FATIMA Czech pilot

Karel Charvát*[1], Petr Fučík[2], Renata Duffková[2], Vojtěch Lukas[3], Karel Charvát Jr[4], Jiří Kvapil[5], Michal Kepka[6]

1 Baltic Open Solution Centre
2 Research Institute for Soil and Water Conservation
3 Mendel University
4 Lesprojekt služby
5 Mecenas
6 University of West Bohemia

Abstract

In FATIMA project, a pilot site in Czechia was established to demonstrate how precision agriculture may serve for optimizing crop yields as well as for protection of water quality, since the pilot is located in Czech largest drinking water reservoir catchment. The pilot site Dehtáře is situated in the south-west Bohemo-Moravian Highland. The site contains tile drainage and is of very heterogeneous soil conditions; from shallow, light and stony Haplic Cambisols to heavy Haplic Gleysols, with profoundly different water regimes. For the field trial (spring barley in 2016), crop yield potential was determined from crop statuses as captured by satellite images) eight years back, assessed by Enhanced Vegetation Index. Based on this, as well as on a detailed soil survey and repeated soil sampling, variable fertilizer application zones (70 – 120%) were delineated and mineral fertilizers distributed accordingly with GPS operated spreader three times from late April to late May. The rest of the site was fertilized uniformly. Soil water regime (soil moisture, soil water potential) was monitored continuously on eight spots and real-time broadcasted by wireless sensor network to WEB GIS interface via SensLog solution, adopted from FOODIE project. In the same spots, soil water was sampled by gravitational soil lysimeters. Precise harvest showed a general agreement with the delineated application zones and yield potential, however, some ambiguities were revealed, most probably due to changeable soil water regime, as documented by the sensors, as well as due to variable soil chemical properties (low soil pH). Nevertheless, precisely applied fertilizer doses in the application zones brought about 10% higher crop yields with simultaneous better N crop efficiency. Soil water quality samples confirmed that heterogeneous doses of fertilizer in correctly delineated zones is a promising approach for improvement of groundwater quality especially in shallow soils with low water and nutrient retention ability.

Keywords: variable fertilizer zones, soil heterogeneity, crop yields

Background

Crop yield is the main integrator of landscape and climatic variability and therefore provide useful information for identifying field management zones (Kleinjan et al., 2007). Management zones are in the context of precision agriculture areas possessing homogenous attributes in landscape and soil condition. These areas should lead to the same results in crop yield potential, input use efficiency and environmental impact (Schepers et al., 2004). This presents a basic delineation of management zones for site specific crop management, which is usually based on yield maps over the past few years. Similar to the evaluation of yield variation from multiple yield data described by Blackmore et al. (2003), the aim is to identify high yielding (above the mean) and low yielding areas related as the percentage to the mean value of the field. Also the inter-year spatial variance of yield data is important for agronomists to distinguish between areas with stable or unstable yields. The presence of complete series of yield maps for all fields is rare, thus remote sensed data are analyzed to determine in field variability of crops thru vegetation indices, which is well known relationship Bauer (1975). The aim of this paper is to introduce results how crop harvest reflected variable fertilizer management in different application zones and crop yield areas and how it may affect soil water quality in different management zones.

Materials and Methods

The pilot site Dehtáře (25 ha) is situated in the south-west Bohemo-Moravian Highland, in 3° slope and average altitude of 535 m a.s.l. The site is located in drinking water reservoir catchment Zelivka. The site contains tile drainage and is of very heterogeneous soil conditions; from shallow, light and stony Haplic Cambisols to heavy Haplic Gleysols, with profoundly different water regimes. Haplic Cambisols prevailing in upper parts of the field are light, shallow and stony sandy loams and loamy sands. Stagnic Cambisols medium-deep sandy loams dominate in the lower parts of the slopes.

Figure 1. Location of Dehtáře pilot site, Czechia

Soil samples were taken from 22 sites as a mixture of 3-4 individual subsamples were collected repeatedly (autumn 2015, spring 2016) from two upper horizons (A, B) to determine pH (0.2-mol KCl solution), the organic C content (by chromic acid oxidation followed by iodometric titration), the total N content (the Kjeldahl method), the mineral N content (N-NH4+N-NO3 extracted by 1 % KCl) and available P, K, Ca and Mg concentration (Mehlich III), cation exchange capacity and the total P content (extracted by aqua regia).

