SPOT 5 MULTISPECTRAL DATA POTENTIALITIES TO MONITOR POTATO CROP NITROGEN STATUS AT SPECIFIC FIELD SCALE

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ABSTRACT

The many challenges facing European agriculture and farm of tomorrow are such that they increasingly require the setting up of Decision Support Systems (DSS) that favour integrated crop management at farm or regional level. A valuable DSS for management of split fertilizer N applications was developed in Belgium for potato crop. It combines total N recommendation based on field predictive balance-sheet method along with Crop Nitrogen Status (CNS) monitoring through hand-held chlorophyll meter (CM) Hydro N-tester (Yara, Oslo, Norway) readings. In-season monitoring is realized from 20 to 50 days after potato crop emergence. Using zero N reference plot (10x20m) within supposed homogeneous field areas, relative CM threshold value allows to decide on the need for supplemental N to refine the previous recommendation.

Potentialities of Earth Observation and crop light reflectance data to monitor CNS have been investigated for the growing seasons 2008 and 2009, on plots of different sizes (ranging from 30x30m up to 100x100m) fertilized with various mineral N-rates (0, 70 % and 100 % of N recommendation). Reflectances were acquired from SPOT 5 multispectral images (10 m pixel resolution, Red/Green/Near-Infra Red/Short-Wave Infra Red) or from ground-based remote sensing with a hand-held radiometer. Both observations type were planed to be realize from mid of June up to end of July.

The analysis of satellite image was realized following two approaches: (i) the use of statistical analyses to determine relevant spectral bands and (ii) the calculation of spectral Vegetation Indices (VI's). The R and the NIR bands and several VI's derived from both bands but also from the G band, discriminated well the various N-rates, but particularly the zero-N plots as did CM readings. DN values between pixels of a same plot varied little (cv < 5%), while variations between same N-rate plots of different fields were high. Discrimination between plots of smallest size based on single pixel DN value was also quite effective.

Very good correlations ($r^2 > 0.80$) appeared between VI's based on satellite DN values and radiometer readings. This prospective study indicates that SPOT 5 MS images show promise to monitor CNS using small size reference plots. The main limitation remains the availability of at least one SPOT 5 image within the required phenological period.

Keywords: In-season nitrogen management, potato, remote sensing, reflectance

INTRODUCTION

To develop sustainable cropping systems, enhancement of nitrogen use efficiency (NUE) is an important prerequisite. Current nitrogen management strategies for worldwide crop production systems are characterized by low NUE and environmental contamination hazards to soil, water and atmosphere due to gaseous plant emissions, soil denitrification, surface run-off, volatilization and leaching. As clearly and recently reviewed (Shanahan et al., 2008; Goffart et al., 2008), low NUE can be due mainly:

- (a) To poor synchrony between fertilizer-N supply and crop N demand.
- (b) To failure to account for temporally variable influences on soil mineral N supply and crop N needs mainly related to in-season weather conditions.
- (c) To uniform fertilizer N applications within fields that do not consider the fact N supplies from the soil, crop N uptake and crop N response are spatially variable.

This last decade, a general agreement appeared on the potentialities of in-season soil-based and/or plant-based responsive strategies for N management to enhance NUE (Vos, 2009). All crops are of concern in the debate regarding the improvement of fertilizers NUE management, but those such as potato with shorter period of crop N uptake and shallow rooting system are particularly of concern for low NUE. In Western Europe, current N management strategies generally lead to fertilizer-N recovery (meaning the percent of applied fertilizer-N recovered in the above and under ground biomass during the growing season) of only 40 to 50% for the potato crop, while 70 to 90% for cereals or sugar beet crops.

In Belgium, focusing on solutions to alleviate points (a) and (b) here above, CRA-W has developed and validated a Decision Support System (CRA-W DSS) for N management of potato crop, in irrigated or rain-fed environment, based on split fertilizer-N applications (Goffart and Olivier, 2004). This DSS now applied by farmers, combines total N recommendation based on a specific field predictive balance-sheet method with in-season Crop Nitrogen Status (CNS) monitoring through chlorophyll meter readings (Hydro N-tester chlorophyll meter (HNt CM), YARA, Oslo, Norway). In practice, from the recommended N-rate, only 70% is applied around planting time. At this time a reference plot of about 200 m^2 size is left without N (zero-N window) within a supposed homogeneous area representative of the whole field. Weakly HNt CM readings, based on the leaf absorbance/transmission of two active wavelengths, one in the red at 650 nm and one in the near-infrared at 940 nm, are completed from 20 to 50 days after crop emergence (DAE). Based on the average value of 30 individual HNt CM readings in the zero-N window, compared to readings in the remaining field of maximum 3 ha receiving 70% of the recommended N-rate, the CRA-W DSS allows to decide on the need for supplemental N to refine the previous recommendation (Olivier et al., 2006). Globally, it allows enhance by 10 to 30 % the global fertilizer NUE either through better in time positioning of in-season N applications according to detected crop N need or through the saving of 30% fertilizer-N (Goffart et al., 2005).

Such plant-based approach, while useful for farmers, is based however on a small number of data collected with an hand-held CM from single leaves across part of a whole canopy field. It is then also very difficult to extend the collecting procedure to manage large fields, or homogeneous parts of them. Several recent optically based technologies are available to assess in-season potato CNS (Hatfield et al., 2008; Goffart et al., 2008) and should be able to overcome such limitations.

