Optimisation of Technical Steps of a Rural Land Consolidation Using a Geographic Information System: Land Reallocation Step

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Key words: Land consolidation, Land reallocation, Data Base, PC ArcInfo, GIS.

SUMMARY

The Land Consolidation project in general, and land reallocation in particular, are time consuming and less accurate when using traditional methods. This has a negative impact on the purpose and the initially fixed objectives of Land Consolidation.

The main objective of this study is the optimization of technical steps of a land consolidation project using a Geographic Information System (GIS). The methodology developed for this purpose has three main steps: 1) establishment of a conceptual model for different phases of a land consolidation project; 2) development of a new method to determine the landowner lists for reallocation inside a block; 3) development of a specific GIS prototype for the purpose of solving the issues of land consolidation in general, and land reallocation in particular.

A new approach for "Temporary Land Reallocation" was developed to determine the landowner list for reallocation inside a block by giving a weight to each land consolidation qualitative and quantitative parameters. The developed interface using the SML language based on PC Arc/Info (ESRI,CA), allows the acquisition, process, query, analysis, and archiving of the data base.

RESUME

L'élaboration d'un projet de remembrement rural en général, et le recasement parcellaire en particulier, avec les méthodes conventionnelles, exige un processus de longue durée et de longue haleine; ce qui a un impact négatif sur la région à remembrer et sur les objectifs du remembrement initialement fixés.

Cette étude a comme objectif principal, l'optimisation des différentes étapes techniques d'un projet de remembrement en se basant sur un SIG. La méthodologie développée a cet effet comporte trois étapes fondamentales : 1) établissement d'un schéma conceptuel des données d'un projet de remembrement ; 2) développement d'une nouvelle méthode de détermination de la liste des propriétaires à recaser à l'intérieur d'un bloc; et 3) développement d'un prototype de SIG dans le but de résoudre le problème d'un projet de remembrement en général, et celui du recasement parcellaire en particulier.

Une nouvelle approche a été développée pour le "Recasement Provisoire" dans le but de déterminer la liste des propriétaires à recaser à l'intérieur d'un bloc, en tenant compte des différentes contraintes du remembrement, quantitatives ou qualitatives, et ceci en affectant des poids à chacune d'elles. Le prototype, développé en langage de programmation SML en se basant sur le logiciel Arc/Info sur PC (ESRI, CA), permet de faire la saisie, le traitement, l'analyse, le storage et la mise à jour des données, et offre la possibilité d'interroger la base de données d'un projet de remembrement.

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1. INTRODUCTION

Since the beginning of the sixties, Morocco always granted a big importance to the farming sector in general and to irrigation in particular, by investing in the big, small and medium hydraulics. Moreover, the policy of the irrigated million hectares acquired an important economic and social dimension.

The land consolidation, or regrouping, of parcels contributed to this effort for the benefit of agriculture, by guaranteeing a better productivity, the stability of the rural population, the creation of jobs, and the development of the national economy.

In spite of all these results and in spite of the Moroccan experience of more than forty years in irrigated and rainfed (bour) land consolidation, its progress is below expectations and planned projects. Several factors contributed to this situation, such as the drought, the degradation of the agricultural lands, the texts of land consolidation, etc.

Most often, a land consolidation project is based on legal, administrative and technical tasks. Among these technical operations, we can distinguish:

- land surveying tasks;
- social and economic inquiries;
- soil studies;
- network studies (water management and network access to fields);
- reallocation procedures;
- implementation.

The main objective of this study (Essadiki, 2001) is to develop a new approach and a new conceptual methodology using a Geographic Information Systems (GIS), that considers all types of data involved in a rural land consolidation project (e.g., soil types, social and economic inquiries, and spatial data), and to establish a specific GIS prototype for the purpose of solving the issues of land consolidation in general, and land reallocation in particular. Indeed, the development of models for land consolidation based on a GIS will support decision makers and will respond to present and future needs.

2. ISSUES AND METHODOLOGY

One of the most important and decisive technical step in Land consolidation is Land Reallocation. It is the synthesis, the analysis and the decision making step. All the land

consolidation process is identified in this application. However, this step still lacks a good approach to process the large volume of data. Given the mass of data and the diversification of documents, some difficulties arise at different levels:

- The manipulation of different documents (land surveying plans, soil classes, parcels plans).
- The data treatment.
  The preferences (wishes) of farmers for a particular spatial location.

