OPTIMUM LAND-USE ALLOCATION USING BINARY INTEGER PROGRAMMING AND GEOGRAPHIC INFORMATION SYSTEMS: CASE OF ÇESME

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ABSTRACT

OPTIMUM LAND-USE ALLOCATION USING BINARY INTEGER PROGRAMMING AND GEOGRAPHIC INFORMATION SYSTEMS: CASE OF ÇESME

Spatial decision making is a very complex process that basic strategy of decision analysis is to divide the decision problem into small, understandable parts; analyze each part; and integrate the parts in a logical manner to produce a rational solution. Recently, Multicriteria Decision Making (MCDM) integrated with geographical information system (GIS) has been promising in producing analytical tools for analyzing many real-world spatial planning and decision making problems.

In Turkey, natural, archaeological and cultural assets are conserved according to the decisions of the conservation regional councils. The conservation regional councils decide boundary, type and degree of conservation areas but these areas and their features is changed frequently according to economical, environmental and political atmosphere.

The conservation decision is one of the most important input criteria in preparing urban land-use plan since the type and degree of conservation area directly determines which kind of land-uses can and cannot be allocated in a conservation area. The aim of this dissertation is to analyze the effects of changing conservation decisions on optimum land use allocation when all other criteria are constant. This analysis was made with five different perspectives. The thesis uses the land assignment model provided by Hanink and Cromley (1998) that integrates the geographical information systems (GIS) with a generalized assignment model by using MCDM techniques to determine optimum level of conservation scheme. The case study is the master plan area of Çeşme in İzmir province in Turkey. The results show that the theoretically proposed method is indeed very useful and promising to answer complex issues on a more rational basis.

ÖZET

TAM SAYI PROGRAMLAMASI VE COĞRAFİ BİLGİ SİSTEMLERİ KULLANARAK OPTİMUM ARAZİ KULLANIM DAĞILIMININ BELİRLENMESİ: ÇEŞME ÖRNEĞİ

Mekânsal karar verme süreci çok karmaşık bir süreçtir. Rasyonel bir çözüm üreten karar analizinin temel stratejisi: karar problemini küçük ve anlaşılır parçalara bölme, her bir parçayı analiz etme ve mantıksal bir biçimde parçaları birleştirmeden oluşmaktadır. Son zamanlarda, coğrafi bilgi sistemleri ile entegre edilmiş Çok Kriterli Karar Verme tekniği, bir çok planlama ve karar verme probleminin analizinde kullanılacak analitik araçların üretilmesinde umut vaat etmektedir.

Türkiye'de, kültür ve tabiat varlıkları bölge koruma kurullarının verdiği kararlara göre korunmaktadır. Bölge koruma kurulları sit alanlarının sınırına, çeşidine ve derecesine karar vermektedir fakat sit alanları ve onların özellikleri ekonomik, çevresel ve politik ortama göre sık sık değişmektedir.

Sit kararları, kentsel arazi kullanım planın şekillendiren en önemli girdi kriterlerinden biridir çünkü sit alanı olarak belirlenmiş bir alana hangi tür arazi kullanım türlerinin tahsis edilebileceğini ve edilemeyeceğini sitin çeşidi ve derecesi belirlemektedir. Bu tez çalışmasının amacı; diğer tüm kriterler sabit iken sit kararlarının değiştirilmesinin optimum arazi kullanım atamasındaki etkilerini analiz etmektir. Bu analiz çalışması beş farklı bakış açısıyla yapılmaktadır. Bu tez çalışmasında Hanink ve Cromley (1998) tarafından geliştirilmiş arazi tahsis modeli kullanılmaktadır. Bu model ile Coğrafi Bilgi Sistemleri (CBS) ile genel atama modeli entegre edilerek optimum sit şeması belirlenmektedir. Örnek çalışma alanı olarak İzmir deki Çeşme Çevre Düzeni Planı alanı seçilmiştir. Çalışmanın sonuçları, teorik olarak önerilmiş yöntemin karmaşık sorunlara mantıklı ve umut verici çözümler ürettiğini göstermiştir.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Spatial decision making process and their results are so complex that decision makers, academicians and professionals need decision making tools. In the last 20 years, the advances in Geographical Information Systems (GIS) and Multicriteria Decision Making techniques (MCDM) have provided new analytical tools that can be used in answering real-world argumentative practical and professional planning issues.

MCDM techniques integrated with GIS have been used as a decision making tool in resource allocation problems of environment/ecology, transportation, urban/regional planning, waste management, hydrology, agriculture, forestry and etc. There are two basic MCDM techniques suitable for implementation in GIS. The first is multicriteria analysis (MCA), which involves the evaluation of a predetermined and limited number of allocation alternatives. These predetermined and limited alternatives are evaluated against each other. In this context, MCA is a useful and simple evaluation and selection technique when the alternatives are available. The second technique of MCDM is Multiobjective Decision Making (MODM) that generates an optimal allocation alternative using optimization techniques. MODM is a design technique because it defines best solution or alternatives with mathematical optimization techniques. Although MCDM has a potential to solve city planning and decision making issues, it has not been applied significantly to the complex domain such as urban scale.

Urban land-use plan is formed by the criteria which are categorized as spatial, environmental, social and economical. Determination of the criteria and their effects on an urban plan is determined by the planner but some of the criteria are given as inputs in the urban planning process. The conservation scheme is one of them since the type and degree of conservation areas legally dictate which kind of land-uses can and cannot be allocated in a conservation area in Turkey. However, rationality and reasoning of these schemes have never been resolved among different parties of interest, and the discussions still continue. Thus, conservation schemes have been changed frequently. At this point, the effects of conservation decisions on land use allocation should be analyzed using analytical tools. The MCDM techniques can be one of them.

In this regard, the main aim of this dissertation is to analyze the effects of various conservation decisions on optimum land use allocation when all other criteria are constant and to try to find out whether an integrated model which employs MODM&GIS could support human decision making to determine optimum conservation scheme in the concept of "conservation and usage equilibrium" as a sustainable planning approach in city planning.

The framework proposed by Hanink and Cromley (1998) is a promising MODM tool for land use planners and decision makers. Their study is theoretically based on Von Thünen tradition of location analysis and methodologically on MCDM. The study described a method of land allocation in the absence of complete market values integrating the multicriteria decision making tools and a binary integer programming. They illustrated the method application with a hypothetical example including three competing land uses.

The model used in this thesis is a MODM (single objective problem) technique formulating the land allocation as a binary linear programming. Suitability indexes, instead of market prices, are used as proxies for the market prices of such assets in the model because complete market prices are not directly observable for social utilities or environmental assets. Estimation of the suitability indexes again uses MCDM techniques. Economic, social and environmental criteria and benefits are combined to compute suitability scores of each parcel for each land use in raster based GIS.

The case study, Çeşme, is a town at the Aegean Coast of Turkey. The town, located on the coast of Aegean and Mediterranean Sea, has been the destination of national and international mass summer tourism and is a summer resort centre that has grown rapidly since 1980. Since 1990, rising awareness of the environment has brought the concept of "conservation and usage equilibrium" as a sustainable planning approach in these towns. Çeşme has many natural, environmental and archaeological endangered assets due to such high demand and mass consumption of tourism. During the last two decades, the conservation schemes of Çeşme were changed in 1991, 1992, 1995, 1996, 1998 and 2007 totally.

In the second chapter, multicriteria decision making process is introduced with basic concepts, major types and applications.

The third chapter includes the land assignment model and its use in the conservation decisions analysis.

The description of Çeşme case is given in the fourth chapter with its master plans and conservation schemes.

The fifth chapter consists of data preparation. It involves the determination of land use, the selection of evaluation criteria and input criteria, the determination of weights of the evaluation criteria, and the trade-off weight values of land-uses.

In the sixth chapter, the empirical land assignment model is implemented and its overall results are discussed. And finally, the research question and future researches are explained in the seventh chapter.

CHAPTER 2

MULTICRITERIA DECISION MAKING

Malczewski (1999) defines (spatial) multicriteria decision making as a collection of techniques for analyzing geographical events where the results of the analysis (decisions) depend on the spatial arrangements of the events. In this context, decision analysis is a set of systematic procedures for analyzing complex decisions. This can be accomplished by dividing the decision problem into small, understandable parts; analyzing each part; and integrating the parts in a logical manner to produce a meaningful solution. MCDM is applied widely in the area of operations research and management science for investment, logistics, location selection, and allocation of resources.

MCDM problems include the following components (Keeney & Raiffa, 1993; Malczewski, 1999):

i. A goal or a set of goals the decision makers want to achieve,
ii. The decision maker/makers participate the decision-making process along with their preferences with respect to evaluation criteria,
iii. A set of evaluation criteria (objectives and attributes)
iv. The set of decision alternatives (decision or action variables),
v. The set of uncontrollable variables or states of nature (decision environment),
vi. The set of outcomes or consequences associated with each alternative-attribute pair.

These components should be organized hierarchically. The first level is a goal which specifies a desired resulting from decision making activity. Decision problems include a number of decision makers that can be individual or groups. They make preferences or judgments that are operationalized in terms of weights assigned to the evaluation criteria. Criterion is defined as a standard judgments or rule to test the desirability of alternative decisions (Hwang & Yoon, 1981; Malczewski, 1999). Criterion is a generic term including both attributes and objectives. Decision problems have decision alternatives that can be limited or infinite. All decisions are made in some kind of environmental context that could not be controlled by the decision maker. These uncontrollable factors are referred to as the decision environment, for example weather conditions. For each decision alternative there is a set of possible outcomes. Finally, the set of outcomes are ordered so that the best alternative can be identified for decision making (Malczewski, 1999).

MCDM is a blanket term that includes both MADM/MCA (multiattribute decision making/ multicriteria analysis) and MODM (multiobjective decision making). It should be noted that the terms multicriteria analysis (MCA) and multiattribute decision making (MADM) are used interchangeably in the literature. Attributes are measurable quantity or quality of a geographical entity or a relationship between geographical entities. In other words, attributes include measurable site and situational factors. In this context, an attribute is used to measure performance in relation to an objective (Starr & Zeleney 1977; Malczewski, 1999). On the other hand, an objective is a statement about the desired state of the system under consideration. It shows the direction of improvement of one or more attributes. The objectives are functionally related to, or derived from a set of attributes. For any given objective, several different attributes might be necessary to provide complete assessment of the degree to which the objective might be achieved (Malczewski, 1999).

Comparisons of MODM and MADM/MCA approaches are given in Table 2.1. MODM involves designing the alternatives and searching for the "best" decisions among an infinite or very large set of feasible alternatives (Malczewski, 1999). MODM provides a framework for designing a set of alternatives. Alternatives is defined implicitly in terms of the decision variables and evaluated by means of objective functions. On the other hand, the multiobjective problem becomes a multiattribute decision problem when there is a direct correspondence between the attributes and objectives. MADM/MCA is a simple evaluation and selection technique since it makes a selection among alternatives described by their attributes. The set of attributes given explicitly are used both as decision variables and decision criteria.

Further, MADM/MCA techniques get preferences in the form of function forms and weights, directly for levels on the attributes but MODM techniques obtain these from the preferences among objectives and the functions relating attributes to objectives (Malczewski, 1999). Objectives are more abstract variables while attributes are concrete descriptive variables. Solving an MODM is a design process, as opposed to selection process since MODM have infinite alternatives, as opposed to predetermined alternatives (Malczewski, 1999).

Tablo 2.1. Comparison of MODM and MADM/MCA approaches
(Source: Malczewski, 1999, p. 86)

	MODM	**MADM/MCA**
Criteria defined by:	Objectives	Attributes
Objectives defined:	Explicitly	Implicitly
Attributes defined:	Implicitly	Explicitly
Constraints defined:	Explicitly	Implicitly
Alternatives defined:	Implicitly	Explicitly
Number of alternatives	Infinite/large	Finite/small
Decision maker's control	Significant	Limited
Decision modeling paradigm	Process-oriented	Outcome-oriented
Relevant to:	Design/search	Evaluation/selection
Relevance of geographical data structure	Vector-based GIS	Raster based-GIS

2.1. Steps of Multicriteria Decision Making

Multicriteria decision making is a process that starts with problem definition and ends with recommendations. The Figure 2.1 shows a framework that is organized in terms of the sequence of activities involved in the spatial multicriteria decision making. A spatial decision making problem can be structured into three phrases: intelligence phrase defines the problem, evaluation criteria and constraints in GIS environment; design phrase determines decision matrix, alternatives and decision maker's preferences; and choice phrase decides decision rule and best alternative (Malczewski, 1999, p.95).

In MADM and MODM, a similar process is followed. However, comparing these two approaches, it can be seen that the differences between them are related to question of whether alternatives should be generated first and then the value structure should be specified, or conversely, the alternatives are derived from the value structure (Malczewski, 1999, p. 95). The major elements involved in multicriteria decision making process are discussed below.

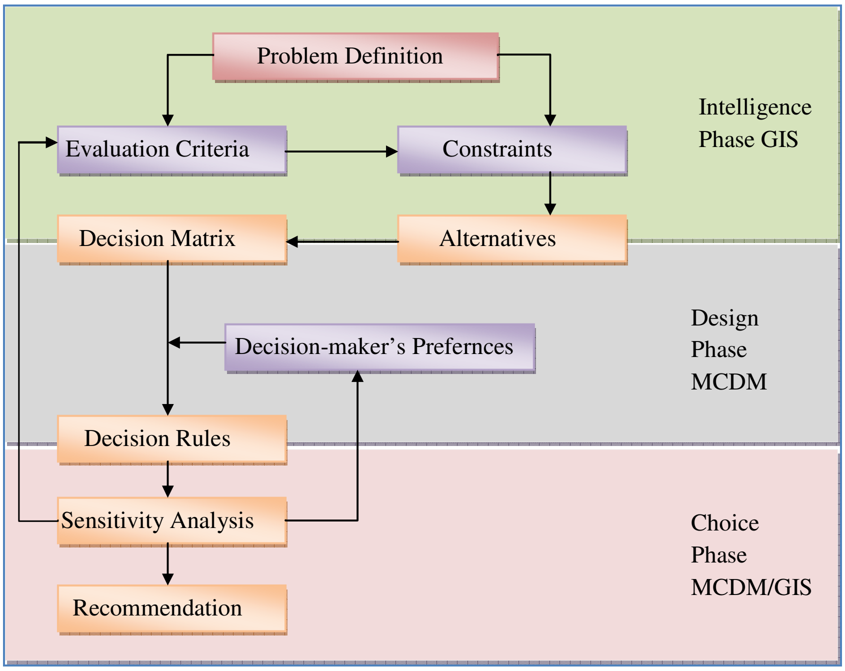

Figure 2.1. Framework for spatial multicriteria decision making
(Source: Malczewski, 1999, p. 96)

2.1.1. Problem Definition

A decision problem is defined as a difference between the desired and existing states of a system. Thus, it is a gap which is recognized by a decision maker. MCDM process starts with definition of the decision problem. The stage of problem definition is in the intelligence phase of MCDM and it includes searching the decision environment for conditions, obtaining, processing and examining the raw data for clues that may identify opportunities or problems. GIS is used for data storage, management, manipulation and analysis in the stage of problem definition (Malczewski, 1999).

2.1.2. Evaluation Criteria

After the definition of problem, a set of evaluation criteria that includes both objectives and attributes should be determined. This stage involves specifying a comprehensive set of objectives that reflects all concerns relevant to decision problem and measures for achieving those objectives. Such measures are defined as attributes. A measurement scale should be established for each attribute because each attribute map holds cell values for original map codes that are nominal, binary, ordinal, ratio and interval measurement scale. The evaluation criteria are associated with geographical entities (cells) and relationships between entities are represented in the form of maps. These maps are raster based maps which are called as evaluation criterion map or attribute map in MCDM and thematic map or data layers in GIS terminology. The evaluation criterion map is used to evaluate the performance of the alternatives. GIS is used to generate inputs to spatial multicriteria decision analysis. Malczewski (1999) proposed three techniques for selecting evaluation criteria that are examination of relevant literature, analytic studies, and survey of opinions.

2.1.3. Alternatives

In MCDM process, each alternative is assigned to a decision variable so that a set of decision variables define the decision space. The decision maker uses the variables to measure the performance of alternative decisions and this is called criterion suitability score. The decision variable can be deterministic, probabilistic, or linguistic. Generally, all spatial decision problems have constraints that represent restrictions on decision space. They determine the set of feasible alternatives (Malczewski, 1999).

2.1.4. Criterion Weighting

After determining the set of evaluation criteria, each criterion must be weighted depending on the decision maker's preferences since MCDM problems involve the criteria of varying importance to decision makers. The preferences must be converted to relative weights that express the importance of each criterion relative to other criteria. In multicriteria decision making literature, ranking, rating, pairwise comparison and trade-off analysis are most popular procedures for deriving the weights (Malczewski, 1999).

2.1.4.1 Ranking Method

Ranking method is the simplest method for assessing the weights of criteria. Every criterion is ranked according to the decision maker's judgment. Straight ranking or inverse ranking can be used. After ranking all evaluation criteria, the most popular ranking approaches; rank sum, rank reciprocal and the rank exponential method can be used to derive the weights of criteria. Rank sum weights are calculated by Formula 2.1 (Malczewski, 1999, p. 178):

$$w_i = \frac{n - r_i + 1}{\Sigma\ (n - r_k + 1)} \qquad (2.1)$$

Where w_i is the normalized weight for the *i*th criterion, n is the number of criteria under consideration ($k=1,2,3,...,n$), and r_i is the rank position of the criterion. Each criterion is weighted and then normalized by the sum of all weights. Additionally, formula 2.2 can be used to calculate the rank of reciprocal weights:

$$w_i = \frac{1/r_i}{\Sigma\ (1/r_k)} \qquad (2.2)$$

The rank exponent method needs additional information which specifies the weight of the most important criterion on a 0-1 scale. Formula 2.3 is used to calculate the weights:

$$W_i = \frac{(n - ri + 1)^p}{\Sigma\ (n - r_k + 1)^p} \qquad (2.3)$$

It can be solved for p by an iterative procedure. For $p = 0$, the equation assigns equal weights to the evaluation criteria and for $p = 1$, the method results in rank sum weights (Malczewski, 1999, p. 179).

