Slutrapport

Gradering av vallar i norra Sverige med hjälp av satellitbilder

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Del 1: Utförlig sammanfattning

Fodergrödor, framför allt i form av blandvall, utgör en dominerande del av jordbrukslandskapet i Sverige. Detta gäller särskilt norra delen av landet där den utgör mer än 70 % av den totala åkerarealen. Det vallfoder som produceras är ekonomiskt viktigt, eftersom det är den främsta foderkällan för våra idisslare och därmed i förlängningen för mejeriindustrin och all annan verksamhet som bygger på produkter från idisslare. Ett verktyg för kartläggning av vallens biomassa, kvävestatus och näringskvalitet kan vara till hjälp vid planeringen av gödsling, skörd och utfodring, och så småningom resultera i en mer ekonomiskt och miljömässigt hållbar produktion. För detta ändamål har vi utvärderat användbarheten hos satellitbilder för att övervaka vallars biomassaproduktion, kvävebehov och näringskvalitet.

Totalt samlades 216 prover in från fyra platser i norra Sverige under 2019. Även om arbetet är en del av ett pågående projekt har de resultat som hittills förvärvats gjort det möjligt att förkasta flera av de testade tillvägagångssätten för att uppskatta produktionen av biomassa hos en vall. Detta minskade antalet kandidatmodeller som behöver testas. Ännu viktigare var att en av modellerna visade sig kunna upprätta ett linjärt samband mellan biomassa och satellitinformation med tillfredsställande noggrannhet. Det fortsatta arbetet inom området innebär bland annat att prova olika maskininlärningsmetoder för att uppskatta biomassa. Den arbetsprocess som utvecklats för biomassa kommer också att tillämpas systematiskt på egenskaper för näringskvalitet och kväveupptag.

Resultaten från projektet bekräftar satellitbildernas potential för att uppskatta biomassaproduktion hos vallar. Det har också visat på de begränsningar som kan finnas i provtagningsmetoden. Dessa begränsningar har korrigerats vilket bör resultera i mer exakta uppgifter de kommande provtagningssäsongerna. Projektet har också initierat flera samarbeten med fjärranalysexperter från de nordiska länderna, vilket i slutänden bör bidra till möjligheten att bygga mer robusta modeller för användning i lantbruket.

Projekt har fått finansiering genom:
Stiftelsen Lantbruksforskning

Del 2: Rapporten

Introduction

Forage crops, predominantly mixed leys, are a dominant part of the agricultural landscape in Sweden, as they represent approximately 45% of the total arable land acreage in the whole country and more than 70% in Northern Sweden. The grassland forage produced on ley fields is economically important, as this is the principal feed source for ruminant livestock production. A tool for mapping biomass, N status and nutrition quality of a ley will assist farmers with feed budgeting, harvest logistics, efficient use of fertilizer, and eventually, result in an economically and environmentally more sustainable system.

Remote sensing in agriculture enables retrieval of information on crop status based on specific spectral signature analysis. More specifically, satellite remote sensing is a widely used tool to monitor within-field changes of crops over large areas. Sentinel-2 satellite constellations provide open access to optical images with high spatial resolution and high frequency of revisit. As this frequency increases with latitude, the average revisit time ranges between 2 and 3 days in Sweden. Time series of satellite images can be used to monitor the dynamics of growth and vigour of crops (see examples with Figure 2) and provide useful information, such as dates of harvests.

The first aim of this project is to develop a satellite-based method to estimate the biomass, crude protein, and nitrogen (N) uptake of forage crops in Northern Sweden. The second aim is to assess the potential of the Sentinel-2 images for retrieving the digestibility of forage crops, which would provide a valuable tool to optimise the harvest date.

Data acquisition

Please note that the project is ongoing and that a new dataset is being acquired for 2020. The materials and methods presented in this report only relate to year 2019.

