SUGARCANE GROUND REFERENCE DATA OVER FOUR FIELDS IN SÃO PAULO STATE

Document created: 23/02/2016 by R.A. Molijn.

INTRODUCTION

This document is meant as a guide to the dataset and gives an insight into the methodology of the acquisition of the measurements. If there are any questions, one can email me on r.a.molijn@tudelft.nl or ramolyn@gmail.com.

FOLDER AND FILE DESCRIPTION

For description of the methods and meaning of the measurement taken, see next section.

- /Layers/
  - Fields.*: polygons of the sugarcane fields that were measured
- /Layers/ESUs/
  - Biomass ESUs.*: polygons of the ESUBs (for description of meaning, see next section)
  - Point_ESUs.*: points of the ESUs (for description of meaning, see next section)
- /Layers/Photo Layers/
  - Folders with photo shapefiles that were taken in the field during measurements corresponding with the geotagged photos in */Ground Observations/Measurements/Photos/*
- /Ground Observations/Measurements/Biomass and water content/
  - Plant water content information at different dates.
- /Ground Observations/Measurements/Biophysics/
  - Biophysics_IM_VARIATIONS.xlsx: the intensive measurements of two dates
  - Biophysics_processed_detailed.xlsx:
    - IM: the intensive measurements taken spatially on 19/12/2014, including repetitive measurements
    - Detailed: the raw measurements from the fields
    - Processed: the averaged measurements per ESU and ESUB from the fields
    - It has to be noted that possible outliers are not removed from the dataset. In tab 'Processed' the averages are taken of the available data without filtering. In the 'notes' column some remarks are given when suspicious data is present.
- /Ground Observations/Measurements/LAI Original/
  - The original LICOR LAI-2000 files. The 'original' files contain the raw txt output, the 'corrected' files contain the calibrated output by the FV2200 software
- /Ground Observations/Measurements/Descriptions/
  - Text files with quick description of conditions during the measurements, when applicable
  - Fields overview.docx with description of the fields

- /Ground Observations/Measurements/GPS/
    - The GPS points that were taken in the field at the ESUs and ESUBs.
- /Ground Observations/Measurements/Photos/
    - The photos taken in the field. Most are geotagged.
    - */20141219_LAI_Validation_Photos/* and */20150714_LAI_Validation_Photos/* contain the ground reference pictures from green leafs taken off the sugarcane plants which are compared to the measured LAI by the LICOR LAI-2000 device. The document *TrueLAI_measurements.docx* shows the results of this verification process.
- /Ground Observations/Measurements/Precipitation/
    - Preliminary precipitation information of weather stations in the vicinity of the sugarcane fields.
- /Ground Observations/Protocols/
    - Illustrations of the protocols and measurement forms.

STUDY SITE AND DATA DESCRIPTION

The map delineating the overview of the sugarcane fields study area is illustrated in FIGURE 1. TABLE 1shows the characteristics of the fields.