Further, crop yield potential was assessed based on the multi-temporal satellite data. As the main data source, ESPA repository of LANDSAT 5 and 8 satellite images was used, which offers surface reflectance products, main vegetation indices (NDVI, EVI – reflecting crop biomass) and clouds identification by CFmask algorithm. A selection of scenes from recent 8 years was made for the specific farm area to collect cloud-free data related to the second half of the vegetation period. Yield potential was calculated for separate scenes as the relation of each pixel to mean EVI value of the whole field. In the next step, all scenes were combined and median value for each pixel was calculated as the yield potential value. Due to the spatial resolution of Landsat data (30 m per pixel), the final map was smoothed by kriging interpolation into a spatial resolution of 5 m per pixel (Fig. 2). After the full operation of Sentinel 2A/B satellites and with the presence of imagery for an increased number of years, calculation of yield potential will be enhanced by these vegetation products in 10-m spatial resolution planned for 2017 FATIMA trial).

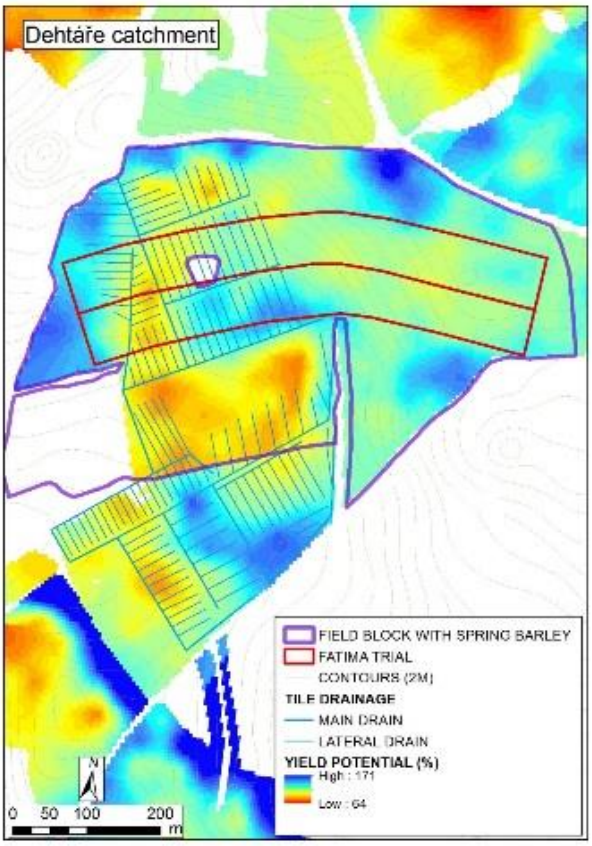

Figure 2. Yield potential for Dehtáře pilot site (Kojcice farm), Czech Rep.

Based on this as well as on a detailed soil survey and repeated soil sampling (mineral N content), variable fertilizer application zones (70 – 120%) were delineated (VAR trial, around 35% of the site) and mineral fertilizers distributed accordingly with GPS operated spreader three times from early April to late May. The rest of the site (65%) was fertilized uniformly (UNI trial), (Fig. 3).

Ground measurements of Chlorophyll and NDVI in Dehtare

Ground monitoring of spectral dynamics of cereals provide useful supplementary information on crop biomass amount as well as chlorophyll content. This data could be employed for adjustment of N fertilizer doses taking into account the current plant nutritive status. Ground monitoring of spectral characteristics for spring barley was done in Dehtáře during 2016 by two offline hand devices; Yara N-tester and GreenSeeker. N-tester scans crop chlorophyll content (in correlation with N content in leaves) based on different reflectance of red (653 nm) and infrared (931 nm) radiation. Chlorophyll content is recalculated by N-tester for a given crop variety (cultivar) and displayed as N need in kg N/ha. The N-tester is usually employed for setting N doses for cereals in production fertilization (BBCH 30-31, start of stem elongation) and qualitative (late) fertilization (BBCH 39-49, end of stem elongation to start of heading), as for central European conditions. GreenSeeker monitors and records NDVI as canopy-reflected radiation in RED and near-infrared spectrum (NIR). NDVI is in a close correlation with crop biomass and chlorophyll. Fertilizer N dose is given by a reference value (from the densest crop cover) and expected yield.