In a land consolidation project, one can find qualitative and quantitative data. Taking into account all these factors and parameters, we propose to develop a new methodological approach integrating steps of land consolidation in a GIS framework in general, and the step of land reallocation in particular, accounting for Moroccan conditions. The use of a G.I.S. provides significant advantages and allows a user to:

- valorize better the soil, land surveying and parcel information;
- analyze data correctly;
- update easily geographic information;
- make appropriate decisions in space;
- model already existing data;
- create and manage data bases for local collectivity.

To maximize the benefits from Land Consolidation technical steps in general, and the Land Reallocation in particular, a new approach was developed using the following methodology:

1) Design of a conceptual model for all phases of a Land Consolidation project (Essadiki & al, 2002 c);
2) Establishment of the landowners list to be reallocated inside a block or "Temporary Land Reallocation" (Essadiki, 2002 a);
3) Development of a specific GIS prototype for the purpose of solving the issues of Land Consolidation in general, and Land Reallocation in particular (Essadiki & al, 2002 b).

However, this study will focus more on the "Temporary Land Reallocation" step, which deals with the qualitative and quantitative data.

3. LAND REALLOCATION PROCESS

Land Reallocation is a very important technical stage in the Land Consolidation process. It is also a lengthy process. This procedure consists of four main operations:

- Preliminary calculations
- Temporary Land Reallocation
- Definitive Land Reallocation
- Implementation

3.1 Preliminary Calculations

Before starting Land Reallocation, the operator needs various documents in order to carry out a number of preliminary calculations:
- parcel plans before land consolidation (fig. 1),
- social and economic inquiries,
- soil class maps (fig. 2),
- hydrographic network maps (fig. 3).

The following calculation steps should be undertaken:

1. Calculation of the area and the value of the parcels before land consolidation, by digitizing the limits of parcels and their soil classes.
2. Calculation of the area and the value of the blocks by digitizing the area of different soil classes inside the blocks.
3. Calculation of the value (rock mass, roads, hydraulic networks, etc)
4. Calculation of the reduced values for landowners.

In theory, the total land value of all the land parcels should be the same as the total value of blocks. In practice, it is impossible to have this result, because of digitizing errors. All of these calculations will be needed in the following steps of the Land consolidation procedure.

3.2 Temporary Land Reallocation

Before its implementation, land reallocation can be divided in two main phases:

- Temporary Land Reallocation
- Definitive Land Reallocation

The “Temporary Land Reallocation” allows for the determination of the placement of the owners inside the hydrographic network frame (blocks) and the landowner’ list affected to each block, taking in account some factors:

- existing ”plus-value” e.g. building, house, well, or rock mass.
- Existing parcel inside the ”block”.
- Landowner’ requirements or wishes.
- Existence of a dominant class of soil inside a ”block”.
- Existence of a parcel whose value is higher than the mean of all parcels of a specific area.

3.3 Definitive Land Reallocation

The “Definitive Land Reallocation” involves knowing the exact position and “definitive” location of each landowner’s parcel in a given ”block”. It’s more than a geometric problem, because the operator has to take into account more than one factor:

- The value of the new parcel.
- The value of the block.
- The soil classes.
- The “plus value”, which could be a house, well, or other variable.
- The different types of irrigation networks (“trames” in French) (fig. 7,8, 9, 10).

At this stage, the implementation of land reallocation could be carried out. However, one of the main problems with land consolidation in general and land reallocation in particular, is the manipulation and combination of qualitative and quantitative data. To overcome this challenge, a new approach has been developed for “Temporary Land Reallocation”.

4. NEW APPROACH FOR “TEMPORARY LAND REALLOCATION”

The determination of landowner lists is time consuming when using conventional methods. To resolve this problem, the request model for Land Reallocation becomes an absolute necessity and a necessary condition for good data management and consequently for a successful land consolidation project.

Before elaboration of the request model to determine the landowner' lists inside the blocks, a questionnaire was created and sent to different persons involved in land consolidation projects (local authorities, private companies, governmental offices, etc).

4.1 Determination of Owners Weights

From the results, a model was developed by assigning weights for each block, taking into account ranked criterions and various constraints. Consequently, every criterion is attributed with a value according to its quality and its importance.

In order to emphasize the importance of the ”PLUS VALUE”, it was decided to give this criterion the highest weight. In this way, it is assured that the farmer or the owner who have a ”plus value” will be served first, i.e. selected and reallocated in the concerning block.

4.2 Landowner Reallocation Algorithm

The methodology applied to determine the list of landowners to be reallocated inside a block is based on the following algorithm:

- Calculate the number of points for each landowner, based on criterion ranked inside each block.
- Calculate the sum of points for the landowners in each block.
- Classify blocks in ascending order according to the sum of points.
- Determine the landowners to reallocate, starting with the block which has the maximum points of landowners.
- Reallocate the landowners possessing a “plus value” in a specified block.

