Research grants on northern cultivated grasslands (Taff - Nibio)

1. Effect of climatic changes on grassland growth, its water conditions and biomass (FINEGRASS) – (2013 – 2016)
   - Norway-Poland bilateral research grant scheme
   - Supplemented by funds from the Fram Center, Terrestrial Flagship, Tromsø
2. Use of remote sensing for increased precision in forage production (2015 – 2018)
   - Funds from the Norwegian Foundation for Research Levy on Agricultural Products and the Agricultural Agreement

Modeling of grass biomass using remote sensing

FINEGRASS

Norway-Poland Grant, Nov 2013 – Oct 2016

Supplemented by Fram Center –Terrestrial Flagship funds

Gregory Taff, Jørgen Mølmann, Marit Jørgensen, Hans Tømmervik, Francisco Javier Ancin Murguzur, Ilina Kamenova, Monika Tomaszewska, Stanislaw Twardy, Piotr Golinsky, Piotr Golinski, Marek Czerwinski, Barbara Golinska, Katarzyna Dabrowska-Zielinska

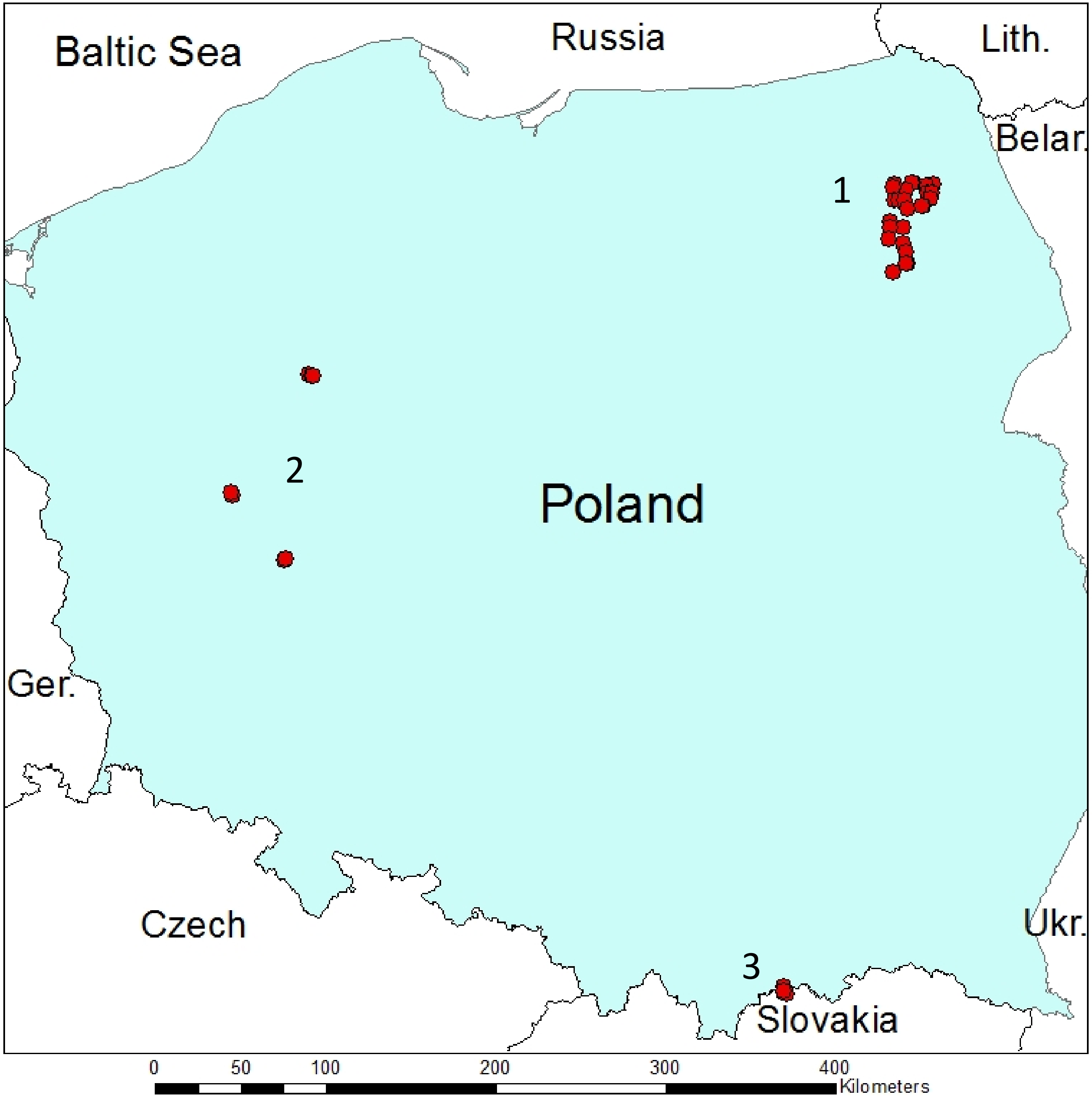
Effect of climatic changes on grassland growth, its water conditions and biomass

