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# Changing vulnerabilities: some perspectives on management of rapid land-use change on dispersive materials in Almeria, Spain.

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## Abstract

This paper tracks the nature and pace of local clearances for arboriculture, using both agricultural statistics and maps of an 70km$^2$ study area SW of the town of Sorbas, Almeria SE Spain, and assesses the extent to which the physical vulnerability of the cleared sites has been increased following these land-use changes. Using repeat air imagery for 1996 and 2001 a GIS showing clearances over this period in the study area. By applying a simple physical risk algorithm and a rule-based expert system, the spatial variability in the vulnerability of the cleared sites to erosion has been mapped.
A final discussion hypothesises that to the farmer, soil erosion has a low profile in relation to other livelihood choices available to them. We suggest that *risk* is perceived not so much as an understanding of environmental sensitivity (or *physical vulnerability*) to an intermittent *hazard*, rather it is perceived and experienced at a much deeper level. Farmers' reportage suggests that vulnerability is experienced in terms of both social and environmental *functionality*, making it a physico-social construct. The possible future impact of the full implementation of the second pillar of CAP reforms, which links subsidies to conservation agriculture rather than production targets, is discussed in the context of these findings.

## *Introduction*

On the local dispersive Tortonian and Messianian marls of the Sorbas basin, agricultural use of the native *matorral* was traditionally been managed by piecemeal clearances in valley heads only where terracing could be incorporated ('*secano*'). However, since joining the EU in 1986, the availability of agricultural subsidies for almonds and citrus fruits has resulted in rapid horticultural expansion in SE Spain. In merely 30 years, the province of Almeria has converted from subsistence-orientated agriculture to one of Europe's most productive agricultural regions, conducting global market-dominated agriculture. This change has been technologically driven and economically sustained by the EU Common Agricultural Policy (CAP) i.e. financial incentives have acted as a catalyst for the reworking of the landscape. On rural inland sites, EU Structural Funding has until very recently offered aid for re-terracing for plantation aboriculture and the installation of pump irrigation systems, prompting an influx of agricultural development to areas such as the Municipality of Sorbas. The rate of change of the human-induced modification of the landscape in this municipality has been unprecedented.

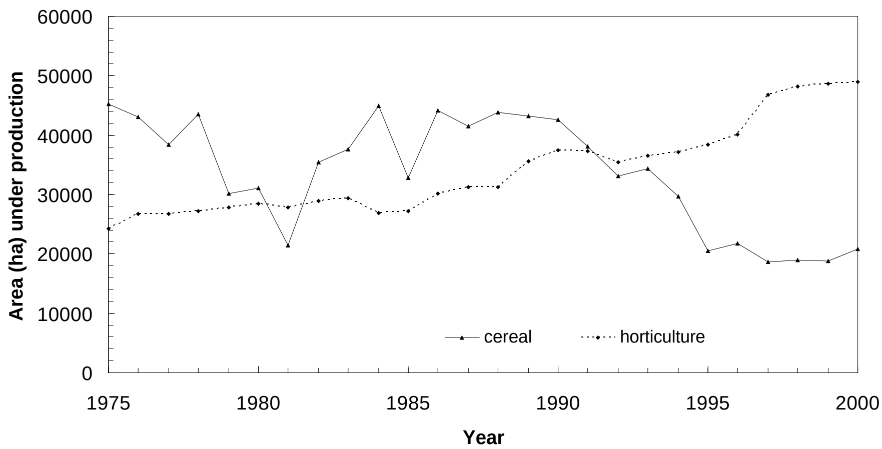


*Figure 1* The pace of agricultural change since subsidisation of arboriculture in Sorbas since 1986 in particular

The so-called 'Almeriense economic miracle' (Mota *et al*, 1996; Downward *in press*) has occurred partly via the rapid expansion of orchards for arboriculture previously used either for cereal production, or abandoned in the 1950s – and cereal production has suffered in response. Most of the clearance in the municipality of Sorbas has not been terraced. Rapid removal of matorral using rotovators, and its replacement with large, frequently steep, unterraced orchards with