Field data

Field data have been acquired in Umeå, Ås, Lännäs and Öjebyn (Figure 1). A total of 72 field samplings were performed, resulting in 216 forage samples. Field measurements included the average and maximum (highest plant) height of the canopy for the primary grass and clover species. In Umeå, additional measurements were performed and included (i) mean leaf chlorophyll contents of grass and clover and (ii) spectral measurements using a Yara-N sensor. For all sites, harvested samples were taken back to the laboratory to be hand separated. Samples were weighed before and after drying to calculate plant water content and to compute the dry matter yield. Finally, the samples have been milled and sent to a laboratory for chemical analysis.

This first year of measurements underlined some limitations in the current sampling protocol. The major issue relates to the acquisition of precise GPS coordinates to link field measurements to a precise pixel of the satellite images. Field operators at Ås and Lännäs did not have a GPS receiver and used a smartphone-embedded GPS to estimate the spatial coordinates, resulting in a potentially poor geographical precision. However, these data can still be used as averaged values of the studied field to relate to satellite data. This issue has been solved by purchasing precise GPS receivers. The other issue in 2019 was related to using a field at one location with a high weed proportion, which resulted in time consuming hand separation of the samples. This highlighted that for this pilot project the focus of the data collection should be from fields with a high proportion of sown species.

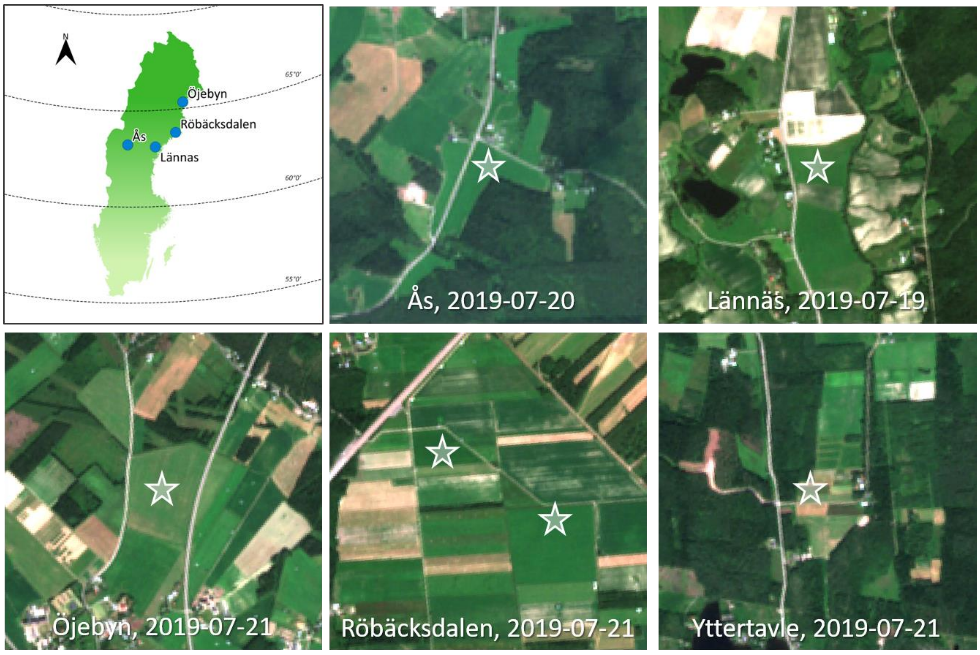

Figure 1. Locations and satellite images of the fields used for measurements (2019). White stars indicate the location of the fields. Röbäcksdalen and Yttertavle are both located close to Umeå. Note that there are two fields monitored at Röbäcksdalen.

Satellite data

A total of 133 Sentinel 2 images have been downloaded from end of March to late September 2019. The satellite images were processed to remove unwanted pixels (i.e., snow, clouds and cloud shadows), resulting in an average frequency of acquisition of cloud-free images of approximately 5 days (Figure 2). Satellite images were further processed to compute various vegetation indices, including the normalised difference vegetation and red edge indices. Finally, spectral information (including vegetation indices and individual spectral bands from the Sentinel-2 sensor) were extracted for the fields of study and the coordinates corresponding to samplings.

