# DEMMIN – a test site for the validation of Remote Sensing data products. General description and application during AgriSAR 2006.

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## ABSTRACT

This paper gives an introduction to the agricultural test site DEMMIN which is operated by DLR-DFD since 1999. The paper provides a description of the specific characteristics of the area, the existing data base and its in-situ measuring instrumentation.
During the AgriSAR campaign in 2006, numerous airborne radar and optical data sets were acquired over the north-eastern part of DEMMIN. All airborne data acquisitions were accompanied by intensive ground measurements which were carried out by the international AgriSAR team. This paper outlines the contribution of DLR-DFD Neustrelitz which was involved in weekly measurements of vegetation and soil parameters in close cooperation with the Leibniz-Center for Agricultural Landscape Research (ZALF) Müncheberg. The acquired ground data set is presented and discussed in terms of spatial variations and temporal evolution. Data accuracy is evaluated and potential sources of error are pointed out.

## INTRODUCTION

Sustainability is by now generally accepted as the paramount objective of human activities. An essential precondition for the analysis and the sustainable management of environmental resources is the knowledge of biophysical or physicochemical parameters and their spatial distribution. With respect to the growing demand for reliable information on the status of our environment, conventional methods of in-situ data collection alone can no longer satisfy our needs. On the other hand, earth observation from space has become an outstanding tool for the retrieval of environmental parameters, especially with regard to their spatial and temporal dynamics. Diverse environmental applications of Earth observation have been successfully demonstrated over a wide range of monitoring activities, mostly with the aim of measuring the spatial distribution and time course of different physicochemical parameters. This development has been confirmed and encouraged with the set off of the European GMES (Global Monitoring for Environment and Security) initiative. To assure and to quantify the reliability of satellite products that are now routinely generated and to approve new algorithms and methods, validation is mandatory. The establishment and long-term operation of test sites therefore an important role for the successful application of earth observation data.
This paper introduces the agricultural test site DEMMIN (Durable Environmental Multidisciplinary Monitoring Information Network) in north-eastern Germany, operated by the German Aerospace Center (DLR). In the first section, the characteristics of the test site, its objectives and the existing data base will be outlined. The second part focuses on the ESA funded campaign AgriSAR 2006 on the test site DEMMIN. This campaign was carried out in support of ESA's future Sentinel-1 and -2 missions within the framework of GMES to collect in-situ, airborne SAR and optical measurements as well as satellite data for geophysical algorithm development, validation activities, and the simulation of future spaceborne earth observation missions. Hereafter, ground data sampled by the DLR-DFD during weekly measurements are presented. The applied sampling methods and the derived data base are described and discussed in terms of reliability.

## DESCRIPTION OF THE TEST SITE

The DEMMIN test site is located in Mecklenburg-Western Pomerania in North-East Germany, approximately 80 km north of Neustrelitz and 220 km north of Berlin (Fig. 1). The test site extends from 54°2′54.29″ N, 12°52′17.98″ E to 53°45′40.42″ N, 13°27′49.45″ E. The landscape belongs to the north german lowlands formed during the last Pleistocene period (Pommersches stadium). It is characterized by glaci-fluvial and glaci-limnic deposits, and moraines which are reflected in a slightly undulating relief. Soil substrates are dominated by loamy sands and sandy loams alternating with pure sand patches or clayey areas.

