RGS-IBG Annual International Conference 2005
Programme book

Royal Geographical Society
with IBG

Advancing geography and geographical learning

Flows and spaces in a globalised world

05

31 August - 2 September 2005
1 Kensington Gore, London

2.	**Brian Ilbery & Damian Maye**	Coventry University	Governing food chains: an institutional survey from the Scottish-English borders
3.	**Catherine Walkley**	University of Wales	The alternative food economy, supply chain integration and rural development: the role of institutions in West Wales
4.	**James Kirwan & Carolyn Foster**	University of Gloucestershire	Public sector food procurement in the UK: examining the creation of an alternative system
5.	**Jane Ricketts Hein**	University of Coventry	"… we were still living here, we were still farming…": Differing expectations of the local food system in England and Wales
6.	**Brian Ilbery, David Watts, Andrew Gilg, Jo Little & Sue Simpson**	Coventry University & University of Exeter	Producers' perspectives on food quality and networking, and their conceptual implications for 'alternative' food systems
7.	**Colin Sage**	University College Cork	"Blessed are the cheese makers; guilty is the state". Construction of risk and interpretations of science in the speciality food sector

Biogeography Research Group (BRG) & GISc Research Group (GIScRG)

Landscape ecology, remote sensing and GIS: monitoring ecosystem responses to landscape change (1) – landscape mapping and application: land cover pattern, biological diversity and ecosystem fragmentation

Abstract:
This session aims to examine dynamic flows and spaces in a globalised world with specific reference to ecological landscapes and the utility of remote sensing and GIS. Ecological landscapes are evolving under increasingly prominent global socio-demographic and politico-economic forces. This can be witnessed in intensification/de-intensification of agricultural landscapes, fragmentation of tropical forest, rangeland degradation, alien species invasion, species over-exploitation and altered animal range distributions. Many of these changes are confounded by the potential impacts of future climate change. Landscape ecology examines the relationships between pattern and process at the synoptic scale. Remote sensing offers capabilities of land cover (habitat) and species assemblage mapping, and quantitative estimates of land surface biophysical properties. GIS is used to capture, store and model data spatially, with the inherent capability of scale manipulation. Thus, integrating theoretical concepts and findings of landscape ecology with the capabilities of synoptic level technology offers a means of monitoring/modeling ecosystem responses to landscape change. Together, the concepts and technologies can enhance evaluation for nature conservation, including prioritizing protected areas and informing policy guidelines.

Convenors:		Chair:	
Jenny Hill	University West England	**Jenny Hill**	University West England
Robert Abrahart	University of Nottingham	**Robert Abrahart**	University of Nottingham

Speakers:

1.	**Jennifer Hill & Paul J. Curran**	University West England & University of Southampton	Remote sensing and landscape ecology: some recent developments
2.	**Bernard Bevereux, Gabriel Amable, Harriet Allen & Roland Randall**	University of Cambridge	Spatial patterns in the structure of semi-natural vegetation communities on the slopes of Mt. Psiloritis in south central Crete
3.	**Paul Zukowskyj, Roy Alexander, Richard Teeuw, Hazel Faulkner, Adriano Sofo, Mandy Sullivan & Jose-Luis Ruiz**	University of Hertfordshire, University College Chester, University of Portsmouth, Flood Hazard	Assessing changes in semi-natural and agricultural vegetation extent around Sorbas, south-east Spain

		Research Centre, Universitá degli Studi della Basilicata, & University of Hertfordshire	
4.	**Niall Burnside, Chris Joyce & Elle Puurmann**	University of Brighton & Centre of Vormsi Landscape Reserve	Vegetation classification of coastal wetland landscapes in Estonia: development and application
5.	**Niels Nielsen & George Alan Blackburn**	Syddansk Universitet & Lancaster University	Fragmentation revisited
6.	**Adrian Boots, Jackie Rogers & Susan Marriott**	University West England	Woody species diversity in palaeorefugia hedgerows connected to neorefugia woodlots. The Mendip Hills, Somerset
7.	**Thomas Etherington & Shelley Alexander**	University of Calgary	A multi-species reserve network for the Evan-Thomas Valley, Alberta, Canada
8.	**Pam Berry & Peter Wood**	Environmental Change Institute Oxford	Using GIS in the 3-d visualisation of future landscapes

Participatory Geography Working Group (PYGYWG)

Participatory geographies

Abstract:
Recently there has been a surge of interest in the study and application of participatory research approaches and methods in geography, partly owing to growing disillusionment about the impacts of geographical research, and partly to geographers' engagement with participatory working in other disciplines and outside the academy. Participatory research involves working in bottom-up ways with the goal of actively engaging and benefiting groups outside academia, so that traditional barriers between 'expert researcher' and 'researched community' are broken down. A range of principles underpins this approach, including empowerment, continuous learning, reflection, inclusion, challenging established beliefs and power relations, reliability and ethical practice. Nonetheless, the theories and practices of participation take many forms and are subject to debate and development in the discipline. Current questions being asked include: What do geographers bring to the theories and techniques of participation? How does participation change what geographers do? What more effective contributions does it enable them to make to the pressing social, economic and environmental issues currently faced in different parts of the world?

