Monitoring crop growth at JECAM sites in Poland and South Africa using in-situ and satellite data

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INTRODUCTION

This study investigates satellite-based approaches for crop growth monitoring and yield forecasting in two different geographically located countries, Poland and South Africa.

The joint project between the two countries, investigated satellite based crop growth monitoring approaches using Terra MODIS, Sentinel2 in conjunction to ground based meteorological data to determine crop water requirements, time for irrigation, as well as crop yield predictions for winter wheat in both countries. Ground data acquired from the same period were used to develop the model for crop yield estimates and irrigation time requirement. The MODIS data consisted of eleven years of observation (between 2003 and 2021) and covered over 100 crop wheat fields. The data were analyzed using the accumulated eight days of NDVI (MOD09Q1) and accumulated 8 days' differences between LST (MOD11A2) and air temperature (TA) from meteorological data. The rapid increase in accumulated NDVI curve occurs at lower accumulated difference between LST and TA (∑LST-TA) and this resulted in high value of yield at the end of the season. During the dry season, however, the accumulated difference between LST and TA increased enormously resulting in lower rate of accumulated NDVI.

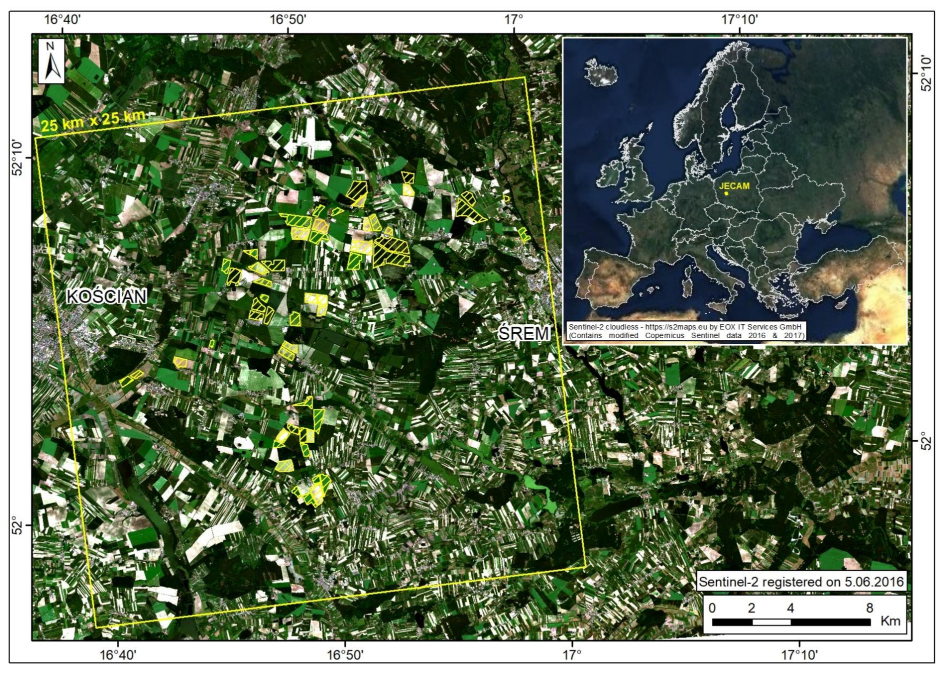
At good crop growing season, crop heading occurred earlier at lower accumulated difference in temperature (∑LST-TA) than in the dry season and this has a direct response to crop yield. Crop water demand at development stages has been extracted from the analysis of crop growth conditions. The FPAR was used to determine the different crop phenologies. The results have been verified using meteorological data such as rainfall between the different crop phenologies, measured crop yield and ground truthing data.