- Funding from Norway-Poland grant scheme:
  3 993 042 PLN (973 106 EUR)
- Project Promoter: Institute of Geodesy and Cartography in Warsaw (PI: Prof Dr. Hab. Katarzyna Dąbrowska-Zielińska)
- Norwegian partners
  - Nibio. Norwegian project leader: Gregory Taff.
- Polish partners
  - Institute of Technology and Life Sciences, Malopolska Research Centre in Krakow
  - Poznan University of Life Sciences, Department of Grassland and Natural Landscape Sciences

Objectives

- Develop methods to estimate cultivated grassland yield based on remote sensing data
- Model cultivated grass growth with environmental variables under multiple growing conditions
- Assess recent climatological and phenological changes/trends in study sites, and their effect on cultivated grassland growth

Poland Field Sites



1. Biebrza National Park
2. Arable lands of Greater Poland Voivodeship
3. Vicinity of Jaworki


Norway Field Sites
Norway
Sweden
Finland
Estonia
Latvia
Lithuania
Denmark
Kilometers
0
125
250
500
750
1 000

Satellite Data

- Poland
  - MODIS – for biomass/feed quality modeling and ground temperature estimation
  - NOAA/AVHRR – for biomass prediction and monitoring phenology
- Norway
  - Landsat, UAV – for biomass/feed quality modeling
  - MODIS – for tracking phenology since 2000

