GIS Application to Establish Hydraulic Development Plans

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Key words: GIS, Hydraulic, Development Plan, Framework, ArcView, Slope, Aspect, Irrigation.

ABSTRACT

GIS provide powerful tools for data acquisition, data processing and the spatial analysis of various geographical information. They are considered to be very useful for planning and decision making.

Hydro-agricultural development presents a great importance to the Moroccan national economy, accordingly it requires the introduction of new techniques to improve the results.
In fact, studies of hydraulic development plans are conducted in order to define the limits of irrigation units (blocks), taking into account irrigation network, internal draining network and road network. These blocks' limits are conceived not only to respond to some economical and technical objectives, but should also satisfy some irrigation constraints for a better agricultural exploitation of the future parcels such as in a land consolidation project.

Knowing the basic data about the terrain, the parameters and the constraints to take into account, the present study consists on showing the contribution of GIS in the establishment of hydraulic development framework. An interface is developed using Avenue programming language of ArcView. The developed interface permits to integrate several constraints involved in hydraulic development. The interface allows introducing, processing and analyzing graphical and attribute information as well.
This GIS application could have a great contribution to the achievement and the management of irrigation projects in Morocco. Compared to the conventional method, the introduction of GIS in this kind of project shows that hydraulic development plans are established with more precision and within a reduced time.

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1. INTRODUCTION

For several years, Morocco has undertaken a great program of hydraulic development. This program relies on the fulfillment of infrastructures and agricultural development, in order to improve irrigated areas. The role appointed to hydraulic development is to reply to the demands of social and economical development of the country considering its need and its agricultural production potential.

Morocco is confronted to insure food needs by the national production taking into account the demographic increase, the improvement of the standard of living of the population and inescapable climatic accidents

The contribution of hydraulic development to the national economy considering the cluster of its indirect and direct effects is appreciated through the narrow correlation between the evolution of the Gross Domestic Product (GDP) and that of the Agricultural Gross Domestic Product. Irrigated zones, although they represent only less than 11% of the total cultivated area, they contribute to approximately 45% of the agricultural added value and insure more than the third of the job in rural areas (Yacoubi, 1995).

GIS are considered to be very useful for data acquisition, data processing, planning and decision making.

Knowing the basic data about the perimeter, the parameters and the constraints to take into account in a project of hydraulic development, this paper outlines a methodology to establish hydraulic development plans using GIS tools. First, some basic definitions related to hydraulic development projects are given, followed by a description of the conventional method used in Morocco. Then, a GIS methodology applied to this kind of project is presented. Finally, results and concluding remarks are discussed for a case study.

2. ESTABLISHMENT OF AN HYADRAULIC DEVELOPMENT PLAN

2.1 Definition

A hydraulic development plan (also called hydraulic development framework) represents the hydraulic circuit disposition such as irrigation network, internal draining network, external purification systems and roads network. The establishment of a hydraulic development plan has a fundamental impact on the cost of the equipment to be used. Therefore, it requires the maximum care and practice.

An hydraulic framework is defined according to a certain number of considerations, namely:

- Protection of soils against streaming of external waters by evacuating waters to rivers
- Development of parcels for irrigation purposes
- Realization of various works (pumping station, water pipes, etc. ...)
- Insure a susceptible road sideboard to allow circulation inside the perimeter.

2.2 Conventional Method

The conventional method used for the establishment of a hydraulic development framework is composed of several stages that differ from a project to another according to the specifications of each region. The procedure used in two regions of Morocco (Gharb and Doukkala) involves three main phases (Semlali, 1999)

- Demarcation of the zones to exclude from the hydraulic structure
- Adjustment of the perimeter's limits
- Dividing the perimeter into units of irrigation

Each step will be described succinctly in the following sections.

2.2.1. Demarcation of the Zones to Exclude from the Hydraulic Development Plan

This phase is based on the analysis of soils studies, nature of terrain and aerial photographs of the region to be studied. Using these elements, and after terrain recognition, we can determine all exclusions that affect the establishment of the hydraulic framework. Such exclusions are (ORMVA, 1992):

- Soil's exclusions like zones of plantations, private areas, unused soils
- Land exclusions such as habitations and cemeteries
- Terrain exclusions like terrains of great slopes
- Existing infrastructures like main road axis and tracks
- Natural thalwegs and rivers.

Once these exclusions are determined, they are established on plans at scale 1/5000 or 1/2000.