- Determine the list of landowners to be reallocated by priority order, and by comparing the sum of reduced value landowners with the value of the block.
- Proceed in the same way with other blocks, by eliminating each time the reallocated landowner.

With this method, the landowners possessing the maximum number of points will be the first selected inside a specified block. The operation is repeated until the land consolidation operator is satisfied.

The adjustment of the block value with the total value of landowners will be achieved interactively, if it is deemed necessary. Determination of the landowner list to be reallocated in a ”block” is realized by different possible combinations of the sum of the landowner reduced value, which should be equal to the ”block” value, with a tolerance not exceeding 1%.

Once the approximate position of new parcels and the landowner list are established, the determination of the exact position of parcels inside the blocks could be applied: it is the step of “Definitive Land Reallocation”.

5. DEVELOPMENT OF THE PROTOTYPE

Due to the complexity of the Land Consolidation process, the use of a data analysis tool is very important to accomplish the distinct technical steps of a project. In this case, a prototype was developed using the Simple Macro Language (SML) based on PC Arc/Info (ESRI, CA). This prototype is used to deal with complex tasks of information gathering, processing, querying, analyzing, displaying, and archiving the data base which is spatially referenced.

5.1 The Prototype Functionalities

The developed prototype has two main menus : the first one is concerned with “the “Temporary Land Reallocation”, and the second one deals with the “Definitive Land Reallocation”. This prototype has a friendly user interface with various pull-down menus.

5.2 Evaluation of the Prototype

To evaluate the degree of success of this prototype, an actual project was tested using this application. The chosen area had already submitted a project of land consolidation a few years ago (Ouled Zidouh,Tadla, Morocco). After data gathering of essentially all various maps and alphanumeric data, all steps of the menus were applied. Landowners were reallocated in all blocks, with respect to constraints and to the tolerance already programmed. The following illustrations show the results of some tasks of the developed prototype (as displayed on the screen):

Fig. 1: Scattered parcels before Land Consolidation process (Oulad Zidouh, Tadla)