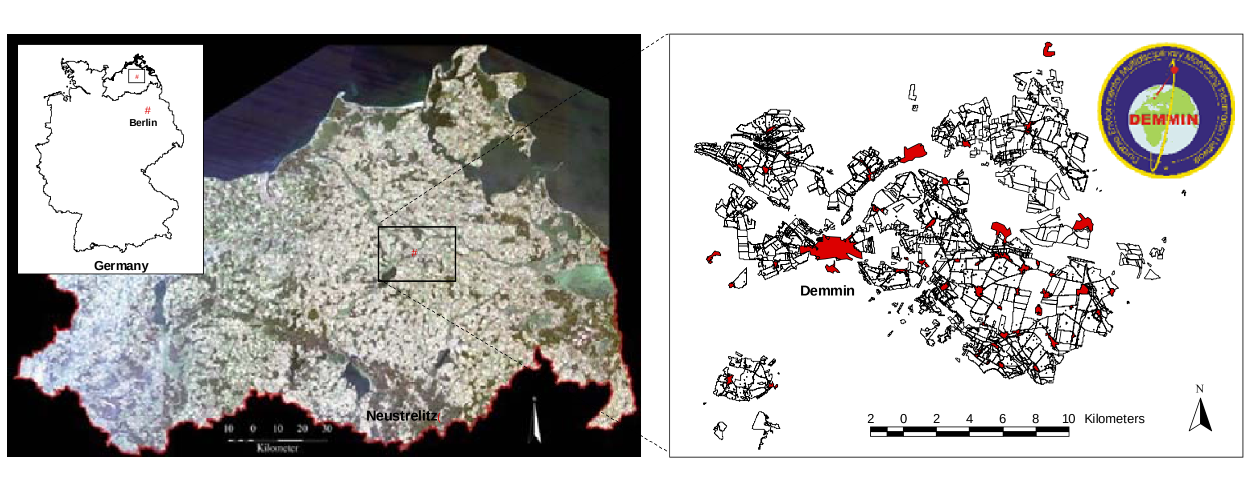


Fig. 1. Location of the DEMMIN test site. Landsat TM Image of Mecklenburg-Western Pomerania with DEMMIN (left) and agricultural fields of IG Demmin (right).

The altitudinal range within the test site is around 50 m with some slopes of considerable gradients (12 °) along the Tollense River in the southeastern part of the test site. Mean annual temperatures vary from 7.6 to 8.2 °C. Precipitation ranges from about 650 to 500 mm [1]. Due to micro-relief, climate conditions may vary significantly on a local scale.
The test site has been established in 1999 closely linked to a cooperation of DLR and the Interest Group Demmin (IG Demmin), an association of local farmers. The IG Demmin consists of 5 limited and joint stock agricultural companies covering approximately 25.000 ha of agricultural fields. Field sizes in this area are very large, averaging 80 - 100 ha. The main crops grown are winter crops covering almost 60 % of the fields in the area. Maize, sugar beet and potatoes make up about 13 % (Table 1).

## DEMMIN DATA BASE

Since the kick-off of DEMMIN in 1999, the data base successively expanded over the years. On the one hand, farmers annually provide new precision farming information such as yield and nutrient maps. On the other hand, the data base broadens during various research activities accompanied by airborne image acquisition and ground measurements. Therefore, a large number of data are now available. The data base can be subdivided in digital quasi-static-data, data derived from precision farming (digital dynamic data) and data from previous campaigns and monitoring activities. Table 2 gives an overview of the current state of the DEMMIN data base.
Since 2004, a network of 15 agro-meteorological stations is operated on the test site. It comprises the following atmospheric and soil science instruments: two pyranometers to measure up- and downwelling short-wave radiation, two pyrgeometers for up- and downwelling long-wave radiation measurements, devices for the measurements of relative air

Table 1. Typical crops with their approx. share 2005 and sowing and harvest dates on the DEMMIN test site.