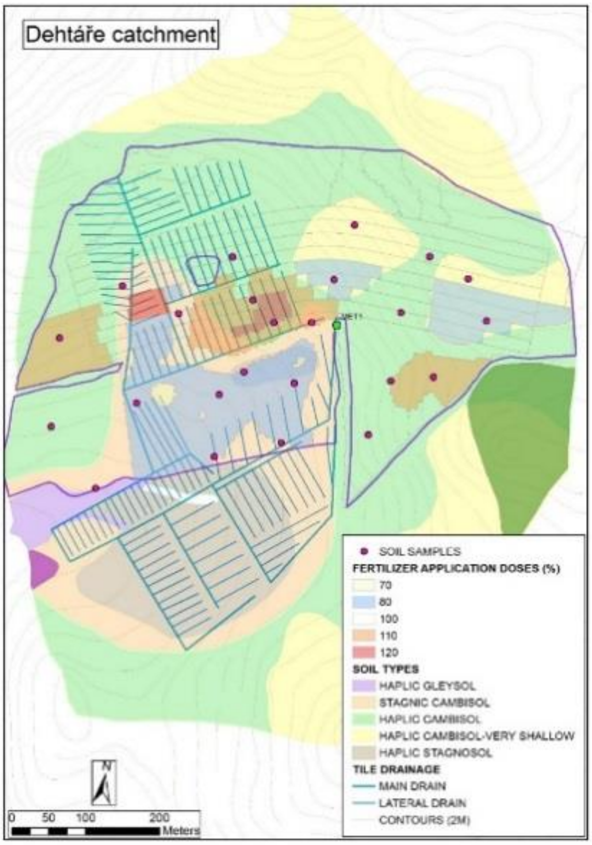

Figure 3. Variable fertilizer application zones for Dehtáře pilot site

Monitoring of crop spectral characteristics by the aforementioned hand devices took place in Dehtáře between 24.5.-7.7.2016, in a fortnight interval, on 22 sites within the pilot field trial polygon (Fig. 4). The N-tester was used only till 21.6. (BBCH 55-59, Heading), the GreenSeeker was applied till 7.7.2016. Results of N-tester from 24.5.2016 were incorporated in adjustment of late N fertilization and applied on the same day. Recommended values for N doses from N-tester were averaged and this value (28 kg N/ha) was applied in the reference application zones (100% yield potential). In the other application zones, the applied N dose was set according the appropriate zone (e.g. 80% = 0.8 x 28 kg N/ha, etc.).

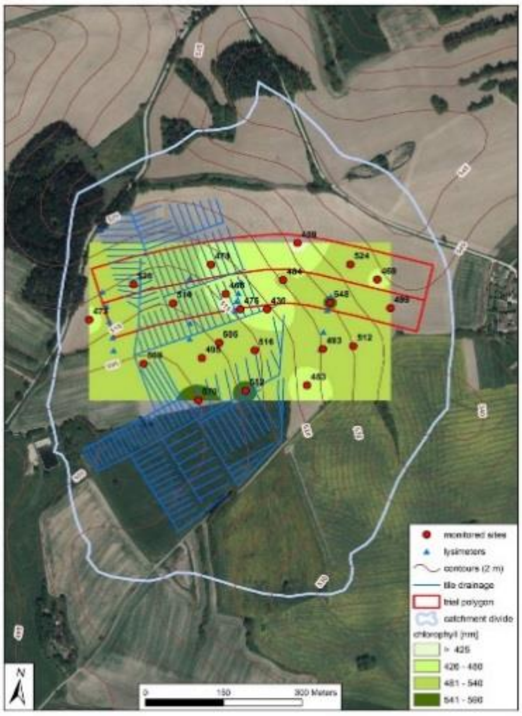

Figure 4. Chlorophyll content captured by Yara N-tester, 24.5.2016, Dehtáře pilot site

Results and discussion

Precise harvest (dated 15.8.2016) showed a general agreement with the delineated application zones and yield potential. However, some ambiguities were revealed, most probably due to changeable soil water regime as well as due to variable soil chemical properties (low soil pH) (Fig. 5). Nevertheless, precisely applied fertilizer doses in the application zones of the trial polygon brought about higher crop yields compared to homogeneous doses with simultaneous better N crop efficiency (kg grain / kg N – 56 for UNI, 60 for VAR).