2.2.2. Adjustment of the Perimeter's Limits

At this stage we adjust the limits of the perimeter's sectors in order to fit with other limits such as limits of parcels, limits of existing roads and habitations, and limits of exclusions. It is also necessary to coincide the limits of irrigated zones with main hydraulic structures.

2.2.3. Divide the Perimeter into Units of Irrigation (Blocks)

At this step we proceed to the establishment of the framework in areas delimited by imposed axis, according to usual standards of irrigation. The most important determinant constraint is the slope in the direction of the irrigation. This slope has to be comprised between 0,1% and

1%. As a general rule, the slope should be inferior to 1%. But, when the slope of the natural terrain is superior to 1%, water pipes are set up such that the slope in the direction of irrigation never exceeds this value.

Local topographic data determine the geometry of the block and consequently the structure of the hydraulic framework. In case of regular local and global slope, blocks are regular. If terrain's slope is irregular, then, blocks get an uneven geometric shape and the structure of the hydraulic framework becomes irregular

The network circulation contains a system of sideboard track of the irrigated perimeter. It allows both the access to exploitations for the return of crops and the maintenance of the irrigation network.

During this stage, it happens that the topography varies from one part of the sector to another. In this case we should take into account two recommendations:

- For sectors of regular topography, the framework of adjustment corresponds in general to the framework-type defined by the study of the hydraulic development framework, in this case, the implantation of the hydraulic framework is based on the dimensions of the typical block.

- For sectors of irregular topography, the framework-type is not respected, blocks' dimensions are defined by crest lines and depression lines that constitute main imposed axis.

2.3 GIS Methodology

In this methodology we have used ArcView software and Avenue programming language to develop several programs that facilitate drawing hydraulic development framework for a given perimeter. The established programs need the following vector data (El Fadili and El Maftouhi, 2000):

- A file containing limits of the perimeter to be treated
- A file containing exclusion data
- A file containing imposed axis networks (roads, tracks, natural rivers)
- A file containing known coordinate points covering the perimeter (plane coordinates X,Y and heights H).

Figure 1, at the end of this paper, summarizes main steps of this methodology.

2.3.1 Constraints

a. Constraints due to exclusions

Exclusion zones, are intended to habitats (existing or future agglomeration grouping), or soils not favorable to agriculture or terrains of difficult topography. The elimination of these exclusions from the perimeter is made by adding an attribute (called “exclus”) to the table of attributes of the exclusions layer. This added attribute is given a value of one. The union of the perimeter’s layer and the exclusions layer will generate polygons with a field “exclus”, whose values are one or zero. The value one designates all polygons that belong to exclusions and must be eliminated from the processing.

b. Constraint due to imposed axis

The existence of a road infrastructure, canals of irrigation or other natural axis should be taken into consideration in this kind of study. For this reason, the perimeter is subdivided into sectors, separated by imposed axis, each sector will be treated separately.

Because the software used does not allow the superposition of a linear theme to a polygon theme, we have created a polygon theme from the layer of imposed axis, using the Buffer operation with an insignificant distance of 10 cm. A field "Buffdist" having a value X is added to the attribute table of the buffer result. The superposition of this result to the perimeter’s layer creates several polygons. Resulting polygons whose attribute "Buffer" equals to X, have to be eliminated. Then, for the purpose of processing facility, each sector is saved in its proper theme.

c. Constraint due to irrigation method

The irrigation method used is a very important constraint in the establishment of a hydraulic framework. The chosen irrigation method in our study depends directly on the heights of the terrain. For this reason, spot height survey that represents all the perimeter of study is necessary. From this data, Digital Terrain Model (DTM), slopes and aspects can be derived.

2.3.2 Direction of Flow

a. Aspect

Direction of flow will serve for the aspect of the future blocks and consequently for the layout of different networks. The aspect’s map of the zone is established by creating a raster mask of pixels having the same value 1 inside the zone, and multiplying it by the aspect’s map of the perimeter. This resultant pixels will be classified according to their aspect values. Then, the weighted mean of the classes and the number of pixels of each class, will give the direction of the flow.

b. Adjust the grid

After that, the program applies a change of the origin of the coordinate system for each sector, such that the Y axis is parallel to the determined direction of flow. From the left low extremity (X0, Y0) and dimensions of the typical block (L, l), coordinates of typical blocks constituting the grid, are calculated. The typical block grid is drawn in a theme, the Clip operation between the grid’s theme and the sector’s theme is accomplished. Then, using the obtained result, the program calculates the area of residual polygons. Residual polygons are small blocks that should be merged with common blocks.