The ranking method is very attractive since it is very simplistic. However, it is not useful when a larger number of criteria are used and the lack of theoretical foundation is also another disadvantage.

2.1.4.2. Rating Methods

In the rating methods, the decision maker estimates the weights according to a predetermined scale. The point allocation approach is the simplest rating method. In this method, the decision maker assigns 100 points across the criteria of interest. After the rating of weightings, each criterion’s normalized weight must be computed with a spreadsheet (Malczewski, 1999).

Another rating method is the *ratio estimation procedure*. First, an arbitrary weight is assigned to the most important criterion; for example, a score of 100 is assigned to the most important criterion. And then the weighting is continued in order until the least important criterion is given a weight. Then the score assigned to the least important criterion is taken as an anchor point for calculating the ratios and each criterion score is divided by the score of the least important criterion, that is, the ratio is equal to w_i/w_l, where w_l is the lowest score and w_i is the score for the *i*th criterion. Finally, the weights are normalized by dividing each weight by the total. Like the ranking methods, the rating methods do not have a theoretical foundation (Malczewski, 1999).

2.1.4.3 Pairwise Comparison Method

The pairwise comparison method was developed in the context of Analytic Hierarchy Process (AHP) by Saaty (1980). The method is based on pairwise comparisons to create a ratio matrix. The pairwise comparisons are taken as an input and the relative weights are given as an output. The weights are derived by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix. The method involves three steps:

1. Development of pairwise comparison matrix: In a pairwise comparison matrix, each criterion is compared against every other criterion by assigning a relative dominant value between 1 and 9 to the intersecting cell (Table 2.2). When the criterion on the vertical axis is more important than the factor on the horizontal axis, this value's between 1 and 9. Conversely, the value varies between the reciprocals 1/2 and 1/9.

Tablo 2.2. Scale for pairwise comparison
(Source: Saaty, 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Very strong importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between adjacent scale values	When compromise is needed

2. Computation of the criterion weights: the criterion weights can be computed in three steps. The first step is the summation of the values in each column of the pairwise comparison matrix. The second step is to divide each element in the matrix by its column total. The resulting matrix of the second step is called as the normalized pairwise comparison matrix. The third step is to compute the average of the elements in each row of the normalized matrix. This is to divide the sum of normalized scores for each row by the number of criteria. As a result of the second step, the eigenvector corresponding to the largest eigenvalue of the matrix provides the relative priorities of the criteria. The components of the eigenvector sum to unity. Thus the vector of weights which reflects the relative importance of various criteria can be obtained.
3. Estimation of consistency ratio: The pairwise comparisons must be consistent since this matrix is a consistent matrix. The consistency ratio involves the following steps (Saaty, 1980; Malczewski, 1999):
   - Determine the weighted sum vector by multiplying the weight for the i*th* criterion times i*th* column of the original pairwise comparison matrix, and then, sum these values over the rows,
   - Determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously,
   - Compute lambda (λ) which is the average value of the consistency vector and Consistency Index (CI) which provides a measure of departure from consistency and has the formula as follows:

     $$CI = (\lambda - n)/(n-1)$$

   - Compute the consistency ratio (CR) which is defined as follows:

     $$CR = CI / RI$$

   Where RI is the random index (Table 2.3) and depends on the number of elements being compared. A consistency ratio (CR) of 0.1 or less is a reasonable level of consistency. Otherwise, a consistency ratio above 0.1 requires revisions of the judgments in the matrix because of inconsistent rating (Saaty, 1980).

The advantages of Pairwise comparison method are: (i) it has a theoretical foundation, (ii) it can be incorporated into GIS environment and (iii) only two criteria have to be considered at a time. On the other hand, in each pairwise comparison matrix

7±2 elements can be compared in each pairwise comparison matrix with any reasonable (psychological) assurance of consistency. If the elements are more than 9 they must be divided into subgroups. Another disadvantage is that the relative importance of evaluation criteria is determined without considering the scales on which the criteria are measured (Saaty, 1980; Malczewski, 1999).

Tablo 2.3. Random inconsistency indices (RI) for n = 1, 2, 3,..., 15
(Source: Saaty, 1980)

n	RI	n	RI	n	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

2.1.4.4. Trade-off Analysis Method

In the trade-off analysis method, the decision maker compares two alternatives with respect to two criteria at a time and assess which alternative is preffered. The comparisions is continued until one can deduce how much weight the decion maker must have given to the various criteria. The trade-offs determine a unique set of weights that will allow all of the equally preferred alternatives in the trade-offs to get the same overall value/utility. There is an assumption in this method that the trade-offs the decision maker makes are only between any two criteria that are independent on the levels of other criteria (Malczewski, 1999).

The trade-off analysis method can be used with objectively quantified evaluation criteria while it is more difficult to use with subjective rating criteria. Another weakness of this method is that the decision maker is presumed to obey the axioms and can make fine grained distinctions in difference judgments (Malczewski, 1999). On the other hand, it has been advantage that the method can be applied within either a spreadsheet environment or a computer system.

Tablo 2.4. Summary of methods used in estimating weights
(Source: Malczewski, 1999, p. 190)

Methods/ Feature	**Ranking**	**Rating**	**Pairwise Comparison**	**Trade-off Analysis**
Number of judgments	n	n	n(n-1)/2	< n
Response scale	Ordinal	interval	Ratio	interval
Hierarchical	Possible	Possible	Yes	yes
Underlying Theory	None	None	Statistical/ heuristic	Axiomatic/ deductive
Ease of use	Very easy	Very easy	Easy	Difficult
Trustworthiness	Low	High	High	Medium
Precision	Approximations	Not precise	Quite precise	Quite precise
Software availability	Spreadsheets	Spreadsheets	Expert Choice (EC)	Logical Decisions (LD)
Use in a GIS environment	Weights can be imported from a spreadsheet	Weights can be imported from a spreadsheet	Component of IDRISI	Weights can be imported from LD

2.1.5. Decision Rules

The multicriteria decision rules combine evaluation criteria maps, alternatives, and decision-maker preferences for ordering the decision alternatives and for choosing the most preferred alternative. This means that it integrates the criterion map layers and the weights of criteria into an overall assessment of alternatives. The multicriteria decision rules are divided into multiattribute and multiobjective decision rules.

2.1.5.1. Multiattribute Decision Rules

The aim of MADM is to evaluate a predetermined and limited number of alternatives with respect to each other, to sort out alternatives and/or to select the best or the most preferred alternatives. A number of decision rules are used in MADM problem. In this section five MADM decision rules are described which are the simple additive weighting method, value/utility function approaches, the analytic hierarchy process, ideal point methods and concordance method.

2.1.5.1.1 Simple Additive Weighting Methods

Simple additive weighting methods (SAW) are also called weighted linear combination or scoring methods interchangeably. SAW methods are very easy so that they are the most often used MADM techniques. The methods are based on the concept of a weighted average. An evaluation score is computed for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of criterion/attribute directly assigned by decision maker, and summing the products for all criteria/attributes. After calculating overall score for each alternative, the alternative which has the highest overall score is chosen. Simple additive weighting methods evaluates each alternative, A_i, by the following formula:

$$A_i = \sum_j w_j \, x_{ij} \qquad (2.5)$$

Where x_{ij} is the score of the *i*th alternative with respect to the *j*th attribute, and w_j is the normalized weight of the attribute/criterion.

SAW methods involves following steps (Malczewski, 1999):

1. Define the set of evaluation criteria and alternatives,
2. Standardize each criterion map layer,
3. Define the criterion weights,
4. Construct the weighted standardized map layers,
5. Calculate the overall score for each alternative,
6. Rank the alternatives according to the overall performance score.

Each criterion map is measured on different scales that they must be standardized to a common measurement. Voogd (1983) proposed two procedures for standardizing each criterion map layer. First of them is to divide each raw score by the maximum score for a given criterion. The formula is written as follows:

$$x'_{ij} = {x_{ij}}/{x_j^{max}} \qquad (2.5)$$

where x'_{ij} is the standardized score for the *i*th alternative and *j*th attribute, x_{ij} is the raw score, and x_j^{max} is the maximum score for the *j*th attribute. The advantage of this method is that it is a linear transformation of the raw data. The disadvantage of this procedure is that the worst standardized value does not equal to zero (Malczewski, 1999).

Second proposed approach is to divide the difference between the max raw score and a given raw score by the score range. The formula is written as follows:

$$x'_{ij} = {x_{ij - x_i^{min}}} / {x_j^{max} - x_j^{min}} \tag{2.6}$$

where x_j^{min} is the minimum score for the jth attribute and *j*th attribute, x_j^{min}- x_j^{max} is the range of a given criterion. As a result of the procedure, the standardized score range from 0 to 1. In other words, the worst standardized score is always equal to 0 and the best score equals 1.

There are two assumptions in the SAW method that are the linearity and additivity of attributes. The linearity assumption means that the desirability of an additional unit of an attribute is constant for any level of that attribute. The additivity assumption means that there are no interaction effects between attributes (Malczewski, 1999).

In GIS environment, evaluation criterion map layers can be aggregated to determine the composite map layer by using SAW methods. The methods can also be used in raster and vector GIS environments. Some GIS software which has MCDM tools have been built, for example IDRISI and SPANS. The SAW methods are widely used in location selection problems for landfill site selection (Massam, 1988; Janssen, 1992; Eastman et al., 1993; Şener et al., 2006), in preparation of a land suitability evaluation map for a given land use/s or facility (Pereira & Duckstein, 1993; Malczewski, 1996, 2006b; Dai et al., 2001; Joerin et al., 2001; Banai, 2005; Natividade-Jesus et al., 2007) and evaluation of a predetermined and limited number of allocation alternatives with respect to each other (e.g., Carver, 1991; Bodini & Giavelli, 1992; Zucca et al., 2007).

2.1.5.1.2. Value/Utility Function Approaches

The method is based on multiattribute utility theory (Keeney & Raiffa, 1993). The utility is a generic term that includes the concepts of utility and value functions. The value function approach is applicable in the decision situations under certainty since this approach assumes that the attributes are known with certainty. On the other hand, the utility function approach includes uncertainty since the concept of a utility function is probabilistic in nature. The value/utility function approach involves the following steps (Malczewski, 1999, p. 206-207):

1. Determination of the set of attributes and the set of feasible alternatives,
2. Estimation of the value/utility function for each attribute and use the function to convert the raw data to the value/utility score may layer,
3. Derivation of the scaling constants or weights for the attributes,
4. Construction of the weighted value (utility) map layers; that is multiply the weights of importance by the value (utility) map layers,
5. Combination of the weighted value (utility) maps by summing the weighted value (utility) map layers,
6. Ranking of the alternatives according to the aggregate value (utility); the alternative with the highest value (utility) is the best alternative.

The value/utility function includes a single attribute utility (value) function and trade-off analysis. The single attribute utility (value) function is used to transform the attribute levels into an interval-value scale and the trade-off analysis is used to determine the relative importance of the attributes (Keeney, 1980). By multiplying the utilities by the weights, the trade-offs among the attribute utilities are taken into account in the multiattribute utility function. The overall utility or value for alternative i is a weighted average of the single attribute utilities. The value function model is written as follows (Keeney, 1980; and Malczewski, 1999):

$$V_i = \sum_j w_j \; v_{ij} \tag{2.7}$$

Where V_i is the total value of the ith alternative, v_{ij} is the value of the *i*th alternative with respect to the *j*th attribute measured by means of the value function, and w_j is a normalized weight. As a result of the process, the highest value of V_i is the most preferred alternative (Malczewski, 1999).

The utility function model is similar to the value function that is written as follows (Keeney, 1980; and Malczewski, 1999):

$$U_i = \sum_j w_j \, u_{ij} \tag{2.8}$$

There are two assumptions in the value/utility function approaches which are preferential independence and utility independence. Preferential independence refers that the relative preferences of attributes are not altered by changes in other attributes and utility independence means that the utility function over a single attribute does not depend on the other attribute (Malczewski, 1999).

The most important advantage of this method is the independence assumptions that enable the decision maker to focus initially on deriving utility function for one attribute at a time. In addition, there are computer–based systems for deriving value and utility function such as MATS-PC and LOGICAL DECISIONS. Nevertheless, the method is difficult, impractical and impossible to obtain a mathematical representation of the decision maker's preferences because the procedures to obtain utility function with a moderate number of criteria can be very time consuming and they need a considerable information processing demands on decision maker (Malczewski, 1999).

Value/utility function approach method is used in route selection (Jankowski & Richard, 1994), park boundaries selection (Keisler & Sundell, 1997), agricultural land use (Janssen & Rietveld, 1990), and improvement of habitat suitability measurements (Store & Kangas, 2001).

2.1.5.1.3 Analytic Hierarchy Process

This method (AHP) was developed by Saaty (1980). The method is based on the three principles which are decomposition, comparative judgment, and synthesis of priorities. The decomposition principle means that the decision problem can be decomposed into a hierarchy. The principle of comparative judgments requires pairwise comparisons of the elements. The synthesis principle takes each of the derived ratio-scale local priorities in the various levels of the hierarchy and constructs a composite set of relative weights for the elements at the lowest level of the hierarchy (Saaty, 1980; Malczewski, 1999). According to these principles, the AHP procedure involves three major steps.

The first step is to decompose the decision problem into a hierarchy. The top level is the ultimate goal of the decision problem. The hierarchy decreases from the general to more specific until a level of attributes is reached. Each level should be connected to the next-higher level. Generally a hierarchical structure consists of four levels: goal, objectives, attributes, and alternatives. The alternatives are referred grids (parcels) in GIS databases. Each layer consists of the attribute values assigned to the alternatives which are related to the higher level elements (attributes) (Saaty, 1980; Malczewski, 1999).

The second step is to compare the decision elements on a pairwise base. Pairwise comparisons are the basic measurement in the AHP. The AHP procedure decreases the conceptual complexity of decision making because only two elements are considered at a time. It involves three steps: (i) develop a comparison matrix at each level of the hierarchy; (ii) calculate the weights for each element of the hierarchy; and (iii) compute the consistency ratio (Saaty, 1980). After this tree-step process, the procedure for estimating weights of importance for evaluation criteria is executed. The procedure must be performed for the objective level, the attribute level, and the alternative level respectively. For each given comparison matrix, a pairwise comparison should be generated to estimate vector of priorities (relative weights) of each element at a particular level with respect to the next higher-level. Detailed information is given in pairwise comparison section.

The third step is to construct an overall priority rating. The relative weights of the levels computed in the second step combine to produce composite weights. This is made by means of order of multiplications of the matrices of relative weights at each level of the hierarchy. This process is continued until all levels from the second level to the bottom level have been multiplied together, forming a vector of composite priorities.

The AHP is a very popular and widespread method in MCDM since it is very flexible, useful and has softwares such as Expert Choice, Hibre3+, and Which & Why. AHP method is incorporated into the GIS (Banai-Kashani, 1989; Eastman et al., 1993; Jankowski, 1995; Siddiqui et al., 1996). IDRISI is a software that has integrated GIS and Multicriteria analysis (Eastman, 1993). Furthermore, Xiang et al. (1992) used fuzzy group AHP in land use planning. In the spatial AHP, the vector of attributes priorities serves as the weights of the relative importance of the attributes (map layers). The method is criticized due to the ambiguity in the meaning of the relative importance, the number of comparisons for large problems and the use of a 1 to 9 scale. Additionally, the type of questions asked in the pairwise comparison may be thought meaningless. Making pairwise comparisons dealing with concrete comparison such as distance or area are very easy but when dealing with comparisons like comfort, image or quality of life which are not clear making reasonable pairwise comparisons is very difficult.

Besides, for large problems too many pairwise comparisons must be performed (Malczewski, 1999).

2.1.5.1.4. Ideal Point Methods

In the ideal point method, a set of alternatives are ranked according to their separation from the ideal point. The ideal point can be defined a hypothetical alternative which is the most desirable weighted standardized level of each criterion. The alternative, closest to the ideal point is the best alternative. The separation is measured in terms of metric distance. The ideal point decision rule is mathematically stated as follows (Malczewski, 1999):

$$s_{i+} = \left[\sum_j w_j^p \left(v_{ij} - v_{+j}\right)^p\right]^{1/p} \quad (2.9)$$

Where s_{i+} is the separation of the *i*th alternative from the ideal point, w_j is a weight assigned to the *j*th criterion, v_{ij} is the standardized criterion value of the *i*th alternative, v_{+j} is the ideal value for the *j*th criterion, and p is a power parameter ranging from 1 to ∞. The negative ideal point decision rule can be written as follows (Malczewski, 1999):

$$s_{i-} = \left[\sum_j w_j^p \left(v_{ij} - v_{-j}\right)^p\right]^{1/p} \quad (2.10)$$

Where v_{-j} is the worst value of the *j*th criterion (the negative ideal). The best alternative can be determined by the maximum separation from the negative ideal.

