

ECOSat (Estimation of carbon offsets with satellites) -Final report

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Abstract

This study aimed to assess whether radar (Sentinel-1) and optical (Sentinel-2) satellite data could detect residue management practices and differentiate between conventional, minimal, and no tillage fields in Guanajuato, Mexico. The study used in-situ data collected by the CIMMYT-led MasAgro Guanajuato project, which tracks land preparation and crop management. Various tillage and residue indices were tested, including NDSVI, NDTI, and NDI5, based on Sentinel-2 bands. The conclusion suggests that most successful remote sensing applications for tillage detection and residue management rely on survey data. These data can then be used to train machine learning based algorithms.

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Introduction

The purpose of this study was 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 site was 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, 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 results

In-situ data acquired in 2021 were used for the sensitivity tests of various tillage and residue indices. They had been described in different 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 of 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	$B11 / B12$

The published papers showed that these indices work well when they are tested against field observations that were sampled at the same time. In our study, however, we had field specific information on crop management collected at the time a tillage operation occurred.

In Guanajuato, 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, can result in various degrees of soil roughness and burying of residues. Some of the tested indices could detect trends, but none of them was consistent. Soil moisture variability, caused by irrigation and rainfall, also distorted the satellite signals (Begué et al., 2018). These diverse conditions made it impossible to test the performance of the various algorithms reliably.

Conclusion

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 at a given point in time, so that the conditions of all fields can be directly compared to each other. It is therefore recommended that we conduct field surveys at bi-monthly intervals for testing in other projects. These data can then be used to train machine learning based algorithms.

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