Research on New Residential Areas Using GIS

A case study

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Abstract: Planning is a decision-making process which is about “the future”. In each scale of planning process, spatial rules of the social life are formed. In this process, firstly series of spatial analyses should be practised. Throughout the world, spatial planning strategies which focus on the sustainable development adapt an ecological approach and both the regional and urban planning processes are based upon ecological bases. Under the guidance of this notion, also in Turkey, spatial planning strategies should be urgently reviewed and any level of planning process should be directed to ecological bases. Furthermore, in all these steps, natural resources and ecological characteristics should be taken into consideration. In the city of Bartin, where Bartin River flows through, a case study has been carried out regarding the above mentioned planning strategies. The case study has three stages. These stages also frame the data, analysis and evaluation stages. In the case study, a combination of McHarg’s ecological evaluation method and Kiemstedt’s usage value analysis in planning has been employed. With the help of ecological analyses, in the rural areas that have not been settled yet, the potential of the natural resources has been examined for the new residential areas. As a result, in the city of Bartin, the potential residential areas have been defined on the unsettled regions. What is more, concerning the subject, a map has been formed on the scale of 1/25 000. As a result of the case study, it has been concluded that in Bartin city because of the physical planning which ignores the potential of the natural resources, some of the existing residential areas have been chosen improperly.
1. INTRODUCTION

In a broader term, planning is the formation of spatial arrangements so as to improve the social welfare and to supply the needs. Land use decisions which have been made during the process of physical planning determine the relations of human/life/nature and their interrelations with each other. With regard to this relation and interaction, while man is provided with the new and better life conditions, the formation and sustainability of a healthy environment should be a “must” in order not to ruin the life conditions of the future generations (Celikyay, 2005a).

Nowadays, in the world, the strategies of residential planning gain a new perspective which utilizes natural resources and potentials, and focuses on the sustainable residential development. Furthermore, it is observed that both regional and residential planning are focused on the ecological bases. All over the world the principle that provides the harmony of the socio-economical development with the geographical aspects of the residential area and preserves the ecological balance has been accepted (Atabay, 1998). Since the use of natural resources without total consumption is one of the major concerns of the sustainable development, the major goal of planning should be preserving the ecological balance. The most damaging activities that are being done for the urban development, the pollution in the cities, all these brought the necessity of taking the primary precautions related to the preservation of nature in urban planning strategies. In Turkey a planning process which takes environment into consideration should be developed since the environmental problems are getting worse (Celikyay, 2005a).

Since land use decisions related to residential areas influence economic activities, these activities also influence the physical environment, the topography on which these activities take place, soil, and natural biotopes. These activities constantly affect ecological structure and thus environmental problems occur (Atabay, 1991). In this case, when the subject is discussed under the principle of benefit-cost theory, it is seen that these decisions provide economical benefits in the short run; but in the long run they eventually cause the destruction of the natural environment and ecological collapses that lead to ecological costs attributed to the whole society. Hence, in both settled and unsettled areas, ecological planning must be taken into consideration in order to preserve and develop the urban and rural environment (Celikyay, 2004). Built environment improving together with the economical growth has created a great deal of damage on the natural resources. Thus, the land uses should be determined by rational and environment-sensitive planning process. Potentials of the natural resources have to be investigated by ecological threshold analysis (Celikyay, 2005b).
2. MATERIAL AND METHOD

2.1 Material

In the process of saving and analysing the natural resources data the following computer software and programmes have been applied.

2.1.1 Geographical Information System

GIS is an effective computer based tool that has been employed in the study of area-based analysis. The analyses which have been carried out by GIS provide the occasion of evaluating the area in an appropriate manner. GIS give the opportunity of the input, storage, preservation, analysis, output and presentation of the data. In the study, the multi layer processes, surface analyses, and grid analyses have been carried out with GIS.

2.1.2 ArcView 3.2

The GIS software that has been utilized in the study is ArcView 3.2. The processes such as the digitalization of all data related to the research, integration of the data with the given grid system, determination of the dominant surface type with grid analysis by calculating the area in each grid are all done by ArcView 3.2 software.

