First Results Of Development Of A Smart Farm In The Netherlands

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Abstract

Global Positioning systems (GPS, GNSS) have been introduced on about 20 % of the Dutch arable farms in The Netherlands today. Use of sensor technology is also slowly but gradually being adopted by farmers, yielding making available large amounts of spatial data on soil, crop and climate conditions. Typical spatial data are soil organic matter, crop biomass, crop yield, and presence of pests and diseases. We still have to make major steps to use all this data in a way that agriculture becomes more sustainable.

In 2012 we took up the objective to transform a Dutch farm of ca. 180 ha into a Smart Farm. The farm combines arable (winter wheat, potatoes, sugar beet and onion crops) and dairy farming (cows plus grassland and maize crops). Smart Farm means that spatial information on cow condition, feeding, soil, crop, pests, diseases, and yield data are available and used in strategic and operational decisions.

Scanning more than 70 ha obtained soil maps on variation in soil organic matter and clay in 2013. Variation in biomass of crops was determined with satellite, airplane, Unmanned Aerial Systems (UAS) and tractor mounted sensors. Yield monitoring was done in the cereal crops and on grassland. We studied correlations between soil, crop and yield maps. In 2013, we also started with experiments on variable planting density of potato, variable rate application (VRA) of soil herbicides, VRA of N-fertilizers and VRA of potato haulm killing herbicides.

First results of the data collection and analysis are presented. The outlook of smart farming is discussed.

Introduction

Precision farming (PF) (Skotnikov & Robert, 1996; Kempenaar & Kocks, 2013) is an innovation in agriculture allowing the right treatment of crops and livestock at the right time and smallest scale possible (up to treatment of individual plants or animals). It requires a seamless integration of different technologies (sensors, GNSS, data-infrastructures (ICT), Farm Management Systems (FMS), implements) and intelligence (data, DSS, implement control software, auto-guidance systems). Optimisation of treatments at the lowest scale possible will improve yields and resource efficiency in agri-food chains, so reducing the agricultural footprint. More and more, PF will become the 'licence to produce' for modern farmers. Key technologies required for PF have become available for farmers, e.g. Farm Management Information Systems (FMS) and Global Navigation Satellite Systems (GNSS), providing a basis for implementation of PF.

However, the step to giving plants and animals the right treatment at the smallest scale possible, is still a difficult one. This is e.g. because it is still not easy to acquire useful and reliable spatial data on soil or crop properties at the right scale and right time. In addition, farmers face problems with the data handling and analysis. The required data-infrastructure is not yet mature. Communication between sensors, farm computers and machines is hampered by poor standardisation. And finally, farmers lack validated decision support rules for different variable rate application and various farm management activities.

In 2012, we took up the challenge to transform a 180-ha farm into a Smart Farm. Smart Farm means that spatial information on cow condition, feeding, soil, crop, pests, diseases, and yield data are available and used in strategic and operational decisions. Economics and social aspects are weighed. The internet platform that was used to store and visualise the spatial data and to make task maps, is Akkerweb. First results of the data collection and analysis are presented. The outlook of smart farming is discussed. In the manuscript, we limit ourselves to the arable part of precision farming on the Smart Farm.

Materials & Methods

The 180-ha farm 'De Drieslag' we worked with is located in the province of Flevoland in The Netherlands. The farm had available various production statistics and crop management data, but had not yet started with collecting data on spatial variation within crops. Because of this lack of spatial data, we started collection within field data on soil and crop conditions and properties. Details on the fields of the farm are given in the Results section together with experimental results.

Various data sets were collected in 2013 for different fields and crops on the farm. Soil scans were made with gamma radiation sensor technology of Dacom and Altic companies. For details of this sensor technology, see www.nplg.nl/uploads/documenten/presentaties/Altic_Dacom_-_bodemscan.pdf.

Biomass scans were made with remote and proximal sensors (Greenseekers and Yara N-Sensor). Reflection data were used to calculate e.g. NDVI at resolutions of 2 by 2 to 25 by 25 m. Details on biomass sensing and NDVI calculations are given in the paper on potato haulm killing by Kempenaar *et al.* in the proceedings of ICPA2013. For details on the remote sensing, see www.spaceoffice.nl/nl/Satellietdataportaal.

We focussed the desk study on finding relationships between soil, biomass and final yield data on winter wheat. The yield map was obtained from a Claas 9-m wide harvester equipped with a yield monitoring device. Spatial data were analysed with the Q-Gis program. In addition, Microsoft Excel was used to do regression analysis on specific parameters. The Dutch Akkerweb, open source software platform, was used to store data (tst.akkerweb.nl). Akkerweb is designed for precision farming data handling on arable and grassland farms, including the making of VRA task maps.