Convenors:		**Chair:**	
Duncan Fuller	University of Northumbria	**Duncan Fuller**	University of Northumbria
Rachel Pain	University of Durham		
Paul Chatterton	University of Leeds		

Panellists:

1.	**Duncan Fuller**	University of Northumbria
2.	**Rachel Pain**	Durham University
3.	**Paul Chatterton**	Leeds University
4.	**Hester Parr**	Dundee University

Assessing changes in semi-natural and agricultural vegetation extent around Sorbas, south-east Spain

Paul Zukowskyj[1], Roy Alexander[2], Richard Teeuw[3], Hazel Faulkner[4], Adriano Sofo[5], Mandy Sullivan[1] & Jose-Luis Ruiz[1]

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[5] Dept of Crop Systems, Forestry and Environmental Sciences, University of Basilicata, Italy

Abstract

Spain's membership of the European Union (EU) has brought obligations and opportunities under the Common Agricultural Policy (CAP). The CAP provides subsidies for the planting of tree crops, such as olives and almonds, and has resulted in the development of extensive plantations on previously abandoned and unproductive land. In semi arid Almeria, such development typically begins with mechanised clearance of the native, semi-natural vegetation, which is dumped or burned. This study uses airborne imagery from 1982, 1996 and 2001 to examine the changing status of vegetation in undeveloped areas near to the town of Sorbas in Almeria province, a region where extensive clearance for tree crops has been occurring for at least a decade.

Initial estimates made from the imagery were surprising, with the density of semi natural vegetation in certain areas seeming to have increased during the five-year interval. Shrub counts made from aerial photography indicated a significantly increased shrub density in parts of the study area. Further analysis of NDVI images from the two later dates, in conjunction with detailed Digital Elevation Models (DEMs) revealed an apparently significant increase in vegetation, mainly on north, east and west facing slopes. Virtually no change was detected on south facing slopes.

A series of hypotheses was assessed to account for this change. Recent climate records for the area show no significant change in rainfall patterns, although there is substantial inter-annual variation. Fire recovery was also considered, but municipality records indicate that the area has not been burnt since at least 1977, when municipal logging of detailed fire records began. Recovery of maquis/matorral vegetation is expected to be significantly quicker than this. Anecdotal evidence suggested the potential importance of changes in grazing patterns and, upon further investigation, the number of goats recorded as being grazed in the Sorbas area was found to have fallen significantly since the 1960s, despite the total for Almeria province remaining effectively the same.

In an attempt to validate results from the airborne data, a set of large (15m x 15m) quadrats, initially surveyed in 1997/98 for a different project, was resurveyed in April 2003. No statistically significant change in vegetation density was detected, though this may be due to the small sample size (many quadrats could not be precisely re-located), a change in survey personnel, and the inherent subjectivity in assessing ground cover.

If the apparent vegetation succession is validated and if, as suspected, the semi-natural vegetation sequesters more carbon than the agricultural crops, then the EU would appear to be subsidising the destruction of what might be a substantial European carbon sink.

Introduction

This study reports on work on archive aerial photography collected by both the Spanish mapping agency in 1982 and by NERC in 1996 and 2001 and airborne scanner data, collected by NERC in 1996 and 2001 simultaneously with the aerial photography from these dates. This photography was analysed to assess the natural vegetation status for a small study area within Almeria province. The study then suggests directions for further work to address the questions raised.

Almeria is widely regarded as one of Europe's most arid regions (Lazaro, *et al*, 2001). Annual rainfall varies significantly, with ranges from <120 mm to >350 mm according to Armenteros (2004). Almeria region is economically deprived, meeting objective 1 of the EU structural funding criteria, 1999/502/EC,: region GDP per capita is <75% of the EU average.

Implementation of the Common Agricultural Policy (CAP) in Andalucia has led to a rapid expansion of extensive olive and almond plantations in the eastern, most arid areas of the region, through subsidies provided to encourage agricultural production and aid development of the rural economy. Andalucia accounts for over 20% of world production of olive oil (De Graaff & Eppink, 1999), and the area under olive production has been increasing year on year since 1986 when the CAP subsidies became widely available, with a substantial jump in 1990 (Faulkner *et al*, 2003). This expansion follows decades of land abandonment, especially in the 1950's and 1960's (Bonet, 2004).

Typical preparation for olive planting begins with deep ploughing of the area and consequent removal and disposal of all above-ground and shallow below ground plant biomass (Martínez Raya, 2002). A drip irrigation system is usually established and olives are then planted. The preparation process clearly releases stored biomass carbon into the atmosphere, whether the biomass removed is dumped, burnt or buried. The olive trees will eventually address this to some extent through increasing biomass as they grow, but no studies could be found which compared agriculture and natural vegetation in this area from a carbon sink/source perspective.

Carbon sequestration in both natural vegetation and agricultural vegetation has been studied for a significant period, but current estimates of carbon sequestration for natural vegetation in the region vary widely. There are a variety of dominant vegetation types, but three dominant types define their communities and allow a modicum of categorisation. These are *Stipa Tenacissima* dominated areas (Gauquelin *et al*, 1996), *Anthyllis cytisoides* dominated areas (Haase *et al*, 2000) and *Retama Sphaerocarpa* dominated areas (Domingo *et al*, 2002). Bare ground also appears across significant areas in the region, typically on southern-facing slopes where water stress, solar heating and low-stability slopes produce a poor environment for even the hardiest plants. Gauquelin *et al* (1996) reviews the total carbon storage of Stipa dominated steppes in southern Spain, leading to the conclusion that a typical area contains ~43 metric tonnes of carbon per hectare. These figures for carbon storage in Stipa produced by Gauquelin (1996,1998), relate to both above and below ground (to a depth of 40cm) separately (~ 3 and 40 t C ha $^{-1}$ respectively). Furthermore all the values obtained for carbon storage were based upon true chemical measurements, and given that the study area (Baza Basin) is also in Andalucia with the same climatic regime and similar landscape characteristics, the results obtained are particularly relevant to this study.