DATA

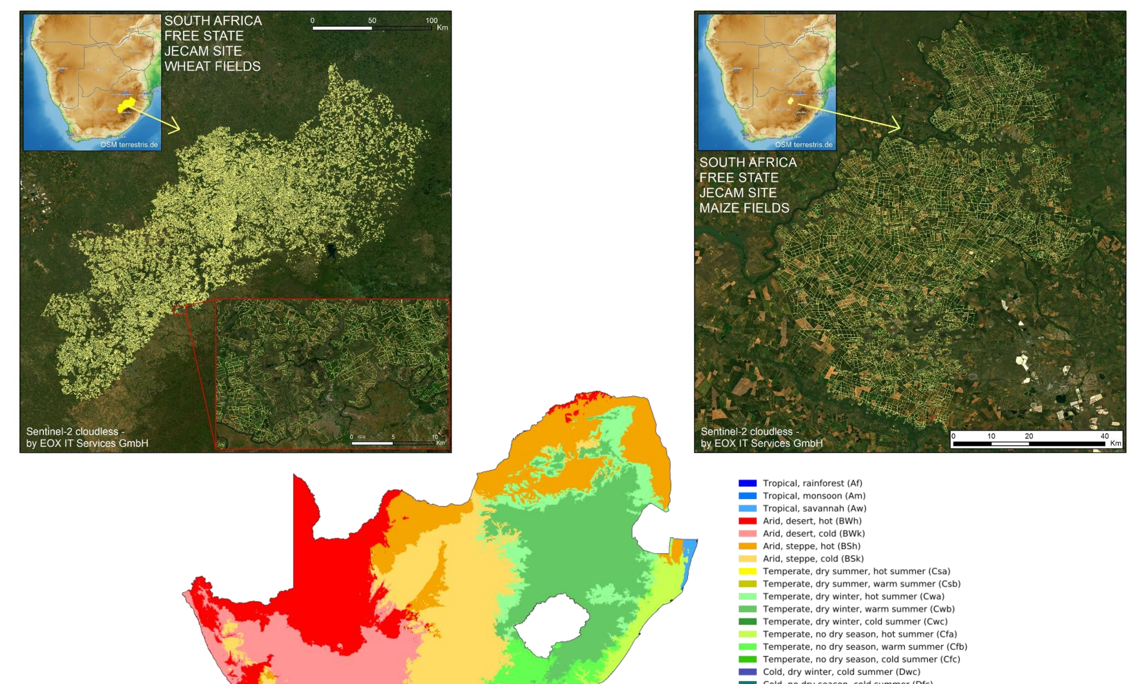
SENTINEL 2

SENTINEL 3

TEST SITES in POLAND



TEST SITES in AFRICA

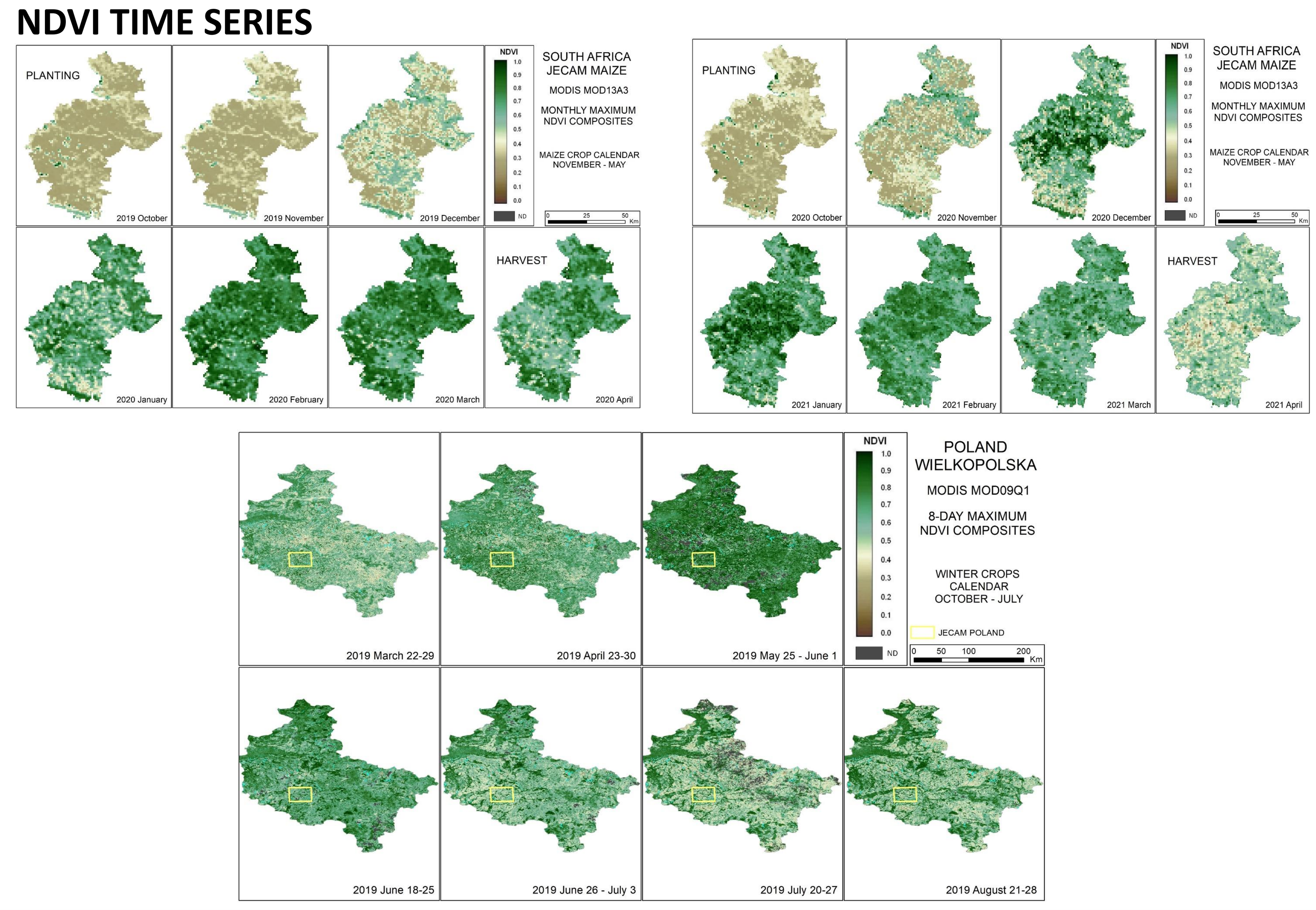


Koppen-Geiger climate classification map for South Africa (1980-2016)

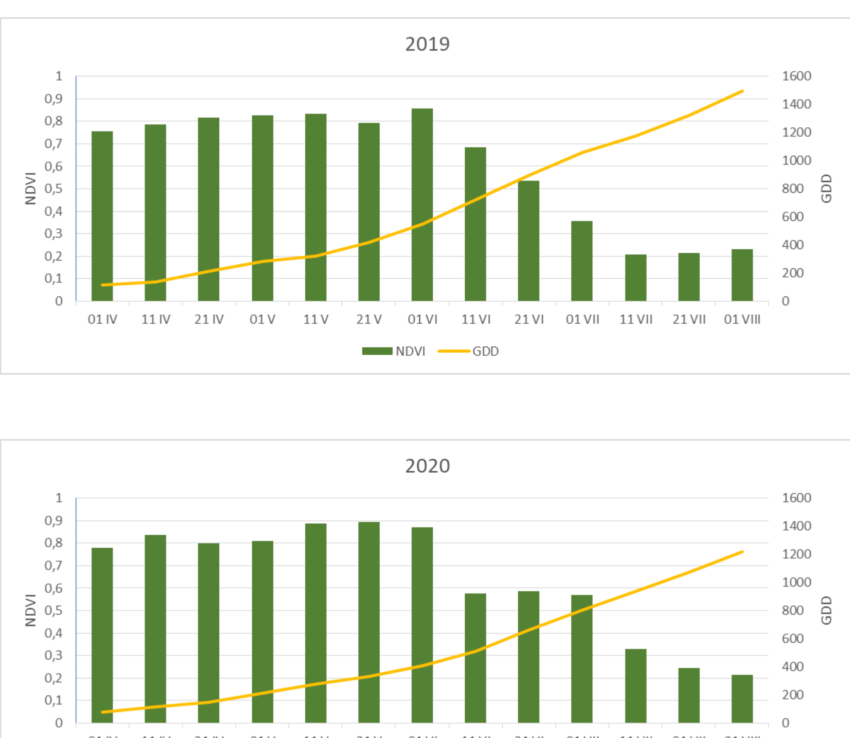
IN-SITU MEASUREMENTS

1) Leaf Area Index (with LAI 2200 Plant Canopy Analyser)
2) Spectral responses by the ASD FieldSpec4 Hi-Res
3) Chlorophyll fluorescence (with OSP5p+)
4) Radiation temperature (with EVEREST AGRI-THERM II)
5) APAR (with AccuPar 80 instrument)
6) Chlorophyll (with FieldScout CM 1000 Chlorophyll Meter)
7) Ground measurements in Poland and Africa

