Land Evaluation and Geographical Information Systems for Land Use Planning

A Case Study of the Municipality of Texcoco, Mexico

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1. Introduction

The actual methodologies of land evaluation (LE) (FAO, 1976; FAO 1983; FAO 1985; FAO 1991) are used for supporting government planning (FAO, 1993), in a top-down approach from resource base to land use. Where the need to grow a crop is for social, economic or political reasons, the physical resource base is less important and contextual characteristics about socio-economic variables (land tenure, infrastructure, labour, distance to market and others) become more important (Burrough, 1996). This is the case with Mexican agriculture where more than fifty percent of the land (1.03 million sq. km.) is controlled by organised communities, that is, groups that hold property in common. Mexico introduced a communal village system, the so-called 'ejido', after the revolution of 1917. Heterogeneity is a dominant characteristic of the Mexican ejido and variability in size, resource base, availability of irrigated land, technology and productivity is striking (Ireson, 1987; Wilson and Thompson, 1993). Ejido land was to be communal, and worked either in the form of co-operatives or individually. In 1992 the prohibition on selling and buying land ceased with changes in the political constitution and a kind of structural adjustment in the ejido started (Burger, 1994). The change in the law gave the ejidatario the title and rights of the land (for rent or sale) and the freedom in decision-making about the use of individual parcels or communal land in association with the private sector (PROCEDE,1993). The association would be for a maximum of 30 years.

The land reform, which began in Mexico in 1992, is termed the 'third generation'. It does not concern itself with landless groups, but also seeks to use reform as a means to strengthen the economic and productive potential of existing producers who are constrained by pre-existing tenure arrangements and institutional disfunction. This type of land reform has a direct impact on the production process, decision-making and the allocation of resources (Gordillo de Anda et al, 1996).

Because the land tenure system has been in continuous flux since 1917 there is no inventory of land resources at ejido level. This lack of information at the ejido level, especially in terms of socio-economic issues and decision-making, makes both the development and application of a government policy difficult. Ideally, informed decision-making at all levels should be based on a knowledge system incorporating both bio-physical and socio-economic factors as they influence land use systems. A Geographical Information System (GIS) would help to improve the understanding of the processes of land evaluation and decision-making. It can improve the efficiency

of data processing, can help to solve data integration problems and can support spatial analysis (Bronsveld, et al, 1994; Rossiter, 1996). Moreover it can help to improve the description of land utilisation types required for land evaluation (Van de Putte, 1989; Bronsveld et al, 1994; Rossiter, 1995).

The present proposal is focused on the integration of information generated from the various programs of Rural Development instituted by the Mexican government in a Geographical Information System. This will involve three levels of generalization for the characterization of the resource database and analysis of the decision-making process for land use i.e. at municipality, ejido and farmer level. The overall aims and objectives of the project can be summarized as follows:

2. Objectives

1. To integrate maps and databases at municipality and ejido level, from different government agencies, in a GIS.

2. To develop an information system for the spatial location of different land uses that stratify the environment in the ejido for the description of land use types and characterisation of the decision-making process at ejido and farmer levels.

3. To evaluate individual farmer decision-making processes in relation to land use in communal lands and on individual parcels by using techniques of participatory and rapid rural appraisal (PRA and RRA).

4. To develop a means of integrating qualitative information from PRA and RRA into a GIS, in a “participatory GIS” framework.

3. Literature Review

3.1 Land Use Planning and Land Evaluation

Land use planning can help decision-makers (such as government or land users) to use land in such a way that current land use problems are reduced and specific social, economic and environmental goals are satisfied (sustainability, income generation, self-sufficiency, etc.). The main objective of land use planning is to identify the uses that best satisfy specific goals for different tracts of land and the formulation of projects, programmes or management plans to implement these uses. Land use planning becomes important when the government or land users feel that there is a need for land use change. This requires not only the political will and the ability (instrument, budget, manpower) to support and implement the plan. It is also essential that the planned changes are acceptable to the people and land users involved (FAO, 1993).