2.1.3 AutoCAD

In the stage of ecological analysis of the study, AutoCAD programme was used to question the factors within the grid size on the 1x1 km².

2.1.4 Potential Value Analysis Programme

A computer programme has been prepared for the study. The numerical weights of the ecological factors and the numerical values of the ecological sub-factors in the table of the potential evaluation formed according to the method used in the study are entered as data in a computer programme called ‘Potential Value Analysis Programme’. In the case area, the storage of the data, which has been questioned by grid analysis, the calculation of the total potential values, the selection of the new potential areas for new settlements are all conducted with the help of this programme.
2.2 Method

Ecological planning is based upon the analysis of the areas, which have natural resources, in terms of ecology. The method of McHarg (1992) employed in this study is also based on the determination of the utilization potentials of an area in terms of natural resources and the use of this analysis in physical planning. The study consists of data, analysis and evaluation stages.

2.2.1 Data

The input data of natural resources related to case area have been digitized. Through the application of GIS, related to natural resources the following maps have been obtained.
- Topographic structure
- Geological Structure
- Hydrology
- Soil Structure
- Soil Type
- Flora
- Existing Land Uses

2.2.2 Analysis

The stage of analysis consists of the research on whether the natural potential of the unsettled areas in the case area is suitable for the residential land use or not, and the analysis of the ecological factors according to this aim. Land resources are the ultimate natural sources that provide man, animal and plants with the suitable life conditions and produce various things needed for sustainable and easier life. When land resources are under the danger of deterioration as a result of natural events and inappropriate land uses, they cannot sustain their functions properly. Hence, the land as a limited source has significant economical, social, and ecological roles in the realization of the sustainable development; in order to achieve all these roles in a balanced way, its components and their responses to different impacts should be considered. This can be achieved through a comprehensive study on soil, climate, water, and geological structure and their characteristics that create the land resources.

An appropriate mathematical research and evaluation method has been developed by making use of McHarg’s (1992) and Carl Steinitz’s (1996) landscape evaluation methods, Golany’s (1976) method on the analysis of urban settlement, Kiemstedt’s method of “Usage Value Analysis” –
translated by Köseoğlu (1982) in order to define natural resources data and to determine potential residential areas. The mathematical method is preferred because it makes the grouping and analysis of the data related to the case area easier and it also makes the determination of the appropriate and inappropriate ones simple. In the process of analysis and evaluation, if mathematical method was not used, it would be necessary to frame a map for each criterion, as a result during the process of analysis there would be so many maps. The integration of these maps would be another problem. However, with the help of the mathematical method employed in the study, only a map has been framed as the result of the analysis.

2.2.2.1 Mathematical Analysis
Within this method, the natural and the ecological factors’ suitability thresholds, related to residential areas, have been studied and the evaluation criterions have been formed. The numerical weights of the ecological factors determined as the evaluation criterions have been decided according to their suitability for residential land uses. The sub-factors of each ecological factor have been determined, and these sub-factors are given numerical values according to their importance in the determination of the residential land use.

With the help of Kiemstedt’s usage value analysis method, the formula of “the suitability value analysis of the natural potential” has been formed:

$$RLU_{PV} = \text{Factor}_1_{PV} + \text{Factor}_2_{PV} + \text{Factor}_3_{PV} + \text{Factor}_{(n)}_{PV}$$

$$RLU = \text{Residential Land Use}$$

$$PV = \text{Potential Value}$$

The potential of a land for residential use is the sum of the potential values of the ecological factors related to the land. This expression has been mathematically formulated:

$$RLU_{PV} = \sum \text{Factor}_{PV} = g_1.e_1 + g_2.e_2 + g_n.e_n$$

$$RLU_{PV} = \text{Total potential value related to residential land use}$$

$$PV = \text{Potential value of the ecological factor related to residential land use}$$

$$g = \text{The ecological factor’s level of importance in determining the residential land use}$$

$$e = \text{The numerical value of the ecological factor (functional value)}$$

2.2.2.2 Grid Analysis
Research on the suitability of natural resources potential in the case area for residential land uses has been carried out through the grid analysis. The case area has been divided into the grids of 1x1 km² according to geographical
coordinates on maps drawn to a scale of 1/25 000 and thereby geographical grid system has been developed. Through the grid analysis, the presence of ecological factors in grid units has been researched according to the mathematical method with the help of geographical information system (GIS). Firstly the data of the natural resources has been digitised and then, whole data has been questioned separately for the residential land use according to the formula of “the suitability value analysis of the natural potential” through the programme of the potential value analysis.