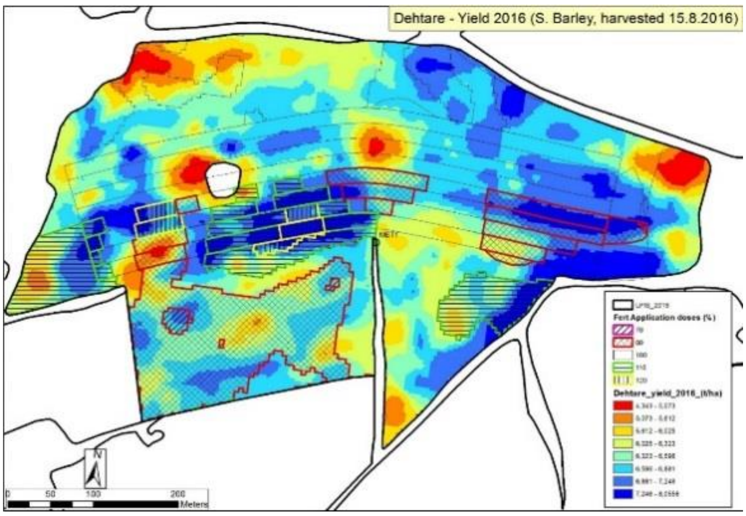

Figure 5. Precise harvest on Dehtáře pilot site

Heterogeneous fertilizer application increased spring barley yields by 8 % compared to homogeneous application (6.7 t grain/ha vs. 6.5 t/ha, respectively) in parallel with lower fertilization consumption per hectare (113 vs. 118 kg N/ha, respectively). This resulted in higher nitrogen efficiency of crop production (59 kg grain/kg N applied vs. 55 kg grain/kg N applied under homogeneous fertilizer application). The total soil nitrogen balance was negative due to taking up soil mineralized nitrogen coming from cow manure applied in autumn 2014.

The crop yield in 80 % application zone of the whole field, which was located especially in the lower part of the field, was higher than in the part applied with the homogeneous nitrogen dose (100 % application zone). This could be explained by nitrogen utilization which had been leached away from upper field parts.

A comparison of ground monitoring data (N-tester, Greenseeker) with Sentinel-2 images was done from the days when ground measurements took place and with the yield from precise harvest. So far, using cloudless images and without atmospheric corrections, we got the only one date with a satisfactory correlation of yield with GreenSeeker data from 21.6.2016 (r = 0.594), (Fig. 6). A better output is expected as the indexes from red-edge images are ready.

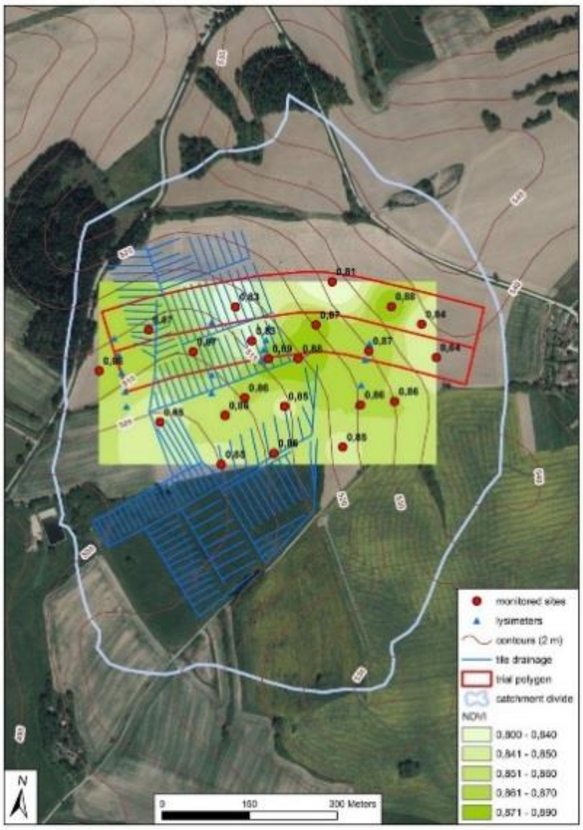

Figure 6. NDVI as captured by GreenSeeker, 21.6.2016, Dehtare.

Conclusion

The second year of a detailed, site specific application of fertilizers showed a general agreement with the delineated application zones and yield potential. Soil water quality samples confirmed that heterogeneous doses of fertilizer in correctly delineated zones is a promising approach for improvement of groundwater quality especially in shallow soils with low water and nutrient retention ability. Further research is needed to broaden the knowledge which combines and harmonizes different farming and environmental goals and expectations in an agricultural landscape.

Acknowledgments

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