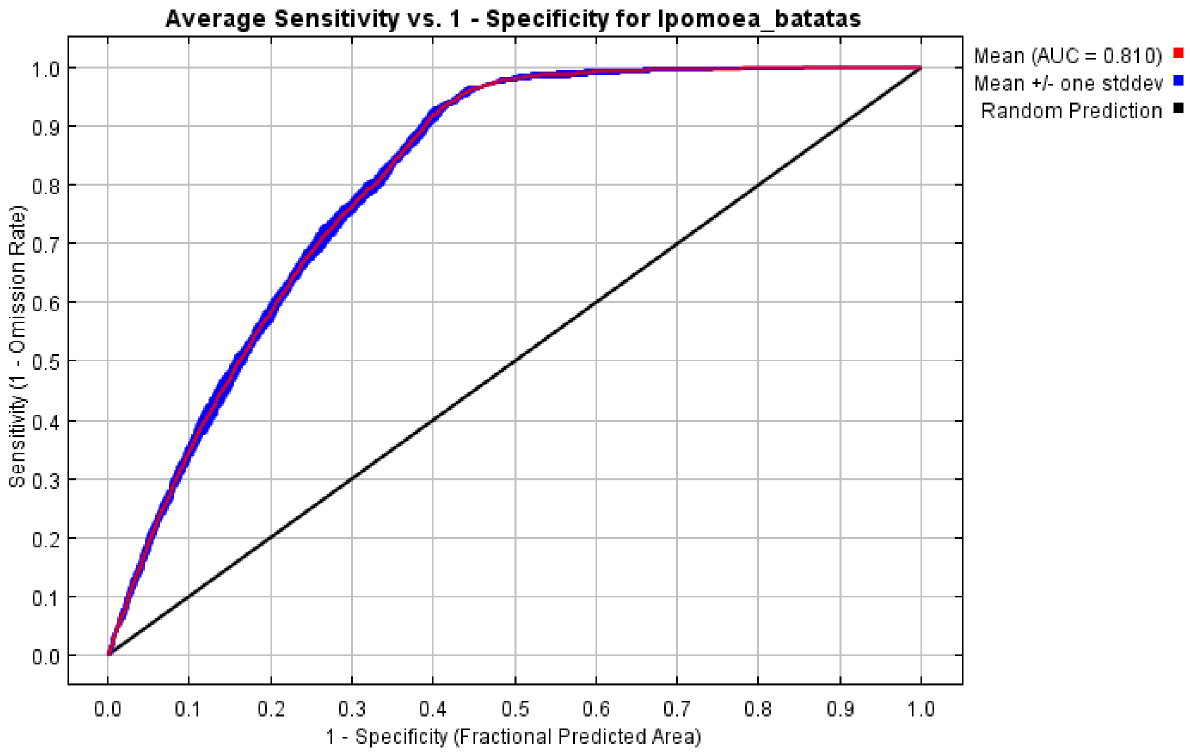

Figure 3 Receiver operating characteristic (ROC) curve of the 5 runs.

The response curves for my MAXENT prediction can be found below in figure 4. Bio01 and Bio04 are shown to be large predictors for this model. Bio01 shows the preference of the sweet potato for an annual temperature around 25 degrees Celcius, while Bio04 shows that the sweet potato prefers some variance in the temperature between the seasons, but not too much. The same trend can be seen in figure 5 below, which shows that Bio04 appears to have the most useful information by itself, but also that Bio04 decreases the gain of the model the most when it is omitted.

Figure 6 shows us in which areas environmental variables in the model using RCP 4.5 are outside the range present during the training. The figure shows red areas in Greenland and in the Sahara, predictions of the model in this area should not be trusted, but the model itself does not predict any occurrences in these places.

