Project information

Keywords

Biology, agronomy, grassland yield and quality, climate change, technology, remote sensing, Geographic Information Systems, statistical modelling.

Project title

Use of remote sensing for increased precision in forage production ("Remote sensing")

Year

2017

Project leader

Marit Jørgensen

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

In Tromsø at 18°65' – 18°90' E and 69°58'- 69°65'N, in Harstad 16°16' - 16°37' E and 68°74' - 68°79' N, in Vesterålen 15°27' - 15°34' E and 68°64' - 68°66' N. in Malangen 18.90° – 18.92°E and 68.45° – 68.46°N. As the project is national, there are also fields in the south, but those are not listed here.

Participants

Dr. Jørgen Mølmann, NIBIO Holt, Dr. Gregory Taff NIBIO Ås;

Dr. Audun Korsæth, Dr Jakob Geipel, Dr Tor Lunnan, NIBIO Apelsvoll and Løken;

Dr. Stein-Rune Karlsen and Dr. Corine Davids, Norut;

Dr Hans Tømmervik, NINA

Francisco Javier Ancin Murguzur (engaged with Fram centre funding);

Dr. Yang Shao, Department of Geography of Virginia Tech, Blacksburg, Virginia US

Norsk Landbruksrådgiving (NLR), Advisory Service (several units)

Flagship

Terrestrial

Funding Source

NRC (Matfondet) 1 309 743 NOK for 2017

Private and other funding: 116 000 NOK for 2017

In kind funding Norut 50 000 NOK for 2017

In kind funding Aranica 50 000 NOK for 2017

In kind funding NLR 35 000 NOK for 2017

Funding from Fram Centre: 440 000 NOK for 2017

Summary of Results

WP1 and 2 (not supported by Fram Centre funding): During summer 2015, we measured the plant canopies' spectral signatures right before the 1st and 2nd cut of timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis)* and red clover (*Trifolium pratense* L.) monocultures at NIBIO locations in the north (Holt-Tromsø) and in the south (Apelsvoll-Kapp) with the handheld spectroradiometer ASD FieldSpec3 (ASD). Principal Component Analysis (PCA) of the spectral similarity of the different species revealed only small differences between the grass species, while red clover had a different spectral signature and may be modelled separately. Summer 2016 we used ASD (60°off-nadir) and measured similarly in field trials with a mix of timothy, meadow fescue and some red clover, at 3 fertilizer levels at 3 NIBIO sites (Apelsvoll, Kvithamar and Holt). In addition, a Rikola hyperspectral imager, mounted on a drone (UAV), was used to gather nadir measurements in the same field at Apelsvoll. Yield samples from Apelsvoll were analysed for feed quality with NIRS and Kjeldahl-N. Powered partial least square regression analysis (PPLS) was used to model the relationship between spectral and yield data for both sensors. The ASD data sets are suitable to model DM yield on the pooled data only, with lower accuracy than the Rikola data sets. The Rikola data sets are suitable to model DM yield on all data sets, with high accuracy. The ASD data sets are suitable to model N (Kjeldahl) and NDF on the pooled data only, with lower accuracy than the Rikola data sets. The Rikola data sets are suitable to model N

(Kjeldahl), protein, and NDF on the pooled data. In summer 2017, we repeated the measurements from 2016, but we chose to use a nadir viewing angle for the ASD due to the good experience we made with the Rikola system in 2016. The UAV/Rikola measurements were extended and carried out in Apelsvoll and Kvithamar. More than 50% of the samples from these two locations were selected to be analyzed in the lab for quality parameters. The results are not yet at hand, but we expect to start with the analysis, soon.

WP 3 (Extra support from Fram Centre): Estimate variation in grassland production at regional levels by satellite remote sensing imagery