The GIS-based ideal point method involves the following steps (Malczewski, 1999, p. 224-225):

1. Determination of the set of feasible alternatives,
2. Standardization of each attribute map layer by transforming the various attribute dimensions (x_{ij}) to unidimensional attributes (v_{ij}),
3. Definition of the weights assigned to each attribute; the set of weights must be such that $0 \leq w_j \leq 1$ and $\sum_j w_j$=1.
4. Construction of the weighted standardized map layers by multiplying each value of the standardized attribute layer v_{ij} by the corresponding weight w_j,

5. Determination of the maximum value (v_{+j}) for each of the weighted standardized map layers,
6. Determination of the minimum value (v_{-j}) for each weighted standardized map layers,
7. Using a separation measure, calculate the distance between the ideal point and each alternative,
8. Using the same separation measure, determine the distance between the negative ideal point and each alternative,
9. Calculation of the relative closeness to the ideal point (c_{i+}) using below equation

$$c_{i+} = \frac{s_{i-}}{s_{i+} + s_{i-}}$$

10. Ranking of the alternatives due to the descending order of c_{i+}; the alternative with the highest value of c_{i+} is the best alternative.

The most popular ideal point method is the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) (Hwang & Yoon, 1981).

The ideal point methods in the GIS environment were used in the spatial decision problems (Carver, 1991; Eastman et al., 1993; Pereira & Duckstein, 1993; Malczewski, 1996). One of the advantages of the model is to provide complete ranking and information on the relative distance of each alternative to the ideal point. Second advantage is that these approaches avoid some of the difficulties associated with the interdependence-among-attributes. In the ideal point model, an alternative is assumed as an inseparable bundle of attributes. This makes the ideal point methodology an attractive approach to decision problems when the dependency among attributes is difficult to test or verify (Malczewski, 1999).

2.1.5.1.5 Concordance Method

Concordance method is based on a pairwise comparison of alternatives. It gives an ordinal ranking of alternatives. In other words, these methods only express that alternative A is preferred to alternative B, but it cannot indicate by how much. ELECTRE I (Elimination et Choice Translating Reality) is the best known concordance method and this approach has been modified such as ELECTRE II, III, IV, and

PROMETHEE. The concordance method involves the following steps (Malczewski, 1999, p. 228):

1. Determine the set of feasible alternatives,
2. Standardize each attribute by transforming the various attribute dimensions to nondimensional attributes,
3. Define the weights assigned to each attribute; the set of weights must be such that $0 \leq w_j \leq 1$ and $\sum_j w_j=1$.
4. Generate the concordance matrix by calculating the concordance indices for each pair of alternatives,
5. Sum the rows of concordance matrix to obtain the overall score for each alternative,
6. Rank the alternatives according to descending order; the alternative with the highest value is the best alternative.

The most important advantages of the concordance methods are to contain both objective and subjective criteria and the need for least amount of information from the decision maker. On the other hand, the fact that a complete ranking of the alternatives may not be achieved is the major disadvantage (Malczewski, 1999). The concordance methods have been implemented within GIS environment (Carver, 1991; Can, 1992).

2.1.5.2. Multiobjective Decision Making

While the attributes include both decision variables and decision criteria in MADM, decision criteria (objective functions) and decision variables are separated in the MODM. MODM decision rules define the set of alternatives in terms of a decision model consisting of a set of objective functions and a set of constraints imposed on the decision variables (Malczewski, 1999, p. 237). Whereas decision variables and objective functions are defined explicitly, the alternatives are defined implicitly in the MODM. In mathematical terms, MODM is formulated as follows (Malczewski, 1999):

$$F(x) = max\{f_1(x), f_2(x), \ldots, f_q(x)\} \tag{2.11}$$

subject to

$$g_v(x) \leq 0, \qquad v = 1, 2, \ldots, c$$

$$x = x_1, x_2, \ldots, x_m$$

Where x is a vector of decision variable, F(x) is the q-dimensional objective function, f_k (x) (k = 1, 2,...,q) are the objective functions and g_v(x) are c distinctive constraint functions; the constraints define the set of feasible solutions.

The aim of the MODM problem is to find a set of values for the decision variables which optimizes objective functions. The objective functions can be maximization, minimization and sometimes both of them together. Some of the multiobjective decision rules which are value/utility function methods, goal programming, interactive programming, compromise programming, and data envelopment analysis are widely applied to spatial decision problems (Malczewski, 1999).

2.1.5.2.1 Value/utility Function Methods

The value/utility function methods in MODM are based on multiattribute utility theory. These methods assume that an individual or group has a value/utility function and the decision maker behaves due to the value/utility maximizing decision rule (Keeney & Raiffa, 1993; Malczewski, 1999). Whereas the value function techniques are used in deterministic decision situation, the utility function techniques are used in probabilistic decision situation when uncertainty measure is incorporated into a decision maker's preferences (Malczewski, 1999). An additive form of the utility function is widely used in spatial decision problems. This approach uses a weighting scheme to combine criteria into a single measure of value/utilities. The additive value function can be written as follows (Malczewski, 1999, p. 239):

$$F(x) = \max \{\sum w_k v(f_k(x))\} \qquad (2.12)$$

subject to

$$x \in X, \ \ w_k \geq 0 \qquad for\ k = 1,2,\dots,q$$

Where w_k is the weight of importance assigned to the kth objective. The solution determines the alternative that has the highest functional value or utility of the value/utility function.

The difference between the value/utility approaches in MODM and MADM should be explained. In MADM problems, the value/utility function decision rule selects an alternative from among a finite set of alternatives. The alternative has the highest value of the value/utility function. On the other hand, in MODM problems, where a large or an infinite set of feasible alternatives is evaluated, the problem must be solved using mathematical programming. In summary, the value/utility function in MODM is an optimization process, while the value/utility function in MADM is a selection process (Malczewski, 1999).

An important advantage of the value/utility function approach is that the multiobjective function F(x) is reduced to a scalar-valued function. The disadvantage of the utility/value functions is to construct value/utility functions (Malczewski, 1999). The value/utility function methods have been used in spatial decision problems, such as the location of hazardous waste disposal facilities (DiMento et al., 1985), and the fire fighting unit location problem (Mirchandani & Reilly, 1987).

2.1.5.2.2 Goal Programming

Goal programming is a form of linear programming that optimizes multiple goals. While the goal programming determines the point that best satisfies the set of goals in the decision problems, linear programming determines the point that optimizes a single objective. The aim of the goal programming is to minimize the deviations from the goals. In the goal programming, the decision maker should determine the most desirable value (goal) for each objective as the aspiration level. The objective function for goal programming is expressed as follows (Malczewski, 1999, p. 242):

$$f_k(x) + d_k^- - d_k^+ = a_k \qquad for\ k = 1, 2, \ldots, q \tag{2.13}$$

$$d_k^-, d_k^+ \geq 0, \ (d_k^-, d_k^+) = 0$$

Where $\square_k$ is the aspiration level for the *k*th objective, d_k^- is negative goal deviation, and d_k^+ is the positive goal deviation. The negative and positive goal deviations are positive variables that measure deviations of the current value of the *k*th criterion function from the corresponding aspiration level. The decision variables, *x*, and the deviational variables, *d*, are used in the goal programming. The objective function is minimized and should be composed of deviational variables. An optimal solution minimizes the deviations from the aspiration levels (Malczewski, 1999).

Three types of goal programming approaches have been widely used in spatial problems that are weighted goal programming, Chebyshev goal programming, and lexicographic goal programming (Malczewski, 1999).

The advantage of the goal programming is its computational efficiency since the goal programming approaches give us an efficient linear programming computational environment. On the other hand, the approach has several conceptual and technical problems. First, it needs fairly detailed a priori information about decision maker's aspiration levels, preemptive priorities, and the importance of goals in the form of weights. The decision maker can find them difficult or even impossible. Second, the goal programming has a poor controllable interactive process in the case of discrete problems (Malczewski, 1999). The goal programming is widely used in spatial decision problems (Massam, 1988; Carver, 1991; Malczewski & Ogryczak, 1996; Ridgley & Aerts, 1996).

2.1.5.2.3 Interactive Programming

Aim of the interactive programming is to determine the best decision outcome among the set of efficient solutions by means of a progressive communication process between the decision maker and computer-based system (Nijkamp, 1979; Malczewski, 1999). Unlike the above MODM methods, this method does not require a priori information about decision maker's preference structure. The model assumes that there is a utility/value function implicitly and the function is maximized by means of a formal mechanism that involves an interactive exchange of information between a substantive model of the decision situation (computer-base system) and the decision maker (Malczewski, 1999, p. 247). The interactive programming involves a judgmental and a computational phase. In the judgmental phase, the decision maker evaluates information provided by a computer-based system and decides his or her preferences with respect to the values of the criteria. In the computational phase, a solution is generated due to the decision maker requirements specified in the judgmental phase. This interactive process is continued until the decision maker accepts that a criterion outcome is acceptable. The interactive approach has been used in spatial decision problems (Nijkamp, 1979; Massam & Malczewski, 1991; Fischer et al., 1996)

2.1.5.2.4 Compromise Programming

Compromise programming is based on the displaced ideal concept (Zeleney, 1982; Malczewski, 1999). Aim of the compromise programming is to minimize the distance from the ideal solution. The solutions which are the closest to the ideal solutions are called compromise solutions. Compromise programming is expressed mathematically as follows (Malczewski, 1999, p. 252):

$$\min \quad L_p = \left\{ \sum_k w_k^p \left[\frac{f_{k+}(x) - f_k(x)}{f_{k+}(x) - f_{k-}(x)} \right]^p \right\}^{\frac{1}{p}} \qquad (2.14)$$

subject to

$$x \in X, \quad w_k \geq 0 \quad for\ k = 1,2,\ldots,q$$

Where L_p is the distance metric, w_k is the weight of the kth objective function, f_{k+} (x) is the ideal solution of the kth objective function, f_{k-} (x) is the nadir or antiideal value of the kth objective function, and p is a power parameter ranging from 1 to ∞.

The advantage of compromise programming is its simple conceptual structure. This model is very useful when decision makers tend to rely on their intuition and insight. Another advantage of the model is that the set of preferred compromise solutions can be ordered between the extreme criterion outcomes, and consequently, an implicit trade-off between criteria can be performed. The disadvantage of the method is that there is no clear interpretation of the various values of the parameter p (Malczewski, 1999). The compromise programming has been applied in spatial decision problems (Shafika et al., 1992).

2.2. Using Multicriteria Decision Making and Optimization in Planning

Malczewski (1999) defines GIS-based (or spatial) multicriteria decision analysis as a rich collection of techniques for analyzing geographic events where the results of the analysis (decisions) depend on the spatial arrangement of the events. Many researches in information sciences recognize that the multicriteria decision problem is at the core of decision support (Angehrn, 1992; Malczewski, 1999). In this context, MCDM is recognized as a decision support system (DSS) in land use planning. MCDM techniques integrated with geographical information systems (GIS) have been extensively used in resource allocation problems of environment/ecology, transportation, urban/regional planning, waste management, hydrology, agriculture, and forestry since the 1990's (Malczewski, 2006a). One sub-section of MCDM techniques is MADM/MCA which may involve in preparation of a land suitability evaluation map for a given land use/s or facility (Pereira & Duckstein, 1993; Malczewski, 1996, 2006b; Dai et al., 2001; Joerin et al., 2001; Banai, 2005; Natividade-Jesus et al., 2007) and evaluation of a predetermined and limited number of allocation alternatives with respect to each other (e.g., Carver, 1991; Bodini & Giavelli, 1992; Zucca et al., 2007). MCA is a useful and simple evaluation and selection technique when the alternatives are available.

However, in many cases the set of allocation alternatives are not available, or difficult to define. In such cases, MODM is used as the second basic technique of MCDM that generally generates optimal allocation alternatives using optimization techniques. MODM is widely used for optimum land use allocation in land use planning (Bammi & Bammi, 1979; Gilbert et al., 1985; Chuvieco, 1993; Dokmeci et al., 1993; Grabaum & Meyer 1998; Gabriel et al., 2006; Ligmann-Zielinska et al., 2008), in determination of facility locations (Malczewski, 1991; Minor & Jacobs, 1994; Eastman et al., 1995; Maniezzo et al., 1998; Cheng et al., 2003), in land allocation problem with a shape constraint such as compactness (Aerts & Heuvelink, 2002; Aerts et al., 2003), convexity and contiguity (Williams, 2003; Shirabe, 2005; Minor & Jacob, 1994) and environmental conflict analysis (Malczewski et al., 1997). Besides, Malczewski and Ogryczak (1995 and 1996) discussed multiple criteria location problem with MCDM methods. MODM is a design technique because it defines a best solution or alternative with mathematical optimization techniques, especially when competing land uses are present.

Generally, MCDM has been used for allocation of only one land use or facility location. Bammi and Bammi (1979) were the only planners who applied MODM techniques for overall urban area for allocation of all urban land uses. They developed an optimization model to prepare a comprehensive land use plan of DU Page Country that considers several objectives simultaneously and also satisfies constraints on desired growth patterns. Objectives of the optimizing function were to minimize conflict between adjacent land uses, travel time, tax costs, adverse environmental impact, and the cost of community facilities. Besides, Hanink and Cromley (1998) developed a land-use assignment model that combines MCDM and GIS. They illustrate the model by a hypothetical case study which includes only commerce, recreation, and wild land uses.

In conclusion, it can be said that MCDM techniques can be used as a decision making and evaluation tool for analyzing urban issues but it has not been applied sufficiently in urban planning issues yet.

CHAPTER 3

LAND ASSIGNMENT MODEL

3.1. Background of the Model

The land assignment model which is a part of optimum land use allocation problem is based on the Von Thünen's model of land use (Hanink & Cromley, 1998). The relationship between accessibility, land uses and land values was first set out in von Thünen's theory of land use (Hall, 1966). The Isolated State which was his treatise developed the first serious treatment of spatial economics, connecting it with the theory of rent. He developed the basics of the theory of marginal productivity. It can be expressed mathematically as follows:

$$R = Y\,(P - C) - \;YFm$$

Where *R* is the location rent, *Y* is the yield of (agricultural) production per unit of land, *P* is the market price per unit of production, *C* is the cost per unit of production, *F* is a transport charge per unit of output per unit of distance, and *m* is the total distance between the site of production and the market place. His model is based on the following assumptions:

- The city is located centrally within an "Isolated State".
- The Isolated State is surrounded by an unoccupied, unused land.
- The land of state is completely flat, having no rivers, and mountains.
- The soil, climate and all other factors on agriculture are the same.
- Farmers in the Isolated State transport their own goods to market via oxcart, over land, directly to the central marketplace. There are no roads in the Isolated State.
- Farmers in the state behave rationally to maximize profits.

The Von Thünen theorized that four rings of agricultural land use would surround the city (see Figure 3.1). Dairying and intensive farming occur in the ring closest to the city. Since dairy products such as milk, fruit, vegetables etc. must get to market quickly, they would be produced close to the city. The second ring consists of timber and firewood. Wood was a very important fuel for heating and cooking. It is very heavy and difficult to transport so it is located as close to the city. In the third zone, extensive fields such as grain would be produced. They can be located further from the city because they last longer than dairy products and are much lighter than fuel. The final ring would be allocated for ranching. Animals can be raised far from the city since they are self-transporting. Beyond the fourth ring lies the wilderness.

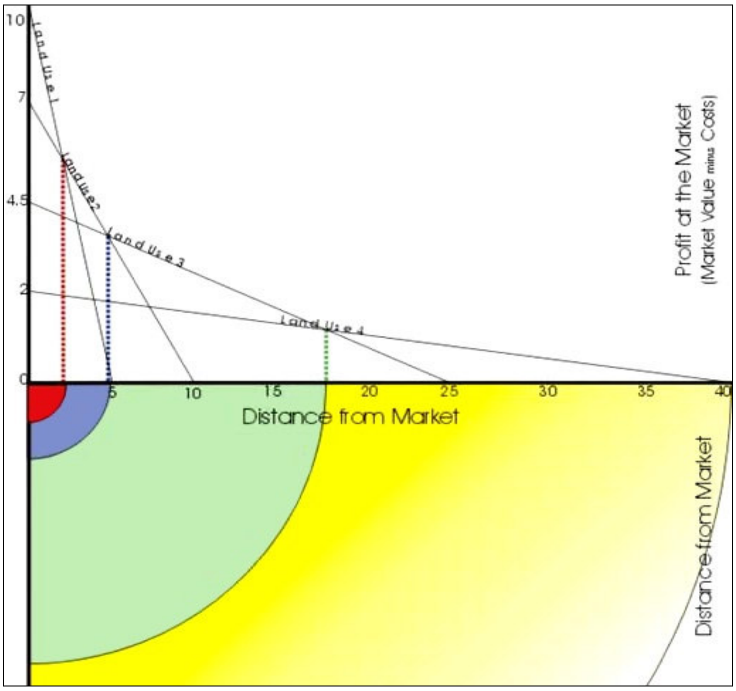

Figure 3.1. Von Thünen’s model of agricultural land-uses allocation
(Source: http://www.csiss.org/classics/content/9)

The von Thünen model has been criticized since it assumed unlikely conditions such as the production taking place around an isolated market and soil being of constant fertility. However, it should be noted that the von Thünen model established a distance-cost relationship which has recently become the basis of urban location theory (Balchin et al., 2000)

According to von Thünen model, uncompetitive land uses such as recreation and afforestation are residuals that will only be found after the market is satisfied with respect to its demand for competitive land uses. Unfortunately, the market’s optimal allocation of land under which conventional location rents and, therefore, conventional land values are maximized is not necessarily the socially optimal allocations of land uses under which aggregate societal benefits are maximized (Hanink & Cromley, 1998, p.469). Hanink and Cromley (1998) developed the land assignment model for optimal allocation of land to competing uses that do not have consistently determined market values. To achieve this, social, environmental and economic benefit is combined together in the model. They think that unpriced land uses also provide benefits such as environmental and social that can be construed as unconventional location rents because of their spatial gradients.

