APPLICATION OF A CANOPY MULTISENSOR

Anton Thomsen and Kirsten Schelde

Department of Agroecology and Environment
Faculty of Agricultural Sciences
Aarhus University
Tjele, Denmark

ABSTRACT

The MobilLas mobile canopy sensor was initially developed for variable rate fertilisation and plant protection. Because of the several canopy variables sensed the sensor has wider application in crop and soil variability studies, detailed crop water balance studies, spatial modelling of photosynthesis as part of carbon dioxide flux studies, etc. The current version of the MobilLas sensor includes three integrated measurement systems: A near-infrared laser range finder, a two-band radiometer (Crop Circle ASC-210), and a global positioning system. The MobilLas sensor frame and electronics are placed at the front of a farm tractor. The Crop Circle ASC-210 is an active canopy sensor providing its own illumination. From reflectance measurements made at near-infrared (NIR) and visible (amber) wavelengths the spectral index, RVI, is calculated as the ratio (NIR/amber) of the reflectance values. Laser range measurements are made at a 50 deg. off nadir angle. Canopy height and leaf area index (LAI) are calculated from 1024 range measurements made within 1 s. During 2009 MobilLas measurements were made in a small winter wheat (Triticum aestivum var. Ambition) field fertilised at four nitrogen (N) levels: 40, 80, 120, and 160 kg/ha. The 2009 data are used to show the measuring capabilities of the sensor. The use of the sensor for precision N fertilisation is also introduced.

Keywords: Mobile canopy sensor, RVI, laser range finder, crop height, LAI, precision nitrogen fertilisation

INTRODUCTION

MobilLas is a mobile canopy sensor developed for variable rate fertilisation and plant protection. A field experiment was planned for the 2009 growing season in order to test the measuring capabilities of the current configuration of the instruments, further develop the software for data analysis etc.

THE INSTRUMENT

The current version of the MobilLas sensor includes three measurement systems:

- Near-infrared laser range finder, AccuRange 4000 (Acuity Research Inc., CA, USA)
- Two-band radiometer, Crop Circle ASC-210 (Holland Scientific Inc., NE, USA)
- Global positioning system, GPS 16 (Garmin International Inc., KS, USA)

The Crop Circle ASC-210 is an active canopy sensor providing its own illumination and measurements are made independent of solar radiation. From reflectance measurements made at near-infrared (NIR; 880 nm) and visible (yellow; 590 nm) wavelengths the spectral index, RVI, is calculated as the ratio (NIR/yellow) of the reflectance values.

Laser range measurements are made at a 50 deg. off nadir angle. From 1024 range measurements canopy height and leaf area index (LAI) are calculated (Thomsen and Schelde, 2007).

The GPS position is received at a rate of 1 Hz and a full measurement is recorded approximately every 1.6 seconds. Selected measured and derived data are displayed in real time on the system monitor placed in the tractor cab.

The driving speed is variable but here typically between 4.0 and 4.5 km/h.

At this speed and sampling rate a measurement is recorded for every approximately 2 meters travelled.

The MobilLas sensor is mounted at the front of a farm tractor as shown in Fig. 1.

FIELD MEASUREMENTS

During 2009 measurements were made in a small (1.2 ha) winter wheat (Triticum aestivum var. Ambition) field fertilised at four nitrogen (N) levels: 40, 80, 120, and 160 kg/ha. The field included four 200 m long tramlines defining the four sub fields. Sensor measurements were made at the right side of the tractor while driving in both directions along tramlines resulting in 400 m sampled within each sub field. Most of the data presented here are either average values calculated for each of the four sub fields or for groups of five individual measurements.

Fertiliser was applied during early spring on March 20. The previous year the field was planted with uniformly managed spring barley. Measurements were made once or twice per week until the beginning of crop germination. Here only measurements made during late April to late May (stem elongation and early booting stages) are included. The last measurements included here were made at growth stage Z40 on the Zadoks scale.