In accordance with the method, ecological factors have been determined in order to research on the suitability of natural resources for residential land uses. Numerical values of the ecological factors and ecological sub-factors have been determined. Considering not only one sub-factor but also several sub-factors existing in these grids, the dominant type method has been used in the assessment of ecological sub-factors researched in the grid system. Through the dominant type method, numerical value of grid units has been assigned according to the type of the largest surface value and sub-factors covering the largest area, in grids have been taken into consideration as the dominant characteristic related to the grid unit in question while the other sub-factors have been eliminated and have not been taken into consideration.

A computer programme has been developed and employed in order to calculate the numerical values of potential values related to grid units with the help of grid analysis. According to the presence of these sub-ecological factors in grid units, total potential value of each grid unit has been calculated by this programme called ‘Potential Value Analysis Programme’.

2.2.3 Evaluation Process

According to the interpretations of numerical values of grid units obtained through the grid analysis, the grids which received a value less than the minimum potential value indicated in the natural factor evaluation table related to residential areas through the computer programme developed for this purpose have been determined as the areas lack of potential and extracted from the evaluation.

The grid units having numerical value between minimum potential value and mid-potential value are the second degree potential areas, the grid units that have numerical value above mid-value degree are determined as the first degree potential areas. In this way, a map illustrating two optional residential areas has been acquired.
3. CASE AREA: BARTIN SETTLEMENT

The city of Bartin is situated in the northern part of Turkey and in the West Black Sea Region. The city takes its name from Bartin River, which was called as “Pharthenius” -meaning the God of Water and The Young Virgin- in the ancient times.

The city once was a trade centre since Bartin River provides 12 km waterway, related to that, in time the city became a residential area with the emergence of the need for accommodation. As a trade route, Bartin River has a great influence on the establishment and development of the residential areas. The city of Bartin was an important commercial and cultural centre in the nineteenth century, and today the settlement still keeps its historical characteristic and its importance as a commercial centre. The case area includes three sites: urban site in which characteristic of its being a historical trade centre are dominant, archaeological and natural site. By the Ministry of Culture and Tourism, the areas alongside the river are declared as the first degree of natural site area.

3.1 Existing Land Uses

The settled areas in the centre of the city of Bartin have historical characteristic, and within this historical structure there are some wooden constructions as the types for the traditional architecture, a fountain, a Turkish bath, and two inns. The heights and the scales of these wooden houses are the distinguishing aspect of the urban settlement. So in the areas, houses have three floors, but outside of these areas, in the developing areas, it can be observed that houses can have 3 floors to 5 floors.

In application plan of 1970, it can be seen that there are some residences on some of the first class agricultural lands in spite of the inappropriate conditions resulting from the erosion risk, high subsoil water and earthquake movements. Because of these negative conditions, old residences are placed on slightly sloppy hillsides which consist of eosen layers over the level of 20m.

In the developing residential area- outside of the settled areas- the housing areas started to be built as they were suggested in 1980’s plan on the scale of 1/5000. These housing groups having 4 or 5 floors were built by cooperatives. Some of these residential areas have fourth class land use ability and they are on 12-20% gradient hillsides. Some of the residential areas are on valuable agricultural lands that have first class land use ability. In the areas outside of the district’s borders, residences having 2 or 3 floors can be observed. These residential areas also have first class land use ability and they are set on the most fertile agricultural lands (Figure 1).
3.2 The Research on the New Residential Areas Suitable to the Potential of the Natural Resource

The ecological factors employed as the criterions for the determination of the residential areas are ability classes of the lands, slope, erosion and aspect.