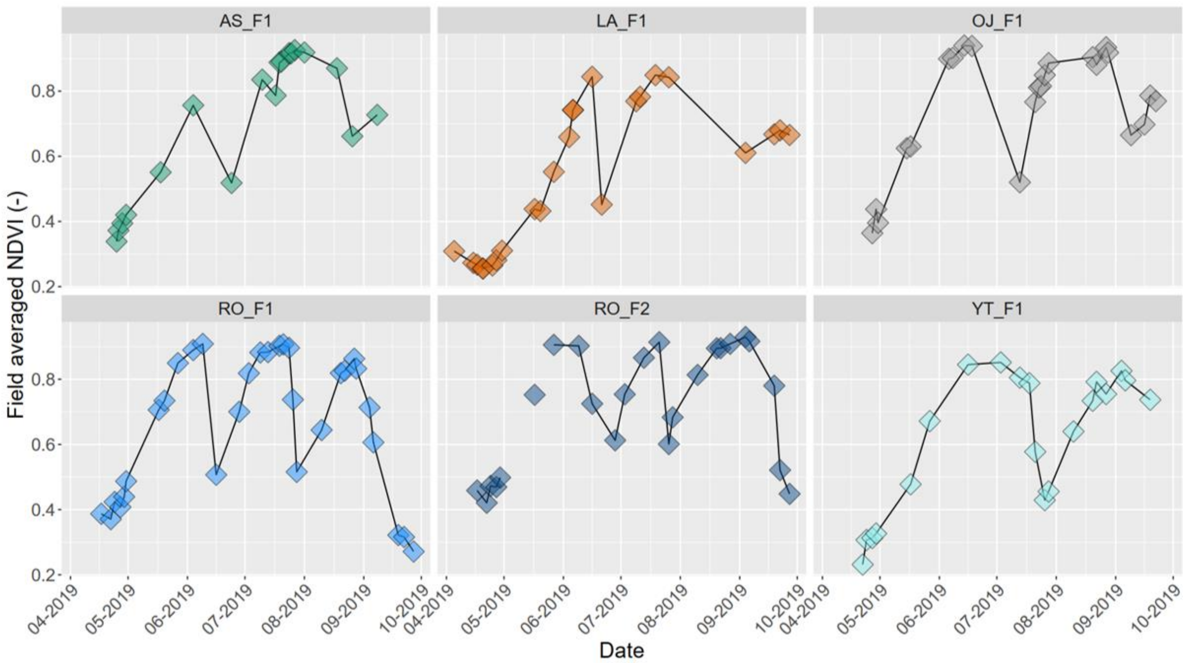

Figure 2. Time series of Sentinel-2 images for the fields of the study. Values toward 1 indicate very healthy and vigorous plants, values toward 0 indicate dead vegetation, less vegetation, or bare ground.

Results and perspectives

As mentioned previously, this work is related to an undergoing project, and more results will be available within the next months. The results presented here only relate to the estimation of the biomass production (wet chemistry results were only recently received).

Several linear regression models were built using the various vegetation indices computed form the satellite imagery. The first attempt consisted of linking the biomass with the values of the different vegetation indices derived from satellite imagery, at the pixel level. Overall, the results indicated poor accuracy, although trends could be noted. Here we only present the results of the normalized difference vegetation index (NDVI, Figure 3).

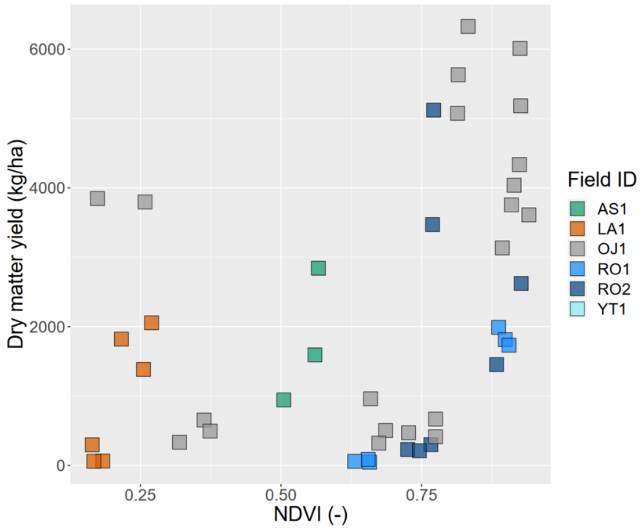

Figure 3. Dry matter yield as a function of NDVI (Normalized Difference Vegetation Index) at the pixel level. An exponential relationship tends to appear. However, the accuracy of this method decreases concomitantly with the increase in biomass and appears to be inefficient for levels of dry matter biomass greater than 2000 kg/ha.

