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STATISTICAL APPROACHES IN GIS-BASED TECHNIQUES FOR SUSTAINABLE PLANNING: KAYAÇUKURU CASE

Abstract: *There are many empirical studies related to the use of GIS technologies. However, an attention still needs to be paid on the use of statistical tools within an integrated GIS-based medium especially for complex processes like sustainable planning. This paper makes particular emphasis on the use of statistical analysis tools in such a medium. The analyses explained in this paper, comprise a part of the developed "loose-coupled" "decision/planning support system" for a case study on Kayaçukuru Plain to explore the contributions of this approach in sustainable planning. In this paper, the used statistical analytical tools are explained within the structure of the developed system and their results are evaluated for assisting in sustainable planning process.*

Keywords: *Sustainable development, decision/planning support system, non-spatial and spatial statistical analyses, statistical testing, modelling.*

1. INTRODUCTION

Although an explicit definition of sustainable development has been made in "Our Common Future" (WCED,1987), its exact criteria are still undefined. However, planning process to achieve such development requires efficient and effective use of resources, respect to cultural heritage, and to be a friend of nature and agriculture. This calls for not only at a time coordinated management but also analysing many variables with many criteria.

These requirements can be approached by one of the four types of GIS-based urban modellings (Sui,1998). In this paper, the loose coupling type of these modellings is developed as a decision/planning support system (Batty,1992; Batty,1995). According to Sui (1998) loose-coupling involves a standard GIS package and an urban modelling program or a statistical package. Urban modelling and GIS are integrated via data exchange among several software packages without a common user interface.

The loose-coupled framework developed here, includes mainly the components of Geographic Information System (GIS), Statistical Package (SP), Relational Database Management System (RDBMS) and Models, which are Multiple Linear Regression produced in the SP and Mathematical Linear Combination and Hansen Gravity/Potential Models produced outside. This integrated framework enables the spatial and non-spatial data to be processed in a more efficient and effective way.

The purpose of this paper is to show that the statistical analyses performed within such a framework particularly valuable in sustainable panning practice. The developed system, and the analytical tools used in this paper are applied on a case area, which is Kayaçukuru Plain. It is a vulnerable place for its natural, cultural heritage, agriculture and tourism potentials situated in Fethiye-Göcek Specially Protected Area in Muğla Province. The tools utilized provide with not only means of understanding and explaining but also means of exploration and prediction for the sustainable planning process of the Plain.

2. METHODOLOGY

Steps followed in the development of loose coupled system are summarized in Table 1.

Table 1. Steps that are followed during study

Step 1	Step 2	
Raw data (Some processed before using, some directly used for checking)	Database preparation	
Spatial: Analog or digital maps coming from the "1/5000 and 1/1000 scale Structure and Implementation Protection Planning" researches (Sönmez,1999) and from the results of "Water Resources Management Project" of the Plain (Doyuran et al,1999)	Spatial: Overlapped maps with attributes under five main map groups:	1: Administrative, Protection, Mapping related (6 layers): Shores, Specially Protected Area boundary, Map index, Regions, Designated protection points
		2: Land-use related (6 layers): Cadastre, Land-use, Buildings, Trees, Squares, Roads
		3: Infrastructure related (3 layers): Power transmission lines, Water distribution system, Wells etc.
		4: Physical (4 layers): Contours, Slopes, Aspects, Faults
		5. Geological, Hydrological (4 layers): Geology, Rivers, Inundated areas, Flood etc. areas
Non-spatial: Questionnaire forms, tabular lists coming from the "1/5000 and 1/1000 scale Structure and Implementation Protection Planning" researches (Sönmez, 1999)	Non-spatial: Relational Database Model with five tables finalized after feedbacks between itself and the Entity-Relationship Model (Silberschatz et al.,1997)	1: Buildings (13 variables): Region no, Building no, Situation, Number of storey, Number of room, Construction date, Ownership, Additional Structures, WC, Drink Water, Building type, Usage, Building quality
		2: Traditional buildings (5 variables): *Building no*, Protection level, Original use, Construction techniques, Changes made
		3: Family (14 variables): Region no, Family no, *Building no,* Household size, Family type, Migration situation, Income resource, Hand artisanship, Local development trend position, Owned farmland in 1000 sqm, Management of the land, Total yearly income in Millions TL, Total yearly agricultural income in Millions TL, Notes
		4: Households (12 variables): *Region no, Family no*, Individuals, Sex, Age, Birth place, Literacy, Education level, Job/Occupation, Work place, Position at job, Monthly income in Millions TL
		5: Local problems (7 variables): *Region no, Family no*, Economic, Environmental, Constructional, Administrative, Infrastructure related
Step 3	**Step 4**	
Databases' Integration	Development and use of the loose coupled decision/planning support system	
Via either Visual Basic Application or Open Database Connectivity		

The fourth step includes integration of mainly four components mentioned: GIS, SP, RDBMS and Models. In this system, the connection between GIS, RDBMS and SP are supported by open database connectivity. One of the two outside Models, the Hensen

Model, required a worksheet medium additionally. The developed loose coupled system can be seen in Figure 1 and the statistical analyses focused in this paper, can be traced through the paths intersecting the dashed red boxes in Figure 1. The advantages of adopting such methodology comes with its potential for utilizing the full capacities of the used systems for coordinated management and detailed analysis of many spatial and non-spatial variables that can be used in one another after being processed.