In order to evaluate the land use related to residential areas, the following formula has been developed by adding the following elements up: potential value related to ability classes of the lands, slope potential value, erosion potential value and aspect potential value (Table 1).
Research on New Residential Areas Using GIS

\[ \text{PRA}_{pv} = \text{Ability Class}_{pv} + \text{Slope}_{pv} + \text{Erosion}_{pv} + \text{Aspect}_{pv} \]

(3)

PRA = Potential residential areas

Table 1. Assessment criterions related to the potential residential areas.

<table>
<thead>
<tr>
<th>Grid unit no.</th>
<th>Ecological factors</th>
<th>Ability Class</th>
<th>Slope</th>
<th>Erosion</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Factors’ values (g)</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sub-factors’ values in grid area (e)</td>
<td>Max: 4</td>
<td>Min: 1</td>
<td>Max: 4</td>
<td>Min: 1</td>
</tr>
<tr>
<td></td>
<td>Total values (g,e)</td>
<td>g,e</td>
<td>g.e</td>
<td>g,e</td>
<td>g.e</td>
</tr>
<tr>
<td></td>
<td>Total potential value of grid unit ((\Sigma g,e))</td>
<td>Max. value: 40, Min. value: 10, Mid-value: 25 (\Sigma g,e = \text{PRA}_{pv})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The suitable residential areas should be those outside of the fertile agricultural lands. With regard to this principle, it is concluded that the most important factor in the determination of the residential areas is the ability classes of the lands. Its sub-factors are the fourth class, fifth class, sixth class and seventh class lands.

Table 2. Assessment criterions related to the ability class factor of the lands.

<table>
<thead>
<tr>
<th>Grid unit no.</th>
<th>Ecological factor</th>
<th>Ability Class of Land</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Factor’s value (g)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sub-factors</td>
<td>IV.Class</td>
</tr>
<tr>
<td></td>
<td>Sub-factor’s value (e)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>The value of grid (e)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential value of grid unit (g,e)</td>
<td>AC_{pv}=</td>
</tr>
</tbody>
</table>

The classification of the suitability of the land ability classes according to the residential areas has been carried out by giving the highest value (4) to the fourth class lands, giving high value (3) to the fifth class lands, giving mid-value (2) to the sixth class lands, and finally by giving low value (1) to the seventh class lands (Table 2).

Table 3. Assessment criterions related to the slope factor.

<table>
<thead>
<tr>
<th>Grid unit no.</th>
<th>Ecological factor</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Factor’s value (g)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sub-factors</td>
<td>0-6%</td>
</tr>
<tr>
<td></td>
<td>Sub-factor’s value (e)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>The value of grid (e)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential value of grid unit (g,e)</td>
<td>Slope_{pv}=</td>
</tr>
</tbody>
</table>
The classification of the suitability of residential uses according to slope of the land is done by giving the highest value (4) to the slope until 6%, giving high value (3) to the slope between 6% and 12%, giving mid-value (2) to the slope degree between 12% and 20%, and finally by giving low value (1) to the 20% and higher slope (Table 3).

In the classification of the sub-factors- related to erosion factor- so as to determine the suitable lands for residential purposes, the following evaluation has been applied. The lands where no or little erosion takes place are given the highest function value (4), the lands with mid-degree erosion risk are given high value (3), the lands that have high risk of erosion are given mid-function degree (2), and the lands that carry the highest erosion risk are given low value (1) (Table 4).

<table>
<thead>
<tr>
<th>Grid unit no.</th>
<th>Ecological factor</th>
<th>Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor’s value (g)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sub-factors</td>
<td>The highest</td>
<td>High erosion</td>
</tr>
<tr>
<td>Sub-factor’s value (e)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>The value of grid (e)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential value of grid unit (g.e)</td>
<td>Erosion PV=</td>
<td></td>
</tr>
</tbody>
</table>

