Integration of Sentinel-1 and Sentinel-2 Data for Improved Fresh Crop Biomass Estimation

Sugandh Chauhan[a], Andy Nelson[a], Roshanak Darvishzadeh[a], Mirco Boschetti[b]

[a] Department of Natural Resources, Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, Enschede, Netherlands - (s.chauhan, a.nelson, r.darvish)@utwente.nl

[b] IREA-CNR, Institute for Electromagnetic Sensing of the Environment, Via Bassini 15, 20133 Milano, Italy - Boschetti.m@irea.cnr.it

Abstract

Crop lodging is one of the major yield-reducing and grain quality deteriorating factors in cereals like wheat. Timely detection of crop lodging can help to better evaluate losses, plan harvest operations, and predict yield. Since lodging severely affects the status and distribution of fresh crop biomass in the canopy, variation in its temporal profile can be used to distinguish between lodged and non-lodged fields. The objective of this study is to improve the retrieval accuracy of wheat fresh crop biomass by synergistic use of Sentinel-1 derived crop volume and Sentinel-2 red-edge bands as components of wheat lodging assessment.

Introduction

"Good detection solves lodging" – *Farmers Weekly (2000)*

Increasing wheat production to meet demand requires sustainable, cost-effective, and innovative management, which in turn requires spatial and temporal information on factors that can affect productivity. Lodging, defined as the permanent displacement of the crop stems from their upright position (Fig. 1), has been identified as a major agricultural hazard causing extensive damage to many crop species on a global scale. Studies report that lodging-induced yield reductions can range from 31% (Weibel & Pendleton, 1964) to 80% (Easson et al., 1993), and cause other knock on effects such as a delayed harvest. A rapid and quantitative evaluation of crop lodging, including its risk factors, detection, and characterization would support better crop management to increase productivity.

Fig. 1: Severe lodging in Bonifiche Ferraresi (study site) farm near Ferrara, Italy (Image date: 6 June 2017)

During lodging, the photosynthetic light use efficiency of the lower canopy is disrupted and the distribution of fresh biomass in the canopy changes (Robertson et al., 1996) (Fig.2). This change in fresh crop biomass in a temporal domain can be exploited to distinguish between lodged and non-lodged fields. Fresh crop biomass is an important ecological indicator of carbon stocks in agroecosystems and in the context of farm management, timely information about fresh crop biomass during the growing season can guide management interventions.

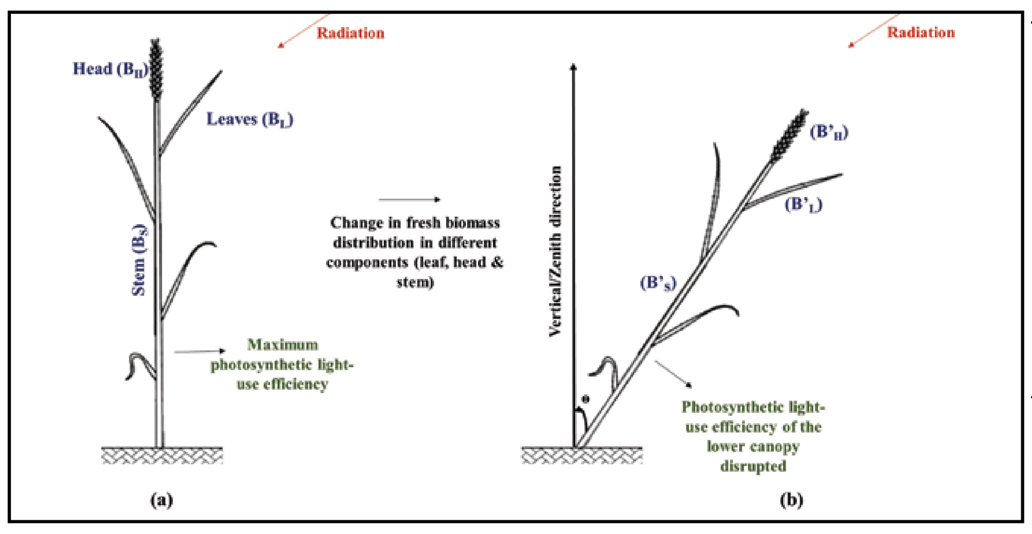

Fig. 2: Biomass distribution in (a) non-lodged and (b) lodged crop conditions

Remote sensing based biomass estimation is challenging due to the saturation of the signal associated with dense canopies. Successful examples demonstrating the sensitivity of SAR-derived volume in forest canopies and that of red-edge position (computed from hyperspectral data) to variations in high fresh biomass, motivate us to extend these relationships to an agricultural framework on a satellite level. The advent of multispectral Sentinel-2 and Sentinel-1 (SAR) satellites offer a unique possibility to exploit the red-edge spectral bands and dual-polarimetric channels, i.e. VV and VH (which are highly sensitive to vegetation properties), respectively with high temporal resolution while allowing the synergistic use of different sensors. Since lodging usually happens in adverse climatic conditions, the integration of optical (Sentinel-2) and microwave (Sentinel-1) satellite data would be of particular interest to implement a crop lodging detection system when cloud-free optical data is scarce. With the main aim of using Sentinel-1/2 data for lodging detection and risk mapping, a sub-objective related to the fresh biomass estimation is presented here.