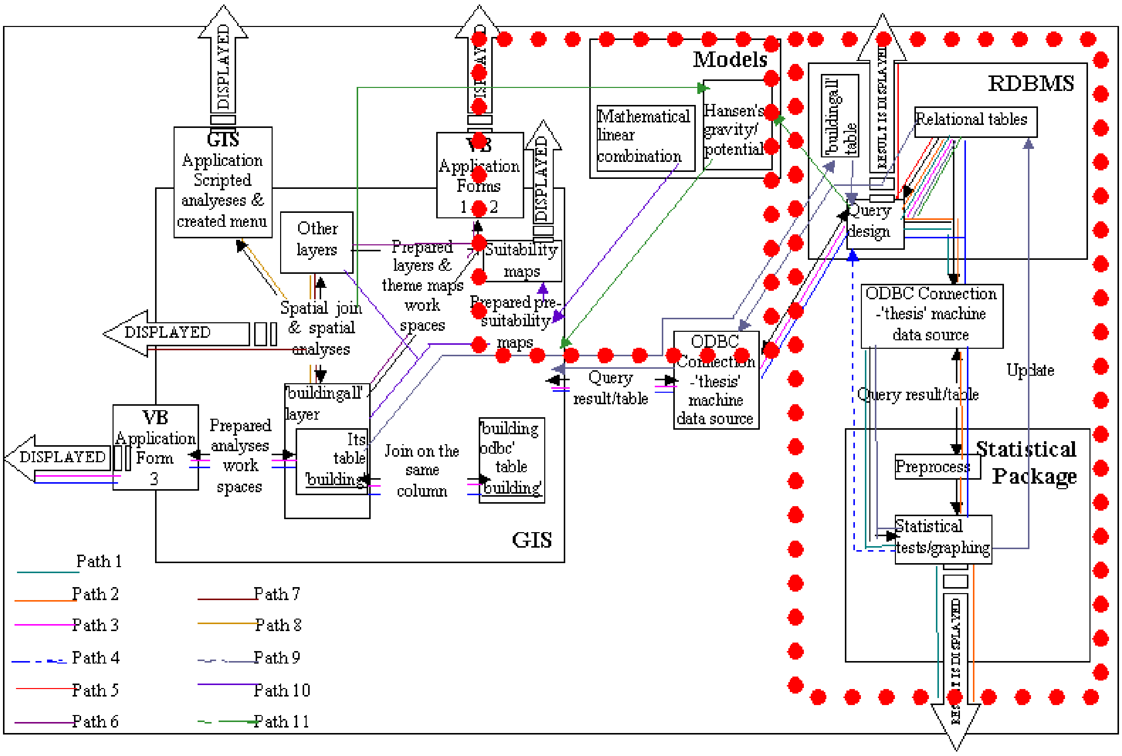

Figure 1. Decision/planning support system via loose-coupling among the systems
Source: Erdoğan, 2000

3. STUDY AREA

The study area (Figure 2), Kayaçukuru Plain, is located in the Fethiye-Göcek Specially

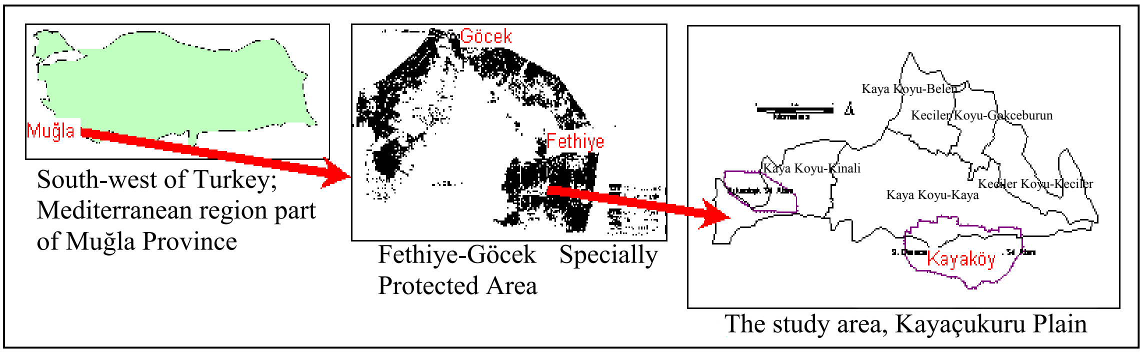

Figure 2. The study area, Kayaçukuru Plain and its location
Source: MI, 1998; ÖÇKK, 1998; Erdoğan, 2000

Protected Area and it is important for its natural, historic, cultural wealth and tourism potentials. The Plain consists of Kaya and Keçiler villages with their small dispersed settlement areas (Kınalı, Belen, Gökçeburun) and agricultural lands. Kayaköy (former Levissi) is an old Turks-Greeks village abandoned after the population exchange in 1922 and is situated in the south-east of the plain (Sönmez, 1999).

The conclusions reached by the various studies carried out for Kayaköy and Kayaçukuru between the early 1980s and the late 1990s are as follows:

- The ecological planning and landscaping works should be finished and 'terms of construction' should be determined to prevent unpermitted restorations, etc.;
- Infrastructure related problems/revisions should be solved/made;
- By restoring the traditional ruin buildings in the plain both some tourism sector development (in the form of village pensions) should be supported and future local population demand should be met to a certain extend;
- Environment friendly approaches like alternative/soft/eco tourism activities, eco-agriculture planning, use of renewable energy sources, recycling and reintroduction of old values like certain types of agricultural production, and hand artisanship should be achieved (Uyar,1995; TB, 1997; KTGK, 1998).

In 1998, the Authority for the Protection of Special Areas gave the task of "Structure and Implementation Protection Planning (1/5000 and 1/1000 scales)" of Kayaçukuru Plain to a city planner, and "Water Resources Management Project" of the Specially Protected Area to Middle East Technical University, Geological Engineering Department in 1999 (Doyuran et al,1999; Sönmez,1999). Although the later project was concluded, the former was still in progress at the time of this study finished. Without trying to accomplish the formal procedures/decisions in preparing this plan, the study utilised almost all the data (Table 1) coming from these two agents.

4. ANALYSES, RESULTS AND DISCUSSIONS

4.1. Descriptive Analyses of Spatial and Non-spatial Data

Non-spatial analyses and their spatial implications covers the results first obtained in the

RDBMS medium and then displayed through either one of the four media of RDBMS, SP, GIS and finally both SP and GIS. In this context, RDBMS medium is useful in visualizing aggregate results that are performed on one or more fields (variables) of the tables (Path 5 in Figure 1). Shortly, they provide results in table form to have opinions about the socio-economic and demographic structure of the Plain. An example is seen in Table 2.