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drip-feed irrigation (‘*regadio*’) would appear to be increasing the vulnerability of local soils to rapid degradation, a problem most affecting particular dispersive marl units. Yet although evidence suggests that plantation aboriculture wil accelerate sediment yield in an already highly sensitive landscape, issues concerning landscape erosion appear to be of low priority to a society reaping the rewards of socio-economic growth, and concern has been expressed that this growth outstripped the capacity of the environment to sustain this trajectory (Faulkner *et al* 2003). Thus an important goal of our research has been to draw attention to this increasingly vulnerable context of change for farmers, by producing an erosion vulnerability map based on experts’ assessments of risk-associated factors and a rule-based mapping schedule applied to the study area on a GIS.

**The Study area**.

The Municipality of Sorbas is situated in the Province of Almeria in the Spanish autonomous region of Andalucia. Almeria has a climatic character that straddles the Mediterranean/ semi-arid threshold (between 200 mm and 300 mm p.a.). Whereas at the wetter end of this spectrum the regime retains its winter precipitation maximum, at the drier end, the majority of this precipitation occurs as high intensity late summer events (Peco *et al*, 2000, Thornes, 2001). Perry (1997) has shown that Global Circulation Models predictions show a general increase of 1$^{o}$C in the Mediterranean basin by 2030, which would result in a mean annual increase in Almeria of 1.8$^{o}$C, and a loss of winter precipitation of between 27 and 44 mm. Even without the contemporary land-use changes, this climatic trend threatens the stability of the native *maquis* vegetation. With the clearances, common sense suggests that soil loss will be considerable.Lopez-Burmudez and Romero-Diaz (1989) and Faulkner, Spivey and Alexander (2000) have demonstrated that there is an enhanced erosion risk associated with the widespread, sodic marls in Almeria, which are to varying degrees dispersive.When certain physico-chemical process thresholds are exceeded, these marls deflocculate and disperse in contact with water. Where hydraulic gradients allow, large pipes can develop which can collapse, forming gullies of considerable size. The soil loss from gullies with this origin is substantially greater that soil loss from rills and gullies formed by surface wash. Plio/Pleistocene deposits of the Gochar Formation are particularly affected (Faulkner *et a*l 2000; 2003a and b; 2004). The southern part of this unit comprises a lower Triassic Rich Unit (TRU), which is fine-grained, sodic and dispersive; in fact on visual inspection the TRU has an apparently limitless capacity to pipe. Pipes are encountered in a large proportion of gully beds, in abandoned terraces, and within river bed terrace fronts, and can reach 3-4 metres in depth and over a metre in diameter in a few years when cleared for agriculture.

**Aims and Methods**

A physical soil erosion vulnerability map was prepared for a 70 km$^2$ study area SE of the town of Sorbas using a rule-based GIS-based expert-system mapped across the areas that had been cleared between 1996 and 2001. To produce vulnerability assessments of cleared sites, a land-use map for 2001was produced for the study area using traditional photo-interpretation methods from ortho-rectified colour aerial photo-mosaics. The original data was collected by a NERC-funded survey 1996, and a repeat survey of the same area was flown in April, 2001. Preliminary analysis of these photomosaics allowed a classification of land-use in 2001 to be produced for the surveyed area. The map of land-use changes between 1996 and 2001 map was produced by overlaying the second ortho-rectified colour aerial photo-mosaic derived from 2001 photography, onto the 1996 orthophoto mosaic. The classes used for map production is indicted on the key to Figure 3. By switching between the two images, small and subtle changes could be identified. Ground-truthing of many of the change areas was undertaken during fieldwork in December 2001. Further assessment of vegetation change was undertaken in fieldwork in April 2002 (Faulkner *et al* 2003).