| **Crop** | | **Area 2005** | **Sowing -Harvest Dates** |
|---|---|---|---|
| Winter crop | Winter wheat | 59.6 % | Mid September/early October - early August |
| | Winter barley | | Mid September - mid July |
| | Winter rape | | Mid-end August - mid July |
| | Winter rye | | |
| Root crops | Maize (for silage) | 12.7 % | End April - mid September/end October |
| | Sugar beet | | End March/mid April – October |
| | Potatoes | | End March/mid April – September |
| Others | Meadow<br>Pasture<br>Set-aside | 27.7 % | |

moisture, air temperature, leaf moisture, wind direction and speed in 2 m height, an electronic rain sensor, soil moisture C-Probes at 0, 5, 15, 20 and 50 cm depth and soil temperature sensors at 10, 30 and 90 cm depths. Stations are uniformly distributed on the test site that guarantees access to local weather conditions and variability. Measurements are usually taken every 15 minutes, though the sampling rate of the precipitation device is programmable. It can be adjusted for example to heavy rainfall intensities if a high temporal resolution is required. All measurements, agrarian meteorological and soil data are transmitted automatically to a receiving station and a data server.

Table 2. Overview of DEMMIN data base

| Category | Data |
|---|---|
| Digital quasi-static data | - Geological maps<br>- Soil maps<br>- Hydrological maps<br>- Agricultural field maps<br>- Digital Elevation Model |
| Digital dynamic data | - Annual yield maps (Combine measurements)<br>- Annual nitrogen-sensor measurements (Track measurements)<br>- Annual application maps<br>- Macro and micro nutrients<br>- Measurements of vegetation stages |
| Campaign data I (In-situ data or equivalent data) | - Destructive measurements for determination of leaf area and leaf area index (since 2004)<br>- Biomass measures (dry and wet),<br>- Nitrogen measures,<br>- Photographical documentation for measuring crop height and crop density<br>- Spectrometric measures on ground |
| Campaign data II (airborne data) | - Annual hyperspectral airborne campaigns (e.g. HyMap)<br>- Simultaneous ground measurement program for data validation, e.g. spectrometer measurements, vegetation parameters |

## DEMMIN WITHIN AGRISAR

The AgriSAR campaign 2006 focused on the north-eastern part of DEMMIN, the farmland of Görmin (Fig. 2). Fields are very flat in the area with few depressions and topographic variations. Main soil textures range from loamy sand to strong loamy sand on monitored fields.

DLR-DFD Neustrelitz accomplished two tasks during AgriSAR. That was the local coordination, such as arrangements for ground measurement teams, meetings with farmers, communication of relevant news such as field applications, and transfer from and to the test site. Beyond, the team was involved in a weekly measurement program in close cooperation with the Leibnitz-Center for Agricultural Landscape Research (ZALF) Müncheberg. Data sampled during these weekly measurements and first results are presented and discussed in the following section.

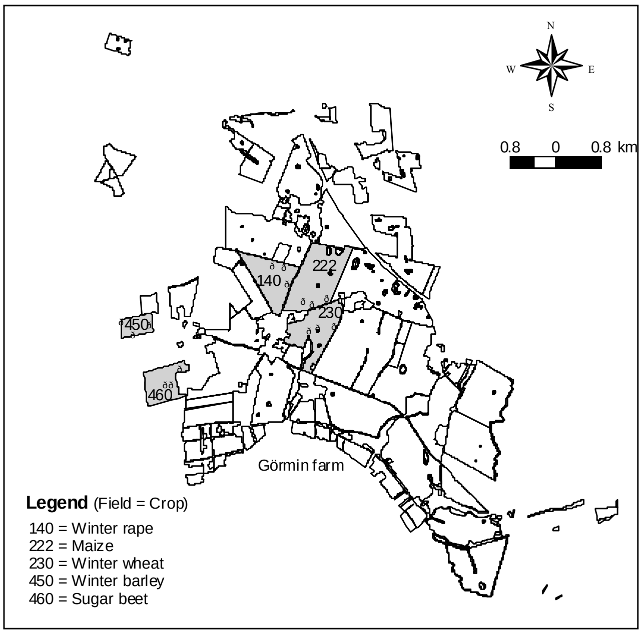


Fig. 2. AgriSAR test site on Görmin farmland as part of DEMMIN with sampling locations of DLR-DFD/ZALF during weekly measurements. Sampled fields are colored in grey.