a) Developing methods for monitoring the extent and severity of winter damages using satellite data: We obtained all available Landsat 5 and 7 images and MODIS 16-day NDVI products for Rogaland for 2009 to 2013. Spectral signals for grassland polygons were extracted for early growing season (e.g., April-June) each year and analysed for intra-annual and inter-annual variability. A number of outlier detection algorithms were examined to detect spectral signals associated with winterkill events/locations. We used air photos and GIS point locations from a farmers' self-reporting database for subsidy applications as reference data to guide and validate the outlier detection algorithms (outliers being areas with severe winterkill). The GIS locations are of the farm businesses (farm house), and not the fields themselves, however. Therefore, our ground truth locations were only approximate for this analysis. However, our results showed significant correlations between remote sensing-determined areas of winterkill and farmer self-reported areas of winterkill. In 2017, a year with significant winterkill, we obtained excellent ground truth data from the Målselv Kommune Agriculture Department, specifying the farmers that experienced winterkill, along with the percentage of their fields that experienced winterkill in 2017. We combined these data with property boundary data and Areal Resource maps of field boundaries to obtain excellent ground truth. In addition, we solicited expert knowledge about the timing in 2017 of 'normal' green-up vs. green-up of fields experiencing winterkill. We are now downloading and will soon analyze available Landsat and Sentinel-2 imagery from the "inter-green-up" period when 'normal' fields and fields experiencing winterkill should exhibit clearly different spectral signals. We expect this analysis to provide more specific and more accurate information about which fields in Målselv experienced winterkill. If successful, this method will be detailed for future use, though knowledge of when local "inter-green-up" periods occur in different regions each year will be key for carrying out such future analyses, as well as retrieving cloud-free satellite imagery during these (approximately 2-week) periods.

b) Estimating productivity of grassland fields with the use of remote sensing from different platforms:

In 2016, we used a multirotor UAV with a Rikola multispectral camera, recording 15 bands in the visible and near infrared (NIR) (500-900 nm), and a MAPIR NIR camera to map the variation in spectral reflectance in 3 farmers' meadows in the Harstad region just before the first cut. Immediately after the UAV measurements, we measured the spectral reflectance using an ASD Fieldspec3 (350-2500 nm) using 2 methods (60° off-nadir and nadir), at 12 sample locations in each field. The advisory service (NLR) estimated species composition and phenology, and recorded biomass at each sample location. The correlation between biomass and spectral reflectance was explored using different vegetation indices, which were then used to map the variability within each field. In addition, the ASD data was analysed with PPLS to identify a correlation between spectral reflectance and biomass. The 2 measurement methods, 60^{o}off-nadir and nadir, were compared: 60^{o}off-nadir gave better results; however, it was decided to continue with nadir angle to better integrate these data with data obtained from UAV and satellite.

We repeated the work in 2017, collecting UAV based data and ground measurements from 4 fields in Malangen. This time we used 22-28 sample locations per field to increase the number of datapoints for the analysis and modelling. The UAV data is currently being processed and the data will be analysed together with the data from 2016, with the aim to develop algorithms to estimate grass yields and map the spatial variability within and between fields. As part of the project, two summer students from UiT and NTNU helped to build a gimbal to stabilize the cameras on the multirotor UAV and integrate the cameras with the flight controller. They also assisted with the UAV measurements in Malangen.

Sentinel-2 data from the same areas as well as from areas in Møre og Romsdal, Finnmark and Vesterålen have been downloaded for 2016 and 2017. They will be analysed together with results from yield recordings made in these fields (see under WP4) to develop algorithms to estimate productivity. Unfortunately, due to sick leave, this work had to be postponed to 2018.

The ASD spectrometer data and ground truth dry biomass data from Malangen (collected in 2017) and Harstad region (collected in 2016) will also be added with data are from 2014 and 2015 from other location in North Norway (collected with FINEGRASS project funds). We modeled dry biomass with the spectral data and the preliminary results were mixed, with 2014 data having accurate results (R^2 around 0.85), 2015 data quite poor (R^2 in the 0.4-0.5 range), 2016 data having good results (R^2 between 0.6 and 0.8), and the 2017 data being quite poor (R^2 for the calibration data around 0.2 and for the validation data around 0.6). We are now putting all the datasets together into one large dataset, and combining it with more data collected from fields at Holt to attempt to get a more robust model, and we are also trying new data analysis procedures. These analyses should be complete by December or January.

