GIS-Supported land consolidation planning information system: ARTOP

S. Tülin Akkaya Aslan and İ. Arici

GIS-gestütztes Informationssystem für die Flurbereinigungsplanung: ARTOP

1 Introduction

Agriculture plays an essential role in restructuring and country planning. However, the agricultural world is under economic pressures that affect the efficiency of landowners. To ensure good productivity, the farmer needs his land to be spatially well organised and well equipped. To use the agricultural land most efficiently, it is important first to understand the area by collecting together all the available information. These types of data are continuously increasing, making their management and manipulation increasingly difficult, but the recent development of Geographic Information Systems (GIS) technology renders the task easier and can make a significant contribution to the improvement and management of agricultural land (SEMLALI, 2001).

Land consolidation is a highly complex spatial planning process because it involves many tasks, actors (landowners,

Zusammenfassung

Für die Flurbereinigungsplanung und ihre Entwurfsstudien werden unzählige und verschiedenartige Daten benötigt. Der Datenumfang nimmt mit der Größe der geplanten Fläche zu. Für schnellen und zuverlässigen Zugriff und verwendung der Daten – sei es auf Dorfgemeinschafts- oder Einzugsgebietsebene – müssen diese mit Hilfe spezieller Computersoftware gesammelt, eingegeben, organisiert, verglichen, nachgefragt und analysiert werden. In der vorliegenden Arbeit wurde mit Hilfe der Fähigkeiten und Eigenschaften des GIS-Programmes für die Planung und den Entwurf der Flurbereinigung großer Flächen das sog. ARTOP-Modell entwickelt. Durch Eingabe der Daten von 10 Dörfern in der Bursa-Karacabey-Ebene in der Türkei wurde das Modell getestet und hinsichtlich seiner Anwendbarkeit und Effektivität beobachtet. Indem man das Modell Benutzern in verschiedenen Stadien vorführte, wurden seine möglichen Probleme und Schwachstellen bestimmt und entsprechende Verbesserungen vorgenommen.

Schlagworte: Flurbereinigung, Planungsinformationssystem, GIS.

Summary

A large amount and different types of information are needed for land consolidation planning and design studies, and the volume of information increases with the size of the planning area. In order to access and use information fast and reliably in land consolidation planning studies, be they based on village groups or entire river basins, it is necessary to collect, enter, organise, compare, query and analyse the information using specialised computer software. In this study, a model called 'ARTOP' has been developed to help in the planning and design of land consolidation in large areas, using the capabilities and characteristics of Geographic Information System (GIS). By entering data from 10 villages in the Bursa-Karacabey plain (Turkey), the model was tested and its usability and effectiveness observed. By presenting the model to operators at various stages, its potential problems and deficiencies were determined and corrections accordingly made.

Key words: Land Consolidation, Planning Information System, GIS.

rural engineers, local and regional administrations, consultants), and a high volume of information (BANGER, 1992; TOURIÑO et al., 2001).

In order to ensure that land consolidation is appropriate for the uses planned, it is necessary first to gather sufficient information and to store and organise it efficiently, so that the data can be compared and used repeatedly, and in a variety of ways. (HOISL, 1982; KIK 1990; STARK, 1993).

HOISL and STÜTZER (1988), have researched the wide range of relationships and structural variations in the information used in land consolidation planning studies and have established that there are many connections. However, it has been seen that relationships between the more complex types of information may result in work being concentrated in one area and information being lost in another. To prevent this, a computer and GIS assisted system has been developed.

ESSADIKI et al. (2003) developed a new approach and a new conceptual methodology using GIS, that considers all types of data involved in a rural land consolidation project (e.g. soil types, social and economic surveys, and spatial data), and established a specific GIS prototype for the purpose of solving the issues of land consolidation in general, and land reallocation in particular. Significantly, the development of models for land consolidation based on GIS will support decision makers and respond to present and future needs.

