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Linking structure and agents to evaluate the regional economic and environmental implications of agro-ecosystems management in Southern Spain*

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Abstract

The sustainability of land management in any agro-ecosystems is certainly shaped by those who are managing land within these systems. In the midst of increasing land degradation pressures which present critical environmental constraints (e.g. water scarcity) to agricultural production in the long run land managers may have to modify their current management practices by trying different strategies to respond to such critically limiting biophysical conditions posed by dryland degradation. Ultimately, their decisions will not only affect the local environment but also the economy of the region. This research studies agro-ecosystems experiencing land degradation in southern Spain as a basis to develop a conceptual framework and computational model that can be used to better understand the dynamic interrelationships between individual land managers' decision-making, their diverse socio-economic characteristics, the heterogeneous biophysical features of the land they manage, agro-ecosystem management strategies (including remediation strategies), and the future sustainability of the region. Thus the study is expected to shed light on the different factors that influence individual land managers' decision-making, which can be used as a means to explore the future dynamics of agro-ecosystems management in the study area. Methodologically, the study seeks to develop an integrated biophysical and socio-economic modelling framework by incorporating an Agent-Based Model (ABM) and Geographical Information System (GIS) with an Input-Output analysis. Findings from the coupled agent-based and input-output analysis will be spatially explicit, as land use opportunities and constraints vary across the region. The study will help inform stakeholders including policy makers about how decisions made by land managers (including farmers) at the local level can exert notable environmental and economic implications at a broader scale.

Keywords: integrated model, water consumption, agro-ecosystems, spatially explicit agent based IO

*** The paper is work in progress; more updates will be presented during the conference.**

1. Introduction

1.1. Situating Economic Agents in a Changing Landscape

Rarely have studies devoted to input-output analysis, especially in the context of agricultural sector, attempted to probe deeper into the complexity and dynamics within a given economic sector. In fact the emerging economic patterns at the regional scale are essentially built upon such interactions at the lower levels (Deguchi et al., 2003; Boero, 2007). As such, it thus becomes interesting to investigate this phenomenon by disaggregating the scale of the analysis down. This can be done by closely looking at what is happening within a particular sector at localities within a given region. Then, within each locality further investigation is designed to uncover the inter- and intra-sector monetary flows made by agents that make up a sector under investigation. This can be viewed at both individual level and collective network which given agents are parts of. When such study is undertaken to encompass a sufficiently long temporal scales, the dynamic element of the interaction can be revealed. This kind of studies can capture how individual agents respond to changing biophysical, market, social, and political landscapes. In the context of this study, agents refer to individual households that have influence upon how land parcels within the agro-ecosystem under examination would be managed in medium (3-5 years) and long (above 5 years)term scales. As such agents are unique and are distinguishable by their individual biophysical endowment features (e.g. land productivity, water access, the degree of degradation pressure), socio-economic characteristics, and social networks. The agents may therefore develop or adopt different strategies, from a selection of available alternatives, to respond to and to co-evolve with the changing landscape.

1.2. Local Decision Making – Regional Implications

Decisions made by land managers are critical in framing the past, current, and future sustainability of agro-ecosystem management. Many studies have explored the complexity and implications of decision-making in agro-ecosystem management. Most of these studies have focused on developing decision support systems. This research has taken two broad methodological approaches: 1) economic farm level optimisation models; and 2) broader scale future scenarios modelling and their implications.

While the first group primarily aims to design tools that can be potentially used by land managers to assist their decision-making for securing optimal return from their prospective land management strategies, the other is often developed for informing policy makers on the implications of particular future scenarios and policies usually at the regional and/or national level (see for example Van Delden et al., 2007; Oxley et al., 2004). The latter have been combined with participatory approaches by inviting stakeholders to think of their future sustainability goals and of possible future scenarios they would anticipate (Kok and Van Delden, 2007; Dougill et al., 2006; Prell et al., 2007). However, rarely have studies been carried out to investigate the dynamics of the actual decision making process in the light of preferred future land or agro-ecosystem management strategies by individual households at a local level confined by heterogeneous biophysical features, unique political-institutional arrangements and diverse socio-economic characteristics.

