EGU General Assembly 2011

SSS2.6/HS12.12/NP3.12
Spatial and temporal scaling in soil erosion: measurements, theory and modelling
(EGU2011-7673)

Inversion of the Hapke model with diurnal multispectral reflectance data for assessing soil surface roughness

Rodríguez González, J., Zarco-Tejada, P. J., Gómez, J. A.

Institute for Sustainable Agriculture (IAS)
Consejo Superior de Investigaciones Científicas
Córdoba, Spain

Contact: jrodriguez@ias.csic.es
Web: http://quantalab.ias.csic.es

Soil Surface Roughness (SSR)

SSR is as an important factor that affects and influences a variety of surface processes on bare surfaces and soils.

- Water and wind erosion processes
- Surface and sub-surface temperature variations (thermal inertia)
- Gaseous diffusion (CO2, water vapour) and nutrient flux and exchange
- Albedo of bare soils and surfaces

Several erosion models include quantitative measures of SSR as input parameters (RUSLE, STREAM, WEPP , KINEROS).

Soil Surface Roughness Characterization

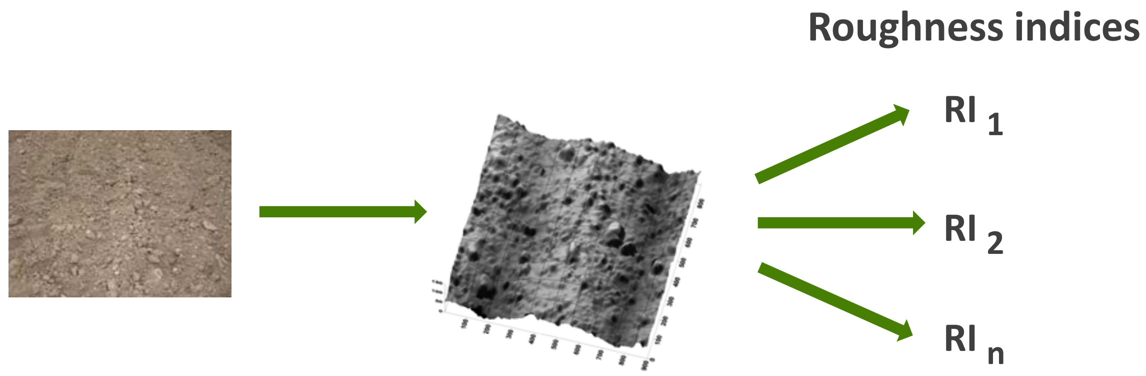

Figure 1: Soil surface roughness characterization

DEM acquisition methods:

- Laser scanning instruments (point and line scanners)
- Digital close-range stereo-photogrammetry
- Terrestrial laser scanning or LIDAR systems

All these methods have limited spatial coverage and thus lacking the potential to assess SSR over areas on the plot or field scale under operational conditions!

Remote Sensing and Soil Surface Roughness

- Soil reflectance varies with view and illumination angles as a function of its surface properties.
- *Shadow-hiding theory*: Reflectance anisotropy is caused by shadow casting and mutual shadowing between soil particles and soil aggregates, facets or clods and other topographic features – in other words surface roughness!
- The angular reflectance behaviour is quantified by the bidirectional distribution function (BRDF).
- The BRDF can be described by suitable BRDF models.

The reflectance signal carries information on the surface it has interacted with before reaching the sensor.

Inversion of BRDF models against reflectance data like the Hapke allows for extracting and assessing this information.

The Hapke BRDF Model - Overview

$$R_{(i,e,g,\bar{\theta})} = \frac{w}{4} \cdot \frac{1}{\mu_{0e} + \mu_e} \cdot \left[\left(1 + B_{(g)}\right) \cdot p_{(g)} + M_{(\mu_{0e},\mu_e)} \right] \cdot S_{(i,e,g,\bar{\theta})}$$

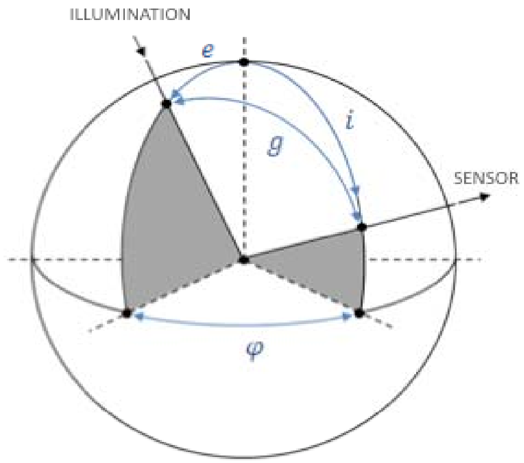

Figure 2: Relevant angles of the model.

