AN EFFICIENT METHODOLOGY TO SIMULATE MIXED SPECTRAL SIGNATURES OF LAND COVERS THROUGH FIELD RADIOMETRY DATA

The mapping of land cover and land use is a key application of remotely sensed data. A thematic map shows the spatial distribution of identifiable earth surface features; it provides an informational description oven a given area, rather than a data description. Image classification is the process used to produce thematic maps from imagery.

Traditionally, the production of maps from satellite imagery assumes that each pixel of the image can be assigned to a single land cover class. In the remote sensing imagery, the measured spectral radiance of a pixel is the integration of the radiance reflected from all the objects within the Ground Instantaneous Field Of View, GIFOV, also called Ground Sample Distance, GSD (Schowengerdt 2007). Mixed pixels are generated if the size of the pixel includes more than one type of land cover. Obviously, spectral mixing is inherent in any finite-resolution digital imagery of a heterogeneous surface. Solving the spectral mixture problem is, therefore involved in image classification, referring to the technique of spectral unmixing.

Spectral unmixing has been used as a technique for analyzing the mixture of components in remotely sensed images. The technique is based on the assumptions that several primitive classes of interest can be selected, that each of these primitive classes has a pure spectral signature, which can be identified and the mixing between these classes can be adequately modelled as a linear combination (Small 2004) of the spectral signatures.

Spectral mixture analysis (SMA) techniques have overcome some of the weaknesses of full pixel approaches by using linear statistical modelling and signal processing techniques (Keshava 2002) (Rand 2001) (Tu 1999). The key task in linear SMA is to find an appropriate set of pure spectral components which are then used to estimate the fractional abundances of each mixed pixel from its spectrum and the *endmember* spectra by using a linear mixture model (Heinz 2000). The identification of the pure pixel value is often difficult. Because of sensor noise and within-class signature variability, *endmembers* only exist as a conceptual convenience and as idealization in real images.

In this investigation, it is proposed a methodology to simulate mixed spectral signatures of land covers, from *endmember* data obtained through Field Radiometry, using linear statistical modelling. Previously, the authors have experience to collect a optimal set of *endmembers* by measurements *in situ* with a field spectroradiometer (Vazquez 2004, 2008). They propose the use of new sub-pixel methods based on statistics and certain “units of sampling” to apply to the landscapes. The resultant point estimations for these new units will be the “observations” that will be crucial later to simulate signature spectral models. Good results about correlation remote and near spectral response have been obtained.

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ABSTRACT

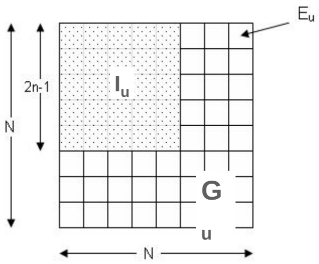
An efficient methodology to simulate mixed spectral signatures of land covers, from *endmember* data, using linear statistical modelling based on the least squares estimation approach, is proposed. The optimal set of *endmember* has been obtained by measurements *in situ* with a field spectroradiometer GER 1500. Also, it is proposed the use of new sub-pixel methods based on statistics and certain "units of sampling" to apply to the landscapes. The resultant point estimations for these new units will be the "observations" and all of them will carry out an special role to simulate the final spectral signature. This methodology is used to simulate spectral signatures of a Mediterranean forest landscape near to Madrid (Spain). Furthermore the spectral signature model obtained through Field Radiometry data will be correlated with the image data of the same zone provided by the Landsat 7 Enhaced Thematic Mapper Plus (ETM+) sensor once corrected. The results obtained in correlation studies seem to conclude its efficiency. At the same time, the results open new research guidelines.

M E T H O D O L O G Y

IDENTIFICATION OF THE LANDSCAPE UNITS TO BE ANALYSED

The Global Unit (G_u) has equal dimension of the pixel of remote sensor. This one will be submitted to a process of successive subdivisions, in order to get smaller units or Intermediate Units, I_u, composed, in turn, by indivisible ones called Elemental Units, E_u.

