Preliminary outcomes and challenges in modeling of grass biomass using remote sensing

FINEGRASS

Norway-Poland Grant

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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 (officially merging on July 1 - NIBIO)
  - Norwegian Forest and Landscape Institute
  - Norwegian Institute for Agricultural and Environmental Research, Center for Arctic Agriculture and Nature Use
- 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 grassland yield based on remote sensing data
- Model grass growth with environmental variables under multiple growing conditions
- Assess recent climatological and phenological changes/trends in study sites, and their effect on 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

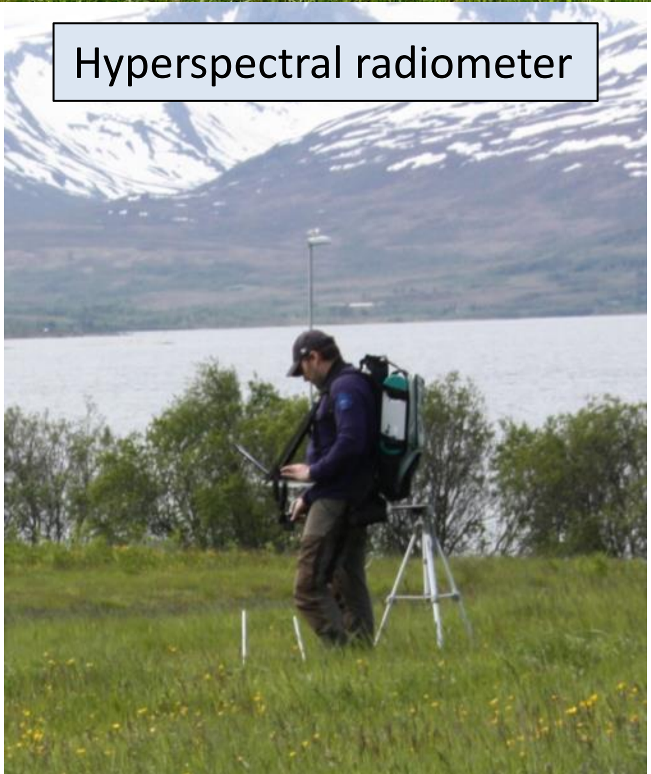
Field Data Collected 2014, 2015

- 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

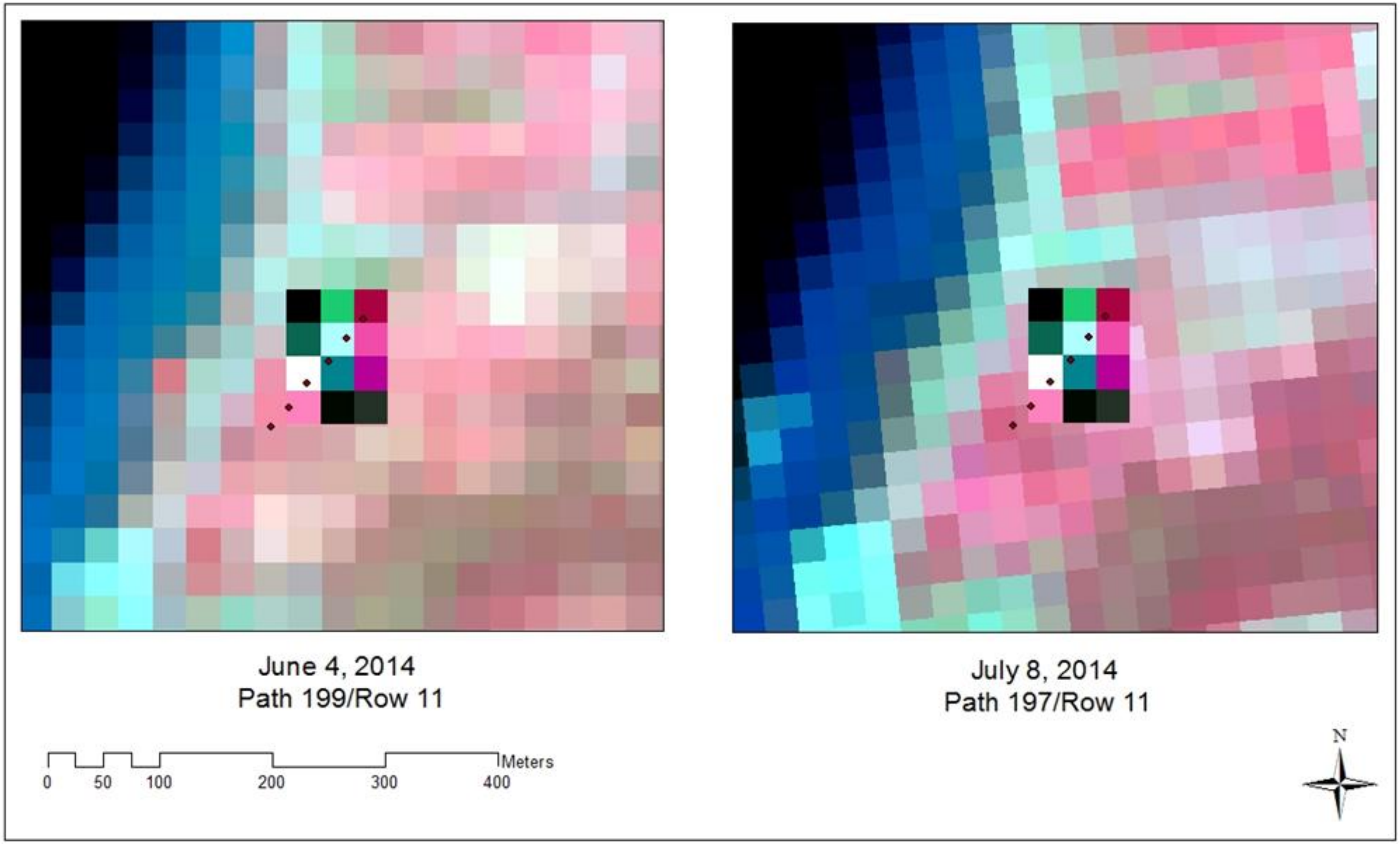
Specific Challenges in Grasslands

- 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

Field and Satellite Data Compilation



