Evaluation of Soil Data Interpolation Methods

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Abstract: Applying geostatistical interpolation methods that predict soil properties of the surrounding area may present an efficient solution to create interpolation maps for site-specific field management. These statistical methods produce different distributions of interpolated data. According to the data type, different methods are appropriate. In this study, we compared Kriging and Inverse Distance Weighting to determine the potential application within management zones. Therefore, we interpolated soil mineral nitrogen content (N_{min}) data. We evaluated the accuracy of real vs. predicted data by bootstrapping and considering the standard error. Both interpolation methods were able to predict the Nmin content with a root mean square error of below 0.025.

Keywords: Interpolation, site-specific fertilisation, management zones, Nmin

1 Introduction

Overfertilization of soils presents a main cause for nitrogen (N) leaching into the environment and has been sharply criticized by society. Farmers, however, depend on high yields, and therefore, apply standard amounts of fertiliser to their fields; for winter wheat in Switzerland usually in three split applications. Uprising technologies now allow to apply fertiliser site-specifically. Kindred et al. [Ki15] reported a large spatial variation of soil N supply (120, 75 and 60 kg/ha), resulting in a spatial variation of fertilizer recovery between 30 and 100% in wheat fields and thus demonstrating the large potential. Hereby it is essential to apply the fertilizer according to the nutritive state of the plants and the amount of N already stored in the soil. This allows increasing N use efficiency and decreasing N leaching. The nutritive state of the plant can be derived from satellite and drone imagery. However, due to its nature of depending on the plants reflectance, the spectral information is rather useful for the second and third fertilizer application where canopy cover is less impacted by soil background.

The status of Nmin concentration in the soil can only be derived from soil samples. Hereby, soil samples are taken at the beginning of the vegetation period, but as these samples are expensive, it is of interest to interpolate the data from the soil samples into a map, so that higher spatial information can be achieved from fewer samples [Na17]. “Interpolation is the process of predicting the value of attributes at unsampled sites from measurements made at point locations in the same area or region” [BM98]. Nawar [Na17]

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describes that the classification of a field into specific areas that are similar would allow decreasing or correcting for soil variability and can be defined as management zones. An interpolation map would allow the farmer to create a fertilization map to support the first split fertilisation. However, the process of creating management zones requires expert skills. To make this process easier and applicable to farmers, Albornoz et al. [Al17] have developed a software that automatically defines management zones and creates ESRI-Shapefiles that are needed to create application maps. Such interpolation maps can be generated with a variety of different interpolation methods such as inverse distance weighting (IDW), kmeans clustering or most commonly kriging (KRIG). Only few studies have evaluated the quality of these interpolated maps. In the current study, we aimed to compare the ability of IDW and KRIG to predict the spatial variation of Nmin values in fields of about 2 ha.

2 Material and Methods

The experimental procedures were carried out at the Swiss Future Farm in Tänikon Ettenhausen, Switzerland (47.4790021°N, 8.9059287°E) 500 meters above sealevel. 1170 mm annual rainfall and an average annual temperature of 8.6°C (1970-2018) characterize the climate. The experimental fields were part of a trial comparing the effect of variable rate nitrogen application to standard application in winter wheat [Ar19].

2.1 Experimental Procedures

Soil samples for the comparison of real vs. predicted data were derived from one field where 18 soil samples were taken at depths of 0-30 cm, 30-60 cm and 60-90 cm (Field 2018). Soil samples for the interpolation maps were taken in 6 different locations across the field on 3 fields (Table 1) (Fig.1). From each of these soil samples, 3 subsamples were analysed from soil depths of 0-30 cm, 30-60 cm and 60-90 cm. In the current study, we focused on the data from the 0-30 cm soil sample because it is more representative of the initial Nmin pool available for the small plants in early spring.

Field Properties	**Field 2018**	**Field 1**	**Field 2**	**Field 3**
Area (ha)	2.2	1.9	1.6	2.5
Soil Type	**Gleysol**	**Luvisol and Alisol**	**Gleysol and Alisol**	**Cambisol**