In fact collectively, individual decisions on the management of single parcels within an agro-ecosystem will determine the sustainability of the whole system for both local managers and wider society. This issue becomes even more crucial at regional, national and supranational levels, as the management of agro-ecosystems at these scales, is ultimately expected to meet various objectives in addition to agricultural production, including sustainable water management, biodiversity conservation, landscape integrity, and economic attractiveness for ensuring socio-economically viable rural areas.

In Spain as well as other parts of the EU where multi-purpose, highly valuable agro-ecosystems increasingly face land degradation, measures to enhance the sustainable management of these agro-ecosystems are crucial. To date, measures to combat land degradation in Spain have focussed primarily on soil erosion in non-agricultural environmental settings (Martinez-Fernandez and Esteve, 2005). More efforts need to be devoted towards the management of agricultural areas that are prone to land degradation, especially under increasing water scarcity expanding irrigation. Nevertheless, two major challenges for effective land degradation remediation policies and initiatives are to 1) enhance the current sustainability of agro-ecosystem management; whilst 2) facilitating greater buy-in from stakeholders.

To achieve these, they need to incorporate insights about the dynamics of biophysical and socio-economic factors influencing decision-making of individual land managers. In this context, it may be possible to determine how land managers in this study area are likely to respond to land degradation remediation policies or initiatives and to develop effective and viable future strategies to sustainably manage the agro-ecosystem. With such an understanding, one can further explore the consequences that external socio-political drivers (i.e. potential policies and remediation initiatives) may have on their decisions on managing their land resources locally in the future and how this in turn alters the regional economy and environment. Therefore, this project will investigate these multidimensional inter-linkages by mapping agents' decision making based on their individual economic production function and biophysical features of the land that constrain their productions. What is more, it will as well be exploring the consequences.

2. The Study Area

The study will be carried out within the Guadalentin drainage basin which is situated in the south-eastern part of Spain (Figure 1). This area has very interesting geological and topographical characteristics and has been exposed to a particular climate regime of dry summers and heavy rainfall in the autumn. These features coupled with current and predicted future climate change make the area becoming increasingly vulnerable to land degradation. Moreover, various political and socioeconomic drivers that are at play in the area for a long time have escalated the degree of the problem. Therefore, due to its unique characteristics as a socio-ecological system, a number of EU-funded projects have been invested in the area including MEDALUS, DESERTLINKS, MEDACTION, and RECONDES (de Vente et al., 2007).

Figure 1. Map of Guadalentin basin area (approximate – red dashed rectangle)

Recently, another global project, DESIRE, has been launched aiming to tackle desertification problems in a number of land degradation and desertification hotspots in different parts of the globe. In Europe, research under this project is targeting arid and semi arid Mediterranean ecosystems, especially in the context of agro-ecosystems where long term interactions between biophysical characteristics and human socio-political dimensions have been evident. For Spain, the Guadalentin basin has been selected as the study area focussing on the 'Rambla de Torrealvilla' subcatchment (Figure 2). This particular study, partly designed to meet some objectives of the DESIRE project in the area, will thus also focus on the Torrealvilla subcatchment.