In this frame, potentialities of crop light reflectance has been investigated to monitor potato CNS, either through ground-based near remote sensing (using a hand-held passive radiometer) or through spatial remote sensing (using SPOT 5 MS satellite image) ideally collected within the optimal phenological period as stated in the CRA-W DSS. This paper presents first 2-years study results on reflectance data collected in Belgium, on sub-field zones of variable sizes receiving increasing fertilizer-N rates. Promise results were acquired through a recent and similar approach by Wu et al. (2007) from Quickbird satellite images.

MATERIAL AND METHODS

Field trials

Respectively 11 and 9 commercial fields in 2008 and 2009, located on loamy soils of the area of Gembloux (50°34'N, 4°42'E; 170m above sea level, Belgium) and planted with potato crop were used to conduct the study. Cropping characteristics of each field are given in Table 1. For each of them a recommended N rate was established according to the balance-sheet method used in the DSS developed by CRA-W. In 2008 and 2009 in 4 and 9 fields respectively, plots receiving increasing N fertilizer rates (zero-N as reference plot, 70% of recommended N rate, 100% of recommended N rate) were delimited. In 2008, according to field situation, plot size was 30x100m to 50x100m for the reference 0N plot (no N applied) and the 70%N plot, and 100x100m for the 100%N plot. In 2009, in the 9 fields plot size was drastically reduced to 30x30m for the three N-rates, aiming to assess potentialities of reflectance data acquisition in the smallest plots acceptable according to SPOT 5 image spatial resolution (10m). In 2008 for each of the 7 remaining fields, only one plot of 100x100m receiving 100% N was considered. Both years, fertilizer-N was applied pre-planting as ammonium nitrate (27% w/w) or nitrogen solution (39% N w/v), and as urea solution (46%N w/v) or nitrogen solution (39%N w/v) foliar applied as supplemental-N when required according to HNt CM readings and CRA-W DSS.

Table 1: Cropping characteristics of the potato field trials in 2008 and 2009

	2008				2009			
Field Number	**Variety**	**Planting date**	**Full emergence date**	**N-rate (1)**	**Variety**	**Planting date**	**Full emergence date**	**N-rate (1)**
1	Bintje	April 22	May 17	170	Bintje	April 22	May 28	156
2	Bintje	May 12	June 3	170	Bintje	May 2	June 3	156
3	Bintje	May 13	June 3	150	Lady Claire	May 3	June 5	160
4	Désirée	May 7	June 3	140	Bintje	April 15	May 14	198
5	Fontane	April 25	May 19	140	Exempla	April 26	May 31	120
6	Bintje	May 12	June 3	200	Exempla	April 26	May 31	120
7	Fontane	May 9	June 3	200	Victoria	April 15	May 22	180
8	Bintje	May 7	May 31	200	Challenger	April 26	May 31	160
9	Bintje	May 8	June 3	200	Charlotte	April 10	May 8	100
10	Fontane	May 9	June 3	200				
11	Bintje	May 9	June	200				

(1) Field specific recommended N-rate (kg Nha^{-1}) based on a provisional N balance-sheet method

Optical data acquisition

SPOT 5 satellite multispectral (MS) images were acquired on July 25th 2008 and August 5th 2009. Clear sky conditions existed for both overpass dates and the potato crop was at its end of vegetative stage more or less ranging from 55 to 75 DAE depending of the situations. Scene parameters characteristics for the two image acquisition dates are given in Table 2. Four spectral wavebands of the electromagnetic spectrum are available from SPOT 5 image: green (G), red (R), near-infrared (NIR) and short-wave infrared (SWIR), i.e., 500 to 590 nm, 610 to 680 nm, 790 to 890 nm and 1580 to 1750 nm respectively.

Ground-based optical data were acquired at intervals of 7 to 10 days from 20 to 70 DAE. Four mean values of 30 individual at random HNt CM readings each were collected across each N-plot along two transects distant of 10 to 20 m and centred in the plot. Potato canopy radiance and incoming irradiance were measured simultaneously across each plot with a hand-held radiometer CROPSCAN model MSR87 (Cropscan, Rochester, USA). This radiometer consists of eight wavebands from 460 to 810 nm at 50 nm intervals and a computed data logger that sample and store the readings of irradiance and radiance for each wavebands.

Table 2: Scene parameters of multispectral images SPOT5 satellite acquisition dates

Parameter	**Acquisition date**	
	25 July 2008	**5 August 2009**
Acquisition time, GMT	11:01:42	10:59:21
Sun zenith angle,°	57.77	55.43
Sun azimuth angle,°	159.37	159.59
Sensor view angle,°	19.64	16.48
Target azimuth angle,°	22.36	18.15
Pixel resolution, m	10	10

The radiometer is extended on a boom to a height of 2.0 m above ground and faced downward perpendicular to the crop surface (nadir view). For each reading, a circular field-of-view of 1 m^2 in diameter is obtained at ground level. The radiometer plat-form provides a two-way levelling to keep the radiometer level. Data collection occurred between 10:00 am and 2:00 pm (GMT) under clear sky conditions. Twenty single readings were randomly realized and averaged across each plot avoiding the plot borders (buffer of 5 m). Canopy reflectances were calculated in each of the eight wavebands as the ratio between radiance (down-looking) and irradiance (up-looking) values.