The aspect as a significant factor makes hillsides take little or much sunlight during a day time, so this factor should be taken into consideration in the choice of the residential areas. Since mostly in Turkey south (S), south-east (SE), south-west (SW) and west (W) aspects receive much sunlight, these exposures are hotter than the other ones. North (N), north-east (NE), north-west (NW) and east (E) aspects are shadowy and cooler since they receive little sunlight. The appropriate choice for the settlements in order to reduce the dependency of people on exhaustible energy, and to make them benefit from solar energy and natural air conditioning, shortly to benefit from the natural sources in a maximum level. To achieve these, the choice of the settlement area should be parallel to the climate of that area. Hence, north hill sides are not preferred since they receive low sun light degree. The top of the south-east and east hill sides are suitable for the settlement when the relationship between climate appropriateness and settlement is considered. In the evaluation of the appropriateness of aspects to settlements, aspects of south-west, south and south-east take the highest function value (4), west and east aspects are given high function value (3), north-west and north-east aspects are given mid-function value (2), and finally north aspect takes low function value (1). The ecological factors for determining the evaluation criterions of the residential areas, the ecological sub-factors used
as the thresholds for settlement areas and their weights, finally their functional values are illustrated in Table 5.

Table 5. Assessment criterions related to the aspect factor.

<table>
<thead>
<tr>
<th>Grid unit no.</th>
<th>Ecological factor</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor's value (g)</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub-factors</th>
<th>SW, S, SE</th>
<th>W, E</th>
<th>NW, NE</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-factor’s value (e)</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>The value of grid (e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential value of grid unit (g.e)</td>
<td>$\text{Aspect}_{pv} =$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Potential areas related to the new residential uses.
3.3 Results of the Analysis and New Residential Areas

In order to determine the potential residential areas, after the questioning of the factors-given above-with grid analysis, new potential residential areas are determined for residential purposes. As a result of the grid analyses, the fourth class lands having slope between 12-20%, the lands having mid-erosion degree, and aspects of south, south-east and east were determined as first class potential areas that are suitable for residential uses (Figure 2).

The hill sides around the settled areas are the places that have high potential in terms of residential land uses. Contrary to the settlements on the first class agricultural lands, and the places having risks in terms of level of the subsoil water and earthquake, these areas have characteristic of strong ground in terms of geological structure.

4. CONCLUSIONS

In the comparison of the potential residential areas with the existing residential areas (Figure 1), it can be seen that while some of the existing residential areas are established on the fertile agricultural lands that are around the Bartin River at the same time on the natural site area. The suitable areas for residential land uses have been used for agricultural purposes.

It has been concluded that in the city of Bartin the direction of the urban development is not determined according to the potential of the natural resources. Furthermore, developing residential areas and the choice of some of the agricultural areas are not suitable for natural resources. Therefore, the natural structure of the city of Bartin has been deformed day by day. In the later strategies of urban development of Bartin, ecological methods should be used as the primary principle of regional, urban and local planning processes and in any kind of land use decisions. With the help of residential planning strategies that relate to economical development with ecological balance, the utilization of the natural resources without total consumption would be provided and our natural and cultural inheritance would be handed over the next generations.

Without a proper planning process which is based upon ecology (ecological master plan) and application plan which lacks comprehensive approach, urban and sectoral development should not be directed to a proper way; therefore, socio-economical development and ecology should not be reconciled. Since ecological development is not interconnected with ecology, its existing and future negative impacts on the natural resources would not make the sustainable development possible and it would be
impossible to establish a protection-use balance. Hence, with the land use decisions made during the physical planning process, a healthy environment and its sustainability should be provided without destroying the life-conditions of the future generations. Ecological planning should be the basic principle in the settled and unsettled areas of Bartin, and in the process of the protection and development of the urban and rural lands.

In the process of urban development in which natural resources are being destroyed, it should be considered that natural resources are limited and they can be used up; so, socio-economical development strategies should be focused on ecological bases. It should be considered to provide the balance between conservation and usage of the natural resources.

GIS is the primary tool in forming a wide range of data bases in the planning processes, in the analyses of both natural resources and ecological threshold analyses, in both determination and sustainability of the appropriate ways of land use with regard to the potential of the natural resources.

In order to provide sustainability, both ecological approach should be the major principle and geographical information systems should be used as the major tool in planning process.

5. REFERENCES

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