WP 4: Farmers' fields inventory and capacity building (extra funding from Fram Centre to advisory service):

Grassland yields and feed quality in farmers' fields have been recorded by counting the number of silage bales harvested, and weighing

and sampling a representative sample of them for feed quality. Approximately 120 fields in total were sampled by the Advisory Service (NLR) in Vesterålen, Harstad/Ofoten region, Tana, and in parts of Møre og Romsdal county in 2016. In 2017, approximately 90 fields are sampled in Finnmark, Troms and Nordland. Botanical composition has been recorded in spring 2017. The data from some of these fields will be used as ground truth for Sentinel-2 satellite data to model productivity of these fields. The results from the inventory is being used to monitor grassland productivity, and as background for discussions with advisory service and with farmers on trends in grassland productivity. The results will also be related to ways in which agronomy in north Norway can address climate change. The preliminary results show large yield variations. In the mountainous regions, there was a clear yield decline from the youngest meadows to medium aged meadows (4-6 years) and further a decline to older meadows. Most of this decline was in the 2nd cut. In Møre og Romsdal, there were small differences between the age groups, but also here the largest aftermath was in the young meadows. In Northern Norway, there was no yield decline the first six years, but decline for older meadows. The botanical inventories show rapid decline of timothy and meadow fescue after three years, while *Poa* spp. and coach grass increase. In several districts, the average dry matter (DM) content of the bales is 30%, and the average DM per bale was 240 kg in 2014 (around 200 FEm/ball). These figures are higher than those used in yield statistics from Statistics Norway (SSB) and by "Driftsgranskninger" in Nibio.

Highlights:

1. Grass dry matter yields and quality of yields in field experiments could be modelled with high accuracy with Rikola, but less accuracy with ASD FieldSpec3.
2. We have found significant correlations between remote sensing-determined areas of winterkill and farmer self-reported areas of winterkill.
3. UAV-based maps of vegetation indices give an excellent indication of the variation between and within farmers' fields. However, initial results gave poorer correlation with yield than the experimental plots (WP1) due to greater variation in species composition, soil conditions and quality and other environmental influences.
4. Yield and botanical inventories of farmers' fields show generally decline in yields and change in botanical composition with increased age of swards, but with high variation between fields.

For the Management

Forage is a key resource for ruminant meat and milk production. Information on yields and forage quality on the standing crop could help farmers make appropriate management decisions concerning i.e.: harvesting sequence of different fields according to yield and feed quality, sorting according to feed quality, purchasing the appropriate supplements, stocking rate etc. More precise information on variations at field and regional level can give better knowledge on the links between yields and agricultural practices, soil and climate.

Results on satellite image-assessed extents of grass winterkill can be particularly useful for statistical offices in the future because Norway has now ceased to offer subsidies for winter-damaged lands, and therefore data on winterkill has ceased to be collected.

Published Results/Planned Publications

Refereed scientific papers

Geipel J. & Korsaeth A. 2017. Hyperspectral Aerial Imaging for Grassland Yield Estimation, *Advances in Animal Biosciences* **8**(2), 770-775.

Conferences

2017

Geipel, J. 2017. "Underlag för webbaserat beslutsstödesystem för smart växtodling". EU-Interreg project meeting (Innovationer för hållbar växtodling). 7 November 2017, Apelsvoll, Kapp, Norway

Geipel J. 2017. "Hyperspectral Aerial Imaging for Grassland Yield Estimation". Presentation at the 11th European Conference on Precision Agriculture (ECPA 2017), John McIntyre Centre, Edinburgh, UK, July 16–20 2017

Shao Y, Taff G, Jørgensen M. 2017. "Detection of winterkill in grasslands in Norway using spatial-temporal satellite data mining". Abstract and presentation at the annual meeting of the American Association of Geographers, 5-9 April 2017, Boston, MA, USA.

Geipel J. 2017. "Pitfalls and a Best Practice Procedure for Agricultural Aerial Imaging with the Rikola Hyperspectral Camera". 10th EARSeL SIG Imaging Spectroscopy Workshop. Apr. 19 – 21, 2017 in Zurich, Switzerland.

2016

Geipel J. 2016. "Close-range remote sensing and geo-data handling in precision agriculture". NJF Seminar 492. Agromek and NJF joint seminar - Advances and Innovations in Agricultural Engineering. The 2nd NJF - Agromek- EurAgEng joint seminar, Nov. 28 - 29, 2016 in Herning, Denmark. Foredarg og abstract (Proceedings 2nd NJF-EurAgEng Agromek workshop 2016, s 21).

Korsæth A. «Precision agriculture and mobile sensor platforms – any trade-offs for the breeder community»? Presentasjon på The 2nd Annual - Nordic Plant Phenotyping Network Workshop, Advances in Plant Field Phenotyping – New Tools in Plant Breeding, 23.11.2016 , Båstad, Sverige.