Extraction of SPOT 5 satellite data (Digital Number, DN)

Spot 5 Multispectral images were geo-referenced according to the Control Ground Point procedure using identifiable objects between satellite image and a geo-referenced photography with a maximum tolerance of 0.5 pixel as Root Mean Square Error (RMSE). Although longitude and latitude of the corners of each N treatment plot was recorded with GPS measurements, the accurate localisation of each plot N has been realized using ground metric measurements from official field borders data and also using photo-interpretation as image contrast between pixels of the various N treatment was sufficiently high enough. For the trials of 2008, a 10 m negative buffer zone was created inside the borders of each N plot to avoid pixels located in the buffer being used in the analyses. For 2009, the objective was to consider single pixel from each small sized plot to evaluate the smallest area of interest that could be considered with SPOT 5 images. The number of whole pixels within the buffered area of each plot varied from one for the smallest sized plot in 2009 to 30 for the larger plots in 2008. Pixel digital number (DN) values were extracted for the four MS bands and average DN values were calculated for 2008 for each spectral band within each N-rate plot.

Establishment of Vegetation Indices (VI's)

The different wavebands, either as absolute or as normalized wavebands, and various VI's based on combination of the G, R and/or NIR values (Table 6), were calculated from SPOT 5 images and compared to ground-based optical observations from the radiometer. To assume this comparison, readings from radiometer filters of 510 and 560 nm were associated to assume data for the G waveband, 610 and 660 nm for the R band and 760-810 nm for the NIR band, and respective average of both filters were calculated to be compared to SPOT 5 data as absolute or normalized spectral wavebands ratio and VI's.

Statistical analyses

For each N-rate plot area, average of HNT CM readings and of Cropscan radiometer readings have been calculated with their associated standard error and coefficient of variation. Average values of pixels DN and their associated standard deviation and coefficient of variation have been calculated for each N-plot, aiming to characterise the variation between pixels of a same N-plot within a same field, but also between plots belonging to different fields. To discriminate average values between different N-rate plots, analysis of variance and Newman-Keuls tests have been performed. Correlations between DN and ground-based radiometer reflectance values of 2008 were checked by single linear regression and significance Pearson test for single waveband and associated vegetation indices values collected at the same date that the SPOT 5 image acquisition.

RESULTS

Results of both years are presented to compare HNt CM readings values (as used in the CRA-W potato DSS) and ground-based radiometer values time-courses with DN values acquired from SPOT 5 images for the different N-rate plots within and between investigated fields.

Year 2008

Within the four studied fields including increasing N-rate plots, evolution of the HNt CM readings given in Fig.1 confirms the significant discrimination already known (Olivier et al., 2006) between the reference 0N and 70% N plots, while the 100%N plot does not always discriminate very well from the 70%N plot. Average HNt CM values also show low variation and good precision and accuracy. Same observation can be made with the time-course of ground-based reflectance values (Cropscan readings) but mainly for the NIR bands, while variation of average values are larger comparatively to HNt CM mean values due to higher standard errors (Fig. 2). As a consequence, differences between the 0N and 70%N plots for the three considered wavebands are not generally significant.

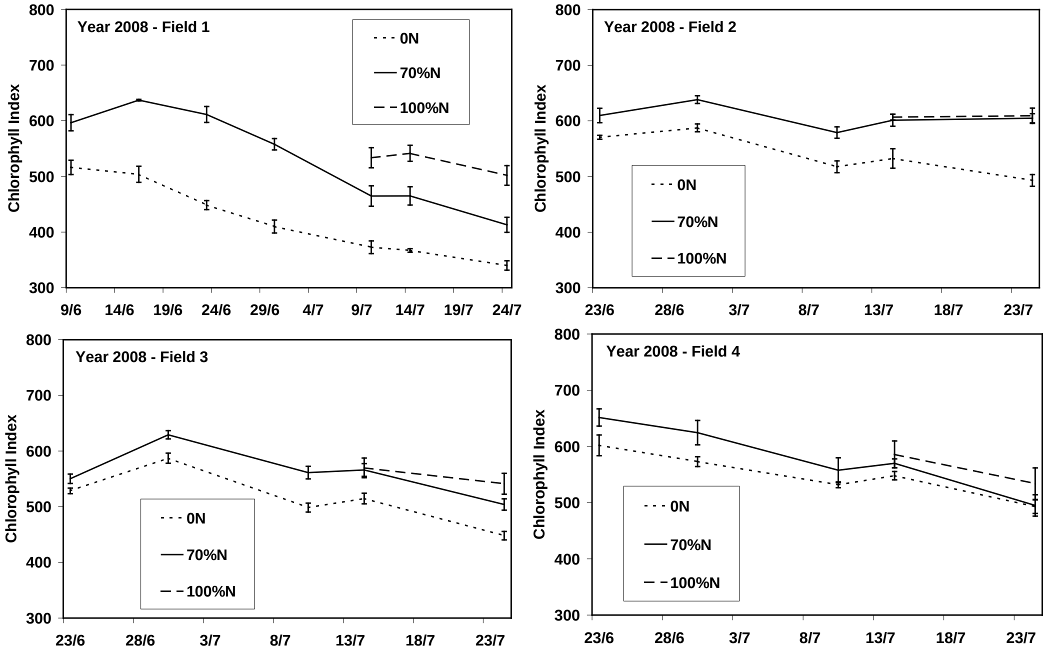

Fig. 1: Time-course of HNt CM average readings from 20 to 70 DAE in 2008 for the different N-rate plots within four potato fields