Model component	Name/ Description
$\frac{w}{4} \cdot \frac{1}{\mu_{0e} + \mu_e}$	Lommel-Seelinger coefficient
$p_{(g)}$	Particle single-scattering phase function: Describes the angular distribution of scattered radiation
$B_{(g)}$	Shadow-hiding opposition effect (SHOE) function: Describes the shape of the opposition surge
$M_{(\mu_{0e},\mu_e)}$	Contribution to the total radiance scattered by anisotropic multiple-scattering
$S_{(i,e,g)}$	Hapke's shadowing or macroscopic roughness function: Provides correction for macroscopic roughness

Table 1: Summary overview of the components of the Hapke BRDF model.

The Hapke BRDF Model – Shadow function

- The reflectance of an arbitrary rough surface can be described by a perfectly smooth surface of identical optical properties, but larger effective surface area A_e. The effective surface is inclined towards the sensor by angle θ (*photogrammetric roughness* or *slope angle*).

$$r_{rough}(i,e,g) = r_{smooth}(i_e,e_e,g) \cdot S_{(i,e,g,\bar{\theta})}$$

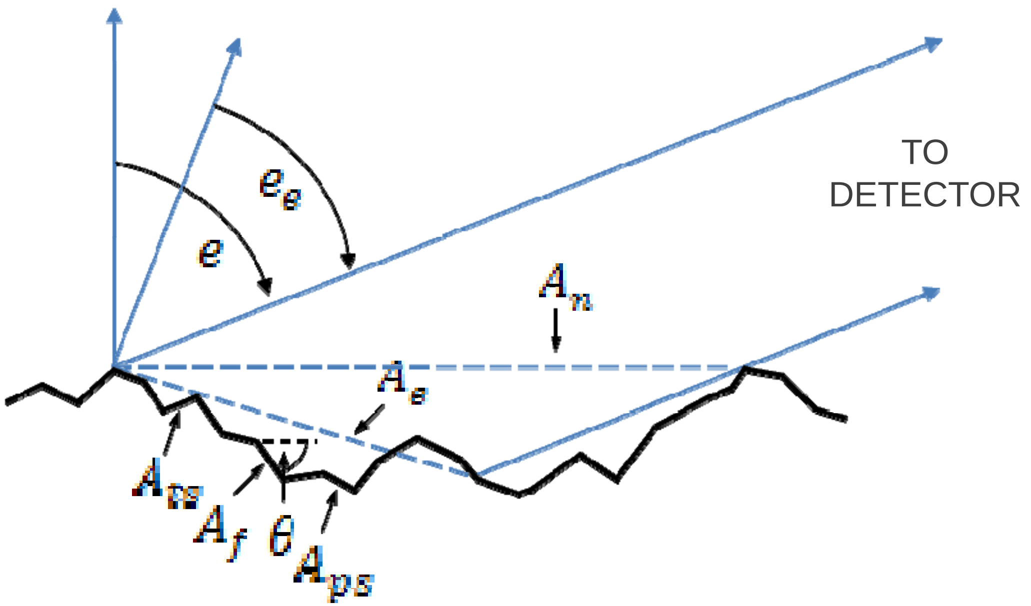

Figure 3: Vertical cut through the plane of observation containing the detector and an arbitrary rough surface

Hapke Model Inversion Procedure

Hapke model forward mode execution

Look-up-table (LUT)

ADC imagery soil reflectance (8:30, 9:30, 11:00, 12:30)

Minimize difference between modelled and measured reflectance

Model roughness parameter θ

Physical roughness indices (DEM)

Field Site and Experimental Treatments

Site description:

- Soil type: Eutric Fluvisol
- Soil texture: loamy alluvial soil
- Extension: 100 x 40 m

Figure 4: View of the study site

Tillage treatments:

- Chisel plough
- Cultivator
- Moldboard plough
- Roller
- Rotary tiller

Figure 5: Images of the applied tillage tools

Date of experiment: 12th March 2009

Field Site and Experimental Treatments

ADC imagery of the field site showing the final distribution of treatment subplots on the field site.