Table 2. Example for analysis of socio-economic structure (average monthly income and count of households for employment statuses)

COUNT of Households	Position at job	AVERAGE(Monthly income in Millions TL)
175	irrelevant/inapplicable	4,65
6	employer	75
45	self-employed	31,39
1	self-employed, employer	120,8
3	self-employed, wage earner	88,43
42	wage earner	83,32

Source: Erdoğan, 2000

The difference of SP medium displayed analyses from the pervious ones is that they have relatively longer RDBMS results to be either graphically represented and/or statistically tested. While some of these analyses follow the Path 2 in Figure 1, some others follow the first one. Examples for these analyses are seen in Figures 3 and 4, respectively.

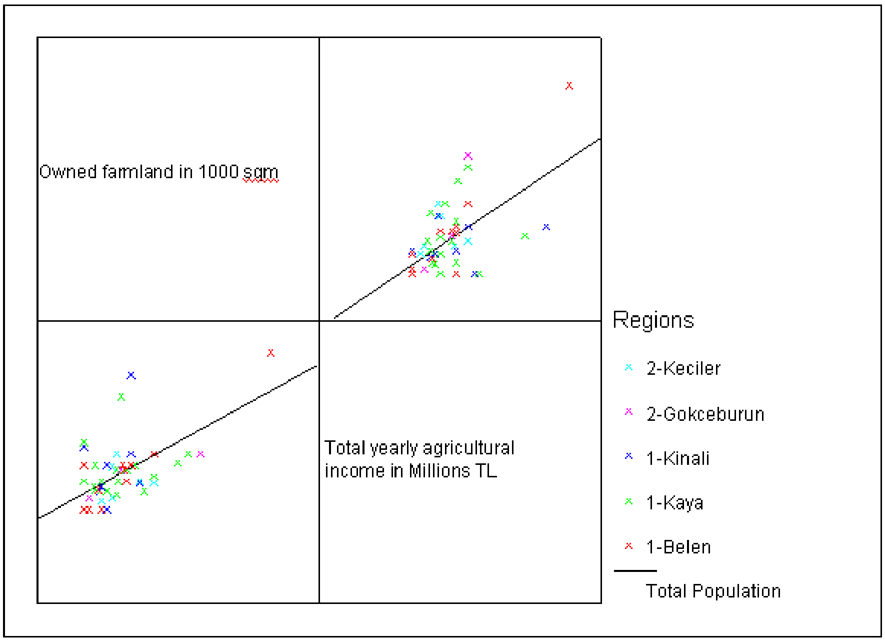

Figure 3. Example for analysis of socio-economic structure (matrix scatterplot of the owned land quantity and total yearly agricultural income)
Source: Erdoğan, 2000

		Owned farmland in 1000 sqm	Total yearly agricultural income in Millions TL
Pearson Correlation	Owned farmland in 1000 sqm	1,000	,605**
	Total yearly agricultural income in Millions TL	,605**	1,000
Sig. (2-tailed)	Owned farmland in 1000 sqm	,	,000
	Total yearly agricultural income in Millions TL	,000	,
N	Owned farmland in 1000 sqm	66	66
	Total yearly agricultural income in Millions TL	66	66

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4. Example for analysis of socio-economic structure (results of 'Correlation' test between the owned land quality and total yearly agricultural income)
Source: Erdoğan, 2000

The analyses that are displayed from GIS are again results of some RDBMS queries of two types: The ones that were directly presented in GIS (following Path 3 in Figure 1) and the ones that were designed after the statistical processing of some preliminary queries and tables in SP (following Path 4 in Figure 1). While the former provided indirect opinions for the planning, the latter in a sense display directly the 'intervention strategies' that may be used for restoration and traditional redevelopment in the short, medium and long terms. The SP analyses prior to RDBMS queries to be displayed in GIS are summarized in Tables 3-6.

Table 3. Tests between 'construction date' (CD) and 'building type' (BT) for "traditional redevelopment" SP analyses

Measures of Degree of Relationship	**Directional/Symmetric Test Statistic**	**Significance Level**
-1<Kendall's tau-b<1	Sym.=0.549	0.00005
-1<Kendall's tau-c<1	Sym.=0.503	0.00005
-1<Gamma<1	Sym.=0.628	0.00005
-1<Somer's d<1	Sym.=0.548; CD Dep.=0.593; BT Dep.=0.509	0.00005 for all

(n=135, N=943)

Table 4. Tests between 'construction date' (CD) and 'building quality' (BQ) for "restoration" SP analyses

Measures of Degree of Relationship	**Directional/Symmetric Test Statistic**	**Significance Level**
-1<Kendall's tau-b<1	Sym.=-0.491	0.00005
-1<Kendall's tau-c<1	Sym.=-0.449	0.00005
-1<Gamma<1	Sym.=-0.681	0.00005
-1<Somer's d<1	Sym.=-0.491;CD Dep.=-0.481; BQ Dep.=-0.502	0.00005 for all

(n=113, N=943)

Table 5. Tests between 'building quality' (BQ) and 'building type' (BT) for "restoration" SP analyses

Measures of Degree of Relationship	**Directional/Symmetric Test Statistic**	**Significance Level**
0<Lambda<1	Sym.=0.203; BQ Dep.=0.304; BT Dep.=0.000	0.00005;0.00005;*
0<Goodman & Kruskal tau<1	BQ Dep.=0.275; BT Dep.=0.292	0.00005 for all
0<Uncertainity coefficient<1	Sym.=0.307; BQ Dep.=0.249; BT Dep.=0.401	0.00005 for all
0<Contingency Coef.<0.87(for4x4 table)	Sym.=0.592	0.00005
-1<Kendall's tau-c<1	Sym.=-0.279	0.00005
-1<Gamma<1	Sym.=-0.861	0.00005
-1<Somer's d<1	Sym.=-0.560;BQ Dep.=-0.781;BT Dep.=-0.437	0.00005 for all