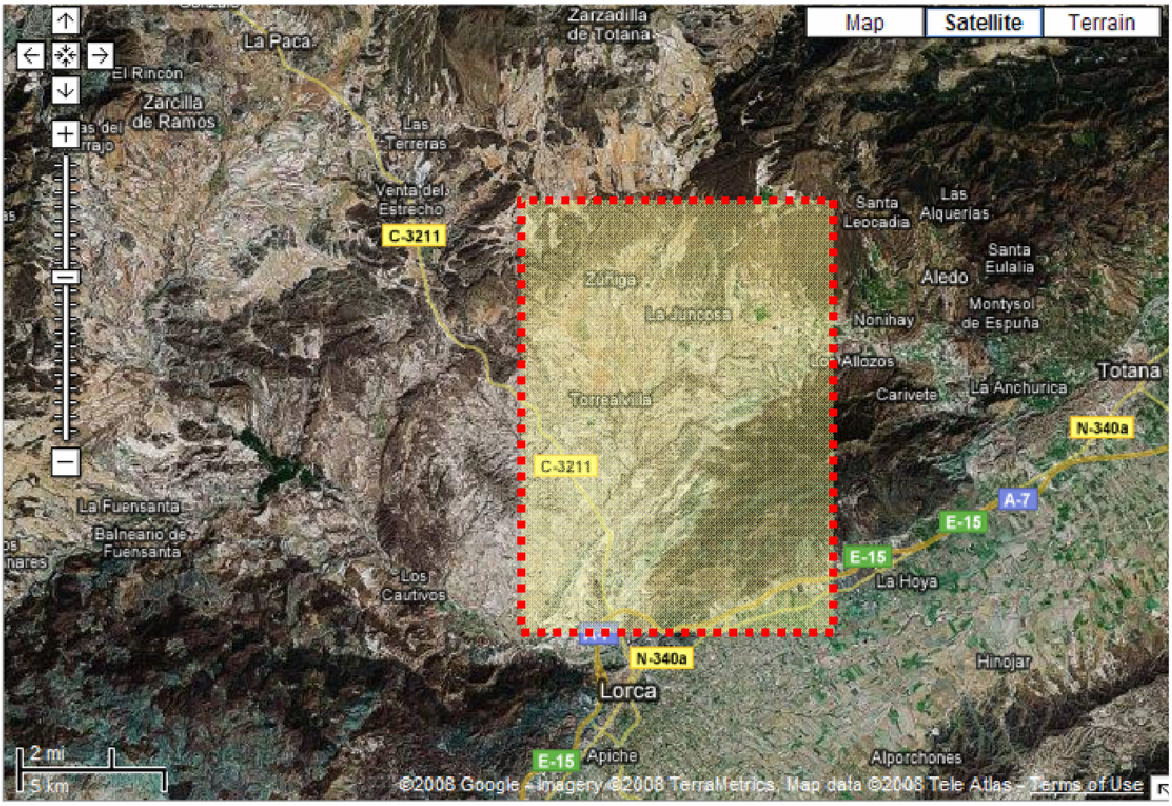

Figure 2. Map of Torrealvilla subcatchment (approximate – red dashed rectangle)

3. The conceptual framework

Generally speaking, four main components of the methodological framework will be employed at different stages of the proposed research. Figure 3 provides a visual summary of these approaches. Nevertheless, these individual methods are interrelated. In the end, a final approach is designed to integrate principal mechanisms and their associated outcomes in order to generate an integrated perspective on the issues under study. It should be noted that dotted line signifies interrelationships. On the contrary, lines with arrows indicate that outcomes from one stage feed into the next one of the analysis.