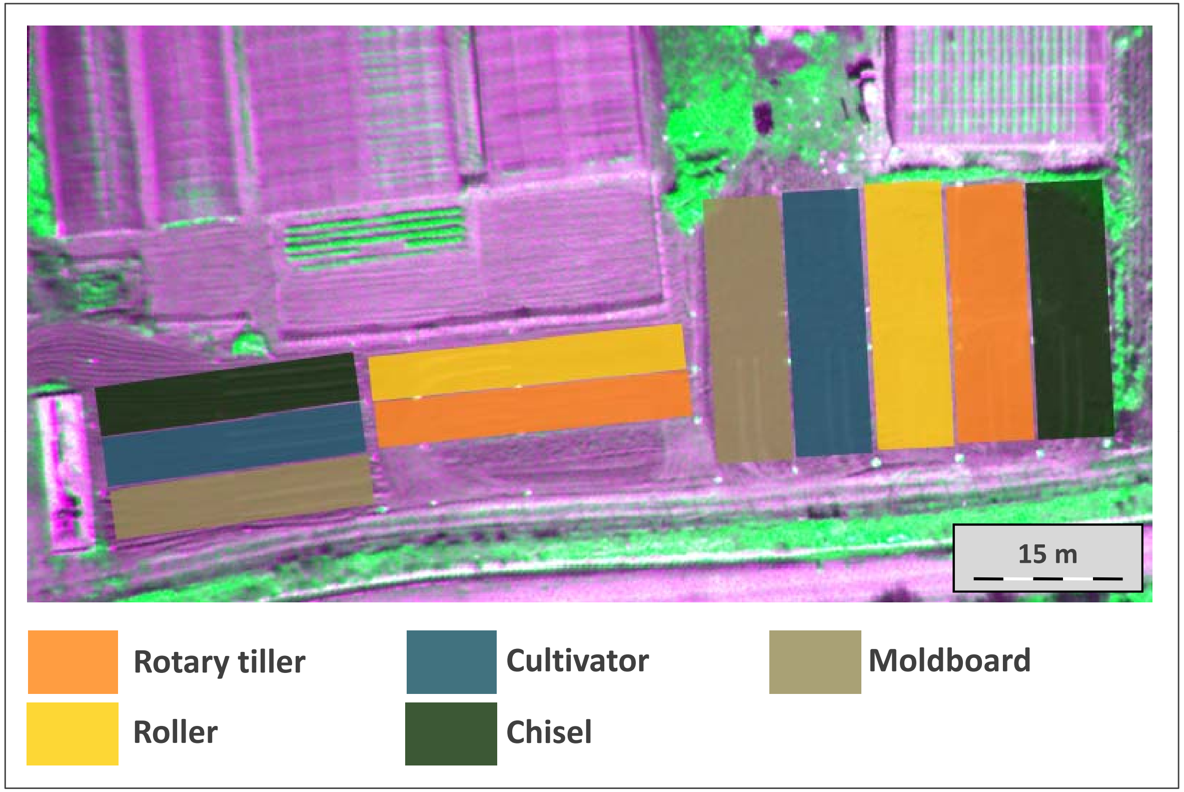

Figure 6: Airborne ADC imagery showing the location and distribution of treatment subplots.

Soil Surface Roughness Characterization

For each treatment, three representative DEMs were scanned on different subplots (dGPS logged).

Laser scanning instrument:

- Design type: two-axis line-by-line point laser
- Resolution: 0.1 mm
- Grid size: 7.2 x 7.2 mm
- Area scanned per DEM: 900 x 900 mm

1. Introduction
2. **Materials and Methods**
3. Results
4. Conclusions

Soil Surface Roughness Characterization

SSR was quantified using three roughness indices.

- **Root-mean-square height RMSH [mm]**

$$RMSH = \left[\frac{1}{n-1}\sum_{i=1}^{n}\left[z_{(i)} - \bar{z}\right]^2\right]^{\frac{1}{2}}$$

- **Mean surface slope S [º]**

$$S_{ij} = \left(\frac{180^\circ}{\pi}\right)\cdot atan\left[\left(\frac{z_{(i-1,j)} - z_{(i-1,j)}}{2\Delta x}\right)^2 + \left(\frac{z_{(i,j-1)} - z_{(i,j+1)}}{2\Delta y}\right)^2\right]^{\frac{1}{2}}$$