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

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

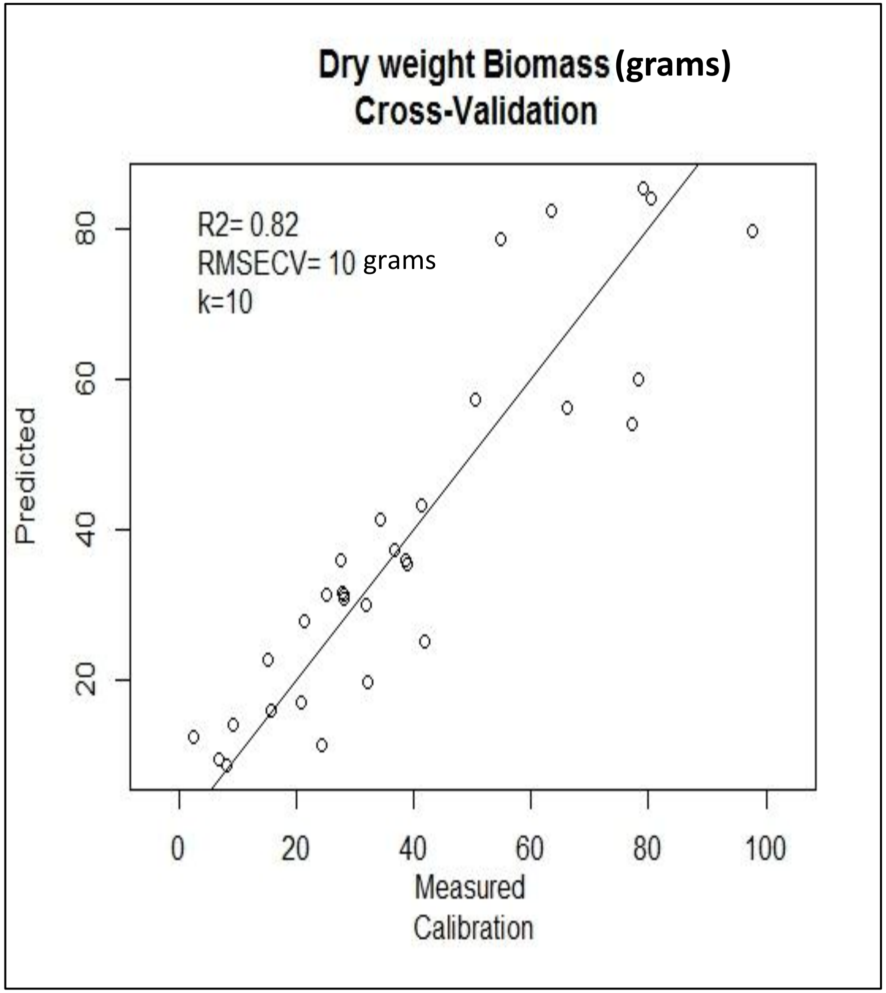
Processing Steps for FieldSpec data

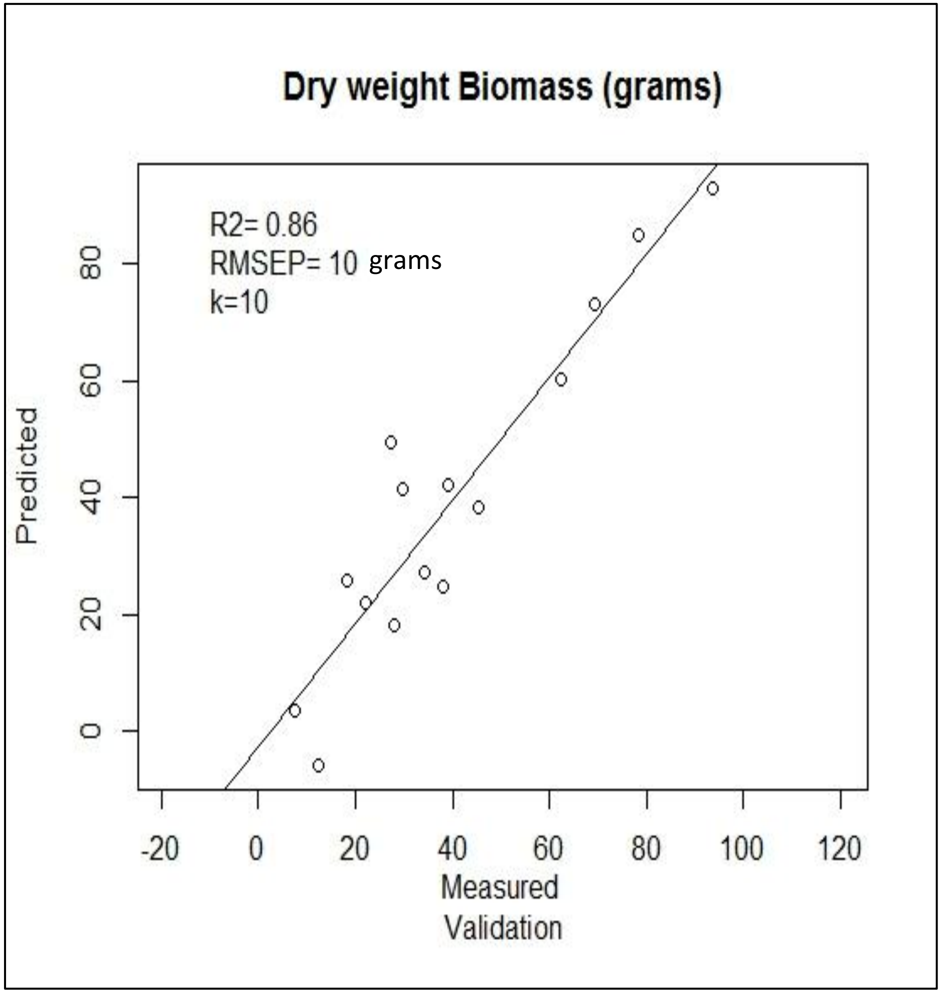
- Eliminated noisy ranges in electromagnetic spectrum of FieldSpec samples corresponding to atmospheric water absorption
- Smoothed each sample spectrum using a Savitzy-Golay filtering procedure
  - Window size: 15nm
  - Derivative order: 1
- Averaged three samples for each point

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.

