SENTINEL-1 DATA USE FOR MONITORING OF AGRICULTURAL ACTIVITIES

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ABSTRACT

European Union Paying Agencies have to control activities of farmers who receive their support. Field visits are very expensive and time consuming, therefore remote sensing has to be used as much as possible. Freely available data from *Copernicus Sentinel* missions have already boosted research on radar and optical data use in agriculture. Summer of 2016 was very cloudy in Latvia and showed that most of the *Sentinel-2* acquisitions were not usable and other monitoring practices should be adopted. *Sentinel-1* radar imagery which is almost independent of weather could fill the gap between optical images.

Colour composite images of radar backscatter coefficient and coherence between two dates are useful for visual interpretation revealing bare soils when there are no optical images available. Radar image time series show agricultural activities (ploughing, harvesting, mowing) which are described by an increase in coherence and change in the backscatter coefficient. Data from these images can also be used for change detection to select parcels where no activity has been detected during agricultural season or until specified deadlines.

Monitoring of agricultural activities could be used to direct controls on the field exactly towards those farmers, who might violate regulations, although this approach still needs testing and verifying.

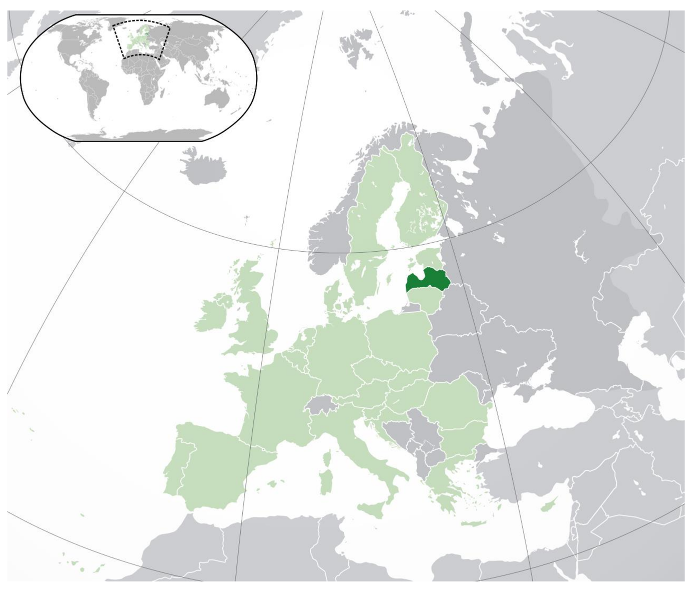
INTRODUCTION

The first year of operation of the *Sentinel-2A* satellite proved that even sunny summer days are very cloudy. Hopes for image time series had to be abandoned, and it was not possible to monitor agricultural activities during the season based solely on optical imagery. However, ESA's *Sentinel* satellite fleet already had the *Sentinel-1* SAR satellite, which can deliver imagery day or night, and through clouds. As its data is more difficult for interpretation and SAR data is less known and not so widely used, it was a challenge to begin working with them.

Sentinel-1 satellites have a C-band radar, which means that it senses microwaves which were transmitted by itself. It does not need any other energy sources (like the Sun for optical satellites) and C-band wavelength allows the signal to penetrate atmosphere even through clouds and light rain. SAR backscatter information reveals information about the Earth surface's roughness and wetness [1]. A six day repeat cycle with two satellites provides an opportunity to discover changes in surface properties in a short time which can be useful to find out when some agricultural activities (ploughing, harvesting, mowing) have been done.

OBJECTIVE

The objective of the study is to find methods for Sentinel-1 data processing to monitor agricultural activities in Latvia. The main goal is to select farmers who violate the terms of European Union or Latvian Government financial support. This means that there are two main risk groups – fields that are declared for support but there is no agricultural activity and grasslands that are not mowed. Successful detection of areas with no agricultural activity would improve administration of financial support by reducing the need for manpower on field visits.



METHODS

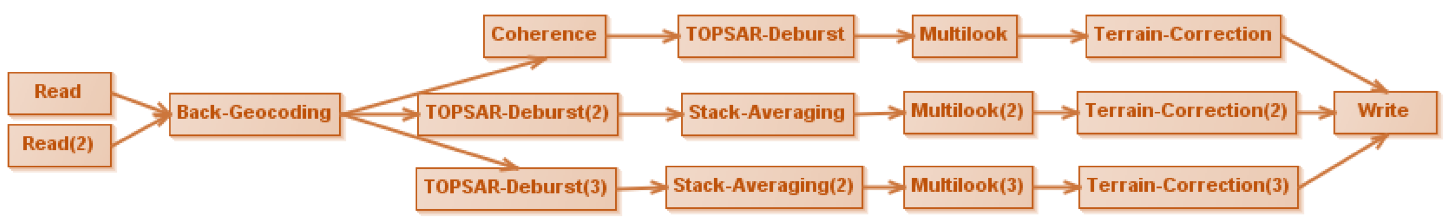
Study area is covered by several Sentinel-1 orbits but only afternoon acquisitions are used (relative orbits No. 131 and 160) because research on grassland mowing detection by coherence changes carried out by Tartu Observatory [2] proves that morning dew decreases SAR coherence.