## Methods and data

The localization of sampling points for weekly measurements was undertaken during a field inspection in the run-up of AgriSAR in March 2006. Sampling points were identified in the field with assistance of preliminary information on soil substrates and topography based on maps, adjusting pre-selected positions on-site to local conditions. This procedure was chosen to find the best trade-off between within-field heterogeneity and a feasible number of sampling locations. In total, 15 locations on 5 fields with three sampling units per field were set up for the weekly measurements. Selected fields were grown with winter rape, winter wheat, winter barley, maize and sugar beet (Fig. 2). All parameters sampled are listed in Table 3. Weekly measurements were accompanied by airborne radar and optical data acquisition. In the majority of cases, overflights were operated simultaneously with ground measurements. In exceptions, ground sampling varies in one day if bad weather conditions hampered airborne data acquisition (Fig. 3).
Sampling units cover an area of approximately 9×9 $m^2$ around a marked GPS point and are located in the center between two farmers driving lanes. Measurements followed a standard sampling scheme to avoid disturbance of measurements by movement of people, soil sampling and destructive measurements.
Volumetric soil moisture was measured employing the gravimetric method using cylindrical tubes with a calibrated volume of 100 $cm^3$. At each location three samples at 0-5 cm and at 5-10 cm depth were drawn. Samples were weighted in the lab before and after oven-drying at 105 °C for 48 h with a balance of 10 mg accuracy. Biomass was assessed by twice cutting one square meter field crop and a gravimetric measurement before and after oven-drying at 70 °C. The balance used had an accuracy of 20 g with 15 kg maximum capacity. Consecutively, the percentage of vegetation dry mass was calculated as the ratio of dry biomass (kg/m²) and wet biomass (kg/m²) multiplied by 100. In the same place, where biomass was cut before, crop density was determined by twice counting the plants per one meter (winter wheat, winter barley) or per two meter (sugar beet, maize). These values were then extrapolated to one square meter. Crop density for winter rape was determined by directly counting the plants within one square meter.
Leaf chlorophyll content was measured in digital count units employing the SPAD-502 from Minolta. The instrument makes use of the optical absorbency at two wavelengths in the blue and in the red region of the spectrum which accounts for chlorophyll concentrations. Digital units were converted into chlorophyll concentrations (µg/cm²) via calibration functions from posterior instrumentation calibration which was done by the University of Valencia who extracted chlorophyll samples during AgriSAR for determination in the lab using isocratic HPLC method based on [2].
LAI was sampled in a non-destructive way using the LICOR LAI-2000. Two LAI measurements were taken at each sampling unit where single values are an average out of 4 measurements performed by the instrument. Crop coverage was estimated in the field in percentage vegetation cover. A digital photograph was also taken with a wooden frame of 0.5x0.5 m for documentation and subsequent estimation by means of image analysis. Vegetation height was assessed with a rule and photographed in front of a gridded backboard. Plant phenology was assessed applying BBCH code [3].