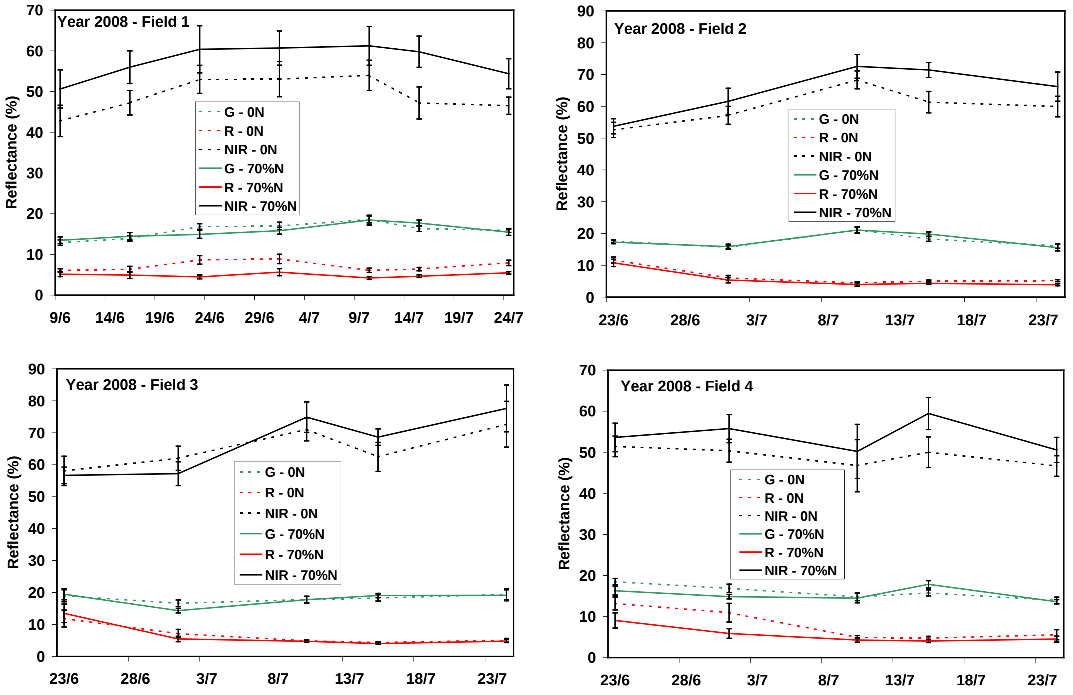

Fig 2: Time-course of ground-based radiometer mean reflectance readings for the green (G), red (R) and near-infrared (NIR) wavebands from 20 to 70 DAE in 2008 for the 0 and 70% N-rate plots within 4 potato fields

SPOT 5 image acquisition date was unfortunately out of the required phenological period for the CRA-W DSS. However average DN values, extracted from several pixels per N-rate plot (Table 3, Fig 3) for the on July 25th SPOT 5 image, still show significant discrimination between the different N-rate plots particularly in the NIR waveband, with very low standard errors and coefficient of variation between pixels of a same N-rate plot (Table 3). For the reference 0N rate, higher average DN values were observed in the G and R wavebands while lower values in the NIR waveband (Fig.3). No DN difference appear in the SWIR band between the different investigated N-rate plots. Reflectance ground-based mean values on the same date indicate clearly higher coefficient of variation within a plot, with values ranging from 3.1% to 22.1%.

Average DN values (Table 4) and ground-based reflectance values (Table 5) across the four investigated fields in 2008 for each N-rate plot and each waveband show higher variation than within a N-rate plot of a same field.

Table 3 : Average DN values (with coefficient of variation) within N-rate plots of four fields extracted from several pixels (n) of SPOT5 satellite image on 25th of July 2008 for the G, R and NIR wavebands (values belonging to a same field and followed by the same letter are not significantly different at p> 0.05)

N-rate plots	Field	n	Green	Red	Near Infrared
reference 0N	1	15	**131** a (1.1)	**111** a (2.3)	**156** a (2.1)
	2	15	**126** a (1.3)	**98** a (1.0)	**201** a (1.3)
	3	26	**125** a (0.9)	**95** a (0.9)	**201** a (3.2)
	4	24	**130** a (0.9)	**117** a (2.6)	**162** a (2.1)
70% of N-recommendation	1	11	**124** b (0.8)	**100** b (1.9)	**170** b (2.2)
	2	15	**116** b (1.0)	**92** b (1.1)	**214** b (0.9)
	3	31	**120** b (0.9)	**93** a (1.4)	**216** b (1.4)
	4	14	**122** b (1.2)	**97** b (2.6)	**181** b (1.9)
100% of N-recommendation	1	11	**120** c (1.1)	**93** c (1.7)	**189** c (1.2)
	2	15	**115** b (0.8)	**91** b (1.2)	**221** c (0.9)
	3	10	**118** b (1.5)	**91** a (0.5)	**216** b (1.5)
	4	9	**118** b (0.9)	**93** b (2.1)	**197** c (2.0)