NDVI TIME SERIES



GDD vs. NDVI
Sentinel-2 data and air temperature



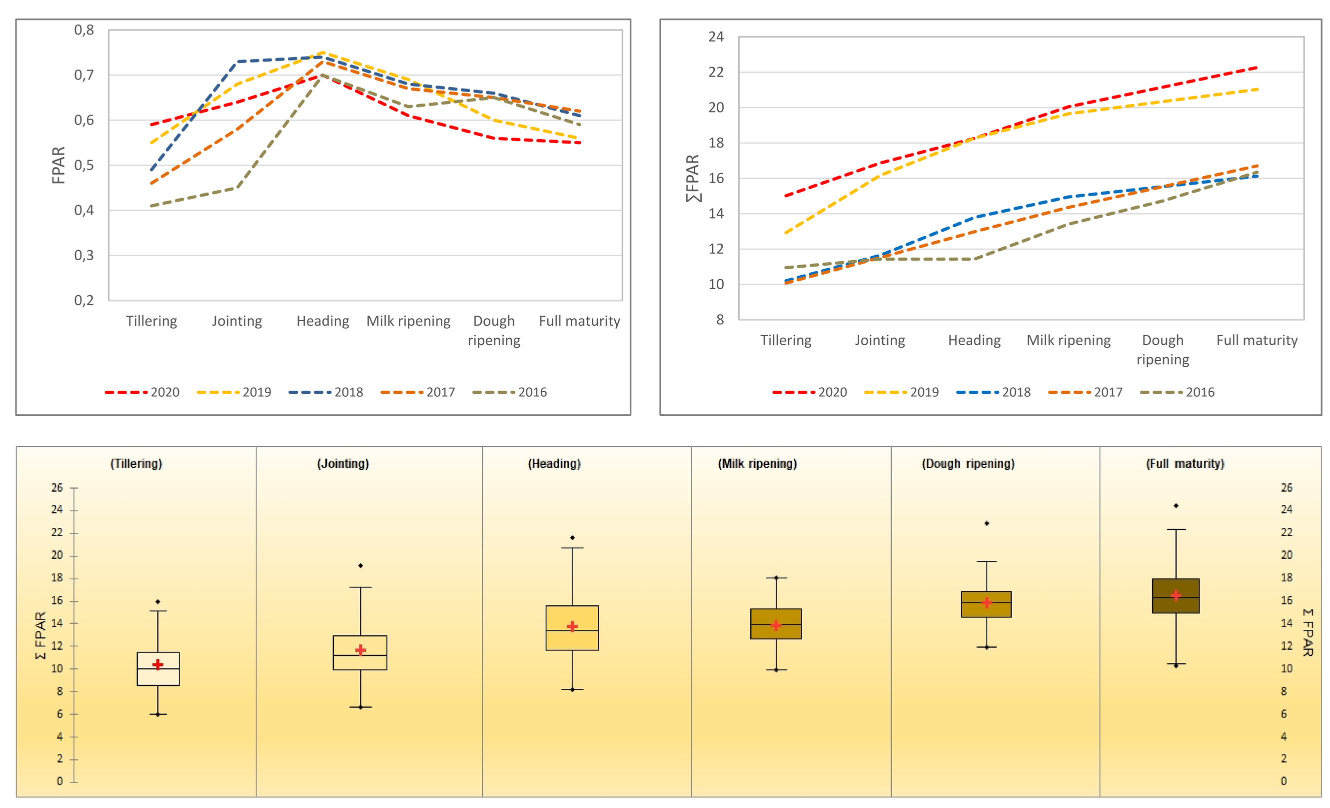
Crop yield modeling – TerraMODIS

$$1/\,Yield = -19.98 + 8.9 * \sum_{start}^{head} NDVI + 9.09 * \sum_{head}^{matur} NDVI$$