Laser measured leaf area index, LAI, was compared to LAI measured using the LAI2000 canopy analyser (Licor Inc., NE, USA). Figure 2 shows a comparison of reference and laser measured LAI. Laser measurements shown before and after multiplication with a 1.24 calibration factor applied to all laser measurements.

Laser measure canopy height is shown in Fig. 3. It is seen that only the sub field fertilised at the lowest N-rate (40 kg/ha) had a deviating (lower) height development compared to the other three sub fields.

Laser measured canopy LAI is shown in Fig. 4. It is seen that the LAI development is comparable for the two sub fields that received the largest amount of nitrogen (120 and 160 kg/ha) and for the other two sub fields that received the least amount of nitrogen (40 and 80 kg/ha).

Fig. 1. MobilLas sensor mounted at the front of a farm tractor. PC, power supplies etc. are housed in the box placed at the centre of the sensor frame. System monitor and keyboard placed in the tractor cab. GPS receiver and ASC-210 radiometer are mounted at the end of the long boom. The laser range finder is mounted on the short boom at an off nadir angle of 50 deg.

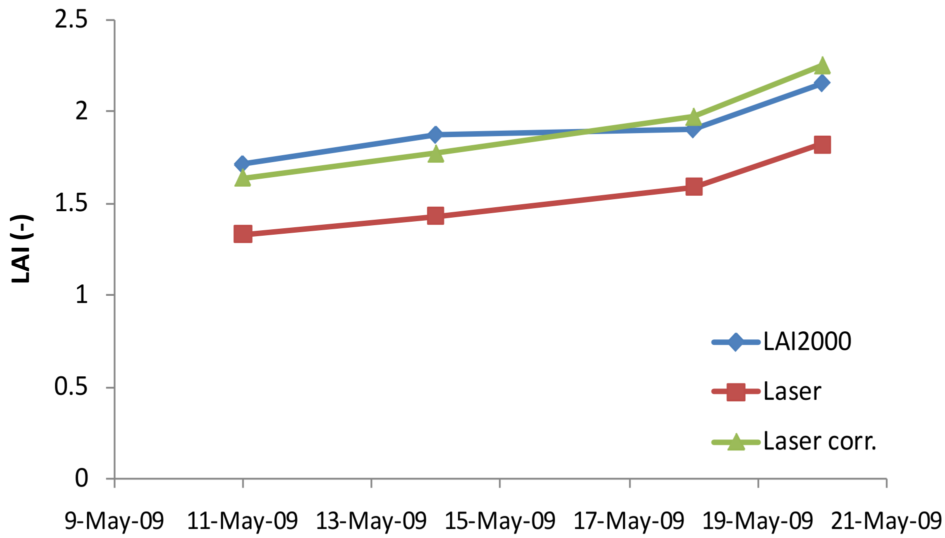

Fig. 2. Leaf area index, LAI, measured using the LAI2000 canopy analyser and the MobilLas laser instrument. Measurements made in the sub field fertilised at an N-rate of 80 kg/ha along a 20 m transect. Laser measurements shown before and after multiplication with a 1.24 calibration factor calculated from a larger data set.