Hanink and Cromley (1998) illustrated this approach as in Figures 3.2 and 3.3 and also called this approach the "second-best" because it is not what the market would normally yield. Land use II is referred to recreational land use in Figure 3.2 and wild land use in Figure 3.3. As seen in Figures 3.2 and 3.3, the location rent to use II is lower everywhere in the region. Normally, the allocation of land under these conditions would first maximize values with respect to land use I because of its higher potential location rent, and then allocate land use II to remaining parcels. Nevertheless, such an allocation may not be socially and environmentally optimal because land use II's return is also maximized at the regional center or another segment. The realization of land use II's highest return would require its occupation of range AF, pushing out land use I to range FG in the figure 3.2. And land use II should be occupied in segments AD and JL rather than in segments AD and DJ in Figure 3.3. This second-best arrangement of land use would be a social and environmental improvement if total land rent is maximized in the aggregate (Hanink & Cromley, 1998).

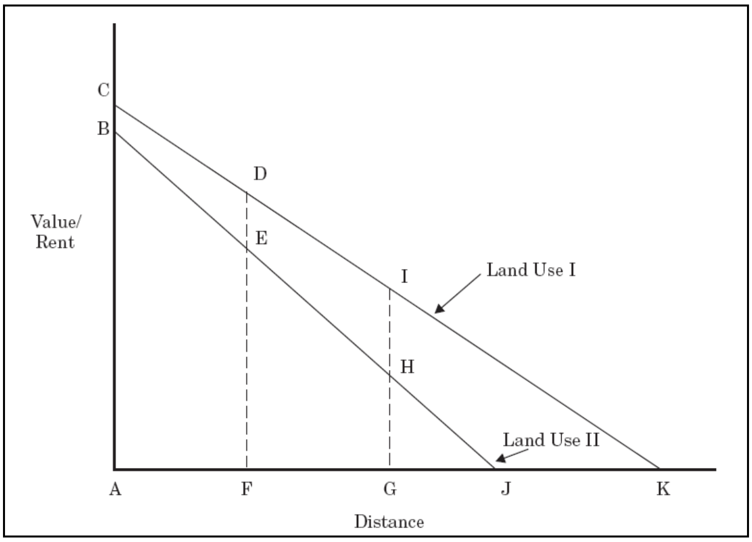

Figure 3.2. Competing land uses with different centers of maximum value
(Source: Hanink & Cromley, 1998, p.469)

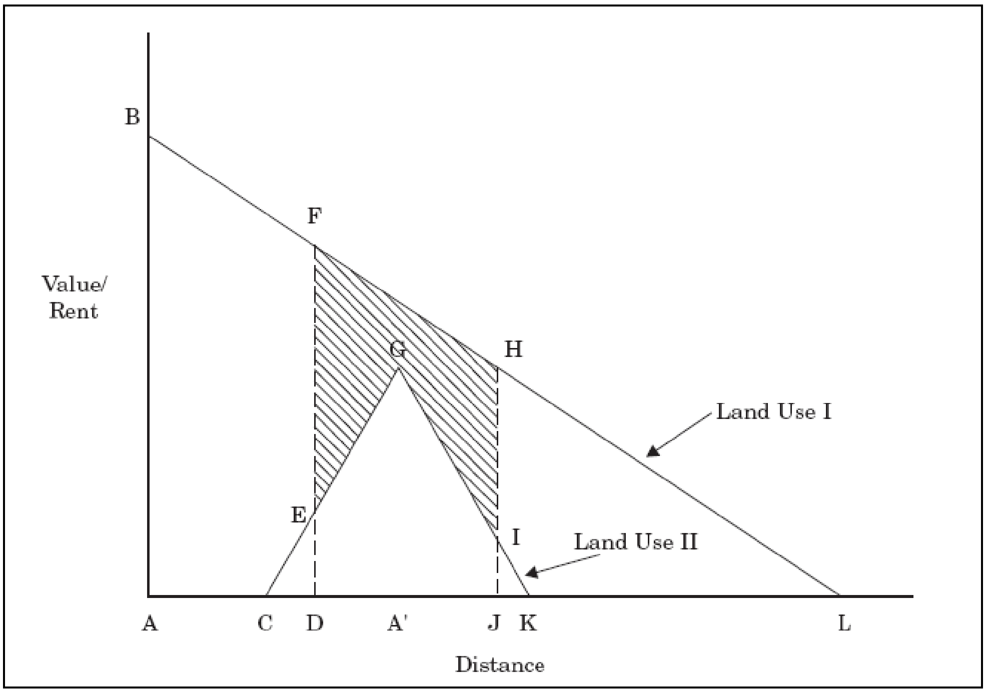

Figure 3.3 Competing land uses with different centers of maximum value
(Source: Hanink & Cromley, 1998, p.471)

3.2. Overview of the Model

The land assignment model used in the thesis is based on the "second-best" principle of opportunity-cost minimization. Due to the model, urban area is formed from discrete equal sized grids (i.e. each grid represents one distinct parcel) and there are *m* land-uses. The model assigns only one land use between *m* land uses to each parcel that makes optimum land-use allocation. This land allocation is made according to parcel's suitability score. The suitability scores of each parcel are combined from a set of quality characteristics (site) and accessibility characteristics (situation). Site characteristics measure the quality of the parcel while situation characteristics measure the accessibility of the parcel. Multicriteria evaluation procedures with geographical information Systems (GIS) is used to determine each parcel's suitability scores with respect to each land use. The suitability scores show the attractiveness with respect to given land use. In calculating suitability scores for each land use, the first step is to measure and standardize all criteria score considered. A method for measuring criterion weights is pairwise comparison technique in the context of Analytic Hierarchy Process (AHP) (Saaty, 1980). After the criterion scores have been measured and standardized, the composite suitability index, S_{ij}, is calculated as the weighted linear combination of criterion scores (Hanink & Cromley, 1998);

$$S_{ij} = \sum_{k=1}^{P_j} w_{ijk} A'_{ijk} \tag{3.1}$$

Where

S_{ij} : is the composite suitability index,

P_j : is the number of criteria for the jth land use,

w_{ijk}: is the weight of the k th criterion with respect to the j th potential land use for the i th parcel

A'_{ijk} : is the suitability scalar of the i th parcel for the j th land use with respect to the k th criterion

To obtain the suitability measures to use in the model, a trade-off weight, W_j, must be established for each land use so that more important land-uses can occupy the most suitable sites. In addition, the composite suitability indexes are scaled to the same interval so that the weights trade-off values on the same interval of measurement. They can be estimated using pairwise comparison technique. Assuming that S_{ij} is the net benefit, the scaling transformation is (Carver, 1991; Hanink & Cromley, 1998);

$$S'_{ij} = W_j \frac{S_{ij} - \min_i S_{ij}}{\max_i S_{ij} - \min_i S_{ij}} \tag{3.2}$$

The land assignment model can be formulated as either benefit maximization or cost minimization. In this thesis, the objective function is formulated as maximize total benefit and the model is formulated as a binary integer programming. The generalized assignment problem is expressed mathematically as follows (Hanink & Cromley, 1998, p. 474):

$$\text{Maximize: } \sum_{i=1}^{n} \sum_{j=1}^{m} S'_{ij} X_{ij} \tag{3.3}$$

$$\text{Subject to: } \sum_{i=1}^{n} X_{ij} = D_j \tag{3.4}$$

$$\sum_{j=1}^{m} X_{ij} \le 1 \tag{3.5}$$

$$X_{ij} = 0 \text{ or } 1 \quad \forall i, j \tag{3.6}$$

Where

n : is the number of land parcels,

m: is the number of land uses,

X_{ij}: is the decision variable assigning the i th land parcel to the j th land use,

S_{ij} : is a suitability measurement of the parcel i when it is assigned to the j th land use, and

D_j : is the demand level for the j th land use.

Equation (3.4) states that total assignment of a given land-use must be equal to a predetermined number of parcels (i.e. total demand). Equation (3.5) guarantees that each parcel is assigned to only one land use among m alternative land uses. Equation (3.6) states that the decision variables must be binary variable, which is 0 or 1. It should be noted that there may not be a constraint for every land-use. If total number of grids for a land use is not specified then it will be determined internally. Furthermore, the constraint could also be specified as "greater/smaller or equal than" to a predetermined value. The dual formulation of this program is (Hanink & Cromley, 1998)

$$\text{Minimize:} \quad \sum_{j=1}^{m} D_j C_j + \sum_{i=1}^{n} R_i \tag{3.7}$$

$$\text{subject to:} \quad C_j + R_i \geq S_{ij}^{'} \quad \forall i, j \tag{3.8}$$

Where

C_j: is the shadow price associated with the demand for each land use,

R_i: is the shadow price associated with the demand for each parcel.

In terms of market prices R_i is interpreted as the ideal market price in a perfect equilibrium (Barr, 1973) while C_j is the total urban utility of respective land-use that one additional unit increase total urban benefit as much as C_j as long as total amount of *j th* land use is defined as a constraint in the program. Even if we do not have explicit market prices, derived values of these shadow prices are very useful proxies, and give us immense opportunities to evaluate land-use policies in an urban area.

In conclusion, to run the general assignment model, one need to compute suitability scores of each parcel with respect to each land use as (i) the evaluation criteria for each land-use, (ii) the suitability scalars of the parcels for the land uses with respect to suitability criterion, (iii) the combinatorial weights of suitability criteria for each land-use and for each parcel, and (iv) the trade-off weights for each land-use types in the models.

3.3. Use of the Model in the Conservation Decisions Analysis

The aim of the model is making optimum land-use allocation depending on the parcels' suitability scores. One of the criteria which changes parcels' suitability scores with respect to each land use is conservation decisions since the type and degree of conservation area directly determines which kind of land-uses can and cannot be allocated in a conservation area. Thus, changing boundary, degree or type of the conservation areas bring about a new optimum land-use allocation. In this context, the model can be used to analyze the effects of changing conservation decisions on land-use allocation when all other criteria are stable. A detailed explanation is given below about conservation decisions and land-use allocation in natural and archaeological conservation areas in Turkey.

In Turkey, the law of 2863 has been adopted in order to conserve natural and historical areas since 1983. According to the law, conservation of every immovable cultural and natural asset is responsibility of the Ministry of Culture and Tourism. The Ministry has been established a "High Committee for the Conservation of Cultural and Natural Assets" and "Regional Conservation Committees". Tasks and authorities of the High Committee for the Conservation of Cultural and Natural Assets are as follows;

- To determine resolutions in connection with conservation and restoration of immovable culture and nature properties,
- To provide coordination between the regional conservation committees,
- To give opinions to the Ministry about problems in application.

The High Committee determines the resolutions about all culture and nature assets that need conservation including natural areas, historical urban areas, archaeological areas, buildings, trees and etc. Because of its aim and scale, this study includes only conservation areas. The conservation areas may have three kinds of conservation types and degrees. The types of conservation areas are natural, archaeological, and urban. The degrees of natural and archaeological conservation areas are first, second and third. As a general guideline, there is a positive correlation between the conservation degree and importance, virginity and scarceness. In other words, the first degree natural conservation areas are more important, virgin and scarce than the second degree natural conservation areas. The urban conservation areas are not graded.

The High Committee set a resolution about archaeological conservation areas that was published in the Official gazette in 1999 and numbered 658. Due to the resolution, the archaeological conservation areas are divided into three categories according to the importance and quality of conservation areas. First degree archaeological conservation areas have to be conserved in their existing states which can be made only through scientific studies for conservation. Second degree archaeological conservation areas are conserved like 1st degree archaeological conservation areas but the regional conservation committees can determine conservation and use conditions. Third degree archaeological conservation areas can be allocated to every land use due to bore results.

The High Committee has designated the last resolution about natural conservation areas that was published in the official gazette in 2007 and numbered 728. According to the resolution, the natural conservation areas are divided into three categories according to scarcity, virginity and beauty. First degree natural conservation areas have to be conserved in their existing states that in these areas a construction is not permitted. But recreative facilities can be constructed such as toilet, restaurant, sideboard, cafeteria, undressing cabin, pedestrian lane, open-air car park, landing place, fishing port, etc. In these areas, afforestation can be made. In conclusion, first degree natural conservation areas can be allocated only to recreation and afforestation land-uses. Second degree natural conservation areas can be allocated to only recreation, afforestation and tourism activities. Third degree natural conservation areas can be allocated to recreation, afforestation, tourism and residence.

The High Committee determined a resolution about urban conservation areas in the official gazette in 2006 and numbered 720. The aim of the resolution was to describe the design process of urban conservation. According to this resolution, urban conservation areas have to be conserved in their existing states.

The Ministry of Culture and Tourism has established 20 Regional Conservation Committees each of which is authorized to conserve cultural and natural entities in its region. The task of the regional conservation committee is to determine boundary, type and degree of conservation areas which needed conservation as a cultural and natural asset. Each regional conservation committee has 5 members, 3 of which specialized in archaeology, art history, museum, architecture and city planning and are selected by the Ministry of Culture and Tourism. And the other two are academicians in archaeology, art history, museum, architecture and city planning disciplines and are selected by the Council of Higher Education (YÖK).

CHAPTER 4

DESCRIPTION OF THE STUDY AREA: CASE OF ÇEŞME

4.1. The Description of Çeşme

Master plan area of Çeşme, covered municipality and adjacent area of Çeşme municipality is selected as a case study area (see Figure 4.1). Çeşme is a county of the İzmir Province in Turkey, and located at the far west corner of the peninsula called with the same name. Çeşme has been an important destination of national and international mass summer tourism since 1980's. The county has many natural, environmental and archaeological endangered assets due to such high demand and mass consumption of tourism. Since 1990, rising awareness of the environment has brought the concept of "conservation and usage equilibrium" as a sustainable planning approach in these towns.

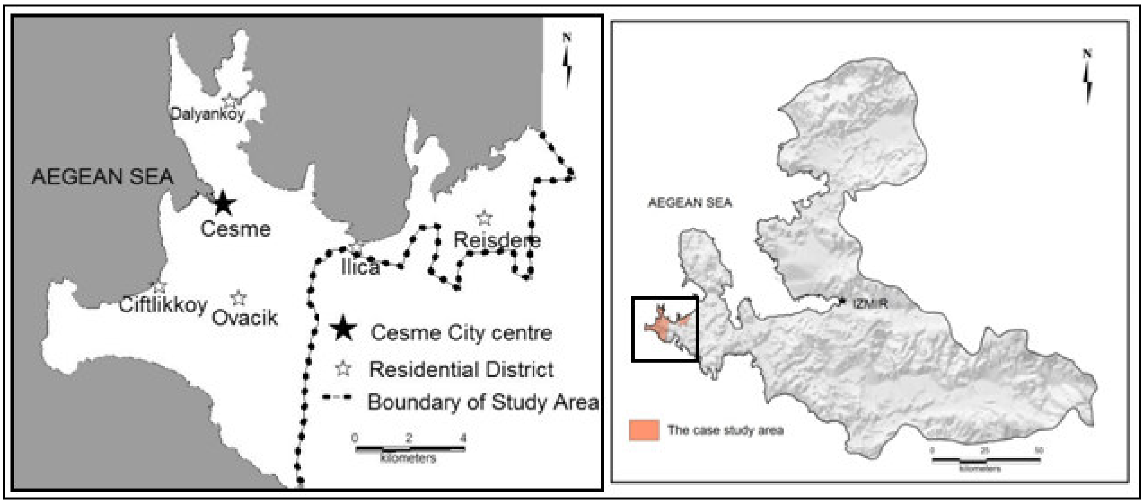

Figure 4.1. Location of İzmir and the study area

İzmir Conservation Committee 1 is the authorized regional conservation committee in Çeşme. Boundary, type and degree of conservation areas in the study area were changed totally in 1991, 1992, 1995, 1996, 1998 and 2007. In other words, within last 20 years, six different conservation schemes were ruled and imposed in the city with different geographical coverage. Before year 1991, there was not any conservation area in the study area. Starting in 1990's, İzmir Conservation Committee 1 has declared the first conservation areas within the city. In these modifications, even though total area of conservation was not decreased, the share of the 1st degree conservation areas was gradually decreased by half. These modifications were pushed by the investors in the city. This time, the environmentalists were the complaining side. Obviously, the struggle between environmentalist and entrepreneur groups played an active role in conservation decisions. However, the rationality and reasoning of these schemes have never been resolved among different parties of interests, and the discussions about them still continue. The spatial configurations of the conservation schemes over time are discussed below.

Changing the conservation scheme in Çeşme has caused to make a new master plan according to the new conservation decisions. The master plans of the case study area were approved in 1991, 1992 and 2002 years and studies for a new master plan have been continuing since 2007. Frequently changing conservation decisions and making a new master plan is a result of the dilemma between conservation and usage. Recently, a new planning effort in the city has ignited the same discussions about the geographical extension and classification of the conservation areas. To come up with a somewhat rational answer to these discussions is the primary motivation of this thesis.