*(n=555, N=943), * Could not be calculated*

Table 6. Tests between 'building quality' (BQ) and 'protection level' (PL) for "restoration" SP analyses

Measures of Degree of Relationship	Directional/Symmetric Test Statistic	Significance Level
0<Lambda<1	Sym.=0.292;BQ Dep=0.192;PL Dep=0.722	0.00005;0.00005;0.001
0<Goodman and Kruskal tau<1	BQ Dep.=0.181; PL Dep.=0.740	0.00005 for all
0<Uncertainity coefficient<1	Sym.=0.325;BQ Dep=0.204;PL Dep=0.787	0.00005 for all
0<Contingency Coef<0.78*(for4x2 table)*	Sym.=0.652	0.00005
-1<Kendall's tau-c<1	Sym.=0.147	0.00005
-1<Gamma<1	Sym.=0.998	0.00005
-1<Somer's d<1	Sym.=0.394;BQ Dep=0.984;PL Dep=0.246	0.00005 for all

(n=464, N=494)

For all of these tests the null hypothesis is set as "The association between those coupled variables is not statistically significant". Except for one result in one test (Table 5), in all of them, the null hypothesis is rejected. According to the results of these tests, the following statements can be made:

- The worse the architectural quality of the building, the more likely that it has been constructed recently or vice versa (see Table 3);
- The older the building, the more likely that it is traditional or vice versa (see Table 3);
- If the building is traditional, it is likely that it is in a deteriorated condition and even in ruins or vice versa (see Table 5);
- It is possible that the older traditional buildings are worse in quality and less protected or vice versa (see Table 4 and Table 6);
- If a traditional building's protection level is low, it is likely that the building has worse condition of construction quality or vice versa (see Table 6).

By utilizing these statements the "restoration" and "traditional redevelopment" strategies for short, medium, and long terms are designed in the RDBMS medium (Figure 5).

```
• • •
RESTOREmap1only
SELECT DISTINCT building.BuildingId, ConstDate, BuildQual, ProtecLevel
FROM building, tradBuild
WHERE ConstDate="1900" AND BuildQual="in ruins" AND
building.BuildingId=tradBuild.BuildingId
UNION SELECT DISTINCT building.BuildingId, ConstDate, BuildQual, ProtecLevel
FROM building, tradBuild
WHERE ConstDate="1900" AND ProtecLevel="none of the required maintanence
made" AND building.BuildingId=tradBuild.BuildingId UNION SELECT DISTINCT
building.BuildingId, ConstDate, BuildQual, ProtecLevel
FROM building, tradBuild
WHERE ConstDate="1900" AND BuildQual="bad" AND
building.BuildingId=tradBuild.BuildingId;
• • •
```

Figure 5. Example of RDBMS medium final results for 'traditional redevelopment' and 'restoration' decisions
Source: Erdoğan, 2000

When Path 4 in Figure 1 is completed, these short, medium, and long term proposals are made ready to be seen in GIS (Figure 6) as long as the data for these fields are available for each building.

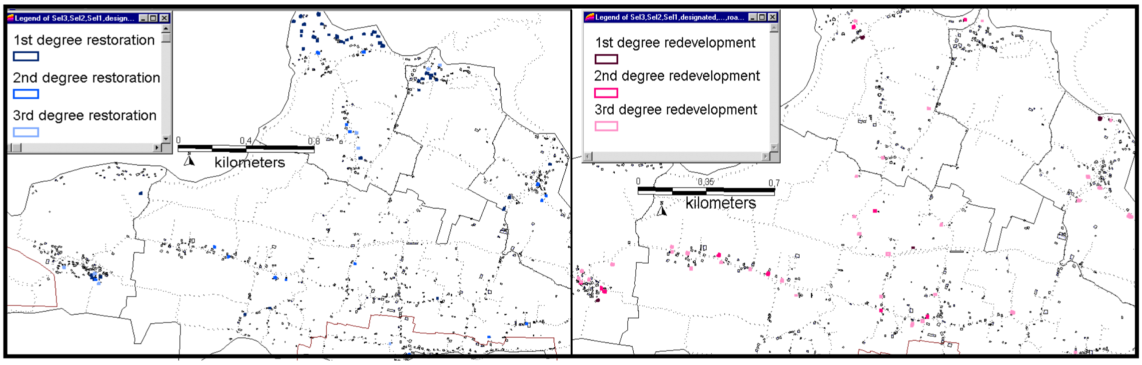

Figure 6. Traditional redevelopment and restoration strategies in the short, medium and long terms for the Plain
Source: Erdoğan, 2000

Similarly, SP (Path 3 in Figure 1) and GIS (Path 1 in Figure 1) displayed RDBMS analyses utilise both media for better exploration and interpretation of their results.

4.2. Predictive Analyses of Spatial and Non-spatial Data

The developed decision/planning support system was further used to give an opinion about how the Plain would appear if it is developed in a sustainable way through predictive modelling approaches. For this purpose, the Preliminary Protection Plan Regulation's principles on meeting a certain amount of future proposed density by restoring and making additions to traditional ruin buildings and conditions for new development are assessed in the first place. The related article is as follows:

“ 1. First, the space is obtained by restoring the traditional ruin buildings,

2. If required, the new development should take place by making additions to the traditional buildings,

A: In old Levissi architectural style settlements by transforming:

a-the simple characteristic planned structures to compound characteristic planned structures

b-the compound characteristic planned structures to group structures,

B: In the Aegean architectural style settlements by transforming:

a-from one space house to one space-sofa house b-from one space-sofa house to couple space-sofa house

c-from one storey-two space house to two storey-four space house

3. Only after these two steps, the new development (traditionally appropriate) would be possible in Kayaçukuru.” (TMMOB, 1994).