Results & Discussion

Farm 'De Drieslag' combines arable farming and grassland production on 180 ha of clay soil divided over around 40 fields with milk production. The dairy part produces 700,000 kg of milk per year (80-90 cows). The farm land is located in two of the youngest polders of The Netherlands. In Figure 1, we show these fields, which boundaries are known at Field sizes and boundaries are known to the national authority (*Dienst Regeleningen* of Dutch government), and downloadable via GeoBoer webservice into Akkerweb portal.

Figure 1. Overview of fields of the farm 'De Drieslag' in two polders of The Netherlands (Oostelijk Flevoland on the left, and Noordoostpolder on the right).

Spatial data on soil and crop properties were collected on various parts of the farm. We focussed on a 42-ha unit of five fields, named Roodbeenweg (Figure 2, also in Figure 1 on left side picture). On these fields, four crops are grown in a 4-year rotation: winter wheat, potato, sugar beet and onion. Other crops studied are grassland and maize.

The 42-ha was scanned e.g. with a gamma radiation sensor of Altic company in winter 2012-2013. This company also took soil samples for calibration purpose of making interpolated lutum and soil organic matter maps. The total gamma radiation count map is shown in Figure 2. The interpolated lutum map of one field, made by Dacom company, is shown in Figure 2 as well. Lutum content varied between 25 and 35 %. Regular patterns were not observed.

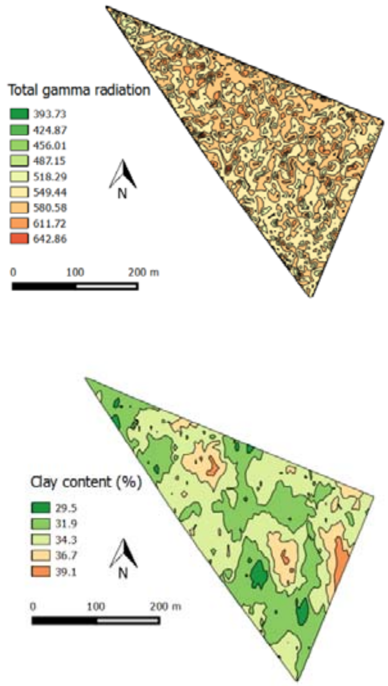


Figure 2. Total gamma radiation count map of five fields of the farm (left, in total 42 ha), and interpolated lutum content map of one of the fields (right, in total 8 ha)

Satellite images of the fields and crops were downloaded from the Dutch satellite data portal. In total, 126 NDVI maps are available for the period May – October 2013. Of these, 77 maps had a resolution of 25 by 25 m (DMC satellite) and 49 had 2 by 2 m (Formosat-2 satellite). Weather conditions during that period were such that less than 50 % of the satellite images could be processed into NDVI maps because of too many clouds.

In Figure 3, we show NDVI time series of one of the winter wheat crops at the Roodbeenweg in 2013. Medium (25 by 25 m) and high (2 by 2 m) resolution maps are shown. Early May, the crop was still in its late tillering phase (GS 5) due to a cold spring period. Up to early June, we can see the effect of seeding density on NDVI of the crop. The left side of the field had half the seeding density than the right part of the field. By July, this seeding density effect on NDVI had disappeared (see also Figure 4, Row 1 low seeding density and Row 3 high seeding density). In Figure 5 we show the yield map of the winter wheat field, as measured with a Claas 9-m wide combine. The best correlation between an individual NDVI observation and yield data was on early July. The R^2 of the regression analysis on the geo-referenced NDVI data and yield data was 0.61 at that moment. Earlier or later dates gave poorer correlations. Best correlation was between the cumulated NDVI values over the period May, June and July, and the yield data ($R^2 = 0.76$).

For the results on observations with the proximal biomass sensors (Greenseekers and N-Sensor), we refer to the paper on potato haulm killing by Kempenaar *et al.* in the proceedings of ICPA2013. Other observations we did in 2013 were sensing with hyper spectral camera's underneath a small airplane and an Octocopter. Typical results are shown in Figure 6. We show e.g. a WDVI map of a potato field used for assessment of the amount of Nitrogen in the aboveground biomass. We also show contours of a 3-D map of the winter wheat field.

Data from the national satellite data-portal were not only used to study biomass growth of crops on the 'De Drieslag' farm, but also for benchmarking. In Figure 7 we show the NDVI development of the winter wheat crop presented earlier and 49 other winter wheat crops. We observed that the NDVI was relatively low at the start of the season compared to neighbours. This was due to the low seeding density. Later on, NDVI caught up and was about average for the region. In Figure 7, we also see the development of (green manure) crops after the harvest of the wheat.

