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Original Research Article

Evaluating spectral indices for determining conservation and conventional tillage systems in a vetch-wheat rotation

Iraj Eskandari [a],*, Hosain Navid [b], Kazem Rangzan [c]

[a] *Dryland Agricultural Research Institute, Agricultural Research Education and Extension Organization (AREEO), Maragheh 5517643511, Iran*
[b] *University of Tabriz, Faculty of Agriculture, Department of Biosystem Engineering, Tabriz, Iran*
[c] *Shahid Chamran University of Ahvaz, Faculty of Earth Sciences, Department of Remote sensing and GIS, Ahvaz, Iran*

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ABSTRACT

Conservation tillage (CT) systems, which consist of reduced and no-tillage systems, retain considerable quantities of crop residues on the soil surface. These crop residues perform as a barrier to wind and water to decrease soil erosion and evaporation. The use of remote sensing technology provides fast, objective and effective tool for estimating and measuring any agricultural event. The challenge is to differentiate the tillage systems by the crop residue cover on the soil surface. Spectrally derived normalized difference tillage index (NDTI), Shortwave infrared normalized difference residue index (SINDRI), cellulose absorption index (CAI) and Lignin-cellulose absorption index (LCA) were examined to distinguish their value as remote sensing methods for identifying crop residue cover in conventional and conservation tillage systems. Tillage treatments included conventional tillage (MD: Mouldboard plow+Disk harrow), reduced tillage (CD: Chisel plow+Disk harrow), minimum till (MT: Stubble cultivator), and no-tillage (NT_1 and NT_2: with standing stubble and standing stubble plus threshing residue, respectively).

CAI had a linear relationship with crop residue cover, which the comparative intensity of cellulose and lignin absorption features near 2100 nm can be measure by it. Coefficients of determination (r^2) for crop residue cover as a function of CAI and LCA were 0.89 and 0.79 respectively. Absorption specifications near 2.1 and 2.3 μm in the reflectance spectra of crop residues in minimum and no- tillage systems were related to cellulose and lignin. These specifications were not evident in the spectra of conventional tillage system. In this study the best index to use was CAI, which showed complete separation tillage systems, followed by LCA and NDTI. Four tillage intensity classes, corresponding to intensive ($<6\%$ residue cover), reduced (10–20% cover) minimum (25–40%) and no-tillage ($>60\%$ cover) tillage, were recognized in this study.

1. Introduction

Crop Residue Cover (CRC) after planting is used to determining the classifications of soil tillage intensity. Intensive (conventional) tillage returns less than 15% CRC, while conservation tillage allows to remain at least 30% CRC on the soil surface. No-till (or strip till) system usually disrupts $< 25\%$ of row width (USDA-NRCS, 2006).

Retaining crop residue on the soil surface decrease evaporation and soil erosion, increase soil organic matter and improve soil quality (Truman et al., 2003; Jarecki and Lal, 2003; Derpsch, Friedrich, Kassam & Li, 2010). Therefore, crop residue management is the basic part of the various conservation tillage systems. Based on annual roadside surveys of crop residue levels, regional estimates of conservation tillage practices for selected counties has been collected by the Conservation Technology Information Center (CTIC, 2004). These surveys are particular and the methods differ from county to county (Thoma, Satish & Marvin, 2004). Traditional methods of residue cover measurement, i.e. line-point transect or photographic techniques (Laflen, Amemiya & Hintz, 1981) are often error prone due to operator bias, lack of contrast, and spatial variability, and are inefficient for use at the county and state levels (Morrison, Huang, Lightle & Daughtry, 1993).

Discriminating of the spectral signatures of conventional and conservation tillage systems has been acquired mainly using bare soil imagery by effectively applying remote sensing methods (Gowda, Dalzell, Mulla & Kollman, 2001; Bricklemyer, Lawrence & Miller, 2002; Yang, Prasher, Whalen & Goel, 2002; Viña, Peters & Ji, 2003; South, Qi & Lusch, 2004; Yang et al., 2002). The mainly restrictive factor in residue estimation by using remote sensing

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* Corresponding author.
E-mail address: eskandarei1343@yahoo.com (I. Eskandari).

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Table 1
Tillage and planting implement specifications.

Equipment	Working width (cm)	Tillage/planting depth (cm)	Number of row/shank	Type of tine/furrow opener
Moldboard plow	108	20	3	General purpose, three bottom regular share cut
Chisel plow	270	25	9	C- Shape, mounted, two row
Stubble cultivator	220	15	5	Split chisel wing share, roller
Tandem disk	250	8–10	7 in each gang	Spherical (53 cm)
Deep-furrow drill	225	5–7	13	Shovel
No-tillage drill	272	5–7	16	Double disc

spectra lies in the fact that soil and crop residue have similar spectral reflectance (McMurtrey, Craig & Thomas, 2005; Streck, Augusto, Rundquist & Connot, 2002). Crop and soil spectra rise without curvature through the visible (VIS) and near-infrared (NIR), differing in scale of spectral response (Aase and Tanaka, 1991; Daughtry et al., 1995; Sullivan et al., 2004). Thus, variation in surface soil properties, such as soil water content, particle size repartition, and iron oxide content can cause the terrain to be more or less reflective than crop residue spectra (Chen and McKyes, 1993; Daughtry et al., 1995; Nagler, Daughtry & Goward, 2000)