Çeşme is a summer resort of Turkey for the nationals and a very attractive destination for the international tourism. For this reason, there are big differences in the population of the city in winter and summer seasons. It can be seen in Table 4.1 that the population of the city is around 30.000 in winters while it can reach up to 150.000 and even to 200.000 with daily visitors for seasonal attractions in the summer time. This mass demand of tourism has inevitably put very high pressure on the fragile assets that include geo-thermal resources, very pristine bays, sceneries, coast lines, archaeological sites, and historical urban architecture. Construction demand for resort houses and tourism facilities with varying type, quality and magnitudes in these sensitive areas has been very high to increase the economic benefit.

The study area is approximately 9.450 ha. The total area of the land-uses that was included in the model is 9.068 ha. Approximately 390 ha. is kept out of the model since they were built-up areas and infrastructure facilities. This new plan would accommodate approximately 180,000 residing people in the future.

Tablo 4.1. The census of case study area
(Source: The Master Plan report, 2002)

	Residential Districts/Year	1955	1960	1965	1970	1975	1980	1985	1990	2000
Study Area	*City Cen. of Çeşme*	4196	3712	4068	3940	5284	6451	10124	20622	25257
	Dalyanköy	480	488	488	543	559	567	-------	-------	-------
	Çiftlikköy	417	419	453	459	547	783	-------	-------	-------
	Ovacık	665	665	652	647	584	587	618	792	1554
	Germiyan	374	345	390	400	369	399	346	388	1181
	Reisdere	436	400	485	405	424	579	-------	-------	-------
	Sum	***6568***	***6029***	***6536***	***6394***	***7767***	***9366***	***11088***	***21802***	***27992***

4.2. Master Plans of Çeşme

The struggle between environmentalist and entrepreneur groups led to frequently change of not only conservation schemes but also master plans. Since 1990, the master plans of Çeşme have been changed 3 times and they were approved and put into practice in 1991, 1992 and 2002 year respectively (see Figure 4.2-4.3-4.4-4.5). In 2007 year, the conservation scheme was changed and Çeşme Municipality began a new planning study that is still continuing. It is expected that the new plan will be designed depending on the Environmental Plan of Manisa-Kütahya-İzmir with a scale of 1/100000 approved by the Ministry of Environment and Forestry in 2007 since the Environmental plan determines general planning decisions about study area.

As it can be seen from Figure 4.2, the largest tourism and residential development area was planned in the master plan of 1992 and the smallest residential development area was planned in the master plan of 2002. In this context, it can be said that the master plan of 2002 is the most conservative plan and the master plan of 1992 is the most constructive plan. The residential development area was increased in the environment plan of 2007 when compared to the master plan of 2002. The environmental plan generally conserved the decisions of the master plan of 2002 but the south of study area was planned as a “special tourism centre” and the residential development area was increased.

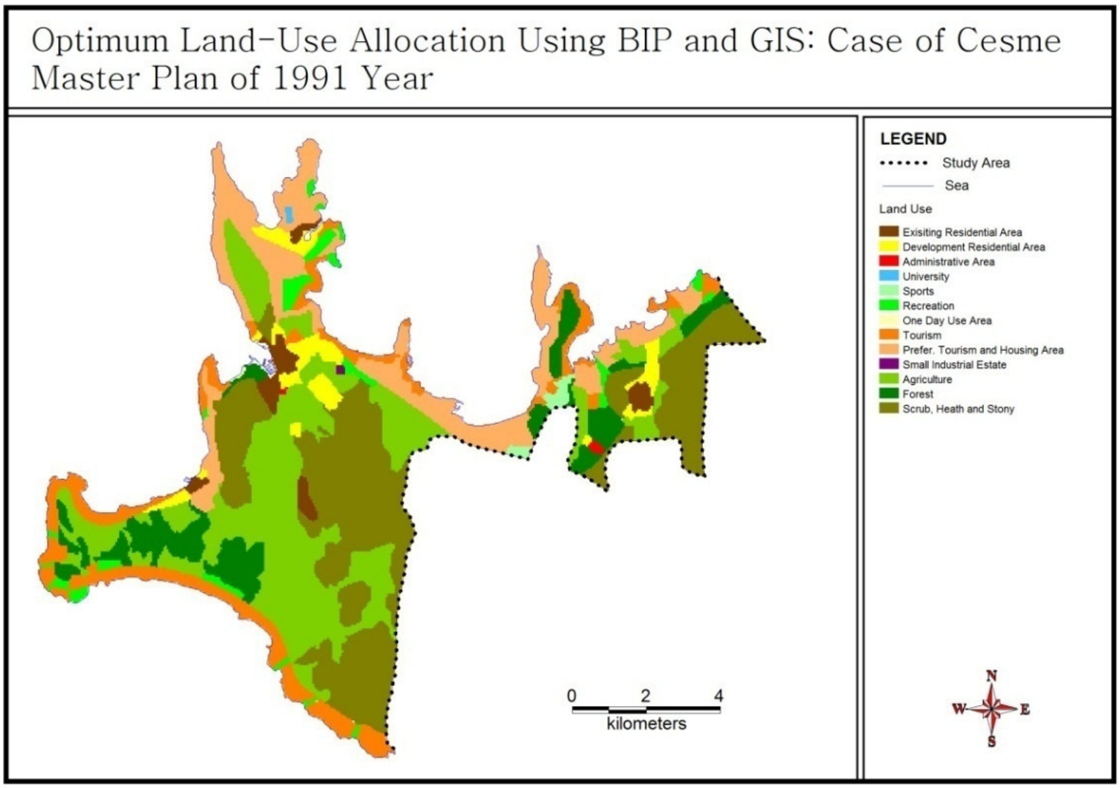

Figure 4.2. Master plan of 1991
(Source: İYTE, 2002)

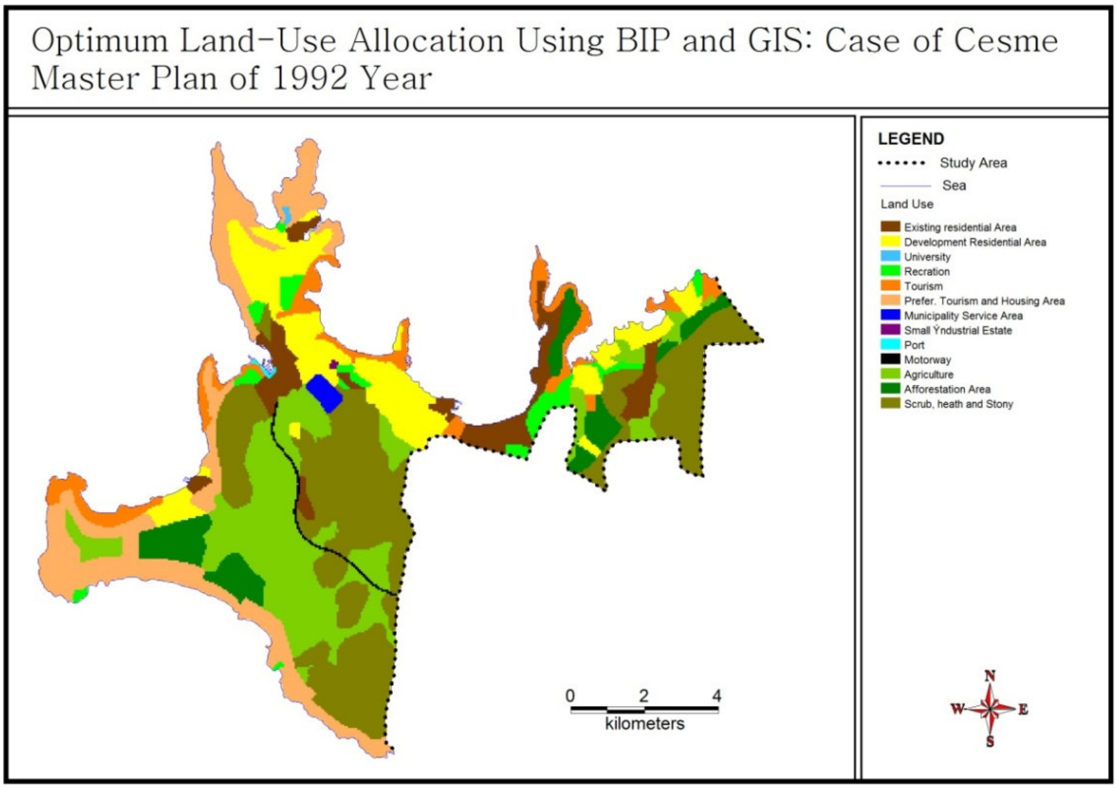

Figure 4.3. Master plan of 1992
(Source: İYTE, 2002)

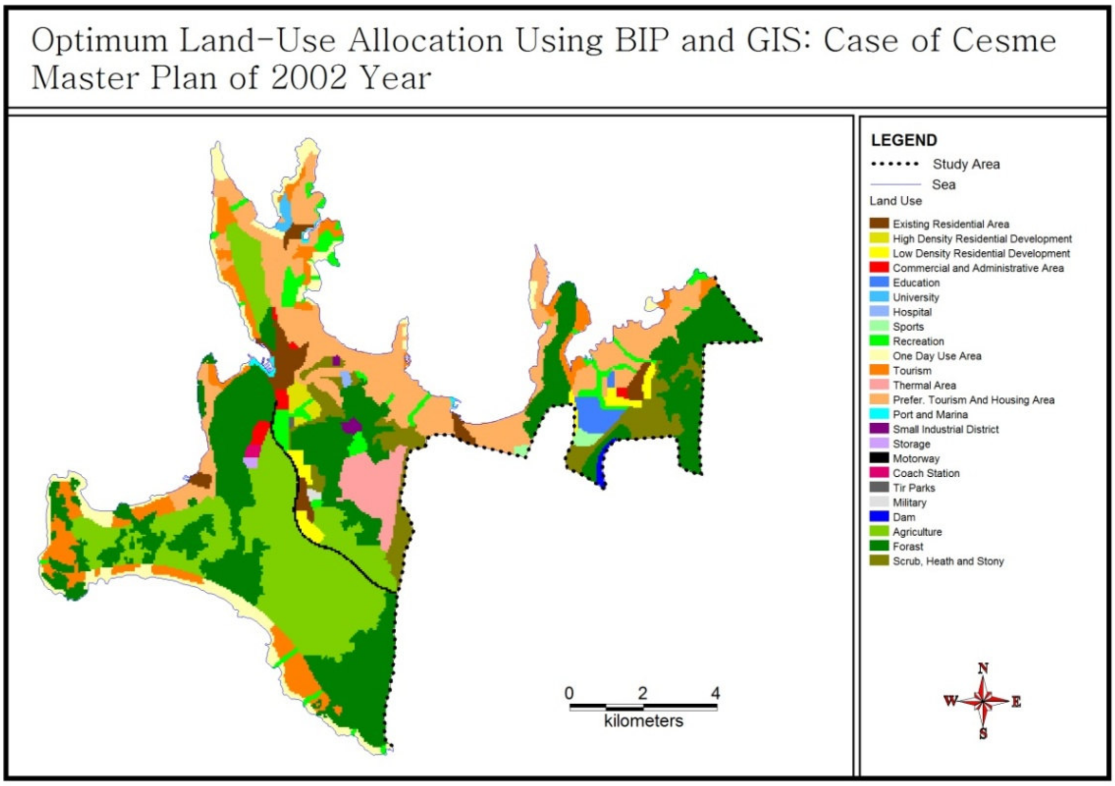

Figure 4.4. Master plan of 2002
(Source: İYTE, 2002)

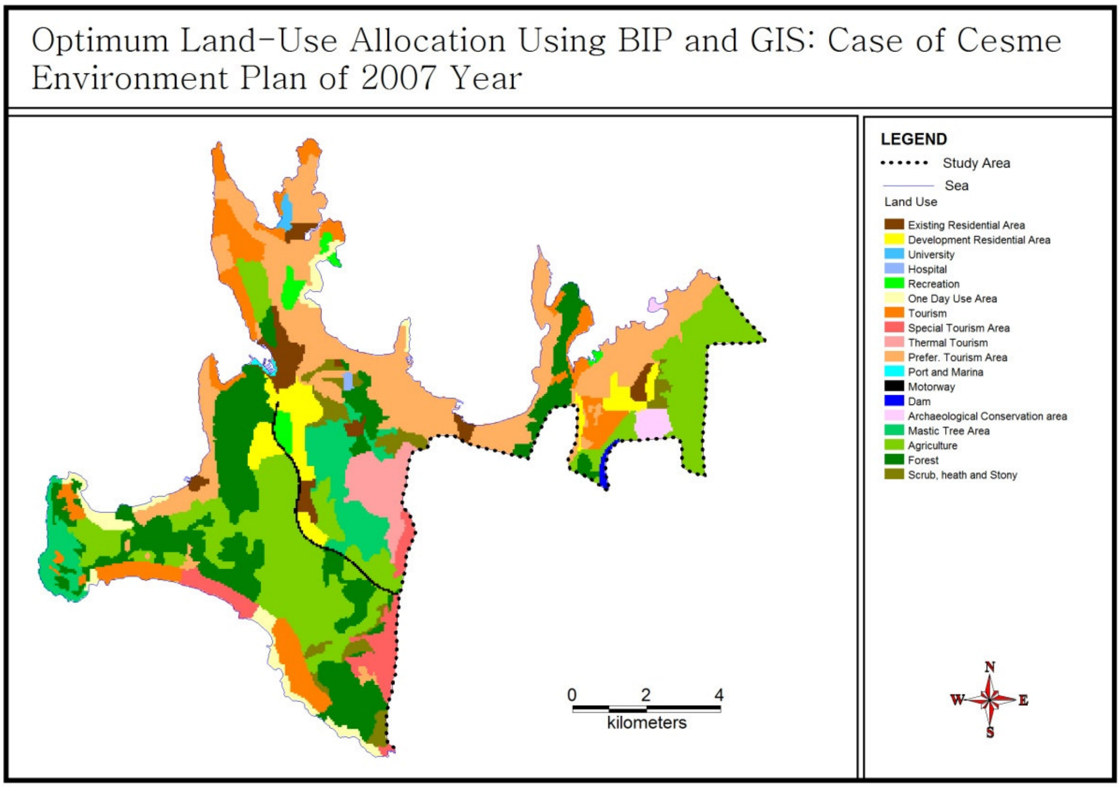

Figure 4.5. Environment plan of 2007
(Source: Ege Plan, 2007)

4.3. Conservation Schemes of Çeşme

Conservation schemes of case study area were changed entirely in 1991, 1992, 1995, 1996, 1998 and 2007 year. Before 1991, there was no conservation area in the study area. In 1991, a part of southwest coast of the study area was determined as a 2nd degree natural conservation area that was 413 hectares (see Figure 4.6). In 1992, a part of coast of the study area was described as natural, archaeological or urban conservation areas (see Figure 4.7). The conservation areas at coast were 2nd degree natural or archaeological conservation areas. In 1995, nearly all study area was ruled as natural and archaeological conservation areas (see Figure 4.8). First and second degree natural conservation areas covered quite a lot area and some of them were determined both as archaeological and natural conservation areas. Only agricultural and settlement areas were not declared as conservation areas. First and second degree natural conservations in the conservation scheme of 1995 were divided and their conservation degrees decreased in 1996 (see Figure 4.9). Compared to 1996 conservation scheme, there were not considerable changes in the conservation scheme of 1998 (see Figure 4.10). In 2007, generally the degrees of natural conservation areas were decreased (see Figure 4.11). Especially, first degree natural conservation areas in the south and north of the study area were converted to second or third degree natural conservation areas. This decreasing allows these areas to allocate tourism land-use.

