How will Anthropogenic Climate Change Impact the Geographic Distribution of Chilean Rhubarb (*Gunnera tinctoria*) in Scotland

Student ID: 2184848 Word Count: 1255

University of BRISTOL

Introduction

Chilean rhubarb (*Gunnera tinctoria*) is a perennial species, non-native to the UK [1], which has been introduced into gardens globally establishing itself as a locally invasive species in Britain and elsewhere [2]. Frequently distributed along banks of watercourses, Chilean rhubarb is becoming a nuisance in the UK [1] and like many other invasive species, it can have negative environmental impacts – reducing biodiversity and altering ecosystems [3]. Henceforth, it is important that countries can control the introduction, establishment, and abundance of invasive species. As such, restrictions apply to activities involved in breeding, transporting, selling, and cultivating Chilean rhubarb in the UK [4]. However, global climate change has the potential to alter the abiotic environment [5] – like precipitation and temperature changes – which in turn can facilitate the distribution of invasive species and alter the hierarchy of the biotic environments [6]. Therefore, it is important for governments and countries to examine and understand the reaction of invasive species to environmental changes [7]. Species distribution models (SDMs) are used to predict species distribution in response to climate change [7]. In hopes to understand how climate change will affect invasive species, this research aims to investigate and examine changes in the distribution of Chilean rhubarb in Scotland using species distribution modelling.

Method

This investigation made use of secondary data sources like spatial data on the distribution of Chilean rhubarb to be able to predict the distribution of the species in future climate scenarios compared to the modern climate. Contemporary climate data and two different future scenarios were used. The scenarios were used to predict the distribution of Chilean rhubarb within the timeframe of 2041 and 2060 where the degree of radiative forcing differs. Both future climate data sets represent different representative concentration pathways (RCPs), specifically RCP 8.5 represents a future scenario where radiative forcing reaches 8.5 Watts per Square meter and global warming exceeds 3.7^0c. Whereas RCP 2.6 represents an ideal scenario where radiative forcing reaches 2.6 Watts per Square meter and temperature increase stabilises at 1^0c. SDMs were generated in the open-source software MaxEnt, which using the principals of maximum entropy, takes data and predicts species occurrence by deriving the probability of species distribution [8]. To avoid potential limitations and produce a robust SDM, the data was resampled in MaxEnt, for each SDM the data was replicated 10 times with each replication using a subsample of the original datasets. The MaxEnt output could then be imposed on QGIS, where map creation occurred.

Fig 1: Area Under the Curve (AUC) of ROC plot (*fig 2).*

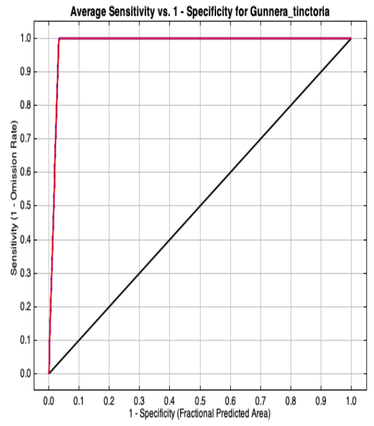


Fig 2: Potential distribution areas for Chilean rhubarb (*Gunnera tinctoria*) in Scotland's modern climate

*Blue gradient indicates predicted distribution areas with higher occurrence probability

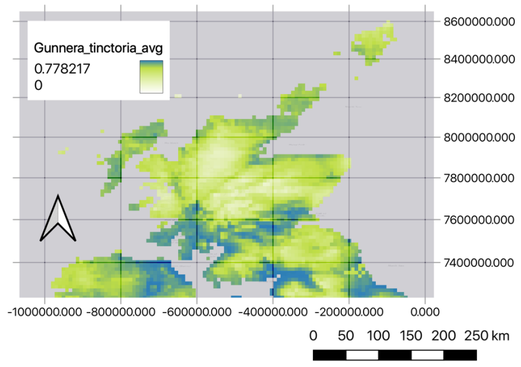


Fig 3: Area Under the Curve (AUC) of ROC plot (*fig 4).*

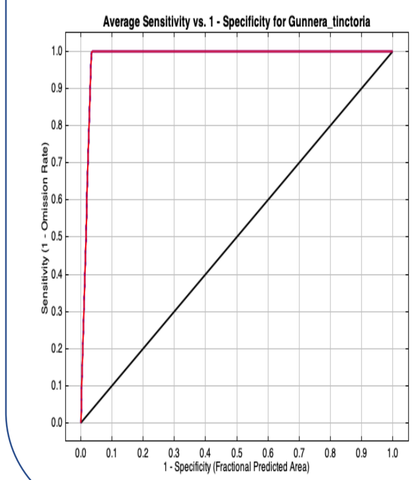


Fig 4: Potential distribution areas for Chilean rhubarb (*Gunnera tinctoria*) between 2041 and 2060 in Scotland under the RCP 2.6 scenario

