

EGU24-1367, updated on 23 Oct 2024

<https://doi.org/10.5194/egusphere-egu24-1367>

EGU General Assembly 2024

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## Perspectives for expanding sorghum production in Europe in the face of climate change

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Sorghum holds the fifth position worldwide in terms of both grain production and cultivation area. However, sorghum is still a minor crop in Europe where, on average, only 0.12% of the cropland area was used for sorghum production between 2017 and 2021. Nonetheless, its production is expanding in this region, with a 57% increase in total sorghum production during the last decade compared to the first decade of the 21<sup>st</sup> century. Indeed, sorghum is considered a crop of interest for climate change adaptation in Europe due to its high heat tolerance compared to other crops, especially maize. In this study, we aimed to investigate the feasibility of expanding sorghum cultivation in Europe under current and future (middle and end of the 21<sup>st</sup> century) climatic conditions. We also explored the possibility of replacing maize with locally-produced sorghum for feeding livestock in Europe.

To this end, we developed a machine-learning model that predicts sorghum yields from high-resolution climate data using a random forest algorithm. The model was trained on historical sorghum yield data collected in France, Italy, Spain, and the USA, covering the period from 2000 to 2020. The historical sorghum yield dataset comprises 11,644 data points at subnational administrative levels. The set of predictors included monthly climate variables such as solar radiation, minimum and maximum temperature, rainfall, and relative humidity calculated over the growing season (April–November) from the ERA5-Land dataset. The model's performance was evaluated based on cross-validation ( $R^2=0.83$ ,  $RMSE=0.94 \text{ t ha}^{-1}$ ) for the 2000 to 2020 period.

In total, we ran the model for 30 future scenarios using bias-corrected climate data produced by five Global Climate Models of the Coupled Model Intercomparison Project phase 6 (CMIP6), following three Representative Concentration Pathways scenarios (SSP1-RCP2.6, SSP3-RCP7.0, and SSP5-RCP8.5), and focusing on two periods (2041–2060 and 2081–2100). In almost all scenarios, sorghum yields decreased up to  $-1.5 \text{ t ha}^{-1}$  in the southern part of Europe (e.g., center of Spain, south of France, and Italy) but increased substantially up to  $+3 \text{ t ha}^{-1}$  in the northern part (e.g., north of Germany, Poland, and Lithuania) compared to historical yields. In all scenarios, at least 39% of European croplands were projected to support sorghum yields higher than  $4.6 \text{ t ha}^{-1}$  (the

average sorghum actual yield in Europe in the last decade). Our results showed that sorghum production could increase significantly in Europe under future climates. Regardless of the scenario, if sorghum was grown in one out of three years (respectively, one out of six years), at least 90% (respectively, 45%) of maize used as livestock feed could be replaced by sorghum in Europe. These results could provide valuable information for improving feed security in Europe in the face of climate change.