- **Tortuosity T_A [%]**

$$T_{A(dir)} = 100\cdot\left(1 - \frac{L_0}{L^*}\right)$$

Soil Surface Roughness Characterization

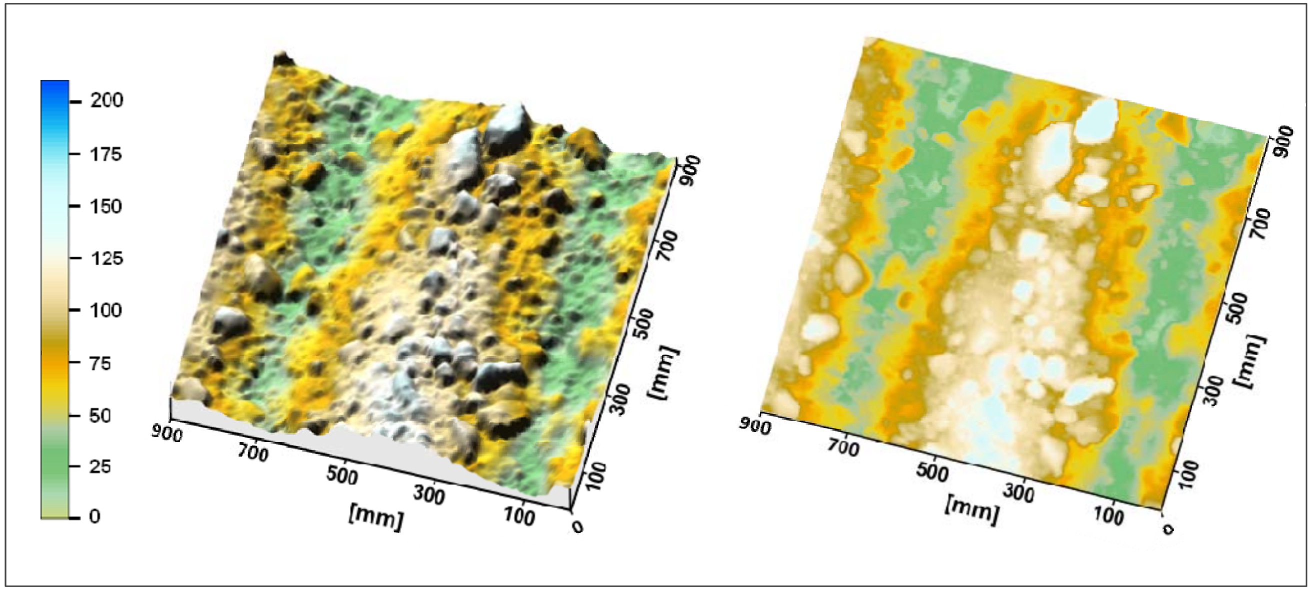

Figure 9: Rendered DEM (left) and image map (right) for the chisel treatment.

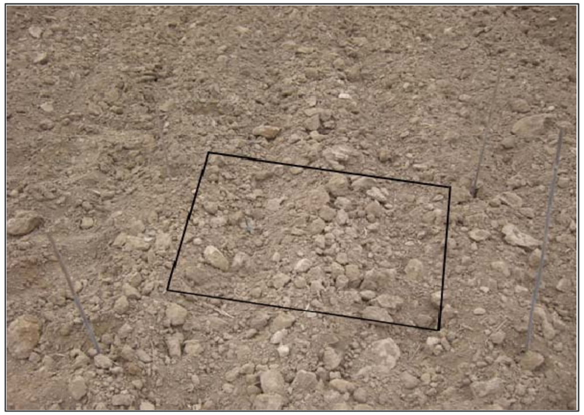

Figure 10: Detailed image of the chisel treatment. Black box shows scanned surface above.

