Agricultural Planning in Arid Zones with SIG: ESTIARA*SIG

Ayala[1], R.; Becerra[1], A.; Iribarne[1], L.F.; Bienvenido[1], J.F.; Bosch[1], A.; Díaz[2], J.R.

[(1)]Dpto. Lenguajes y Computación.
[(2)]Dpto. Economía, Sociología y Política Agraria
Universidad de Almeria
Crta. Sacramento S/N, 04120-E Almeria (Spain)
Phone:++34-950215684 Fax:++34-950215129
e-mail: rmayala@ualm.es, jrdiaz@ualm.es

ABSTRACT

The main objective of the work has been to carry out an exhaustive analysis of the factors involved in rural planning, identifying the most important agricultural possibilities and risks related to the province of Almeria. The most relevant result of this project has been the development of a decision support system for agricultural planning. The main stages in the creation of this system were:

a) Information preparation
b) Data integration
*c) Construction of ESTIARA*SIG exploitation tool*
d) Exploitation of the information in the Ministry of Agriculture of the government of Andalusia, and its updating in FIAPA/University of Almeria

Some examples of the use of the tool are centered in the determination of the zones with least agricultural resources, identification of optimum areas for the development of intensive agriculture and determination of fire danger areas. Finally, we are researching into the development of simulation models and their incorporation to the system, modeling different evolution processes (forest repopulating), resources use (alternatives of water utilization) and diffusion (pollution processes).

Keywords: Geographic Information Systems, Decision Support Systems, Rural Planning, Agricultural Planning

INTRODUCTION

The province of Almeria, located in eastern Andalusia, offers a great diversity and particularity, highlighting the fact that it holds the only european desertic area.

Water is the principal protagonist of both life and activity in the province of Almeria. The typically Mediterranean climate, with high temperatures, very low pluviometric values, with few rainy days, but torrential, and a great number of sun hours per year, causes the existence of the topmost aridity levels of the Iberian Peninsula and Europe. The rivers do not flow along a great period of the year. The drought problem compels to restrict the irrigation in a good part of the province, limiting the sowing of cultivation with greater hydric needs.

The introduction of forced cultivation, transforming unproductive coastal flatness into economic spaces with greenhouses, where early products are obtained, has introduced a new development model into our zone, causing the abandonment of the mean mountain zones. The underground aquifers are suffering an increasing overexploitation, presenting in some instances salinization problems, with a negative influence on the agricultural production. The control of the exploited underground aquifers is difficult, increasing the difficulties in obtaining an accurate information.

All these peculiarities, which also exist in other environments, requires a particular risk and opportunities management. This leads to the need of an adequate planning, which requires a correctly updated information. The GIS (Geographic Information Systems) provides suitable support to manage all the information required in the land-use and agricultural planning, as in Bosque (1992) and Yialouris et al. (1995).

Related to all the former facts and needs, the GIS a research project called ESTIARA has been accomplished, financed by the Ministry of Agriculture and Fishing of the Andalusian government. Its objective has been to make a detailed and exhaustive analysis of the situation that allows to detect the main problems that can affect to the province of Almeria; its ultimate goal is to offer a support tool for the decision making, based on the duly updated objective data, as Ayala et al. (1996).

Besides, to develop the project, we have analyzed and evaluated some researching works related to the GIS using in rural planning, as in Chennamaneni (1996), Engel et al. (1996), Tiilikkala et al. (1996) and Yialouris et al. (1995). These researching works have provided an important help to reach the most valuable goal of this project: to develop a decision making tool in agricultural planning.

DEVELOPMENT STAGES

The developed work was divided into a set of stages, using a collection of techniques and tools in each of them. In several points of the process there were introduced quality controls, in order to verify the correctness of the information. The different stages were:

(1) Information preparation. Its acquisition implied to do multiple tasks within the socioeconomic and agrarian environment:

- Determination and collection (on the field along all the territory) of the socioeconomic data with a great influence on the province agrarian ordering. The quality control procedures consisted in checking the correctness of all the data.
- Development of the digital cartography, and spatial description of the graphic entities (rivers, underground water resources, water quality, soil typologies, etc) as *thematic layers*, as in Moldes (1995). In this phase the quality control procedures were really complex, since it was necessary an exhaustive review of some digitized coverages to see the error degree that was introduced. In this review, a series of digitized coverages were chosen and displayed, along with the contiguous coverages, in order to prove if they matched.
- Analysis and classification of satellite images, using thematic levels in vectorial format, as in

Anderson et al. (1972). This process has been focused on determining the territorial areas with great influence in water resources management (e.g. areas with plastic covered greenhouses). In this phase, the quality control procedures were simple; we first take ramdomly some zones where the classification indicated the existence of greenhouses on burnt zones, among others, and then we go on the field to actually test their existence.