Korsæth A. «Vision for HIS and spectroscopy sensors». Presentasjon på dialogmøte med IMEC, Leuven, Belgia 17.03.2016

2015

Taff G. 2015. Research grants on northern cultivated grasslands" at Arctic Biomass Final Workshop, October 20-23, 2015, Longyearbyen, Svalbard.

Submitted abstracts for conferences:

Davids C., Karlsen S-R., Murguzur F., and Jørgensen M. UAV based mapping of variation in grassland yield for forage production in Arctic environments. Submitted and accepted for the America Geophysical Union (AGU) Fall meeting, 11-15 December 2017, New Orleans, US.

Lunnan T., Todnem J. and Jørgensen M. Botanical composition of grassland in mountain districts of Norway. Submitted and accepted for the 27th European Grassland Federation (EGF) General Meeting, 17-21. June 2018, Cork, Ireland.

Davids C., Karlsen S-R., Murguzur F., and Jørgensen M. **UAV based mapping of grassland yield for forage production in northern Europe.** Submitted and accepted for the 27th European Grassland Federation (EGF) General Meeting, 17-21. June 2018, Cork, Ireland.

Planned publications :

Tentative titles scientific publications of the whole project:

Paper 1: DM grass yield estimation with hyperspectral imaging systems on-board UAVs

Paper 2: Quality parameter estimation in grassland with hyperspectral imaging systems on-board UAVs

Paper 3: DM and quality parameter estimation in grassland with a portable spectrometer

Paper 4: Detecting regional extent of winter damage on small grassland fields using satellite remote sensing

Paper 5: Modelling productivity of Norwegian grasslands with Sentinel-2, unmanned aerial vehicles and handheld FieldSpec3 data

Paper 6: Causes and ranges of yield variation in grassland fields in Norway

Communicated Results

Newspaper, Web

2017

Schärer J. 2017. Ny teknologi for miljøvennlig produksjon/Overvåker bondens grønne verdier. Intervju med Marit Jørgensen og gårdbruker Stig Olsen Malangen. Publisert under samme innhold:
07.09.2017. s 12-13 i **NATIONEN**

07.09.2017. Web Nibio: https://www.nibio.no/nyheter/ny-teknologi-for-miljvennlig-produksjon?locationfilter=true

07.09.2017. Facebook: https://www.facebook.com/Nibio.no/

07.09.2017. Web Norut: http://norut.no/nb/news/ny-teknologi-miljovennlig-produksjon

07.09.2017. Web Framsenteret: http://www.framsenteret.no/ny-teknologi-for-miljoevennlig-produksjon.6026855-146437.html#.Wg4HolXibX4

2016

Hind L. J. 2016. "Ny fjernmålingsteknologi kan gi bedre fôrproduksjon» - Intervju med Marit Jørgensen. Publisert under samme tittel og innhold:

16.12.2016 Bonde og Småbruker nr. 10 16. desember 2016

15.12.2016 Landbrukstidende Nr. 9 2016, s 8

01.12.2016. Web Framsenteret: http://www.framsenteret.no/ny-fjernmaalingsteknologi-kan-gi-bedre-forproduksjon.5932716-146437.html#.WFOqoFPhCUk

01.12.2016. Web Norut: http://norut.no/nb/news/ny-fjernmalingsteknologi-kan-gi-bedre-forproduksjon

30.11.2016. Web NIBIO: http://www.nibio.no/nyheter/ny-fjernmlingsteknologi-kan-gi-bedre-frproduksjon

Fagblad

2017

Lunnan, T og Jørgensen M. Avlingsregistreringar i eng. Buskap 03-2017, s 70-72, 3 s.

Dissemination for stakeholders

2017

20.05.17 – Bakken A.K. Rådgiversamling Nibio Kvithamar – markvandring og presentasjon av feltforsøk i prosjektet «Bruk av fjernanalyse for økt presisjon i grovfôrproduksjonen". Kvithamar Stjørdal.