The second approach was similar to the first one, except that the regressions were built at the field level (rather than the pixel level). It is indeed expected that this approach will yield better results, as averaging the values obtained from satellite imagery and field measurements will reduce the magnitude of their respective errors

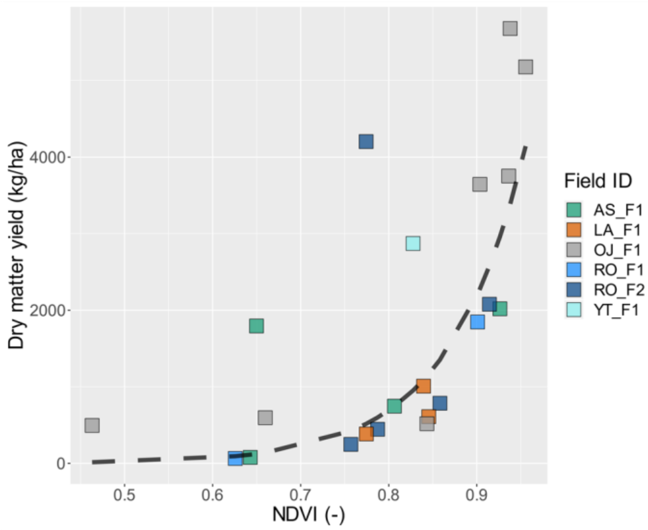

Figure 4. Dry matter yield as a function of NDVI at the field level. An exponential relationship clearly appears which greatly limits the potential of this approach for biomass estimation of harvested leys.

Despite yielding better results (see Figure 4), this approach is still not satisfactory, as the exponential relationship observed previously appears more clearly, meaning that the estimation of dry matter yields becomes less accurate as NDVI increases. These results are consistent with what was expected, as NDVI and most common vegetation indices tend to saturate for high levels of biomass.

The third approach aimed at taking advantage of the change in NDVI through time by summing NDVIs computed from and between different image acquisition dates (the so-called integrated NDVI). The rationale of this approach is that integrating the values of NDVI over a period (between two cuts, for example) helps to reduce the saturation effects. Moreover, this approach allows to account for the history of the field (e.g., time and space constrained nitrogen stresses) that might affect the final yield. At this stage the results are presented only for the field level, and will further be investigated for the pixel level.

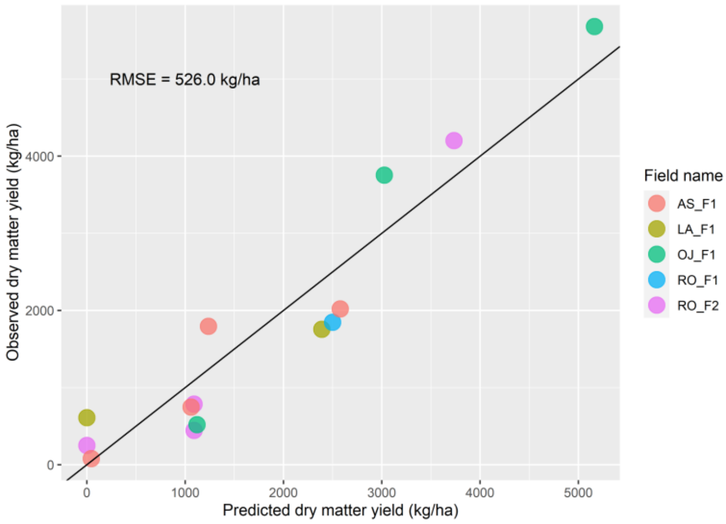

Figure 5. Preliminary results of the biomass estimation using NDVI values integrated over time (field level). The predicted dry matter yield was computed from the values of integrated NDVI using a simple linear regression. This approach shows an interesting potential for biomass estimation. Note that some data, including the measurements performed for the field in Yttertavle, were temporarily discarded from the analysis due to missing information.