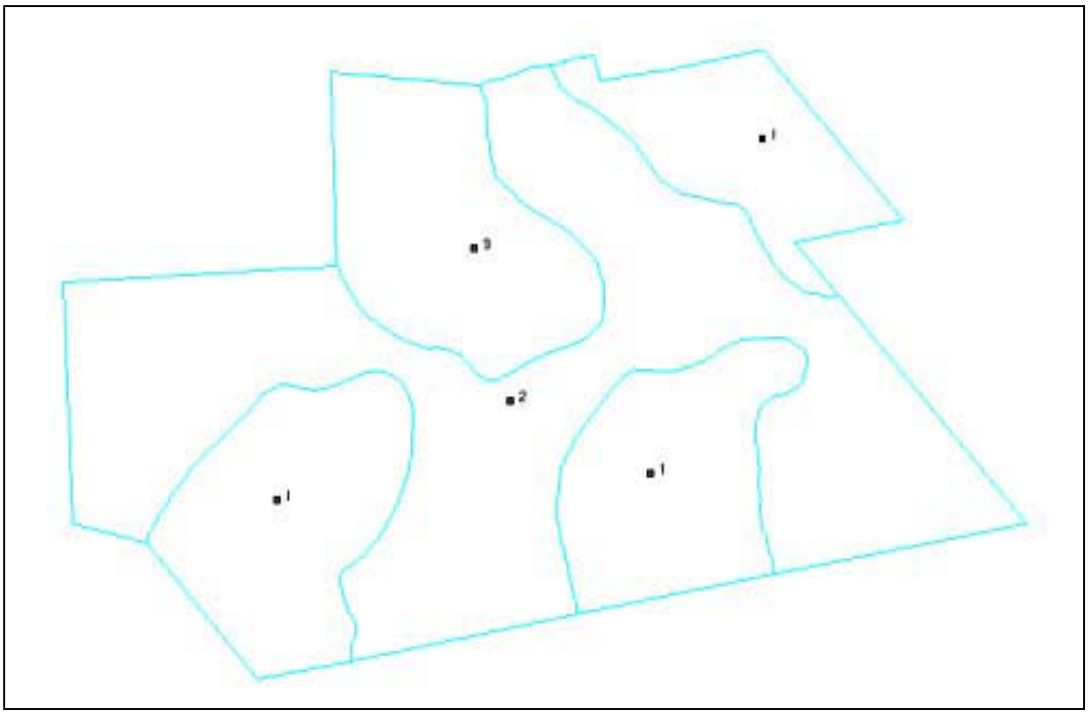

Fig. 2: Soil class map of Oulad Zidouh

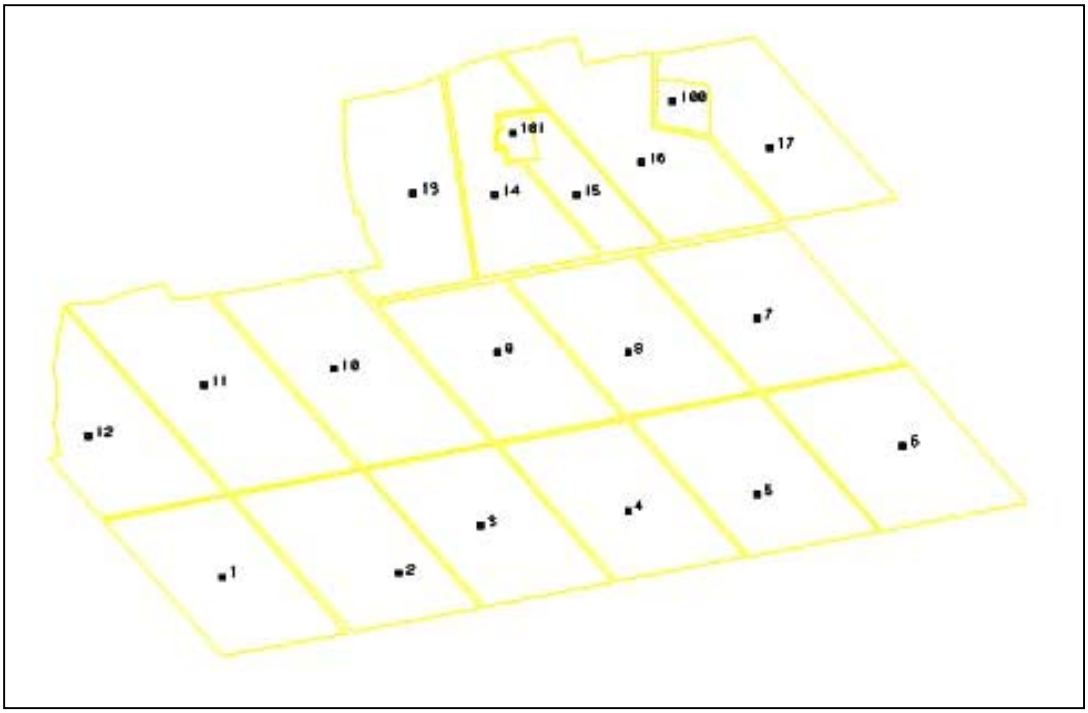

Fig. 3: Irrigation network frames

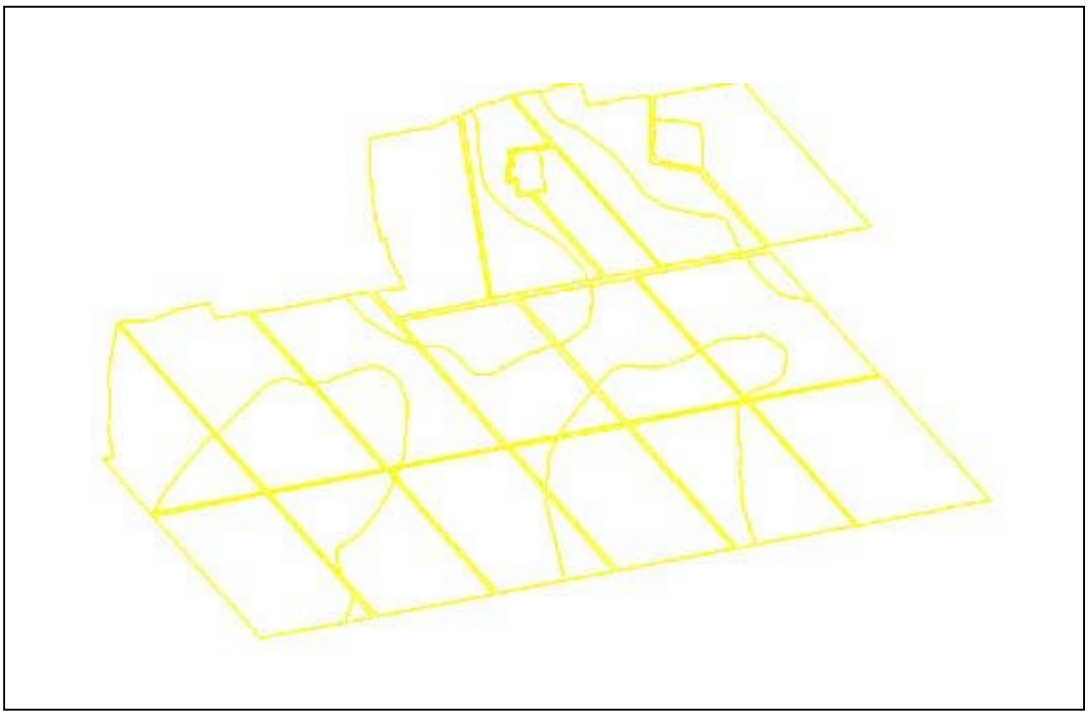