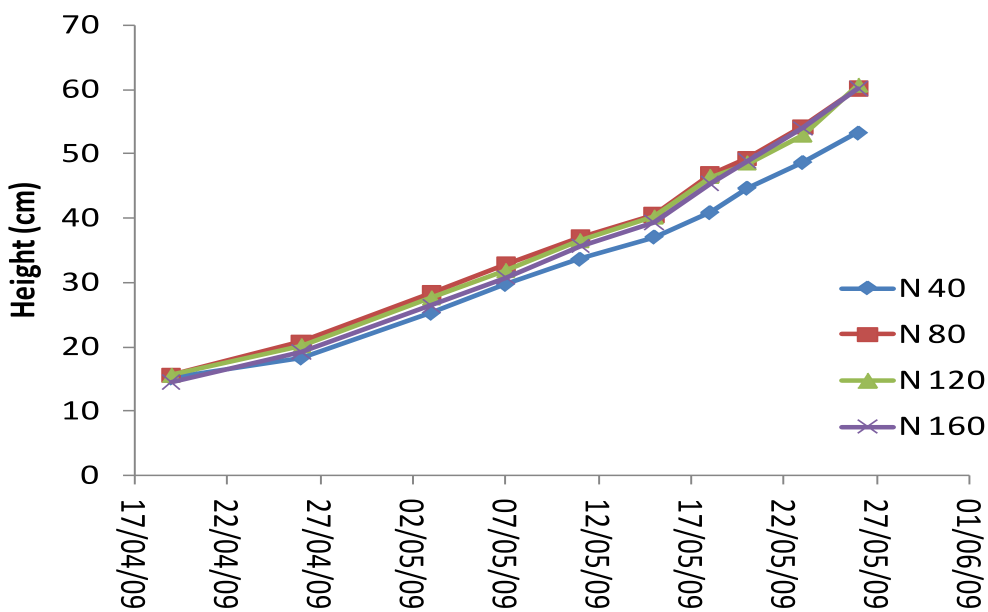

Fig. 3. MobilLas laser measured canopy height.

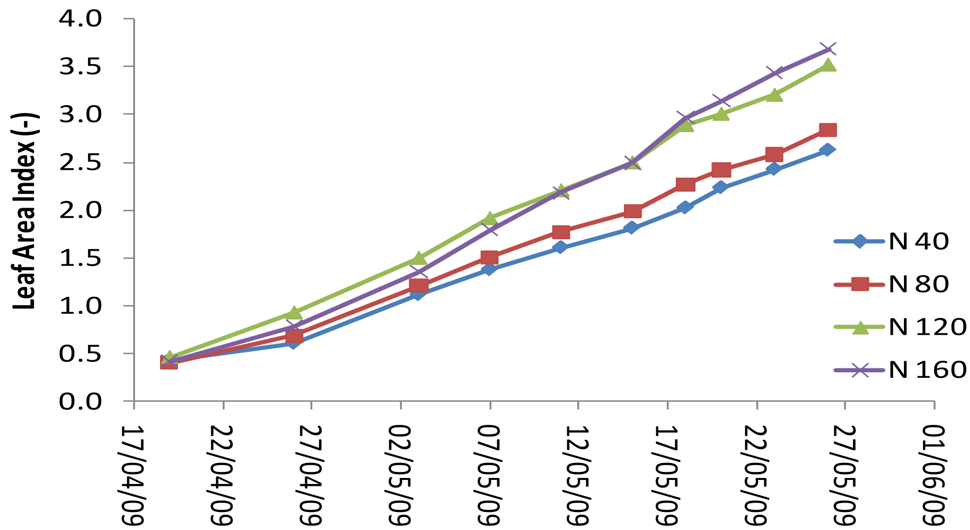

Fig. 4. MobilLas laser measured leaf area index, LAI.

