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MONITORING KEY AGRICULTURAL CROPS IN THE NETHERLANDS USING SENTINEL-1

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ABSTRACT

In this study, we performed ground validation to support the interpretation of Sentinel-1 imagery during a full growing season of five key crop types in the Netherlands. Crop height and growth stage were monitored weekly in a total of 25 parcels of maize, potato, sugar beet maize and English rye grass in the province of Flevoland. Hydrometeorological data were collected throughout the season. Here, these results are used to interpret time series of Sentinel-1 data processed for the province of Flevoland. Results demonstrate that Sentinel-1 data follow the phenological stages and can be used to identify key moments in crop development. Combined with the guaranteed availability of observations regardless of cloud cover, this makes Sentinel-1 data a valuable resource for agencies and commercial entities providing advice to farmers and agro-industrial co-operatives.

Index Terms— SAR, vegetation, agriculture, crop monitoring, radar

1. INTRODUCTION

Real-time information on crop development is essential for many users in the agricultural sector. Farmers use it to make informed crop management decisions, allowing them to optimize their use of resources, increasing their profits while minimizing their environmental impact. Agricultural advisors use it to identify under-performing fields or within-field anomalies, and to provide advice to increase yields and profit. Food producers use it for yield prediction, and planning the collection and processing of harvested crops.

The current abundance of high-resolution optical data offers unprecedented opportunities for real-time monitoring. However, its reliability in the Netherlands is severely undermined by cloud cover. Van der Wal et al. [1] used 20 years of daily weather station data from across the Netherlands to highlight the influence of cloud cover on the availability of optical imagery in the Netherlands. They showed that, even with partially clouded skies, there is just a 25% chance that a given field will appear in daily optical satellite imagery.

Radar offers a solution to the cloud cover challenge in the Netherlands, and is highly suitable for crop monitoring [2]. The two satellites of ESA's C-band Sentinel-1 Mission (Sentinel-1A and 1B) were launched in 2014 and 2015, respectively. They are in the same orbital plane providing an average revisit time of two days above 45° N/S and global exact repeat coverage every two weeks. Prior to their launch, many studies used Radarsat2 data to demonstrate the value of C-band polarimetric SAR for monitoring LAI, crop phenological state and biomass e.g. [3, 4, 5, 6]. More recently, Veloso et al. compared Sentinel-1 data to NDVI estimates from optical data and ground observations [7]. They demonstrated that Sentinel-1 data, particularly the VH/VV ratio, could yield useful information on crop development. However, radar is currently not exploited to its full potential in the Netherlands.

The goal of the current study is to demonstrate the value of Sentinel-1 data for monitoring the growth cycle of key Dutch crops. Weekly crop height, growth stage and soil moisture data were collected in 24 agricultural parcels across 5 crop types. These data will be used to interpret Sentinel-1 imagery collected during the 2017 growing season and will provide validation data against which to test innovative methods to track crop development.

2. DATA & METHODS

2.1. Study Area

The study was conducted in the Flevopolder, a region of reclaimed land which was drained in 1968. Figure 1 shows the location of the Flevopolder in the Netherlands, as well as the spatial distribution of the five crops considered. Soil at the surface is clay overlaying a sand layer at about 2m depth. Capillary rise from the shallow groundwater is a major stabilizing control on soil moisture. Weekly crop growth stage, crop height and soil moisture data were collected in 24 agricultural parcels on the Flevopolder. The crop types were were field maize (5 parcels), 5 sugar beet (5 parcels), potato (4 parcels), wheat (5 parcels) and English ryegrass (5 parcels).