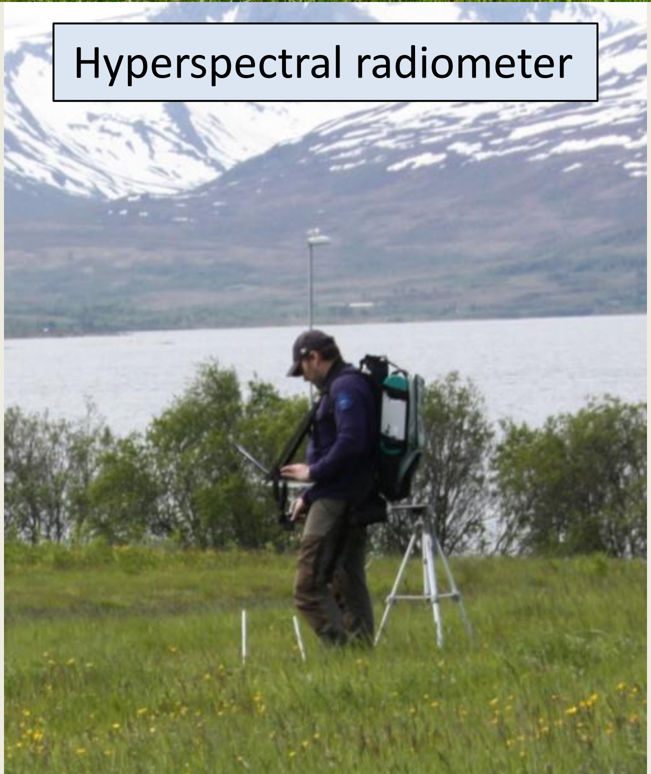
Field Data Collected 2014, 2015

- Field data collected 3 times/season on grassland fields include (some data collected, as appropriate, in only one country):
  - Biomass
    - Wet and dry weight measured
    - Cut at 5cm height and also at ground level (all)
  - Species mix (visual estimate of 3 most prominent species)
  - Handheld spectral data - LAI, chlorophyll content, radiometers (4-band in Poland, hyperspectral in Norway)
  - Soil temperature
  - Soil humidity (between 5 and 15 cm depth)
  - CO_2 exchange using an enclosed transparent plastic chamber
    - CO_2 gas concentration and air temp measured with a portable non-dispersive infrared (NDIR) sensor
  - Plant temperature, taken by infrared thermometer