Retama and *Anthyllis* scrub are likely to be a significantly larger store of carbon given their larger above ground biomass and deep root systems. Balanced against this are the substantial areas of bare ground where carbon storage is very limited to non-existent. In this context, a typical estimate of approximately 43 tonnes of carbon per hectare seems reasonable. This figure is somewhat higher than the figures produced by Ajtay (1979) (32 tonnes C ha $^{-1}$) for the region, which Ajtay defines as 'Chapparal, Maquis & Brushland'. The value of 43 tonnes C ha -1 appears even higher, given that the Almeria area would seem to better fit the definition of 'Semi-desert scrubland' (ascribed a carbon value of ~5 tonnes C ha -1 by Ajtay (1979)). The SCOPE study undertaken by Atjay also estimates carbon sequestration rates of both landcover types, giving a range from 0.9 – 3.6 tonnes ha $^{-1}$ y $^{-1}$. These figures do assume a steady state (carbon sequestration is achieved primarily through soil accumulation of humus), and this may not be the case as progression from bare ground, through alfa grass (eg *stipa* sp) and then shrubs (*Anthyllis* sp or *Retama* sp) to woodland has been documented in this region by Bonet, (2004) upon abandonment of previously active agricultural land.

Olive trees have been assessed for level of carbon storage and sequestration by Sofo (2003). This research was done on a CO^2 fixation per tree basis, allowing conversion to hectare values given a known tree density. Estimating that in Italy average tree spacing along rows was ~6m x 3m gave a typical tree density of 555/hectare. Each tree in Sofo's study sequestered 55 Kg of CO^2 in the seven years the study ran (from planting to established cropping). This would yield a total carbon storage value of just over 8 tonnes per hectare. Assuming similar values for carbon sequestration in Spanish olive trees is open to error, especially given the numbers of trees seen in the area (figure 2 – approximately 64/ha), so the sequestration rates in Spain may be much lower. The carbon accumulates at an increasing rate (Sofo *et al*, 2003), but using linear regression of the data from the seven years of Sofo's study, the trees would not achieve carbon neutrality (43 t C ha^{-1}) until at least year 33 if the trees were as dense as those in Italy. Assuming continued sequestration of carbon by the natural vegetation at the rate mentioned above, carbon neutrality would never be attained. Sofo (2003) reports that farming practice in Italy is to remove mature trees at age 30 and repeat the preparation and planting process, primarily because yield and quality are improved if the trees are within a relatively narrow age range. This process would, clearly, release substantial sequestered carbon back into the environment, significantly reducing the apparent sink potential of olive monocultures. Assuming removal and replanting of olives at year 30, olives would fail to recoup carbon losses from the removal and destruction of the natural vegetation.

The assumption of a steady state in the natural vegetation is also open to question. Many environmental factors can contribute to the succession position of natural vegetation. In semi-arid areas, the three main limiting factors on vegetation are usually temperature, water availability and grazing pressure. In many areas slope stability, intimately linked with lithology and geomorphology, is also a significant factor. Faulkner (2003) provides a comprehensive review of the issue of soil erosion in the area under changing vegetative cover. Faulkner (2003) further reports on climatic variability in the area, which appears to be uncorrelated with vegetation pattern changes seen in the region. Bonet (2004) discusses vegetation succession in the semi-arid regions of southern Spain in some detail, describing a natural succession sequence with *Quercus* sp as the dominant member of the climax vegetation. This species is relatively rare in this study area, indicating succession in the region may yet be ongoing.

The MEDALUS II studies into natural vegetation in the Rambla Honda field site (40km North of Almeria) found that 90% of the total biomass of *Retama* occurs within its deep root system (Puigdefabregas *et al* 1996 in Haase *et al* 1999(a)). It was found that such a system not only gives access to deeper permanent sources of water, but serves as a large nutrient store that can ensure survival through sequences of dry years (Haase *et al* 1999 (a)), which are frequent in the area. As part of the same study Haase (1999 (b)), observed that *Stipa* had the ability to enhance physiological activity in response to favourable climatic conditions to compensate for less favourable ones.

A key question that follows from the above is whether the studies sited above are truly representative of the study area and yield appropriate data on the carbon storage potential of all the semi-arid regions of Almeria. Further to this is the question of how representative of the larger region the areas where clearances are taking place actually are. This also raises the issue of the scale of clearances and their potential effects on total carbon storage. The semi-arid natural vegetation landcover area is also uncertain, so the total carbon sink represented by this region is also unclear. A further question that the above information leads to is whether the natural vegetation is undergoing succession, or is it being degraded by desertification processes, either anthropogenic or natural. .

Study Area

The study area covers approximately 40 km^2, south-east of the town of Sorbas (Figure 1). The area is characterised by 'Maquis' or 'Mattoral' vegetation and a rapidly growing number of monoculture plantations of both almond and olive trees.