Soil Surface Roughness Characterization

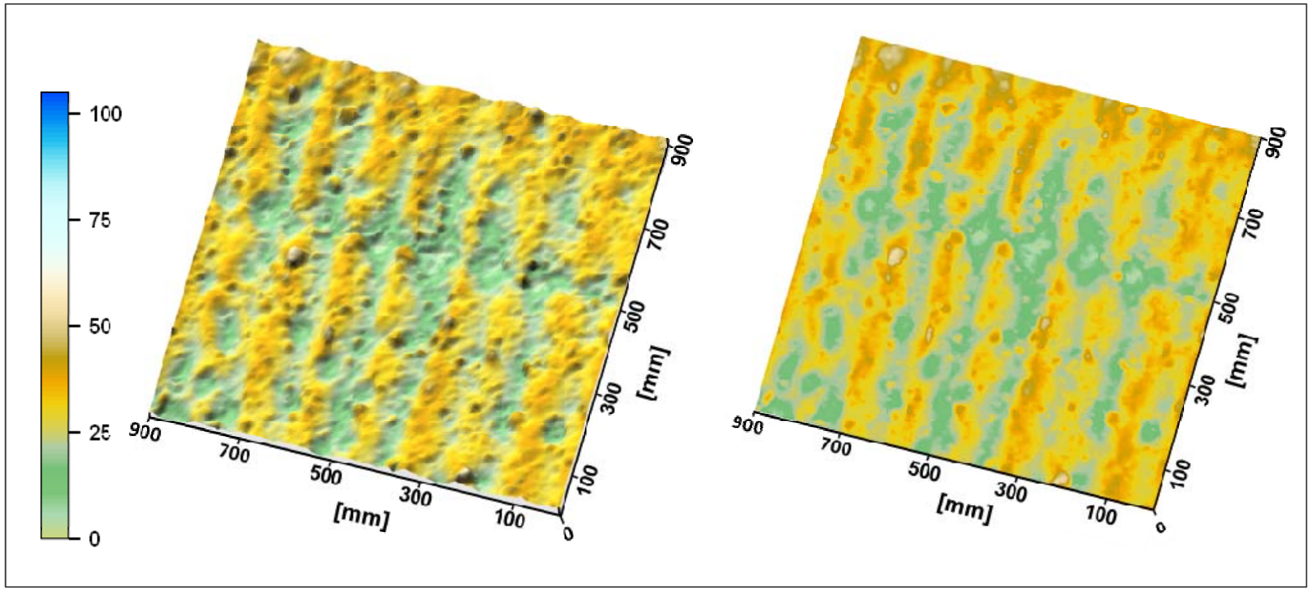

Figure 11: Rendered DEM (left) and image map (right) for the roller treatment.

Figure 12: Detailed image of the chisel treatment. Black box shows scanned surface above.

Soil Surface Roughness Characterization

Main roughness indices for the five tillage treatments.

