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Chillan, Bio Bio (Chile)

Date of Fellowship: September 8 – December 5, 2016

Title: Developing Prescription Maps from Synthetic Aperture Radar (SAR) Satellite Imagery for Variable Rate Irrigation (VRI) Applications

Theme 1: The Natural Resources Challenges

Consent is given to post this report on the Co-operative Research Program's Website

Relevance:
Chile's agriculture production is heavily dependent upon irrigation where 70% of cultivated land is equipped for irrigation. Yet in a 2015 speech Chile's President spoke to the country's on-going drought, acknowledging that "there is no choice but to assume that the lack of water resources is a reality that is here to stay and that puts at risk the development of important regions of our country". As such, efficient use of water is an imperative. Well informed decisions with respect to irrigation needs (applying the right amount, at the right time, in the right place) contribute to this imperative but also gives crops the best water prescriptions in order to be as productive as possible. At the field level farmers, large and small, are able to target resources to maximize production.

Variable Rate Irrigation (VRI) (variable in terms of space and time) offers a technology contribution to improve water use efficiency and to fit irrigation to crop needs. Implementation of VRI requires temporally frequent information about where water is needed and when. This collaboration uses Canadian technology (data from the RADARSAT-2 satellite) to inform VRI for application in Chile. Although the immediate implementation is directed towards assisting agricultural production in Chile, clearly this technology has applications to other important agricultural regions in other countries where access to dwindling water resources is of growing concern.

This project is clearly relevant to OECD Theme 1 (The Natural Resource Challenge) which has as one of its high level objectives, the sustainable use and protection of natural resources to support continued food production.

Objectives of the Fellowship:

The objective of this collaboration was to investigate the use of remote sensing satellite data (specifically Synthetic Aperture Radar or SAR) to estimate surface soil moisture and to create in-field zonal prescription maps. These data are to be used to inform variable application of water and nutrients, as well as to assist in operational decisions to allocate resources (farm workers and equipment) during periods of intense activity (primarily at the time of harvest). The focus was on the Canadian RADARSAT-2 satellite, but with an eye towards other existing and future satellite radars including Sentinel-1A/B, the RADARSAT-Constellation and the Italian-Argentinean constellation (SIAGE), among others. Both field and high value perennial agriculture production (chicory, blueberries, grapes and orchards) were under investigation at sites of ongoing Instituto de Investigaciones Agropecuarias (INIA) research in Chile's central Bio Bio Region.

Explicit objectives were as follows:
(a) Create pre-season VRI prescription maps based on soil variability as detected by SAR imagery. Two specific methods were identified – segmentation of SAR-derived soil moisture maps; change detection based on variances in backscatter and/or soil moisture as soils wet and dry.
(b) Create dynamic in season zonal maps for VRI implementation based on SAR responses to variability in crop growth, spatially and temporally, using segmentation and/or classification approaches.

Major Achievements:

In preparation for this OECD exchange, Agriculture and Agri-Food Canada (AAFC) programmed the RADARSAT-2 satellite to acquire 24 dates of fully polarimetric mode imagery covering three of INIA's research sites. These 2015-2016 data captured early season soil conditions and crop development. Upon arrival at INIA's Chillan research centre, the Sentinels Applications Platform or SNAP (a free SAR processing from Array Systems Computing Inc.) was downloaded and AAFC shared experience in processing these data with INIA researchers.

Initial analysis focused on determining the most appropriate work flow for SAR processing. For soil moisture processing this included assessing meteorological conditions during acquisitions to remove images affected by rainfall, as well as a post-processing step to remove residual noise after soil moisture retrieval. For zonal delineation this meant exploring, visually, the most promising SAR products and optimal soil moisture conditions in order to emphasize within field variations. This led to a work flow which included synthesis of backscatter intensity (HH, VV and HV/VH polarizations), SPAN (total backscatter) and components of the Yamagouchi decomposition (surface, volume and double bounce). Data acquired in the days following a rain event appeared to optimize spatial variations as soils dry. The 24 dates of RADARSAT-2 were processed and research is ongoing to develop a statistical and geo-spatial approach which will determine which product-dates are most informative for zonal delineation, and to segment these products into zones. Soils and yield data already collected by INIA, as well as optical satellite products such as the Normalized Difference Vegetation Index, will be used to validate and interpret the SAR-derived zones.

The figure below demonstrates some early products generated from this workflow. On the left, a time series of soil moisture (volumetric soil moisture in m^3/m^3) for the Carterra site is displayed. From meteorological records 15 mm of rain fell on May 18, the day before the first image. Four days of drying occurred prior to the second satellite acquisition. This combination of images identifies fields with wet soil conditions on both days (white), those that were relatively dry for both (dark) and fields where changes in soil moisture occurred due to drying (blue). The absolute soil moisture estimates are informative for decisions around irrigation of crops such as chicory. In addition, the differential drying of soils is indicative of within field variations in soil conditions which may be useful in precision management of these zones. The figure on the right is the Yamagouchi decomposition of two RADARSAT-2 images. The within field zones are visually obvious with differences in zonal delineation between the two dates a function of changing soil moisture conditions, but also differences in the incident angle with which the SAR images were acquired.