Land evaluation provides essential information on land resources. However this information is often not used in the planning and implementation of better land use systems or land use practices, for a number of reasons. Firstly, the information produced is frequently incompatible both to government’s objectives and/or the preferences of the local people. Secondly, data processing is inadequate, resulting in low quality information. Thirdly, land evaluation is based on a top-down approach; such an approach does not take sufficiently into account the aspirations, capabilities and constraints of the local land users. Added to which**,** land use plans tend not to consider sufficiently the limitations of interventions (subsidies, policy prices, input supply, extension, credit etc.) (Bronsveld et al, 1994).

Land evaluation is defined as the process of assessing the potential production for various land uses (Beek, 1978). This approach is based on the matching of qualities of different land units in a specific area, with the requirements of actual or potential land use. The results of land evaluation should be useful for rational land use planning (FAO, 1993).

Burrough (1996) states that in the top-down approach to land evaluation, the direction of reasoning is always from resource base to land utilization, a perfectly adequate approach where there is plenty of land, and the market is unconstrained. In general the conditions for agriculture will be initially created by the modification of the natural physical resources. This may be done by irrigating, fertilizing and other practices; as the cost of inputs increases, however, physical land resources become less important and factors such as access to the market, infrastructure, skilled labour and organization are more important. Added to this are other aspects concerning social habits and traditions. For example in Mexico, 'almost all farmers grow maize because their culture requires it (any maize is better than none)' (Corbett, 1995).

Rossiter (1996) discusses a theoretical framework for the classification of land evaluation models and concludes that there is no single land evaluation modelling approach. The choice of technique affects the reliability and scope of the application, and also the predictions and purpose. Rossiter added that predictions on land performance are useful only if they are used by decision-makers to make better decisions. ' We should take a step back, away from the question "What predictions can we make with the data we have? ", i.e. a data-driven approach, to the question "Who are the decision-makers, who actually affect land use, how are they making their decisions, and how could their decision be better informed?", i.e. a demand-driven approach'(Rossiter, 1996, p186).

Burrough (1996) states that we need to look more at the interactions between how the various tools for land evaluation can be used in different circumstances, and how physical, economic and social factors can be combined. A demand driven approach to selecting a land evaluation method would help to reveal what predictions are really needed and at what level of certainty.

The process of land evaluation could be improved in several ways. Firstly, by involving local users in the plan formulation, so that their preferences and constraints are taken into account. This would include both the assessment of the impact of interventions by market or government, for example, and of inputs (input supply, extension, credit), as well as the economic, social and environmental outputs of the implementation of the land use plans. Secondly, using existing data but changing the methods of data processing by the use of more flexible data processing methods. Thirdly, by the optimal use and better integration of the existing data like remote sensed data and field data. Finally, by a clear presentation of land evaluation and land use plans in non-technical terms (Bronsveld et al, 1994).

3.2 Geographical Information Systems (GIS)

A GIS has been defined as a computer assisted system for the acquisition, storage, analysis and display of geographic data according to user-defined specifications (Laurini and Thompson, 1992). It has a digital database management system designed to accept large volumes of spatially distributed data from a variety of sources (Jensen and Christensen, 1986). The most powerful characteristics of GIS centre on their ability to analyse spatial data based on descriptive attributes. The use

of GIS software can help to eliminate data integration problems caused by the different geographic units to which different data sets are related (Burrough, 1986). GIS allows overlaying of maps with different thematic data (e.g. soil and land use, watershed, district, village maps) and thereby facilitates map integration and analysis. GIS distance modelling makes it possible to assess the interaction of (potential) land uses, and the physical infrastructure and market. It also permits the combination of maps with data generated by models (Bronsveld, et al, 1994). In short, the primary goal of a GIS is take raw data and transform it, via overlay and other analytical operations, into new information which can support decision-making processes.

GIS was introduced into developing countries during the 1980's, the key agents of delivery being various UN agencies. The approach adopted in the use of GIS was essentially top-down, with ARC/INFO used on mini-computers as the principal schema. As GIS developed, however, more inexpensive systems were introduced using micro-computers, e.g. ILWIS from ITC and IDRISI from Clark University. As these various GIS systems were taken up by both universities and research centres, so a change took place in the application of GIS, with bottom-up approaches being developed, (Taylor, 1991).

