14th International Soil Conservation Organization Conference.
Water Management and Soil Conservation in Semi-Arid Environments. Marrakech, Morocco, May 14-19, 2006 (ISCO 2006).

REMOTE SENSING OF GULLY NETWORKS: THE APPLICATION OF ASTER IMAGERY IN SOUTHERN ITALY

A. Ghaffari, M.L. Clarke, P. Mather, G. Priestnall,
School of Geography, Nottingham University, Nottingham, UK
ghaffari@geography.nottingham.ac.uk

Assessing the rates of Mediterranean land degradation though gully erosion requires an accurate method of mapping gully features and their temporal change. Given the size of these features, field mapping is arduous. A new remote sensing approach using ASTER data with 15-meter resolution has been piloted in a gullied region of southern Italy. A model has been prepared using features such as digital elevation (DEM), slope, aspect, flow accumulation, textured image and normalised difference vegetation indices (NDVI) to recognise gully forms in the field. Supervised pattern recognition techniques, such as artificial neural networks (ANN) and decision trees (DT) have been tested. Decision tree techniques show about 85% overall accuracy presenting a better performance than ANN.

1- Introduction:

Land degradation through gully erosion is believed to be a significant cause of soil loss in Mediterranean regions where gully systems are spatially-linked into ephemeral or perennial river networks. Due to the dimensions of gully systems, morphological changes and associated erosion rates are difficult to monitor in the field. Several researchers have tried to study gully erosion remotely using aerial photos and satellite data. Despite differential success, almost all authors agree that monitoring using remote data will be easier and more cost effective than field surveying (Morgan *et al.*, 1978, 1980; Morgan & Napela, 1982; Stephens *et al.*, 1985; Nachtergaele & Poesen, 1999). This paper presents the results of a remote sensing approach to mapping gully volume in the Basilicata region of southern Italy.

Basilicata is one of the most vulnerable regions in Italy (Gostelow *et al.*, 1997), in which 58% of the 114 *comuni* are classified at high risk and a further 13% at very high risk of landsliding or flooding (Ministero dell'Ambiente, 2000). The landscape ranges from limestone massifs in the west, with mean annual rainfall in excess of 2000mm and mean temperature of 10°C to relatively low-lying basin and range topography occupying the central and eastern parts of the region with mean annual rainfall of less than 700mm and mean annual temperatures in excess of 15°C (Cataudella, 1987). Perennial rivers drain southeastwards from the limestone of the Apennines carving through Miocene flysch and Plio-Pleistocene marine clays, sands, gravels and conglomerates of the Fossa Bradanica fill complex (Sabato and Tropeano, 1994), exposed in the hillsides of the basin and range terrain. In the east of Basilicata, hilltop settlements commonly occupy pedestal outcrops of sands and conglomerates lying up to 300m above the valley floors (Clarke and Rendell, 2000), the high relative relief caused by differential uplift and incision (Boenzi and Guira Longo, 1994).

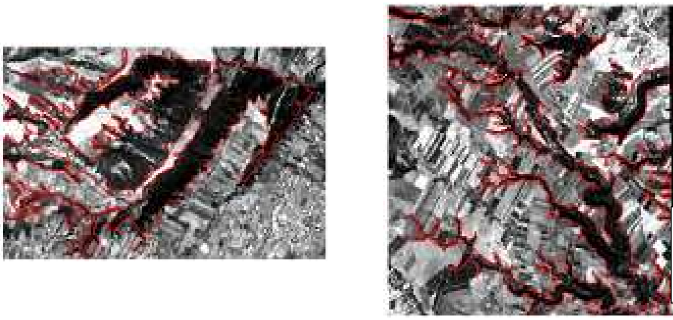
14th International Soil Conservation Organization Conference.
Water Management and Soil Conservation in Semi-Arid Environments. Marrakech, Morocco, May 14-19, 2006 (ISCO 2006).

