ASSESSMENT OF SPECTRAL INDICES FOR CROP RESIDUE COVER ESTIMATION

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1. INTRODUCTION

Agricultural soils are an important terrestrial carbon (C) stock [1]. Soil tillage method is important in agricultural C sequestration models [1, 2]. Traditional intensive tillage systems greatly disturb the soil and have been shown to deplete the soil of soil organic carbon (SOC). Modern reduced- and conservation tillage systems minimally disturb the soil and leave increased quantities of crop residues (non-photosynthetic vegetation, NPV) on the soil surface after harvest and planting [3]. These surficial crop residues act as a barrier to wind and water erosion, and act as a mulch, reducing surface evaporation. The biological breakdown of residues returns nutrients and sequesters atmospheric C to SOC. Furthermore, as reduced- and conservation tillage methods require fewer farm equipment passes in the field, fuel is saved and greenhouse gas emissions are reduced. Furthermore, farmers implementing these modern tillage methods can receive governmental conservation benefits and sell C credits. As such, modern tillage methods can be more profitable for farmers to implement, even with reduced yields [4]. However, recent fluctuations in the price of crude oil has made biofuels an attractive alternative to fossil fuels, increasing demands both for corn grain and crop residues as ethanol feedstock. In rangeland, NPV is an important parameter for soil health and forage quality [5], and in dry grassland, NPV serves as fuel for brush fires.

As such, an efficient method of verification of tillage via crop residue cover (f_R) in needed over large swaths. Since traditional ground-based methods are not efficient nor scale-up well to the field level, remote sensing is an excellent alternative. Of the numerous remote sensing methods have been devised, two indices, the hyperspectral-based three-band Cellulose Absorption Index (CAI) [6] and the ASTER-based two-band Shortwave Infrared Normalized Difference Residue Index (SINDRI) [7], have shown the most promise in spatial portability and minimal calibration [7, 8]. While CAI is preferable, it is more costly to implement of future satellite-based advanced multispectral systems than the two SINDRI bands, which have already been flown on the Terra ASTER sensor. Thus, an analysis needs to be done to see how effective SINDRI will be for global estimation of crop residue cover in comparison with CAI.

2. SPECTRAL INDICES

In this study we used two indices for f_R estimation indices. The first, CAI [6], measures the depth of the cellulose absorption found in crop residues but not soils [8, 9]:

$$CAI = 100 \cdot \left(\frac{R_{2031} + R_{2211}}{2} - R_{2101} \right) \quad (1)$$

where 100 is a scaling factor, R denotes reflectance, and the subscripts 2031, 2101, and 2211 denote 11-nm wide spectral bands centered at 2031, 2101, and 2211 nm, respectively. The second, SINDRI [7], utilizes ASTER shortwave infrared (SWIR) bands 6 (2185–2225 nm) and 7 (2235–2285 nm) respectively:

$$SINDRI = \left(\frac{ASTER6 - ASTER7}{ASTER6 + ASTER7} \right) \quad (2)$$

where ASTER6 and ASTER7 denote ASTER SWIR bands 6 and 7, respectively.

3. MATERIALS AND METHODS

In order to assess index portability, spectral data of 893 surface soil samples [10], 83 crop residues, and 40 live corn canopy samples [8, 9] were utilized to calculate index values. These data were then analyzed against the USDA Natural Resources Conservation Service Soil Survey Laboratory database [11] to evaluate chemical, mineralogical, and spatial issues that affect index values.

4. RESULTS

CAI showed good contrast between crop residues and surface soil samples in all cases (Fig. 1a) [8]. CAI also showed good contrast between crop residues and green vegetation. SINDRI generally showed good contrast between crop residues and soils, but there were exceptions, and SINDRI did not contrast well between live vegetation and crop residues (Fig. 1b). However, green vegetation can be filtered out by using an index such as the Normalized Difference Vegetation Index (NDVI) [12]. For monitoring in the conterminous USA, CAI can be used throughout (Fig. 2a), whereas SINDRI may not be useable in parts of the western USA (Fig. 2b). However, SINDRI should work well for most cultivated areas in the conterminous USA. As such, while SINDRI is less expensive to implement, it may be less applicable for rangeland and fire hazard monitoring than CAI.