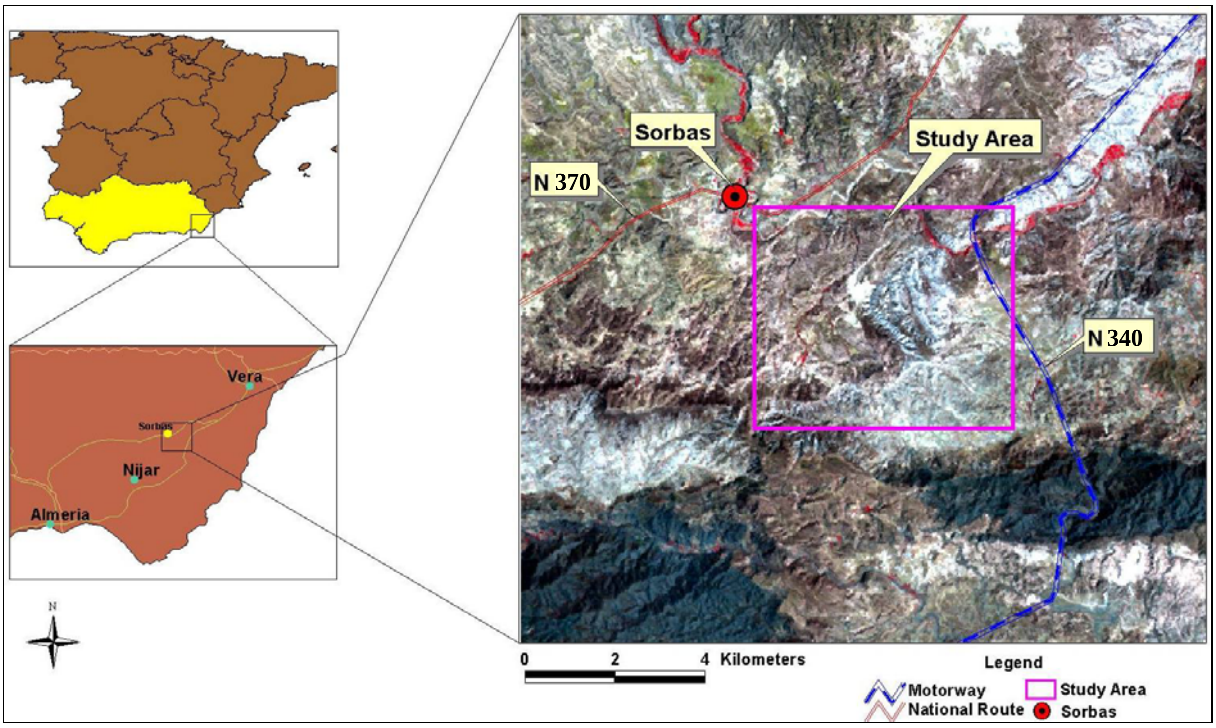

Figure 1. Location and landsat image of the study area, South-West of Sorbas, Almeria, Spain

The area has extensive clearances, a typical example is shown below in figure 2. .

Figure 2. Tree plantation monoculture in Sorbas, Almeria. White square illustrates the extent of one hectare (1ha). Approximately 64 trees are contained in the square.

Methods

Aerial photography for the three dates exists for the whole study area, however only small sections of 2001 photography have currently been orthocorrected. These cover around 25% of the study area (10 km^2) and consist of a strip in the north-east corner and coverage of the western edge. The NERC data from 1996 and 2001 consists of true colour analogue aerial photography at a nominal scale of between 1:3,000 and 1:5,000. The 1982 photography, supplied by the Spanish mapping agency, are visible panchromatic analogue photographs with a nominal scale of approximately 1:10,000. This difference in scale was a cause for concern as the error likely when comparing manually interpreted bush counts from the different images was significant. The error was difficult to address, but as the airborne data allowed a second method for estimating vegetation change, the bush counts were deemed acceptable as long as a significant error was noted and change assessed with this in mind.

The photos were displayed in ArcGIS and two $1km^2$ polygons defined within the areas where overlap of the three dates of imagery occurred. The first square represented an area within easy reach of hard-surface roads. The second square was more remote and only accessible by track. No inhabited structures were evident in either of the two areas. Bush and area counts were undertaken for the two squares for all three dates and then compared. These counts are reported in Table 1.

Airborne ATM data was collected by NERC in both 1996 and 2001 for the entire study area, consisting of three (2001) and four (1996) strips of data running east-west across the area. However due to a loss of data from onboard GPS and INS for a period of the survey in 1996, one of the strips was not supplied with metadata necessary for orthocorrection. The other strips, where overlap between dates occurred, were orthocorrected with the NERC ARSF program AZGCORR. The DEM used for the correction process was derived through digitising the contours visible on scanned 1:10000 maps available from the Spanish mapping agency.

The ATM data was then processed to yield two Normalised Difference Vegetation Index (NDVI) images, for 1996 and 2001 respectively. The NDVI images were then density sliced to yield six classes relating to vegetation vigour and density. Comparison of change between the two images consisted of assessing overall vegetation class coverage for the ATM data in the $14km^2$ of the study area. These results are reported in Table 2. Further analysis on north, east, south and west facing slopes within broad slope angle ranges of $<6^0$, $>=6^0$ and $<9^0$, $>=9^0$ and $<12^0$ and $>=12^0$ was undertaken on a larger area of ATM data and these results are reported in Table 3. The slope aspect and angles were derived from the DEM interpolated from the contour data digitised for orthocorrection of the ATM data, mentioned above. The classified NDVI images are derived from the most northerly runs of ATM data. Overlap areas cover some of the area assessed with the photography but also cover a substantial area further west, outside of the indicated study area in figure 1. The total area assessed is approximately $21km^2$, of which approximately $12km^2$ is within the aerial photo study area defined in figure1. Both the $1km^2$ areas assessed photographically were within the area assessed via the ATM NDVI images.

In an attempt to verify any changes seen in vegetation type (succession) or density, a number of quadrats surveyed in 1997, were resurveyed in 2002. Of the list of 20+ quadrats originally surveyed, only 15 could be relocated, despite use of differential GPS readings. The quadrats were originally marked using metal erosion pins, but some had disappeared or were not found for a significant number of quadrats. The quadrats consisted of either 3x3m or 5x5m squares. They were located by erosion pins in one corner, and their orientation was only roughly recorded relative to the pin.