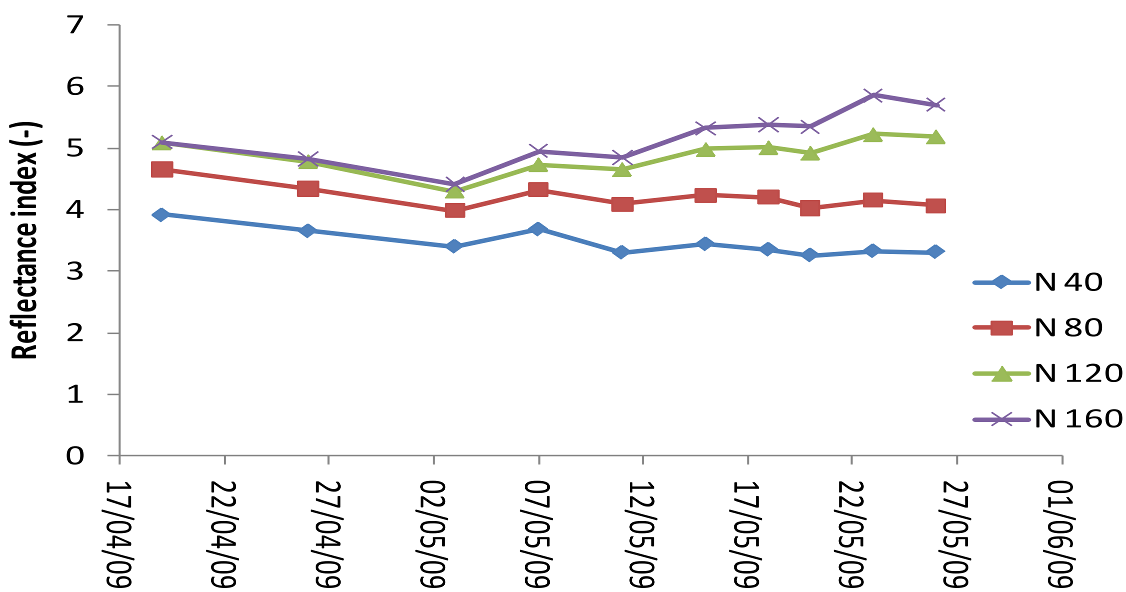

Fig. 5. Spectral index, RVI, calculated from near infrared (880 nm) and yellow (590 nm) reflectance measurements (RVI = NIR/yellow) made using the Crop Circle ASC-210 active canopy sensor.

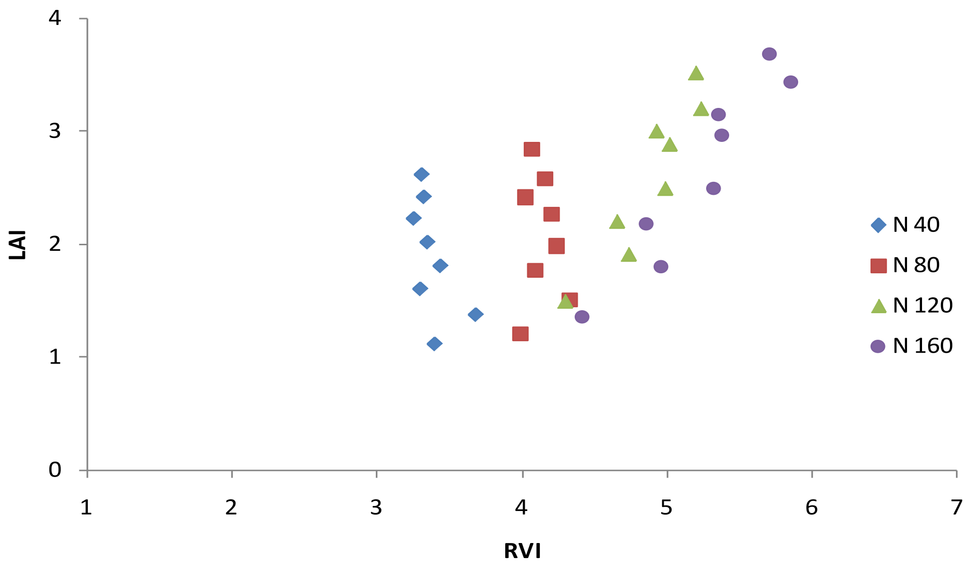

Fig. 6. Plot of leaf area index, LAI, vs. spectral index, RVI, including the data shown in Fig. 4 and Fig. 5.

Figure 5 shows the RVI spectral index calculated from NIR and yellow reflectance measurements made using the ASC-210 canopy sensor. It is seen that the RVI values are decreasing during late April and that RVI values only increase significantly during the month of May for the sub fields that received the highest N-rates (120 and 160 kg/ha).