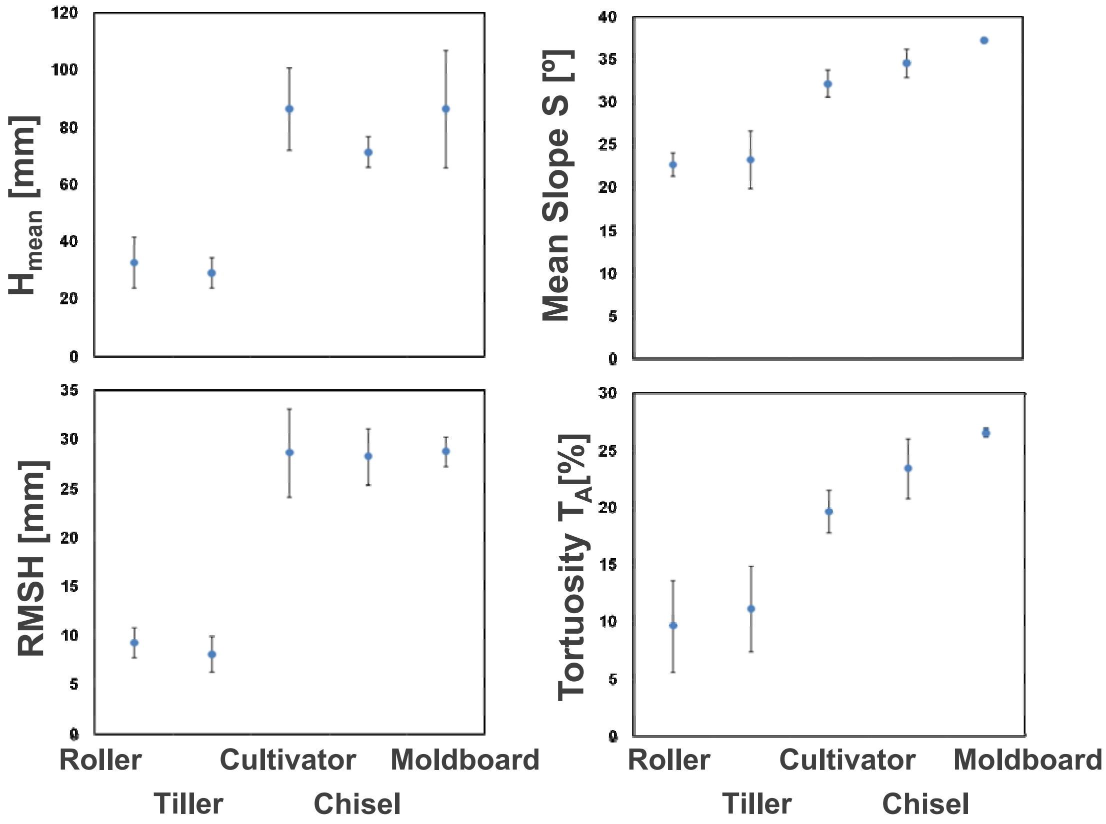

Figure 13: Mean elevation height of DEMs and quantitative roughness indices RMSH, S and $T_{A(X)}$. Values are mean of treatment groups.

Airborne Imagery Acquisition Campaign

Airborne imagery was acquired one week after tillage operations on four times of day under clear-sky conditions.

Unmanned aerial vehicle (UAV):

- Payload: multispectral ADC sensor (Tetracam Inc., USA)
- Sensor wavelengths [nm]:
  B1 = 550 B2 = 670 B3 = 800
- Overflight times: 8:30, 9:30, 11:00 and 12:30 GMT.
- Spatial resolution: 12.5 cm

Figure 14: UAV at take-off.

At-ground reflectance for each DEM location obtained after radiometric and geometric correction, image georeferencing and co-registration, atmospheric correction.