Objective & study site

The objective is to improve the retrieval accuracy of wheat fresh crop biomass by synergistic use of Sentinel-1 derived crop volume and Sentinel-2 red-edge bands as inputs to gradient boosting machine learning algorithm.

The study site is located in Jolanda di Savoia, about 30 km east of Ferrara in the Emilia-Romagna region of Italy (Fig. 3). Jolanda di Savoia has a humid sub-tropical climate and is one of the lowest point in Italy (approx. 3m below sea level). The average annual temperature is 13.6 °C and precipitation averages 691mm. The farm (44°51'39.57"N, 11°57'26.48"E) is operated by the Bonafiche Ferraresi Company and covers around 5,500 hectares. The farm cultivates a range crops including rice, corn, hard wheat, barley, sugar beet, medical herbs, sunflower, soybean, vegetable garden, and fruit plants.

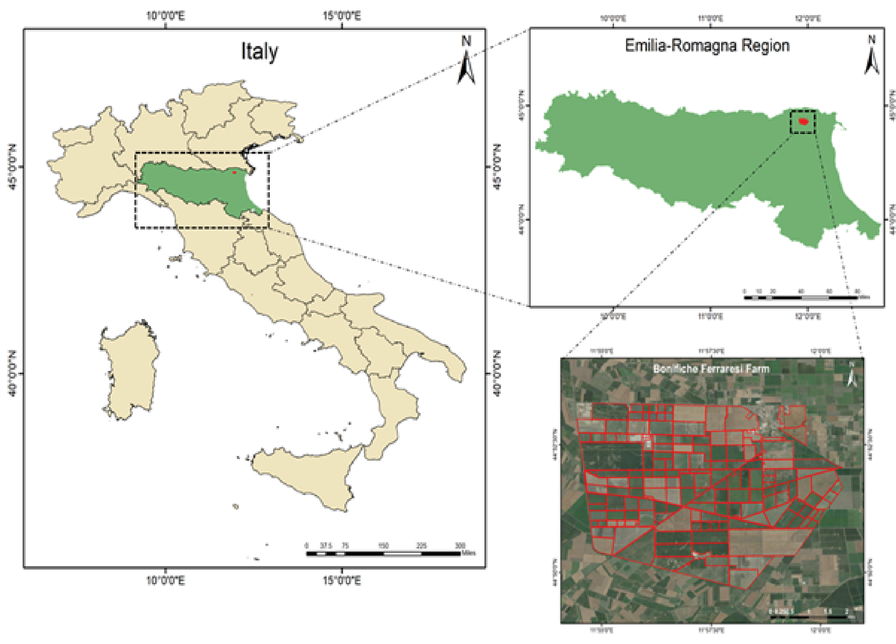

Fig. 3: Location of the study site

Methodology

Example Sentinel-1 and Sentinel-2 images for the study site are shown in Fig. 4.

The methodology consists of two sections (as shown in Fig. 5):

1) Data acquisition and model development: A semi-empirical water cloud model would be parameterised to retrieve crop volume, which along with Sentinel-2 red-edge position will serve as inputs to gradient boosting machine learning algorithm.

2) Retrieval and validation: Retrieval and validation of fresh crop biomass and lodged/non-lodged spatial map.

