Dynamic Soil Moisture and Contributing Drainage Area Monitoring and Modelling using Multi-temporal SAR image

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INTRODUCTION

Water quality in Canadian Prairie pothole region is highly affected by agriculture, while both water quantity (flood & drought) and quality have a great impact on agricultural production and food safety. Climate change enlarges and complicates the effects between water and agriculture. To maintain and further improve public welfare under climate change, sustainable agriculture and water resource management are crucial. However, **in the Prairie Pothole Region, dynamic changes in hydrographic connectivity [1-3] poses a great challenge for hydrological modelling [1, 4] and sustainable irrigation management for agriculture [5]**.

Monitoring temporal and spatial variations of Contributing Drainage Area (CDA), an area of the basin that contributes discharge to local streams is an integral component of sustainable agriculture and water resource management. However, **an approach for dynamic CDA monitoring is still lacking**. CDA can be delineated with remote sensing approaches by mapping Soil Moisture Content (SMC) [3,6,7]. Soil moisture products, including Soil Moisture Active Passive (SMAP, 3 days), typically have high temporal resolution but a low spatial resolution (3-40 km) [8], and therefore cannot meet the spatial resolution (1 km or higher) requirements of agriculture and water resource management [9]. The advanced Synthetic Aperture Radar (SAR), including Radarsat-2 and upcoming Radarsat Constellation Mission (RCM) in 2018 with high spatial resolution and short revisits, offers new opportunities to map dynamic SMC and CDA.

RESEARCH GAP

Currently, soil moisture retrieval in bare soil has good accuracy. Agriculture and Agri-Food Canada piloted soil moisture retrieval for bare soil using C-band Synthetic Aperture Radar (SAR) data in Manitoba [10]. Nevertheless, retrieving SMC in vegetated fields is still challenging due to vegetation and change of surface roughness. **An effective algorithm to retrieve SMC and map CDA in vegetated fields is in urgent need.**

OBJECTIVES

Our research goal is to develop a method for dynamic SMC and CDA monitoring and introduce the dynamic CDA map for flood forecasting and water quality modeling. In the short-term, specifically for this study, we will

- **map dynamic surface soil moisture content by applying integrated decomposition techniques and Bayesian multi-temporal algorithm to quad-pol Radarsat-2 images**
- **delineate dynamic contributing drainage areas and validate them using hydrological modeling**

THEORETICAL APPROACHES

The key to monitoring dynamic SMC and CDA in vegetated fields is to minimize effects of vegetation and surface roughness.

- **decomposition of fully polarimetric SAR data is a solution to minimize vegetation effects on retrieving SMC [11]**
- **applying Bayesian multi-temporal algorithm to multitemporal quad-pol SAR images can minimize the effects of surface roughness [9]**

STUDY SITES

Developing an algorithm for retrieving SMC and delineating CDA will be conducted in the Carman-Elm Creek, Manitoba, part of Red River basin. The developed algorithm will be validated in the Brightwater sub-basin, Saskatchewan. These two study sites are selected, because of (1): the availability of archived Radarsat-2 images and in situ soil moisture and biophysical data and (2): the potential contribution to our ongoing flood forecasting project of the Red River, and the hydrological modeling work conducted by Environment & Climate Change Canada and the University of Saskatchewan in the South Saskatchewan River basin.

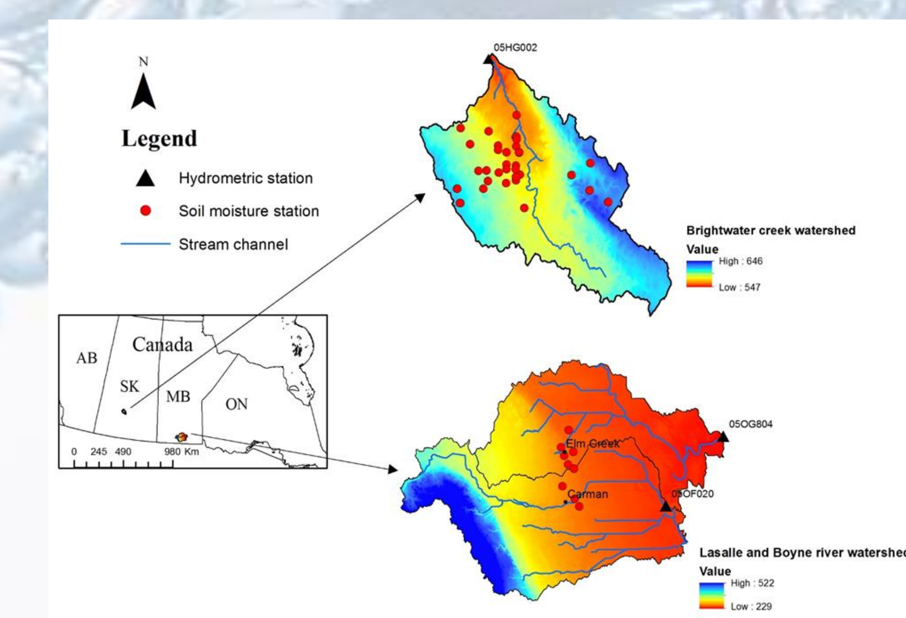

Figure 1: The study sites: Brightwater Creek, sub-basin of South Saskatchewan River basin, and Carman-Elm Creek, part of Red River basin