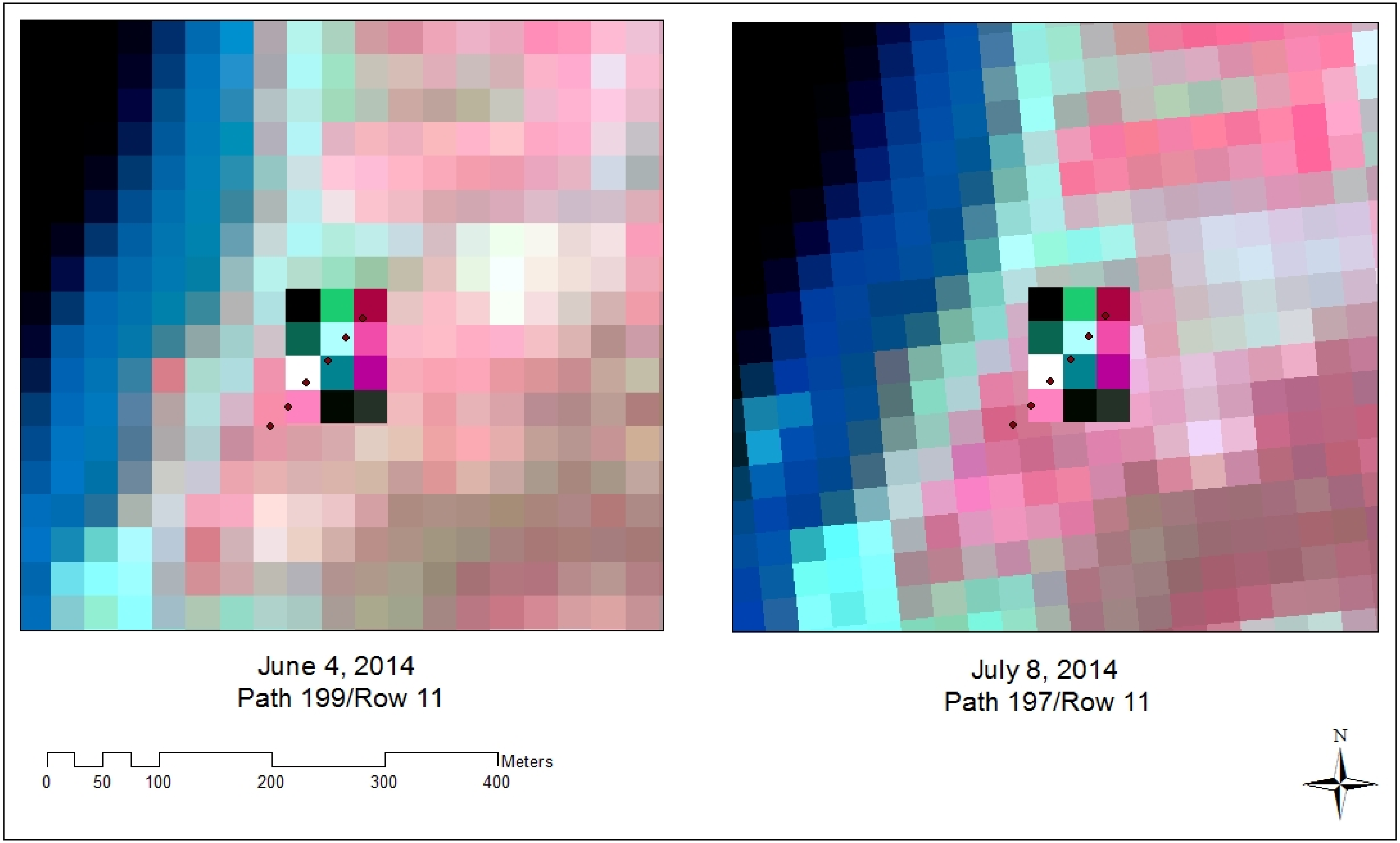

CO_2 exchange


Soil humidity


biomass


Hyperspectral radiometer

Field and Satellite Data Compilation



Landsat images overlayed with transect and pseudo-Landsat images (from FieldSpec) at Holt (Tromsø) study site

Unique issues in Norway

- Small field sizes
  - Can’t use MODIS
  - Can only use Landsat in a few locations
- Cloudy environment
- Hard to obtain integrated NDVI
  - Handheld hyperspectral instrument

Use of remote sensing for increased precision in forage production

Funds from the Norwegian Foundation for Research Levy on Agricultural Products and the Agricultural Agreement

2015 - 2018

Funding

- 3 960 000 NOK (~550 000 EUR) from the Norwegian Research Council
- Partners:
  - Nibio (Project leader: Marit Jørgensen)
  - Norut (Northern Research Institute, Tromsø) – Rune Storvolt, Stein Rune Karlsen, Corine Davids
  - Virginia Tech University (USA)
  - Norwegian Agricultural Advisors of Midtre Hålogaland and Øst Finnmark
  - Agricultural Departments of Oppland, Hedmark, and of Nordland, Troms and Finnmark
  - Aranica (UAV company)

Objectives

- Pre-harvest yield prediction for improved management decisions from UAV and handheld remote sensors
- Pre-harvest feed quality prediction for improved management decisions from UAV and handheld remote sensors
- Estimate variation in grassland production at regional levels by satellite remote sensing imagery (WP Leader: Gregory Taff)
  - Detect extent and severity of winterkill and drought by satellite data
  - Use Sentinel-2 and UAV data to statistically model grassland productivity

Thank you!

Extras

Yield modeling from hyperspectral Field Spec data

- Modeling **biomass**, chlorophyll, LAI
- Predictor: FieldSpec hyperspectral data (350nm – 2500nm, at 1nm intervals)
- Data from 8 field-dates (2014): 3 fields at 3 time points (originally 9, but 1st date Holt field eliminated)
- Total of 46 points put into models