To determine the most likely causes for the changes seen, municipal records on fire dates and locations and numbers of goats were examined, along with rainfall records for

Lucaneina (within 20km of the study area). Similar records for Almeria province were sourced from Armenteros (2004).

Results

Area	Year	Number of isolated Bushes	Contiguous Area (Ha)
Proximal to urban area	1982	370	24.6
	1996	1080	18.8
	2001	1512	17.7
Distal to urban area	1982	816	4.9
	1996	2479	10.3
	2001	3628	14.2

Table 1. Bush counts and contiguous bush area in two 1km^2 regions of the study area. Individual bushes are not included in assessing contiguous area estimates. Some changes between years are due to changes in photograph scale and developing processes.

Table 1 shows contiguous area and bush counts for three dates of aerial photos for two 1km^2 areas. The apparent reduction in contiguous area between 1982, 1996 and 2001 for the proximal area may be the result of either increasing resolution in the imagery or may be due to fragmentation of the vegetation. The difference between the two areas is accessibility for herders and overall terrain variation, the more distal area being significantly more rugged. The terrain differences would go some way to also explaining the contiguous area variation between the two squares.

	1996	2001	%Change
Class 1	8.2	7.7	-6%
Class 2	156.6	149.4	-5%
Class 3	418.2	425.6	2%
Class 4	441.9	429.2	-3%
Class 5	274.2	287.1	5%
Class 6	126.9	127.0	0%

Table 2. Overall NDVI class changes between 1996 and 2001 for 14km^2 of the study area from classification of the ATM data. Figures in hectares (ha).

Table 2 shows the density sliced NDVI classes derived from the airborne ATM data for the northern 14km2 of the study area. Bare ground/annuals would appear in classes 1 & 2, low scrub would appear in classes 3 & 4, whilst bush scrub would appear in classes 5 & 6 whilst agricultural crops would appear exclusively in class 6. The data shows some significant changes, with a reduction in area between dates of classes 1, 2 & 4, increases in area between dates in classes 3 and 5, and minimal change in class 6.

Table 3 shows changes in density sliced NDVI class for the 21km^2 overlap area of the ATM data between 1996 and 2001, broken down into changes for north, south, east and west facing slopes and further subdivided into slope angle categories. The data illustrates the relationship between increasing vegetation density and slope angle and aspect, with north-facing slopes showing significant increases in density, as do slopes of $<6^0$. East and west facing slopes show increased vegetation density, but south facing slopes remain broadly comparable. These results have potentially significant error margins due to differences in illumination (images were not acquired at the same solar time, hence shadowing differs between images), quantisation levels (image DN ranges are significantly different due to a refurbishment of the sensor between image dates) and co-registration with the DEM between dates. Changes of <10 ha should therefore be treated with caution.

		1996				2001			
		<6	**>6 and <9**	**>9 and <12**	**>12**	**<6**	**>6 and <9**	**>9 and <12**	**>12**
North Facing / Flat	**Class 1**	*0.5*	0.0	0.0	0.1	*6.4*	0.1	0.1	1.0
	Class 2	*142.2*	9.6	6.7	16.1	*197.7*	10.6	7.1	16.8
	Class 3	*658.0*	51.9	30.3	72.5	*542.3*	37.9	20.4	42.6
	Class 4	*616.2*	58.0	40.7	127.2	*515.2*	48.7	31.0	73.7
	Class 5	*158.8*	17.0	16.3	52.2	*253.4*	30.8	27.1	95.2
	Class 6	*41.8*	2.8	3.3	7.9	*102.0*	11.2	11.6	46.6
			>6 and <9	**>9 and <12**	**>12**		**>6 and <9**	**>9 and <12**	**>12**
East Facing	**Class 1**		0.0	0.0	0.0		0.2	0.1	0.2
	Class 2		10.4	6.8	16.4		13.0	8.0	17.3
	Class 3		53.6	36.1	112.5		45.4	28.2	82.9
	Class 4		45.1	30.9	117.6		39.5	27.7	100.9
	Class 5		11.6	8.7	37.1		18.5	14.8	65.6
	Class 6		2.5	2.3	8.3		6.5	6.0	25.1
			>6 and <9	**>9 and <12**	**>12**		**>6 and <9**	**>9 and <12**	**>12**
South Facing	**Class 1**		0.1	0.0	0.1		0.0	0.1	0.9
	Class 2		11.1	4.5	14.0		6.8	7.3	25.9
	Class 3		27.6	27.1	103.5		31.9	22.1	86.2
	Class 4		19.1	15.0	53.6		22.2	14.5	51.9
	Class 5		6.7	3.2	11.7		5.8	4.9	16.3
	Class 6		4.1	1.1	2.8		2.1	1.8	4.6
			>6 and <9	**>9 and <12**	**>12**		**>6 and <9**	**>9 and <12**	**>12**
West Facing	**Class 1**		0.0	0.0	0.0		0.7	0.7	4.4
	Class 2		7.3	6.0	25.9		11.0	8.6	60.3
	Class 3		40.0	34.5	117.3		32.9	27.2	107.8
	Class 4		38.1	31.5	114.1		31.5	26.8	74.3
	Class 5		9.5	7.7	29.2		15.1	14.0	35.9
	Class 6		1.2	1.2	4.6		4.8	3.7	8.5

Table 3. Changes in NDVI classes for the ATM overlap area (21km2) between 1996 and 2001 broken down into slope angle and aspect divisions. <6 – less than 6^0 slope in any direction. >6 and <9 – more than 6^0 and less than 9^0 in direction indicated. Other column headings follow the same format. All figures in hectares (ha).