Fig. 4: Overlay of soil classes and irrigation network frames

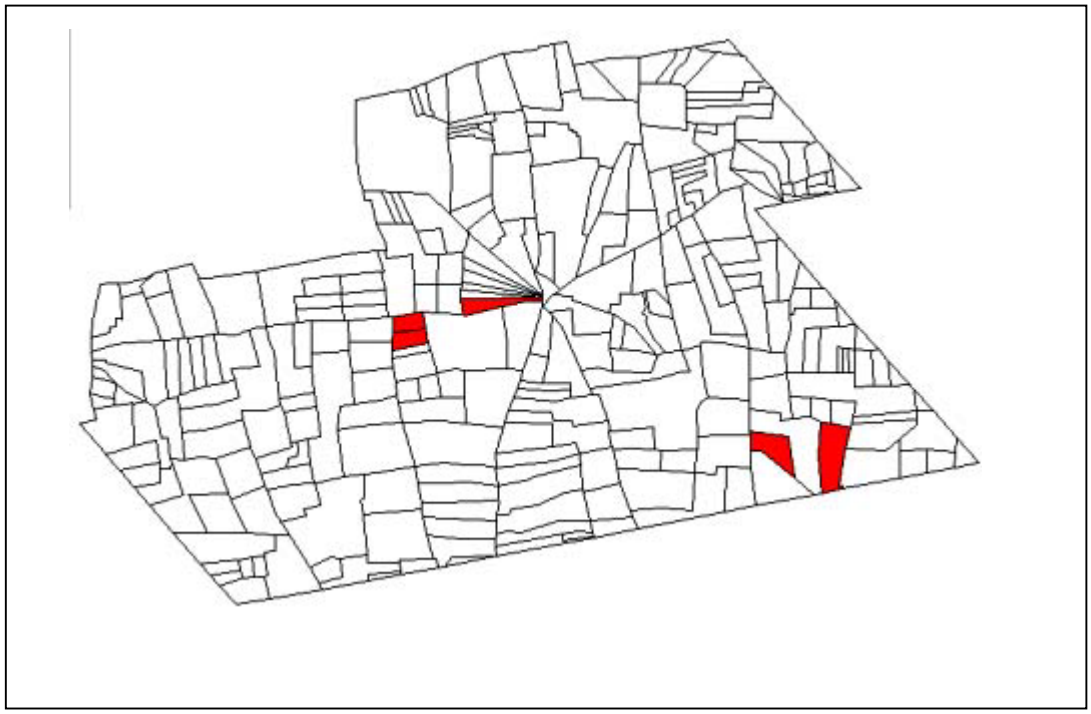

Fig. 5: Parcels of landowner N° 50 before land reallocation