Although land consolidation studies have previously been carried out in relation to large irrigation schemes (of great benefit in a semiarid region like Turkey), they are most frequently practised at the village scale. This is because land consolidation projects require intensive labour and time. Consequently, land consolidation studies can be performed only in certain regions and limited areas, independent of irrigation projects, and without consideration of integration. When working in large areas such as an irrigation area, it is divided into smaller units making consolidation both time-consuming and expensive. As for working in new irrigation areas parallel to, but independent from the irrigation project, consolidation is unable to match the pace of the irrigation project. This situation creates big problems for both land use planning and irrigation projects (ARICI, 1994; AKKAYA et al., 2002).

In this study, a model has been designed which facilitates rapid and reliable access to the information needed for land consolidation planning and designing studies, stores the information on computer (making the planning and designing easier), organises the information to a standard format (in order to be able to compare all data), and analyses the information according to specific objectives. The model has been developed in Arc-Macro programming language called ARTOP. Using this model it is possible to carry out planning studies fast and accurately, either together with, or independently from irrigation projects.

2 Software

In this study, GIS software *ArcInfo Ver 7.1.2.* and *Arc Edit, Grid* and *ArcPlot* modules were used (ANONYMOUS, 1997). Due to the complexity of the land consolidation process, the use of a data analysis tool is vital for accomplishing all the distinct planning steps. In this study a model was developed using the Arc Macro Language (AML) based on PC ARC/INFO (ANONYMOUS, 1994). This model is capable of dealing with the complex tasks of information organising, processing, querying, analysing, displaying and archiving, all of which is spatially referenced. The input data can be edited in various ways and displayed in tables. Many inputs and outputs can be displayed graphically and printed as reports. All the geo-referenced information (inputs and outputs) can be displayed as maps through the GIS facility of ARTOP.

3 The ARTOP land consolidation information system

The ARTOP land consolidation information system has been developed in order to organise the huge amount of information collected during land consolidation planning, to facilitate the comparison and consideration of different types and combinations of data and thus help project engineers in making their decisions. By this means, land consolidation planning studies covering large areas can be prepared rapidly and reliably.

There is an increasing need to undertake rapid consolidation studies. For instance, in Turkey, basin-wide or village group studies in relation to irrigation schemes are being considered. However, as these studies will contain more than one village, or maybe even more than one district, consolidation work will become increasingly complicated to carry out.

For this reason the information system has been set up to deal with large areas and to follow the accepted land consolidation procedure. The system provides an organised

way to enter and store information, the facility to view, relate and compare different combinations of information graphically, and to carry out analysis to facilitate planning. The ARTOP information system is comprised of three main modules:

- *Basic Information System* – for data on current land use and ownership,
- *Planning Information* – for drafted plans and projects in the project area,
- *Assessment (Analysis)* – where the basic and planning data are organised and combined (Figure 1).

In the following sections of this paper these modules are discussed in greater detail.

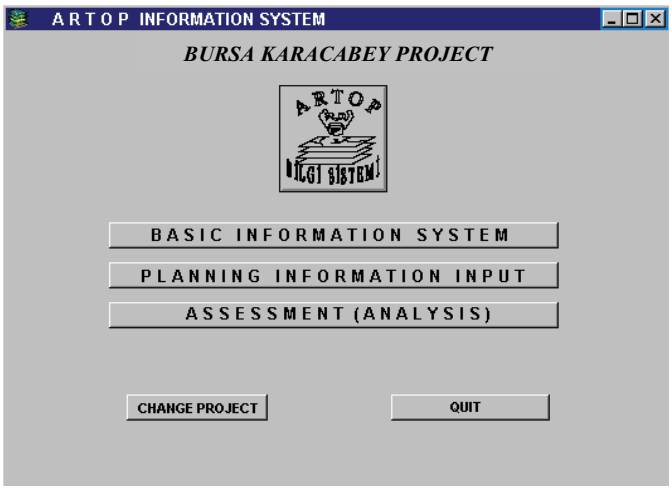

Figure 1: A screenshot of ARTOP information system
Abbildung 1: Bildschirmausschnitt des ARTOP-Informationssystems

3.1 "Basic Information System"-module

The Basic Information System is where the information that forms the foundation of land consolidation projects is entered (Figure 2). Once entered, the information can be checked, reorganised and adjusted as necessary. Information can be entered both directly and by transferring digital information to the system from other environments. Thus information in other databases can be gathered together in ARTOP. In land consolidation, information on property such as land registry and plot boundaries, topography and soil types are all basic information. It is extremely important to check these pieces of information against one another, to correct mistakes and fill in gaps before analysis takes place. The ability of GIS to connect graphic and non-graphic information is fundamental to this module. As GIS is a programme designed for broad and multipurpose use, its direct use in land consolidation planning is not easy, and it was for this reason that a specifically designed module was developed. The system thus provides a standard format for data input which is faster to use, and less prone to errors.