By including independent measurements of crop leaf area index, LAI, and spectral index, RVI, the relationship between LAI and RVI can be explored. Figure 6 shows that the relationship depends on the nitrogen status of the canopy. Based on extensive manual measurements of LAI and RVI in research plots a seemingly robust fertilisation algorithm able to handle differences in canopy density had previously been developed (Thomsen et al., 2005).

FERTILIZATION ALGORITHM

The MobilLas sensor was originally developed for precision nitrogen fertilisation. Early work including manual measurements of canopy spectral reflectance (RVI) and canopy structure (LAI) had shown that a robust algorithm could be based on a combination of RVI and LAI measurements (Thomsen et al., 2005). Following this work Fig. 7 is based on the same combination of RVI and LAI measurements. Figure 7 is based on measurements made during the month of May including development stages between Z30 and Z40. The spectral index, RVI, is closely related to the amount of green biomass or chlorophyll per ground area unit and Fig. 7 is interpreted as the amount of green biomass (on an area basis) vs. the amount of chlorophyll (on a leaf area unit basis). It is seen that lines with a common origin can be fitted visually to the four N-levels. By fitting lines this way a simple fertilisation algorithm that translates combined measurements of RVI and LAI into a recommended N-rate based on interpolation results (Thomsen and Schelde, 2007). In the interpolation of recommended N-rates the target development is defined by the 160 kg N/ha line. By specifying other target lines the recommended N-rates can either be increased or decreased.

RECOMMENDED N-RATES

During off line analysis of MobilLas measurements averaging of the initial measurements is used to reduce scatter in the results. The following data are based on averaging groups of five measurements before final analysis. Averaging this way results in measurements representing approximately 10 m.

Canopy development and nitrogen status varies considerably within typical fields. Figure 8 shows averaged measurements made on May 18 plotted together with the visually fitted regression lines shown in Fig. 7. On May 18 the winter wheat had reached development stage Z32. Figure 8 is included in order to illustrate the high degree of variability present in the measurements and to be expected in most fields. Figure 8 shows a considerable overlap in measurements made in the subfields that received the highest N-rates (120 and 160 kg N/ha).