Tab. 1: Description of field properties

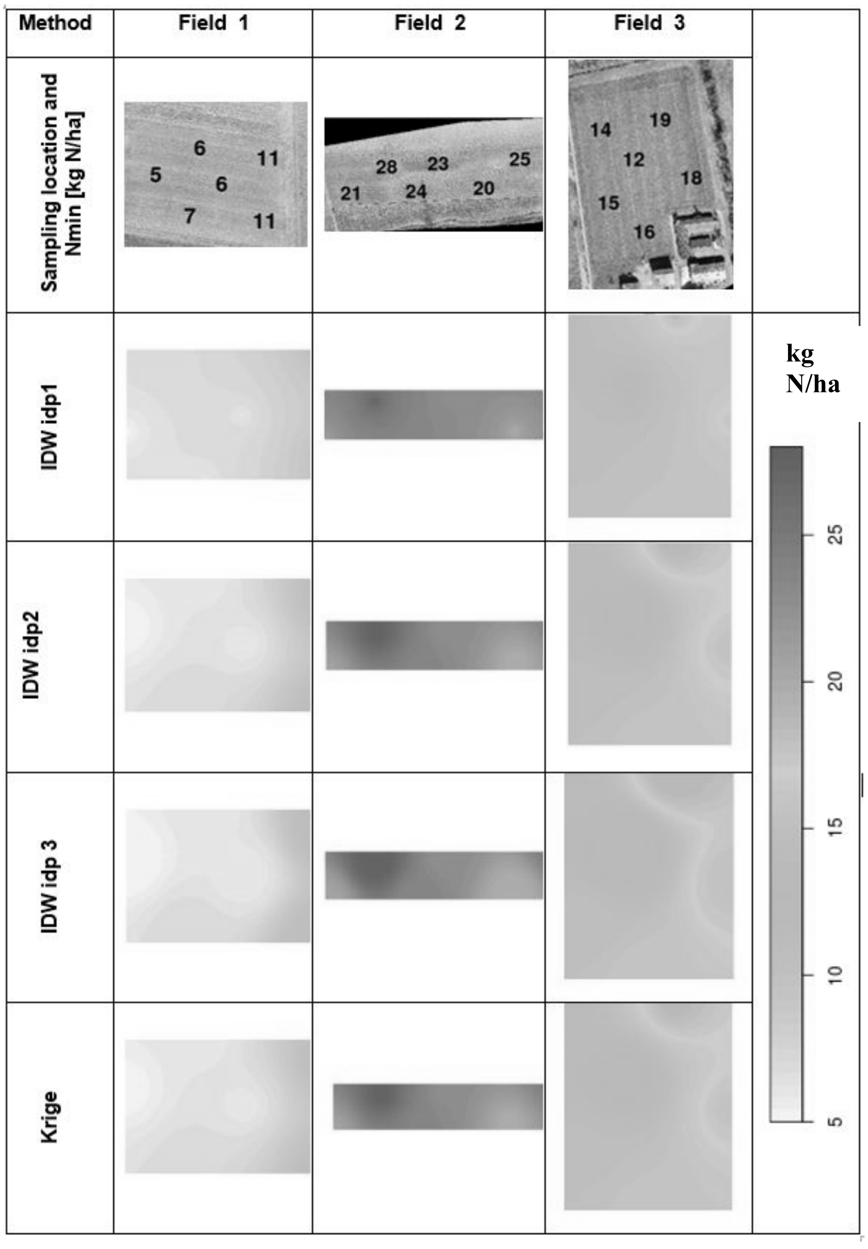

Fig. 1: Location and levels of Nmin samples along with interpolated Nmin data. Interpolation methods used were Krige and the Inverse Distance Weighting (inverse distance weighting power (idp 1, 2 and 3). Data from three test fields at 0-30 depth.

2.2 Data Processing and Analysis

The data were initially pasted into an excel sheet and further processed in R version 3.6.1. The Packages “sp” (for managing spatial data), “rgdal” (for reading shapefiles), “gstat” (for interpolation functions and statistical analysis of geospatial data) and “raster” (for handling raster format (plotting, distance between points)) were used to perform the analysis. For the comparison of real vs. predicted data, we performed a 1000 fold bootstrap, always removing one point from the sample, which was then predicted, to find the interpolation method that generated the smallest root mean standard error of real vs. predicted data.

3 Results

The within-field variation was much smaller than the between-field variation (Figure 1). Interpolated maps created with IDW inverse distance weighting power (IDP) 1 predicted the highest levels of soil Nmin. The availability of N_{min} in all fields was generally low, ranging from 5-28 kg N/ha. Field 1 had the lowest values, whereas Field 2 and F3 showed higher N availability. The confidence interval of Field 1 is presented in Figure 2. The Confidence Interval (CI) in this field varied between 0.05 and 0.3. The CI indicate that the method performs less accurately, where we find bigger differences between Nmin soil samples.

The root mean standard error (RMSE) of true vs. predicted interpolation results hardly differed between IDW and KRIG (Figure 3, KRIG will be presented at the conference). The RMSE always remained below 0.025 in both methods.