First Article was mainly covered in the analyses for restoration strategies (Figure 6). For the Second Article, an example regression analysis modelling and its impacts is given to present the idea of more effective outside processing of data from and into the GIS medium (Path 9 in Figure 1). Since modelling of the Second Article does not exactly follow this order due to lack of such architectural details, only Part B is exemplified with the assumption that the 'building area', 'number of storey' and 'number of room' collectively determine the evolution characteristics of each traditional building in typical Aegean architectural style, and thus the amount of population supply when the density remains unchanged. For this purpose, the incomplete information of the 'number of room' variable for the 'traditional buildings' is attempted to be predicted by performing bivariate linear regression with totally known population data of 'building area' (calculated in the GIS) and ‘number of storey’ variables. However, finally, this variable is predicted by multiple linear regression model of the two others due to their relatively high contributions in explanation (Figure 7).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,570[a]	,325	,318	,6858

a. Predictors: (Constant), AREA, NoOfStorey

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	,664	,192		3,453	,001
	NoOfStorey	1,236	,138	,563	8,985	,000
	AREA	1,941E-03	,001	,085	1,355	,177

Figure 7. Multiple linear regression results between 'room number' with 'area' and 'storey number'
Source: Erdoğan, 2000

Then, each traditional building (for its storey(s) and room(s)) is updated to one level up in its evolutionary trend in RDBMS. In this analysis, the equivalent terms within the 'Preliminary Protection Plan Regulation' (a, b, c respectively in Article 2-B.) were assumed as; from 1 storey 1 room house to 1 storey 2 room house, from 1 storey 2 room house to 1 storey 3 room house, and from 1 storey 3 room house to 2 storey 6 room house. Out of total 494 traditional buildings (N=494), the results are as follows:

- 18 houses can be converted to 1 storey 2 room houses;
- 426 houses can be converted to 1 storey 3 room houses;
- 12 houses can be converted to 2 storey 6 room houses.

In the next step, it would be possible to input these two newly updated fields ('number of storey' and 'number of room') into the GIS again to compute the additional population supply that the rehabilitated buildings would provide within the existing density. However, since all these are based on assumptions and the aim was to illustrate the predictive capacity of such a statistical technique, at this step the process was not continued. Sparsely dashed lines of Path 9 in Figure 1 stand for this purpose.

The Third Article consisted of another statistics related path (Path 10) in Figure 1. This approach in the assessment of the regulation deals with modelling for the suitability of new development areas of different land uses. This predictive modelling involved a 'mathematical linear combination' method. It requires a rating for each land use and weighting for each type (theme/attribute) and factor (theme map/layer). Moreover, it uses the standard formula for a weighted average to give suitability index on the final grid (raster) map for each land use (Hopkins,1977; Yeşilnacar,1998). In this method the ratings and weights are subjective, and the obtained results are just "some" examples from a cultural, environmental and agricultural protection and development point of view by utilizing the 17 map layers out of the total 23 ones (Table 1). In Figure 8, the resultant suitability maps for different land uses are given. During the maps' interpretation (Figure 8), the quartile ranges is ordered as follows:

75-100 : Very suitable / first rank areas that should be checked in the field
50-75 : Suitable / second rank areas that should be checked in the field
25-50 : Less suitable / unpreferable areas
0-25 : Not suitable / unpreferable areas

At a first glance, it is seen that the suitability maps of the four land-uses which are residential, touristic, commercial, and social-recreational facilities fairly resembles each other. However, a deeper look at the summary descriptive statistics (Table 7), and the quartile values on the legends would verify this interpretation with a slight change.

