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Assessing soil surface roughness using reflectance band indices obtained with an airborne multispectral sensor at very high spatial resolution

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Introduction

Soil surface roughness (SSR) is a key parameter in hydrological processes such as wind and water erosion. It is usually quantified using numerical roughness indices derived from digital elevation models (DEMs) as representation of soil surfaces. Current methods to obtain DEMs and quantitative measures of SSR however lack the potential to conveniently assess SSR over larger areas (Jester & Klik, 2005).

Given the relationship between SSR and measured reflectance, optical remote sensing methods have the potential to provide useful quantitative information on SSR and its spatial variability (e.g. Mushkin & Gillespie, 2005; Moreno et al., 2008).

Materials and Methods

The first study site was an experimental field (100 x 40 m) on which five tillage tools (*roller, rotary tiller, cultivator, chisel, moldboard plough*) were applied on different subplots. (Figure 1, left). The second site was an olive orchard with bare soils between tree rows (Figure 1, right). Two different cultivators (*cultivator1, cultivator2*) and one cultivator with a spiked tooth harrow attachment ($cultivator_{sha}$) were applied. The original soil state (unknown meaning tilled months before and degraded by rain and traffic) was included in the experiment.

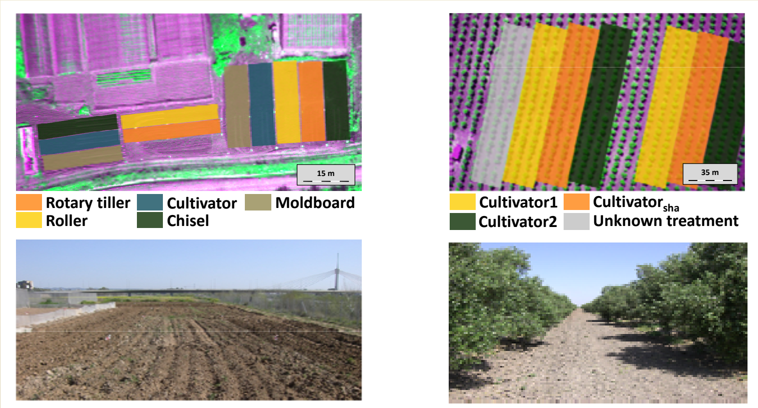

Figure 1: Views of the two sites and corresponding airborne ADC imagery with the location and distribution of treatment subplots.

Each treatment was scanned three times on different subplots. A laser scanner with 0.1 mm resolution was used to obtain representative DEMs covering an area of 900 x 900 mm at a grid spacing of 7.2 x 7.2 mm (Figure 2).

The DEMs were used to obtain the four quantitative roughness indexes: standard deviation of heights *RMSH*, the tortuosity indices T_A and T_B, and mean surface slope *S* (Table 1).

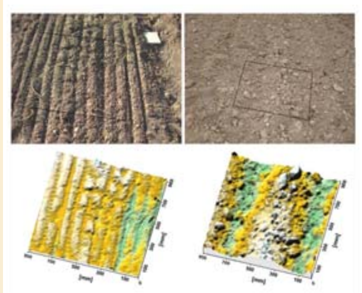

Figure 2: Images and DEMs for the roller and chisel plough.

TREATMENTS	H_{mean} MEAN	H_{mean} SD	RMSH MEAN	RMSH SD	S MEAN	S SD	$T_{A(X)}$ MEAN	$T_{A(X)}$ SD	$T_{A(Y)}$ MEAN	$T_{A(Y)}$ SD	$T_{B(X)}$ MEAN	$T_{B(X)}$ SD	$T_{B(Y)}$ MEAN	$T_{B(Y)}$ SD
Roller	32.6	8.9	9.3	1.5	22.6	1.3	9.6	4.0	9.3	1.0	1.11	0.05	1.10	0.01
Tiller	29.1	5.3	8.1	1.8	23.2	3.4	11.2	3.7	9.9	4.1	1.13	0.05	1.11	0.05
Cultivator	86.3	14.2	28.6	4.5	32.2	1.6	19.7	1.9	18.2	2.2	1.25	0.03	1.22	0.03
Chisel	71.5	5.3	28.3	2.8	34.6	1.7	23.5	2.6	21.4	2.7	1.31	0.05	1.27	0.04
Moldboard	86.4	20.4	28.8	1.4	37.2	0.3	26.6	0.3	25.2	0.7	1.36	0.01	1.34	0.01
Unknown	31.2	8.4	10.3	3.5	20.0	1.7	9.1	1.6	9.2	0.9	1.10	0.02	1.10	0.01
Cultivator1	52.2	5.4	22.7	2.5	27.8	1.7	15.5	1.7	13.5	1.7	1.18	0.02	1.16	0.02
$Cultivator_{sha}$	35.7	1.6	11.3	1.0	27.1	2.0	15.4	1.9	15.1	2.2	1.18	0.03	1.18	0.03
Cultivator2	50.2	11.7	20.4	6.0	28.2	3.9	16.3	4.0	15.5	4.5	1.20	0.06	1.19	0.06