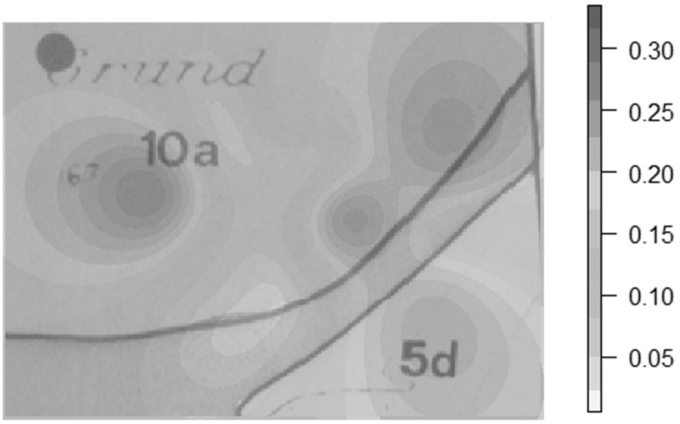

Fig. 2: Interval of Confidence map for Field 1 with Krige interpolation

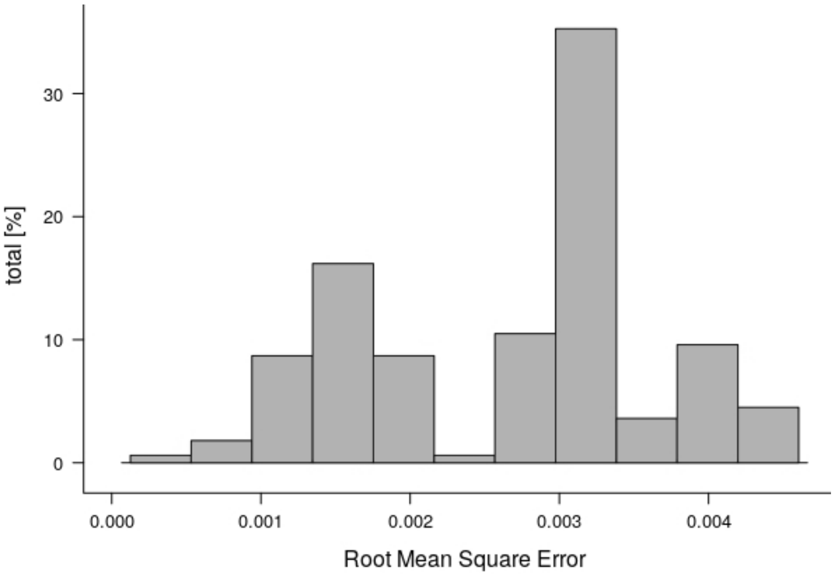

Fig. 3: Root mean standard error for predicted vs. true data. Result shows are Inverse Distance Weighting with inverse distance weighting power 2.

4 Discussion

The results indicate that both methods IDW and KRIG are suitable to create interpolated maps for the definition of management zones. Despite inverse distance weighting giving the option to put more weight on neighbouring values, both methods were more precise than the current fertiliser application technology allows applying. This is in line with Borges [Bo16] who compared a variety of interpolation methods and found IDW and KRIG to perform well. Borges [Bo16] evaluated the suitability of a variety of different interpolation methods and found that IDW, KRIG as well as multivariate regression with interpolation of residuals by IDW and KRIG have performed best in estimating the distribution of precipitation (Correlation coefficient between measured and predicted values 0.95, 0.94, 0.94 and 0.95, respectively). However, Borges [Bo16] stress that these methods all have a deterministic component and therefore advise to consider standard error maps when applying geostatistical interpolation methods. In our study, the RSME between true and predicted data were below 0.025 for both methods. The CI maps indicated a range of variation within the soil maps, giving some insight into the accuracy of the interpolated maps. However, in a bigger picture, this study gives much more practical implications on the definition of management zones for small fields. The variation within fields was minor with a maximum Nmin variation of 8kgN/ha in Field 2, whereas the maximum Nmin variation between fields was 25kg/ha. This indicates that, even for small fields of about 2 ha with little variation, it would already be beneficial to know the Nmin status of every field by the mean of a reduced number of soil samples. This would allow adjusting the first split fertilizer application field specifically, based on the available N supply and would be possible without implementing additional machinery and as such investment. However, questions open regarding the definition of thresholds for the different management zones or how to set the minimum number of samples per area to achieve accurate representation of the N variability remain.

5 Conclusion

Both interpolation methods used in this study performed well in predicting Nmin values and creating interpolated maps. Thus, in this study, both methods, Krige and Inverse Distance Weighting, could be used to create interpolated maps as a base for supporting site-specific N fertiliser application in winter wheat. However, the variation within the small fields was minor and it may be sufficient to consider the individual fields Nmin status.

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