Recent research into land degradation in Basilicata has focused on landslides (Gostelow et al, 1997; Clarke and Rendell, 2000; 2006), floods (Coleoiro and Mercuri, 1982; Clarke and Rendell, 2006) and rates of badland (Rendell, 1986; Alexander, 1980; Clarke and Rendell, 2005) and rill erosion (Clarke and Rendell, 2000), however nothing is known of rates of soil loss from gully systems. From the literature it is clear that gully erosion rates are highly variable globally, ranging from 0.1 to 64.9 t $ha^{-1}yr^{-1}$ (Poesen *et al.* 2003). This study focuses on the use of ASTER remotely sensed data to evaluate gully volume. Once volume can be established, temporal changes in form dimensions can be estimated.

2- Materials and Methodology:

ASTER L1A and L1B data have been obtained for an area of southern Italy focused on Basilicata, which covers ~889 km^2 and is located between 40°:15’:36” (40.26 DD) and 40°:36’:00” (40.60 DD) latitude and 16°:26’:24” (16.44 DD) and 16°:43’:12” (16.72 DD) longitude. Within this region, five sample areas were selected for analysis: three in Plio-Pleistocene clays with landscapes characterised by large topographic gradients, intense dissection and badlands formed in marginal areas of an agricultural landscape dominated by cultivation of durum wheat (Clarke & Rendell, 2000; 2005). Two of the samples derived from the more subdued topography of the Ionian coastal plain, where clays overlie marine sands, gravels and conglomerates. Examples of these terrains are shown in figure 1 were gullies are delineated using red lines.

Sample area one



Sample area Three

Figure 1. Two sample areas in the Ionian Coastal Plain

Analysis of the ASTER data generated layers involving Generation Digital Elevation Models (DEM), slope, aspect, textured image and flow accumulation. Additional information was derived from topography maps and aerial photography (1:50000). Various software packages were used including PCI Geomatic, ERDS, ARC-View, IDRISI, and WEKA.

An automatic stereo-correlation technique was utilised to produce the DEM using L1A ASTER data. Although, the accuracy of the DEM was ± 10 meters (compared to 15m ASATER resolution), using 35 Tie Points (TP), measured using a Garmin 12 GPS in the field. Slope, aspect and flow accumulation layers were automatically prepared using DEM layer and PCI software. Bands 2 and 3 have applied to calculate the NDVI for the study area, using ASTER - L1B data that has been corrected radiometricaly and geometricaly.

A Grey Level Co-occurrence Matrix (GLCM) was applied to study the image texture from ASTER band one using a 3 3 window. The mean image texture range between 0 and 1 has been used to determine five classes of landscape gully density (0 for the lowest density and 1 for the maximum density).

Artificial Neural Network (ANN) and Decision Tree (DT) are two unsupervised classification techniques, which have been applied to classify the entire input layer using the WEKA program after preparation of the data using Visual Basic (VB) prior to feeding the data into WEKA. For gully detection, DT is slightly (overall accuracy 85%) better performing in comparison to the ANN. However, the result shows that detecting gullies in flat areas is less problematic because of size and scale of channels, in comparison to basin and range topography in which marginal areas are dissected into badlands. This more complex terrain makes detecting gullies and their headcuts more difficult.

GIS techniques have been applied to estimate gully volume using the DEM. An arithmetic map overlay between two grid images, e.g. DEM and gully channels detected by decision tree methods have been applied to estimate the elevation of each pixel, as a new layer from the land surface. The area of land immediately adjacent to the gully forms is g iven a zero value for elevation. The volume of gullies can then calculated (Table 1) using following equation.

$$SV = \sum_{n=1}^{n} PixelValue \quad pixelsize^{2}$$

Where *SV* is volume (m3) within the gully channels, the *pixel value* is the difference in elevation for each pixel, *pixel size* equals 15m, and *n* is the number of pixels.

3- Results and Discussion:

The gully forms in Basilicata are flat floored and box shaped in cross section, equivalent to the arroyos of the southwest USA (Cooke and Reeves, 1976). Unlike arroyos which can be continuous and discontinuous in nature, gullies in Basilicata are always continuous with upstream ends forming distinctive head cuts. The forms are incised into gently sloping alluvial and marine terraces and appear to form a relict palaeodrainage network. The application of ASTER data as illustrated above provides the first estimation of total volume of sediment lost by gully formation in this landscape. Nothing is as yet known of the age of initial incision however, this technique provides the first opportunity to identify temporal change or modification as a result of extreme event occurrence (Clarke and Rendell, 2006). The dataset can also facilitate comparison of Basilicata forms with empirically-derived headward erosion rates based on landscape parameters such as catchment area, slope and soil characteristics (refs)