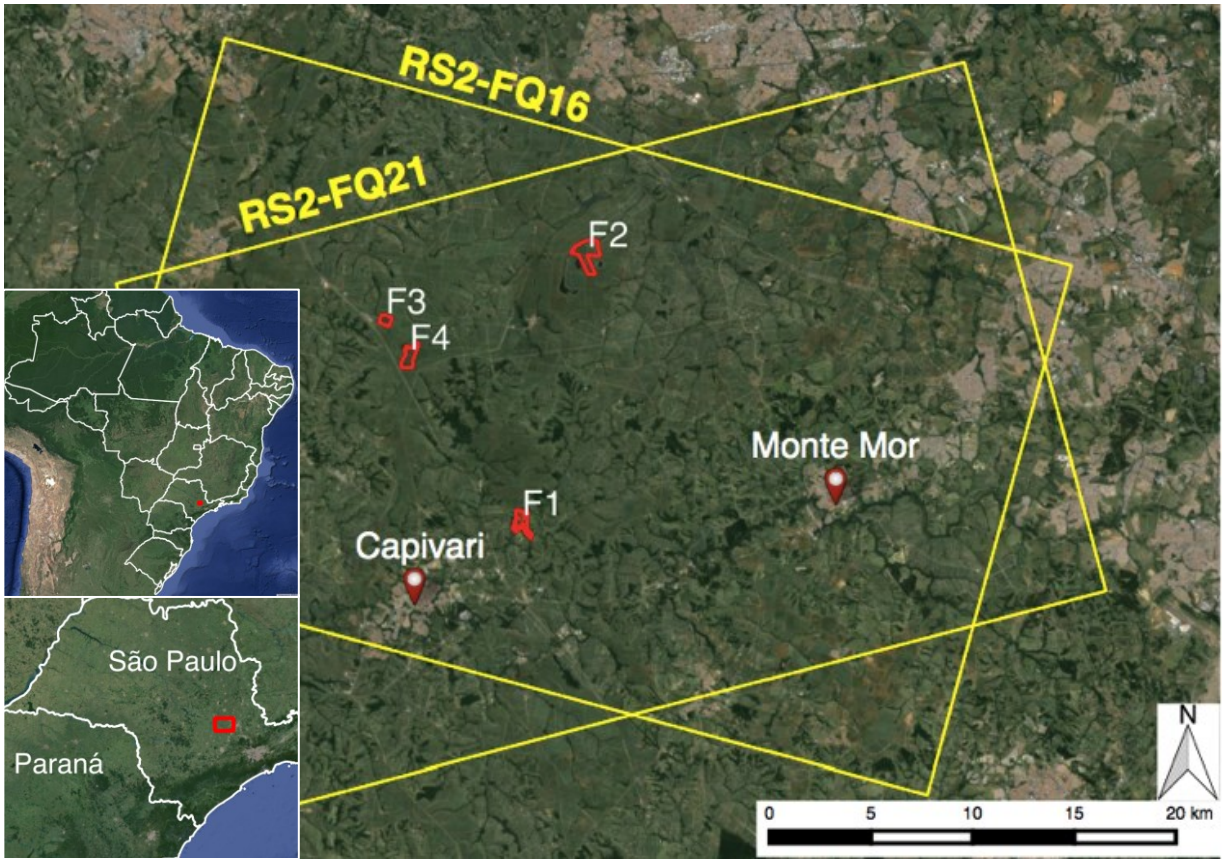


FIGURE 1: OVERVIEW OF STUDY AREA 2 WITH THE RADARSAT-2 (RS2) FOOTPRINTS USED FOR THE SUGARCANR ANALYSIS. THE RED POLYGONS INDICATE THE VISITED FIELDS (DENOTED BY F AND THE FIELD NUMBER).

FIELD NAME	VARIETY	RATOON	AREA [HA]	START OF GROWTH	HARVEST
F1	RB867515	1ST CYCLE	58	30/10/2014	07/10/2015
F2	SP80-3280	1ST CYCLE	115	14/10/2014	07/12/2015
F3	SP80-3280	2ND CYCLE	25	15/08/2014	26/07/2015

F4	SP80-3280	9TH CYCLE	59	01/08/2014	21/07/2015

TABLE 1: SUGARCANE FIELDS CHARACTERISTICS.

FIGURE 2 shows the remote sensing acquisitions and the field campaigns, whereby a distinction is made between elementary sampling units (ESUs) of which only biometrics are taken and elementary sampling units biomass (ESUB) of which biometrics, soil moisture and plant moistures are taken.