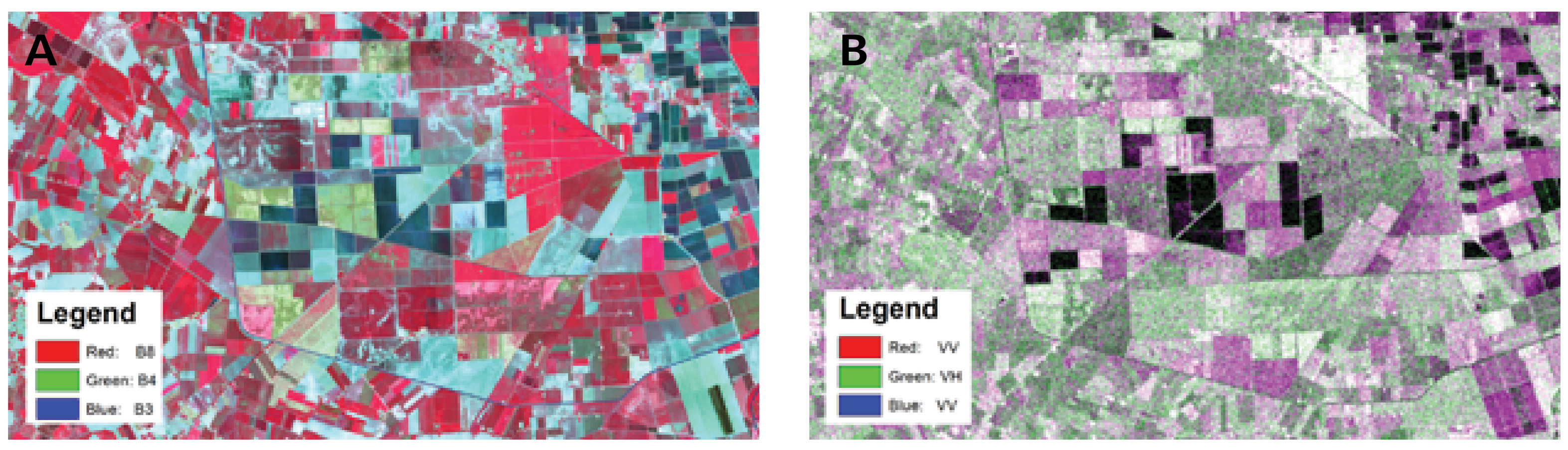

Fig. 4: Sample (a) Sentinel-1 (5 June 2017) and (b) Sentinel-2 (3 June 2017) images for the study site

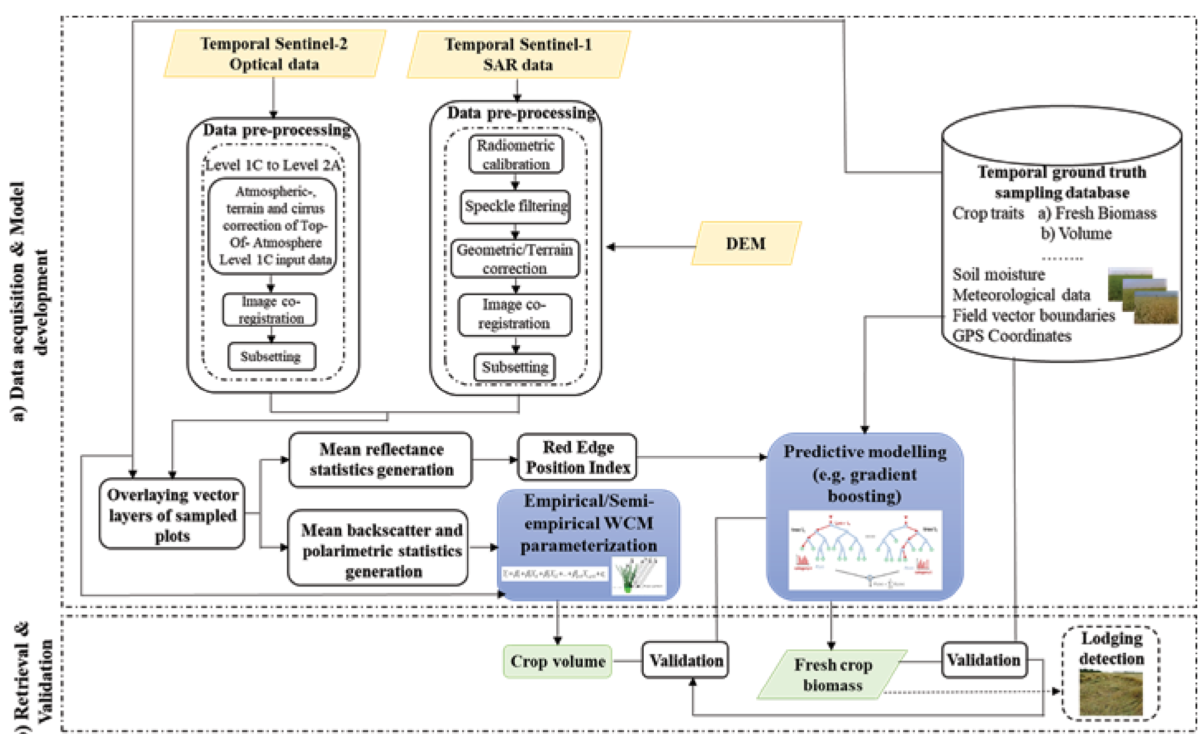

Fig. 5: Methodological flowchart

Expected result

Map of lodged and non-lodged fields based on the spatio-temporal variation in fresh crop biomass across the growing season

Research impact

* Better characterisation of lodging risks
* Estimation of lodged area and severity on a large scale

Major References

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Acknowledgments

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