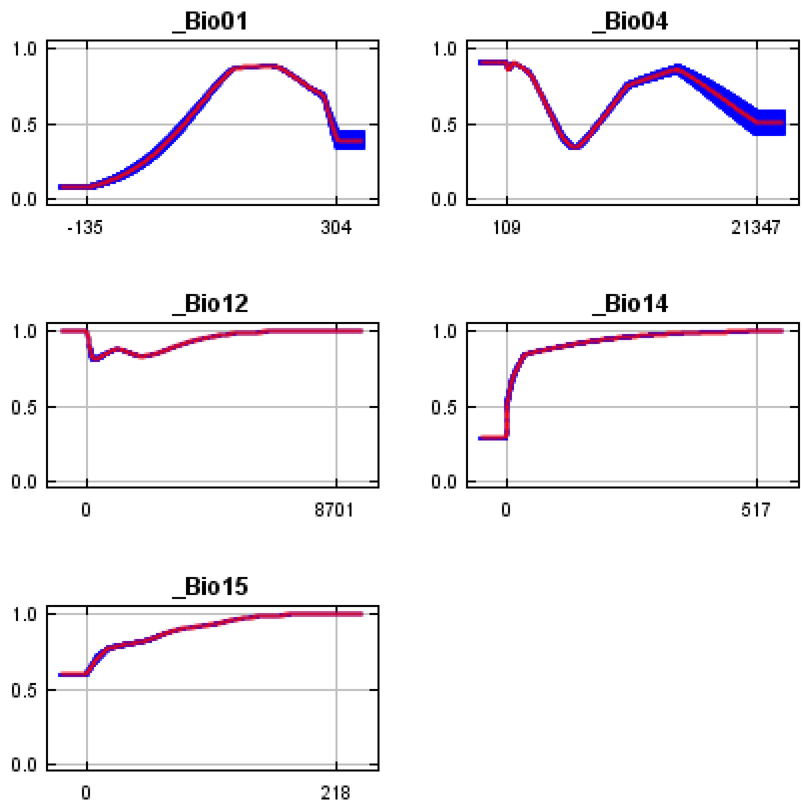

Figure 4 Response curves showing how each environmental variable affects the MAXENT prediction

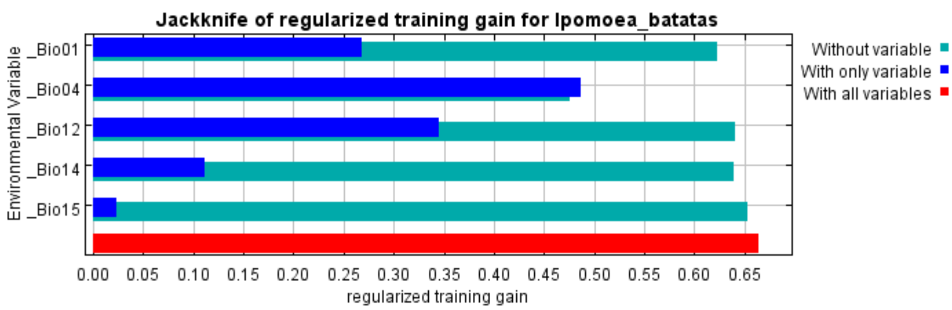

Figure 5 Jackknife test of regularized training gain taken from MAXENT results.

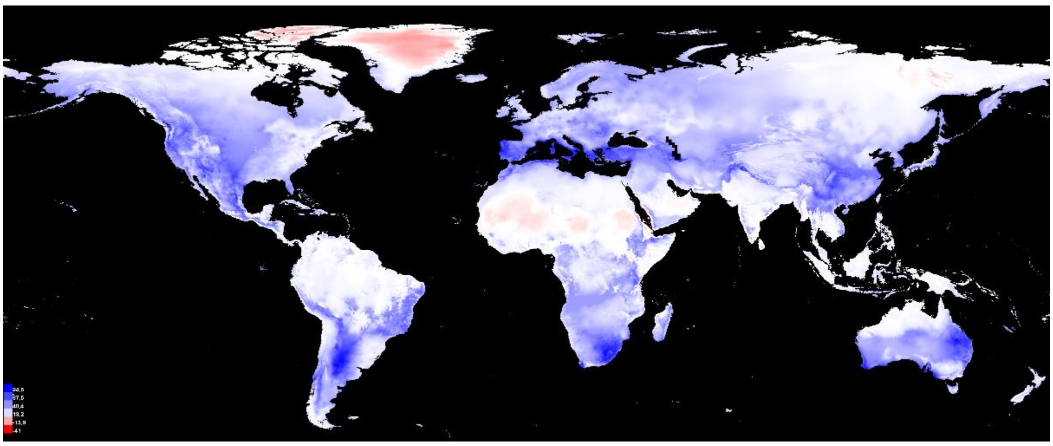

Figure 6 Environmental similarity of variables in the model to the environmental data, areas in red have one or more environmental variables outside the range present in training.

SDM projections

After the MAXENT run, the generated data was used in R to visualize present and future global distribution according to the model. Figure 7 shows the present global distribution modelled from the environmental variables selected before.

