Species distribution modelling of the grapevine *Vitis vinifera subsp. vinifera*

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Introduction

For this project on species distribution modelling, occurrence data of the cultivated grapevine *Vitis vinifera subsp. vinifera* was used. The grapevine was most likely first cultivated in the region between Iran and the Black Sea between the seventh and fourth millennium BC[1]. The grapevine has since been used intensively in the production of wine, first in the 'old world of wine' (Europe, North Africa and the Near East), and later in the 'new world of wine' in countries in North and South America as well as South Africa, New Zealand and Australia. The occurrence data has been extracted from the GBIF database as *Vitis vinifera subsp. Vinifera*[2]. This dataset consists of 2245 georeferenced datapoints concentrated in Europe with sporadic occurrences in North and South America. The global spread of the data is shown in Figure 1. Climate data for the species modelling was downloaded from the Worldclim database for the present and the RCP 4.5 prediction for 2050. Both datasets with a resolution of 5 minutes.

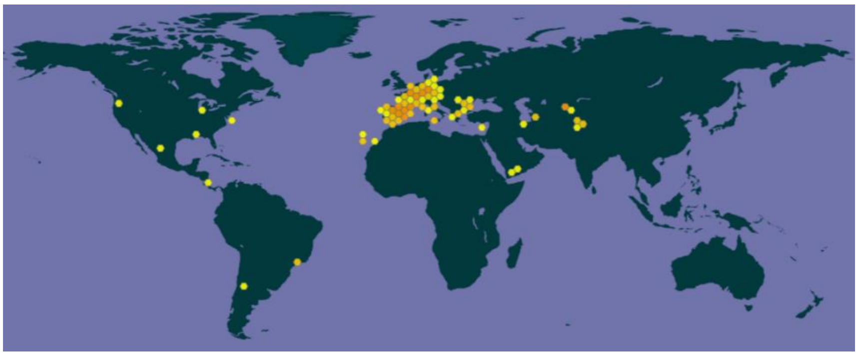

Figure 1 Occurrences in the GBIF database. Data is mostly concentrated in Western Europe

Methods

Species distribution modelling was performed using the MAXENT software. For this analysis, the occurrence data was clipped to the most densely sampled region (Europe) to form the training data. This to avoid sampling bias by the thinly spread samples outside of Europe. The model was cross-validated ten times with 10.000 background sample points. Additionally, jackknifing was done to measure variable importance. Other parameters were left at default settings. This model was the projected on the global climate data. For the climatic variables needed for the model, the extreme temperature values were used, represented by the maximal temperature in the warmest month and the minimal temperature in the coldest month. Additionally, the mean diurnal temperature range was selected. These variables were selected as grapevines are less likely to grow when exposed to subzero temperatures for extended time periods, so information on the extreme temperatures and the range of temperatures is likely important to factor in the model. Furthermore, precipitation data of the wettest and driest month were selected as grapevines benefit from a sufficiently wet spring and a relatively dry fall, when harvest occurs.

Results

Model output

The occurrence map of the sampled area is shown in Figure 2. This shows a clear preference in most of France and northern Spain with a relative high probability throughout most of Western Europe, with the exceptions of dense mountainous areas. The global projection of this model in the present and the 2050 predicted model are shown in Figure 3. The present model projection shows suitable regions for grapevines in locations where viticulture occurs as part of the New World of wine, such as Australia, South Africa and California after being trained on the occurrence data in Western Europe. However, it also shows high probability of occurrence in regions less suitable due to non-climatic variables such as the tropics.

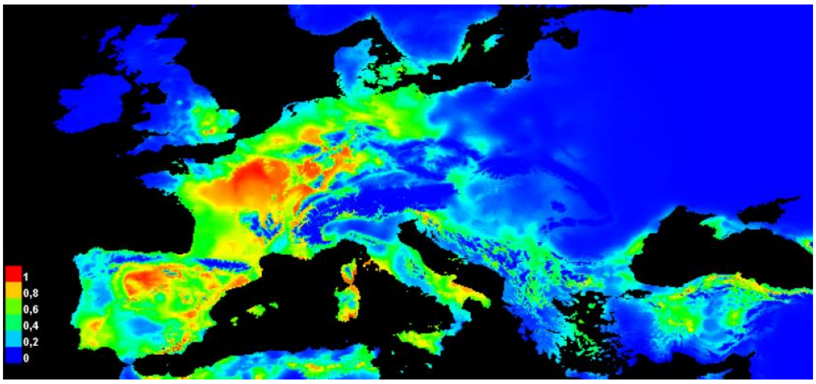

Figure 2 Modelled distribution of training area. Warmer colors indicate a higher occurrence probability