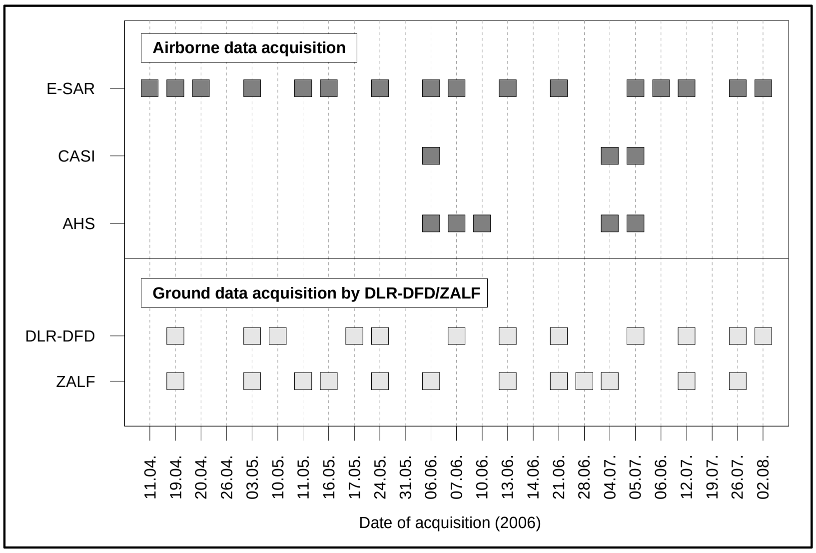


Fig. 3. Overview of airborne and terrestrial data acquisition during AgriSAR campaign on Görmin farm.

Table 3. Ground truth parameters sampled by DLR Neustrelitz in close cooperation with ZALF

| **Parameter** | **Specification/ Measuring device** | **Measurements per SU** | **Ground team** |
|---|---|---|---|
| Volumetric soil moisture | At 2 depths: 0-5 cm and 0-10 cm | 3 | DLR-DFD-NZ |
| Crop coverage | Field estimate and photograph | 1 | DLR-DFD-NZ |
| Biomass | Wet, dry | 2 | ZALF |
| LAI | LICOR LAI 2000 | 2 | ZALF |
| Vegetation density | Plants per m², shoots per m | 2 | ZALF |
| Vegetation height | Ruler and gridded backboard | 1 | DLR-DFD-NZ |
| Chlorophyll | SPAD-502 | 30 | ZALF |
| Phenology | BBCH phase | 1 | ZALF |

**Description of field measurements**

In the course of AgriSAR weekly field measurements, a substantial data base was gathered: 8 different parameters at 12 dates during the growing season 2006. With a few exceptions due to fertilizer applications, failure of instruments or heavy rainfall, parameter time series are complete.

Consecutively, all data have undergone a general plausibility check. That included a revision of the consistency in-between parameters such as soil moisture at the two depths or crop coverage and LAI. The data were further verified by means of analogies to precipitation and temperatures before and after sampling. Direct interrelations could be elucidated in particular for soil moisture. Finally, absolute values were examined in terms of "noticeable" outliers due to instrument or sampling errors. Erroneous data were left out or corrected if sources of error could be identified. Otherwise it remained in the data set with respective annotations. A statistical analysis was performed, if more than two measurements were available per parameter.

To exemplarily illustrate and discuss distinctive features of the data sets, time series are plotted for field 140 (winter rape) and field 222 (maize) in Figs. 4 and 5 respectively. Figs. 4a-b and 5a-b show the soil moisture time series. On the left, the soil moisture in percentage at 0-5 cm is shown. On the right the difference between 5-10 cm and 0-5 cm is displayed. For field 140 (winter rape) only little variation can be stated between the sampling units 25, 26 and 27 during each day of sampling. The distinctively higher soil moisture values for sampling unit 8 on field 222 (maize) can be explained with its position in a small topographic depression. This also accounts for the increased soil moisture differences as indicated in Fig. 5b due to accumulation of water in depressions but fast drying of the upper soil layer. Fluctuations in absolute moisture values between days of sampling, particularly evident for 5 May and 13 June, can be associated with heavy rainfall after these days causing saturation of the upper soil layer (0-10 cm). Regardless of that, there is a general downward drift of soil moisture due to steadily growing temperatures and very dry conditions during July 2006. As a statistical measure of accuracy, the variation coefficient (Eq. 1) was calculated for all measurements.

$$VC = \frac{\sigma}{\bar{x}} \times 100 \qquad \text{(Eq.1)}$$

The overall accuracy of the data were good with less than 10% mean deviation. Higher deviations can be accounted for by the following sources of error: 1) local inhomogeneities due to soil, shadow and micro relief, 2) disturbed sample tubes due to stones or roots, 3) consistence of soil probe (texture, wetness) and/or 4) human induced errors. Error-proneness of sampling raises, the lesser the absolute soil moisture values are.