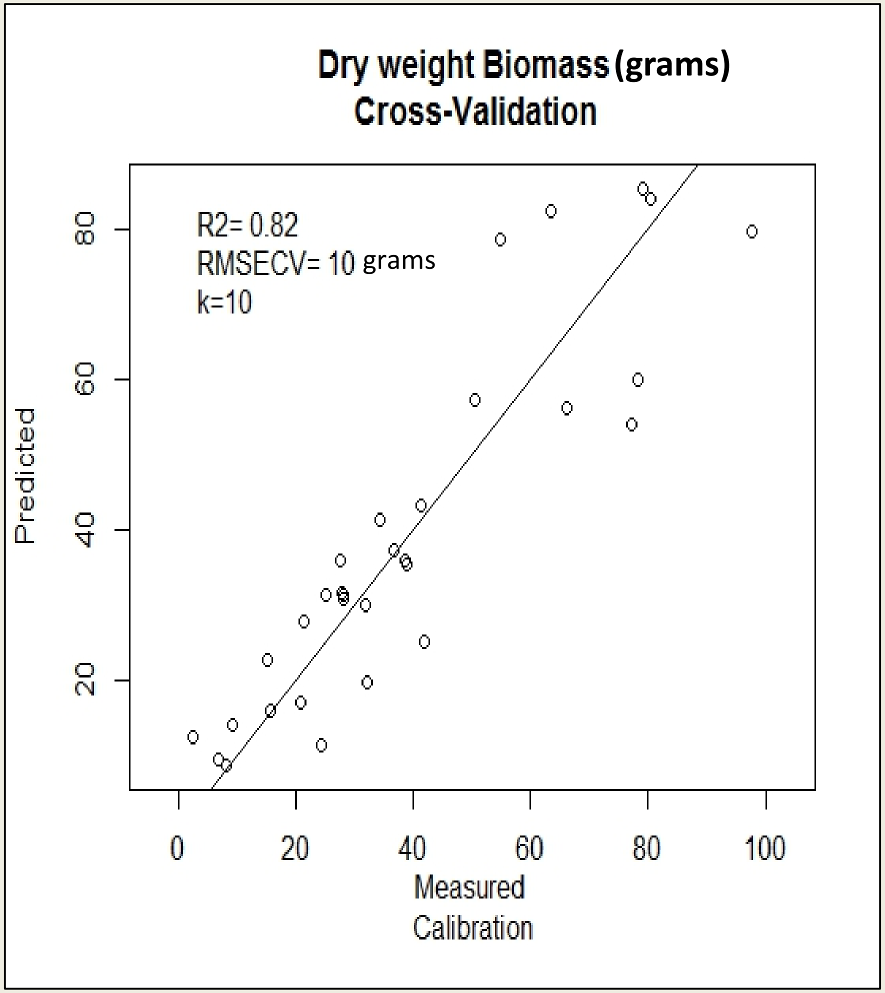
Processing Steps for FieldSpec data

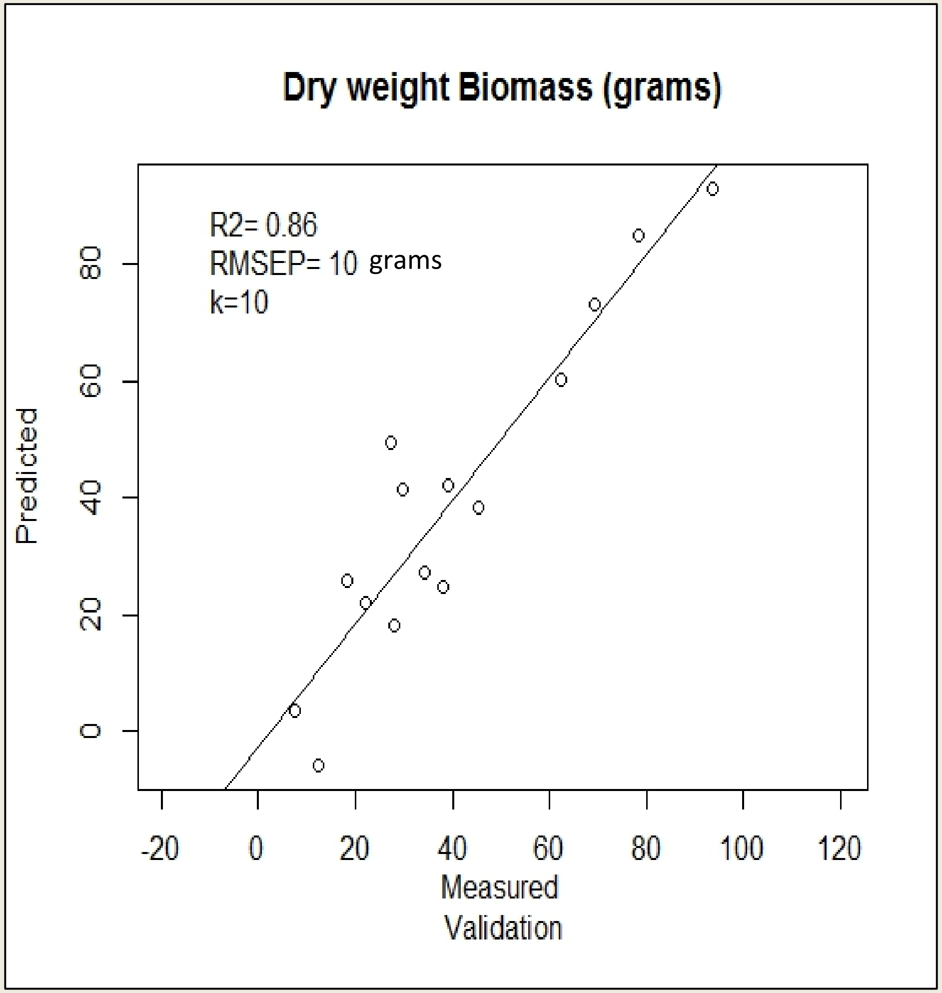
- Eliminated noisy ranges in electromagnetic spectrum of FieldSpec samples corresponding to atmospheric water absorption
- Smoothed each sample spectrum using a Savitzy-Golay filtering procedure
  - Window size: 15nm
  - Derivative order: 1
- Averaged three samples for each point