The main objective of this stage has been the summarizing and updating of all the input information for the decision making support system. The most important results of this stage were:

- A set of tables that interrelates all the socioeconomic and agrarian information relevant for the tool of decision making support.
- Spatial description of an exhaustive collection of thematic variables within the agronomic environment. These thematic variables have been digitized from topographic maps (scale 1:10,000).
- A collection of topographic maps that shows the greenhouses growth evolution, as well as the process of controlling the water resources for vegetation zones and urban sites.

2. Data integration. Construction of a georelational data model that allows to establish spatial relationships between the graphic entities and the data base supporting the thematic attributes, as in Laurini (1992) and Scholl and Voisard (1997). This model allows to interrelate all the agronomic information with the rest of the spatial information, so that they could be accomplished detailed queries for the decision making in the area of rural planning. We have obtained a schema for information representation with various formats, which guarantees its integrity and consistency.

3. Construction of ESTIARA*SIG exploitation tool, an open query system, dynamical and consistent. It is possible the generalization of the application environment, mainly the other arid zones. The most important feature of the tool is the possibility of accomplishing a simple exploitation, and that the user could generate its reports, that help to adopt the adequate agronomical policies. The structure of the reports can be predefined or user made, this can structure new report types with a great flexibility. In this phase, the quality control procedures consisted in passing a series of tests to the tool to prove its correct operation, seeing also the fulfillment degree of the different user levels and needs.

4. Exploitation of the information in the Ministry of Agriculture and Fishing of the government of Andalusia, and its updating in FIAPA/University of Almeria.

METHODOLOGY AND TOOLS

In this section, we will deal with the ensemble of techniques used in each different stage of the construction of the tool, as well as the set of tools that have been used and its justification.

We will begin talking about the techniques used in each one of the stages:

Stage	***Used Techniques***
Information preparation: ➢ Collection of the	Field and bibliographic work. The information was collected with a

socioeconomic data	predetermined form. These data were introduced in a data base using a data base management system that has permitted us to control the quality of the supplied information.
➢ Development of the digital cartography	This process was accomplished using classic techniques of point-to-point digitizing.
➢ Classification of satellite images	The classification process has been accomplished using the rule of the minimal distance, which permits to obtain very good results, especially in arid zones.
➢ Data integration	The technique used for the generation of this model has been the definition of virtual tables, which permits to interrelate the agronomic and spatial information.
➢ Construction exploitation tool (ESTIARA*SIG)	Techniques of specific templates definition have been used, for the development of exploitation functions in a rapid and simple way.

Table 1. Techniques used in the development stages

Next there is the set of tools used for each one of the work development stages, justifying its use through a comparison among with alternative tools.

Stage	Used tools	Evaluated Tools	Selection reasons
Information preparation: • Collection of the socioeconomic data	dBase IV /Excel 97	Access 97	DBase IV is a relational data base system that permits to organize all the thematic attributes according to a conventional data model. It can be imported by our development tool.
• Development of the digital cartography	AutoCAD Ver.13	MicroStation	AutoCAD is the world most used computer-aided design system. It permits to accomplish a point-to-point digitizing. It generates an easily exportable cartography.
• Classification of satellite images	Erdas Ver. 8.3	EASI/PACE	Erdas allows to import directly the spatial coverages coming from ArcInfo for superposing them with the satellite images. It allows to classify the greater interest zones that cover the project objectives.
• Data integration	ArcView Ver. 3.0	IDL Soft Vision	ArcView permits to manage the interrelated information from various formats through the creation of virtual tables.
• Construction of ESTIARA*SIG exploitation tool	Avenue Ver. 3.0	C++	Avenue is an object-oriented programming language, incorporated in ArcView, which allows the development of the predetermined functions of the application.

Table 2. Tools used in the development stages.

MANAGED INFORMATION

The collected and stored information can be classified in several groups:

• Alphanumeric	• Vectorial (graphical)
• Raster (graphical)	• Photographic

All this information is stored in our data base, permitting us to establish relationships between the different data formats.