The introduction of GIS, whether top-down or bottom-up, has usually come from outside and so far GIS has been only marginal to the solution of development problems. Hence Taylor (1991) argues that it is a necessary first step for indigenous scientists to gain a greater degree of knowledge and control of this technology.

There are several restrictions to the implementation of GIS for planning in developing countries. Firstly, few attempts have been made to apply GIS in deriving planning scenarios, in allocating regional investment and in evaluating development proposals. Secondly, the state-of-the art in planning has not advanced much in relation to how planners could employ GIS in conjunction with new planning. Thirdly, the acute shortage of manpower and training have greatly restricted its use. Fourthly, there is a dominance of GIS technocrats in the use of GIS. Finally, there is an over concentration of GIS development and technology at a few key universities and research centres and finally, developing countries need GIS most, but generally do not have the necessary funding to acquire it. (Yeh, 1991).

Yeh (1991) added that in developing countries it is necessary to improve the institutional arrangements and the application of GIS rather than the technology, and that successful implementation of GIS will depend upon a clear understanding of the functions and needs of planning that are translated to system applications.

3.3 Geographical Information Systems and Planning

The utilization of GIS for research, planning, and project evaluation, in the mode of "top-down" data creation and expert "policy making" empowers the powerful and disenfranchises the weak, where it is being used in a planning and/or decision-making capacity. GIS can be integral to defining and implementing agency decision and often reflects the internal rules and value systems of the agency controlling it. Decisions regarding what issues to address, what data to obtain and how the data should be classified and analysed, and what interpretations are drawn from them, all suggest that value-neutral GIS do not exist (Weiner et al, 1995).

GIS as part of a "rational planning discourse" can be a technical legitimisation of historical power relations (Aitken and Michel, 1995; Harris et al., 1995; cited by Weiner et al , 1995). GIS, it is claimed, produces representations tied to the

discourses of the status quo (Taylor, 1991; Pickles, 1993; Goss, 1993, cited by Weiner et al, 1995). The digital landscape becomes a terrain for elite planners to negotiate social differences and territorial conflict. In the process, workers, minorities, women, poor peasants and the unemployed become even further distanced from decision-making processes (Weiner, et al 1995***).*** Moreover, due to lack of equitable access to GIS data and technology, small users, local governments, non-profit community agencies and non-mainstream groups are disadvantaged in their capacity to engage in the decision-making process (Edney, 1991).

Weiner et al (1995) in the construction of a GIS in Kiepersol, South Africa argued that it is concerned with multiple realities and the politics of resource access and the use of different scales of analysis. The GIS production process is informed by two bodies of literature that are not generally associated with GIS and remote sensing: political ecology and post-developmentalism. Political ecology encompasses a number of loosely configured areas of scholarship (Thrupp, 1993; Bryant 1992; cited by Weiner, 1995).

For Blaikie and Brookfield (1987) the operationalization of regional political ecology (RPE) follows a chain of explanation which starts with local land managers and land use practises***.*** Specific social relations of resource use are then contextualized more broadly in terms of their relations with each other and other land users within the state and the world economy

Regional political ecology is therefore concerned more with connecting scales of analysis than with the regional scale per se. Other important RPE concerns include the politics of resource use, environmental knowledge production and representation, the agency of nature, and multiple meaning and practice of sustainable development (Weiner et al 1995).

With participatory GIS the structural distortion can be reduced by the inclusion of local knowledge from socially differentiated communities whose everyday lives are tied to local conditions. This requires an approach to complement more traditional planning methodologies with the expertise and knowledge of communities who have a long standing relationship with the land (Weiner et al, 1995).