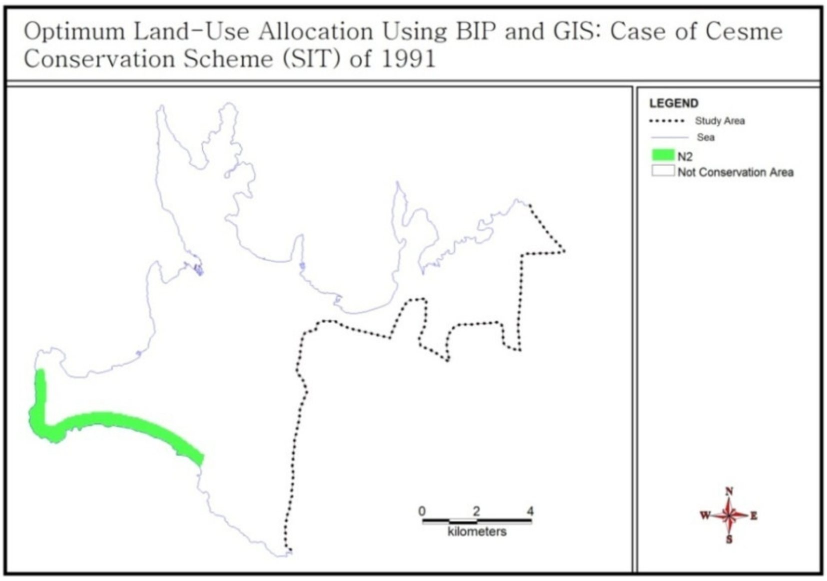

Figure 4.6. Conservation scheme of 1991
(Source: İYTE, 2002)

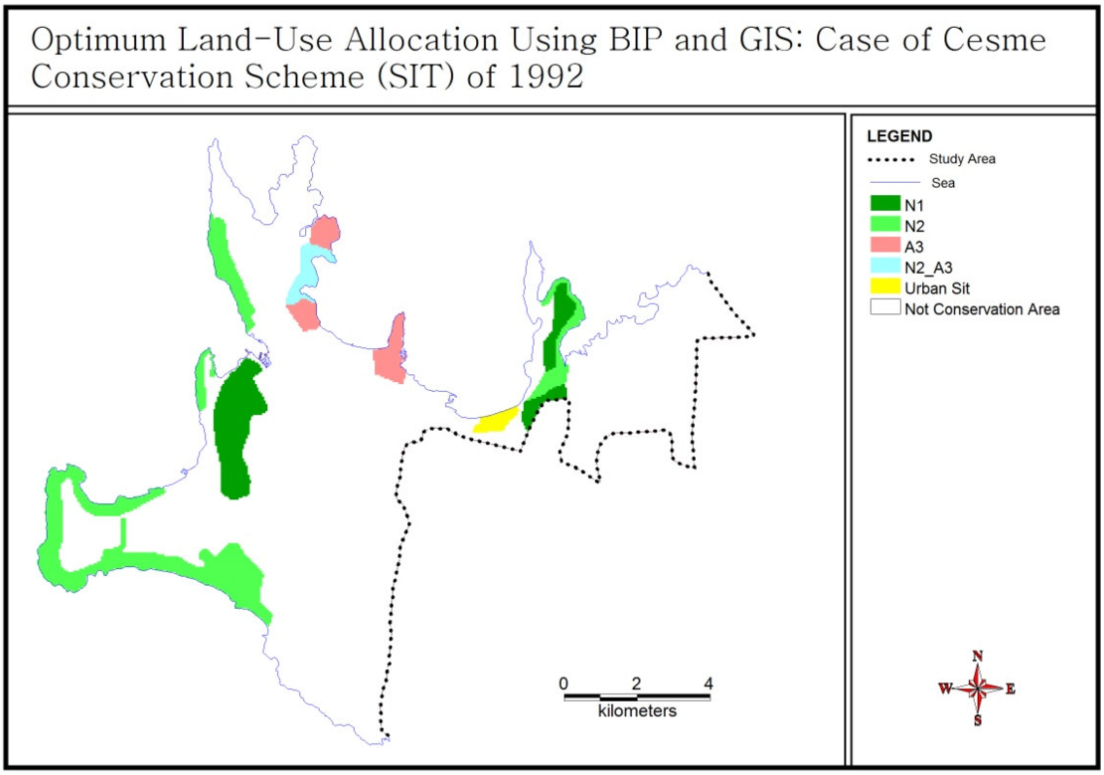

Figure 4.7. Conservation scheme of 1992
(Source: İYTE, 2002)

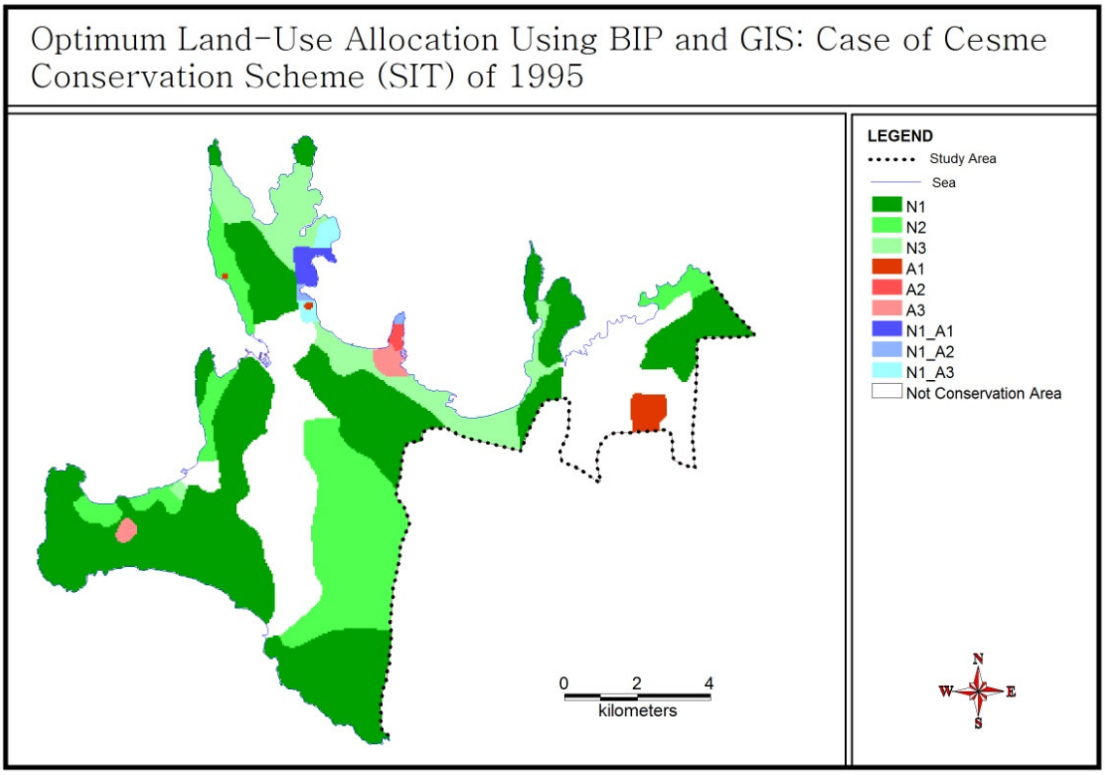

Figure 4.8. Conservation scheme of 1995
(Source: İYTE, 2002)

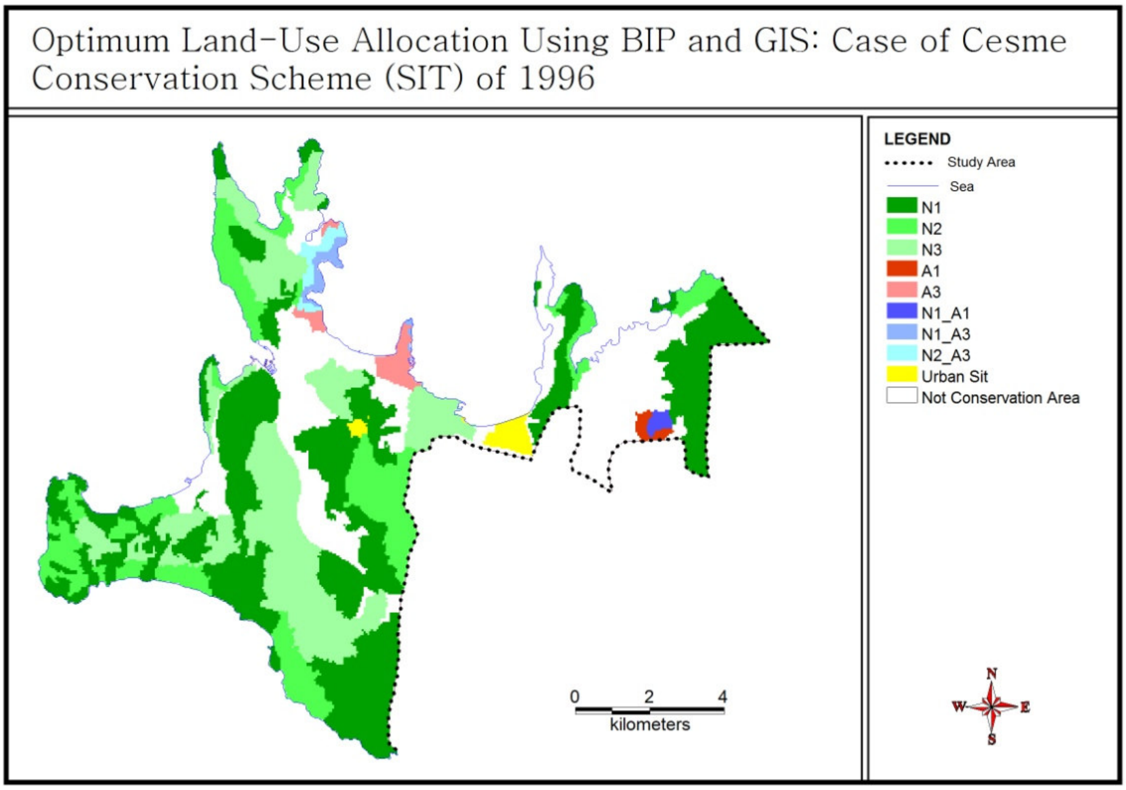

Figure 4.9. Conservation scheme of 1996
(Source: İYTE, 2002)

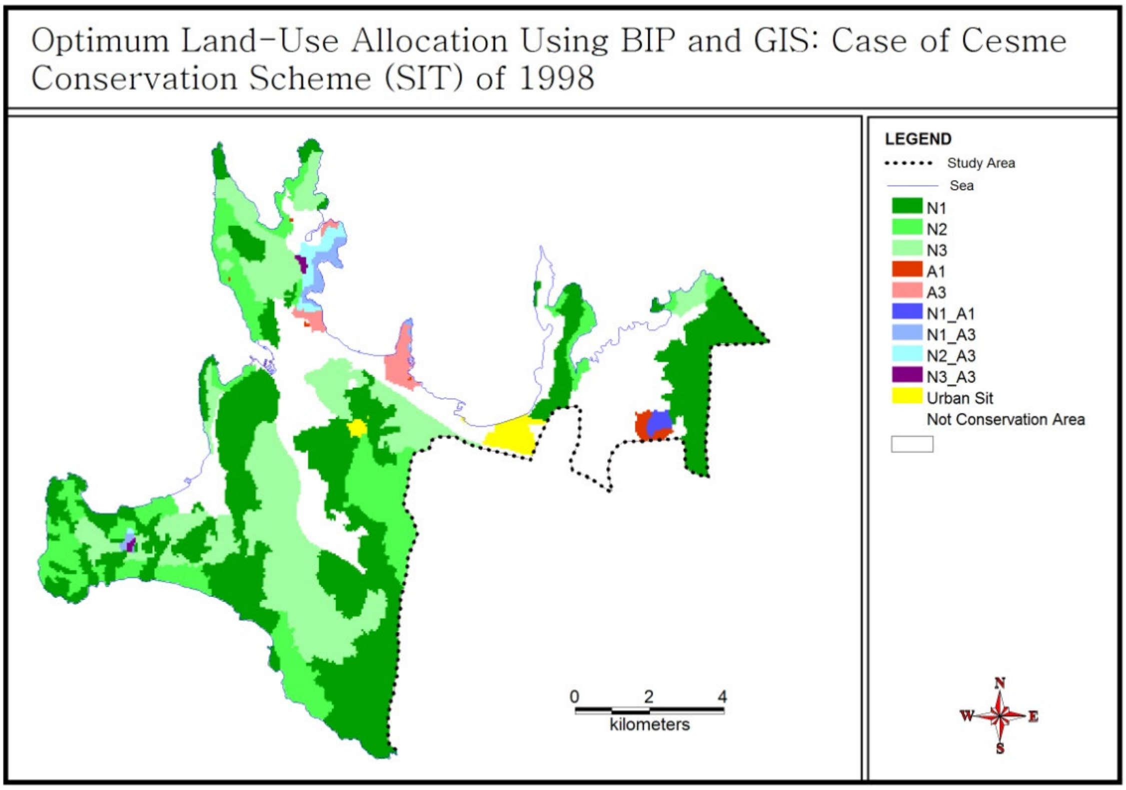

Figure 4.10. Conservation scheme of 1998
(Source: İYTE, 2002)

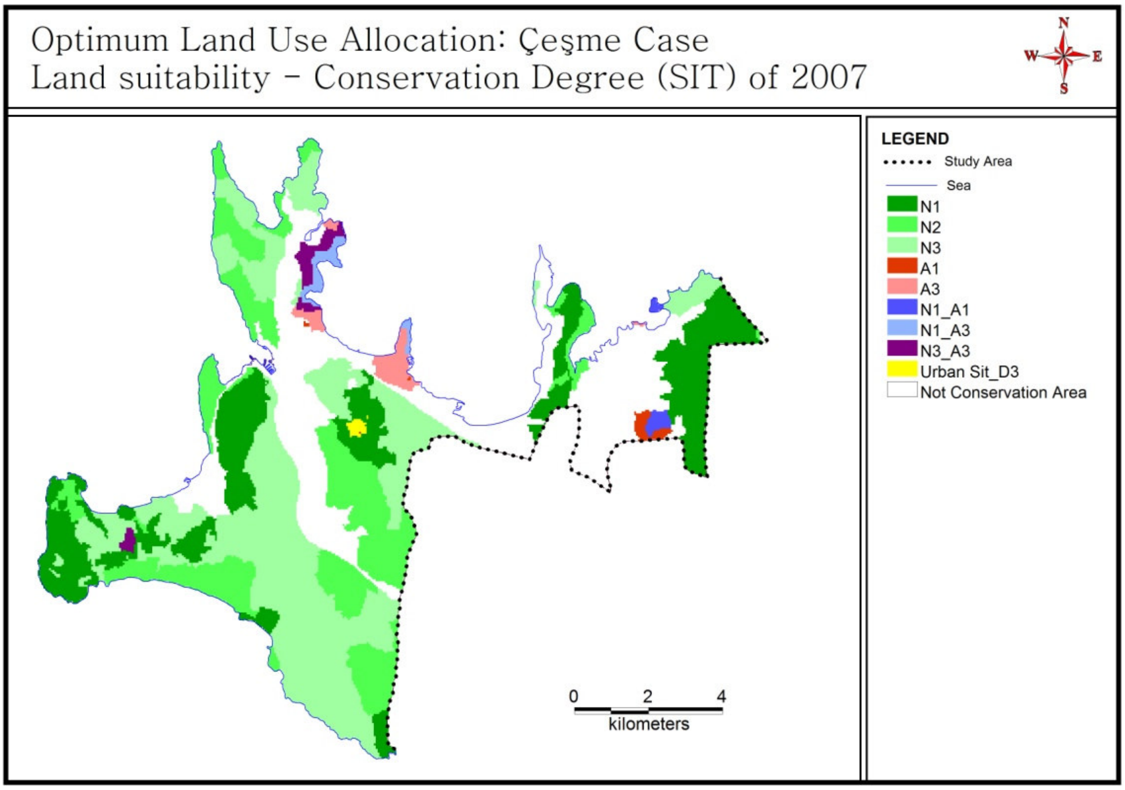

Figure 4.11. Conservation scheme of 2007
(Source: The municipality of Çeşme, 2007)

As it can be seen in Table 4.2, a drastic increase and exaggeration in all classes, especially in the 1st degree natural conservation areas, was ruled by the committee in 1995. Obviously, the environmentalist groups played an active role in this decision. However, between 1995 and 2007, total conservation area was not changed considerably but 1st degree natural conservation areas gradually decreased from 4199 ha to 1825 ha. The entrepreneurs, the Ministry of Culture and Tourism and local government may have been effective in ruling conservation scheme of 2007. Conservation scheme of 2007 would pull the tourism investors in the city. This time, the environmentalists were the complaining side. Recently, a new planning effort in the city has ignited the same discussions about the geographical extension and classification of the conservation areas.

Tablo 4.2. Conservation schemes in different years

	Conservation Schemes (hectares)					
	1991	**1992**	**1995**	**1996**	**1998**	**2007**
1st Natural&1st Archeological			74	32.5	32.5	42
1st Natural&3rd Archeological			86.5	68.5	79.5	75.75
1st Natural		486	4199.25	3371	3345.75	1825.5
2nd Natural&3rd Archeological		89.5		76.5	79.25	
2nd Natural	413.75	982.5	1720.75	1419.5	1359.25	1785
1st Archeological			98.75	38.5	41.5	41.25
3rd Natural&3rd Archeological					15.25	103.75
3rd Natural			790.5	1983	2061.5	2971.5
3rd Archeological		212	114.75	142.25	127	140.75
Urban Cons. Area		49.25		106.75	123.25	19.75
Total Conservation Area	413.75	1819.25	7084.5	7238.5	7264.75	7005.25

CHAPTER 5

DATA PREPARATION

To compute each parcel suitability score with respect to each land use, three questionnaires were conducted. First questionnaire was conducted for the selection of the evaluation criteria which effect each land use allocation. Second questionnaire was conducted to estimate the weights of selected criteria for each land use. Third questionnaire was conducted to estimate trade-off weight of each land use.

5.1. Determination of Land Uses

To be able to operationalize the general assignment model, firstly land uses which are used in the model must be determined. The master plan of 2002 was selected as a case plan to determine the land-uses and the number of parcels allocated for each land use. In this plan, there are 23 different land uses. However, some of the land uses which were dam, military area, existing residential area and university were protected at the current location and size. Thus, these land-uses and their parcels are kept out of the model. Except the excluded land use, there were 19 land uses but in AHP 7±2 elements can be compared in each pairwise comparison matrix with any reasonable (psychological) assurance of consistency (Saaty, 1980). In this context, the land uses were grouped according to feature and location selection. For example; in the master plan of 2002, urban and regional recreation area, urban and regional big sports area and daily recreation area were planned separately. In this thesis these land uses are grouped as a land-use activity and named as recreation area. As a result of the grouping, new land uses were used as development residential area, commerce and administrative area, tourism area, preferential tourism and residential area, thermal tourism area, public establishment area, recreation area, agricultural area and afforestation area.

Total master plan area is 9.458 hectares. Nevertheless, approximately 390 hectares is kept out of the model since they were built-up areas and infrastructure facilities so that the total area which allocates land-uses in the model is 9.068 ha. The available parcels (cells) which can be assigned any land uses are 36270. Most of the parcels are allocated to afforestation, agriculture and preferential tourism and residential areas respectively in the case based plan. The supra-grouped land uses and number of parcels which were allocated to each land use are given in Table 5.1.

