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Assessing area suitable for diversification crops: an example on soybean in Europe under climate change using machine learning

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1 Introduction

Crop diversification is often considered as a pillar of agroecology, based on an increasing amount of evidence showing that crop diversification can improve the productive and environmental performances of farming systems, as well as their resilience, in different ways (Beillouin et al. 2019). A key question to assessing the potential adoption of diversified cropping systems is to identify areas suitable for the cultivation of so-called diversification crops. This task is challenging because (i) diversification crops are usually minor crops with limited harvested area, making identification of their climatic niche difficult, and (ii) on-going climate change might shift suitable areas in the future. Legume crops are often regarded as interesting diversification crops because they provide many benefits, such as reduced nitrogen fertilization due to their ability to fix atmospheric N₂, and increased yield of the following crop in the rotation. Among grain legumes, soybean is the species experiencing the fastest expansion rate in Europe, with an increase of its harvested area by more than three-fold from 2004 (1.2 Mha) to 2014 (4.5 Mha) according to the FAO.

2 Materials and Methods

Here we present an estimation of areas suitable for soybean in Europe under current and future climate scenarios. Using machine learning techniques (Random Forests, Neural Network, Generalized Additive Models, Multiple linear regression), we develop and evaluate a series of niche models relating soybean yield to relevant agro-climatic indices, and then use the most accurate model (Random Forest, Root Mean Square Error of Prediction = 0.14 t ha⁻¹) to assess current and future soybean potential distribution in Europe according to different climate change scenarios (from high to low Global Circulation Models, and four RCPs). We use two recently published global datasets including historical soybean yields and crop-relevant weather variables, which cover the totality of the world's agricultural land on a 1.125° grid from 1981 to 2010 (Iizumi et al. 2014a,b). Models are trained at the global scale, and then applied in Europe to assess soybean potential distribution under historical climate (1961-2010, and in the 2050s and 2090s, considering contrasted climate change scenarios.

3 Results

Our results indicate that European soybean suitable area extends further out of its actual distribution (Figure 1A), and is likely to shift in the near future (in the next 30 years) under moderate warming (RCP 4.5), with gains in the north and losses in the south (Figure 1B). Projected soybean yields suggest that dramatic shifts are likely to occur by the end of the century under RCP 8.5 (Figure 1C), increasing the presence of soybean in the north while decreasing it in the south compared to 2050.

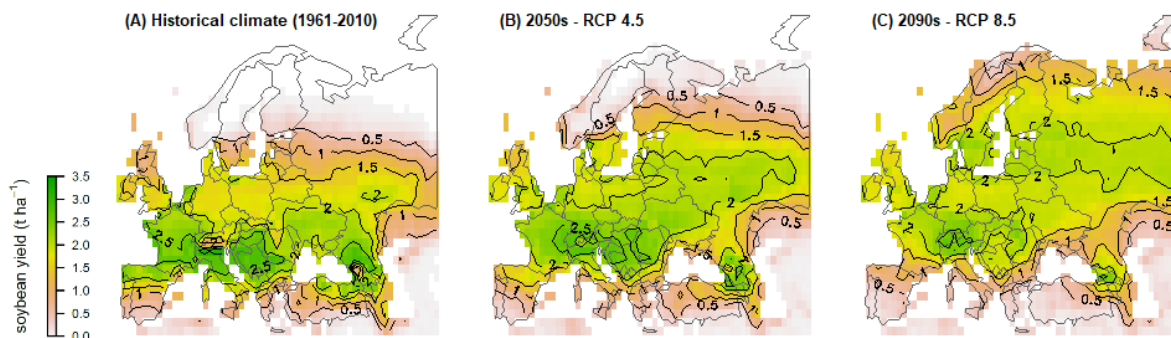


Figure 1. Projections of soybean yield in Europe under historical climate (A), by mid-century (2050-2059) under RCP 4.5 (B) and by the end of the century (2090-2099) under RCP 8.5 (C). Maps show median projected yield using the Random Forest model with the GRASP dataset (Iizumi et al. 2014b) for historical climate (1961-2010), and over the eight Global Circulation Models used in this study for future climate scenarios.

4 Discussion and Conclusions

These results show a strong potential for soybean expansion in Europe during the coming decades. Our study reveals that soybean could become a major lever for diversifying cereal-based cropping systems, especially in Northern Europe. The method developed in this paper could also be used to assess suitable areas for other diversification crops.

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