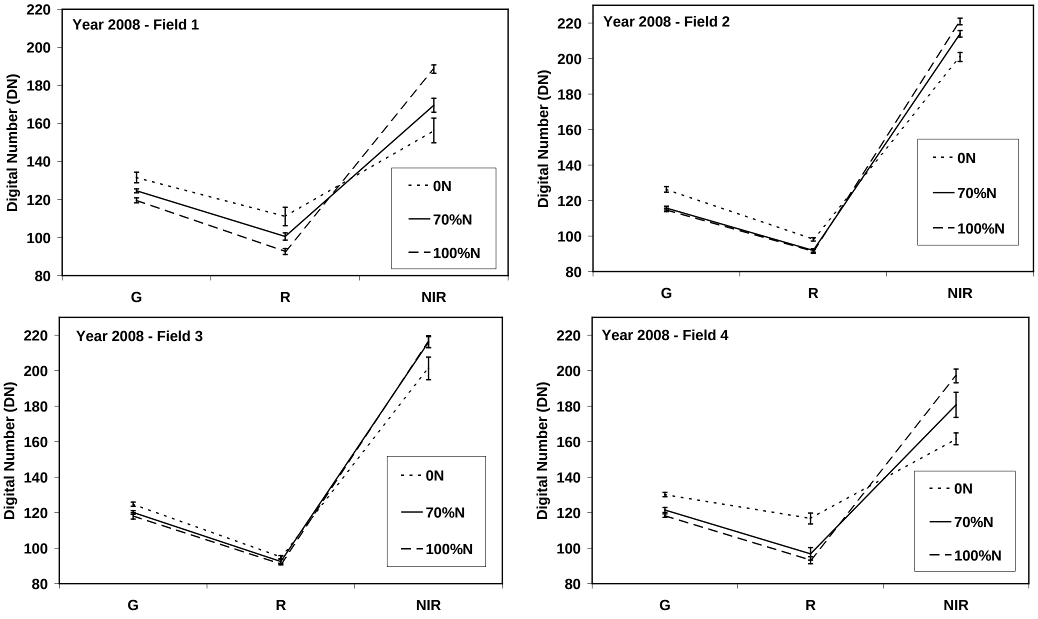

Figure 3: Spectral signature (average DN values with their standard error for the G, R and NIR wavebands) of the potato canopy in different N-rate plots within 4 fields extracted from SPOT5 satellite image on 25th of July 2008

Table 4: Average DN values for the green (G), red (R) and near-infrared (NIR) wavebands and associated coefficient of variation extracted from SPOT5 image on July 25th 2008 within different N-rate plots across four investigated fields

	Reference 0N			70% of N-recommendation			100% of N-recomm.		
	G	R	NIR	G	R	NIR	G	R	NIR
mean	128	105	181	120	94	201	117	92	207
cv (%)	2.5	9.4	12	2.5	3.9	9.8	2.0	1.7	6.8

Table 5: Average ground-based radiometer reflectance (%) values for the green (G), red (R) and near-infrared (NIR) wavebands and associated coefficient of variation on July 25th 2008 within different N-rate plots across four investigated fields

	Reference 0N			**70% of N-recommendation**		
	G	R	NIR	G	R	NIR
mean	16.3	5.9	56.4	15.9	4.7	62.2
cv (%)	13.9	22.7	22.2	14.5	14.4	19.7

Considering satellite optical data (DN) collected from the different N plots within each of the four investigated fields and also from the seven remaining investigated fields receiving 100%N (representing a total of 15 investigated zones), good correlation have also been established between several VI's calculated respectively from SPOT5 DN values and from ground-based reflectance values collected on the same date. Coefficients of determination (r^2, Table 6) are high and all significant ($p>0.05$). Such results are a first validation of the SPOT 5 DN values. Top of Atmosphere and Top of Canopy reflectance values have been determined, and compared to ground-based reflectance observations but without improvement in the correlation (results not shown in this paper).

Table 6: Coefficient of determination (r^2) between SPOT5 DN and ground-based radiometer reflectance values for the green, red and NIR spectral wavebands and several related usual VI's for 15 N plots (n=15) out of 11 fields in 2008

Acronyme	**Name**	**Relation**	**r^2**
G	Green spectral band	G	**0.60**
R	Red spectral band	R	**0.55**
NIR	Near infrared spectral band	NIR	**0.68**
Norm G	Normalized G	G/(G+R+NIR)	**0.80**
Norm R	Normalized R	R/(G+R+NIR)	**0.83**
Norm NIR	Normalized NIR	NIR/(NIR+R+G)	**0.84**
DVI	Difference Vegetation Index	NIR-R	**0.71**
GDVI	Green Difference Vegetation Index	NIR-G	**0.70**
RVI	Ratio Vegetation Index	NIR/R	**0.86**
GRVI	Green Ration Vegetation Index	NIR/G	**0.79**
NDVI	Normalized Difference Vegetation Index	(NIR-R)/(NIR+R)	**0.85**
GNDVI	Green Normalized Difference Vegetation Index	(NIR-G)/(NIR+G)	**0.83**
SAVI	Soil Adjusted Vegetation Index	[(NIR-R)/(NIR+R+0.5)]*1.5	**0.80**
GSAVI	Green Soil Adjusted Vegetation Index	[(NIR-G)/(NIR+G+0.5)]*1.5	**0.81**
OSAVI	Optimized Soil Adjusted Vegetation Index	(NIR-R)/(NIR+R+0.16)	**0.85**
GOSAVI	Green Optimized Soil Adjusted Vegetation Index	(NIR-G)/(NIR+G+0.16)	**0.85**

Year 2009

For 2009, the objective was to examine the potentialities of SPOT 5 image to supply discriminated information from a limited number of pixels (extreme situation) to evaluate the spatial resolution of SPOT 5 satellite and its sensitivity. A single central pixel of 10x10m within N-rate small plots size of only 30x30m was considered. As already mentioned, the SPOT 5 image acquisition occurred only on the 5th of August 2009, meaning to late to match the required period between 20 and 50 DAE of CNS information acquisition according to the CRA-W DSS . However useful DN data were still extracted out of 6 of the 9 fields where the canopy was not yet decaying (senescence phenological stage). Moreover, HNt CM and ground-based radiometer readings were performed over the whole period in the different N-rate plots of all the investigated fields and time-course results are presented respectively in Fig. 4 and Fig. 5 for the 6 remaining fields useful for DN analysis.