Alphanumeric Information

The agrarian socioeconomic information is structured in the following table collection:

• *Soil attributes*	Representation of all the characteristics, by association and incorporation, of the different types of soils existing in the province of Almeria.
• *Agrarian census*	Number of farms, terrain distribution, and cultivable area.
• *Marketing Centers*	Information of the most relevant marketing centers, specifying infrastructures of located character (products, prices, markets and other).
• *Regions*	Limits and municipalities of the different agrarian regions.
• *Bioclimatic conditions*	Climatic variables information (temperature, rain, dampness) by month, for the different municipalities.
• *Economy: Agricultural expenses*	Structure of the expenses accomplished on the farms (transformation, plants, and installation expenses).
• *Economy: Agricultural Investments*	Structure of the investments made on farms (land purchase, irrigation, wind shields, greenhouses construction and other).
• *Economy: Agricultural Revenues*	Description of the different modalities existing on the farms (irrigable or not, under cover or not).
• *Dams*	Location of the different dams, including capacity and surface specification.
• *Cattle exploitations*	Description of the type of cattle, censuses, wages, expenses in food and veterinary.
• *Water springs*	Spatial location of the most relevant water springs, specifying its description and wealth.
• *Greenhouses: Typologies*	Concrete analysis of the typologies and uses of the existing greenhouses.
• *Greenhouses: Technological levels*	Information of the most relevant aspects related to the technological advances in the design and construction of automated greenhouses.
• *Municipalities*	Data from the 103 municipalities of the province of Almeria (limits, agrarian region, description, spatial location)
• *Unemployment: Distribution by age*	Analysis of the existing unemployment rate by municipality and its distribution by age.
• *Unemployment: Distribution by groups*	Analysis of the existing unemployment rate by municipality and its distribution among the different work groups in the area of the agronomic planning.
• *Population*	Structure of the population and agrarian occupation.
• *Wells*	Spatial location of the province wells, including the wealth, depth and an exhaustive analysis of all the indexes that control the of water quality.
• *Irrigation systems*	Description of the different pipeline networks for irrigation of different cultivation, classified by capacity.
• *Subsidies*	Information of the different subsidies received in the local agricultural field: olive oil, cereals, dry fruits, sheep and goats,

	agrarian structures, climbing vine.
• *Subsidies: PER*	Information of the subsidies coming from the outstanding plan for rural employment in the Spanish territory.
• *Subsidies: Reforestation*	Description of the helps received for the reforestation process of zones that suffer forest fires, among other.
• *Surfaces: Cultivation*	Distribution of the province agrarian surface according to the different types of existing cultivation at present.
• *Surfaces: Mountains*	Surface property of the Board of Andalusia; mountain surface (public, private or commonwealth).
• *Technology of the exploitations*	Technological appropriateness of the exploitations, emphasizing the number of hectares and the irrigation surface located with and without automatic fertirrigation
• *Abandoned lands*	Lands that were not cultivated in the last 20 years. Economic uses of rural space

Table 3. Socioeconomic and agrarian information support the system of development

Graphical Information (Vectorial entities)

The digital cartography developed for our project ranges in the following thematic levels:

• *Municipalities*	• *District roads*	• *Cartwright roads*
• *Population groups*	• *Local roads*	• *River basins*
• *Highways*	• *Tracks*	• *Level curves*
• *National roads*	• *Paths*	• *Soils classification*

Table 4. Digital entities of the geographical information system

Figure 1 shows the representation in thematic levels of all the vectorial information that includes administrative information as infrastructures, both general and agronomic. These levels when introduced in our system of support to the decision-making are converted into *thematic layers*, representing a specific type of elements of the real world, as Moldes (1995).

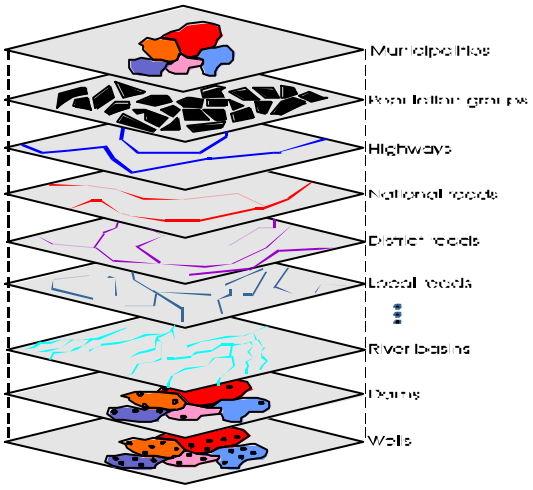


Figure 1. Thematic layers in ESTIARA*GIS

Raster information

The system allows to establish spatial relationships with entities in format GRID. All the results of the treatment of two LANDSAT images have been incorporated with spatial resolution of 20x20 m. for all bands, except for the thermal one that has a spatial resolution of 120x120 m.