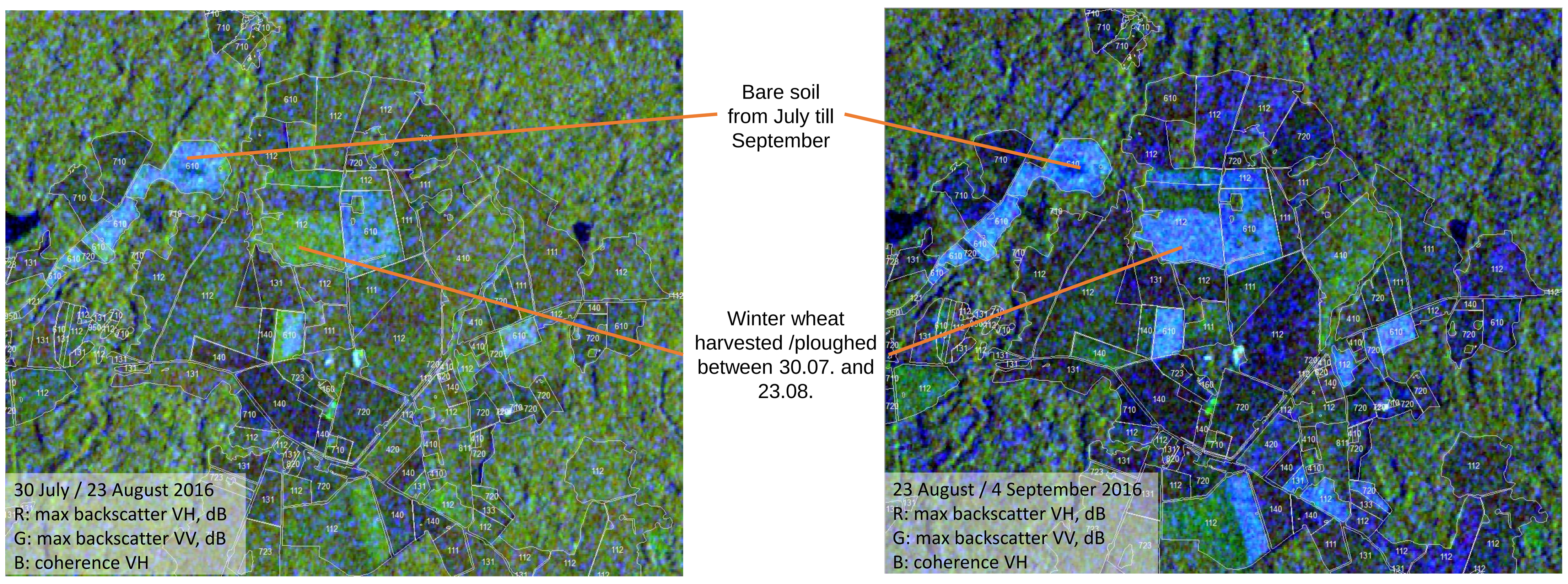
Sentinel-1 data is processed using ESA SNAP software. A Python script was compiled to perform all the processing steps on greater amounts of data.

As agricultural activity can be discovered by change in SAR coherence and backscatter coefficient, coherence and backscatter statistics images are generated which are finally stacked into multiband composites.