From the sampling information of these E_u, it will be possible to model the mixed spectral response of G_u. For that, the size of each E_u, must be such that behaves as a "homogeneous spectral unit". Its spectral content must be as close as possible to the *endmember* in order to represent optimally the cover itself. High land covers variability will involve the existence of a large number of very small ones.



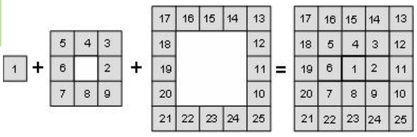
SAMPLING METHODS

The criteria to design the more representative statistics for I_u could be based on a strategy of "considering" more or less the information belonging to the different Elementary Units. In this sense, we propose the "balanced statistic" and the "unbalanced statistic". The first one consists in assigning to each E_u, identical "weights". So, each of them equally will contribute to the total spectral response of the I_u. The second one considers weighing "differently" the information contained in the centre than the contained in the peripheral.

The Global Unit sampling method could be as simple as possible. We suggest a new method for picking up samples: the so-called "double-diagonal". This model reflects with acceptable accuracy the variability of the different land covers, and thus achieves a good representation of the Global Unit.

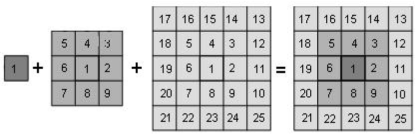
The regression models for each band (mixed hyperplanes) are obtained by linear least squares techniques through balanced and unbalanced statistics.

Intermediate Unit



Balanced

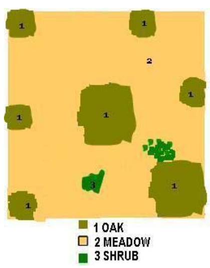
$$i_{balanced} = \frac{\sum_{i=1}^{i=2n-1} \sum_{j=1}^{j=2n-1} x_{ij}}{(2n-1)^2}$$

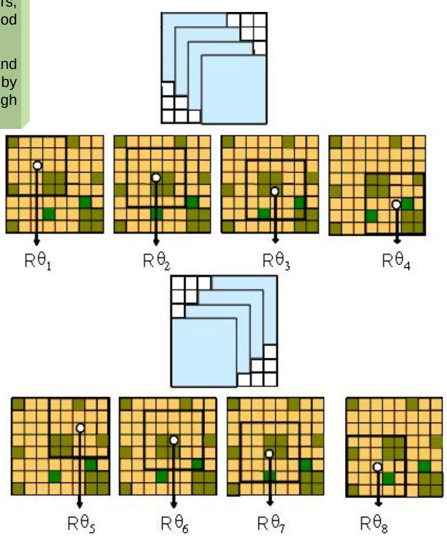


Unbalanced

$$i_{unbalanced} = \frac{x_{ij} + \sum_{i-1}^{i+1}\sum_{j-1}^{j+1} x_{ij} + \sum_{i-2}^{i+2}\sum_{j-2}^{j+2} x_{ij} + \dots + \sum_{i-(2n-1)}^{i+(2n-1)}\sum_{j-(2n-1)}^{j+(2n-1)} x_{ij}}{\sum_{i=1}^{i=n} (2n-1)^2}$$

Global Unit





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DATA

The study zone is situated in the Mountgancedo near Madrid (Spain). This site is located to the south-west of Community of Madrid, and it has a surface area of 125 hectares. The study area selected is located at 40º 24´30´´ N, and 3º49´50´´ W (4473/4474 N, 429/430 W UTM). Several mediterranean species of vegetation can be easily found, such as holm oaks (*Quercus ilex*), spanish lavender (*Lavandula pedunculata*) and the crimson spot rockrose (*Cistus ladanifer*). The surface is also covered by grass and abundant meadows as well as bare soil, and rocks and stones outcrops. The land cover spectral samples have been obtained in the summer by Field Radiometry with the GER 1500, agreement with the date of Landsat ETM+ remote data register. Sampling in situ has been carried out according to a methodology that optimizes the number of samples to pick-up.

Even though the remote sensor (ETM+) has six bands with the same spatial resolution, only the first four ones can be considered according to the spectral register interval of field radiometer; in order to correlate field and remote information.