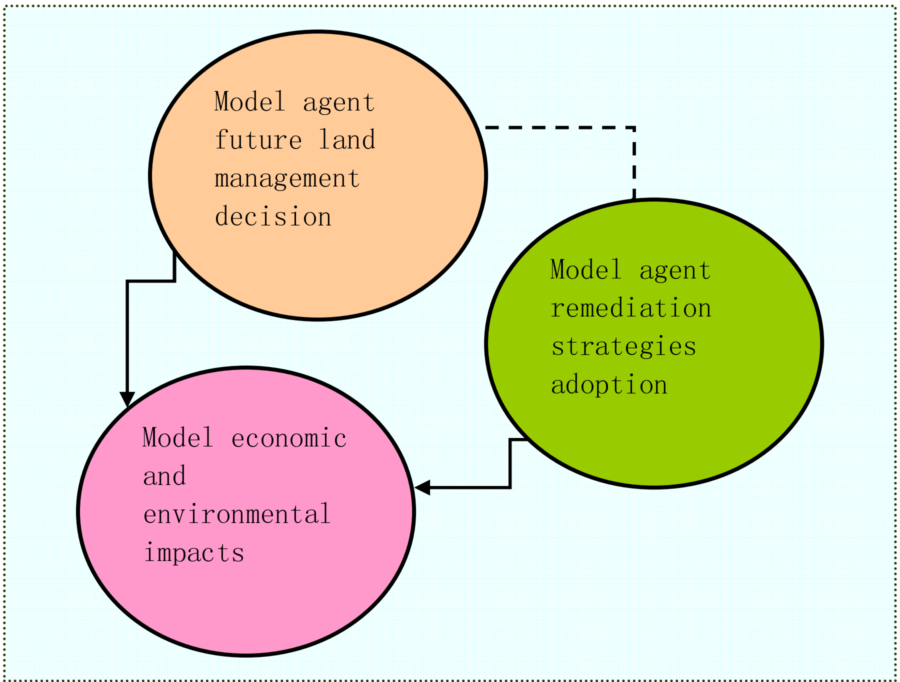

Figure 3. Methodological framework of study

4. Modelling agents' choices

4.1. What happen with the land parcels in the area?

Firstly the study shall quantify future trends on agro-ecosystem management strategies as a consequence of decision-making at the individual farm-based/ household level. Coupled spatial and choice modelling will be adopted (e.g. Geoghegan, 2001; Termansen et al., 2004 & Termansen et al. 2008). This part of the methodological approach examines various options that land managers have in terms of what they may do with a given land parcel in the future and investigates a wide range of factors that explain the reasons or drivers behind individual choices being made. 100 – 200 land managers will be interviewed (see Orme, 1998).

Choices made by these land managers are evaluated in relation to the socio-economic characteristics of the land managers and their respective farms. In addition, the evaluation shall take into account the attributes of the different choices within the set from which land managers can select. As such, conditional and multinomial logit modelling techniques are appropriate and will be used to deal with both situations respectively. By employing these two tools, the study can statistically calculate the extent to which a particular land manager's choice is strongly associated with any of his/her socioeconomic characteristics as compared to the features of the choice itself. This forecasting will be made spatially explicit using GIS. A selection of possible current situations that household farmers and/or landowners are facing and an array of future alternatives they may choose from will be presented. The list has been developed based on insights from the stakeholder workshop and 'talks' during a one-week preliminary study site visit in February 2008. A matrix of possible combinations can then accordingly be pulled out from the list.

At first, the model will be static in that it merely evaluates the likelihood of an agent selecting a particular option as a result of: 1) household/agent/farm characteristics; 2) specific attributes attached to the different options/alternatives; 3) external influence; and 4) possible future 'scenarios'. The model will then be designed to capture the dynamic nature of the decision-making process by enabling a sub-module within the model to portray the dynamic state of (productive) land, water, and labour availability as a consequence of the aggregate impact of individual decision making. Among others, three possible sources of this dynamic elements are: 1) interaction among/between agents; 2) interaction between agents and environment i.e. how agents react to the aggregate effect of individual agent decisions (in terms of water availability for example); and 3) agent's experience i.e. how agents adapt and co-evolve with long term change they observe and encounter. The technicality of incorporating the dynamic elements into the decision-making modelling by means of agent-based simulation is admittedly very challenging. Yet, the design and the development of such a model can potentially benefit from recent applications in other disciplines mainly from the area of transport studies (e.g. Takama, 2008; Dugundji and Gulyas, 2006; Sulistyawati et al., 2005; Feuilette et al., 2003; Kelley and Evans, 2007).

4.2. What would the likelihood of remediation strategies adoption be?

This part models the probability of remediation uptake by household farmers and/or landowners, which is the fourth research objective of this study. This follows on the outcomes of the static modelling in Approach 2. For those land parcels with an indication of agriculture as the future agro-ecosystem management options (regardless of irrigation mechanisms) (Table 3), the likelihood of adoption of remediation measures will then subsequently be modelled. As such responses from the same sample size of 100 – 200 land managers (see Orme, 1998) are used for data input for this analysis.

Discrete choice analysis and agent based simulation with spatially explicit outcomes shall be employed (e.g. Geoghegan, 2001; Termansen et al., 2004 & Termansen et al. 2008). The analysis will involve both static and dynamic modelling with principle elements of the design comparable with those described in the preceding section of the study's methodological framework. Although this implies that the socio-economic characteristics of the agents covered in both approaches remain the same, yet the attributes of the options and the range of possible scenarios can be slightly different. Again, with the use of GIS, the outcome of the analysis will be made spatially explicit.