In 2005, pilot surveys were undertaken to explore the synergistic or conflicting roles that subsidies on the one hand and conservation agriculture advice on the other play in soil management on farms with differing intensity of mapped erosion vulnerability. Pilot qualitative interviews with a purposive sample of farmers in both settings and in three categories of hazard intensity were introduced to farmers as attempts to assess their changing perceptions of a ‘sustainable livelihood’. We hope to elicit by reportage their views of conservation agriculture and its relation to their degree of hazard exposure, and their perceptions of the impact of their land management decisions both pre-and post CAP reforms, and at farm and regional scale. To assess the utility of the resulting map as a management tool, the latter part of the interview, farmers were shown expert’s erosion vulnerability map of their holding and invited to report on its utility in relation to their reported their livelihood decisions.

**The underlying algorithm defining erosion vulnerability**

Factors deemed by ‘soil science’ to be factors associated with increased vulnerability variations on cleared sites were identofoed and weighted. Clearly, a misunderstanding as to the relative importance of the two local prevailing land degradation processes (surface wash, and piping) could lead to inappropriate selection of risk-associated factors. In the Mediterranean context, the loss of the native *matorral* on land cleared for agriculture introduces the risk of surface-led erosion on all cleared slopes. The Hortonian model is usually assumed as the best algorithm to describe this sort of soil loss. However, on the dispersive marls in Almeria, vegetation density and slope angle may not be the main erosion risk-associated factors because of the overwhelming importance of piping risk at some sites. Thus, it may be useful to separately assess risk where materials are dispersive. Material diagnosis of dispersivity is consequently important. The most important dispersive indicators include a high Sodium Adsorption ratio, and high Electrical Conductivity. This suggests extensive laboratory work; but used in conjunction with good mapping of local lithologies, material analysis need not be onerous. For piping, slope angle is again a risk-associated factor, because steep hydraulic gradient through the cleared site will further enhance piping-led erosion. More difficult to include is the requirement for extensive pipes to have a local infiltrating surface to ‘feed ‘pipe growth. We used a modified version of the ‘catchment area’ function in ARCview software to do this. An algorithm was also developed to include slope angle and on dispersive sites, convexity. Using this expert system, variables were weighted and ranked to give a measure by gridded pixels of the relative spatial intensity of vulnerability.

**Method**

Initially, a sslope class map was produced from screen-digitised contour data derived from geo-corrected scans of 1:10000 topographic maps of the Spanish national 1:25000 series. The contour separation on these maps is 10m. The digitized contours were then interpolated, using an inverse distance-weighting algorithm, to produce a 5m DEM of the area. This DEM was then used to produce a slope angle dataset. The angles were calculated based on the DEM values, assuming the centre of the pixel as the point for calculation. Elevation changes between all surrounding pixels were calculated, and the two highest absolute values were averaged to give the slope angle within the pixel. The resulting slope angle values were then assigned to appropriate slope angle class ranges for further analysis. The lithological and structural characteristics of the area covered by the imagery in has also been mapped, and for reasons developed above, vulnerability separately assessed on dispersive and non-dispersive units. Slope angle and curvature were considered to be the most significant elements of erosion hazard and were weighted highest. The influence of both slope convexity and the extent of catchment area with available infiltrating surfaces was finally incorporated. The result is the basis of an erosion vulnerability assessment.

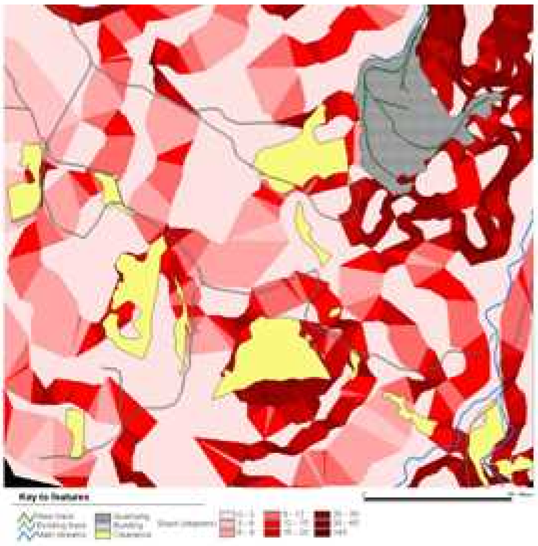

*Figure 2:* sample of the vulnerability map as applied to an area of clearance in the Mocatan study basin.