Airborne Imagery Acquisition Campaign

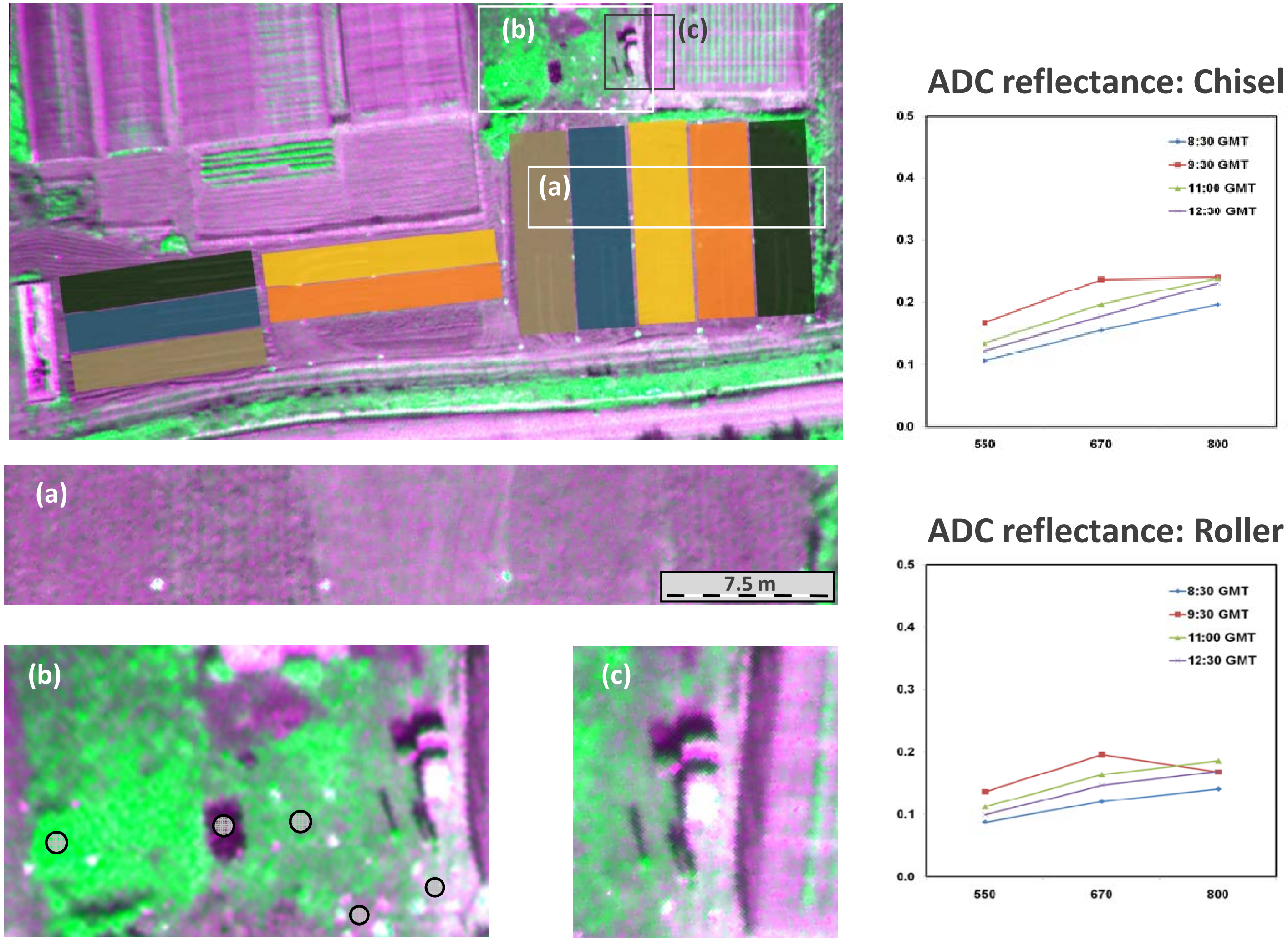

Figure 15: Multispectral ADC image acquired over the Alameda site at 0.125m spatial resolution. Reflectance spectra for the treatments chisel and roller at four times of the day.

Results: Inversion of the Hapke Model

Model fit after LUT inversion procedure: Comparison between measured and modelled reflectance.

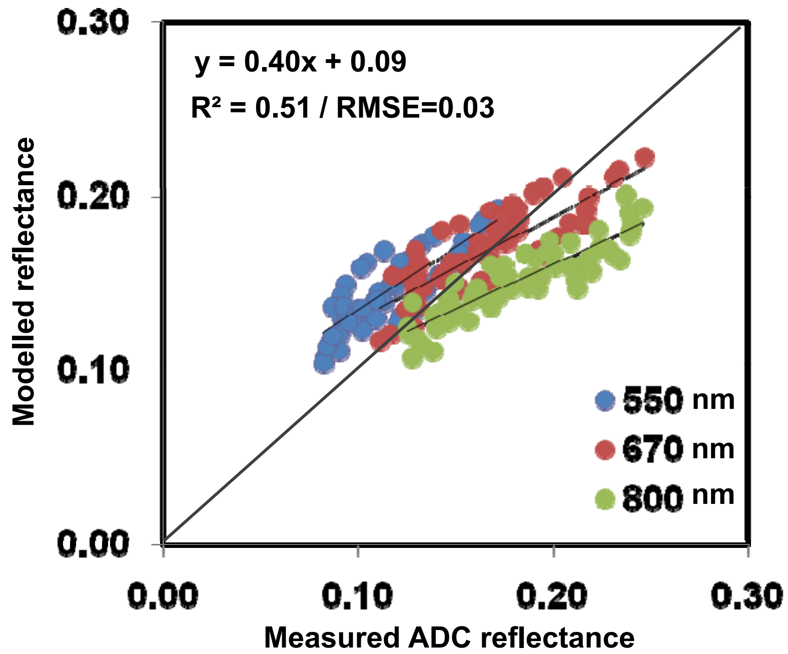

Figure 16: Comparison between measured and modelled reflectance.