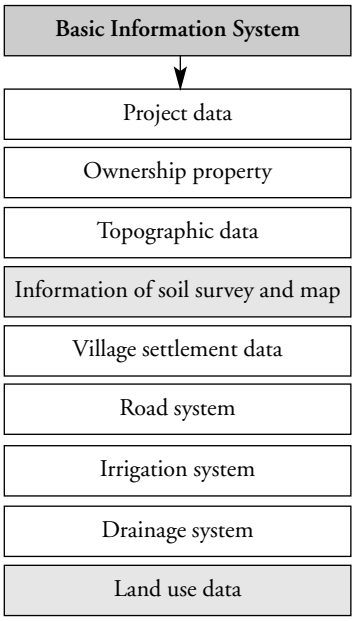

Figure 2: Chart the Basic Information System Module
Abbildung 2: Diagramm eines Grunddaten-System-Moduls

As graphic and textual information are stored in different formats, it is essential to check their compatibility. Thus, after entering property information, the data must be queried and checked in a variety of ways; various options are possible within the software.

1. In land consolidation studies, it is important that the graphic information and all data related to it are complete. The software thus provides the option '**incomplete data control**'; when selected this finds and lists all the parcels for which no data has been entered (Figure 3).
2. Under the '**parcel search**' option searching is done by parcel number. With this it is possible to search for just one, or sets of parcel numbers. On the screen, parcel numbers and colours can be adjusted. Since no interviews have yet taken place with farmers during land consolidation studies, it is not likely that one can identify agricultural areas accurately. The number of people in the project area is determined by giving a single farm number (where the owner's name[-surname] and father's name are all the same) to those parcels which appear to be owned by the same individual. Further, 'farm conditions' are approximated with the help of the village head-

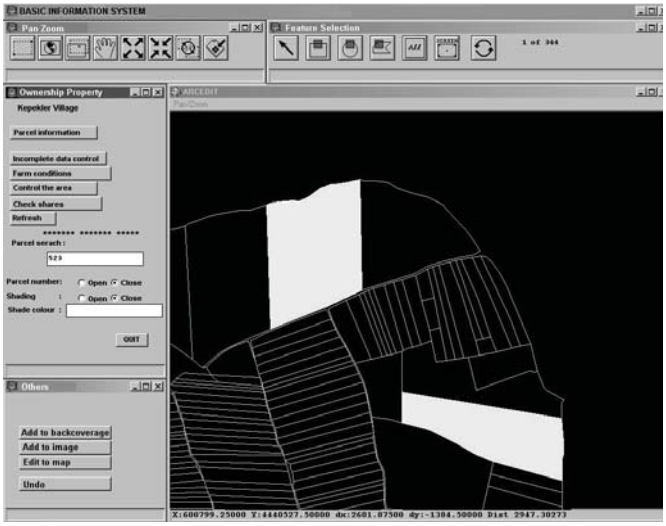

Figure 3: A screenshot of Ownership Property option
Abbildung 3: Bildschirmausschnitt der Grundeigentümer-Option

man, or the water-user associations in projects where irrigation is underway. Under these circumstances, another farm list is made.

3. Under the '**control the area**' option, those parcel sizes that have been calculated from map areas are compared with the parcel values obtained from the land registry information to check that the area values are the same or within a certain margin of error. Where values are above or below the acceptable margin they must be re-checked against the original input data.
4. In the parcel information, the individual shares must add up to one. If the total of shares is more than one this indicates that the same data has been entered more than once, and if it is less than one, it means that some data is missing. In either case the data needs to be checked and corrected. This can be done with the '**check shares**' option and the amount of missing and surplus shares determined fast and easily. If the data is entered manually (as opposed to imported from another programme), the share check is done automatically during data input.