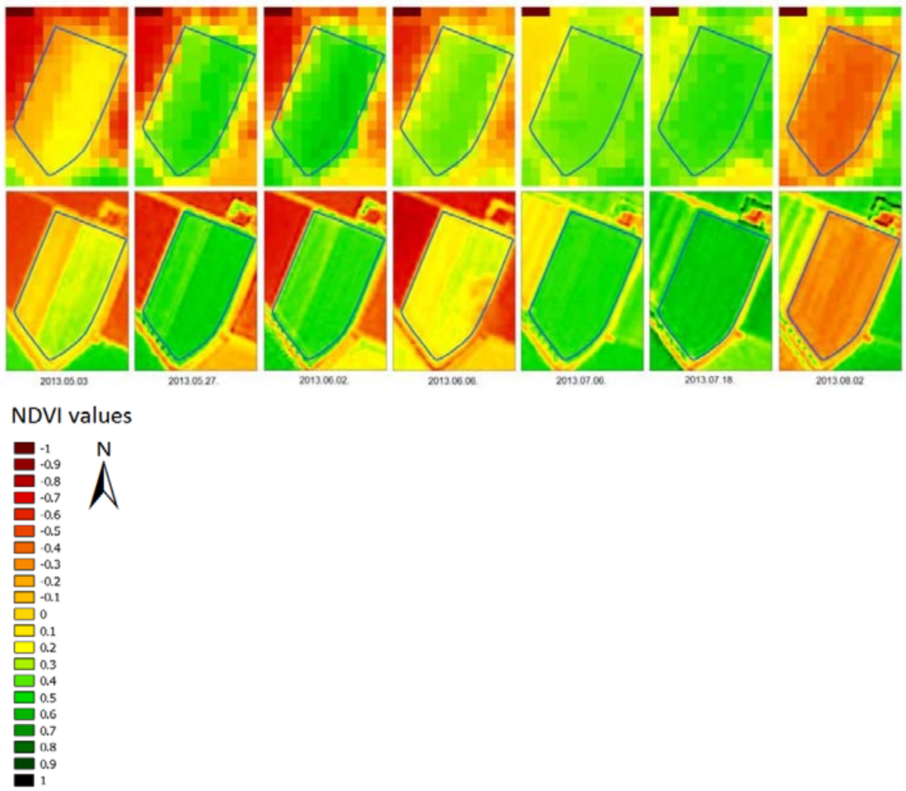
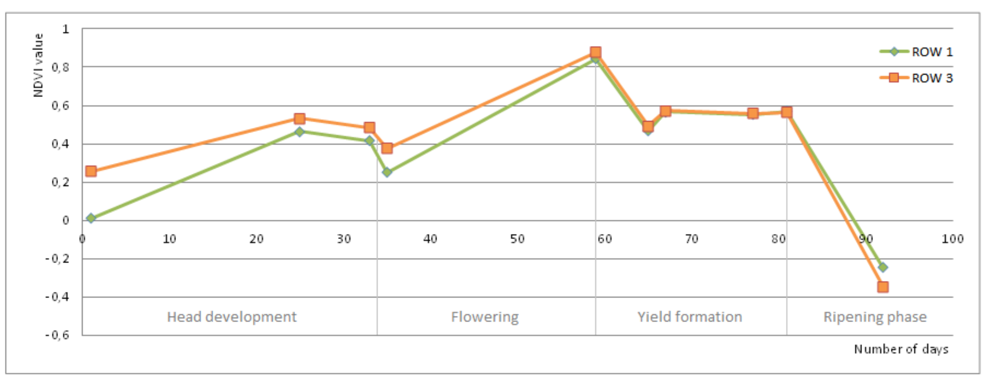


Figure 3. NDVI winter wheat NDVI time series (May - August 2013).
Resolution top row/pixel size is 25 by 25 m, and bottom row is 2 by 2 m.



Date (2013)	03.05.	27. 05.	04. 06.	06. 06.	30.06	06. 07.	08. 07.	18. 07.	22. 07.	02. 08.
Number of days	1	25	33	35	59	65	67	77	81	92
Mean NDVI ROW 1	0,009	0,464	0,417	0,249	0,842	0,468	0,568	0,554	0,568	-0,247
Mean NDVI ROW 3	0,255	0,533	0,486	0,377	0,876	0,494	0,572	0,557	0,565	-0,346

Figure 4. Mean NDVI values between May 3, 2013, and harvest (August 2013) for the part of the winter wheat crop field with low (row 1) and high (row 3) seeding density.