5. Linking local agents' decision and the future economic and environmental condition of the region

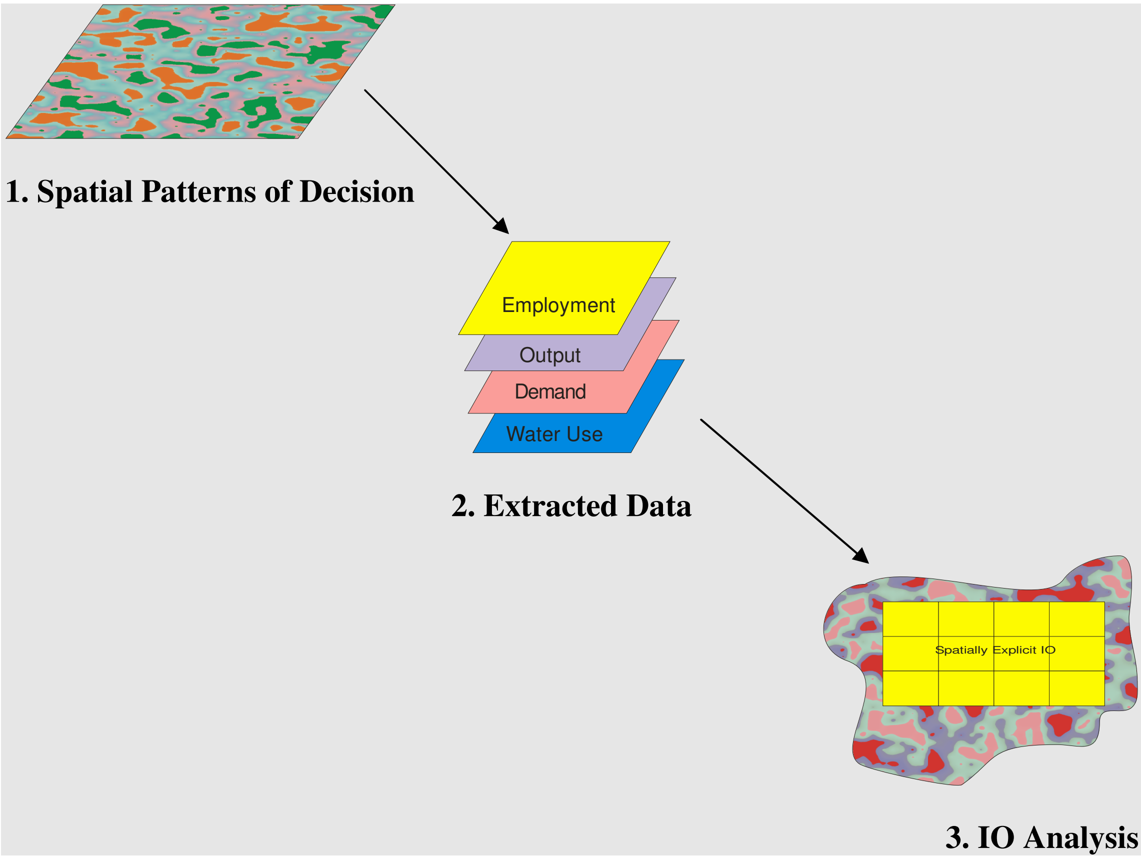

Figure 4. Linking Agents and the Region

This stage is where, in order to further evaluate the effects of household decision-making on the regional environment and economy, outcomes from the agent choice modelling are integrated into a spatially explicit extended Input Output Analysis (Thurau et al., 2004). Figure 4 provides an illustration on how this will be done. In particular, the model quantifies the effects of such decision on the nature of employment and final economic output (Sporri et al., 2007) of agro-ecosystem management, and on this sector's final demand on materials and services purchased from other economic sectors in the region. These will be explored at various levels of the hierarchy; from individual agent up to the locality and region. The observed patterns are linked with information on where agents are located on the spatial landscape under study. To allow this, the study will first sum up the probabilities of the likely change in agro-ecosystem management practices and of the potential remediation strategies uptake as a result of individual land managers or farmers' decision-making trends identified in 4.1. and 4.2.

As data becomes available, the results will be extrapolated for the whole region where the study site is situated. Nevertheless, the probability calculation will serve as a proxy coefficient to modify scenarios for the Input Output Analysis in terms of changes in the final demand and the output of agricultural production and how it links with other economic sectors in the region. By doing so, it is expected that this can capture a dynamic interrelationship between individual decision-making and the economic impacts at regional level. Environmental implications of land managers' decision on future management of their respective agro-ecosystems parcels will be approached by projecting future water consumption (Dabo and Hubacek, 2007) and the availability of productive land as a consequence of such decision. This projection will further inform future water use regimes in the area which shall lay foundation for the evaluation of their future economic effects. What is more, the projection will be further linked with the likelihood of future land abandonment which may be seen as a signal towards a far greater land degradation problem in the area in the future.

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