Predicting subsequent crop types in crop rotation using neural networks and multi-temporal crop rotation data in north-east of Germany

Marco Donat, Jonas Geistert, Mosab Halwani, Kathrin Grahmann & Sonoko D. Bellingrath-Kimura

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Abstract
The prediction of subsequent crops in crop rotation is becoming increasingly important. Upcoming growing season crop types of Brandenburg, Germany are predicted using a baseline model and a neural network. The results show that our neural network predicts both organic and conventional subsequent crop types in crop rotations better than the baseline model. In addition, it was shown that organic crop types were better predicted than conventional crop types.

Introduction
Crop rotations are an important component in arable farming and can regulate weeds and plant diseases, influence nutrient availability through pre-crop effects, soil biological activity and structure and thus soil fertility. If the crop rotation is not properly planned, yields and quality may be reduced due to weeds, plant pathogens, and pest insects. Especially in organic farming, crop rotations are of particular importance due to the absence of mineral fertilizers and chemical plant protection. The integration of grain legumes, the alternation of winter and summer crops, as well as leaf and cereal crops is essential. The prediction of subsequent crop types in crop rotation can be of particular importance for crop models, decision support systems, crop yield prediction, forecasting scenarios or crop survey. Especially the prediction of organic farming upcoming growing season crop types is of crucial importance, as organic farming is not considered in the previous prediction models. At the same time, the self-sufficiency rate of organic cereals is only 85% and the area of organic farming in Germany is expected to increase to 30% by 2030 (Rasche et al., 2022). With a prediction of subsequent crop types in crop rotations of organic arable farming, estimates and planning can thus be improved. The aim of this work is to predict organic and conventional subsequent crop types in crop rotation (preseason crop type prediction).

Method
Information on spatial temporal crop types and management (conventional and organic) of federal the states of Brandenburg was extracted from the field-level land-use data from the Integrated Administration and Control System (IACS) for the years 2016 to 2022. Since the IACS data are georeferenced polygons and field parcel change in size over time, the data were rasterized to a 5m grid (image with 25 m^2 per pixel) with each pixel containing the corresponding crop type code. We used only arable farming pixels and converted all individual crop types into a total of 14 crop type classes (maize, winter wheat, winter barley, oilseed rape, winter rye, sugar beet, winter triticale, spring cereals, potato, arable grass, legumes, vegetables, sunflower, other) (Jänicke et al., 2022).
Additional we used spatial information about the distribution of crop rotations as input. Land cultivation areas (subdivided into 5 major soil classes) and the local neighborhood were used as spatial information. To create the neural network (multilayer perceptrons using *TensorFlow*) we split the dataset. A total of 770'000 ha (69’000 ha organic) was

used as training and a total of 35’000 ha (3’000 ha organic) was used as validation. Among the 7 years of input data, we used a maximum of 4 consecutive years for our analyses. To validate our neural network, we determined the frequency for all possible combinations (14 crop types and 5 soil classes) and calculated probabilities (baseline model).

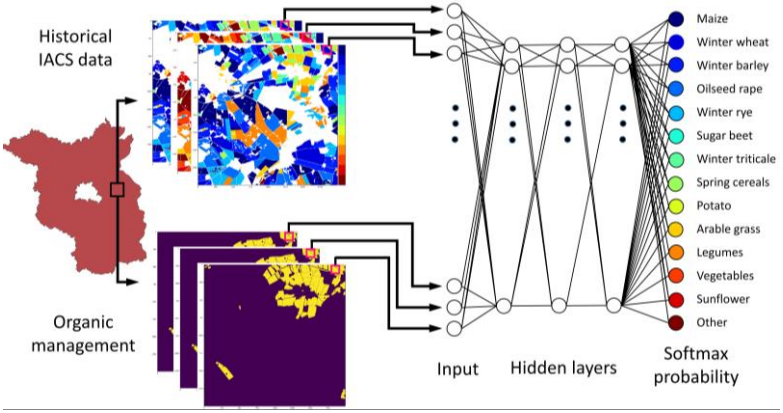

Figure 1: Visualization of our input data, hidden layers and softmax probability of the neural network with a total of 14 crop type classes.

Results and discussion

The results of our models are spatial maps of upcoming growing season crop types and their probability. The baseline model and the neural network showed high accuracy. The baseline model was able to predict organic upcoming growing season crop types with 48% accuracy and conventional pre-season crop types with 43% accuracy. Our neural network was able to predict crop types with higher accuracy than the baseline model (52% accuracy for organic crop types and 50% accuracy for conventional crop types). We further showed that we were able to predict the organic crop type better than the conventional ones. Organic crop rotations are more diverse but follow organic principles and regulations and therefore the sequential crop rotation elements are more predictable than conventional crop rotations. Our analyses showed that it is important to take into account the spatial context (soil fertility index and local neighborhood), as this resulted in higher accuracy. This can be explained by the fact that, due to agronomic decisions, some crop types are not cultivated until certain soil qualities (soil fertility index) are reached and that spatially similar crop types tend to be used.

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