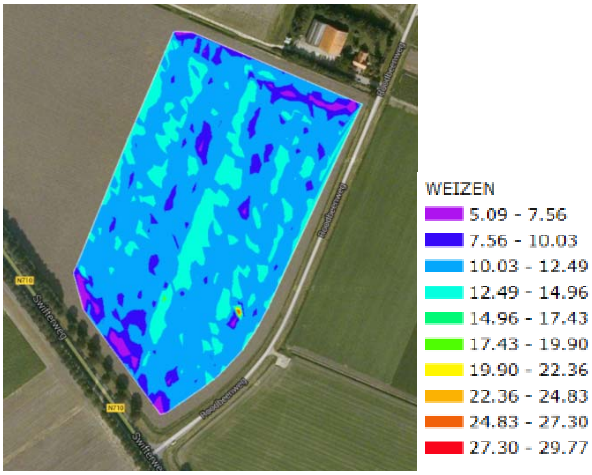


Figure 5. Yield map in 1000 kg wheat grains per ha at harvest (August 4, 2013).

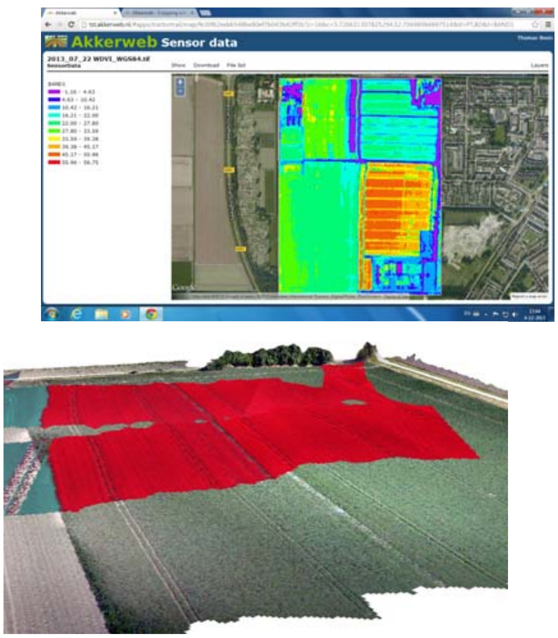


Figure 6. WDVI map of arable fields and a 3-D map of parts of the winter wheat crop at the Roodbeenweg (2-D maps in Figure 3).

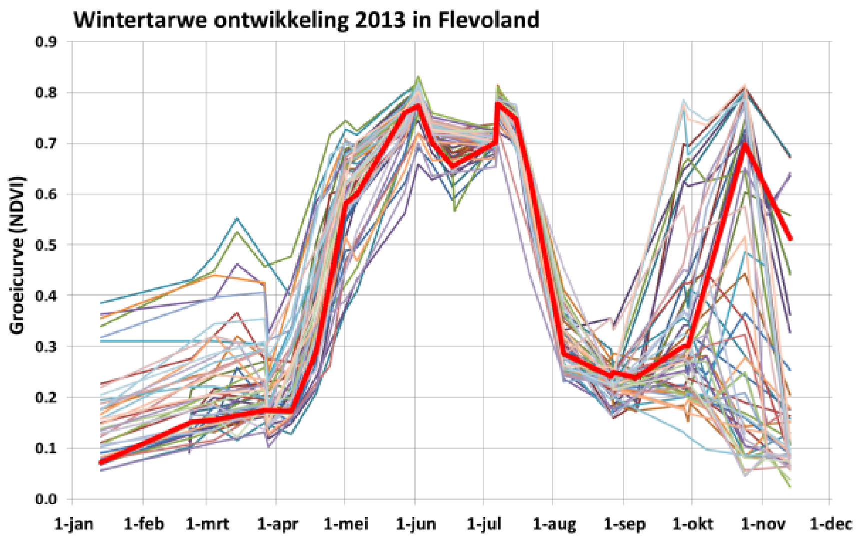


Figure 7. NDVI time series of 50 winter wheat fields near the winter wheat crop of Figures 3, 4 and 6 (ontwikkeling means development).

In our attempts to create a Smart Farm, we made progress at the level of data acquisition. However, we learnt that there are still several hurdles to overcome to arrive at where we want to be: good quality geo-referenced soil and crop data recorded with remote and/or proximal sensors, variable rate technology for crop management, and easy exchange of data and task maps. Improvements are needed on data-infrastructure, standardisation, sensor technology, spatial decision support, reliability of data, and implements. Cost-benefit analysis and good examples are needed to convince farmers to switch to the Smart Farming concept. Some more years of R&D are needed to reach this stage.

Acknowledgements

We thank CAH Vilentum farm 'De Drieslag' in Dronten for allowing us to use the land, crops, farm management data and farm equipment. Various supply companies of farms, amongst which Agrifirm, Agrometius, Altic, CHD, Dacom, DLV Plant, NEO, Kverneland, Sarvision, TerraSphere, contributed to the development of the farms. Also input from Wageningen UR Plant Research International and Alterra is appreciated. The precision agriculture chair at CAH Vilentum is financed by the Dutch government.

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