(a) *(b)* *(c)*

Figure 3. Aerial photo subset of the same ground area from 1982 (a), 1996 (b) and 2001 (c). Red boxes illustrate expansion of fragmented ground cover into a near contiguous surface on a north-facing slope.

(a) *(b)* *(c)*

Figure 4. Aerial photo subset of the same ground area from 1982 (a), 1996 (b) and 2001 (c). The centre of the image shows a dramatic expansion of fragmented ground cover into a near contiguous surface.

Figures 3 and 4 show sections of aerial photo from the overlap regions of the study area from 1982, 1996 and 2001. Figure 3 is from the proximal 1km2 area assessed in table 1. Figure 4 is from the distal 1km also assessed in table 1. The figures illustrate some of the vegetation changes seen in the area. The difference in resolution between the images is clearly seen in these figures, effectively changing the clarity or sharpness of ground detail between dates. Differences in colour or tone should be disregarded as these are highly influenced by film development processes. Differences in orientation, size and shape of features needs to be treated with some caution as differences in view angle and accuracy of orthocorrection procedures have influenced the patterns seen in some areas. Overall vegetative change is therefore difficult to assess with a high degree of accuracy from such small subsets, however overall patterns for larger subsets should not be significantly affected by such effects.

(a) *(b)* *(c)*

Figure 5. Aerial photo subset of the same ground area from 1982 (a), 1996 and 2001 (b). Just right of centre a large patch of bare ground in 1982 (circled) has been converted to almost contiguous ground cover by 2001.

Figure 5 shows three aerial photo subsets from 1982, 1996 and 2001 for an area just south of the distal subset assessed in table 1. Clear expansion of the vegetative cover is visible across the image, especially the central portion.

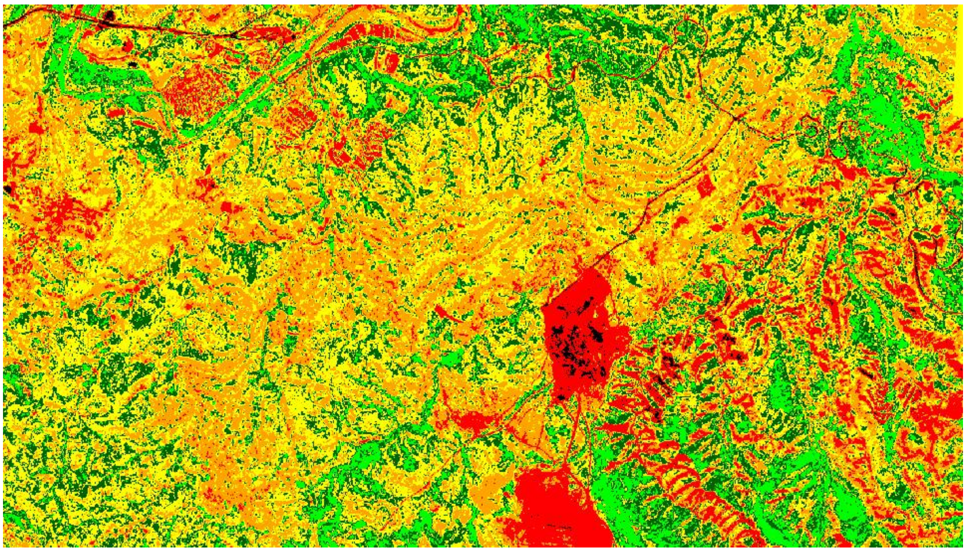

Figure 6. Density sliced NDVI ATM image from 1996. Classes 1-6 represented by black (1), red (2), orange (3), yellow (4), dark green (5) and light green (6). Large black/red patch to lower right of centre is a large working gypsum quarry.

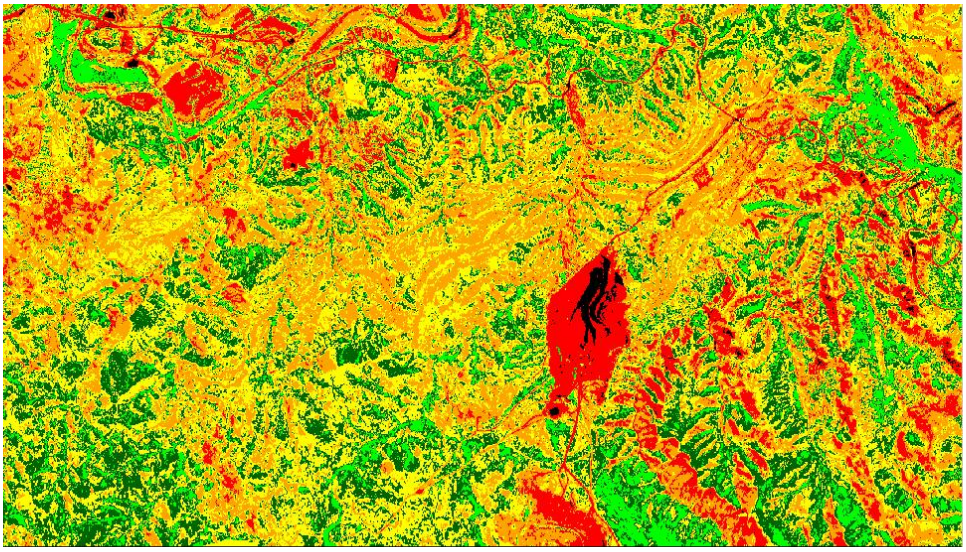

Figure 7. Density sliced NDVI ATM image from 2001. Classes as figure 6. Area covers northern and central portions of the air photo study area illustrated in figure 1.