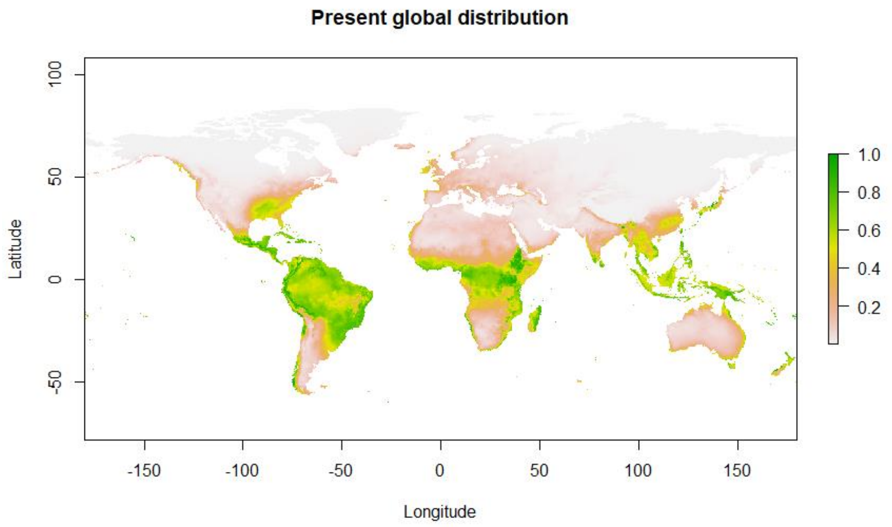

Figure 7 Present global distribution according to the environmental variables

The future scenarios that were selected were modelled against the Representative Concentration Pathways (RCP) 4.5 environmental projections. RCPs are, as described by the RCP Database, "Consistent sets of projections of only the components of radiative forcing that are meant to serve as input for climate modeling, pattern scaling, and atmospheric chemistry modeling"[6]. The RCP 4.5 is a stabilized scenario where total radiative forcing is stabilized before 2100 using a range of strategies and technologies for reducing greenhouse gas emissions. This scenario seemed most likely to be the future scenario and was thus chosen to be used during the modeling section.

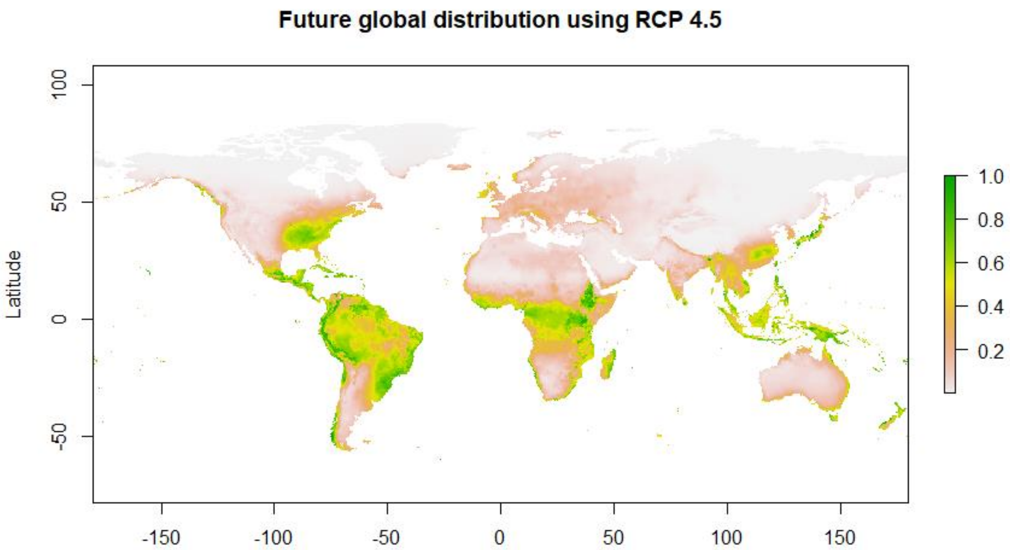

Figure 8 Future global distribution using RCP 4.5. Green areas show high occurrence while red/white areas show low occurrence.

Figure 9 shows the change in suitable climate conditions for the sweet potato in the future. The yellow areas on this map show where the sweet potato will remain, red areas show a loss of suitable habitat and green areas show a gain of suitable habitat. As seen on the map below, there are large areas in South America, Africa and Southeast Asia that experience loss of suitable climate conditions for the sweet potato. North America shows a potential gain in suitable habitat for the sweet potato and since the sweet potato is already present in that area, the chances of the sweet potato to inhabit the newly gained suitable area is rather large, as farmers are likely to take this chance to start cultivating sweet potatoes. In general, the total geographical space available for the species has decreased.