Figs. 4c-h and 5c-h show the canopy parameters Leaf Area Index, biomass, vegetation height and density, chlorophyll and crop coverage. The figures demonstrate clearly the different phenological stages and specific plant physiology of the crops. Whereas winter rape, for example, covers approx. 60 % of the soil in the beginning of the campaign, reaching its maximum plant height in middle of June, maize starts growing in middle of May and gains maximum plant height end of July beginning of August. This is approved by the pattern of biomass and LAI. LAI, defined as the one sided green leaf area per unit ground area [4], decreases for winter rape as do the chlorophyll contents. An explanation for this analogy can be sought in the yellowing of the plants.

As with soil moisture, also canopy parameters reflect the different natural site conditions for single sampling units. Values for LAI, biomass, vegetation height and crop coverage are consistently higher for sampling unit 8 on the maize field. Less distinct, a similar phenomenon can be observed for point 25 on field 140. However, the latter can not be attributed to an increased availability of water and an explanation remains open at this point. Measurement accuracy for

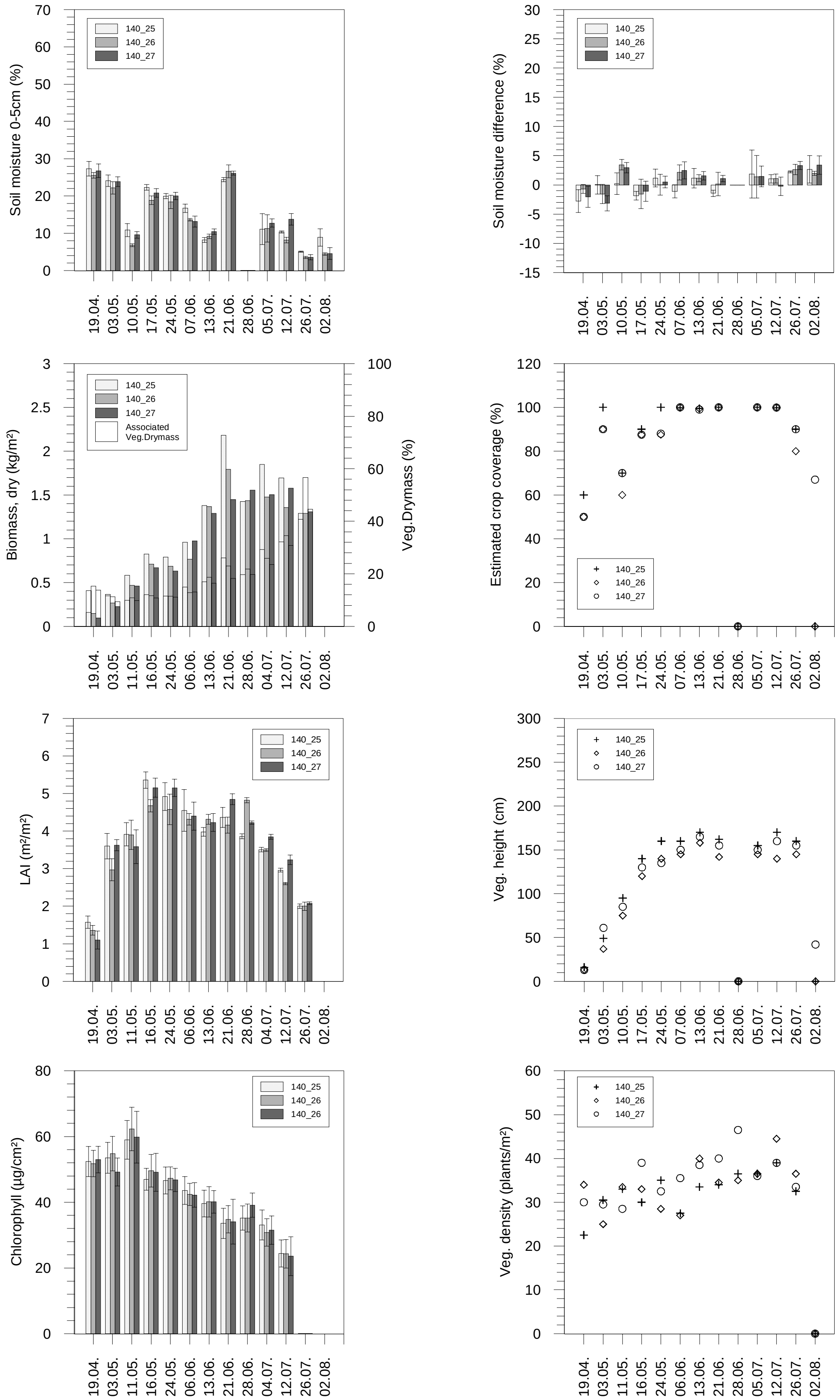


Fig. 4. Field parameters sampled during AgriSAR campaign 2006 for field 140 (winter rape). Error bars indicate standard deviations.

