ECOSat (Estimation of carbon offsets with satellites)
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Progress report for 2023

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Introduction

This progress report builds on the report for 2022, in which the background and the objectives of this study have been described in more detail. In brief, the purpose of this study is to determine whether radar (Sentinel-1) and optical (Sentinel-2) satellite data can be used to detect residue management and whether a field was under conventional, minimal, or no tillage. The study also aims at estimating biomass production, which is an indicator of carbon sequestration by the roots. The study site is located in the state of Guanajuato, Mexico. The in-situ data, which consist of detailed logs on land preparation and crop management, had been collected by the CIMMYT led MasAgro Guanajuato project, which is financed by the state of Guanajuato. CIMMYT operates an innovation hub that investigates, validates, demonstrates and promotes conservation agriculture, amongst other sustainable practices.

Activities and preliminary results

The main activity in 2023 was focused on identifying satellite data based indices which can detect residues and tillage operations. Having such indices in place would greatly facilitate the development of a simple monitoring system, which requires no or few in-situ data for training.

Various tillage and residue detection indices were tested using the 2021 data. These indices had been described in various studies (Beeson et al., 2020; Bégué et al., 2018; Ding et al., 2020; McNairn et al., 1993; Wang et al., 2024; Zhou et al., 2021). They are listed in Table 1.

Table 1: List if optical indices that were tested for their suitability to detect tillage events and residue management.

Index	**Sentinel-2 band based formula**
NDSVI	(B8 - B6) / (B8 + B6)
NDTI	(B11 - B12) / (B11 + B12)
NDI5	(B8 - B11) / (B8 + B11)
NDI7	(B8 - B12) / (B8 + B12)
CRC	(B11 - B3) / (B11 + B3)
STI	B11 / B12

These indices work well when they are tested against field observations that were sampled at the same time. In our study, however, we have information on crop management over an entire year. The Guanajuato region is especially challenging since some farmers grow an irrigated crop during the winter season, whereas others leave their fields fallow. Irrigation gives them flexibility in terms of the timing of land preparation. In addition, they use a wide range of land preparation methods. Some farmers practice a partial removal of residues, which, combined with different land preparation methods, such as reshaping of the permanent beds or furrows, or use of different harrows, etc, can result in various degrees of soil roughness and burying of residues. Some of the tested indices could detect trends, but none of them were consistent. Rainfall, as well as irrigation also distort the satellite signals (Begué at al., 2018). For these reasons, different approaches need to be tested in 2024.

Plans for 2024

Most successful remote sensing applications for tillage detection and residue management rely on survey data (Bhargava et al., 2018; Zhou et al., 2021; Wang et al., 2024), which directly record the field conditions (and not the date and type of farm operation). It is therefore recommended that we conduct field surveys at bi-monthly intervals. These data can then be used to train machine learning based algorithms, which have been implemented in the so called Sen4CAP software system. Detailed information on the system can be found at: http://esa-sen4cap.org and at http://esa-sen4cap.org/sites/default/files/01_Sen4CAP_TrainingforBeginners_SystemOverview.pdf
This approach will then enable us to classify the satellite images directly and determine residue cover.

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