Since the data registered in situ, provides a continuous spectral response, a previous reduction methodology based on the integration of the radiance values into the spectral bands interval selected, was carried out. Thus, the field spectral data had been reduced to field spectral signatures, with four values named R-ETM+1, R-ETM+2, R-ETM+3 y R-ETM+4 in agreement with the first four bands of the remote sensor.

R E S U L T S

Reflectance values obtained by application of balanced and unbalanced statistics to Intermediate Units.

I_u	Reflectance (%/100)							
	Balanced method				Unbalanced method			
	R-ETM+1	R-ETM+2	R-ETM+3	R-ETM+4	R-ETM+1	R-ETM+2	R-ETM+3	R-ETM+4
Θ_1	0.0950	0.1340	0.1621	0.2982	0.0935	0.1331	0.1616	0.2981
Θ_2	0.0990	0.1390	0.1702	0.2936	0.0976	0.1383	0.1694	0.2932
Θ_3	0.0910	0.1330	0.1634	0.2987	0.0908	0.1321	0.1631	0.2983
Θ_4	0.0870	0.1250	0.1523	0.3072	0.0866	0.1244	0.1520	0.3056
Θ_5	0.0870	0.1270	0.1542	0.3009	0.0862	0.1266	0.1540	0.3011
Θ_6	0.0960	0.1410	0.1746	0.2957	0.0955	0.1394	0.1731	0.2963
Θ_7	0.0960	0.1370	0.1696	0.2964	0.0956	0.1355	0.1687	0.2966
Θ_8	0.0930	0.1360	0.1687	0.2973	0.0923	0.1351	0.1691	0.2999

regression models
linear least squares techniques

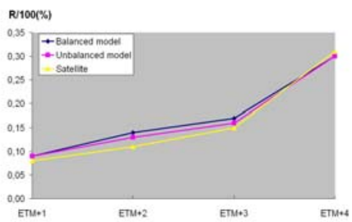
MIXED HYPERPLANES

Balanced method

$$R_{R\text{-}ETM+1} = 0.0471p_1 + 0.0981p_2 + 0.0273p_3$$
$$R_{R\text{-}ETM+2} = 0.0722p_1 + 0.1422p_2 + 0.0755p_3$$
$$R_{R\text{-}ETM+3} = 0.0681p_1 + 0.1952p_2 + 0.0653p_3$$
$$R_{R\text{-}ETM+4} = 0.3675p_1 + 0.2986p_2 + 0.1784p_3$$

Unbalanced method

$$R_{R\text{-}ETM+1} = 0.0441p_1 + 0.1036p_2 + 0.0519p_3$$
$$R_{R\text{-}ETM+2} = 0.0714p_1 + 0.1516p_2 + 0.0843p_3$$
$$R_{R\text{-}ETM+3} = 0.0882p_1 + 0.1912p_2 + 0.0898p_3$$
$$R_{R\text{-}ETM+4} = 0.3765p_1 + 0.2877p_2 + 0.2155p_3$$



Spectral signature values of simulated models (estimated "in situ" percentages of abundances 18.8% oak, 78.1% meadow, 3.1% shrub) and satellite corrected data for the Global Unit

CONCLUSIONS

Mixed hyperplanes for each band have been obtained by linear least squares techniques through balanced and unbalanced statistics.

The modeled spectral signatures are very similar that the one provided by the sensor satellite, once atmospheric correction has been made. The simulation forecasts signatures values slightly higher than those provided by the satellite sensor in the first three bands, whereas in the fourth band this value is slightly lower. The use of unbalanced statistic provides values closest to the satellite sensor.

To sum up, it has been proposed a methodology to simulate spectral mixed signatures. The methodology derives from the use of new sub-pixel methods based on statistics and certain "units of sampling". Furthermore, correlation studies have been carried out with near and remote spectral data in order to evaluate this methodology. Their results seem to conclude its efficiency. At the same time, the results open new research guidelines.

These simulated mixed signatures will feed a Library Spectral of Land Cover Spectral Responses