Tablo 5.1. Land uses and numbers of allocated parcels for each land use

Land uses	**Number of parcels**
Residential development	735
Commerce and administrative	419
Tourism	2716
Preferential tourism and residential	6576
Thermal tourism	1116
Public establishment	424
Recreation	3564
Agricultural	7548
Afforestation	11048
Scrub, heath and stony	2124
Total of parcels	36270

5.2. The Selection of Suitability Evaluation Criteria for Each Land Use

After the determination of land uses, second step in MCDM is to select the suitability evaluation criteria for each land use. Malczewski (1999) suggested three techniques in MCDM for the selection of evaluation criteria that affects the location selection of each land use. They are examination of relevant literature, analytical studies and survey of opinions. In this study, survey of opinions was employed because the problem is very complex and no factual data exist.

Twenty city planners from several universities, municipalities and the Director of Public Works and Settlement of İzmir were participated in this questionnaire. The participated experts have adequate knowledge about Çeşme. The survey is conducted in two rounds. In the first round, a questionnaire including 18 potential criteria was mailed to the participants, and they were asked to score relevance of each criterion to the each land-use between 1 and 5, 1 being counter relevant and 5 very important. In the second round, descriptive statistics of first stage questionnaire and an analysis were sent to the participants and they were asked to revise their previous answer if they want in accordance with the results of the first stage (see Table 5.2). Their revised answers in the second stage were statistically analyzed.

The standard deviation of given points of each criterion is smaller than 1 which implies that the experts are in consensus on being an important or unimportant criterion for location selection of interested land use. As a result of the second round, standard deviation of all criteria for each land use was smaller than 1 which shows that those experts were in consensus. A criterion with a mean value equal to or higher than 3 was deemed as important for the respective land-use (see Table 5.3).

As a result of the questionnaire, slope, property, quality of the soil, geological structure, conservation degree, existing land-use, aspect of the land, visibility of the sea, and location with respect to existing potable water dam were determined as important site factors. Among them, only quality of the soil appeared as an important criterion for all land uses. The degree of conservation was also an important criterion for all except for agriculture. Each factor was not necessarily important for every land use type. Concerning situational factors, proximity to a highway, to a second degree road, to the entrance of motorway, to Çeşme city centre, to a residential district, to the sea, to a beach, to a thermal spring, and distance to a fault line were found as the relevant accessibility factors. The proximity to the motorway entrance was not an important criterion to any land use. Proximity to a collector road and the distance to a fault line were the other two important criteria for almost all land uses. The selected criteria and their relevance to the land uses are presented in Table 5.4.

Tablo 5.2. First round of the survey of opinions for selecting evaluation criteria

Criteria	Residential Development		Commerce & Administrative		Tourism		Pref. Tourism & Residence		Thermal Tourism		Public Establishment		Recreation		Agricultural		Afforestation	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Ratio of Slope	3.5	1.1	4.2	0.89	3.35	1.18	3.3	1.08	3.35	1.23	4.1	0.91	2.55	1.05	2.95	1.23	1.45	0.69
Property	3.6	1.27	3.95	1.1	3.8	1.4	3.75	1.25	3.55	1.32	4	0.97	4.2	0.89	2.8	1.51	3.45	1.47
Quality of Soil	3.65	1.46	3.55	1.43	3.45	1.39	3.5	1.36	2.9	1.48	3.55	1.43	3.45	1.28	4.75	0.55	3.7	1.03
Geological Structure	4.9	0.31	4.8	0.52	4.65	0.67	4.65	0.67	4.65	0.93	4.85	0.37	2.8	1.4	2.1	1.48	2.2	1.47
Conservation Degree	4.7	0.57	4.6	0.82	4.6	0.68	4.6	0.68	4.3	1.13	4.3	0.92	3.25	1.55	2.95	1.57	3.1	1.65
Existing Land Use	3.7	0.86	3.85	0.93	3.5	1	3.6	0.94	3.1	1.02	3.55	0.83	3.65	0.88	3.6	1.5	3.2	1.36
Aspect	4	0.86	3.05	1.1	4.25	0.79	4.2	0.7	3.55	1.19	2.95	1.32	3.1	1.25	1.9	1.29	1.55	1.15
Visibility of Sea	3.3	1.08	2.1	0.97	4.45	0.99	4.15	0.88	3.1	1.29	1.8	0.77	3.05	1.15	1.15	0.49	1.3	0.8
Degree of Prot. Belt of Dam	4.75	0.55	4.6	0.88	4.6	0.75	4.65	0.67	4.5	0.76	4.5	1.05	3.25	1.37	3.1	1.29	2.75	1.52
Prox. to Highway	3.25	1.02	4.2	0.7	3.15	1.09	3.1	1.02	2.8	1.28	3.7	1.03	2.45	1.28	1.7	1.17	1.3	0.92
Prox. to second Degree Road	3.67	1.08	4.56	0.51	3.28	0.96	3.11	1.08	2.94	1.21	3.94	0.64	2.67	1.14	1.67	1.03	1.39	0.98
Prox. to Entrance of Motorway	2.61	1.33	3	1.37	2.94	1.06	2.72	1.02	2.65	1.27	2.35	1.17	2.06	1.09	1.35	0.99	1.29	0.99
Prox. to city centre Of Çeşme	3.56	1.1	4.5	0.62	3	1.03	2.89	1.02	2.44	0.98	3.89	1.02	2.56	1.29	1.33	0.97	1.39	0.98
Prox. to Residential District	3.33	0.91	3.83	0.86	2.72	0.96	2.89	1.02	2.33	1.19	3.67	1.19	2.72	1.07	1.67	1.19	1.5	1.15
Prox. to Sea	3.61	1.2	2.61	1.09	4.89	0.32	4.33	0.59	2.61	1.29	1.72	1.13	3.06	1.35	1.5	1.04	1.5	1.04
Prox. to Beach	3.61	1.33	2.11	1.41	4.83	0.38	4.44	0.62	2.56	1.42	1.44	1.15	2.67	1.33	1.28	0.96	1.39	1.04
Prox. to Thermal Spring	2.06	1.21	1.61	1.09	3	1.41	2.44	1.46	4.67	0.69	1.56	1.2	2	1.28	1.83	1.42	1.33	0.97
Distance to Geo. Fault	4.78	0.55	4.72	0.67	4.72	0.57	4.5	1.04	4.39	1.09	4.83	0.51	2.72	1.6	1.83	1.5	1.89	1.6

Tablo 5.3. Second round of the survey of opinions for selecting evaluation criteria

Criteria	Residential Development		Commerce & Administrative		Tourism		Pref. Tourism & Residence		Thermal Tourism		Public Establishment		Recreation		Agricultural		Afforestation	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Ratio of Slope	3.53	0.9	4.11	0.74	3.16	0.76	3.21	0.79	3.11	0.66	4.21	0.63	2.32	0.75	2.63	0.9	1.37	0.6
Property	3.63	0.9	3.89	0.74	3.63	0.96	3.63	0.83	3.42	0.77	3.89	0.66	3.84	0.69	2.63	0.76	3.26	0.93
Quality of Soil	3.89	0.88	3.74	0.93	3.68	0.89	3.63	0.96	3.47	0.9	4	0.82	3.53	0.9	4.74	0.45	3.68	0.82
Geological Structure	5	0	4.89	0.32	4.89	0.32	4.79	0.42	4.79	0.54	4.89	0.32	2.58	0.9	1.89	0.88	1.89	0.81
Conservation Degree	4.74	0.45	4.84	0.37	4.79	0.42	4.74	0.45	4.63	0.6	4.42	0.61	3.21	0.85	2.74	0.93	3.21	0.92
Existing Land Use	4	0.58	3.89	0.66	3.26	0.65	3.58	0.51	3.05	0.71	3.42	0.61	3.63	0.76	3.63	0.9	3.05	0.71
Aspect	3.89	0.74	2.84	0.69	4.21	0.54	4.05	0.4	3.53	0.9	2.84	0.76	3.11	0.66	1.58	0.61	1.16	0.37
Visibility of Sea	3.05	0.85	2	0.58	4.47	0.96	4	0.67	2.79	0.85	1.79	0.63	3.05	0.71	1.05	0.23	1.16	0.5
Degree of Prot. Belt of Dam	4.84	0.5	4.79	0.54	4.74	0.56	4.68	0.58	4.58	0.69	4.74	0.56	3.11	0.74	2.79	0.85	2.32	0.95
Prox. to Highway	3.11	0.66	4	0.58	3.11	0.81	3.05	0.78	2.89	0.81	3.74	0.81	2.47	0.7	1.37	0.68	1.11	0.32
Prox. to second Degree Road	3.67	0.77	4.33	0.59	3.28	0.75	3.22	0.73	3.06	0.8	3.83	0.51	2.56	0.86	1.44	0.62	1.17	0.38
Prox. to Entrance of Motorway	2.5	0.71	2.78	0.81	2.67	0.69	2.44	0.78	2.39	0.7	2.06	0.54	2.06	0.73	1.17	0.38	1.11	0.32
Prox. to city centre Of Çeşme	3.33	0.69	4.44	0.62	2.83	0.62	3.06	0.64	2.22	0.65	3.89	0.68	2.67	0.77	1.11	0.32	1.28	0.57
Prox. to Residential District	3.11	0.68	3.83	0.51	2.56	0.7	2.78	0.65	2.11	0.76	3.61	0.7	2.56	0.7	1.39	0.61	1.44	0.62
Prox. to Sea	3.67	0.69	2.28	0.75	4.89	0.32	4.33	0.59	2.28	0.89	1.61	0.61	3.11	0.83	1.17	0.38	1.22	0.55
Prox. to Beach	3.5	0.62	2	0.97	4.83	0.38	4.39	0.5	2.28	0.96	1.22	0.55	2.78	0.94	1.06	0.24	1.17	0.51
Prox. to Thermal Spring	1.83	0.62	1.39	0.7	3.22	0.81	2.44	0.86	4.78	0.43	1.39	0.7	1.89	0.83	1.67	0.91	1.11	0.32
Distance to Geo. Fault	4.78	0.43	4.72	0.57	4.83	0.51	4.78	0.43	4.44	0.86	4.83	0.38	2.33	0.97	1.33	0.59	1.39	0.7

Tablo 5.4. Selected evaluation criteria with respect to each land use

	Criteria / **Land uses**	Residential Development	Commerce and Administrative	Tourism	Preferential Tourism and Residential	Thermal Tourism	Public Establishment	Recreation	Agricultural	Afforestation
Site Factors	Slope	✓	✓	✓	✓	✓	✓			
	Property	✓	✓	✓	✓	✓	✓	✓		✓
	Quality of Soil	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Geological Structure	✓	✓	✓	✓	✓	✓			
	Conservation Degree	✓	✓	✓	✓	✓	✓	✓		✓
	Existing Land Use	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Aspect	✓		✓	✓	✓		✓		
	Visibility of Sea	✓		✓	✓			✓		
	Degree of Protection Belt of Dam	✓	✓	✓	✓	✓	✓	✓		
Situation Factors	Proximity to Highway	✓	✓	✓	✓		✓			
	proximity to second Degree Road	✓	✓	✓	✓	✓	✓			
	proximity to Entrance of Motorway									
	Proximity to city centre Of Çeşme	✓	✓		✓		✓			
	Proximity to Residential District	✓	✓				✓			
	Proximity to Sea	✓		✓	✓			✓		
	Proximity to Beach	✓		✓	✓					
	Proximity to Thermal Spring			✓		✓				
	Distance to Fault Line	✓	✓	✓	✓	✓	✓			

5.3. Input Criteria

All needed maps which are referred criterion maps are collected from Çeşme municipality, the Department of City and Regional Planning of İzmir Institute of Technology and the others. All of the suitability criteria maps are firstly vectorized into GIS environment by using MapInfo GIS software. And then all of maps were converted to raster format and made a unique database for subsequent calculations. In MapInfo GIS, a raster grid cell of 50 X 50 m^2 was generated. Each cell which is called a parcel is considered as a homogenous unit for any given criterion. All influential criteria were then measured, standardized and weighted, and then combined for each urban land use, respectively.

5.3.1. Site Factors

Slope Analysis: The slope analysis was developed from the digital elevation model (DEM) data generated from digitized contour lines by using Vertical Mapper Module in MapInfo Software. The slope layer was classified into 5 meaningful scaling intervals. As it can be seen from Figure 5.1, the scale of 0 - 5 % covers the most area in the study area.

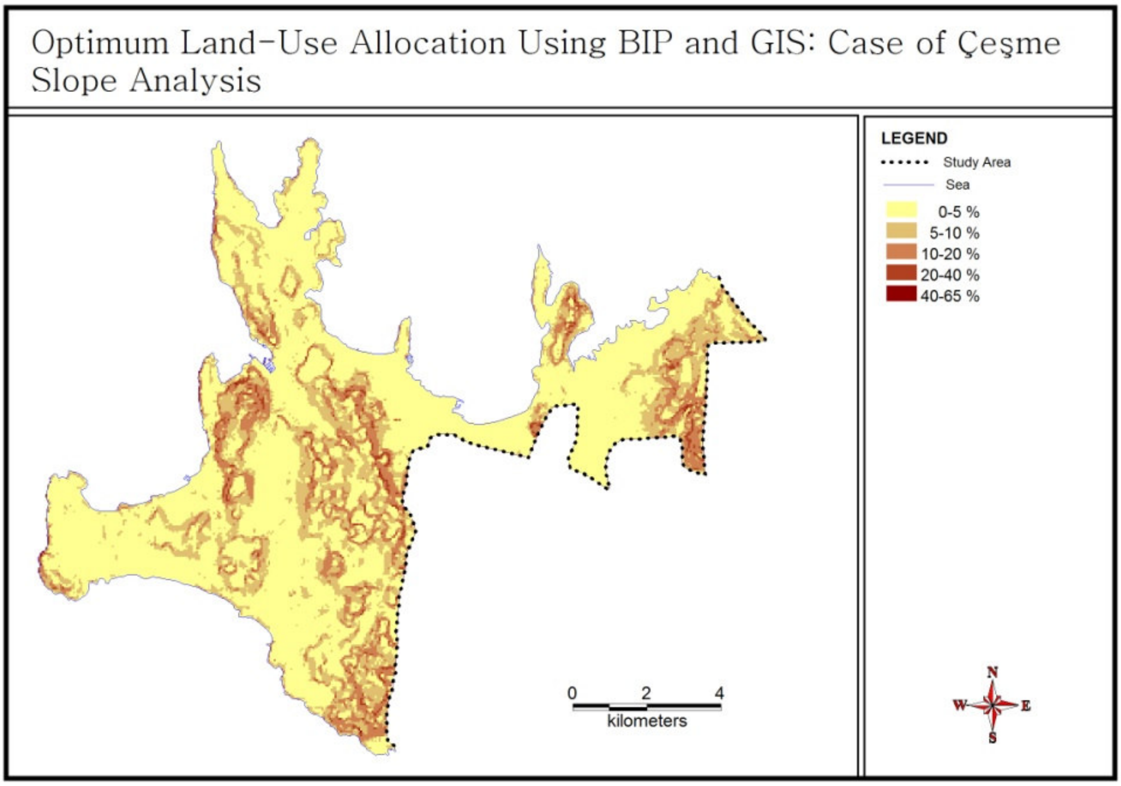

Figure 5.1. Slope analysis
(Source: İYTE, 2002)

Land Property: The land property map was prepared by digitizing the map of land property which was provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. It was divided into 5 scaling intervals. As it can be seen in Figure 5.2, improper land is located in the east and south of the study area, forest property is located in the west of the study area and private and treasury property is dispersedly located.

Soil Quality: The map of soil quality shows quality of the soil for agricultural use. It was prepared by digitizing the soil quality map which was obtained from the archive of Department of City and Regional Planning of İzmir Institute of Technology. The soil quality layer was split into 5 meaningful scaling intervals. As it can be seen in Figure 5.3, 1st degree agricultural soil almost does not exist and 2, 3, 4 degree productive agricultural lands are located at the south of Çeşme city centre. Most of the study area is covered by 6th and 7th degree agricultural soils.

Geological Structure: The map of geological structure depicts geological formation. It was prepared by digitizing the geological structure map which was provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. The geological structure was classified into 8 scaling intervals. Figure 5.4 shows that most of the study area is covered by agglomerate, limestone and marn.