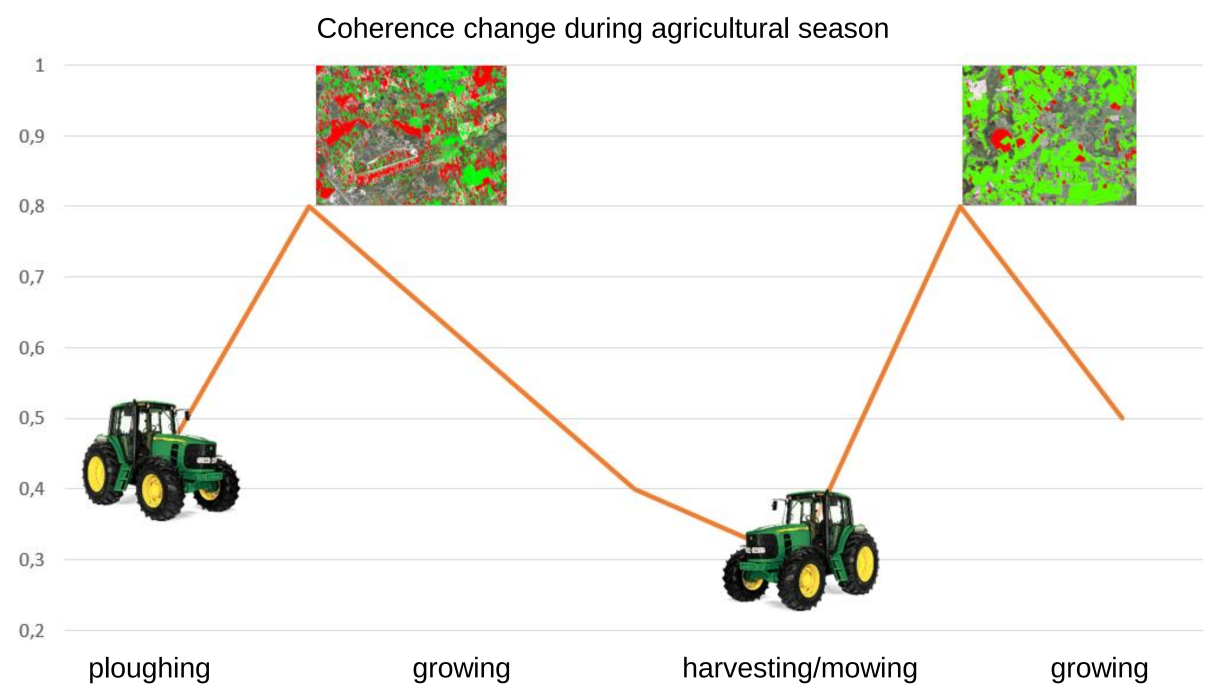
The processing chain is visible in the image below: two sequential SAR images, to whom precise orbits have been applied and that have been calibrated to complex numbers, are back-geocoded. Afterwards, three branches are applied for that stack – coherence estimation, maximum and average backscatter calculation. Products are stacked and mosaicked in GIS software.

Backscatter and coherence images can be further processed to get change of values for each parcel during the season which lead to risk parcel selection where no significant coherence change has been detected and perhaps nothing has been done on the field.