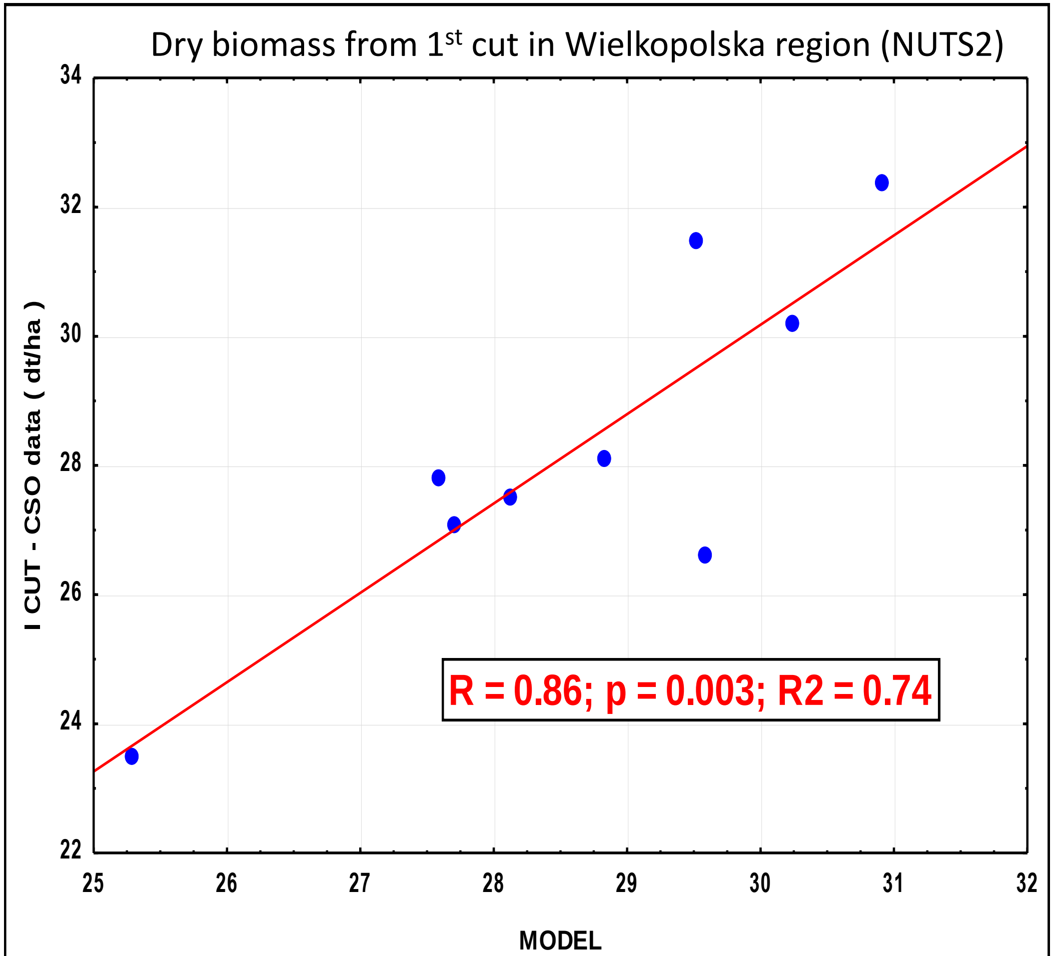
- Hyperspectral FieldSpec will also be used to estimate Landsat reflectance

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