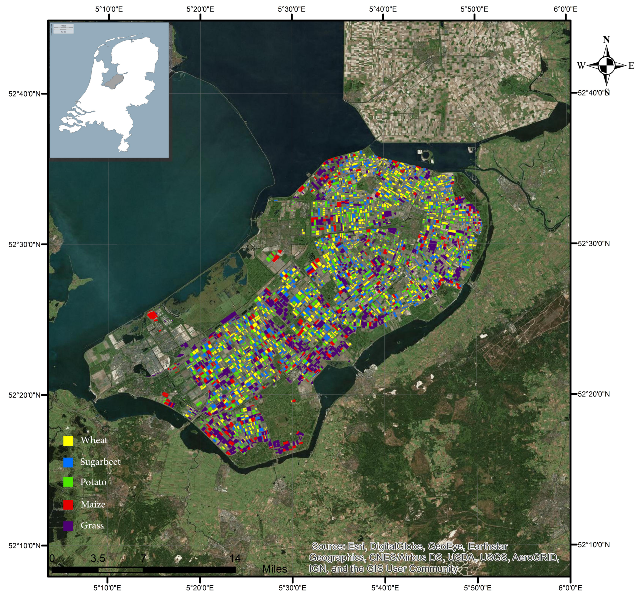

Fig. 1. Agricultural parcels in the Flevopolder.

2.2. Sentinel-1 data

The study takes advantage of the dense Sentinel-1 Interferometric Wide time series over the Flevopolder. Combining data from Sentinel-1A and 1B, the Flevopolder is covered by 4-5 tracks (See Table 1. Note: Track 110 was not considered because it only covers part of the domain). This provides an average of 20-25 acquisitions per month. The normalized cross section ($\sigma°$) time series in VV and VH were extracted from the GRD detection products. The processing chain includes the following steps: radiometric calibration, removal of thermal noise offset and orthorectification with radiometric correction for residual slope effects. Spatial multilooking is performed per parcel polygon. Hence, the radiometric resolution, or precision, for a single field depends on the field area. Typically, about 100 independent looks are available per hectare, resulting in a resolution of 0.5dB for a field of 1ha. Parcel polygons and crop types were determined from the Basisregistratie Gewaspercelen (BRP) [8].

Table 1. Sentinel-1 IW data available over the study area

Relative orbit	Pass	Local Time	Min. Inc. Angle [○]	Max. Inc. Angle [○]
37	DESC	06:49	38.9	41.9
161	ASC	18.32	44.7	46.1
88	ASC	18:24	36.6	40.4
15	ASC	18:15	30.0	31.5
110	DESC	06:58	30.0	33.7

2.3. Meteorological data

Meteorological data were collected every 15 minutes at a weather station installed at the Aeres Practijkcentrum Dronten (52.53N, 5.67E). Precipitation was measured using a Decagon ECH2O Rain Model ECRN-100 tipping bucket. Total solar radiation was measured using an Apogee SP-212 pyranometer.A Davis Cup anemometer was used to measure wind speed (m/s), wind direction [°] and gust speed (m/s) at a 15-minute interval. A HOBO Temperature/RH Smart Sensor (S-THB-M008) was installed to measure air temperature and relative humidity. Decagon Dielectric Leaf Wetness Sensors were used to monitor plant surface water (dew/interception).

2.4. Ground data at the 24 parcels

In each of the 24 parcels, two sampling locations were identified and marked at the start of the growing season. The sampling locations were located 20 m from the field edge to avoid edge effects. These sites were visited approximately once per week. Soil surface roughness parameters (root mean square (rms) height and the correlation length (L)) were determined using digital photos of a grid board during the bare soil period for the maize, sugar beet, potato and wheat fields. Surface soil moisture at each of the 24 fields was measured using ML3 ThetaProbe Soil Moisture Sensors [9]. The parcel's soil moisture was estimated as the average of eight measurements, four at each sampling location. Crop growth stage was determined by visual inspection, based on the BBCH scale[10, 11]. Crop height was measured, and photos were taken to record the development stage and closure.

3. PRELIMINARY RESULTS

3.1. Meteorological data

Cumulative precipitation and daily average air temperature during the growing season are shown in Figure 2. The growing season started with two hot, dry periods in May and June. Rainfall occurred on more than 70% of days between 27th June and the end of the season. September was particularly wet, with more than 150 mm rain. Meanwhile the temperature dropped considerably. Surface soil moisture measurements (not shown) reflect well-watered growing conditions from July onwards.