$$2/Yield = 158.88 + 0.58 * \sum_{start}^{matur}(LST - TA) + 43.7 * \log\left(\frac{\sum_{start}^{head} NDVI}{\sum_{start}^{head} LST - TA}\right) + 20.46 * \log\left(\frac{\sum_{head}^{matur} NDVI}{\sum_{head}^{matur} LST - TA}\right)$$

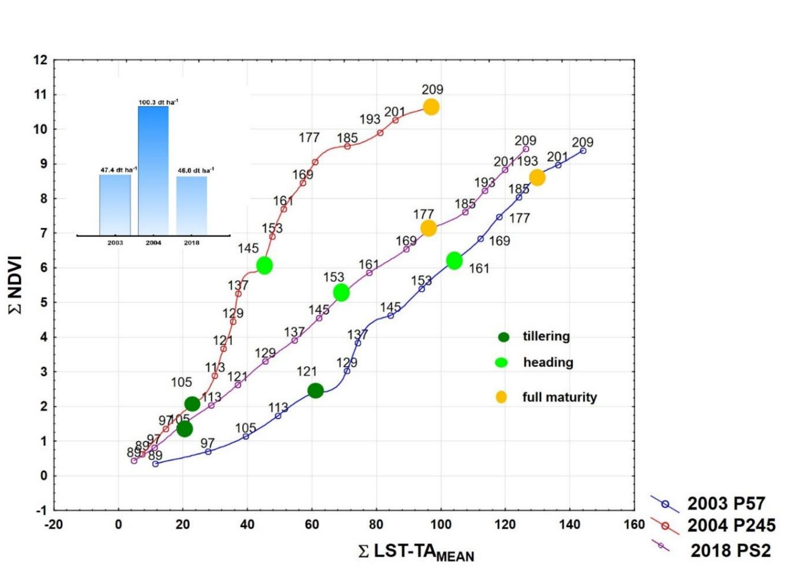
$$3/Yield = 137.2 + 0.29 * \sum_{start}^{matur} LST + 37.95 * \log\left(\frac{\sum_{start}^{head} NDVI}{\sum_{start}^{head} LST}\right) + 10.84 * \log\left(\frac{\sum_{head}^{matur} NDVI}{\sum_{head}^{matur} LST}\right)$$

FPAR

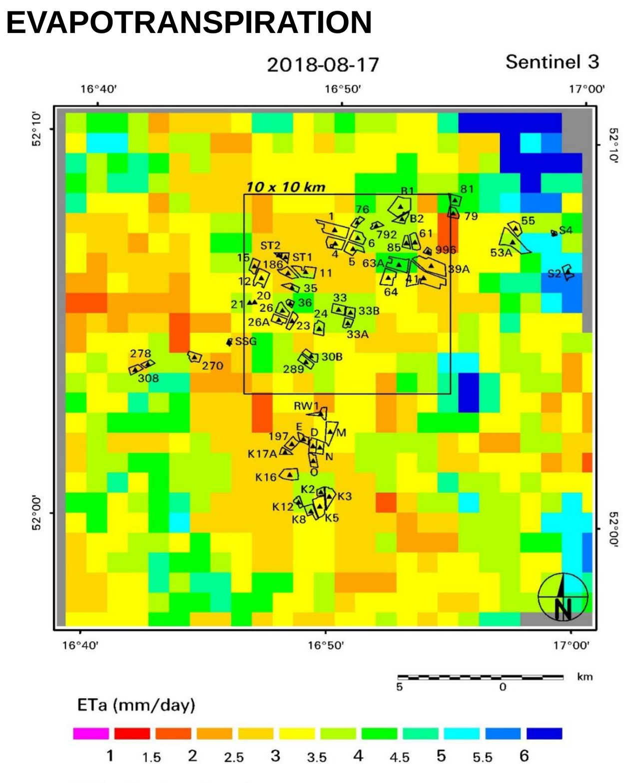


The tillering phase is observed when FPAR totals reach 10.00, jointing closer to 12.00, heading and milk ripening at a similar level of FPAR totals 14.00 and then dough ripening reaching FPAR totals 16.00. Full maturity follows when FPAR totals exceed 16.00