Figures 6 and 7 show the density sliced NDVI images from the ATM data for 1996 and 2001 respectively. There is clearly a close correlation between the class values and topography in both dates of imagery. The quarry area is clearly demarcated in classes 1 & 2 in both dates, with slight variations in the internal patterns, possibly as a result of quarrying operations between the dates. Roads are also visible as class 2 linear features running from the quarry and over other areas of the image.

The large contiguous patch of class 1 (red) near the north-west corner of each image correlates with a field pattern delineated on the southern edge by the Rio Aguas river channel. The field has few plants at this time of year having been recently clear-ploughed in both years. The large patch of class 6 (light green) due west of this also correlates with irrigated agriculture visible in the photography, an area used to provide local produce. The data shown in Figures 6 & 7 were numerically assessed, the results providing data for Table 1.

Results from the quadrat survey were not considered further as the potential error margin was too great. The orientation of each quadrat, in a 'mosaic' vegetation type, is crucial in ensuring a reasonable comparison is made between dates. The only information available was which corner of a square the erosion pin was located, using eight compass points. This could easily lead to a 20-30^0 rotation of the area surveyed between dates, and given the patchiness and variability of the cover, this would lead to substantial error. Further, the original surveyor was unavailable for this re-survey, and differences in interpretation of the amount and density of cover between researchers could be very significant. An estimate of what this potential combined error might be would probably exceed 30-40%, an amount of change not seen in either the ground data or the airborne data. This led to the conclusion that although ground verification was eminently desirable, in this instance it was not possible given the available information.

Data from Sorbas town hall yielded information on fire activity in the local area and it was discovered that the area surveyed had not been burnt since 1976, when detailed fire recording began. Further data available on numbers of goats in the administrative area of Sorbas yielded the information that a dramatic decline in numbers had taken place between 1950 and 1970. This co-incided with a period of rural depopulation throughout Spain. Goat and sheep numbers in Sorbas administrative area had, however, remained relatively static between 1982 and 1999. The number of people in Almeria region involved with economic agriculture has consistently declined since the 1950's, although the goat and sheep population has overall stayed broadly similar since 1900 according to official statistics (Armenteros, 2004). The issue with historic official statistics, however, is that it is uncertain whether the government used the figures individuals declared to levy taxes. Even if not, individuals may have been reluctant to declare their true herd size to official bodies.

Goats and sheep are still herded in the Sorbas administrative area, but many fewer people are now involved than were in the 1950's. The numbers of goats and sheep staying relatively unchanged would indicate the more impoverished herders, who would be constrained to the marginal lands, were driven to leave, whilst larger herders combated changing economics by increasing their herd sizes. The impact this change would have on the area is unclear, but may explain the apparently more significant recovery of the vegetation in the distal 1km^2 compared to the proximal 1km^2.

Discussion

The airborne data reveal a relatively clear pattern in the vegetation in this region. It would appear, from tables 1, 2 & 3, that the density and cover of vegetation in this area has increased significantly in the period 1982-2001, but that the most significant changes have occurred on north-facing and subdued slope areas. Steep slopes ($>=6^0$) facing east and west show some increase, whilst south facing slopes appear to have changed relatively little over the period. The two methods of assessing the vegetative increase support each other in demonstrating that the increase is real, despite significant issues with both techniques in terms of absolute accuracy. Error estimates are difficult to achieve, and although an attempt was made to verify the changes using ground survey of quadrats, the results from these contained significantly higher error margins than the changes indicated by the airborne data.

The range of vegetation communities in the area is wide and their extent is clearly controlled by a number of factors. There does seem to be evidence of vegetation increase in certain areas, possibly on specific lithologies. There is clear evidence from the field that different lithologies in the area support different communities, and there is some evidence from the photography that certain lithologies have increased their vegetative cover more than others. The entire area appears to be undergoing succession to some degree, but certain areas in the photographs appear to have gone from almost bare ground to contiguous bush cover in the 19-year period of this study.

The information regarding changes in livestock in the area would seem to indicate that the change in vegetation is not related to changes in stock numbers. Reported recovery rates (Bonet, 2004) for vegetation types in this area are in the order of years to a decade or two, whereas changes in livestock appeared to have taken place in the 1950's and 1960's.

Recovery should have been effectively complete by the period of first acquisition of aerial photography. The relatively unchanged number of goats and sheep in the area between 1982 and 1999 indicate that changes caused by grazing pressure reduction are unlikely to be the cause of the vegetation change seen. The information on the resident agricultural population may, however, indicate a significant change in grazing patterns. Larger flocks would need to be grazed over a much wider area, they would need to be moved around more and this may leave longer periods of recovery between grazing episodes than had previously been the case. Vegetation that is resilient to grazing, such as the maquis-mattoral vegetation common around Sorbas, tends to recover much more rapidly if grazing pressure is infrequent. The difference between distal and proximal bush counts and area surveys supports this view, since greater mobility of flocks would tend to restrict them from more remote areas. Grazing pressure therefore would be expected to be concentrated closer to areas of habitation, leading to high grazing pressure around urban areas and a reduction in pressure, and consequent vegetative recovery, in more remote regions.