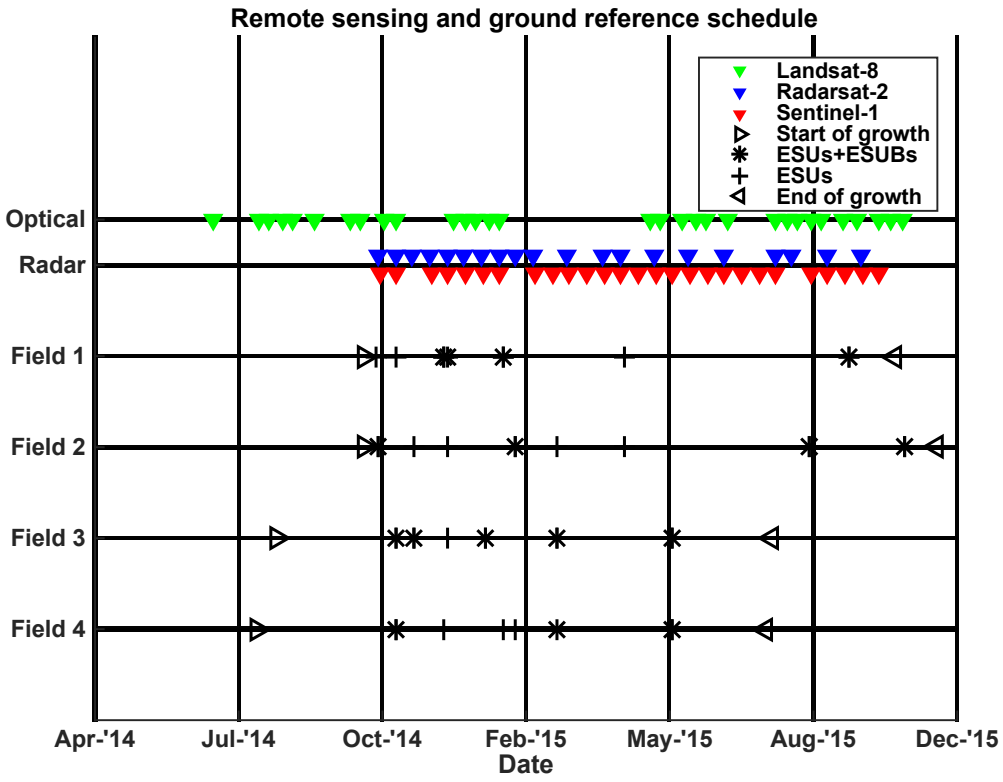


FIGURE 2: REMOTE SENSING AND FIELD CAMPAIGNS ACQUISITIONS SCHEME FOR THE SUGARCANE RESEARCH. 'F' DENOTES FIELD, 'ESU' THE ELEMENTARY SAMPLING UNIT, 'B' BIOMASS.

The fields are owned by the Brazilian Raizen group, which required supervision by an employee during any of the measurements in the fields. FIGURE 3 illustrates the methodology for taking the measurements, which will be referred to in the following sections.

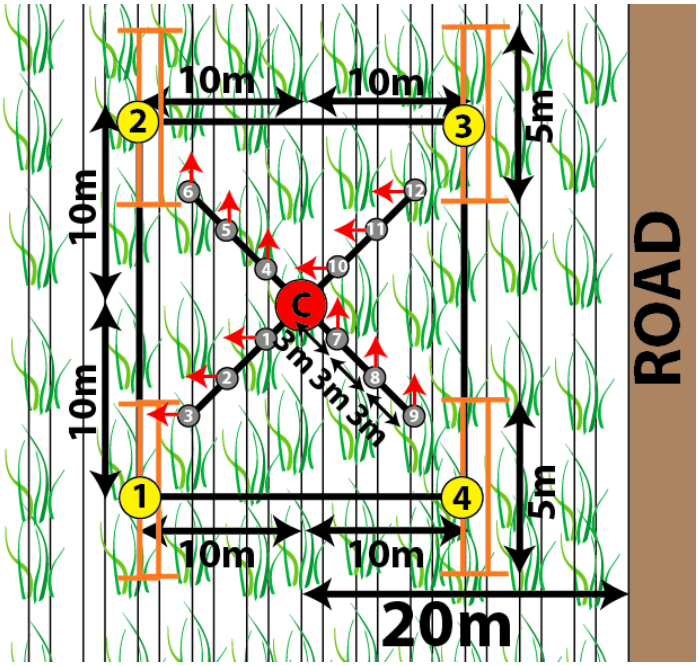


FIGURE 3: SCHEMATIC OVERVIEW OF THE ESU MEASUREMENTS. THE LAI MEASUREMENT IS TAKEN AT 12 DIFFERENT LOCATIONS (GREY CIRCLES) IN FOUR DIFFERENT DIRECTIONS (RED ARROWS) AROUND THE CENTER POINT (C), WHICH LIES ABOUT 20 METER FROM THE ROAD. THE BIOMETRIC MEASUREMENTS ARE TAKEN AT POINTS 1 TO 4 (YELLOW CIRCLES), INCLUDING THE NUMBER OF PLANTS AND STALKS ALONG TWO ROWS SPANNING 5 METERS (ORANGE LINES).

LEAF AREA INDEX (LAI)

A LICOR LAI-2000 Plant Canopy Analyzer with the default calibration values as reported in the LAI manual (LI-COR, 1992) was used with the FV2000 software package for extracting the values from the device. For determining our measurement campaign the same manual and (Leroy et al., 2013) were consulted.