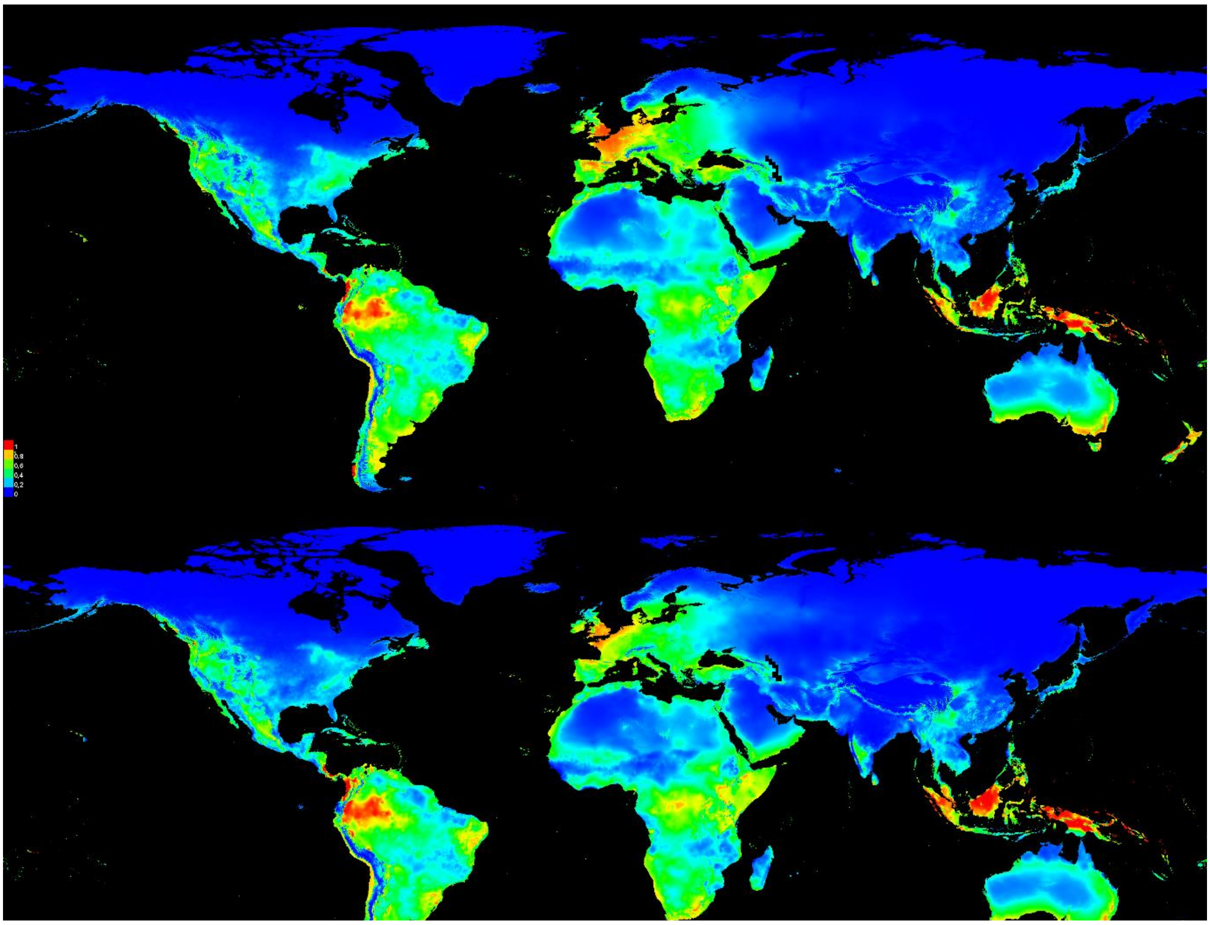

Figure 3 Global projection of the model. Top figure displays the present distribution. Bottom figure shows the predicted future distribution in 2050. Warmer colors indicate a higher occurence probability

Comparing the present and future models shows little difference, with the important exception that most of Spain and France have become less suitable for the grapevine. This model shows an AUC of 0.876. This is a moderately high value, showing a relatively good fit of the model. However, high values of AUC can also occur when a high degree of sample bias is present. This was the case in the explorative model that was created without removing the datapoints outside Europe. The model was in this case too well able to distinguish between the pseudo-absent sites and the present sites. AUC should therefore not be used as a sole indicator of model performance.

The relative importance of each chosen variable are shown in Table 1. This table shows the most important variable to be the diurnal range (62.1%), followed by the minimal temperature of the coldest month (21.9%). The precipitation of the driest month and the maximal temperature of the warmest month show the least relative importance (3.3% and 0.7% respectively), suggesting that the coldest and wettest month are more important to the suitability of the grapevine than the hottest and driest months.