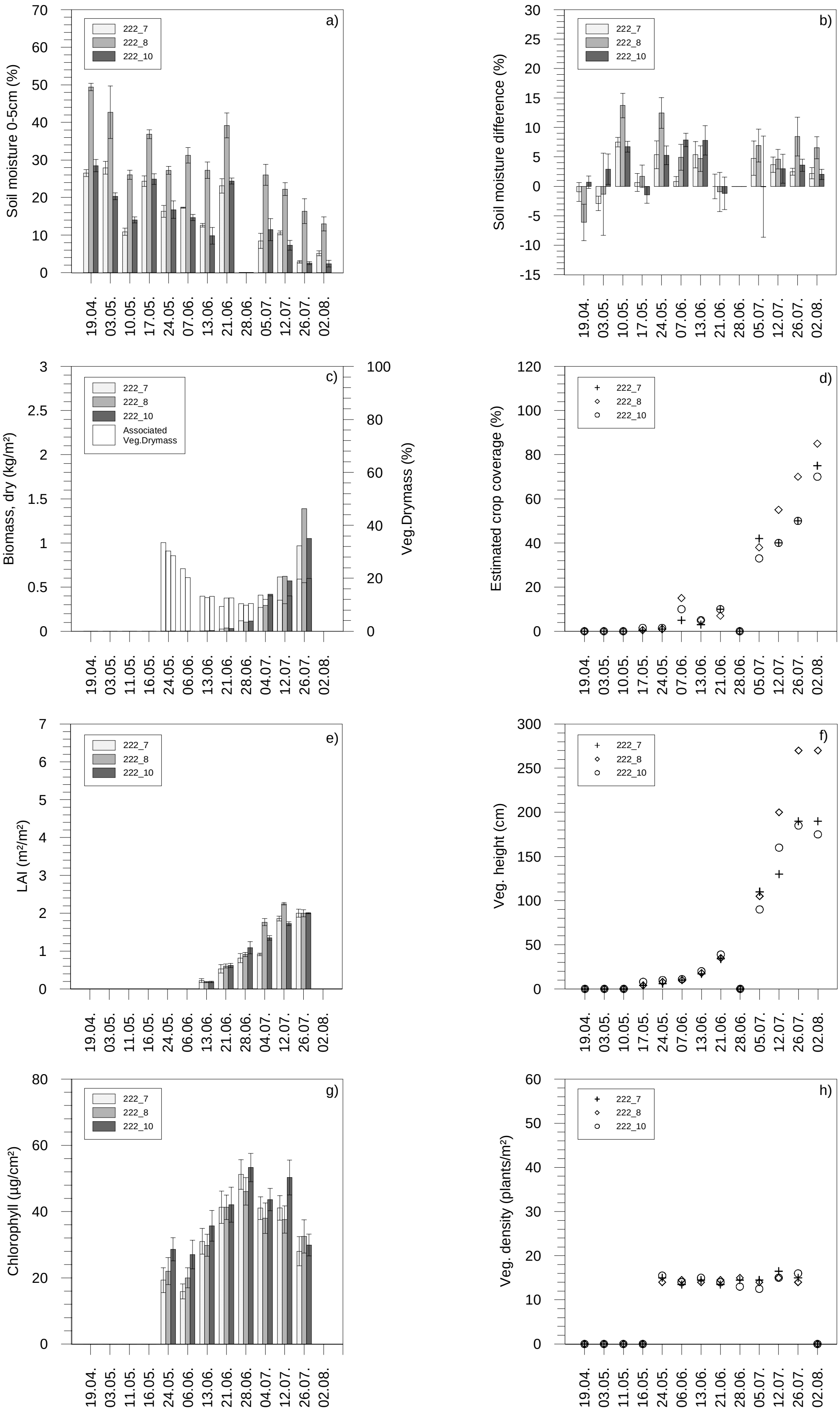


Fig. 5. Field parameters sampled during AgriSAR campaign 2006 for field 222 (maize). Error bars indicate standard deviations.

LAI and chlorophyll expressed as coefficient of variation is 5.5 % and 10 % on average. Irrespective LAI accuracy by means of parameter heterogeneity and error in instrument application, a bias due to the non-destructive way of measuring LAI has to be taken into account. As the employed instruments measure overall crop area index, including stems, ears, and senescent plant material, rather than merely the projected surface of green leaves a significant overestimation of LAI must be taken into consideration, in particular in the case of maturing fruits such as represented by winter wheat, winter rape and winter barley in the second half of the campaign.
Finally, all field data were compiled in excel spread sheets, one each per parameter over time and converted to point vector layers. All layers are provided with geographic information in UTM33 and thus can directly be integrated in a GIS.

## SUMMARY AND PERSPECTIVES

This paper presented the test site DEMMIN which was the center point of the ESA funded AgriSAR campaign 2006. DEMMIN is an intensively used agricultural area in a middle-European environment and is therefore dedicated to the development of remote sensing based agricultural land applications. It addresses a wide range of sensors, from high to low ground resolution due to its overall area and size of single fields. At the same time, on-site instrumentation and a comprehensive data base on quasi-static and quasi-dynamic data provides detailed ground truth information. The existing data base is steadily extended owing to a very close cooperation with local farmers.