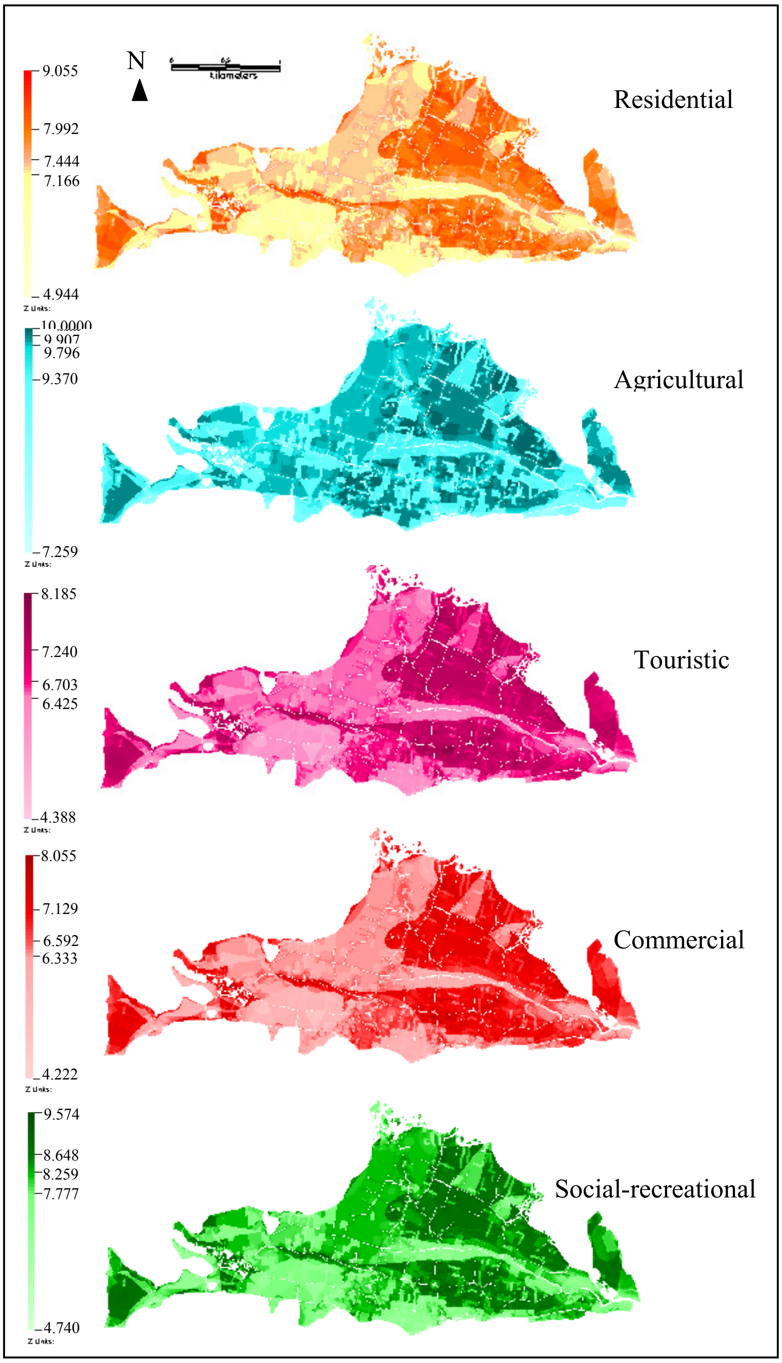

Figure 8. Resultant suitability maps for five different land-uses
Source: Erdoğan, 2000

Table 7. Descriptive statistics of five different land-use suitability maps

Statistics	Residential	Agricultural	Touristic	Commercial	Social-recreational facilities
Min	4.9444	7.2592	4.3888	4.2221	4.7406
Max	9.0555	9.9999	8.1851	8.0555	9.5739
Range	4.1111	2.7407	3.7963	3.8333	4.8333
Mean	7.5124	9.5928	6.7487	6.6447	8.1561
Median	7.4443	9.7962	6.7036	6.5925	8.2591
Standard deviation	0.5684	0.4020	0.5426	0.5430	0.5900
Coefficient of variation	0.0757	0.0419	0.0804	0.0817	0.0723

Source: Erdoğan, 2000

The suitable areas are coincident due to similar suitability conditions for these developments, which mainly require buildings. However, the suitability indexes have higher values on those areas for residential and social-recreational developments. It is also seen from the histograms (Figure 9) that while the distribution of values in these four maps are similar to each other, histograms of the residential and social-recreational suitability maps shift more to the right in the suitability index scale. Therefore, they have higher minimum and maximum values for suitability as compared to commercial and touristic land uses (Table 7).

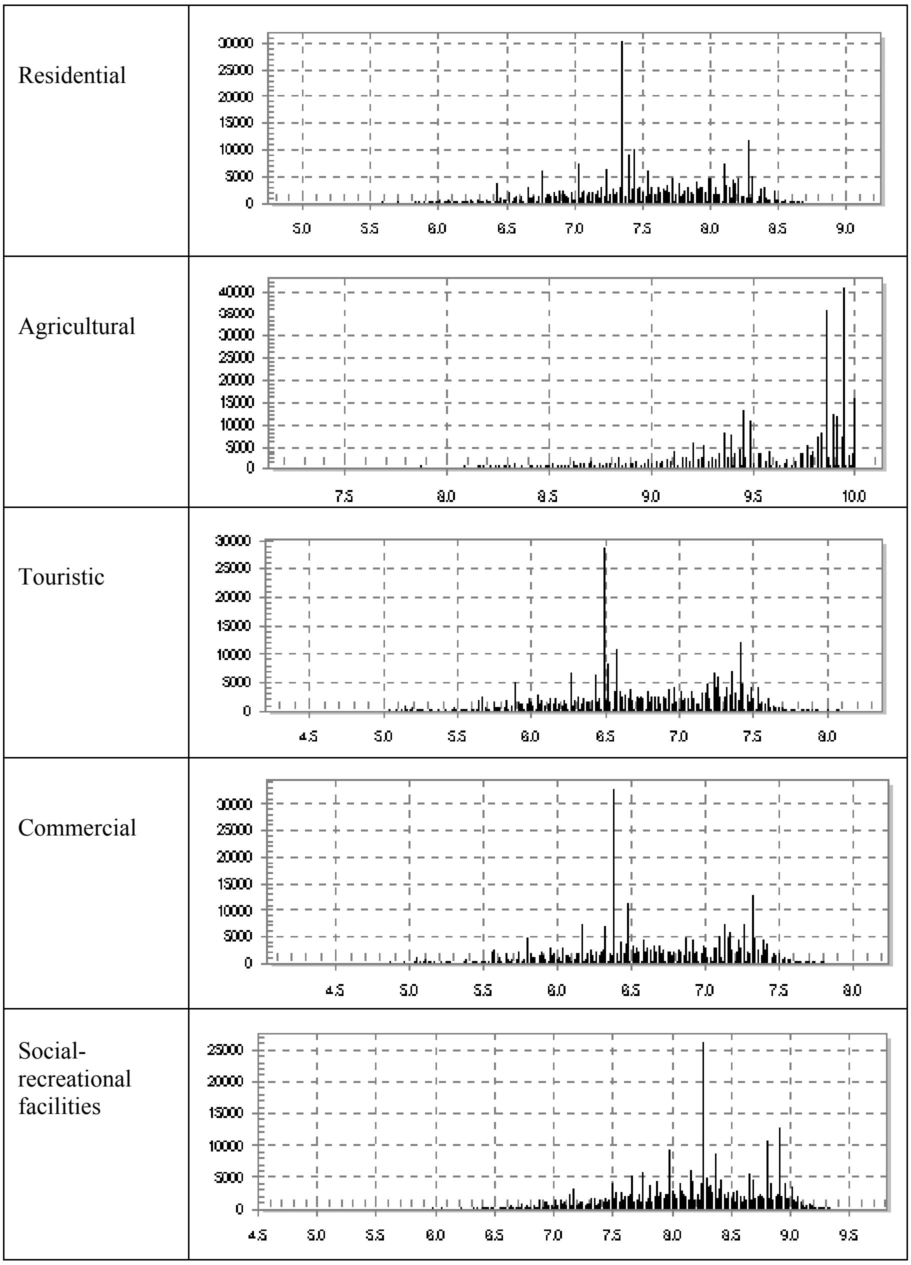

Figure 9. Histograms for suitability maps (suitability index values versus frequencies)
Source: Erdoğan, 2000