During the growth stage of the sugarcane (until ~2m stalk height), the LAI measurements are taken from the middle of the ESU in four different directions with one above canopy measurement followed by three below canopy measurements for every direction. After this period, when we assume the canopy coverage is planar isotropic, the LAI measurements are taken with one above canopy measurement followed by nine below canopy, all of them in row direction divided over three rows. As for the precise placement of the sensor for all below canopy measurements, the distance to the plants was taken into account, i.e. per set of three measurements one measurement was taken adjacent to the cane, one at one third of the row spacing and the last at two third of the row spacing. For both techniques the same schematic holds as illustrated in FIGURE 3. Also the climatic conditions were taken into account by retaking above canopy measurements when clouds were moving.

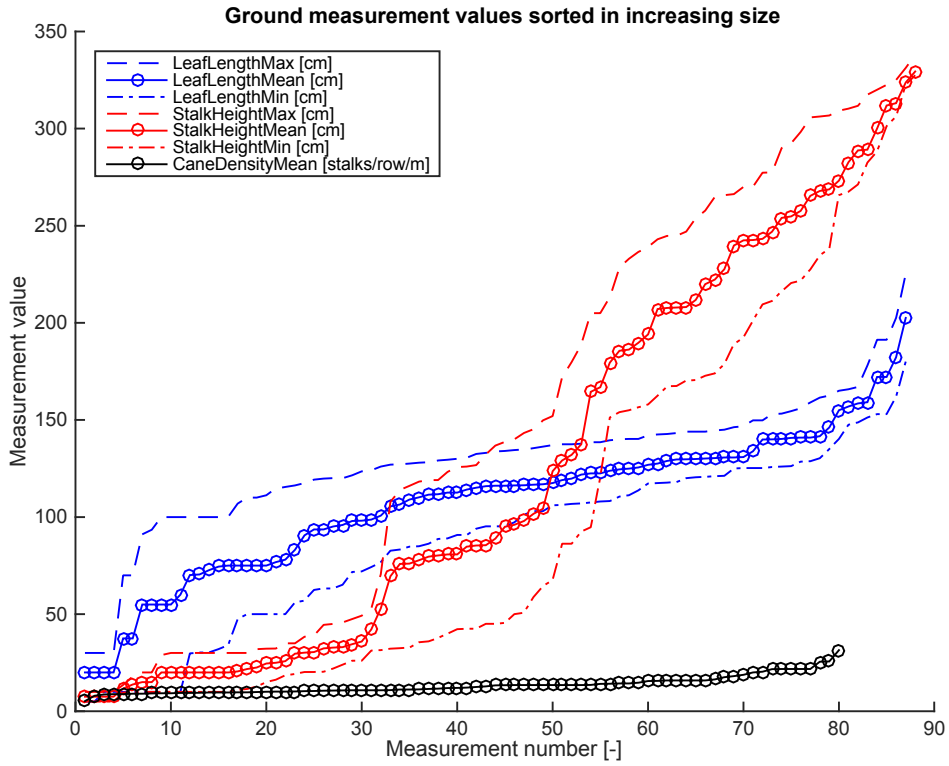
BIOMETRICS

At all four points the following biometric measurements were taken:

- Stalk heights of highest and on average smallest cane. The stalk height is here defined as the length from the stalk at ground level to the crown of the upper leafs.
- Stalk thicknesses of same canes, taken at the stalk at ground level.

- The longest leaf lengths of the same canes.
- Number of canes and plants per meter by counting the number of canes and plants over five meter distance for two adjacent rows.

The highest cane and on average smallest canes were selected by eye. Small canes unrepresentative for the sugarcanes at the measurement location were not taken into account, for example sprouting canes amongst mature canes. In addition to the biometrics, photos embedded with the geo-location were taken for spatial verification and for checking the leaf angle distribution in an eventual later stage when needed.