6. REFERENCES

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FIGURES

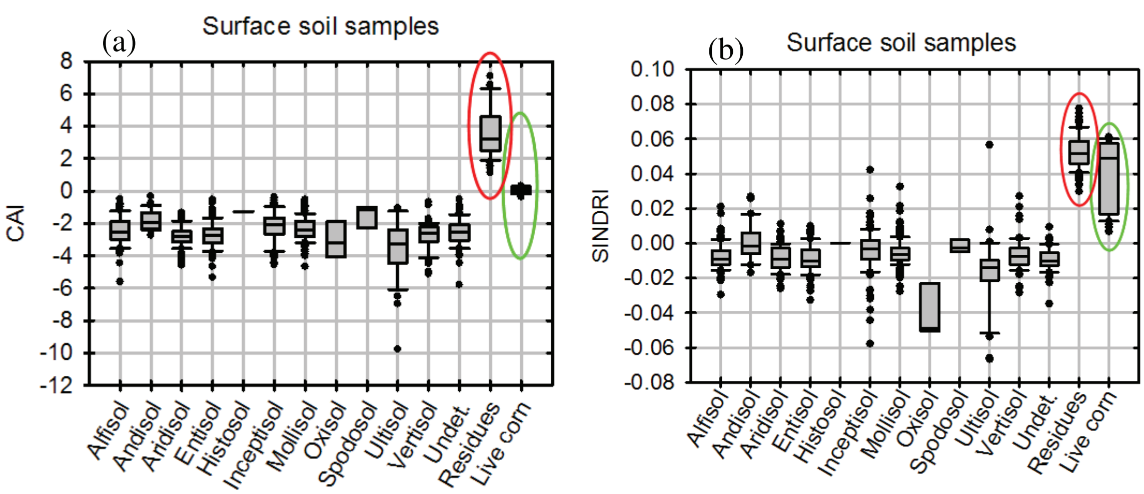

Fig. 1. f_R index values of soils, grouped by taxonomic order, crop residues (circled in red), and live corn canopy (circled in green) for (a) CAI and (b) SINDRI.

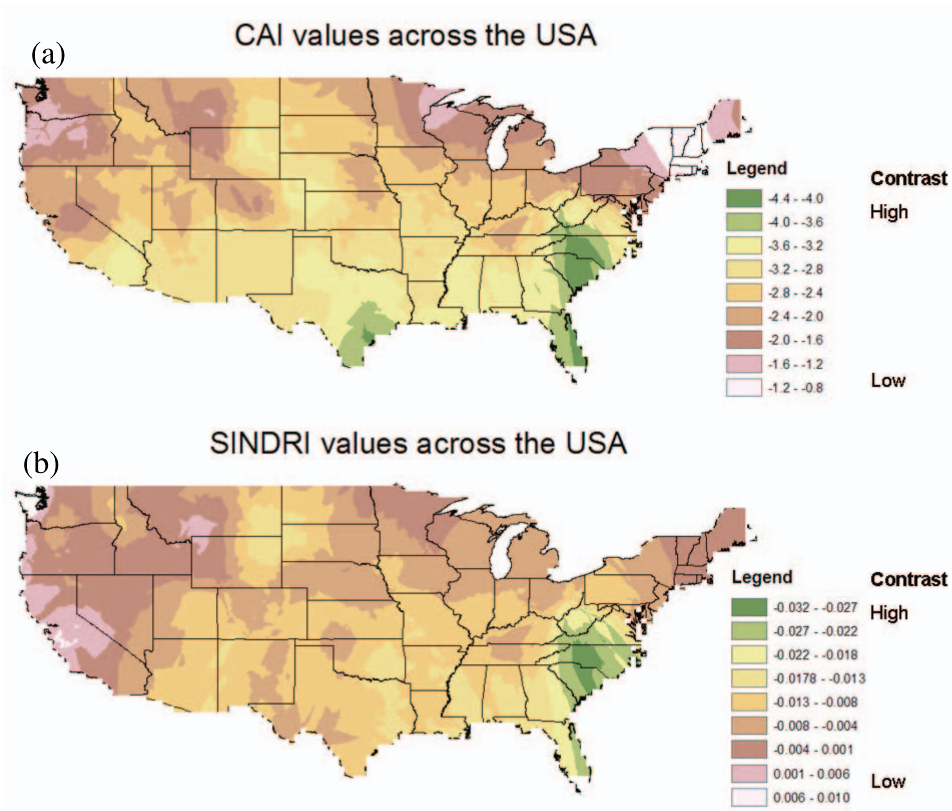

Fig. 2. Spatial patterns of surface soil sample (a) CAI and (b) SINDRI values across the conterminous USA, as calculated from the Brown et al. [10] spectral library and georeferenced with spatial data from the USDA Natural Resources Conservation Service Soil Survey Laboratory data base [11]. Crop residue index values range 1.1 – 7.1 for CAI [8] and 0.030 – 0.078 for SINDRI.