The most important results generated by the analysis of these images incorporated to the system are the classification of vegetation zones, burnt-out zones, populated spaces and cultivation under plastic.

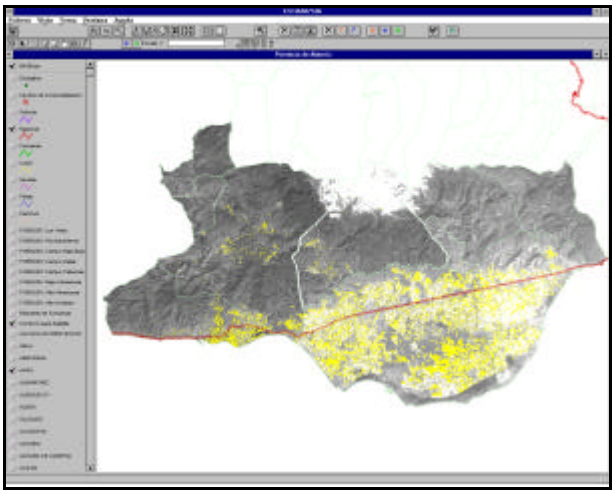


Figure 2. Greenhouses classification

This process focuses on the zones that influence mainly the control of the water resources. Figure 2 shows an example of one of the accomplished classifications (number of greenhouse hectares in one of the agrarian regions).

Information of photographic images

This information is incorporated as a complement associated with any spatial element.

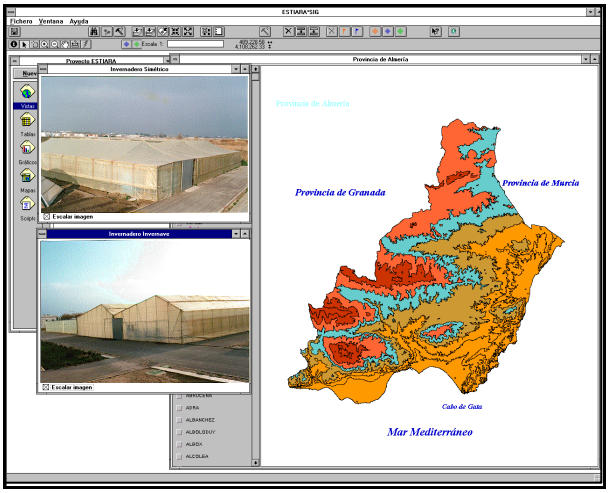


Figure 3. Example of greenhouses typologies

Photographs of the FIAPA center and of some existing greenhouses in its facilities have been included. Some examples of the use of the photographic images can be: displaying the trace of an interesting highway; aerial photograph sequence of a city, photographs of the types of greenhouses built in a given zone, or the type of cultivation of these.

Figure 3 shows an example of the most important greenhouses typologies in our province.

RESULTS

The system permits to generate in a rapid and simple way some reports in order to apply policies in the area of the agronomic planning. One of the principal characteristics of the tool is the incorporation of a flexible user interface that permits to generate queries that present socioeconomic and agrarian information correlation not anticipated.

The tool permits to generate a wide fan of results that eases the process of the decision making in a strongly changing environment. This system has a set of utilities that provide predetermined patterns of development, relating all the socioeconomic and geographical information that is included in the data base. Below, a very summarized description of the different utilities, emphasized on the results that generate is shown:

- *Views:* Interactive maps that permit to visualize, explore, consult and analyze geographical data and the associated thematic information. This utility permits to display all the (agrarian) information related to the province of Almeria and its relationship to the digitized information.
- *Predefined queries:* They allow to select and show (as sets of tables) all the economic and agrarian information related to a determined spatial entity or group of entities.

- *Maps:* They permit to generate a totally dynamical map that includes entities to topological relationships and the entities of the stage that are included as geographical reference for the topological entities. This utility permits to include views, reports results of exploitation generated by the user, graphic results of a query of exploitation, as well as the selected agrarian information of all the alphanumeric data.
- *Graphs:* Dynamic representations with several graphic formats of the results obtained through a query of exploitation. This information is interrelated with all the thematic attributes of the system, and it permits to design a set of patterns for the representation of the information.