For topographic data, the altitude of each contour line is either input to the system manually or digitised by the system. This information is used in planning studies to make some specific analyses in special enquiries. These data also make it possible to produce a digital elevation model of the project area.

By combining soil survey and map information, the special features of each soil group can be defined and form the basis of land evaluation in land consolidation projects. Soil texture, soil profile group, soil depth and land slope are the important parameters to enter.

For the village settlement data, maps showing the areas subject to land consolidation, and information on the locations and boundaries of administrative districts, towns and villages, and construction areas are entered. If village renovation studies are carried out alongside land consolidation, this information may be detailed.

For each road in the network, information such as the name of the road, its classification (village road, major road, motorway, etc.) and its surface are entered.

Before any planned irrigation or drainage scheme or land consolidation project, information regarding the current irrigation and drainage system in the project area are collected and entered. For each canal system, start and end geographical points are defined. For each canal detailed information is entered; how water is circulated and distributed, the name of the canal, its size, extent of expropriation, type of canal lining, its capacity, water depth, and the maximum distance over which water flows. This information is particularly useful for block planning in land consolidation projects.

Under land use data, the two options of '**fieldwork**' and '**evaluation of satellite images**' are provided in order to define the means by which land use has been identified. If it is possible to carry out a survey in the project area, for instance if an irrigation scheme is in operation, then 'land use' can be identified directly from fieldwork data. If land use has to be derived remotely, via interpretation of satellite images and vegetation classification using image processing software, the information finally transferred to the system is unverified by ground-truthing and thus less reliable than other data in the system.

3.2 "Planning Information Input" module

During land consolidation projects, various plans and projects are drafted. These can include various changes to the present system or suggestions made after consolidation land use planning, and include new irrigation or drainage systems, roads, land levelling, conservation areas, village renovation, landscape and sports areas, etc. The number of plans increase according to the characteristics of the area involved (Figure 4).

Within the Planning Information system new planning issues can be added to those which already exist, and existing plans can be deleted or adjusted.

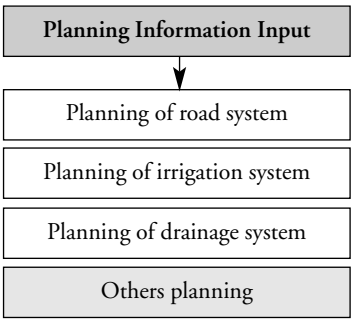

Figure 4: Chart of "Planning Information Input"
Abbildung 4: Diagramm der Planungsdateneingabe

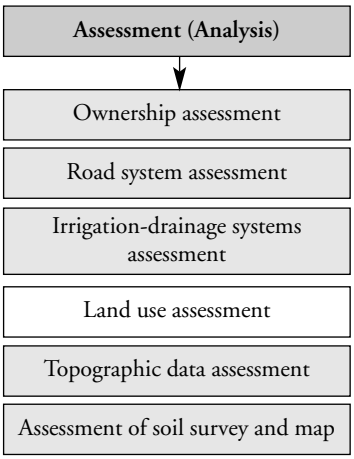

Figure 5: Chart of assessment
Abbildung 5: Bewertungsdiagramm

While working on the Planning Information input module, all the information already transferred to the system can be used to facilitate, and be evaluated in planning studies. For instance, when a new irrigation system is being planned, it is possible to obtain and combine information on soil characteristics, a topographic map or digital elevation model and land area. When the information is queried and displayed, fragmentation and the size of properties in the planning area rapidly become evident.

3.3 "Assessment (Analysis)" module

Here the data entered in the ARTOP information system are evaluated in reporting formats which have been prepared following experience in previous planning studies for land consolidation. By evaluating the information the decision whether or not in each project can be carried out. The module includes consideration of the titles of property, irrigation and drainage systems, road networks, land use, the soil survey map, and evaluation of the topographic map. The number and scope of assessments can be increased according to the characteristics of the project (Figure 5).