This approach was better than the previous ones. A clear linear trend, resulting in a satisfactory capacity of prediction of the dry matter yield, was observed (Figure 5). If this is confirmed with measurements from 2020, this method could eventually be integrated into the existing CropSat webportal and provide farmers with information about the biomass production of their fields.

It is expected, however, that other approaches might yield better results. These methods, rather than using simple linear regressions, will be based on machine learning. Two main ideas remain to be explored: (1) the use of machine learning and regular multivariate statistics (e.g., partial least squares regression) combined with the 13 spectral bands available from Sentinel-2, and (2) the use of a combination of radiative transfer modelling and machine learning. Both approaches take better advantage of the rich spectral information of Sentinel-2, and using multivariate statistical approaches might help to greatly increase the accuracy of estimations while simplifying the computations, as no prior information would be needed (such as cutting date in the case of the integrated approach).

Beyond dry matter yield, further models will be developed to estimate the nutrition of the fields, including the crude protein content, the nitrogen uptake and the digestibility of the crop.

Communications

The work related to the current project was addressed in communications in national events, including various short seminars organized within SLU, the Hushållningssällskapet HIR-konferens and the seminar “Senaste forskningen med RJN” organized in Nordvik. A conference paper has also been accepted for a communication at the Joint International Grassland and International Rangeland Congress (2021). A manuscript that will be submitted to a peer-review international journal is currently being written.

Synergies

The project has gained interest from research institutes of Scandinavian countries and facilitated communication between researchers of different institutes and countries. Several collaboration projects are being planned and would involve researchers from LUKE (Finland), NIBIO (Norway) and Aarhus University (Denmark).

Conclusion

Encouraging results were obtained with the first set of data acquired within this project. The work carried out so far enables a number of approaches for leys biomass estimations from satellite imagery to be discarded, while a potential approach (the time integrated NDVI) has been retained. It has also been possible to identify limitations in the current data acquisition workflow, and overcome these limitations. As this is an ongoing project, these first results are of great importance for ongoing data collection. Further efforts need to be put on the estimation of biomass using multivariate regression techniques. More importantly, the work carried out so far for biomass needs to be applied to the nutritive value traits of ley fields.

The results obtained during this project received positive feedback from national and international partners, and further funding is being searched to continue the work and be able to propose, within 3 years, a tool that can easily be accessed by farmers to help decide on the best practices for their fields and farms.

Del 3: Resultatförmedling

Ange resultatförmedling av projektet, inklusive titel, referens, datum, författare/talare, och länk till presentation eller publikation om tillämpligt. Planerade publiceringar (med preliminära titlar) ska ingå i tabellen. Ytterligare rader kan läggas till i tabellen.

Vetenskapliga publiceringar	Morel, J., Féret, J.-B., Söderström, M., Parsons, D. *Using Sentinel-2 time series to monitor biomass production of managed grasslands fields.* (in prep.)
Övriga publiceringar	Planned scientific paper: Using Sentinel-2 imagery and machine learning to estimate nutrition properties of grasslands fields.
Muntlig kommunikation	Morel, J. (2019). *Vallsat: monitoring forage fields in Northern Sweden with satellite imagery*. Senaste forskningen med RJN. Nordvik, Sweden.
	Morel, J. Gustavsson, A.-M., Parsons, D. (2020). *N-sensors and image analyses in leys. The newest from SLU research.* HIR-konferensen, Hushållningssällskapet. Skara, Sweden.
	Morel, J., Parsons, D., Féret, J.-B., Gustavsson, A.-M., Söderström, M. (2021). *VallSat: monitoring grasslands in northern Sweden with Sentinel-2 imagery*. International Grassland Conference. Nairobi, Kenya.
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Övrigt	