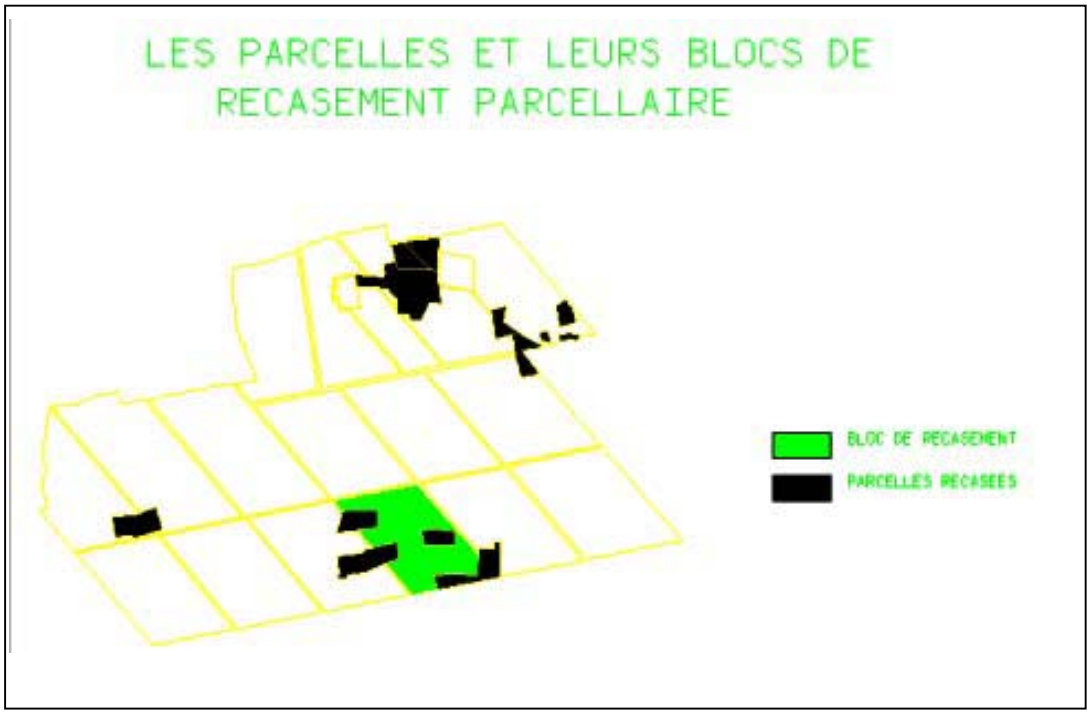

Fig. 6 : Parcels reallocated in the block N° 4

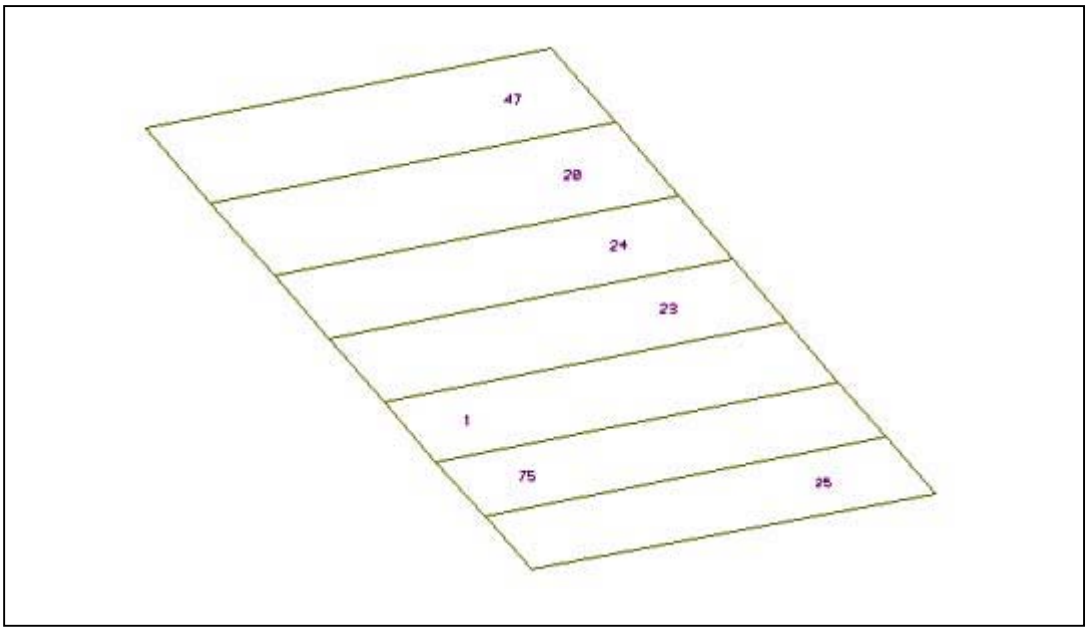

Fig. 7 : Block N° 1 of the irrigation network frames, Subdivision type “Trame A”