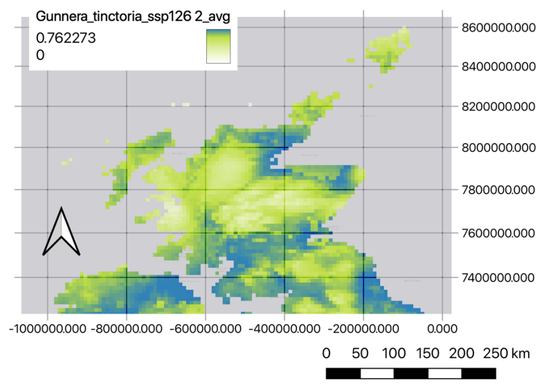


Fig 5: Area Under the Curve (AUC) of ROC plot (*fig 6).*

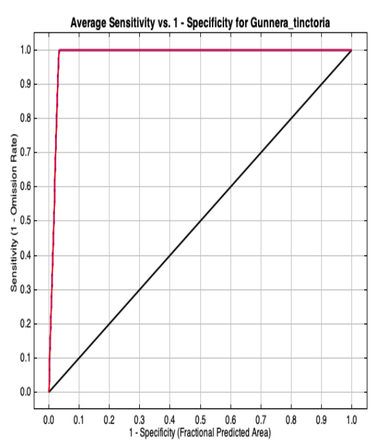
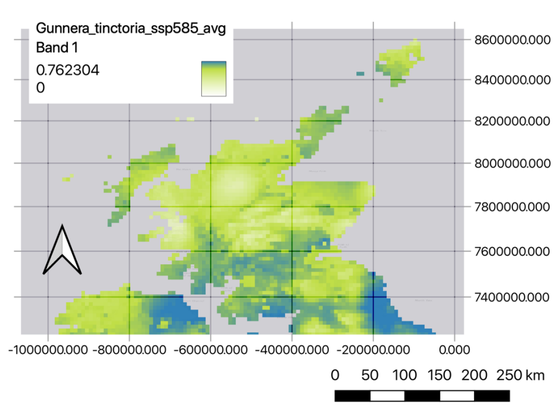


Fig 6: Potential distribution areas for Chilean rhubarb (*Gunnera tinctoria*) between 2041 and 2060 in Scotland under the RCP 8.5 scenario



Results

- Each ROC had an AUC value close to 1 (Figure 1 AUC = 0.984±0.000SD, Figure 3 AUC = 0.983±0.001SD, Figure 5 AUC = 0.984±0.000) suggesting that each SDM was strong and viable.
- The probability of Chilean Rhubarb occurrence in Mainland Scotland is low irrespective of climate change related influences.
- Chilean Rhubarb shows a fair probability of distribution towards the coast.
- Under the RCP 2.6 scenario, the increase in occurrence of Chilean Rhubarb appears to occur countrywide and is densely distributed in the North-East Coastline.
- The predicted occurrence of Chilean Rhubarb appears to be lower nationwide under the RCP 8.5 scenario in comparison to the distribution of the invasive species in relation to modern climate data.

Discussion and Conclusion

Overall, by deriving two SDMs for two different future climate scenarios, it can be predicted that anthropogenic climate change will impact the geographic distribution of Chilean rhubarb in Scotland. It is largely agreed that invasive species may respond to climate change through an alteration to their transport, constraints, distribution, impact, and their effective management [9]. As seen in figure 4, within a 2041-2060 timeframe, the greater potential distribution of Chilean rhubarb in Scotland may be facilitated. Therefore, it could be suggested that under the RCP 2.6 climate scenario, the success of Chilean rhubarb as an invasive species shall increase. Counterintuitively however, the distribution of invasive species appears to lessen compared to the modern climate under the worst climate scenario. Climate change may challenge the definition of invasive species, as some previously invasive species may diminish [9]. Scotland's climate predictions for 2100, predicts higher sea level rises under the RCP 8.5 scenario, especially in the Northeast coastline [10]. As a species prevalent in watercourses, the RCP 8.5 SDM may be predicting that Chilean rhubarb may be unable to persist under new climate conditions, like higher sea levels [11]. However, it should be noted that this observation may be a result of the Chilean rhubarb point data not sampling the climate scenarios representatively. In addition, the data used was worldwide so the resolution of climate data may be too low, and the training area may be too large. Moreover, despite performance of SDMs being maximised through resampling and demonstrating AUC scores, SDMs may fail to account for factors, like physiological and biological interactions and anthropogenic involvement. To conclude, to support decision making of countries about the future of their invasive species, SDMs can provide insight into their predicted distribution but the uncertainty of results should be communicated.

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