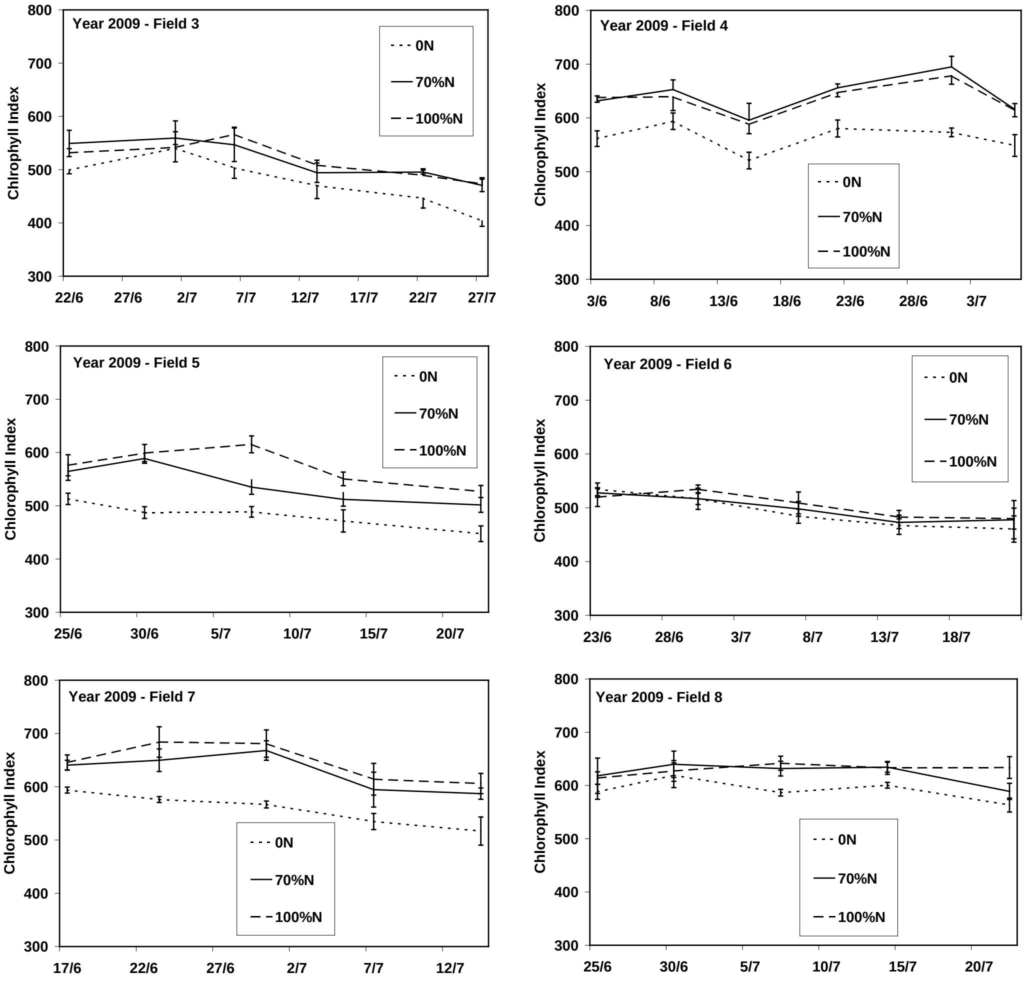

Fig. 4: Time-course of HNt CM average readings from 20 to 70 DAE in 2009 for the different N-rate plots within six different potato fields