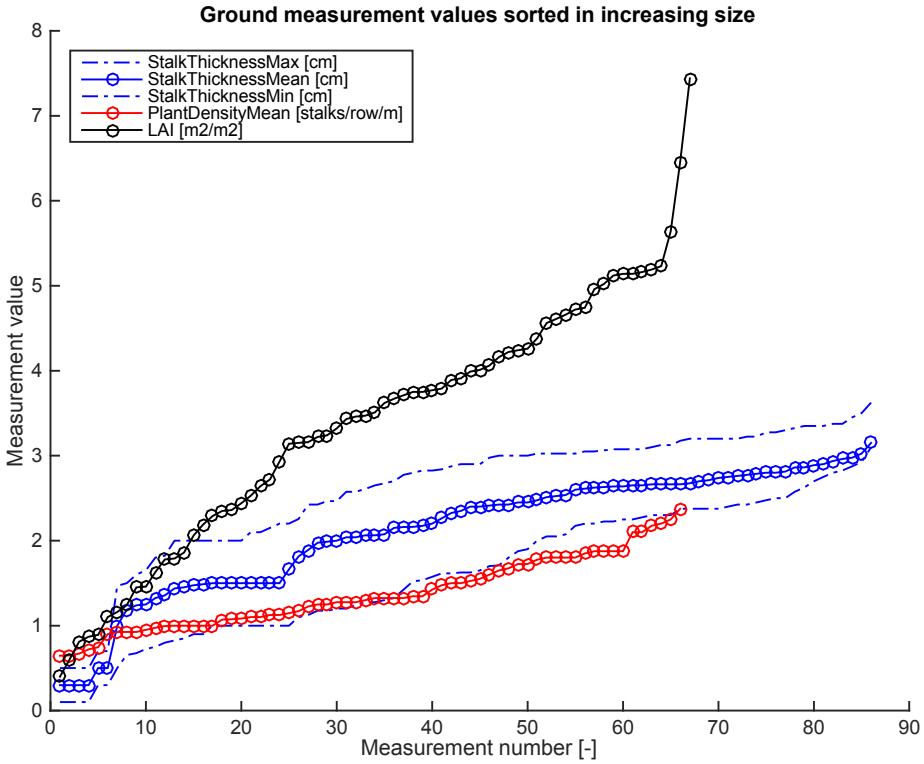


FIGURE 4: THE BIOMETRICAL MEASUREMENTS ACQUIRED IN THE SUGARCANE FIELDS SORTED IN ASCENDING ORDER.

FIGURE 4 shows the biometrical measurements over the number of measurement in ascending order. It shows that there is a fairly gradual increase in measurement value, without evident jumps. One should keep in mind that the measurement number is not connected with time and there can no relation between the different measurements extracted from this figure.

BIOMASS & SOIL MOISTURE

In order to minimize destructive measurements at the ESU's and hence bias our remote sensing signals, biomass ESU's (ESUB's) were selected. Four soil moisture percentage measurements were taken in a radius of 5 meters around the ESUB's center using a Falcker HidroFarm HFM2010 device. In addition, four whole plants (containing generally between 10 and 20 canes) were cut at ground level and the number of canes per plant was counted. The stalk heights, stalk thicknesses and leaf lengths were measured per plant similarly as described above. The weight of the entire plants was measured separately and combined with the number of canes the average and variation in cane weight can be computed. Per plant the highest and on average smallest canes were selected and combined, considered as a representative subset of the four plants. Leafs are then separated from the stalks and weighed separately. From the remaining canes of the fours plants, the stripped leafs and stalks are separately grinded into centimeter-sized pieces, a sample was taken, weighed and dried in the oven at 65°C for 72 hours. The complement of the ratio between the mass of the dried and the mass of the wet samples gives the wet matter content, i.e. computed individually for the leafs, stalks and four different plants.

INTENSIVE MEASUREMENTS

In order to assess the reliability of the field measurements, for two dates intensive measurements were carried out. These consist of repeating every measurement type, as if the same location was visited and measured independently and uncorrelated to the other visits.

One specific location was measured five times consecutively using the same methodology for LAI, leaf lengths, stalk heights and thickness, cane and plant densities and soil moisture. As such the congregate of the device's measurement error and the variability in picking the same feature is estimated.