MODIS data for JECAM site – Poland Modelling Winter wheat

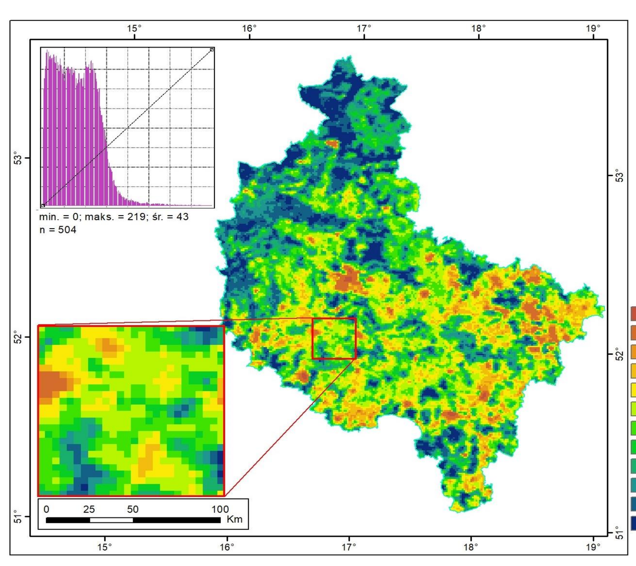


DAILY EVAPOTRANSPIRATION

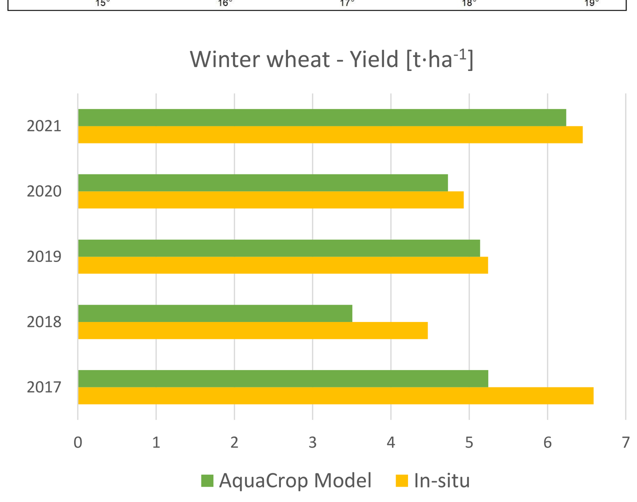


CONCLUSION

The results obtained varied depending on the prevailing meteorological conditions in a given year and the fertilization as well as the irrigation methods used. In Poland, during the surveyed period, the highest yield was obtained for 2004 year (100.3 dt ha-1). Winter wheat had already moved into phenological phase heading at just 145 DOY. Values of ∑NDVI and ∑LST-TA were 6 and 45 oC. The average for the other years in which low yields were recorded was for the same parameters corresponding 5 and 80 oC at the heading stage. In the study area in South Africa, it was noted that in 2019, there were worse conditions for wheat crop development and there was a later increase in NDVI, while in 2020, there were better conditions for wheat crop development and there was already an increase in NDVI one month earlier.