Afterward, the grid is moved by values Dx and Dy, the Clip operation is repeated iteratively and the sum of the residual polygons is recorded. The best adjusted position of the grid is the one that gives the minimum of the sum of residual polygons. Next, residual polygons from the preceding adjustment, are merged with common blocks.

2.3.3 Drawing the Final Layout of the Framework

Once all required public use land axis and their characteristics are known, the program subtracts from the perimeter the areas that are going to occupy public use land. To reach this objective, the program makes an union of various sectors in one theme, then, it creates a Buffer for network axis. These two themes are superposed, and the resulting buffer polygons are eliminated. Finally, the obtained result is the final layout of the hydraulic framework.

3. CASE STUDY DATA

To apply this methodology, we have chosen data from the perimeter of Abda & Doukkala in the west of Morocco. The chosen sector has an area of 320 ha and presents the following characteristics (S.E.T.A., 1997):

- All constraints demanded by the program, are present in the sector chosen.
- The terrain has a regular topography.
- The study and the execution are already realized by the conventional method.
- Block-type has the following dimensions : Length =360 m and width =300 m.
- Available data are: limits of sector, exclusion data, road axis and spot height data.

4. DISCUSSION OF RESULTS

Applying developed programs to these data, we obtain the blocks of irrigation illustrated by figure 2. The comparison of the obtained results to those obtained by conventional methods reveals several improvements. The main advantages of the GIS methodology can be summarized in: time benefit, quality of results, and access to information.

4.1 Gain of Time

With the developed interface, the main steps of a hydraulic framework can be realized in a very reduced laps of time. With digital data of this study case, the program requires an average execution time of 2 hours, using a PC Pentium 166Mhz (32 Mo of RAM). This extent is essentially due to the manipulation of various dialogue boxes, menus and buttons, and to the execution of some procedures. The procedure of adjustment of the grid takes the longest time in execution, it represents 50% of the total execution time. It is mainly due to the number of iterations undertaken to obtain the best adjusted position of the grid.
Using the conventional method, the extent time varies according to the area of the perimeter and to its topography, but it remains always very superior to the time recorded above.

4.2 Results Quality

The estimation of the obtained results quality could be judged based on the following elements: methods of data acquisition, quality of source data, processing procedures and presented documents quality. On the other hand, we could appreciate the quality of any hydraulic development project, by comparing the occupied area of required public use land to the total area of the perimeter. For a well designed hydraulic framework, this area should be contained between 15 and 20% of the total area of the sector. In our case study, the area occupied by required public use land represents 15,53% of the total area of the sector. Because of lack of data, we were unable to evaluate this area for the conventional method.

4.3 Access to Information

The interface developed allows a simple and rapid access to various data. The user can undertake different processing in a simple manner with a minimum set of parameters. Indeed, most of processing are launched by one command, except for the layout where the intervention of the user is needed several times.

The access to diverse information is facilitated by several menus, buttons and specific tools. With simple manipulations we can access any desired information in few seconds. While with the conventional method, this kind of operation may need several research and manipulations.

5. CONCLUSION

In this paper we have presented different steps of a GIS application to establish an hydraulic development framework. In this study, an interface using Avenue programming language of ArcView was developed. This interface permits to integrate several constraints involved in an hydraulic development project. It also allows introducing, processing and analyzing graphical and attribute data of this kind of project. The study case was applied to a regular terrain. Results show that the integration of GIS in the establishment of hydraulic development plans could improve the achievement and the management of irrigation projects in Morocco. However, the programs should be completed to take into account irregular terrains.

REFERENCES

El Fadili M. and El Maftouhi T., 2000, Apport des SIG dans l'établissement du canevas hydraulique, thesis of third cycle, IAV Hassan II, Rabat, Morocco.

ESRI, 1996 (a), Arcview GIS, The geographic Information System for everyone, Environmental Systems Research Institute, ESRI, Inc., Redlands, USA.

ESRI, 1996 (b), Avenue GIS, Customization and application Development for ArcView GIS, Environmental Systems Research Institute, ESRI, Inc., Redlands, USA.

ESRI, 1996 (c), ArcView Spatial Analyst, Advanced Spatial Analysis Using Raster and vector Data, Environmental Systems Research Institute, ESRI, Inc., Redlands, USA.