Table 1. Characteristics of gully networks in sample areas 1 and 3

Sample Area	**Gully area ($x10^6 m^3$)**	**Gully volume ($x10^9 m^3$)**	**Depth (m)**
Area 1	15.26	0.57	37.21
Area 3	8.53	0.29	34.48

4- Conclusion:

This work represents the first application of ASTER-derived remotely sensed imagery to define gully volume in an area susceptible to Mediterranean land degradation. The potential of this approach in terms of monitoring temporal changes in gully form is being fully explored.

References:

Alexander DE. (1980) Calanchi - Accelerated Erosion in Italy. *Geography*. 65: 95-100

Boenzi F, Giura Longo R. (1994). *La Basilicata: i tempi, gli uomini, l'ambiente*. Edipuglia: Bari.

Caloiero D, Mercuri T. (1982) *Le alluvioni in Basilicata dal 1921 al 1980.* Consiglio Nazionale delle Ricerche, Istituto per la Protezione Idrogeologica, Cosenza, Geodata 6, Xpp.

Cataudella M. (ed) (1987). *Atlante della Basilicata: il territorio per immagini*. Regione Basilicata, Potenza.

Clarke ML, Rendell HM. (2000). The impact of the farming practice of remodelling hillslope topography on badland morphology and soil erosion processes. *Catena* **40**: 229-250.

Clarke ML, Rendell HM. (2005). Process-form relationships in southern Italian badlands: erosion rates and implications for landform evolution. *Earth Surface Processes and Landforms*, **30**: in press.

Clarke ML, Rendell HM. (2006). Hindcasting extreme events, the occurrence and expression of damaging landslides and floods in southern Italy *Land Degradation and Development*: in press.

Cooke, R.U., Reeves, RW, (1976) Arroyos and environmental change in the American South-West: Oxford, Clarendon Press, 213 p.

Gostelow TP, Del Prete M, Simoni A. (1997). Slope instability in historic hilltop towns of Basilicata, southern Italy. *Quarterly Journal of Engineering Geology,* **30**: 3-26.

Ministero dell'Ambiente. (2000). *Classificazione dei comuni italiani in base al livello di attenzione per rischio idrogeologico*. Roma.

Morgan, K. M., Lee, G. B., Kiefer, R. W., Daniel, T. C., Bubenzer, G. D., Murdock, J. T. (1978) Prediction of Soil Loss on Cropland with Remote Sensing. Journal of Soil and Water Conservation. 33, (6) 291-293

Morgan, K. M., Morris, D. R., Lee, G. B., Kiefer, R. W., Bubenzer, G. D., Daniel, T. C. (1980) Aerial Photography as an Aid to Cropland Erosion Analysis. Transaction of The ASAE. 23, 907-913

Morgan, K. M., Napela, R. (1982) Appilcation of Aerial Photographic and Computer Analysis to The USLE For Areawide Erosion Studies. Journal of Soil and Water Conservation. 37(6) 347-350

Nachtergaele, J., Poesen, J. (1999) Assessment of Soil Losses by Ephemeral Gully Erosion Using High-altitude (Srereo) Aerial Photographs. *Earth Surface Processes and Landforms,* **24**, 693-706

Poesen, J., Nachtergaele, J., Verstraten, G. & Valentin, C. (2003) Gully erosion and environmental change: importance and research needs. Catena, 50, 91-133.

Rendell HM. (1986) Soil erosion and land degradation in southern Italy. In Desertification in Europe, Fantechi R, Margaris NS (eds).Commission of the European Communities: Brussels; 184-193.

Sabato L, Tropeano M. (1994). Ceni sul sistema catena-avanfossa-avampaese in Italia Meridionale In: *Guida alle escurzione Congresso Società Geological Italia, Bari.* Quaderni Bibliografico della Provincia di Matera, 11-32.

Stephens, P. R., MacMillan, J. K., Daigle, J. L., Cilhlar, J. (1985) Estimating Universal Soil Loss Equation Factor Values With Aerial Photography. Journal of Soil and Water Conservation. 40(3) 293-296