**Results**

The map of land use clearances in the Sorbas area in 2001 revealed a dramatic rate of clearance on new sites, a considerable amount of new roads, and some quarrying activity. In addition, some more inaccessible sites in the interior of the area have actually gained vegetation since 1996, showing a shift from traditional and dispersed agriculture to large scale and intensive development near to main roads. Except in the case of quarrying activity, there seemed to be very little selection of certain materials, and on the newly cleared land, only infrequently are attempts made to terrace the slopes affected. The soil vulnerability map (sample on *Figure 2*) allows the implication that the soil loss from the sites in the a sub-study area in the Mocatan basin is likely to be the highest.

**Discussion**

Why are traditional scientific perceptions of vulnerability of soils cleared wholesale for agriculture not informing the present landscape changes in Sorbas? Twigg (2001) and DFID (2003) both argue that landscapes are managed by stakeholders with many different and contested values points of view which reflect both their particular experience, culture and values as well as their level of economic success, and so attempt to make decisions in relation to these many influences and constraints. Hediger (2003) would view this response, which is informed by a wide range of influences, constraints and opportunities, as striving towards a ‘***sustainable livelihood’*** . In fact, an expanding body of soil conservation literature (Cook, 1982; Blaikie 1995; Boardman, 2002) argues that the hazard paradigm could be seen as just another type of ‘knowledge’ (Callicot, 1987), and that farmers’ decisions are based on a ***risk perception***. Unpicking risk here as ***hazard perception*** plus ***vulnerability perception***, we can hypothesis here that even in settings where soil erosion hazard is an understood threat, information about physical vulnerability of the farmer’s soils were but one of a large spectrum of possible factors how ‘risky’ this threat feels (*Figure 3*).

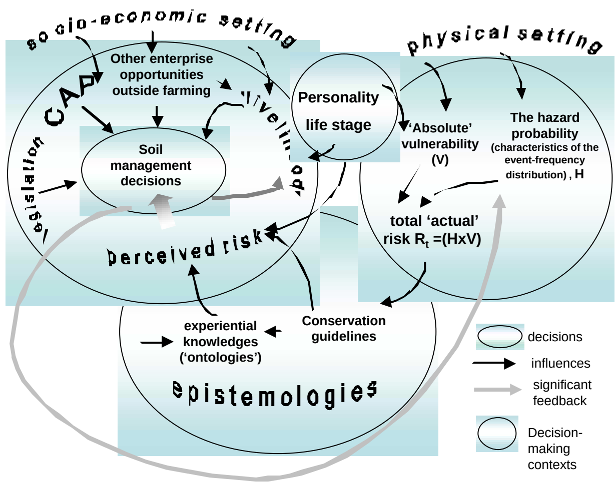


*Figure 3*. The role of farmers' perceptions in forming decisions about livelihoods.

Knowledge of 'total actual risk' of soil erosion hazard (Smith, 2002) is either largely unavailable to farmers and planners, or is so perceptually filtered by various epistemologies (or 'knowledges') that only after considerable cultural filtering is 'science' able to communicate usefully. But soil scientists woulsd argue that in this attempt to carve out a sustainable livelihood, the soil is not being sustainably managed – physical vulnerability is increasing. The issue is: in the context of the complicated lifestyle functions of the farmer, and on the timescales within which they operate (human timescales) they appear to believe this issue has to have a low profile. So does this matter? Perhaps for practical purposes, vulnerability of soil and society have to be a merged concept. This conceptual re-definition would have to be restructured around the argument that *vulnerability is a dynamic and physio-socially defined concept to these farmers*, and it is how this complex, functionality-based vulnerability, as well as an experiental understanding of the temporal variability and probabilities that shape the physical experience of the *hazard*, that informs livelihood decisions.

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