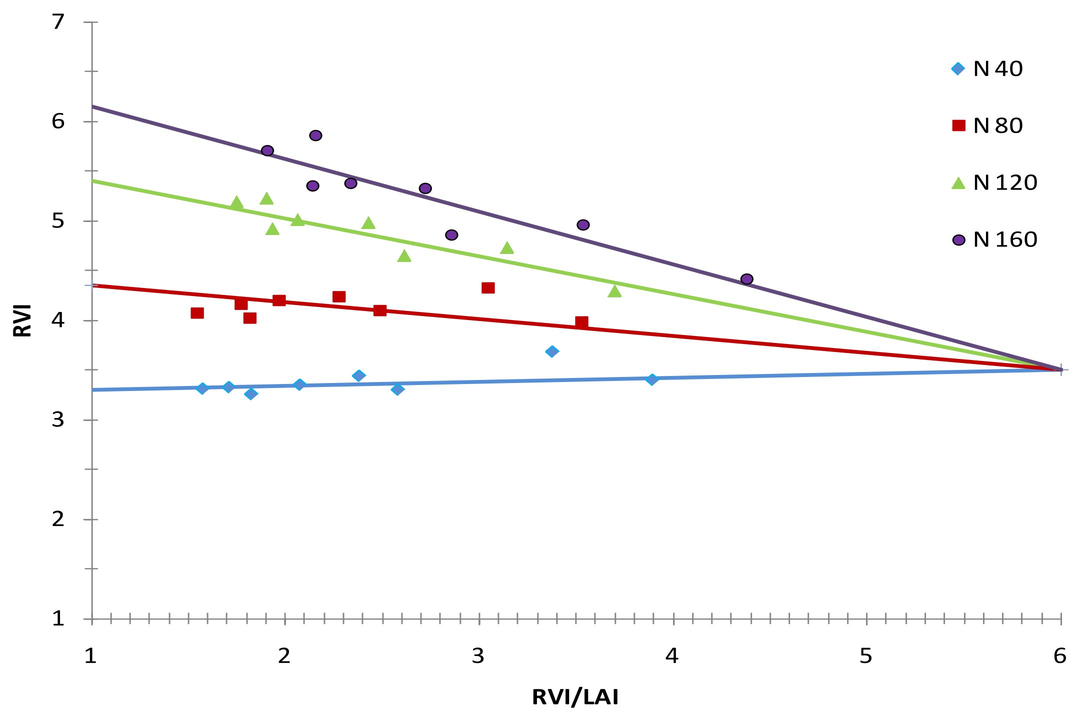

Fig. 7. Plot of spectral index, RVI, vs. the ratio of RVI and leaf area index, LAI. Visually drawn lines with a common origin fitted to the four N-levels are shown. Sensor measurements of RVI and LAI translated to recommended N-rates through simple interpolation. Data includes measurements made during the month of May including crop development stage Z30 – Z40.

By applying the fertilisation algorithm shown in graphical form in Fig. 7 the development in predicted nitrogen needs of the four sub fields during the month of May has been calculated and is presented in Fig. 9. By comparing Fig. 9 and Fig. 5 showing the development in the spectral index, RVI, it is seen that most of scatter is introduced by variation in measured RVI levels. The reason for this scatter has not been investigated. The N-recommendations for the subfield that received 160 kgN/ha relatively high because only measurements plotting below the 160 kgN/ha line included.

Figure 10 and Figure 11 are included in order to show the spatial variation in recommended N-rates for the dates May 3 and May 18 respectively.