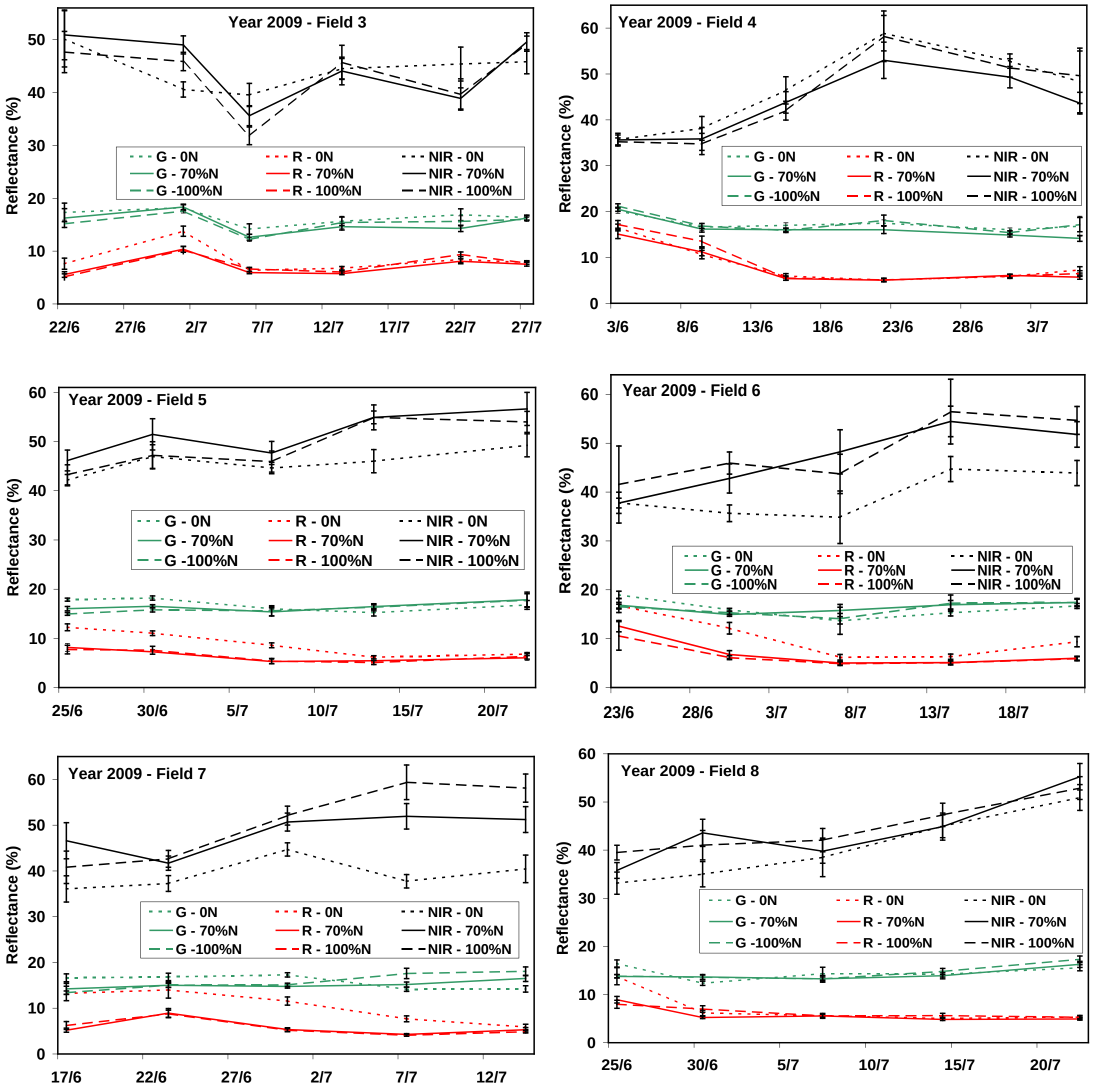

Fig 5: Time-course of ground-based radiometer mean reflectance readings for the green (G), red (R) and near-infrared (NIR) wavebands from 20 to 70 DAE in 2009 for the different N-rate plots within six different potato fields

As observed in 2008, HNt CM values discriminate well the zero-N rate from the fertilized plots, excepted for field 6 (Fig.4) corresponding to a situation were no significant difference appears in final tuber yield between the three N-rate plots due to a high N supply from the soil. For fields 1, 2 and 9 (not represented in Fig.4), the discrimination was also very good. On the other hand, time-courses of ground-based reflectance values (Fig. 5) on the contrary do not discriminate the N-rates as well as HNt CM readings do for 8 of the 9 investigated fields. Moreover, fields 3, 4 and 6 of Fig.5 (and also fields 1, 2 and 9 not represented here) show particular ground-based reflectance time-courses that do no match with the HNt CM values time-courses (Fig. 4). As observed in 2008, coefficients of variation of the average ground-based reflectance values are also higher than those of the HNt CM average values.

The comparison of DN values in the G, R and NIR wavebands of single central pixels value leads to good discrimination between the N-rate plots as observed in 2008 (Fig. 6). The R and mainly the NIR wavebands are particularly discriminating between the reference 0N rate plot on the one hand and the 70% and 100%N on the other hand.

The variation of average DN value of same N-rate plots belonging to different fields is high for the three wavebands (Table 7) as observed in 2008.