Grass Biomass Modeling

- North Norway data only
- We used Partial Least Squares Regression (PLSR) to model biomass
- PLSR reduces the massive amount of hyperspectral data to a few components (linear combinations of the hyperspectral data points) to *maximize correlation with the outcome variable*
- Data was split (systematically instead of randomly due to small sample size) into 2/3 calibration and 1/3 validation

Dry Weight Biomass Model





Modeling Plans

- Add 2015 data to improve models
- Test models with Landsat and pseudo-Sentinel-2 from handheld hyperspectral sensor
- Incorporate environmental variables into models
- Test models on one time period only (early, mid, or late) to see how accurately models predict small differences in biomass, etc.

- Hyperspectral FieldSpec was used to estimate atmospherically corrected Landsat reflectance:

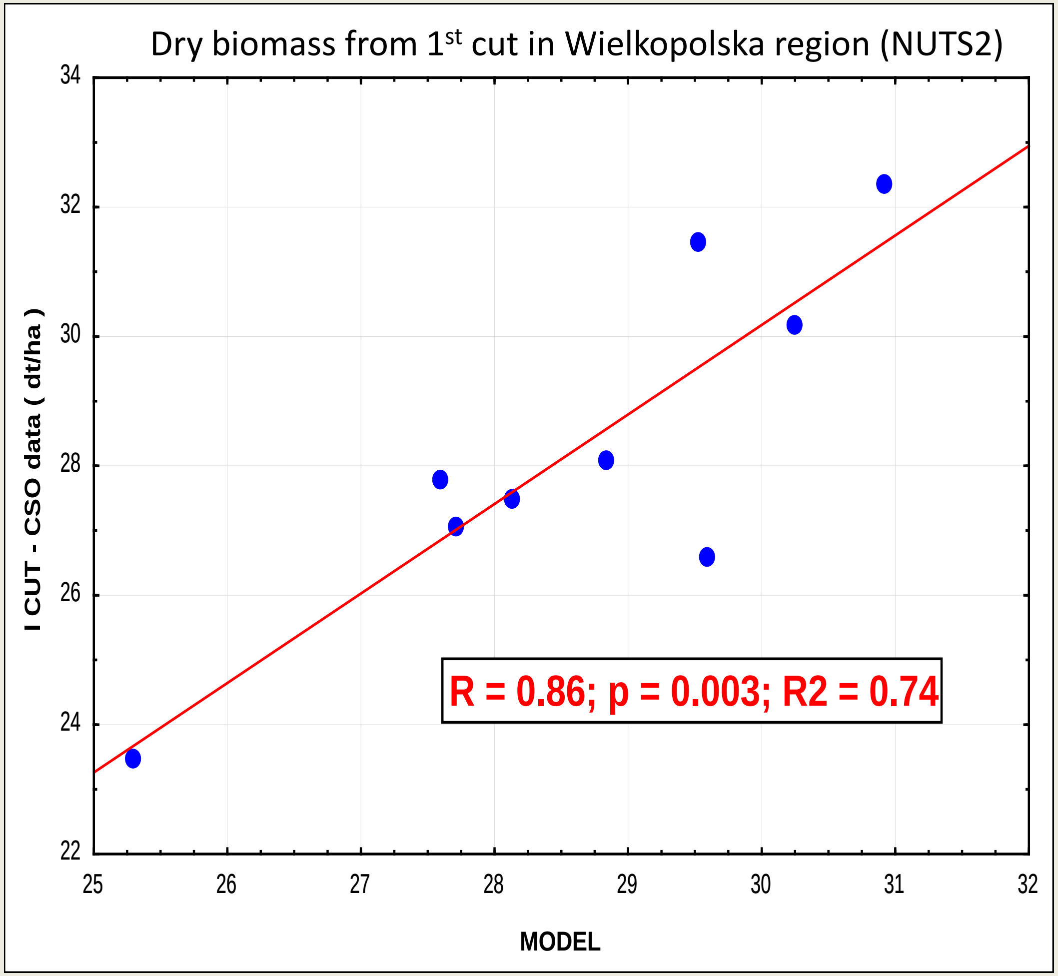
	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7
Correlations:	0,737981	0,754253	0,636778	0,678342	0,549772	0,90519	0,560385

Poland model:

AVHRR (satellite)/CORINE vs. Central Statistical Office data

Model: ***Yield* = 0.2 - 0.66*F1 + 0.73*F2 + 0.92*F3 + ε**

Mean Absolute value Percent Error **(*MAPE*) = 4.5%**



Data from 9 years with cloud-free images between 1997 and 2014

PCA – Principal Components

ndvi/ts	Factor Loadings		
In decades	F1	F2	F3
ndvi-07	0.08	0.91	0.18