Results: Model Roughness θ vs. Physical Roughness

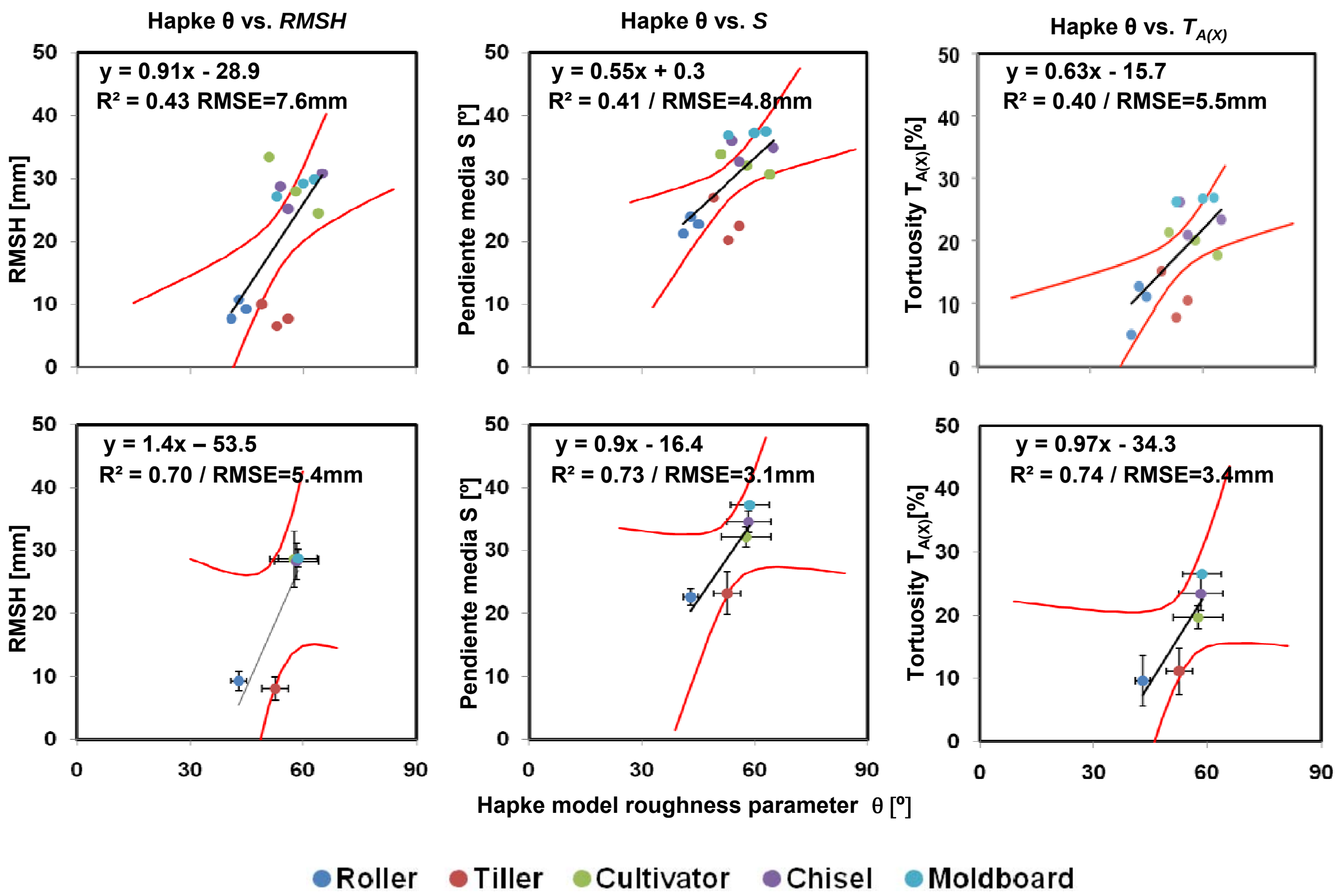

Figure 17: Comparison between the Hapke model's roughness parameter θ obtained by inversion and quantitative roughness indices RMSH, S and $T_{A(X)}$. Above, regression models based on individual values for the 15 DEM sample locations, below regression models based on treatment group means.

Conclusions

- Hapke's BRDF model was successfully inverted against soil reflectance data obtained under different sun illumination angles, but with constant view angles.

- Meaningful prediction models were obtained between the model's roughness parameter θ and different quantitative roughness indices showing that there is a detectable correlation between θ and measured SSR.

- The Hapke parameter θ can be used as a quantitative estimate of SSR on field scales with high spatial resolution.

Future work will concentrate on a full image inversion to map soil surface roughness and its spatial variability using the Hapke model and its roughness parameter.

EGU General Assembly 2011

SSS2.6/HS12.12/NP3.12
Spatial and temporal scaling in soil erosion: measurements, theory and modelling
(EGU2011-7673)

Poster Session
SSS2.3/GM3.7/HS12.11

Hall Z, Board Number Z36
Attendance: 17:30 - 19:00

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

Thank you for your attention!

Rodríguez González, J., Zarco-Tejada, P. J. , Gómez, J. A.

Inversion of the Hapke model with diurnal multispectral reflectance data for assessing soil surface roughness (EGU2011-7673)

Acknowledgments
Part of this study was supported by grants AGL2009-12936-C03-01 and BES-2005-8691-AGL2005-04049 (Spanish Government) and FEDER funds. This support is gratefully acknowledged.

Contact details: Jesus Rodriguez Gonzalez
Email jrodriguez@ias.csic.es
Web http://quantalab.ias.csic.es

Instituto de Agricultura Sostenible (IAS)
Consejo Superior de Investigaciones Científicas
Córdoba, Spain