3.2. Sentinel-1 data

Sentinel-1 VV and VH backscatter and VV/VH ratio for each crop type are shown in Figures 3 to 7. These data correspond to the spatial averages of the 1286 grass parcels, 1048 wheat parcels, 763 sugar beet parcels 886 potato parcels and 335 maize parcels identified across the Flevopolder. Data are plotted from January to November 2017. From January to March, when the soil is bare, the VV and VH backscatter is similar

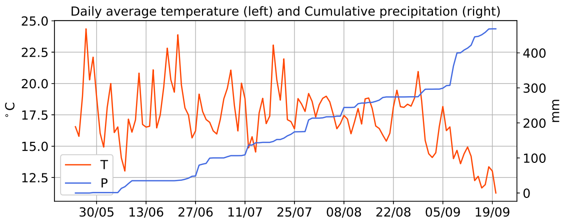

Fig. 2. Precipitation and air temperature measured at our weater station in Dronten (52.53N, 5.67E)

across all crop types except grass. Some grass cover persists throughout the year, and mowing patterns vary considerably. Hence, beyond the slow increase in backscatter from April onwards, the main variations are due to precipitation events (Figure 3).

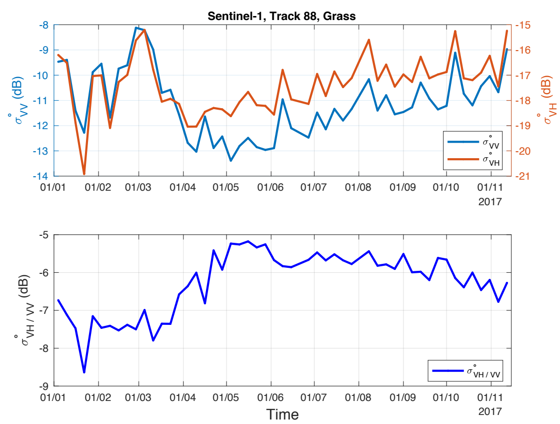

Fig. 3. VV and VH backscatter (top) and VV/VH ratio (bottom) averaged across 1286 grass parcels in the Flevopolder

In wheat (Figure 4), the time series of VV, VH and VV/VH ratio are quite different to those observed by [7], which may be due to differences in soil moisture during the tillering and elongation stages. The backscatter does not decrease due to senescence in July, which might be related to the persistent precipitation during this month. A sharp decrease in backscatter was observed when the wheat was harvested around 10 July.

Rapid leaf development in the sugar beet parcels produces a sharp increase in VV backscatter between the emergence of the first leaves around 4 May, and the closure date around 17 June. The VH/VV ratio decreases during senescence from August onwards. The harvest is difficult to distinguish from the influence of precipitation events in this spatially-averaged dataset.

In the potato parcels (Figure 6), there is a rapid increase in VV and VH after the emergence of the first leaves around 9 May. The backscatter and VH/VV ratio stabilize when the plants are fully grown (4th July). Potato haulming results in

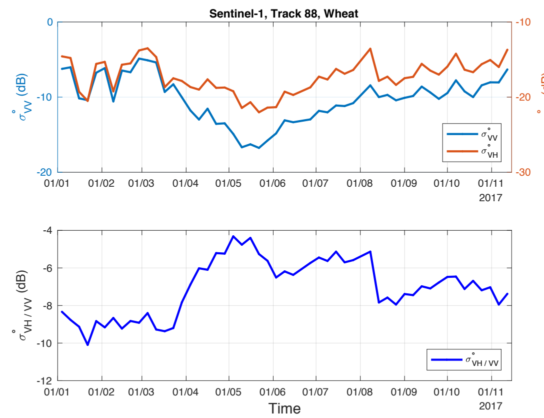

Fig. 4. VV and VH backscatter (top) and VV/VH ratio (bottom) averaged across 1048 wheat parcels in the Flevopolder.