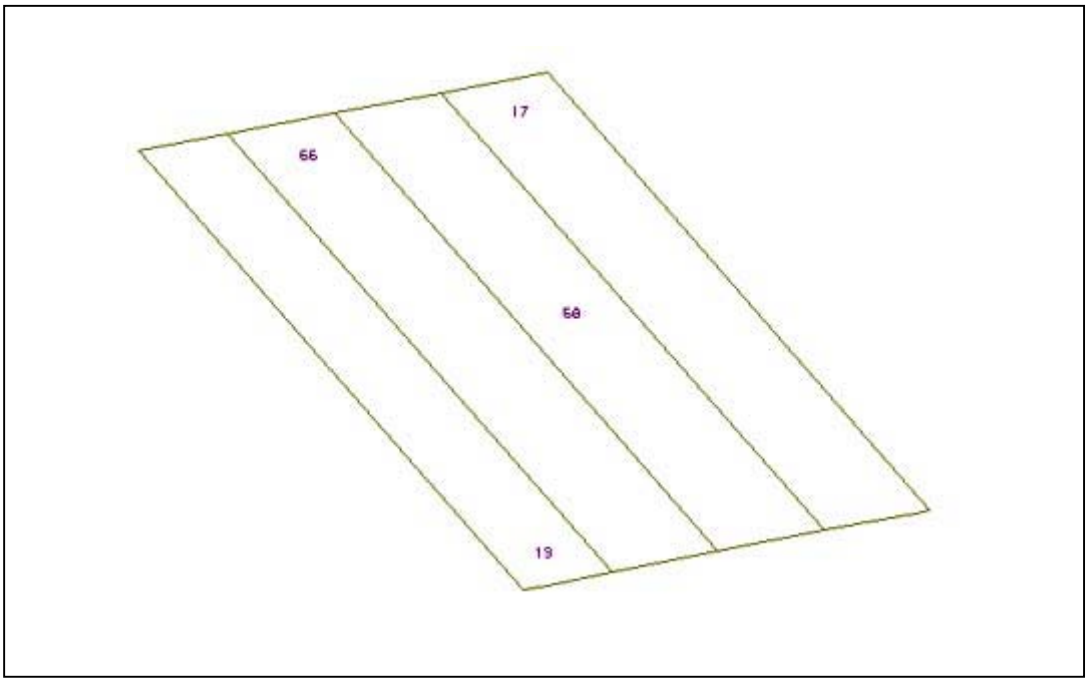

Fig. 8: Block N° 9 of the irrigation network frames, Subdivision type “Trame B”

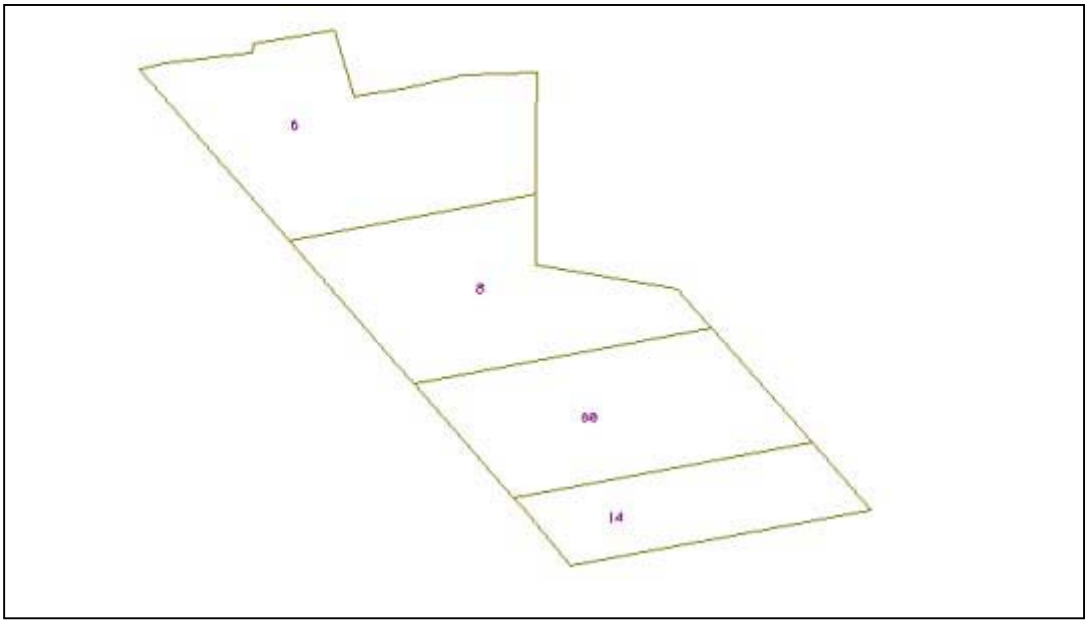

Fig. 9: Block N° 16 of the irrigation network frames with irregular shape, Subdivision type “Trame A”

