Studying heterogeneity in agriculture mechanization level using machine learning and remote sensing

Language: German or English

Contact: Hugo Storm, hugo.storm@ilr.uni-bonn.de

Background:

Novel agricultural technologies (e.g. precision farming or (autonomous) robots) promise to enhance agricultural productivity and to limit environmental impacts (Finger et al. 2019). At the same time our knowledge about current technology use and mechanization levels of farms remains limited (Lowenberg-DeBoer and Erickson 2019). This is problematic because we can expect that uptake of novel technologies will depend on the current technologies available on a farm, for example by influencing the costs of adopting novel technologies (e.g. adoption variable rate application technology is easier/cheaper if I already have a novel machinery fitted with GPS). These dependencies are likely to lead to path dependencies for past and future investment decisions. Further, we can hypothesize that investment decisions and hence current mechanization levels are driven by local dynamics for example competition of local land market, peer pressure/imitation, as well as local knowledge exchange (Dedehayir et al. 2017). Those path dependencies and local dynamics could potentially lead to regional heterogeneity in current mechanization level. In turn, if we empirically detecting that current mechanization levels are heterogenous we could use this as indirect support for the existing of those effects. Detecting spatial heterogeneity in current mechanization level could also be an important information for assessing and predicting potential future (spatial) patters of novel technologies uptake.

Obviously, heterogeneity in current mechanization level could also be driven by other factors for example regional characteristics of the farm population (farm size, specializations, farmers age, etc.) as well as field/landscape characteristics (field size, shape, etc.) and biophysical conditions (climate, slope, soil, elevation, etc.). By controlling for these factors, we can derive the “residual heterogeneity” in mechanization levels i.e. variation in mechanization level that is not explained by these factors.

Studying current mechanization levels requires the availability of spatially explicit data on mechanization levels which is typically hardly available. Therefore, this work should aim to approximate mechanization level at field level by detecting the distance between wheel tracks in cereal fields (see example images). The distance between wheel tracks should provide an approximation of the machinery size used on this field. Distances in wheel track can be measure using remote sensing images (orthophotos). Those images are available for NRW for several years.

Objective: The objective of the thesis is to explore to what extent there is variation in residual heterogeneity of agricultural mechanization levels across regions. In case there is regional variation, regions that are under- /over-mechanized can be identified. Finding such heterogeneity would indicate that local dynamics and path dependencies matter for mechanization levels.

Approach:

- The starting point of the thesis is existing work that provides methods to derive the wheel track distances on field level for all fields in NRW using available orthophotos (see images as an illustration). Using these methods first datasets are already available for NRW (see preliminary results). To use this dataset for this thesis, some refinements of the existing algorithm might be necessary. Also, some validation of the derived data needs to be conducted.
- The main task of the thesis is then to use this dataset to build and train an econometric/machine learning model to predict wheel track distances on field level

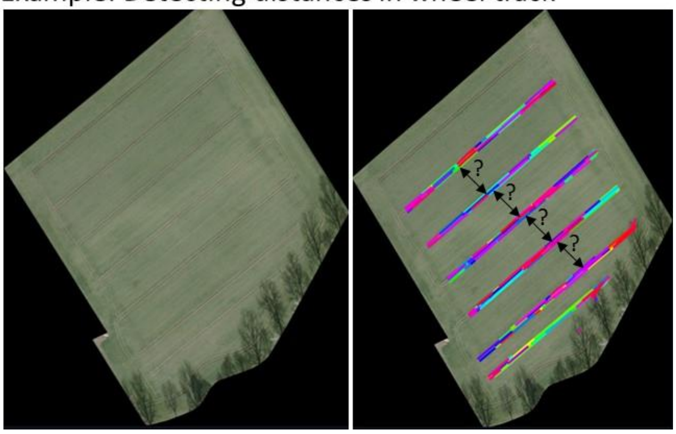
using field characteristics (size, shape, etc.) biophysical characteristics (climate, slope, soil, etc.) as well as characteristics of the regional farm population (farm size, number, age structure, specialization, etc.). In order to use these characteristics, it is also required to collect those data from publicly available datasets.

- The trained model is then used to predict wheel track distances for all fields. Comparing predicted wheel track distances to observed wheel track distances allows to study if there are local clusters in the residuals. Existence of clusters in the residual would indicate local under-/over-mechanization.

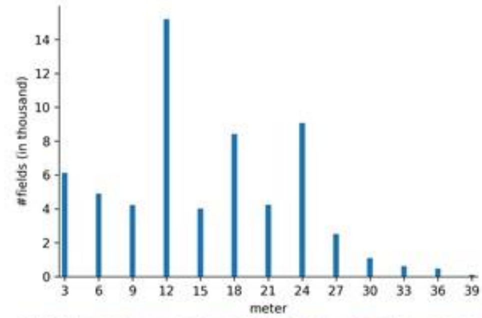
Expected Skills/interests

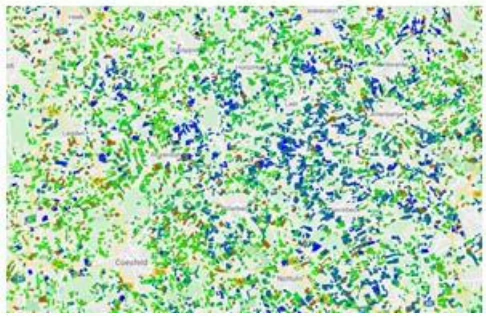
- Basic programming skills (or willingness to learn) ideally in python to understand/fine tune the existing algorithms to derive the wheel tracks from the orthophotos
- Experience in Econometric tools as well as knowledge (or willingness to learn) applying basic machine learning tools (either in python (e.g. scikit-learn) or R)
- Basic experience in data handling/processing, ideally including geospatial data, in python/R
- Basic experience in (or willingness to learn) GIS tools (e.g. QGIS) and working with geospatial data

Example: Detecting distances in wheel track



Preliminary results: Wheel track distance in NRW cereal field 2017-2020 (N=60998)





References:

Dedehayir, Ozgur, Roland J. Ortt, Carla Riverola, and Francesc Miralles. 2017. "INNOVATORS AND EARLY ADOPTERS IN THE DIFFUSION OF INNOVATIONS: A LITERATURE REVIEW." *International Journal of Innovation Management* 21 (08): 1740010.

Finger, Robert, Scott M. Swinton, Nadja El Benni, and Achim Walter. 2019. "Precision Farming at the Nexus of Agricultural Production and the Environment," October. https://doi.org/10.1146/annurev-resource-100518-093929.

Lowenberg-DeBoer, James, and Bruce Erickson. 2019. "Setting the Record Straight on Precision Agriculture Adoption." *Agronomy Journal* 111 (4): 1552–69.