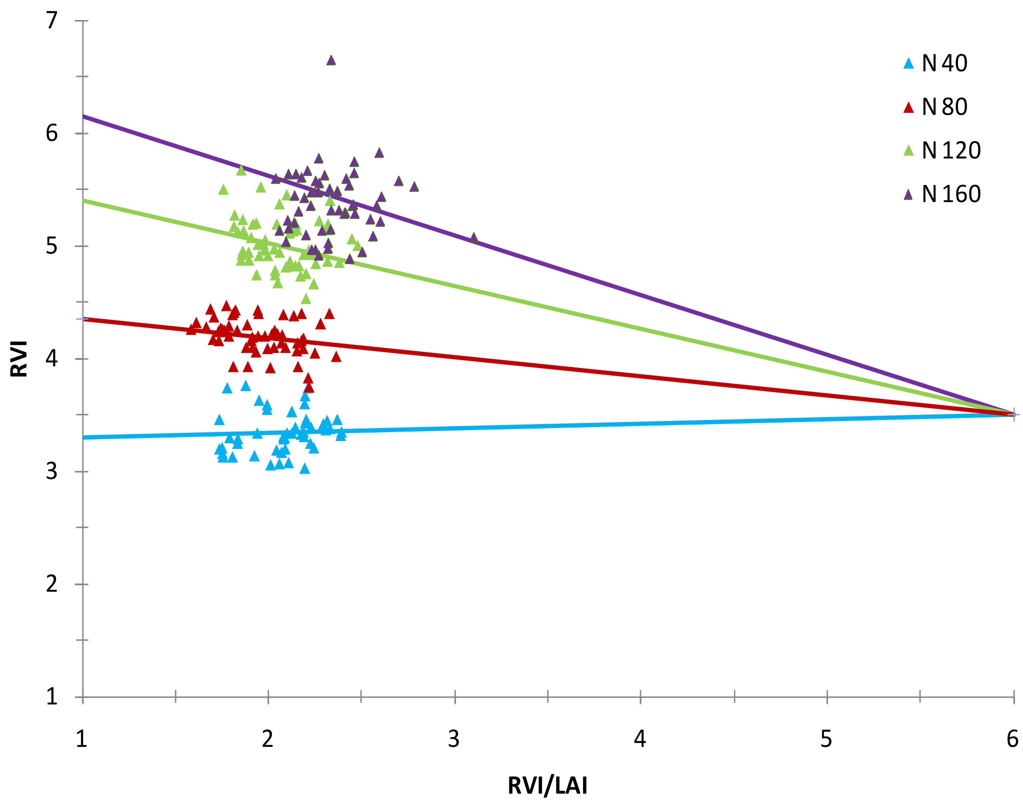

Fig. 8. Plot based on spectral index, RVI, and leaf area index, LAI, measurements made on May 18. The visually fitted regression lines shown in Fig. 7 included. Development stage Z32.

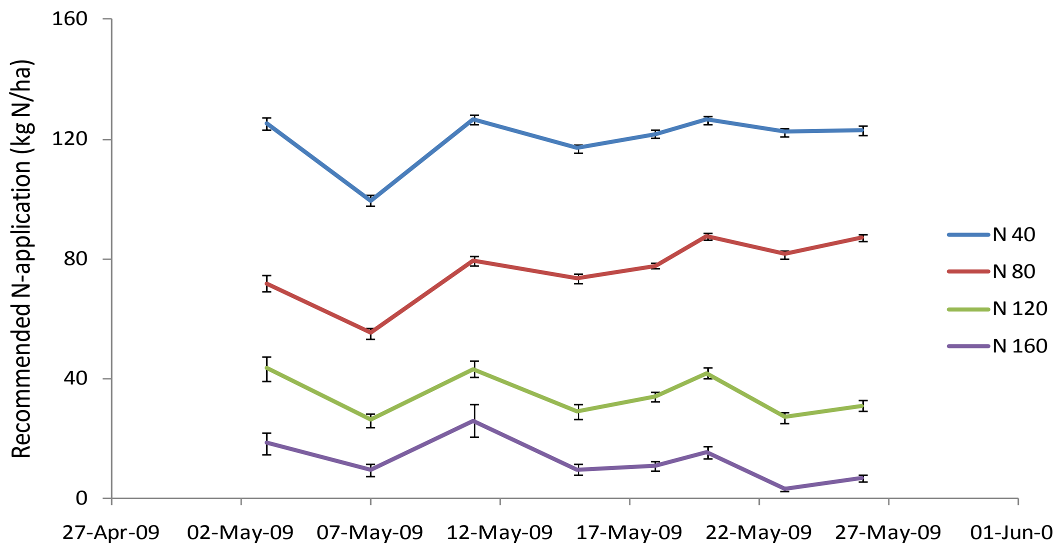

Fig. 9. Recommended N-rates based on measurements made during the month of May. The mean rates and standard deviations calculated for the four subfields are shown. Crop development stage Z30 – Z40.