	19/12/2014	14/07/2015	18/09/2015
LEAF LENGTH SAME [CM±CM/%]	38±1.1/3	155±3.6/2	158±1.8/1
LEAF LENGTH MIN [CM±CM/%]	40±10.4/26		
LEAF LENGTH MAX [CM±CM/%]	131±4.9/4		154±11.4/7
STALK HEIGHT SAME [CM±CM/%]	19±0.8/4	299±10.2/3	347±11.8/3
STALK HEIGHT MIN [CM±CM/%]	19±2.6/14		
STALK HEIGHT MAX [CM±CM/%]	41±5.6/14		328±25.9/8
STALK THICKNESS SAME [CM±CM/%]	1.7±0.2/10	3.0±0.2/7	4±0.3/9
STALK THICKNESS MIN [CM±CM/%]	0.9±0.2/21		
STALK THICKNESS MAX [CM±CM/%]	2±0.2/8		4±0.4/11
CANE DENSITY [STALKS/ROW/M± STALKS/ROW/M/%]	16±0.8/5	14±4/29	
PLANT DENSITY [PLANTS/ROW/M± PLANTS/ROW/M/%]	2±0.4/22	4.0±0.6/17	
LAI [-±-/%]	1.3±0.17/13	3.0±0.2/7	3±0.4/12
SOIL MOISTURE SAME [%±%/%]		16±2.1/13	19±0.6/3
SOIL MOISTURE DIFFERENT [%±%/%]	14.8±1.6/11	12±1.7/15	28±5.8/20

TABLE 2: MEASUREMENT VARIATIONS THROUGH REPEATED MEASUREMENTS

TABLE 2 shows the measurement variations. For LAI, the bias between measured LAI and true green LAI was determined as follows. The LAI was measured with the LI-COR instrument for a two rows (i.e. 0.9m+1.5m) by 2m area in four different directions and three measurements per direction with spacing of one meter (instead of three meters as for the ESU measurements). For this area all plants were cut and the green leafs were stripped from the canes, which were then placed on a white sheet. Through simple supervised classification with ENVI software the area of the green leafs was divided by the total area, i.e. 2.4m x 2m. The average of the differences between the measured and observed LAI observed at the two dates was subtracted from the LAI measurements. This was carried out at the first two dates of TABLE 2.

For the measurements variations of the maximum and minimum leaf lengths, stalk heights and stalk thicknesses the same location was visited five times on the same day. The same measurements denoted by 'same' refer to the biometrics taken at exactly the same plant, in order to determine the device operation measurement error, in this case the measurement tape and a caliper rule. The soil moisture's 'same' and 'different' indicators refer to measurements at exactly the same location and surrounding locations within 3m, respectively.

FIELD VARIABILITY

One other important quantity to take into account is the field variability, which is used to assess the variability one can expect when measuring approximate and different locations. One WorldView-2 image acquired at 15 January 2015 was bought for the sugarcane fields, of which one field is shown in FIGURE 5, with the following characteristics:

- Bands: 8 Multispectral (4 standard colors: red, blue, green, near-IR), 4 new colors: red edge, coastal, yellow, near-IR2
- Resolution multispectral: 1.84 meters Ground Sample Distance (GSD) at Nadir, 2.4 meters GSD at 20° Off-Nadir