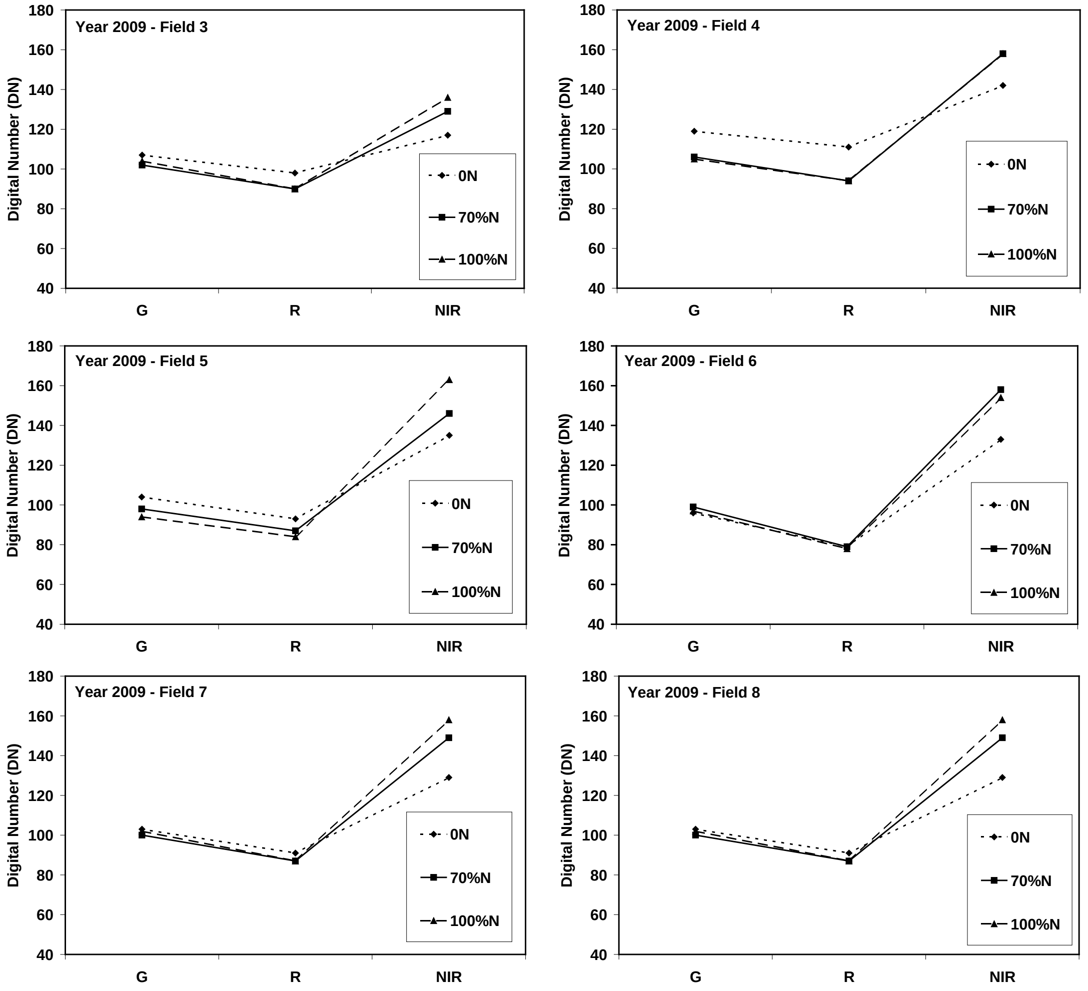

Figure 6: Spectral signature (single pixel DN value, n=1) of the potato canopy for the green (G), red (R) and near-infrared (NIR) wavebands within different N-rate plots of 6 fields extracted from SPOT5 satellite image of August 5th 2009.

Table 7 : Average DN values for the green (G), red (R) and near-infrared (NIR) wavebands and associated coefficient of variation extracted from SPOT5 image on August 5th 2009 within different N-rate plots across 6 fields

	Reference 0N			**70% of N-recommendation**			**100% of N-recomm.**		
	G	R	NIR	G	R	NIR	G	R	NIR
mean	104	93	136	99	86	153	99	85	157
cv (%)	7.8	12.0	10.6	5.0	7.6	10.1	6.1	8.2	7.9

DISCUSSION AND CONCLUSION

The results on SPOT 5 image DN values collected during both years of the current study show promise to perform in-season monitoring of potato crop nitrogen status using satellite observations. SPOT 5 DN values show indeed good sensitivity to discriminate the different N-rates across the whole canopy even considering a limited number of pixels demonstrating the possibility of SPOT 5 (spatial and spectral resolution) to monitor potato CNS. Significant discrimination is particularly obvious between reference 0N plots and fertilized plots, as previously observed with HNt CM readings, while discrimination between different N-rates of fertilized zones shows also realistic. Moreover average DN values across pixels of a same N-rate plot are affected by low coefficient of variation, as also observed for HNt CM mean values. Small sized reference plot (30x30m) seems also to be a credible approach to collect pertinent discriminating DN values. While confirmed in further trials, such results will be practically interesting from one operational point of view, as the use of as small as possible reference 0N plot seems to be requested within each field. Indeed, the large variation of average DN values across reference 0N plots belonging to different fields of a same area will not allow to base the monitoring of CNS within several fields on a unique 0N reference plot for all the fields of a given region or sub-region.

Ground-based reflectance radiometer readings also show potentialities but comparatively to SPOT 5 DN values, average ground-based reflectance values show quite higher coefficients of variation that could hamper accuracy and precision of the measurements, but also discrimination potentialities between N-rate plots. Such results could appear surprising comparatively to HNt CM readings, as ground-based radiometer readings operate on larger sampled areas. A major explanation to this weakness of radiometer readings is that soil reflectance interfere with canopy reflectance within the circular field-of-view of the Cropscan radiometer. For the potato crop phenological stages observed around end of July and start of August, SPOT 5 reflectance values appear to be less influenced by soil reflectance than radiometer observations, probably because satellite remote sensing with SPOT 5 concern higher spatial resolution and then larger global canopy areas within a given N-rate plot.

If one advantage in the use of SPOT 5 image is to allow a N monitoring over a whole field leading to average DN value over all the pixels or a single pixel within a given zone, a major limitation that appeared in this study was the low successful availability in the image acquisition within the required phenological period of the crop to perform CNS monitoring. For both years the image was acquired to late (after 50 DAE) due to bad weather conditions (clouds covering) or to competition with other users' acquisition requests (mainly official stakeholders) according to programming requests of image acquisition during the optimal 20 to 50 DAE period defined by the CRAW DSS.

Current results need to be confirmed in 2010, mainly because during the first part of the optimal phenological period for data acquisition, the crop inter-rows are not yet completely closed with the canopy, and then soil reflectance should probably interfere DN values. If confirmed, the transformation of G, R and NIR DN values into VI’s including soil reflectance interference, will help to lead to discriminate results as observed up to now. Another possibility to explore will be the acquisition of satellite images with a higher temporal resolution or with spectral resolution to study the red-edge region (690-730 nm) that seems powerful to predict CNS (Haboudane et al., 2000).

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