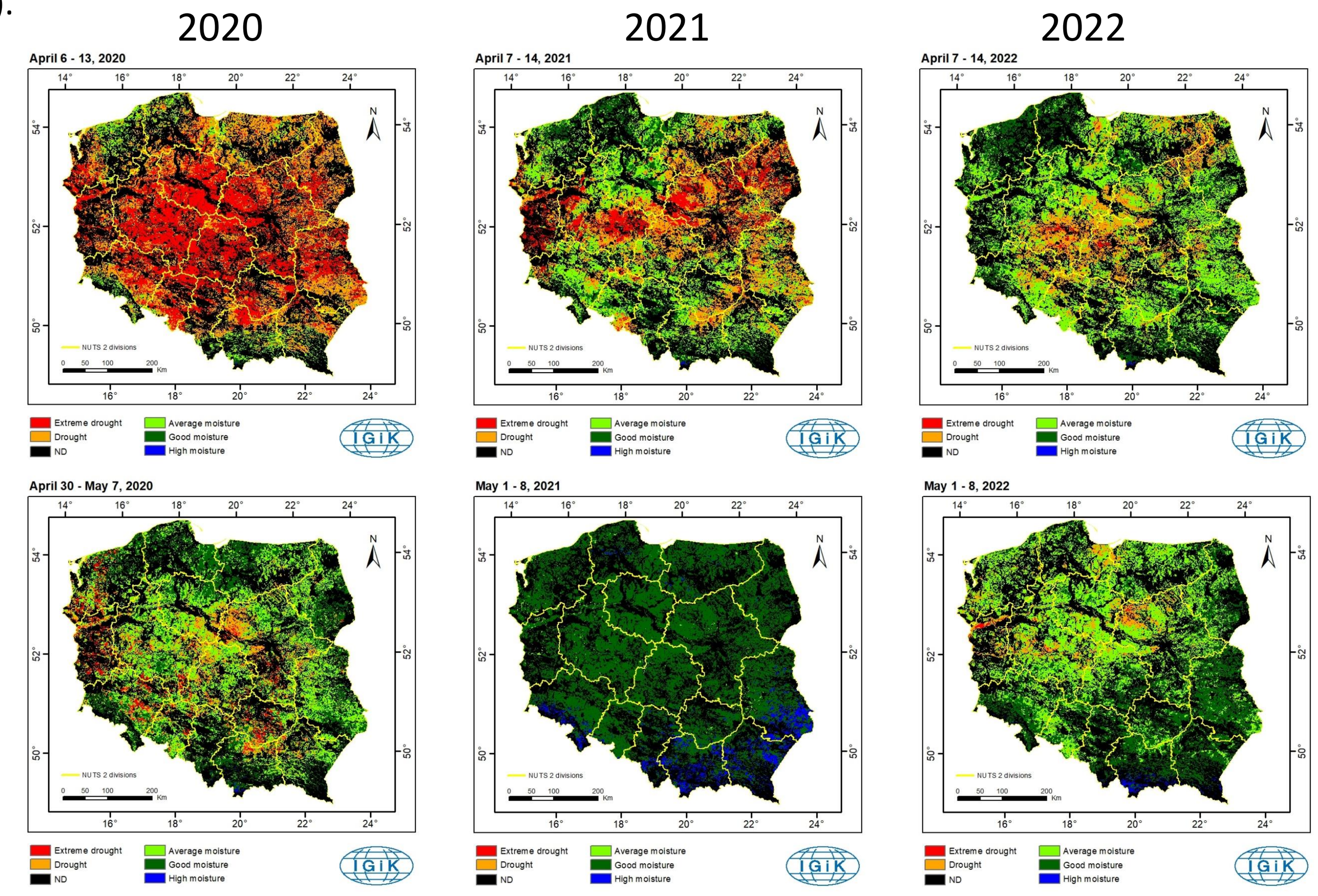
Number of satellite observations with temperatures >= 30° C in the period of IV-XI in 2001-2021



Satellite-based system for drought monitoring

The system for monitoring crop growth conditions has been elaborated at the **Remote Sensing Centre**, Institute of Geodesy and Cartography. It determines crop conditions with the use of the index based on Terra MODIS satellite images with 1 km² spatial resolution. **The index, called *Drought Identification Satellite System* – DISS** is a function of *Temperature Condition Index* – TCI and meteorological index characterizing climatic conditions on the territory of Poland (*Hydrothermal Coefficient* – HTC). DISS drought index is generated at the succeeding eight-day periods within vegetation season, starting from the end of March. Index values are divided into five ranges, characterizing particular level of moisture: extreme drought (red); drought (orange); average moisture (light green); good moisture (dark green) and high moisture (dark blue).

	2020	2021	2022
6-14 April			
1-8 May			



The National Centre for Research and Development

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REMOTE SENSING CENTRE