22.05.2017 - Korsæth A. «Mulighetsbildet for presisjonsjordbruk i Norge». Presentasjon på Go Bio – en workshop i regi av Innovasjon Norge. Oslo

29.03.2017 - Korsæth A. «Presisjonsjordbruket – har vi bare sett starten?». Våronnmøte i Veldre Bondelag, Rudshøgda

20.02.2017 - Korsæth A. «Hvordan utløse potensialet for næringsutvikling i forhold til bioøkonomi?» Presentasjon på Styringsgruppemøte for regionale planer i regi av Oppland Fylkeskommune. Lillehammer

27.01.2017 - Korsæth A. «Senter for presisjonsjordbruk og utvalgte prosjekter». Presentasjon for Regionrådet (ordførere og rådmenn i Gjøvikregionen), Hoffsvangen

2016

15.11.2016 - Korsæth A. «Presisjonsjordbruk – en generell oversikt». Presentasjon på Fagprogram korn, kursuka til NLR 2016, Gardermoen.

26.10.2016 - Korsæth A. «Presisjonsjordbruk i forskningen - hva har vi lært, og hvor går veien videre»? Foredrag på møte i regi av Oslofjorden Frukt & Bær om mekanisering og robotisering, NOFIMA, Ås.

25.08.2016 – Jørgensen M. Rådgiversamling Nibio Holt – presentasjon av prosjektet «Bruk av fjernanalyse for økt presisjon i grovfôrproduksjonen". Holt Tromsø

24.08.2016 - Korsæth A. «High-tech agriculture is up and coming»! Foredrag på Bioforum, i regi av Hedmark Kunnskapspark, Hamar.

04.08.2016 - Korsæth A. «Presisjonsjordbruk». Foredrag for kurs for agroteknikere innenfor planteproduksjon og driftsledelse ved Hvam videregående skole, Apelsvoll.

02.03.2016 - Korsæth A. «Ny teknologi i landbruket – gevinst både for bonde og industri». Foredrag på Landbrukskonferansen i Rogaland, Hotel Clarion Energy, Stavanger

02.02.2016 - Korsæth A. «Landbruksteknologi og systemanalyse». Foredrag og demonstrasjon av teknologi (sensorer, UAVer, robot) for mat- og landbruksminister Jon Georg Dale, Apelsvoll.

01.03.2016 - Korsæth A. «High-tech-jordbruket kommer for fullt». Foredrag på Sparebank 1 sin fagdag for landbruk, Hamar.

28.01.2016 - Korsæth A. «Presisjonsjordbruk - muligheter i grovfôrproduksjonen». Foredrag på Kvithamardagen, Kvithamar.

26. 01.2016 - Bakken A. K. «Grovfôr og teknologi». Foredrag ved Strategiseminar - Grovfôr og ny teknologi. Landbruk 21 Trøndelag.

2015

Korsæth A.2015. «Mulige tema av interesse for NRK». Innspill på dialogmøte med NRK Hedmark og Oppland, Lillehammer. 24.11.2015.

Jørgensen M. 2015. “Can we use remote sensing for estimating yield and quality – background and plans for the “Remote sensing” project”. Foredrag møte med Statistisk Sentralbyrå, Polen og Statistisk Sentralbyrå, Norge, NIBIO, Tromsø, Holt 22-23.09.2015.

Jørgensen M. 2015. “Prosjekt grovfôr”. Foredrag internt for direktør for NIBIO, Holt. 17.06.2015.

Korsæth A.2015. «Landbruk og teknologi – en matnyttig kombinasjon». Foredrag på Særheimdagen 2015. Rogaland Landbrukspark, Klepp 21.10.2015.

Korsæth A.2015. «Technology and food production – The perfect match». Foredrag på «Vertical farming day», Oslo Innovation week, Oslo 12.10.2015

Korsæth A.2015. «Highlights from our research on precision farming». Foredrag og møte med firmaene NORDOX og Leading Farmers CZ, 25.09.2015.

Lunnan, T. 2015. NIBIO projects on grassland surveys – survey of status of Norwegian mountainous grasslands; rationale, methods, and preliminary results. Foredrag møte med Statistisk Sentralbyrå, Polen og Statistisk Sentralbyrå, Norge, NIBIO, Tromsø, Holt 22-23.09.2015.

Mølmann J. 2015. “Field measurements and handheld field spectroscopy, methods and experience”. Foredrag ved møte med Statistisk Sentralbyrå, Polen og Statistisk Sentralbyrå, Norge, NIBIO, Tromsø, Holt 22-23.09.2015.

National meetings, conferences

2017

02.11.2017 - Geipel, J. «Research in precision agriculture and its demand for diverse types of data». Presentation at NIBIO Food and Society division meeting, Gardermoen.