3.4 Participatory and Rapid Rural Appraisal (PRA and RRA)

For Chambers (1994) the reality of most rural people is local, complex, diverse, dynamic and uncontrolled (LCDDU). It leads to questions about how we learn about, and respect, the values, priorities and preferences of those that are deprived and weak. Faced with LCDDU realities, universally valid policy conclusions are difficult to draw. The point of these realities is that each set of conditions needs to be examined in its own right. Chambers proposes differentiating local conditions, and following different policies in different places according to different local priorities. He suggests approaches and methods which can cost less, take less time, and yet remain credible. Moreover, CESS (1991) states that development strategies hardly consider the micro-level variations in terrain, climate, geology and socio-economic factors apart from land holding. A development approach that considers these variations must be built at a grass roots level and should be based on evaluation and response/appreciation of local users and resources. But land, water and socio-economic conditions are not uniformly distributed. There is also a high cross correlation between availability of useful resources, climate, soil fertility, water, landform and socio-economic conditions. Considered in totality as a matrix the diversity of these types of natural regions can ensure a highly diversified production array. Land use has to be planned to conform to such variations and an a

intervention strategy can be worked out only if the status of natural resources along with their spatial distribution is understood fully by the planners, the land owner and the users. The evaluation of the available resources and the mapping of the existing land uses and assets would lead to a desirable development strategy evolved through a series of action plans with the people's participation.

Participatory Rural Appraisal (PRA) is a family of approaches and methods to enable rural people to share, enhance and analyse their knowledge and conditions to plan and to act (Chambers,1994).

3.5 Decision-making processes

Many traditional agricultural systems are adaptations to long-term ecological and economic forces (Bartlett, 1980). Thus the transition from "traditional" to more "developed" farming practices is a transition to a different framework for decision-making. New politics can change the dominant relations of production, the whole structure of income opportunities and necessary access qualifications and hence the land use decision-making process (Blaikie, 1985). The political economy thus both determines and provides the changes in the agrarian structure, that is reflected in the change of circumstances of the land manager. This change may also alter land use and management (Blaikie and Brookfield, 1987).

Blaikie (1985) proposed a bottom-up approach for the understanding of decision-making, the focus being placed on land, land users and the causes of the studied process, starting with the actual people making decisions on how to use land. The scheme conceives of individual decision-making units each of which chooses a form (or forms) of income generation to fulfil some objective function. The income opportunities are expressed in terms of alternative land uses such as specific cropping patterns, communal grazing lands, and other uses.

Blaikie and Brookfield (1987) proposed a land use decision-making approach for land management based on the cumulative land decision approach of Blaikie (1985) and outlined above. It focuses on a different set of decisions and provides a simple decision-tree that traces through the stages in decision-making. They propose that a number of social-environmental data form the initial desiderata for land use and management practice. The data consist of the socio-economic characteristics of the decision-makers and their access to resources. The intrinsic properties of the land system (soil, fertility, slope, etc.) are also essential elements. These models are concerned with present investments to maintain or enhance a future income stream (Blaikie and Brookfield, 1987). The schema for decision-making in land management is shown in figure 1.

3.6 Proposed Methodology.

The research methodology envisaged involves 7 stages:

1. Collection of information about the operation and implementation of government rural development programs.
2. Collection of available databases from government agencies involved in rural development and planning.
3. Integration of the collected data in a GIS. This will enable initial analysis of the data from which sampling decisions can be made, as to which ejidos will be used in stages 4 and 5 below.

4. Development a methodology for the inventory of land use types at ejido level, using Rapid Rural Appraisal (Chambers, 1994) and cumulative decision-making (Blaikie, 1985).
5. Development of an understanding of the land use decision-making processes, by using RRA methodologies. Use will be made of either the model of decision-making in land management (Blaikie and Brookfield, 1987) or real life choice (Gladwin, 1979,1980).
6. Integration of information concerning decision-making into a GIS.
7. Development of a model for improved rural development planning decisions at the municipality and ejido levels.