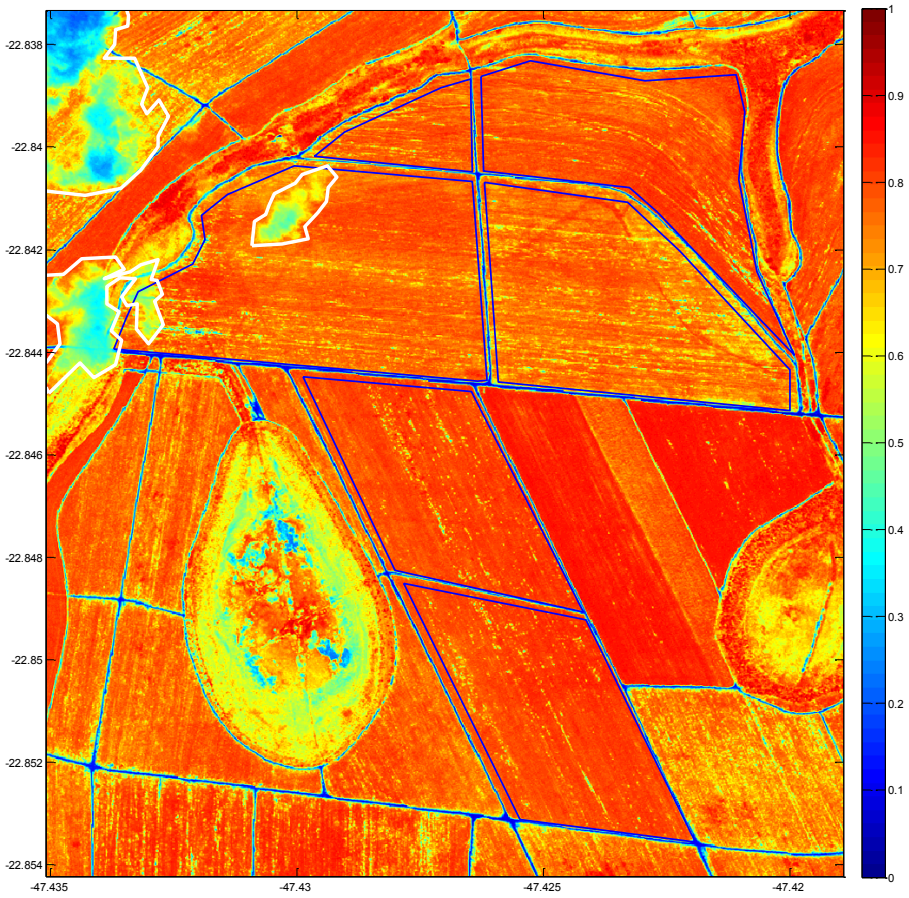


FIGURE 5: WORLDVIEW-2 NDVI IMAGE TAKEN AT 15/01/2015 FOR ONE SELECTED SUGARCANE FIELD. THE BLUE LINES SHOW THE INTRA-FIELD ROADS.

From this figure, a variogram is made, shown in FIGURE 6. The field is divided into five subfields as shown by the blue polygons in FIGURE 5 in order to prevent introducing biases due to low NDVI values at roads. Considering the overall result, the variogram shows that the standard deviation around the pixel resolution (~2m) is 0.035 and around the GPS location accuracy (~4m) is 0.045. With the preliminary result of ground measurements (LAI of zero at NDVI of zero and LAI of 4 at NDVI of 0.8) and assuming a linear trend, these standard deviations come down to 4/0.8*0.035 = 0.18 and 4/0.8*0.045 = 0.23, respectively. Both are similar to the standard deviation of the measurements. When assuming constant variability, this means that if a location error is made of 4m the LAI measurement can vary between 0.6 to 2.0 when the field has an average LAI of 1.3 and between 2.3 and 3.7 when the field has an average LAI of 3.0. When relating LAI to remote sensing indicators, this will be taken into account. The sill of the variogram is around 0.055 with a range of 50m, meaning that one can expect a LAI deviation of 4/0.8*0.055 = 0.28 at distances greater than 50m. One should note though that no anisotropy has been taken into account, which in this case is an ambiguous assumption given the non-uniform distribution due to the row-plantations and low vegetation (see for qualitative indication FIGURE 5).

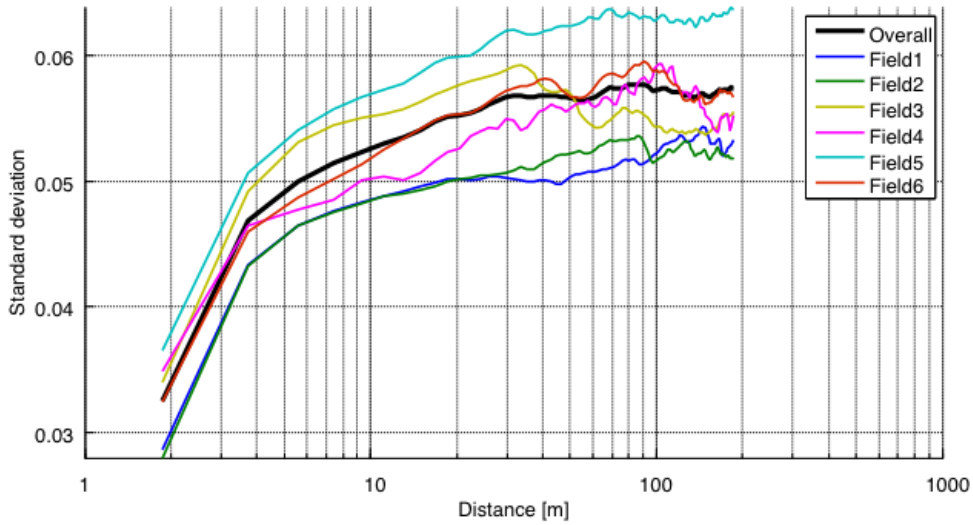


FIGURE 6: VARIOGRAM OF ONE SUGARCANE FIELD, DIVIDED INTO FIVE SUB-FIELDS, BASED ON NDVI VALUES.