These utilities allow to generate, in a simple way, a very wide set of reports that facilitate the process of the decision making in the area of rural planning. The results can be generated from a wide combination of the different features the tool presents; for example, we can combine the views with the predefined queries to generate graphics that present unforeseen correlations of the agrarian information. On the other hand, all the reports generated from documents combinations can be easily printed in detailed maps.

It is quite difficult to estimate the whole volume of output reports the tool allows to generate, taking into account the great range of possible combinations which can be made with the system information and posibilities. Nevertheless, we could give an approximate estimation based on the set of interesting agricultural predefined reports for the agricultural planning which is now being made in the province of Almeria. This volume makes possible to determine fundamentally:

- Plastic covered cultivation surfaces
- Territorial zones with technological delay
- Territorial spaces with greater deficit of water.
- Territorial zones that provide the water resources with greater quality for irrigation and consumption
- Control of the administration on the production
- Control of the number of farms
- Damage forecasts
- Others

Here we show four examples of the different results that our development tool permits to generate. The first is the representation in a view of the men distribution by ages and the graphic of temperatures per month for a selected municipality. In the second example we can see a map with information of bioclimatic conditions (table format), the rainfalls per month (graphs) and the vectorial representation with the selected municipality highlighted. The third example shows a detail of the influence area affected by works on a street of an urban zone in the province of Almeria. This result is of great importance to evaluate the expropriation process of territorial zones in the building of this road. The last example shows the spatial location of the set of wells of a district selected with one of the system features, particularly, the predefined queries.