The main objective of the AgriSAR campaign 2006 in DEMMIN was the buildup of a data set in support of key issues related primarily to the definition of ESA mission Sentinel-1, but also Sentinel-2. During the campaign the test site was monitored by airborne radar and optical sensors along with various in-situ measurements during the whole growing season. This way a valuable data base was established that will enable ESA to further research the potentialities of the Sentinel missions. The article focused on the contribution of DLR-DFD who sampled vegetation canopy parameters and measured soil moisture on a weekly basis. Applied methods and acquired data were described and discussed in terms of temporal evolvement and measurement accuracy. The analysis showed that the provided data sets are a reliable and valuable data base which can be applied for model validation and further development of data products. Where the number of field measurements admitted statistical evaluation, statistical parameters were calculated. Outliers were detected and possible sources of error identified.
Based on the AgriSAR activities and on DLR-DFD's expertise on the development of operational processing chains for remote sensing data, the test site DEMMIN shall be expanded in future to an international test site for the development of methods and algorithms and the validation of environmental and agricultural remote sensing data products. In this respect, it is planned to consecutively enlarge existing monitoring facilities (e.g. Automated Agro-Meteorological Measurement Network, Automated Yield Measurement System) and to extend the cooperation with national and international partners. Future work aims at the development and integration of different thematic processing modules in various processing chains. Corresponding modules are currently developed at the German Remote Sensing Data Center (DLR-DFD).

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