1. Under the '**ownership assessment**' option, distribution of the size of parcels in the work area, the legal status of jointly owned parcels and the distance of parcels from the centre of the village are evaluated.
2. In '**distribution of the size of parcels**' option, by relating the scope of cadastre and the property information chart, areas are classified to give the total area in each class and the total number of parcels (Figure 6).
3. In '**utilisation of shared parcels**' option, the value of each parcel portion is checked using the relationship between the scope of cadastre and the property information chart; if the parcel is jointly owned, the number of shareholders is determined and the parcel is classified according to its joint ownership. The classification follows: 1, 2–4, 5–7, 8–10 and more than 10 portioned parcels. The total number of parcels in each class and their area are estimated by village or project area.
4. Under the '**distance from the centre of village**' option, since there will be more than one village in a project area and every village will have a different settlement centre, to facilitate the process the project area is divided into work areas comprised of individual villages. Thus the central point of all the parcels within the village settlement area is found, and the distance of each parcel from this point is calculated. The parcels are then classified according to distance; 500 m, 500–1000 m, 1000–2000 m, 2000–5000 m, and more than 5000 m, and the total number and area of parcels in each class are calcu-

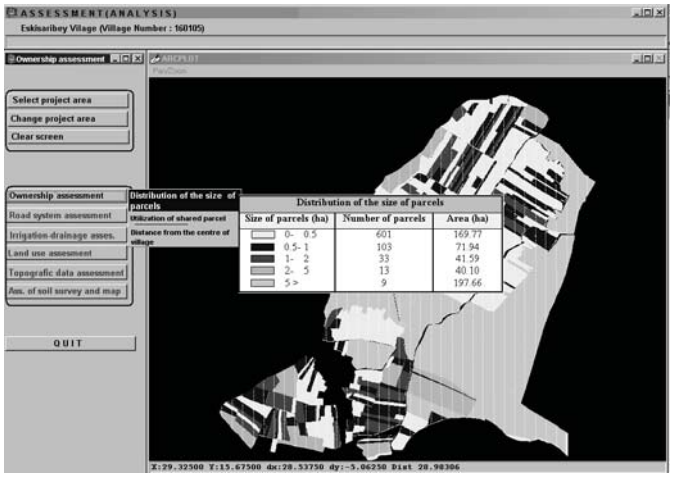

Figure 6: A screenshot of ownership assessment
Abbildung 6: Bildschirmausschnitt der Eigentumsbewertung

lated. The distance of each parcel from the village centre is stored in an info file.

5. In the '**road system**' evaluating option it is possible to make evaluations at the level of the whole project or of individual villages. The evaluations are twofold: existing road systems and planned road systems. Included are the total length and area of all roads, and the number and areas of the parcels in the project/village area able to use them.
6. In the '**irrigation-drainage system**' option, as in the **road system** option (above), evaluations can be made at both the individual village and whole project level. Evaluations can also be of existing or planned irrigation and drainage systems (Figure 7). Under this option the data considered are, existing or planned, total length and area of canals, and the number and areas of the parcels in the project/village area able to use them.

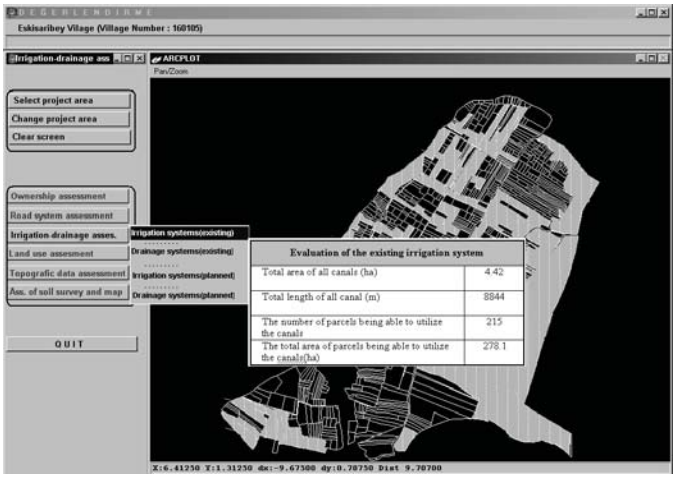

Figure 7: A screenshot of irrigation-drainage system assessment
Abbildung 7: Bildschirmausschnitt der Bewertung des Bewässerungs- und Drainage-Systems