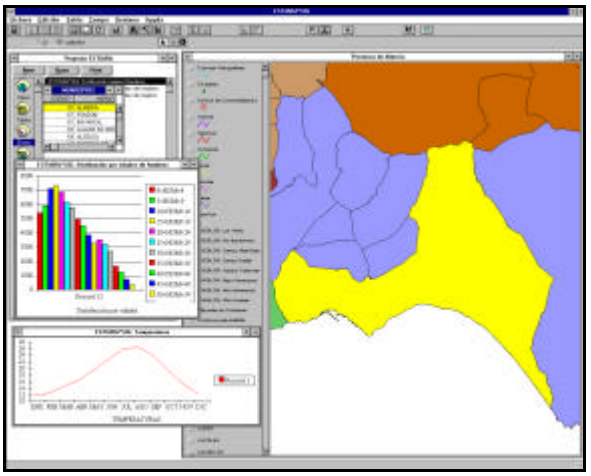


Figure 4.- Example of tables for a municipality selected in ESTIARA*SIG

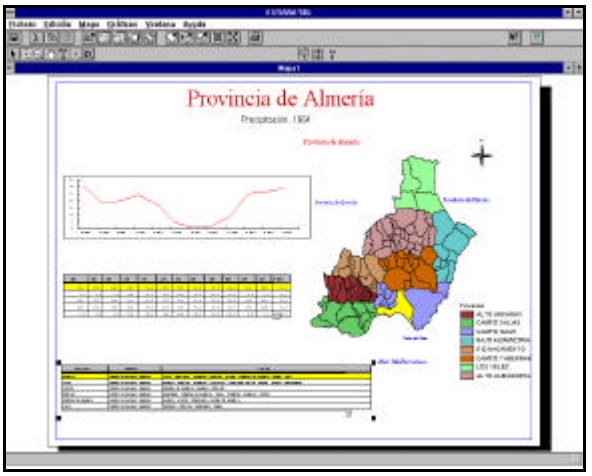


Figure 5. Example of map in ESTIARA*SIG

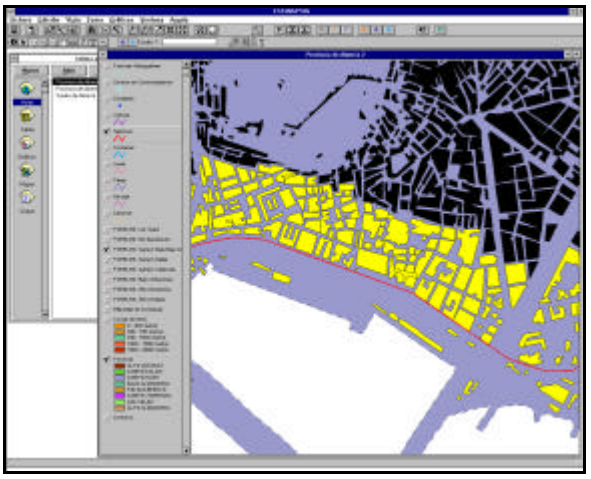


Figure 6.- Example of influence analysis

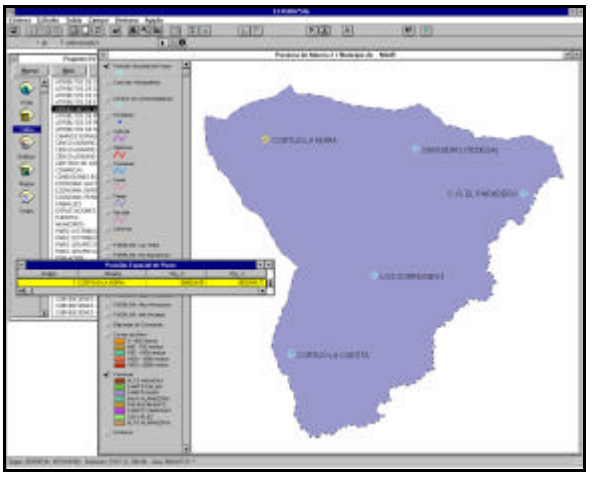
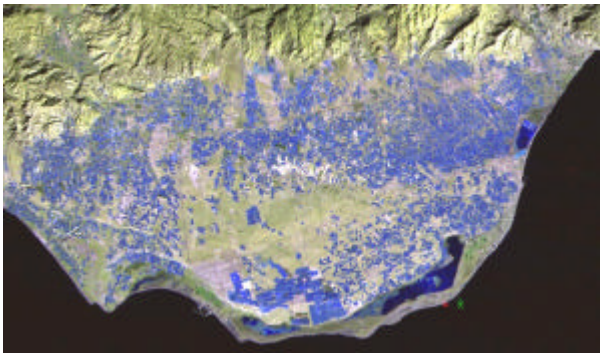
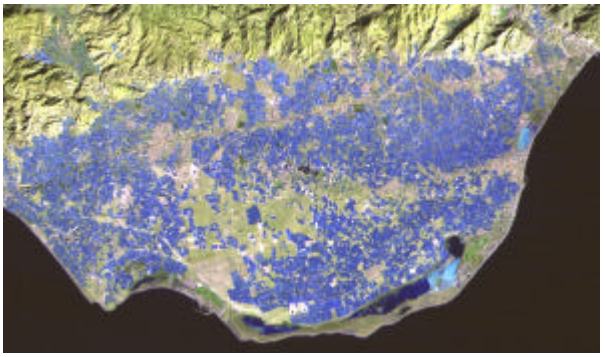


Figure 7. Spatial location of wells

Finally, we show the results of analyzed satellite images. We have used two Landsat images to evaluate the greenhouse evolution from 1985 to 1994 and have been incorporated to ESTIARA*SIG. Maps for the years 1985 and 1994, of certain cultivation area "El Poniente", are shown in the following figures. A simple comparison of the figures 8 and 9 shows that there is a significant increase of the greenhouse area. In 1985 there were 13,000 h and in 1994 there were about 20,000 h for the studied area (only a part of the province).





Figures 8 and 9.- Satellite images of the southwest coast of Almeria.
The greenhouse covered areas are highlighted (1985 - 1994).

CONCLUSIONS

From the accomplish work, we can highlight the following conclusions:

- The use of decision support tools based on Geographical Information Systems is of great interest in the field of the rural planning. This is specially important in regions where the main wealth source is the agriculture. These tools can facilitate to take advantage of the development opportunities and foresee the risks.

- It is possible to develop a specific tool for arid and semi-arid regions taking account of their specific characteristics. We have implemented ESTIARA*SIG for the province of Almeria as a flexible decision tools its rural development. The tool has certain characteristics (interrelate agrarian and spatial information, predefined queries, easy use of data) that allows exhaustive analysis, such as the localization of the most depressed zones in terms of economic and agricultural development, or the classification of the zones which may be affected by forest fires, or the evaluation of the surface of the different cultivations which can be developed in our province.

- The tool, ESTIARA*SIG, allows to obtain a wide set of reports, which can be obtained by the diverse users directly from a set of predefined informs, or elaborated using predetermined elements and combining them on fully different relationships and formats. These late function supposes an great advantage facing new (unknown) possibilities or problems.

- The structure of ESTIARA*SIG is absolutely general, it can be applied on any other arid or semiarid region filling it with the adequate data and an easy parameters and tables adaptation.

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