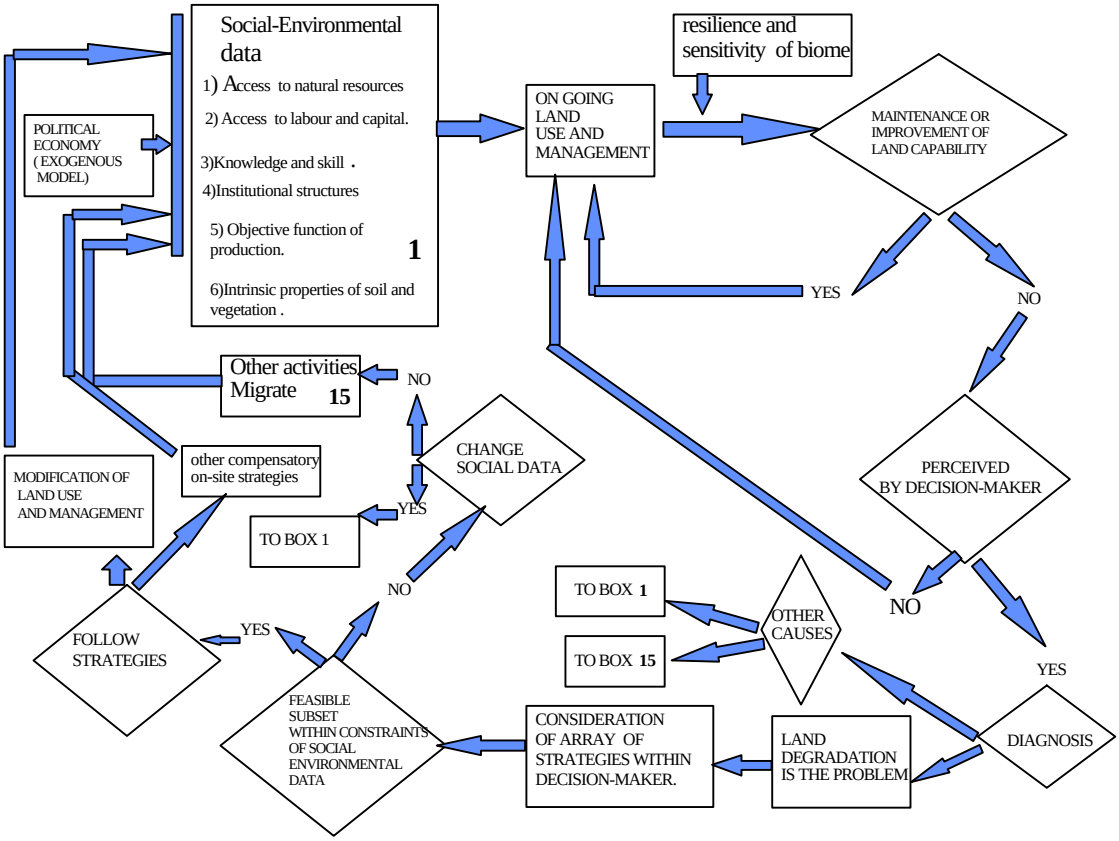

Figure 1. Decision-making in land management(Blaikie and Brookfield, 1987, p.69)

3.7 Rural development programs: identification and collection of data from different government agencies.

The information to be used for the project comes from three sources: the Rural Development District, that generates information about the rural development programs, and databases about users and crops in the municipality; INEGI the official mapping agency that produces maps of the resource base and the ejidal census and the Colegio de Postgraduados Institution for Teaching and Research that has been producing information about land use and resources for the municipality.

The census contains quantitative and qualitative information at ejido level. This information is declarative and concerns the characteristics (acerage, number of ejidatarios, etc.) and activities in the ejidos (crops, credit, machinery, etc.). It will be used here for the identification of the contrasting socio-economic aspects between ejidos. During fieldwork more detailed information about socio-economic aspects will be generated by using techniques of Participatory and Rapid Rural Appraisal..

The information at grassroots levels, related to land use and decision-making, will be generated directly in the field for the selected ejidos.

3.8 Integration of information in a Geographical Information System

The available information exists in a range of formats, some already digitized but much in the form of paper from different government agencies. All this requires transformation to a digital format and standardization to the same cartographic system (UTM) before it can be integrated into a Geographical Information System (GIS). In Figure 2 the stages for inputting the information and the relevant modules in a GIS are shown.