Table 1: Treatment mean values and stanadard deviation for average DEM heights H_{mean}, roughness indices *RMSH* and *S*. Tortuosity indices T_A and T_B, are calculated across (X) and along (Y) tillage direction.

Airborne imagery was acquired with the ADC multispectral sensor onboard a unmanned aerial vehicle (UAV) platform at wavelengths B1=550, B2=670 and B3=800nm at different times of the day (Figure 3). Reflectance values were then extracted from corrected images corresponding to the exact location of each DEM (Figure 4). Several reflectance indices of the kinds of (B_x/B_Y) and $(B_x +/- B_Y)/(B_x +/- B_Y)$ were then calculated.

These reflectance indices were compared to the roughness indices by means of simple linear regression and correlation analysis using single plot data as well as group means.

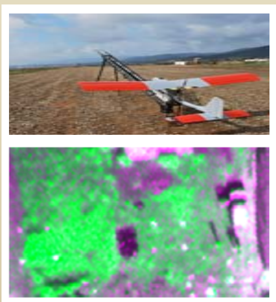

Figure 3: UAV at take-off. Below, detailed zoom into a ADC image.

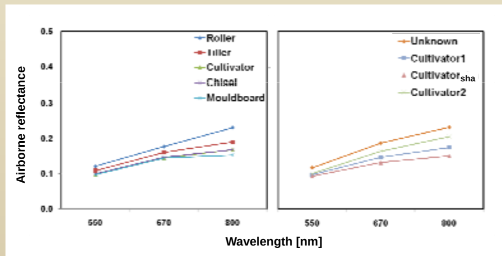

Figure 4: Comparison of mean reflectance for treatments on both sites.

Results

On the first site, statistically significant correlations were found for all tested roughness indices and spectral indices based on combinations of bands B1 and B3 and bands B2 and B3 (Figure 5). Better correlations were obtained using early morning reflectance data (more shadows casting).

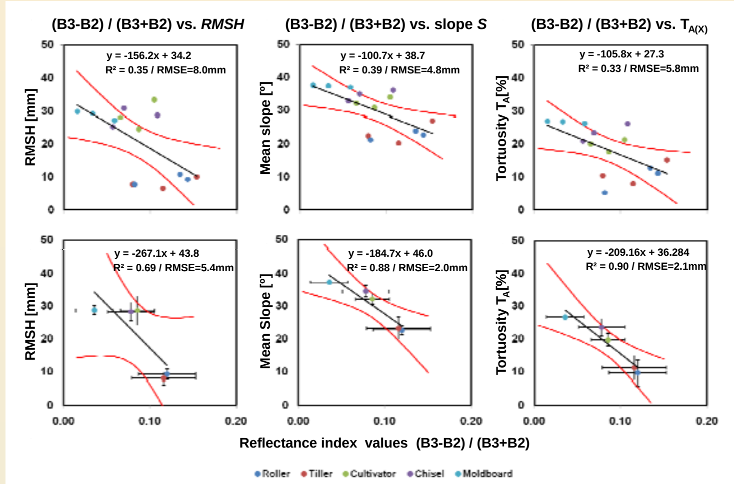

Figure 5: Regression models for reflectance index (B3-B2)/(B3+B2) from 8:30GMT imagery data. Only models for three roughness indices are shown. Upper row are models using single plot data, lower row are based on group means of tillage treatments.

For the olive orchard, no significant correlations were found, whether with single plot data nor with mean values. This suggests that suitable empirical regression models might not be able to capture moderate variations in SSR created by similar tillage tools.

Conclusions

Meaningful prediction models were obtained using a simple and easy-to-implement methodology.

The results show the potential, and limitations, of this methodology for obtaining quantitative estimates of SSR and its spatial variability over larger field sites.

References

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Acknowledgements

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