ESRI, 1996 (d), ArcView 3D Analyst, 3D surface creation visualization and analysis, Environmental Systems Research Institute, ESRI, Inc., Redlands, USA.

Mitchell A., 1999, The ESRI guide to GIS analysis, Vol. 1, Geographic patterns & relationships, ESRI, Inc., Redlands, USA.
ORMVA, 1992, Périmètre Haut service des Abda Doukkala, Etude d'équipement de la deuxième tranche d'irrigation , Canevas hydrauliques, Note explicative.
Rhind, D.W., 1990, Global data bases and GIS, In Foster and Shand ed., the association for geographic information year book 1990, pp. 218-223, London, Taylor and Francis,.
Semlali E.H., 1999, La géomatisation des projets de remembrement rural au Maroc Essai de conception et d'implantation , Laboratoire SURFACES, University of Liège, Belgium. S.E.T.A., 1997, Data of sector 2-1, Abda Doukkala.
Yacoubi, S.M., 1995, Aménagement hydraulique au Maroc : situation actuelle et programme national de l'irrigation., Homme Terre et Eau, Volume 24, June 95.

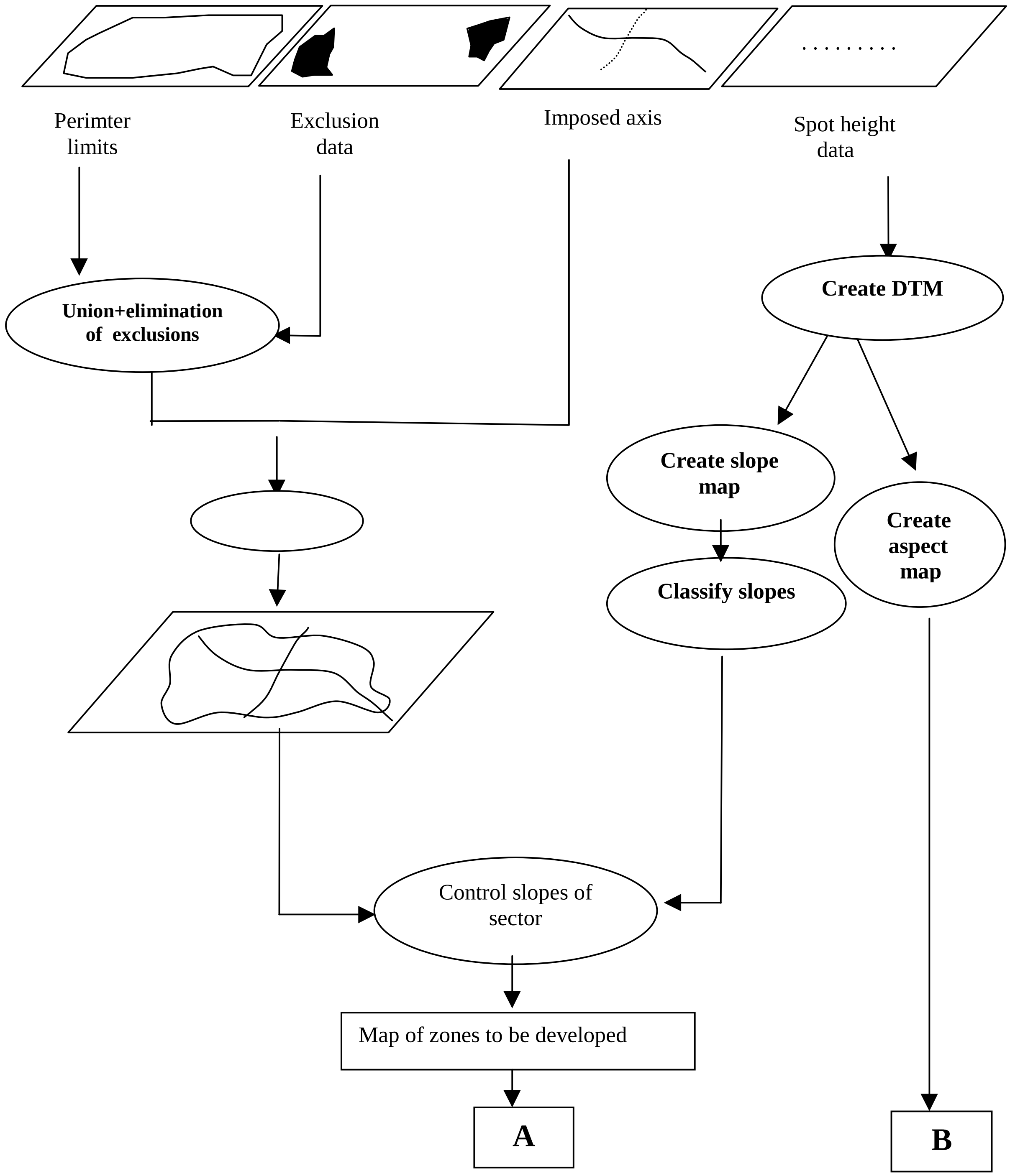

Figure 1. Flow chart of GIS methodology

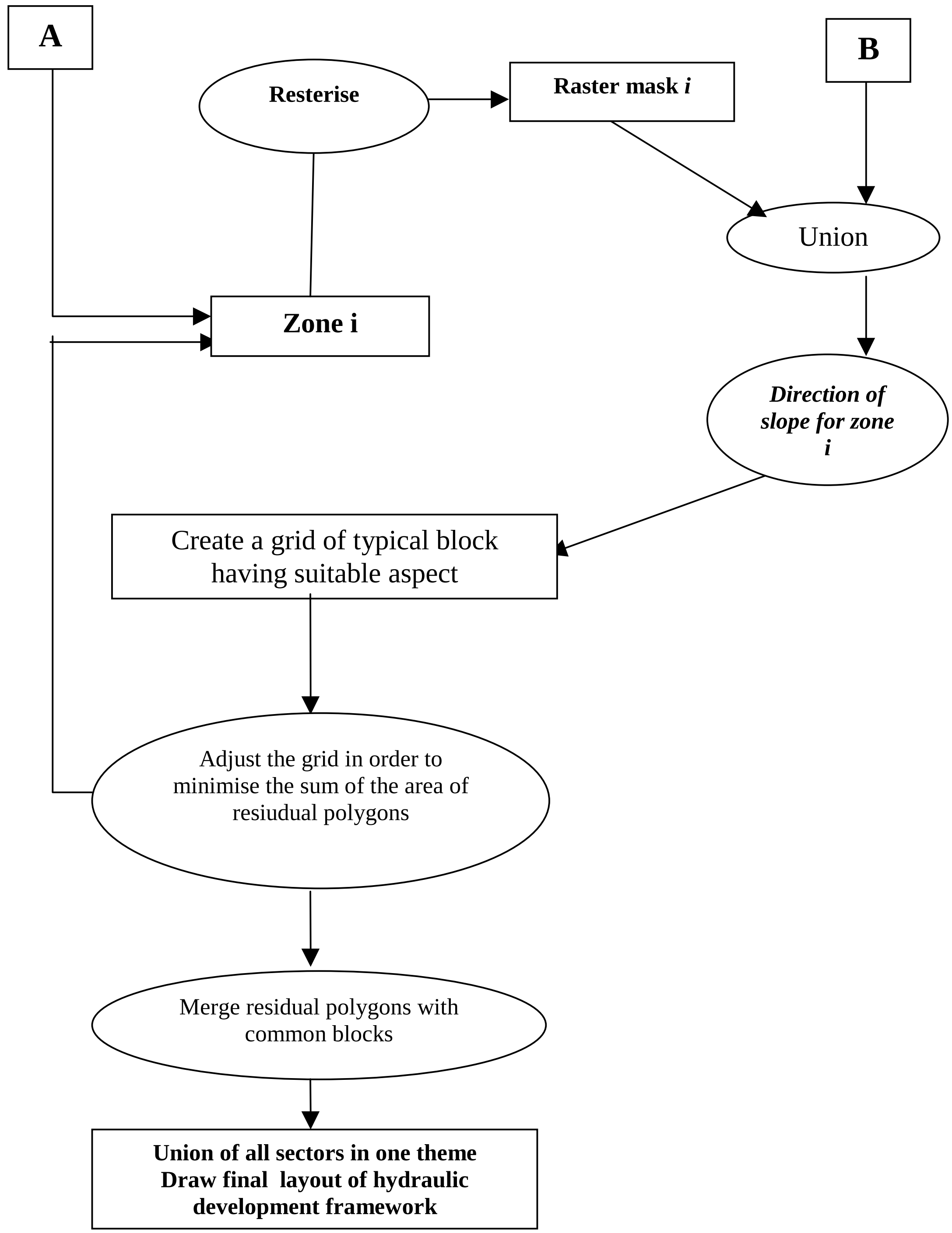

Figure 1. Flow chart for GIS methodology (continued)