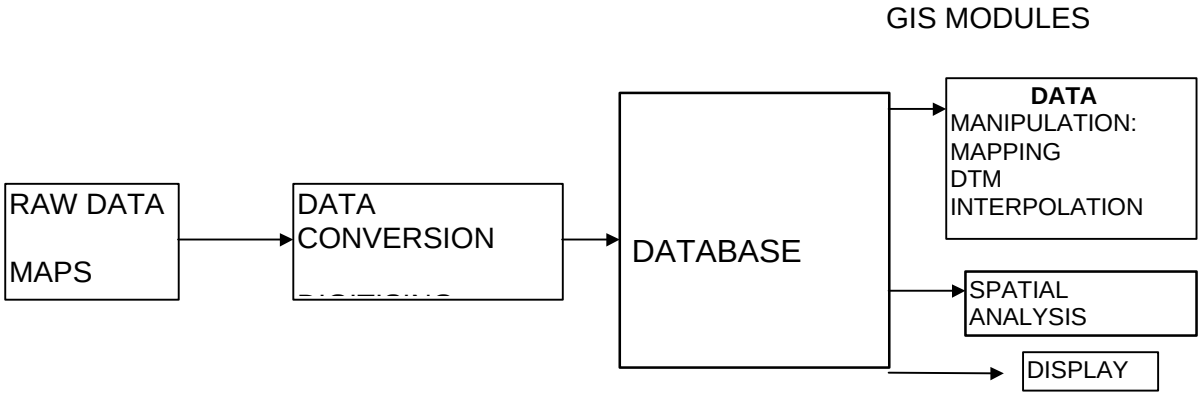

Figure 2. General procedure for inputting raw data into the database and the modules of the GIS for generating, displaying and analysis of information.

Taking the municipality data as an example the following procedures will be carried out for the inputting and integration of information in the GIS: maps of ejido boundaries, and land resources, soils, vegetation and land use at a scale of 1:50,000 will be digitised and the digital information about satellite images (SPOT,1989 and 1994) and Digital Elevation Model will be input in the GIS. With the transformation of maps and digital data into the same cartographic system and the mapping and overlay procedures of GIS the inventory, availability and location of the ejidos and their resources can be achieved at municipality level. This information can then be used for a number of purposes e.g. for the location of forest areas, agriculture, grazing and irrigated land; for identification of the main land use types in the ejidos, and for the identification of the areas with main restrictions for agriculture. All these involve map overlay of different layers such as crops, soil units, land phases (salinity, depth of soil) and slope. Finally this analysis will enable a spatial stratification of ejidos and the identification of them with different resource base, from which representative samples will be selected for field study and data gathering concerning land use and decision-making.

3.9 Identification of the ejidos with different local conditions

Each of the ejidos has specific local conditions of resources and infrastructure, which have influenced local land use decision-making processes. As Blaikie (1985) states: for the understanding of decision-making, attention needs to be focused on land and land users in a bottom-up approach. This should start with the actual people making decisions on how to use land and the identification of income generation to fulfil some objective functions in terms of alternative land uses. At this point with the overlay procedure of GIS, the identification of the differences in cumulative land use decisions and their relation with the resource database can be matched for analysis of the land use and decision-making processes.

Once the location of clustering of land use has been achieved, a qualitative ranking of ejidos with comparative advantages for different resource availability and use will be generated; for example the ejidos with more profitable crops, infrastructure, soils, etc. A sample of two or three ejidos with more variation in their land resource database and degradation will be selected for the characterization of the typology and decision-making processes of land uses.

3.10 Characterisation of the typology of land uses with techniques of Participatory and Rapid Rural Appraisal

Whilst the information generated by the overlay of the maps of land resources , land tenure, land use, irrigated lands and databases of names of ejidatarios will be used as a basis for the characterization of the land uses at ejido level, information about the socio-economic aspects of land use will be collected by means of field work, the approach adopted being the technique of Participatory and Rapid Rural Appraisal (PRA and RRA).

The techniques that will be used for the fieldwork will include:

- evaluation of secondary data and information both published and unpublished
- direct observation of field 'objects', events, processes, relationships of people
- semi-structured interviewing, that is, informal, guided interview sessions where only some questions are predetermined and new questions or lines of questioning arise during the interview (Pretty, 1988). During the discussions satellite images and airphotos will be used to help discussion of land use changes that have occurred, together with other changes e.g. increased degradation.

3.11 Decision-making processes

The decision-making units to be used for characterization of the land uses and decision-making will be selected as representative of the land use types of the ejidos of the municipality and the objective functions (income maximization, subsistence production, etc.) will be identified.

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