There is a question as to whether a change in climate, particularly rainfall patterns, may be influencing vegetation cover and density. The local rainfall records show a high interannual variability, both in length of the wet season and in amount of rainfall, but compared to regional trends, the variation is not significant. Further investigation of this is essential. It is possible that although GCM's predict the area will warm significantly in the coming decades, if the rainfall stays the same and falls over a longer period, the vegetation may cope with the increased aridity. Vegetative patterns in the area appear more strongly related to terrain positions that would be conducive to water storage and retention than to illumination, suggesting water stress is the major limiting factor for most endemic plants. Further work to quantify this is envisaged.

Although the effect on atmospheric carbon sequestration of vegetation clearances for olive production would appear to be detrimental, the scale of the loss is unclear. If vegetation succession is taking place, as this study indicates, the amount of released carbon may be far greater than indicated. Further work is needed to quantify these losses, to allow decision makers to make more informed decisions about agricultural policy. Research on natural vegetation succession in this area would be bolstered by assessing vegetative change over a longer period. To this end, Corona data from the 1960's and access to 1956 aerial photography of this area is being sought. This data will allow a better assessment of vegetation development in the area. Assessments of carbon storage from total biomass measurements for relevant vegetation communities other than Stipa are also being sought. To determine the total carbon storage of the semi-arid vegetation in Almeria, research is currently under way on a 'scaling-up' study, in which landsat TM data is being used in an attempt to estimate the total coverage of the relevant vegetation types in Almeria.

There seems to be some evidence, therefore, that the European Union Common Agricultural Policy, as applied to this area, may be destroying a carbon sink, whether viewed from the short or the long term. Some consideration should perhaps be given to alternative means of funding management of the region to enhance and not destroy its capabilities as a carbon sink. This could perhaps pay for appropriate land management to aid succession to forestry, something the Junta de Andalucia has been involved with in other areas for a number of years. This would provide a significantly larger carbon sink and also potentially a timber harvest in the future if appropriate species were chosen. Given the slope instability, flooding problems and soil erosion issues reported by Faulkner (2003), forestry may be the best option for reducing a significant number of other hazards..

References

1999/502/EC Commission Decision of 1 July 1999 drawing up the list of regions covered by Objective 1 of the Structural Funds for the period 2000 to 2006 (notified under document number C (1999) 1770). *Official Journal of the European Communities*, L 194 , 27/07/1999 P. 0053 – 0057

Armenteros, S.H. 2004. Estadísticas del siglo XX en Andalucía. Instituto de Estadísticas de Andalucía, http://www.juntadeandalucia.es/institutodeestadistica/historicas/siglo20/ accessed 28/8/04.

Ajtay, G. L. Ketner, P and Duvigneaud, P. 1979 SCOPE - 13 the global carbon cycle (chapter 5) Wiley, London.

Bonet A. 2004. Secondary succession of semi-arid Mediterranean old-fields in south-eastern Spain: insights for conservation and restoration of degraded lands. *Journal of Arid Environments*, 56, 213-233

De Graaff, J. & Eppink, L. A. A. J. 1999. Olive oil production and soil conservation in southern Spain, in relation to EU subsidy policies *Land Use Policy*, 16, 259-267

Domingo F., Gutiérrez L., Brenner A.J. & Aguilera C. 2002 Limitation to Carbon Assimilation of Two Perennial Species in Semi-Arid South-East Spain. *Biologia Plantarum* 45, 213-220

Faulkner H., Ruiz J., Zukowskyj P.M., & Downward S. 2003 Erosion risk associated with rapid and extensive agricultural clearances on dispersive materials in southeast Spain *Environmental Science & Policy*, 6, 115-127

Gauquelin T., Jalut G., Iglesias M., Valle F., Fromard F. & Dedoubat J. J. 1996. Phytomass and carbon storage in the *Stipa Tenacissima* steppes of the Baza basin, Andalusia, Spain. *Journal of Arid Environments*, 34, 277-286

Gauquelin T, Jalut G, Iglesias M & Valle F 1998. Phytomass and Carbon Storage in the Steppes of Eastern Andalusia, Spain. *Ambio* **27** (2) 99-103

Haase P, Pugnaire F I, Clark S C & Incoll L D 1999 (a) Diurnal and seasonal changes in cladode photosynthetic rate in relation to canopy age structure in the leguminous shrub *Retama sphaerocarpa Functional Ecology* **13** 640-649

Haase P, , Pugnaire F I, Clark S C & Incoll L D 1999 (b) Environmental control of canopy dynamics and photosynthetic rate in the evergreen grass *Stipa tenacissima Plant Ecology* 145 327-339

Haase P., Pugnaire F.I., Clark S. C. & Incoll L. D. 2000. Photosynthetic rate and canopy development in the drought-deciduous shrub *Anthyllis cytisoides* L. *Journal of Arid Environments*, 46, 79-91

Lázaro, R. Rodrigo, F. S. Gutiérrez, L. Domingo, F. & Puigdefábregas, J. 2001. Analysis of a 30-year rainfall record (1967–1997) in semi–arid SE Spain for implications on vegetation. *Journal of Arid Environments*, 48, 373-395.

Martínez Raya, A., Francia, J. R., Martínez, V. A. & Ruiz, S. 2002. Soil conservation techniques in the cultivation of perennials on steep slopes in semi-arid ecosystems, *in J. L. Rubio, R. P. C. Morgan, A. Sins and V. Andreu (eds), Proceedings of the Third International Congress Man and Soil at the Third Millennium, Logroño, Spain, March 2000*, 779–786.

Sofo A., Palese A.M., Xiloyannis C. 2003 *Can olive growing mitigate the greenhouse effect? A study of carbon cycle from atmosphere to olive tree products* (unpublished)