DATA & METHODS

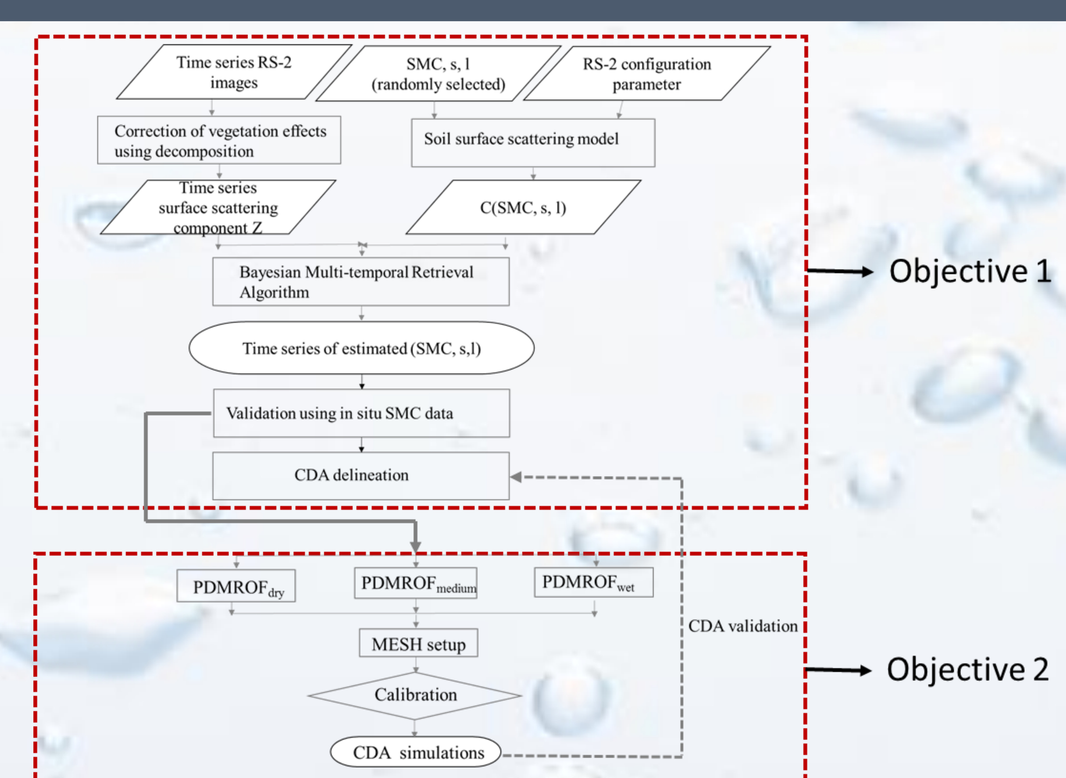

Figure 2: The methods and procedure to retrieve and validate Soil Moisture Content & Contributing Drainage Area (RS-2, Radarsat-2 images; SMC, soil moisture content; "s" represents soil roughness standard deviation (cm); and "l" is the correlation length)

EXPECTED RESULTS

- **Dynamic SMC and CDA monitoring methods are developed in vegetated agriculture fields, towards operation, at 1 km and 400 m spatial resolution**
- **The accuracy of retrieved SMC is in an order of 0.05 m^3/m^3 (Root Mean Square Error) which is required for the applications in agriculture and hydrology[12]**
- **The CDA delineated from Radarsat-2 images is consistent with the simulation of MESH model at dry, wet, and intermediate soil moisture conditions**

CONTRIBUTIONS

This research supports both **immediate applications** by moving forward dynamic SMC and CDA mapping, towards operation as the RCM is launched in 2018, and **long-term applications** by improving water resource management which will fundamentally increase our ability to adapt to, and manage the negative impacts of climate change in agriculture.

- the development of a new algorithm for dynamic SMC & CDA mapping, allows appropriate irrigation management and provides a better understanding of the effects of agriculture practices on environment using hydrological modelling approaches
- timely dynamic spatial variation of SMC & CDA monitoring is crucial for drought and flood forecasting, water quality modeling and priority area identification for agriculture management

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