The reason for this is that relatively higher rates were given for these two uses. Nevertheless, if it is certain that the development of tourism sector would meet the eco-touristic development's requirements (e.g. in the form of village pensions), the rates can be increased for this use. As stated, these ratings can be changed and/or compared with respect to the policy and program achievements of the decision-makers and administrators. For instance, they can assess the calculated maximum population that can be supported by keeping the maximum storey numbers as 2 (TMMOB, 1994) and the existing density. This reminds the 'carrying capacity' phenomenon that is indispensable for sustainable development. It can be stated that in any way, these four maps do not create a conflict among themselves because all of them are related and combined development types. The problem arises when the agricultural suitability map comes into scene. This map shows that the suitable areas are found all around the map, with a suitability index from about 7.2 to 10 (Table 7). Besides, from its left skewed histogram (Figure 9) and quartile ranges (Figure 8) it is seen that the majority of the values condensed to a very small 'first rank' interval with almost half coefficient of variation size (Table 7) showing that almost all areas of the plain are suitable (first and second rank) for agriculture. This can be explained by the fact that all the plain is of first degree agricultural land (Sönmez, 1999), which also explains why the land quality map was not digitized and put into analyses.

The problem is that the areas suitable (first and second rank) for the agricultural activity coincide with the first and second rank areas of the residential use. One solution to this problem might be extracting the first, second, and third rank agricultural suitability areas from the first, and second rank residential suitable areas so that the remaining first, and second rank residential areas would become the suitable areas for this development if agricultural continuation or sustainability is more important.

The subjectivity in this model can be minimized via detailed site investigations and participation of experts with different backgrounds. When this participation is accompanied with several individuals or groups of individuals that have conflicting preferences, some other methodologies like ‘Multiple Criteria Decision-Making’ should come into the scene. When multiple and conflicting evaluation criteria are involved in the process of decision-making most GISs are of limited use. However, such problems could be handled within them by integration of the system capabilities with Multiple Criteria Decision-Making techniques (Massam, 1993; Malczewski, 1996; Nijkamp, 1975).

In order to further illustrate how RDBMS and some spatial statistics output of GIS can be used to model the allocation of projected total population, a spatial predictive model is utilized in the loose-coupling decision/planning support system (Path 11 in Figure 1). This is Hansen's gravity/potential model. It is concerned with the "potential interaction" or relative accessibility of zones…in addition to…the amount of vacant land that is suitable for residential use…" (Lee, 1973: 71-72). This is termed as 'holding capacity' in the model and it again reminds the 'carrying capacity' phenomenon, which is vital in sustainable planning. Although this is an appropriate parameter for the plain since such an interaction is not observed and expected in Kayaçukuru surely, this model might not be appropriate to be used. Furthermore, a statistically significant verification is not necessarily expected. Nevertheless, for illustrative purposes it is the most convenient model in terms of its data requirements in the study. The algorithm of the model is seen in Figure 10.

Calculate accessibility index (A_i) for each zone

↓

Multiply A_i by holding capacity (A_iH_i) for each zone to give development potential (D_i)

↓

Add D_i for each zone to find the total development potential (ΣD_i)

↓

Divide D_i of each zone by ΣD_i to find relative development potential of each zone

↓

Multiply relative development potential by total population growth (G_t) to find population growth in each zone (G_i)

$A_i = \Sigma_j A_{ij}$ and $A_{ij} = E_j/d^b_{ij}$ (A_i is the overall index for zone i and A_{ij} is the accessibility index of zone i in relation to zone j); E_j is total employment in j; d_{ij} is the distance between i and j, b is an exponent or power of d_{ij}; H_i is holding capacity (amount of vacant land that is suitable for residential use); $D_i = A_iH_i$ is development potential of a zone; $D_i/\Sigma D_i$ is the relative development potential of each zone; G_t is the total population growth; and G_i is population growth in each zone

Figure 10. Flowchart of Hansen model
Source: Lee, 1973: 72-77

As far as the study period is concerned, the 1997 population of the Plain was 752. Also, it had an out-migrating and static population with high percentage of elderly population and low birth rate. As a result of this, all population projection methods has given either less or stationary total population in the year 2015. The five results change between a minimum of 542 and a maximum of 754 (Sönmez,1999). Therefore, the land demand of future population is fixed as much as the existing land consumption and for illustrative purposes the model is adopted to reproduce the known distribution rather than to forecast. If the model were used for forecasting it would be operated with the predicted employment and known holding capacities and known travel times (Lee, 1973). In that case, the 'holding capacity' would have been obtained by computing the first rank suitable areas for residential use. However, here, since the model is used to reproduce the known distribution, the data for the existing situation are used (Tables 8-10).

Table 8. Employment, population and holding capacity inputs into Hansen model

Zones	Total employment	Total population	Holding capacity (ha)
1. Kaya	48	347	50.8
2. Kinali	123	117	8.7
3. Belen	48	114	23.0
4. Keciler	14	113	15.2
5. Gokceburun	39	61	3.0
Total	**272**	**752**	**100.7**

Source: Sönmez, 1999; Erdoğan, 2000

In Table 8, total employment values calculated by taking the total employment value 272 (Sönmez, 1999) and calculating its proportions to the regions in RDBMS, which gave results in Table 9 out of the 36% sampling questionnaire data.