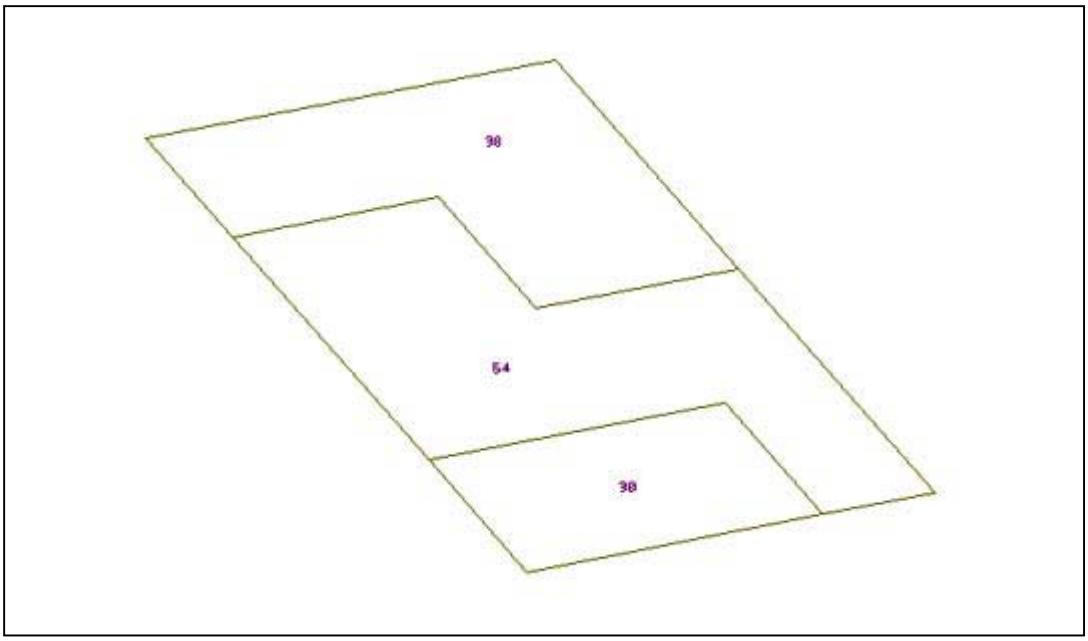

Fig. 10: Block N° 15 of the irrigation network frames, Subdivision type “Trame C”

5.3 Discussion of Results

The most important objectives of this study are the elaboration of a specific prototype for a Land Consolidation project to optimize the various technical operations in general, and the Land Reallocation in particular, using a GIS.

A certain number of questions arises, and should be discussed and considered before drawing conclusions:

- Does the developed prototype answer the various technical operations that a consulting bureau usually executes in a project of Land Consolidation?
- What are the problems resolved for a Land Consolidation project in general, and those of Land Reallocation in particular?
- Do the requests based on the GIS meet the needs of users?
- What are the parts which remain to develop?

According to the results of the prototype, one finds the following tasks:

- except for the topographic triangulation, the various technical operations are present in the developed prototype: the capture, the processing, the analysis, the display and the archiving of data.
- overlying and creation of the layers' topology.
- all calculations of the project are processed.
- the various types of soil classes are taken in consideration.
- constraints and criteria are considered .
- priority is given to the landowners possessing the "plus-value".
- determination of the landowners list to reallocate in a block in a semiautomatic way.
- choice of the order to reallocate an landowners inside the block.
- choice of the type of irrigation network frames ("trame") to be applied in a block.
- treatment of any shape of blocks.
- automatic division of blocks.
- recording of all the coordinates in a ASCII format.
- requests based on the GIS.
- reduced human intervention to a minimum.
- Edition and displaying of the results under appropriate formats.

Consequently, most technical operations which are necessary for a Land Consolidation project are present. The Land Reallocation, which is a decisive step, is made in a semiautomatic way at the level of affectation of the owners in blocks, and completely automatically at the level of compulsory location "definitive land reallocation" and of division of these same blocks.

The alphanumeric and graphic interrogation of the data base developed, based on the concepts of the GIS, answers the various requests that a user can formulate. However, this interface is not static, it can be improved to satisfy other user needs.

6. CONCLUSION

The results of the validation are very promising, and answer, in most cases the compulsory constraints. From another point of view, this product is not the end in itself, but rather the contribution as the solution of the technical problems, by introducing a new methodology and new techniques of management of data base using a GIS.

The performance of this application was increased by the use of GIS, and results were achieved in only a few days, instead of l weeks.

The utilization of a GIS is essential for the success of such projects, especially when dealing with multi-criteria data analysis.

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