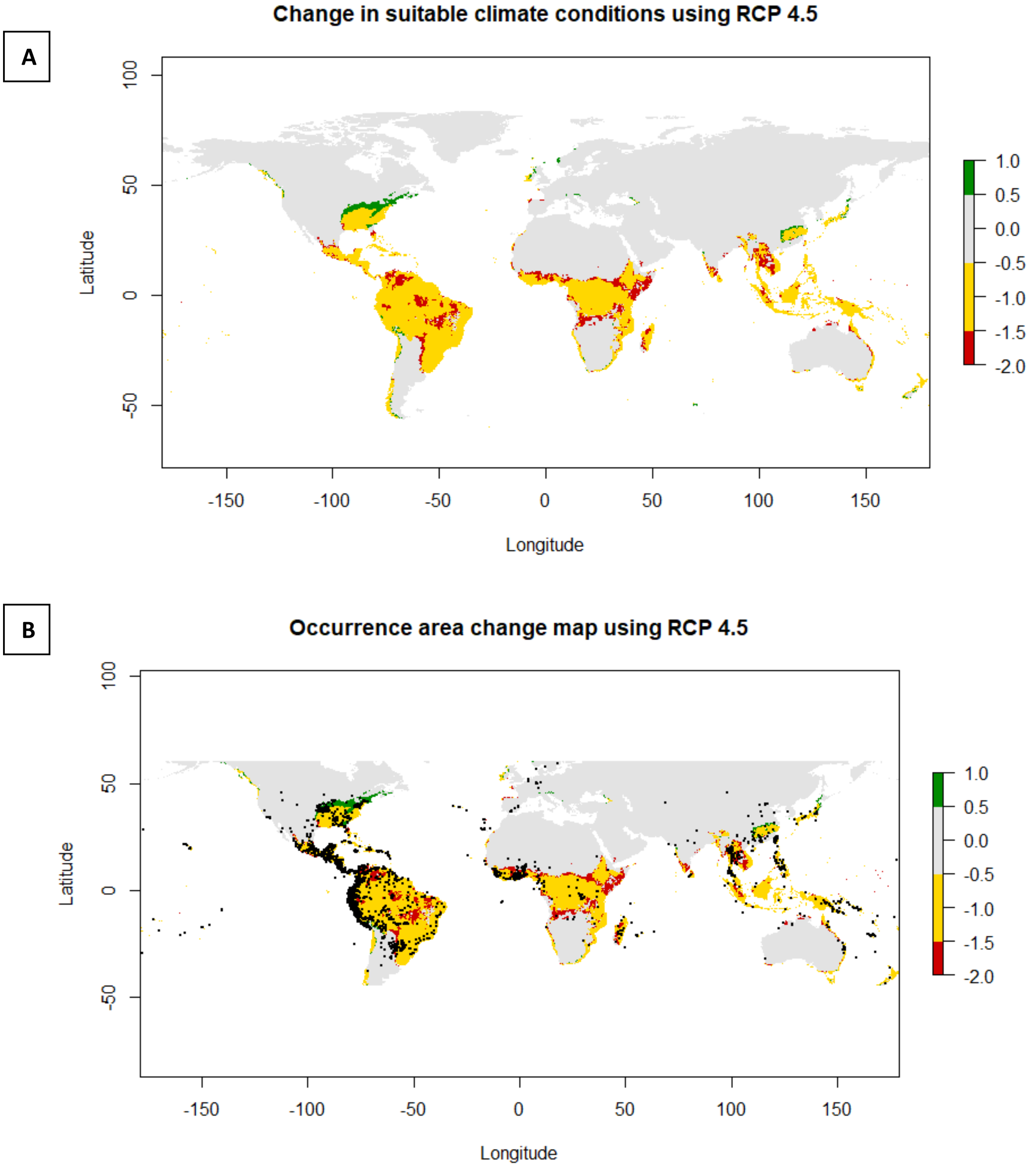

Figure 9 A: Change in suitable climate conditions in the future using RCP 4.5. Green areas show gain, yellow show areas that stayed similar and red shows loss. B: Change in species occurrence, the legend is the same as in A, but the black dots show occurrence.

Discussion

In this report I set out to find how climate change would influence future distribution of the sweet potato. I hypothesized that suitable climate conditions would be lost around the equator and that there would be a gain in the temperate regions. As seen in figure 9A, this hypothesis is largely true. The loss of suitable climate conditions is found in South America, Africa and Southeast Asia, all around the equator, while the gain of suitable climate conditions can be found in North America, in a more temperate region. There is, however, no gain to be found in other temperate regions. This might be explained by the fact that high precipitation can cause rotting to take place in this species, thus limiting its spread in the European and Asian temperate regions. For future modeling on this species, I would like to analyze occurrences in ArcGIS before starting the modeling using MAXENT, since I feel that some data in my occurrences negatively contribute to the model. Furthermore, I would suggest taking Bio6, the minimum temperature in the coldest month as a variable, since frost is described as such an important, negative factor in sweet potato growth.

References

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