Table 9. Count of working people in the plain's settlements

Zones	COUNT of Working people
1-Belen	17
1-Kaya	44
1-Kinali	17
2-Gokceburun	5
2-Keciler	14

Source: Erdoğan, 2000

Table 10. Distance/travel time matrix (in meters) inputs into Hansen model

To j / From i	1	2	3	4	5
1	253,5	2469,5	870	1693	993
2	2469,5	187	3736,5	3649	3463
3	870	3736,5	171,5	2962,5	870
4	1693	3649	2962,5	244	2689
5	993	3463	870	2689	209,5

Source: Erdoğan, 2000

In order to obtain the inter-regional distances in this matrix, in the GIS, first the gravity centre/centroid of each region (pink points in Figure 11) is measured and the vertical and horizontal projection of them (yellow points) to the nearest first and second degree (asphalt and stabilized) road assumed to be the centre of the region. Sometimes this centre fall into the objects of the 'squares' layer (Table 1). Next, the in between distances are measured. For the intra-regional distances the average of all the road lengths are calculated for each region.

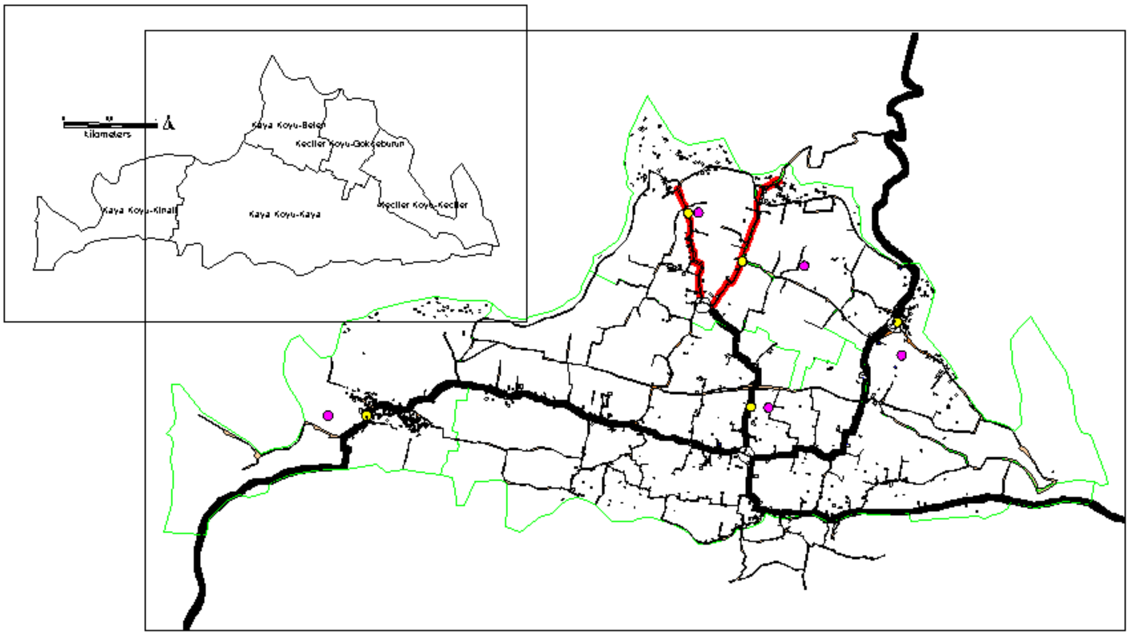

Figure 11. Calculation/measurement of distance/travel time matrix
Source: Erdoğan, 2000

Throughout the distance calculations no new roads, that may change the d value is assumed as supported in the 'Preliminary Protection Plan Regulation' (TMMOB, 1994). Because there is no observed interaction between zones, and it is thought that among such small rural settlements the distance could not be much effective on the development patterns the b value (distance deterrence effect) is assumed as 1 (Lee, 1973). When the model is run and its prediction is compared with the existing population location, the results appear as in Table 11.

Table 11. Comparison of model results with the actual values via Chi-square test

Zone	Predicted population	Actual population	Difference	Difference^2	Difference^2/ Predicted pop.
Kaya	359	347	-12	144	0,401114
Kinali	126	117	-9	81	0,642857
Belen	198	114	-84	7056	35,63636
Keciler	47	113	66	4356	92,68085
Gokceburun	20	61	41	1681	84,05
Total	**752**	**752**	**0**	**Chi-square=213,4112**	

Source: Erdoğan, 2000 (first four columns)

Here, the significance of the difference is tested by utilizing Chi-square test and taking the predicted values as expected ones. Since the tabulated Chi-square values at both 0.05 and 0.01 significance levels are smaller than 213.411, the null hypothesis stating “the insignificance of the difference between the actual and predicted populations in the zones” is rejected. Based on all the assumptions, the significant difference and the model's poor reproduction the existing situation should be expected. On the contrary, it should also be noted that the aim was not to find significantly correct results. The point to be made here is that the data found in the RDBMS and GIS can be used in an outside convenient predictive urban modelling to give more efficient and effective results, which can even further be tested in a statistical package for assessing the accuracy. Then, the result can be put into the GIS again (see sparsely dashed lines of Path 11 in Figure 1) for further manipulations for sustainable development planning.

3. CONCLUSIONS

With this study, it is seen that sustainable planning process, which requires coordinated, systematic, advanced data handling and specialization for many number of variables, can be reasonably practiced within a loose-coupled GIS-based urban modelling. From the case study’s decision/planning support system developed in this way, it is understood that in such integration, it is possible to make use of the maximum capacities and benefits of each component system. Namely, GIS, SP, RDBMS and Models, one of which is produced in the SP (Multiple Linear Regression) and two produced outside (Mathematical Linear Combination, Hansen Gravity/Potential Model).

Particularly, the statistical analysis tools utilized in each of these components and the exchange of their outputs for further processing and best display created broader opportunities for the sustainable planning practices. In this respect, the statistical analytical tools used on non-spatial and spatial data, helped both in understanding/explaining and predicting/forecasting. While sometimes they provided with indirect opinions about the socio-economic and demographic structure of the Plain, sometimes they directly produced the 'intervention strategies' concerning to planning process. Moreover, they further allowed to visualize how the Plain would appear if it is developed in a sustainable way.

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