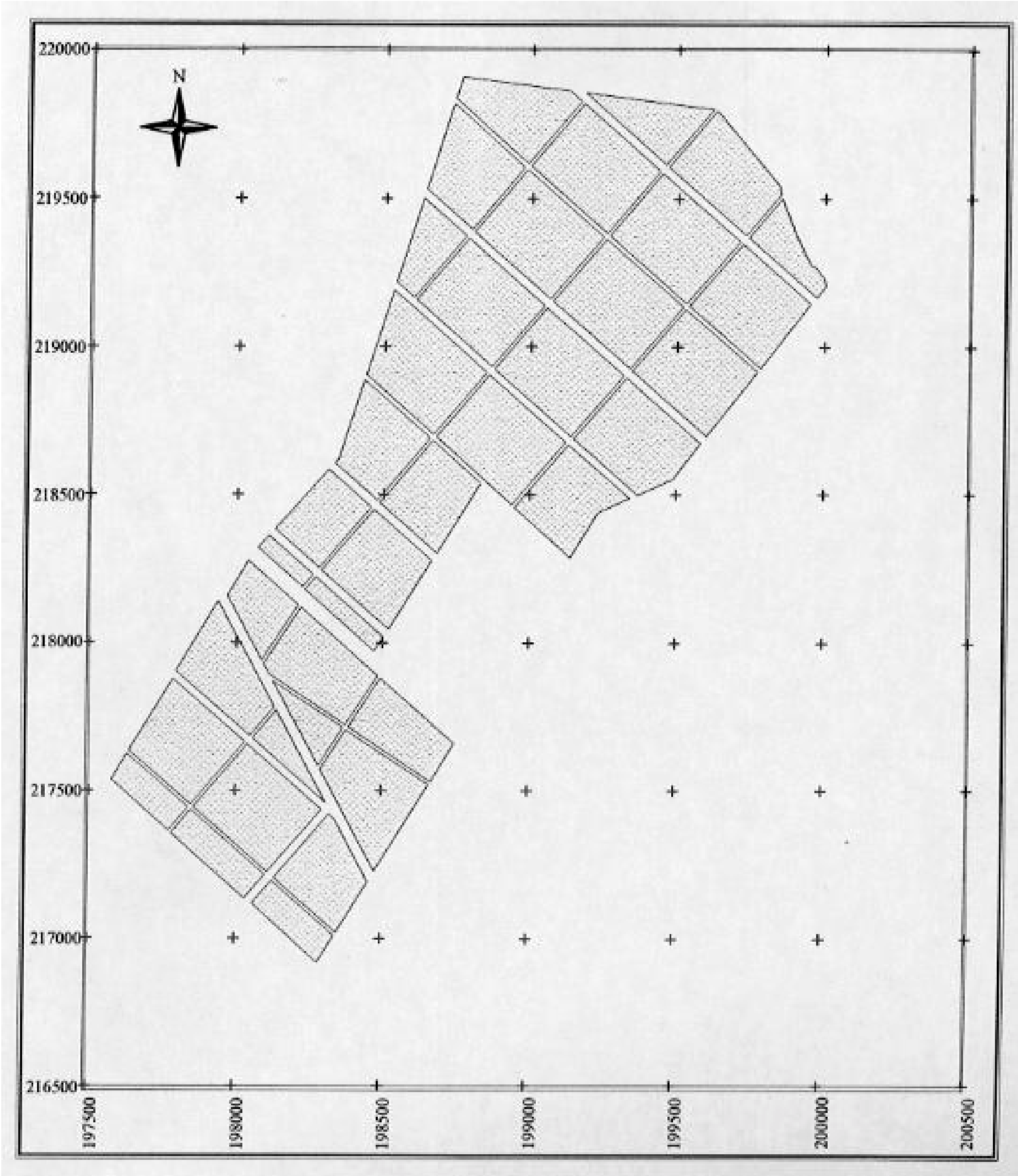

Figure 2. Irrigation blocks of a hydraulic development framework

BIOGRAPHICAL NOTES

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Qualification and career

1979: Diploma of engineer in surveying from IAV Hassan II, Rabat, Morocco
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1999: Doctorate of Sciences from the University of Liege, Belgium.
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