08.03.2017 - Korsæth A. «Senter for presisjonsjordbruk og relevante prosjekter». Workshop i EU-prosjektet SOILCARE. Oslo

2016

15.12.2016 – Jørgensen M. Remote sensing. Foredrag ved Framsenteret - Årsmøte i det terrestre flaggskipet 15. Desember.

24.11.2016 – Jørgensen M. “Kan vi bruke fjernmåling til å få oversikt over avlinger i engdyrkinga”? Foredrag ved Hurtigruteseminaret 2016 –Landbruk i hele landet.

22.11.2016 - Korsæth A. «Kan presisjonsjordbruk redusere jordbrukets klimautslipp». Presentasjon på konferansen Klimasmart landbruk, Gjennestad.

International meetings, seminars, proceedings

2017

Geipel, J. 2017. "Underlag för webbaserat beslutsstödesystem för smart växtodling". EU-Interreg project meeting (Innovationer för hållbar växtodling). 7 November 2017, Apelsvoll, Kapp, Norway

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Shao Y, Taff G, Jørgensen M. 2017. "Detection of winterkill in grasslands in Norway using spatial-temporal satellite data mining". Abstract and presentation at the annual meeting of the American Association of Geographers, 5-9 April 2017, Boston, MA, USA.

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Korsæth A. «Precision agriculture and mobile sensor platforms – any trade-offs for the breeder community»? Presentasjon på The 2nd Annual - Nordic Plant Phenotyping Network Workshop, Advances in Plant Field Phenotyping – New Tools in Plant Breeding, 23.11.2016 , Båstad, Sverige.

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2015

Taff G. 2015. Research grants on northern cultivated grasslands" at Arctic Biomass Final Workshop, October 20-23, 2015, Longyearbyen, Svalbard.

Interdisciplinary Cooperation

This project is a collaboration between scientists focused on agronomy (Jørgensen, Lunnan – studying grassland cultivation and effects of agronomy and climate changes on grassland productivity), plant biology (Mølmann – field methods and yield/feed quality analyses), statistical modelling and geographic information science/remote sensing (Taff, Geipel, Korsæth, Shao, Murguzur, Karlsen and Davids – GIS, modelling and remote sensing of vegetation). We also collaborate with the Agricultural Advisory Service. This brings in different perspectives and competences/knowledge and ensures better and more appropriate choices of methodology from the different fields, etc. It also brings in new ideas. Collaboration with the advisory service who are very close to the end-users ensures that the scientific focus is important and "realistic" for end-users. On the other hand, coming from quite different scientific fields requires some extra time for learning each other's fields.

Budget in accordance to results

With the Fram Centre funding, we could engage Francisco Javier Ancin Murguzur to do Fieldspec measurements in Malangen, and it allowed for detailed ground truth performed by NIBIO. The funding is essential for accomplishing the processing and analysis of Sentinel-2 data and Rikola data for Norut. It covers some of the in-kind funding from Norut, as well as in-kind funding for the advisory service. In addition, the funding covered more time costs for Yang Shao at Virginia Technical University, and the time used by Hans

Tømmervik at NINA for advising.

Could results from the project be subject for any commercial utilization

No

Conclusions

a. To use satellite imagery to assess extent of winter damaged lands, incorporation of a temporal component into analyses has proven key, since winter damaged lands are sometimes resown in the same year, therefore requiring satellite imagery from post-green-up and pre-resowing time points. Such algorithms are currently being tested in the project.

Initial results have shown that UAV-based multispectral mapping is able to detect and map spatial variations in the yield and productivity in agricultural fields based on spectral indices. However, these initial results have also highlighted the need for further research into the understanding and characterization of the bidirectional reflectance distribution functions (BRDF), which is a function of both the illumination angle (sun angle), view angle, and biophysical properties of the vegetation, and the development of correction methods for its effect on the measured reflectance. Results from this project can be used for future research into the development of simple systems (handhold or small UAVs) that can be handled directly by farmers or foresters.

b. The project has helped to further develop a processing chain for the UAV-based multispectral Rikola camera, including initial corrections for the variability of light intensity and viewing angles. This is important to increase the usefulness of UAVs for vegetation monitoring and the ability to extract vegetation parameters and compare directly with satellite data.