Table 1 Variable importance per Worldclim variable

Worldclim ID	Description	Percentage contribution
Bio2	Diurnal range	62.1%
Bio6	Minimum temperature in coldest month	21.9%
Bio14	Precipitation in wettest month	12.1%
Bio13	Precipitation in driest month	3.3%
Bio5	Maximum temperature in warmest month	0.7%

Response to future scenario

The average present and future distribution maps were transformed into a binary format where the occurrence was set to 1 when the average probability of occurrence exceeded a 0.4 threshold. These binary maps were used to calculate a distribution change map. This map is shown in Figure 4. Blue areas are areas that have an occurrence of 1 in both scenarios. Green areas are areas that were

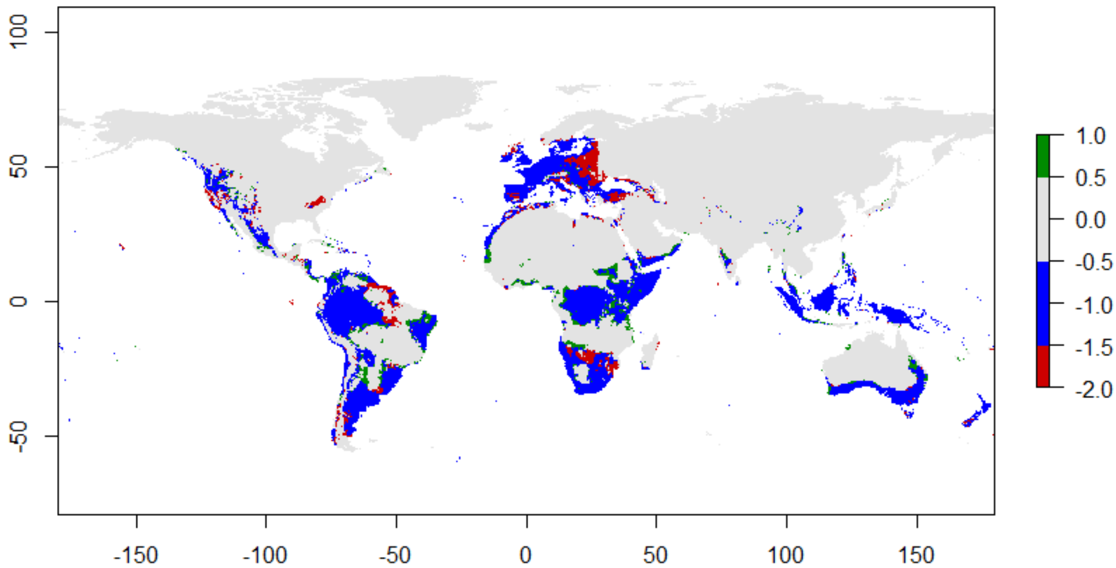

Figure 4 Global distribution change map. Blue colors show unchanged suitability. Red corresponds to loss of suitability compared to the future distribution. Green corresponds to gain in suitability compared to the future distribution.

unsuitable in the present distribution but are suitable in the future distribution. Red areas were found Suitable in the present distribution but were found unsuitable in the future distribution.

Interpretation

The comparison of the present and future distribution shows a largely unchanged projection. Most loss of suitable habitat is seen in Eastern Europe and only small regions are gained around already suitable regions. From a modelling perspective, the loss of suitable habitat is likely caused by a change in diurnal range and minimal temperature in the coldest month, as these are the most contributing variables. The Maxent response curves for the diurnal range show a specific optimum, after which the spread around the mean increases drastically and the suitability drops. Previous research shows that compressed diurnal ranges speeds up the coloration and ripening of grapes[3]. Although this pattern has more to do with viticulture rather than proliferation, modelling grapevines will likely take these human selection pressures into account to a certain extent, as grapevines with undesirable wine yield will be cultivated less intensively and habitats might therefore be labeled unsuitable.

Although this model shows a high AUC value and the present projection shows most of the areas of the New World where viticulture is viable, it lacks in performance in several aspects. This can possibly be due to the fact that the data originates from a cultivated species. Grapevines can be kept alive in a wide range of habitats, but is only intensively grown where commercially viable wine can be produced[4]. This introduces a bias on optimal conditions that are not representing the natural distribution. Although it could be argued that this model then shows a distribution of suitability for cultivation, this distribution is also highly biased. Wine production relies heavily on factors other than climatic factors, such as local soil type, for suitability, for which the model is unable to account. Furthermore, the model does not incorporate accessibility for human cultivation. Due to the combination of these factors, the model reflects neither the natural habitats nor the habitats suitable for cultivation.

References

1. Terral JF, Tabard E, Bouby L, et al. Evolution and history of grapevine (Vitis vinifera) under domestication: new morphometric perspectives to understand seed domestication syndrome and reveal origins of ancient European cultivars. Ann Bot. 2009;105(3):443-55.

2. GBIF.org (4 December 2018) GBIF Occurrence Download https://doi.org/10.15468/dl.mcgky2\\

3. Cohen SD, Tarara JM, Kennedy JA. Diurnal Temperature Range Compression Hastens Berry Development and Modifies Flavonoid Partitioning in Grapes. Am J Enol Vitic. 2010

4. Lavee S. (2000) Grapevine (Vitis Vinifera) Growth and Performance in Warm Climates. In: Erez A. (eds) Temperate Fruit Crops in Warm Climates. Springer, Dordrecht