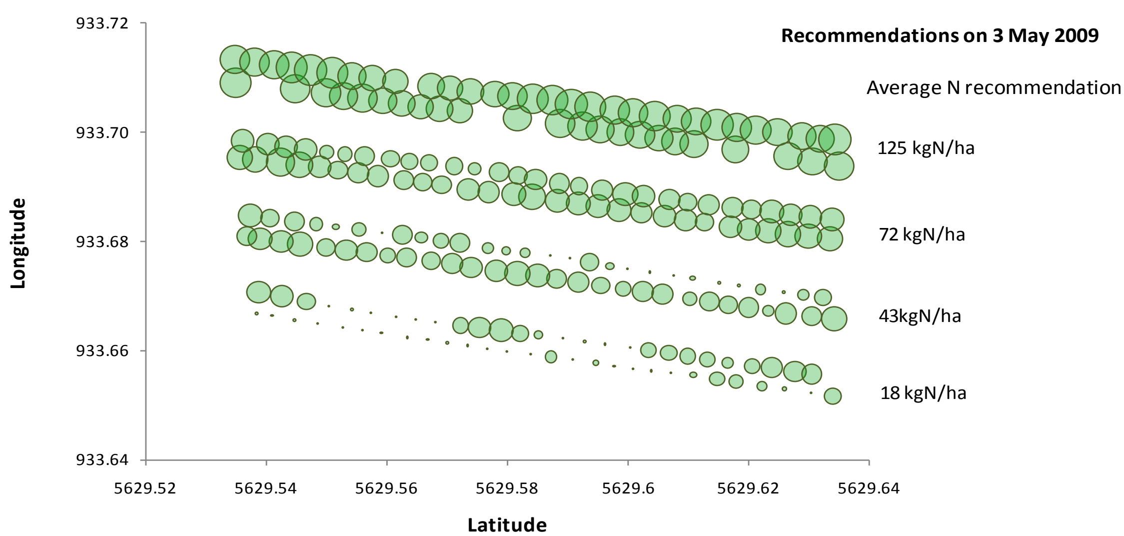

Fig. 10. Relative recommended N-rates calculated from measurements made on May 3. Circle areas proportional to N-rates. Development stage Z30.

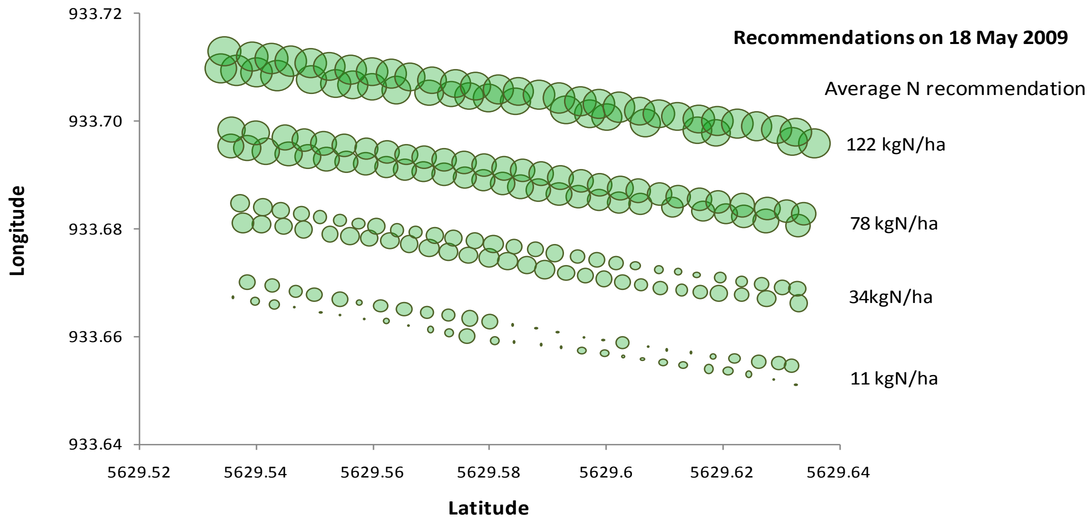

Fig. 11. Relative recommended N-rates calculated from measurements made on May 18. Circle areas proportional to N-rates. Development stage Z40.

CONCLUSIONS

The algorithm originally developed from manual measurements of canopy spectral reflectance, RVI, and leaf area index, LAI, has been implemented with RVI and LAI measured using the MobilLas mobile sensor. Based on measurements made within a small field cropped with winter wheat it is concluded that

- mobile measurements of RVI and LAI are accurate enough to allow the implementation of a nitrogen fertilisation algorithm originally developed from reference quality measurements made in research plots
- the recommended N-rates are stable during more than three weeks including development stages from Z30 to Z40 and approximately a doubling in crop height and leaf area index
- the quality of the measurements and the several canopy variables included makes the instrument interesting for wider application to precision crop management (e.g. crop protection, irrigation etc.)

REFERENCES

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