7. Under '**land use assessment**' the information on land use obtained from fieldwork or the satellite images are assessed. This option handles general land use in either the whole project area or individual villages, together with land use in the individual parcel area. Where land use information is available at the parcel level, information on the crop pattern and the area of each parcel can be stored to a file if wished.
8. In the '**topographic data**' assessment option, a digital elevation model (DEM) of the project area is created by using the contour data entered into the *Basic Information System.* The DEM and topographic maps with contour lines at varying intervals are used in the design and study of new irrigation, drainage, road and land levelling plans.
9. The '**slope groups**' option facilitates assessments to determine the land's slope groups
10. The natural flow direction according to the topography within the project area is determined using the option '**natural drainage network**'.
11. With the '**assessment of soil survey and map**' option, an assessment aiming to determine problematic areas according to soil characteristics can be made. Again this assessment can be done at the level of project or village. It is also possible to produce a special map classified according to soil features.

4 Results and discussion

The aim of this study was to develop an information system which stores, organises and analyses planning information; this was achieved using GIS software.

The model was tested using data from 10 villages in the Turkey-Bursa-Karacabey irrigation project. The model was presented to various establishments at different stages in the land consolidation process, and thus a range of problems and deficiencies were identified and corrections accordingly made.

While creating the model, the aim was to use a common database independent of standard GIS software, which was compatible with existing land consolidation systematics and easy to use. As a result, a system which can be used extensively throughout Turkey has been developed. Thus a user working on land consolidation but unable to use GIS will nevertheless be able to create a database, make analyses and assess planning in large areas, thus producing good comprehensive projects – all with the help of the model.

Since the map and textual information in the model are related to each other, various controls have been developed in order to check for data entry errors. These facilitate rapid and easy data control.

With the topographic information in the system it is possible to generate topographic maps showing preferred levels according to the needs of land levelling, land evaluation, irrigation, drainage, and road system consolidation studies.

The chief advantages of the model are as follows:

1. It will be easier to assess the conditions under which projects are being planned and designed, and thus the effectiveness of each project will increase.
2. As the use of technology in land consolidation studies increases, the time needed for land consolidation will decrease, and the cost of each project will be reduced.

3. It will be easier to carry out planning and designing studies using a private company or engineering offices and this will speed up project implementation. The system will actively help planners during studies of large areas, and will make it possible to classify and examine a large amount of information according to the needs of the planner. Thus, planning and designing will be easier.
4. As the model starts to be used, it will be possible to prepare projects on land consolidation covering groups of villages or river basins as well as in large irrigation projects. With this system, land consolidation planning studies can be prepared parallel to new or existing large irrigation projects and this will increase the demand for project development services. Land consolidation studies need no longer be restricted to the village scale, and the spread of high quality, reliable studies through the country will increase. Further, it will be possible to carry out land consolidation in irrigation projects more fairly.
5. Going beyond traditional land consolidation studies, it is now possible to carry out rural area planning and integrated projects.
6. By creating a river basin wide information system, the information needs of other associations and foundations can easily be met. The time needed for the studies carried out by these associations will become shorter and cost of work will decrease.
7. The model can readily be added to or altered. Any further problems or deficiencies discovered in use can be solved by adjustments to the software.
8. When the cadastre renovation studies are completed throughout the country and the cadastre information system, topographic maps and digital elevation models are transferred to computer, transferring data into the system will become easier, making future assessments faster and more reliable.

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Address of authors

Dr. Ş. Tülin Akkaya Aslan, University of Uludağ, Faculty of Agriculture, Department of Agricultural structures and Irrigation, Gorukle, 16059 Bursa/Turkey
E-Mail: akkaya@uludag.edu.tr
Professor Dr. İsmet Arici, University of Uludağ, Faculty of Agriculture, Department of Agricultural structures and Irrigation, Gorukle, 16059 Bursa/Turkey
E-Mail: arici@uludag.edu.tr

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