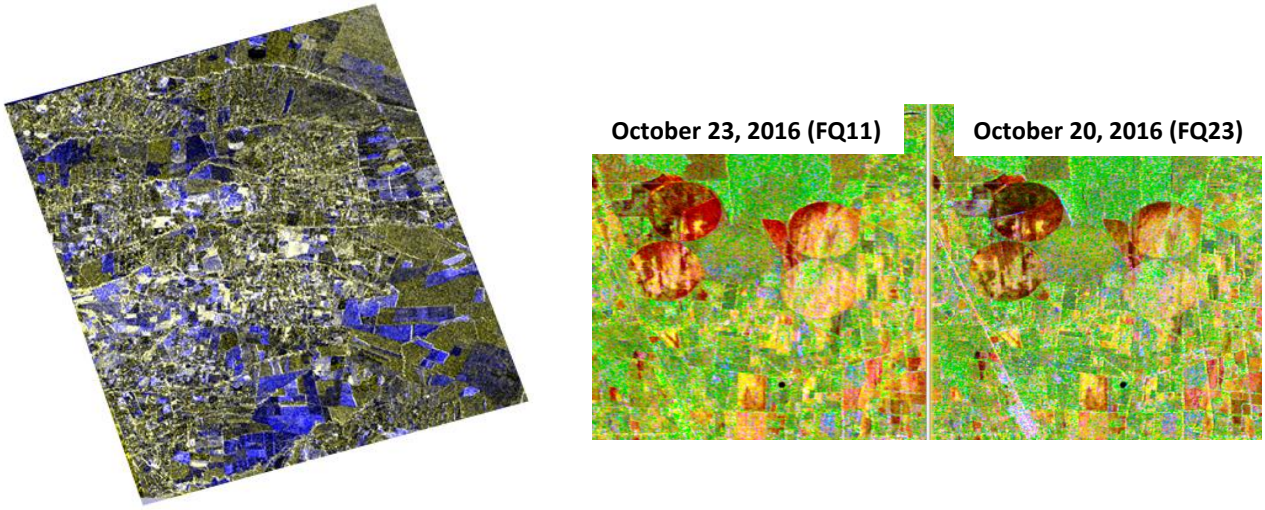

Figure 1. On the left, two dates of soil moisture (m^3/m^3) estimated from RADARSAT-2 are overlaid: May 19, 2016 and May 22, 2016. On the right, the Yamagouchi decomposition is applied to two dates of RADARSAT-2 data illustrating within field variations due to differences in soil conditions.

Several meetings were held with Chilean companies responsible for managing these high value crops. During these meetings the companies learned about how SAR satellite data might assist with monitoring soil conditions, and were provided with preliminary results from the 2015-2016 analysis. These

discussions led to a new project definition for monitoring chicory irrigation needs using SAR satellite data, in the vulnerable first 90 days following planting. Interest in within field definition using SAR was also emphasized for other crops including blueberries and vineyards. Following these meetings, AAFC programmed an addition 195 scenes over INIA research sites of chicory production focusing data collection on this initial period of chicory development. These 2016-2017 satellite acquisitions were also extended to cover a fourth INIA site dedicated to blueberry research.

Follow-up:
Pending results from the statistical and geo-spatial analysis of the 2015-2018 data, a referred journal publication is expected documenting these methods as well as the value of SAR to monitoring high value crop production in Chile. AAFC plans to continue the processing of the RADARSAT-2 data as the satellite continues to acquire data into 2017. INIA will focuses on the geo-spatial analysis and interpretation of these data products for agronomic applications. AAFC and INIA are preparing project proposals to resource this continuing collaboration. In addition, it is expected that INIA researchers will visit Canada in the coming months to discuss project progress and to consider widening the scope of AAFC-INIA collaboration to high value crops in Canada. Finally, pending successful project funding, the placement of an INIA researcher with AAFC is planned to facilitate more extensive training in the use of SAR data for precision management.

Satisfaction:

The Fellowship Programme provided an excellent opportunity to strengthen existing collaboration between AAFC and INIA, expand the scope of future collaboration and develop multiple tangible "next steps". INIA benefited from transfer of AAFC's knowledge in principals, processing and interpretation of SAR satellite data. Data from Canada's RADARSAT-2 satellite collected over INIA research sites provided early assessments of how this sensor technology may be used for precision management of several important crops in Chile. AAFC gained considerable understanding of the challenges faced in monitoring soils and crops in Chile, and how SAR can contribute. INIA has extensive experience in monitoring soils and crops using in situ, drone and optical satellite technologies. AAFC was able to learn from INIA's years of research in this field in particular as it pertains to solving agronomic challenges of importance to farmers and the companies that serve them. The exchange was a clear win-win for both organizations. New project proposals are under development, and discussions are in progress to link INIA's experience in the application of these technologies to high value perennial crops in Canada.

Dr. McNairn would like to thank Dr. Best and all the researchers at INIA for their warm welcome and on-going support during this exchange, and to thank her AAFC management team for allowing her the opportunity to participate in this exchange. A special acknowledgement to Hernan Aguilera (INIA) for his on-going assistance during this visit and to Dr. McNairn's AAFC research team (Anna Pacheco, Amine Merzouki and Mehdi Hosseini) who kept all of our other projects running during this absence. And finally she wishes to extend a load of gratitude to her family who kept everything at home running smoothly while she was away.

Advertising the Co-operative Research Programme:

Agriculture and Agri-Food Canada advertises this OECD program via email distributions and advertising in departmental newsletters. This reaches all scientists within AAFC and is how Dr. McNairn became aware of this opportunity. The OECD Programme provided an excellent opportunity to strengthen the collaboration between Dr. McNairn and Dr. Best, and contributed to broadening of joint research opportunities between Canada and Chile in the application of remote sensing for precision agriculture, benefiting farmers and the agriculture sector, and supporting efficient resource management for the wider benefit. Dr. McNairn and Dr. Best acknowledge OECD for the funding opportunity and congratulate them on a well-run programme.