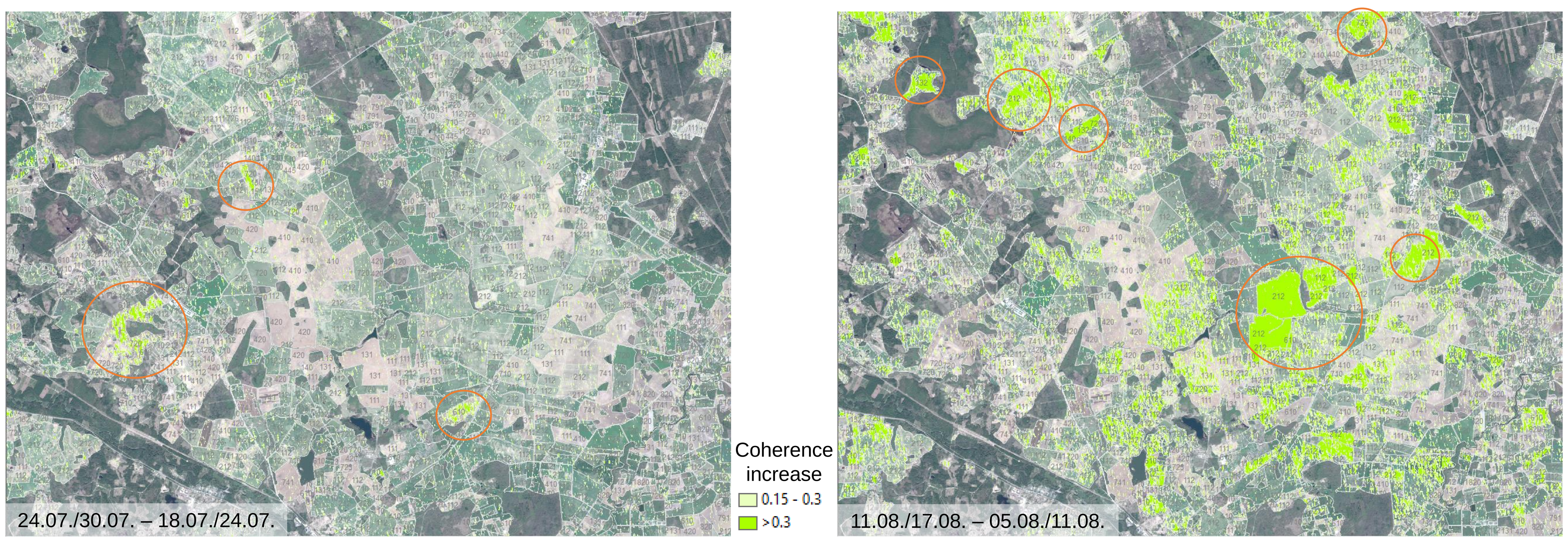




BARE SOIL DETECTION. Three *Sentinel-1* acquisitions are used to create two backscatter and coherence colour composites. Visual interpretation of these allows to skip field visits as agricultural activities are visible remotely. For example: some fields are symbolised blue in both images which means they are smooth and bare soil during the period, which leads to an assumption for an acceptable management of fallows (610). Parcels that appear green on the left image but blue on the right, might be harvested or ploughed between acquisitions of the first image (the first half of August) which is the typical harvesting period for winter crops in Latvia.



RISK PARCEL SELECTION. Coherence time series are analysed to detect significant increases in coherence which happen after ploughing, harvesting or mowing. Information from each SAR image is appended to database, e.g. each parcel receives an attribute whether it has been somehow cultivated or not. Conversely, parcels where no increase of coherence values is present during the season are subject for field visit.



RISK PARCEL SELECTION. EXAMPLE ABOVE. Coherence increase is calculated from coherence images generated from three sequential *Sentinel-1* acquisitions.

Bright green pixels in the image on the left indicate parcels where some agricultural activity has happened between 18th and 24th of July. It is the middle of agricultural season and very low activity is visible. Some fallows (610) are ploughed and some grasslands (710, 720) might be mowed. These parcels can already get an attribute of agricultural activity in database.

Bright green pixels in the image on the right indicate agricultural activity between 5th and 11th of August. Many fields are indicated because end of July and August is the typical harvesting period for winter crops in Latvia. Winter rapeseed (212) and winter barley (132) are visible in the example, also fallows (610) are ploughed and, perhaps, some cultivated grasslands (726, 720) are mowed. A greater number of fields can receive an attribute of acceptable practice.

Images of coherence increase appear quite noisy, there are many separate pixels with a higher increase in coherence. Parcels with agricultural activity should be marked only if many neighbouring pixels indicate activity or limit of coherence increase should be higher (but not too high). Such analysis can be made using many coherence increase images throughout the season and parcels without marks of activity are inspected on the spot or using other remote sensing data.

RESULTS

For now, most of these applications are theoretical. SAR data are processed and backscatter and coherence colour composites are used if there are some doubts about appropriate cultivation of agricultural land. Noteworthy, SAR images are only useful for the inspection of parcels with area that is comparable to *Sentinel-1* image pixel size, therefore only parcels that are larger than one hectare are observed.

Unfortunately, the summer of 2017 was even rainier than the one before, therefore coherence values might be distorted due to heavy rainfall; also, there are almost no cloud free *Sentinel-2* images to check the accuracy of Risk parcel selection. According to some ground truth data, selecting risk parcels by coherence increase still does not represent actual agricultural activities, probably because it is difficult to guess the coherence increase value that is significant enough to indicate activities.

DISCUSSION

The research on agricultural activity monitoring based on *Sentinel-1* time series must be continued. Although risk parcel selection for field visits is not yet truly reliable, sampling parameters (e.g. coherence increase value) can be adjusted to improve that. Of course, search of these values need a lot of processing, experiments and accurate field data.

Also, the author has not found arguments for SAR polarisation selection. In most cases selected polarization depends on available data, but in areas where cross polarization data is available, some authors choose VV, some VH. Processing all the data requires too much computing power, and results with different source data also need analysis and comparison. Besides, it would be interesting to find out how much precipitation makes SAR data unreliable.

CONCLUSION

Changes in SAR backscatter and coherence indicate agricultural activities. Ploughing, harvesting and mowing cause an increase in coherence and change backscatter intensity visible in seasonal time series. More effort should be put to improve automatic monitoring of activities and to create reliable risk parcel selection for directed field inspections. Success will make control activities of paying agencies more efficient by not visiting fields where there is no doubt everything is done correctly.

REFERENCES

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2. T. Tamm, K. Zalite, K. Voormansik, L. Talgre, Relating Sentinel-1 Interferometric Coherence to Mowing Events on Grasslands, Remote Sens. 2016, 8(10), 802