Remote sensing is the way to prepare effective and objective methods for evaluating crops conditions in wide-ranging. However, the many spectral indices that use Landsat TM shortwave infrared bands for evaluating crop residue cover have had indistinct achievement (Daughtry, Hunt, Doraiswamy & McMurtrey, 2005). Sullivan, Lee, Beasley, Brown, and Williams (2008) considered the sensibility of a remotely taken crop residue cover index for illustrating no-tillage, strip tillage and conventional tillage systems in a cotton-corn-peanut rotation in the southeastern coastal plain. Results indicated that emittance spectra represented small, but significant differences between treatments observed.

Optically based remote sensing methods for crop residue identification utilize a number of indices. These remote sensing methods fall into three basic categories: (i) normalized difference indices, (ii) spectral angle methods, and (iii) reflectance-band height indices (Serbin, Daughtry, Hunt, Reeves & Brown, 2009). Of these three methods, reflectance-band height indices usually perform the best, as they are dependent on the distinctive spectral features of soils and crop residues, the former of which vary depending on mineralogy, soil organic carbon (SOC), and particle size (Allen and Hajek, 1989; Clark, 1999; Daughtry et al., 2005; Kokaly, Despain, Clark & Eric Livo, 2003; Serbin et al., 2009). No studies have estimated the potential for remote sensing data to describe residue cover in the Iran, where conservation tillage is becoming to increase in the country recently.

The aims of this study were to (1) assess the spectral reflectance of conservation and conventional tillage systems by the handheld spectroradiometer in dryland vetch-wheat rotation, (2) to evaluate spectral indices for identifying tillage regimes, and (3) to identify relationships of selected indices (NDTI, CAI, LCA, SINDRI) by percent cover and the amount of residue in different tillage systems.

2. Materials and methods

2.1. Site and soil

The field experiment was carried out at Dryland Agricultural Research Station located in a cold semi-arid region of Iran in 2011–2012. The soil (Typic Calcixerept) at the study site had a clay loam texture in the 0–15 cm surface layer (300, 390 and 310 g kg^{-1} respectively sand, silt, and clay) and a clay texture in the 15–60 cm depth (240, 290 and 470 g kg^{-1} respectively sand, silt and clay). The climate of the study area is temperate continental with warm summers based on Koeppen's classification system. The long-term average precipitation, relative humidity and temperature of the study area are 354 mm, 50.2% and 12.5 °C, respectively.

2.2. Tillage treatments

The design of experiment was randomized complete block (RCBD) with 4 replications. The tillage treatments involved of (1) conventional tillage: moldboard plowing followed by one pass of tandem disk (MD); (2) reduced tillage: chisel plow followed by one pass of tandem disk (CD); (3) minimum tillage: stubble cultivator (MT); (4) no-till with standing stubble (NT1) and (5) no-till with total (standing and threshing) previous crop residue (NT2). On NT2 plots, the shredded vetch residue, which was gathered after threshing of the plants from the same plots, was spread evenly before wheat planting. Main tillage depths for MD, CD and MT were 20, 25 and 15 cm, respectively. Tandem disk operations were completed at a depth of 8–10 cm. The explanation of the tillage and planting equipment are given in Table 1.

2.3. Wheat sowing

A winter wheat cultivar (Homa) was planted with a row spacing of 17 cm at the rate of 178 kg per hectare. The planting depth was about 6 cm. Fertilizers were banded the (Triple superphosphate and urea) 3-cm below the seed in one pass. Fertilizer was applied at the rates of 40 kg N per hectare as urea and 10 kg P2O5 per hectare as triple super-phosphate. Supplementary 20 kg N per hectare as urea was used as top dressing on April. The sowing and harvesting date of wheat were on first October and in middle July respectively.

2.4. Vetch sowing

Vetch was planted using the same treatments as used in wheat planting. Forage cultivar Hungarian vetch was planted 6 cm depth at a seeding rate of 80 kg per hectare using deep furrow and Baldan3000 no-till drills for conventional and conservation tillage treatments respectively. Fertilizer consisted of N and P with sources of urea and triple super phosphate banded 3 cm under the seed.

2.5. Remote sensing of crop residue

A portable FieldSpec3 spectroradiometer (Analytical Spectral Device, Inc. USA) was used for collecting reflectance measurements. The field Spec3 utilize the full spectral range (350–2500 nm) by three detectors enabling automation of data collection and ease of use wide variety of operations. Four ASD acquisitions were taken in each plot. A white panel reference correction reading data was used to set the internal ASD correction data for incident solar radiation for collecting reflectance values before each replications measurement.