ndvi-08	-0.00	0.55	0.29
ndvi-09	0.23	0.35	0.24
ndvi-10	0.05	0.01	0.49
ndvi-11	0.03	0.06	0.88
ndvi-12	0.23	0.29	0.86
ndvi-13	0.69	0.14	0.44
ndvi-14	0.71	0.26	0.41
ndvi-15	0.57	-0.19	0.41
ts-07	0.28	0.48	0.08
ts-08	0.35	0.10	0.10
ts-09	0.45	-0.03	0.23
ts-10	0.61	-0.29	0.29
ts-11	0.81	-0.02	0.15
ts-12	0.84	-0.06	-0.01
ts-13	0.88	0.22	0.16
ts-14	0.87	0.12	-0.15
ts-15	0.64	-0.06	0.30

Interpretation:

F2: start of vegetation; **F3**: ndvi in April;

F1: Surface Temperature in April-May

Specific Challenges in Grasslands

- Yield vs. biomass (cut 5cm height vs. ground level)
- Lodging (grass falling down under its own weight) – changes spectral signal
- Grazed grasslands – modeling yield challenging in real pastures due to constant grazing
- Accounting for ley year in models (the number of years after grass was sewn)
- Accounting for species mixes and weeds
- The percent of soil showing through the grass – particularly choosing locations for handheld spectrometer when significant variation exists in amount of soil visible

Specific Challenges in Grasslands

- Soil moisture data:
  - Significant within-field variability, especially at different elevations
  - Likely to be highly influenced by amount of recent precipitation
- For spectral measurements (spectrometers, LAI) and CO_2 exchange, quickly changing cloud conditions (by the minute/second) can significantly influence readings