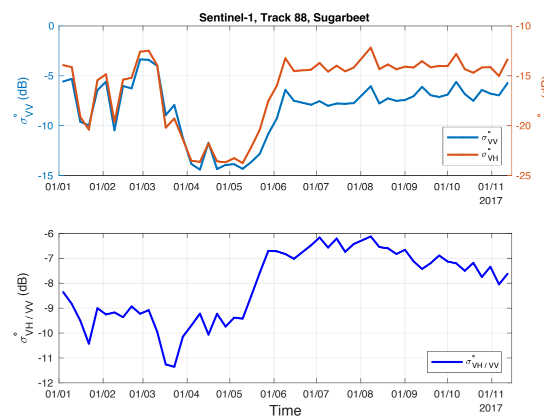

Fig. 5. VV and VH backscatter (top) and VV/VH ratio (bottom) averaged across 763 sugar beet parcels in the Flevopolder.

a decrease in backscatter and a sharp dip in VH/VV ratio in mid-September. The disturbance due to harvest is clear in mid-october.

VH backscatter, and the VH/VV ratio are good indicators of maize biomass accumulation. VH increases from -22.5dB to -15dB from between the emergence of the first leaves around 14 May and 1 August, when the maize reached its maximum height. The VH/VV ratio seems to correspond to water content, as it decreases during senescence in August and September. Harvest, in the first half of October, resulted in a drop in backscatter followed by an increase in sensitivity to soil moisture.

4. CONCLUSIONS

Preliminary results presented here illustrate that VV, VH and the VH/VV ratio reflect changes in wet biomass and struc-

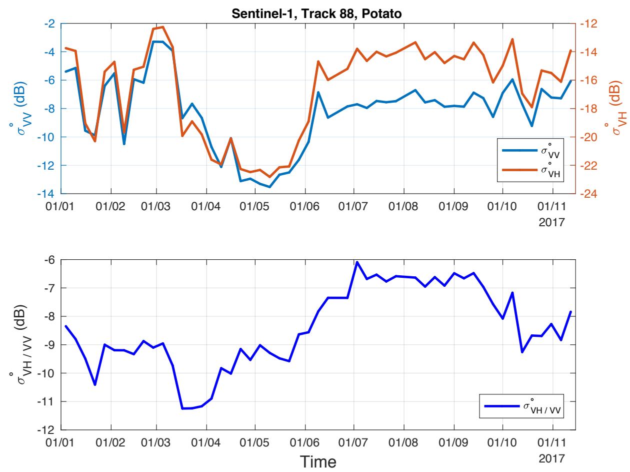

Fig. 6. VV and VH backscatter (top) and VV/VH ratio (bottom) averaged across 886 potato parcels in the Flevopolder.

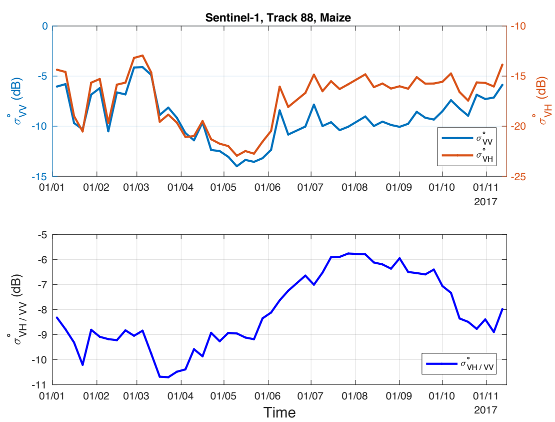

Fig. 7. VV and VH backscatter (top) and VV/VH ratio (bottom) averaged across 335 maize parcels in the Flevopolder.

ture as the plant develops and can be related to phenological stage for these five important crops for the Netherlands. The prevalence of rainy (and cloudy) conditions during this growing season underscore the potential value of using radar by itself, or combined with optical data, for crop monitoring in the Netherlands. A more detailed analysis at a parcel level will be used to explore spatial variability in the growth curves for each crop type.

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