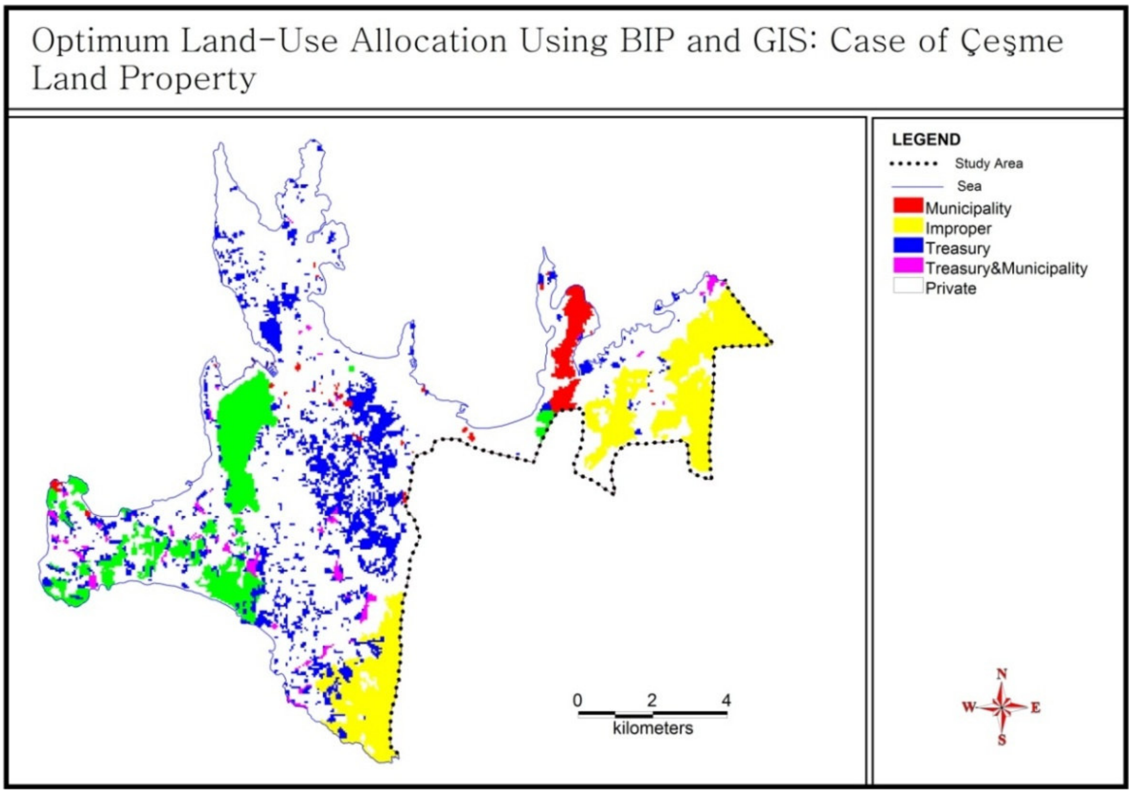

Figure 5.2. Land Property
(Source: İYTE, 2002)

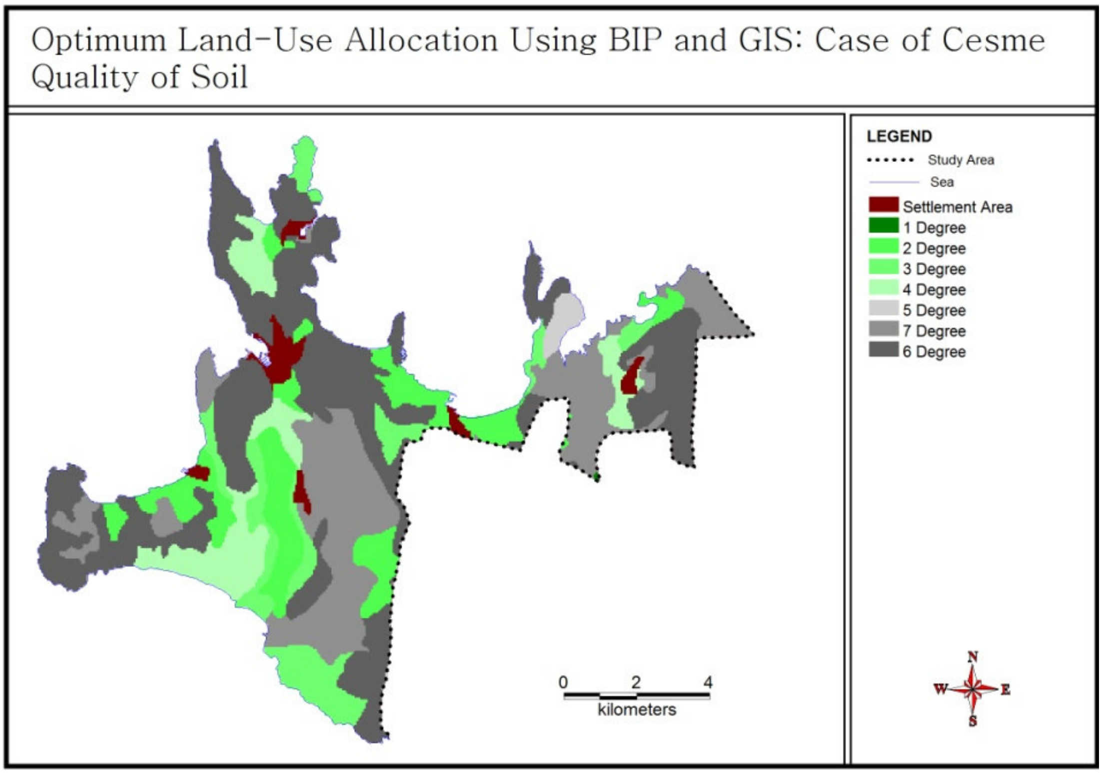

Figure 5.3. Quality of soil
(Source: İYTE, 2002)

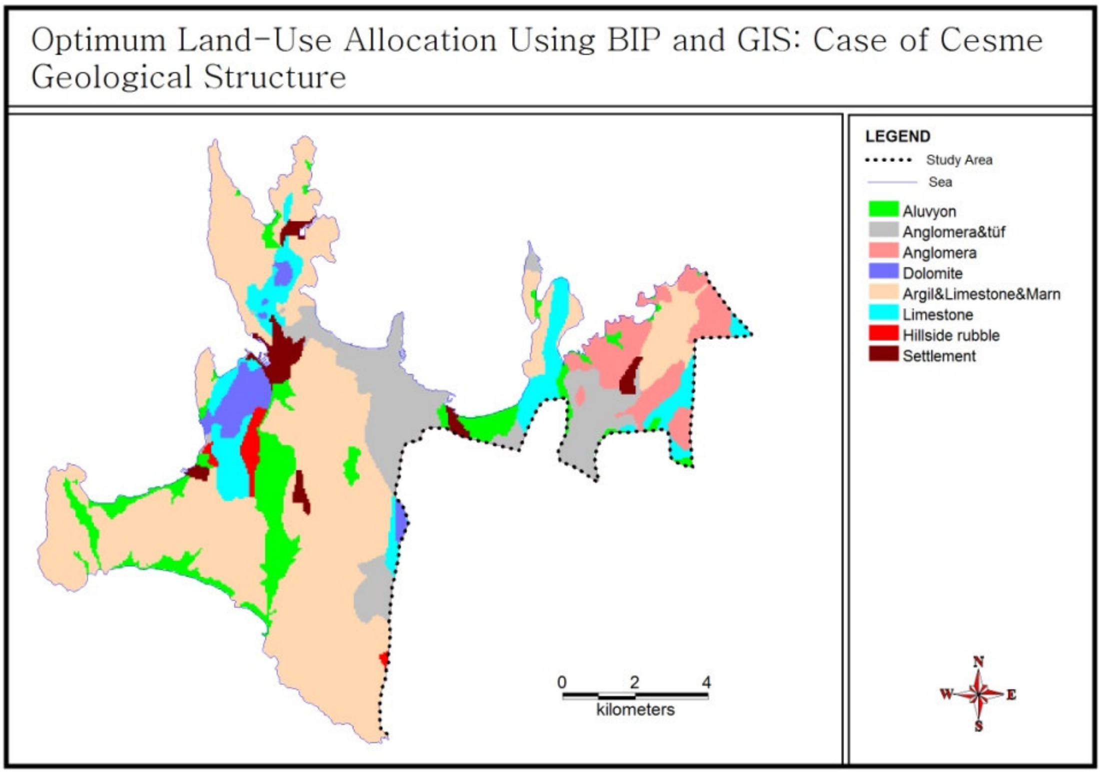

Figure 5.4. Geological Structure
(Source: İYTE, 2002)

Degree of Conservation: Degree of conservation has been examined in detail in the Chapter 4.

Existing Land Use: The map of existing land use was prepared by digitizing the existing land-use map which was obtained from the archive of Department of City and Regional Planning of İzmir Institute of Technology. The existing land use map was formed by 19 different land uses but they were grouped into 4 meaningful scaling intervals. As it can be seen in the Figure 5.5, most of the study area is covered by the fallow land.

Aspect: The map of aspect was developed from the digital elevation model (DEM) data generated from digitized contour lines by using Vertical Mapper Module in MapInfo Software. It was split into 4 meaningful scaling intervals which can be seen in Figure 5.6.

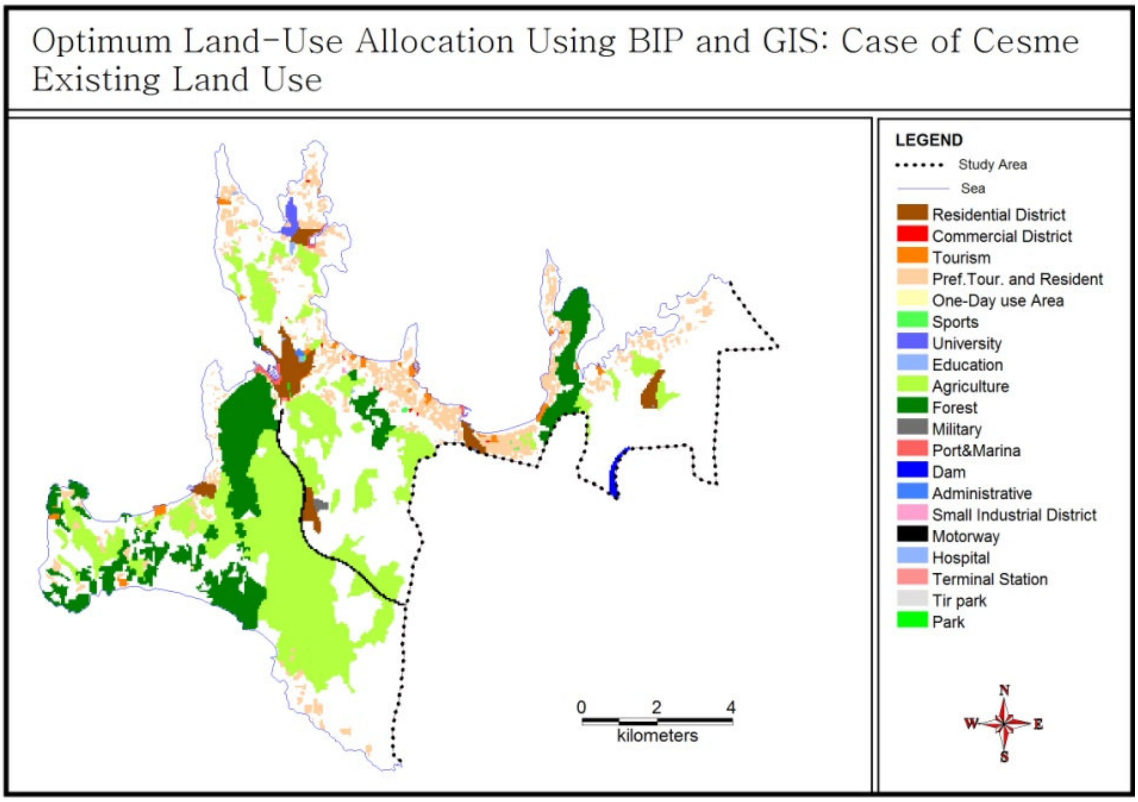

Figure 5.5. Existing land-use
(Source: İYTE, 2002)

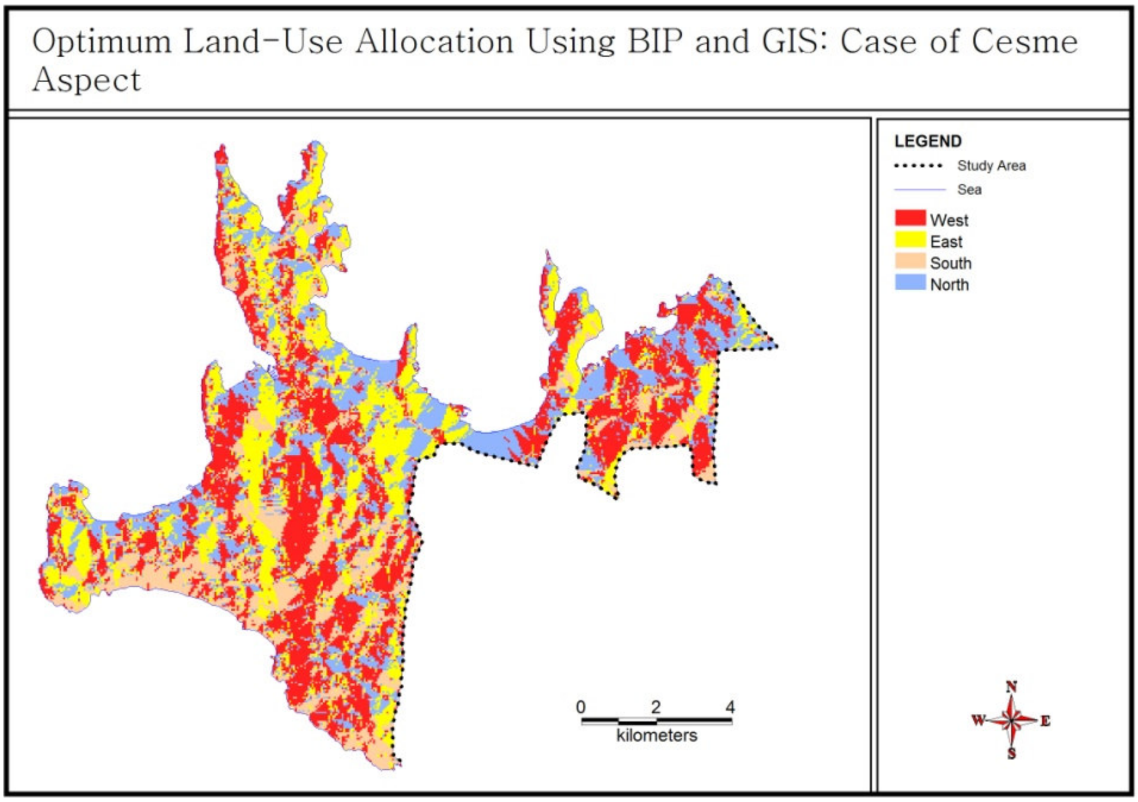

Figure 5.6. Aspect
(Source: İYTE, 2002)

Visibility of the Sea: The map of visibility of the sea analyses visibility of the sea of each parcel. It was derived from the digital elevation model (DEM) generated from digitizing the contour lines. However, MapInfo has not yet the capability to analyze visibility of the sea of each parcel. To achieve such task, a computer code was written in C++ programming language. The visibility of the sea map was classified into 2 meaningful scaling intervals which are "visible" and "not visible". Figure 5.7 shows that most of the study area can see the sea.

Protection Belt of Dam: The map of protection belt of dam was prepared by digitizing the geological structure map which is provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. The protection belt of dam layer was divided into 4 meaningful scaling intervals. As it can be seen in Figure 5.8, most of the study area is covered by outside protection belt of dam.

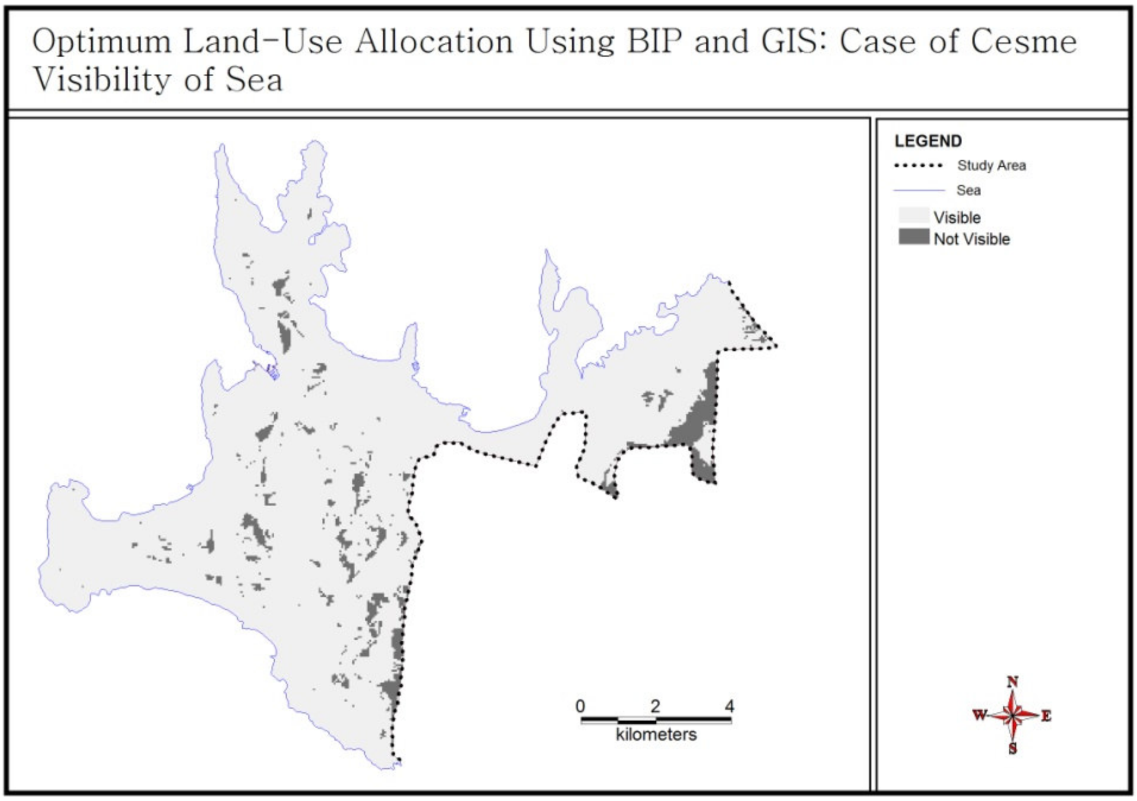

Figure 5.7. Visibility of sea

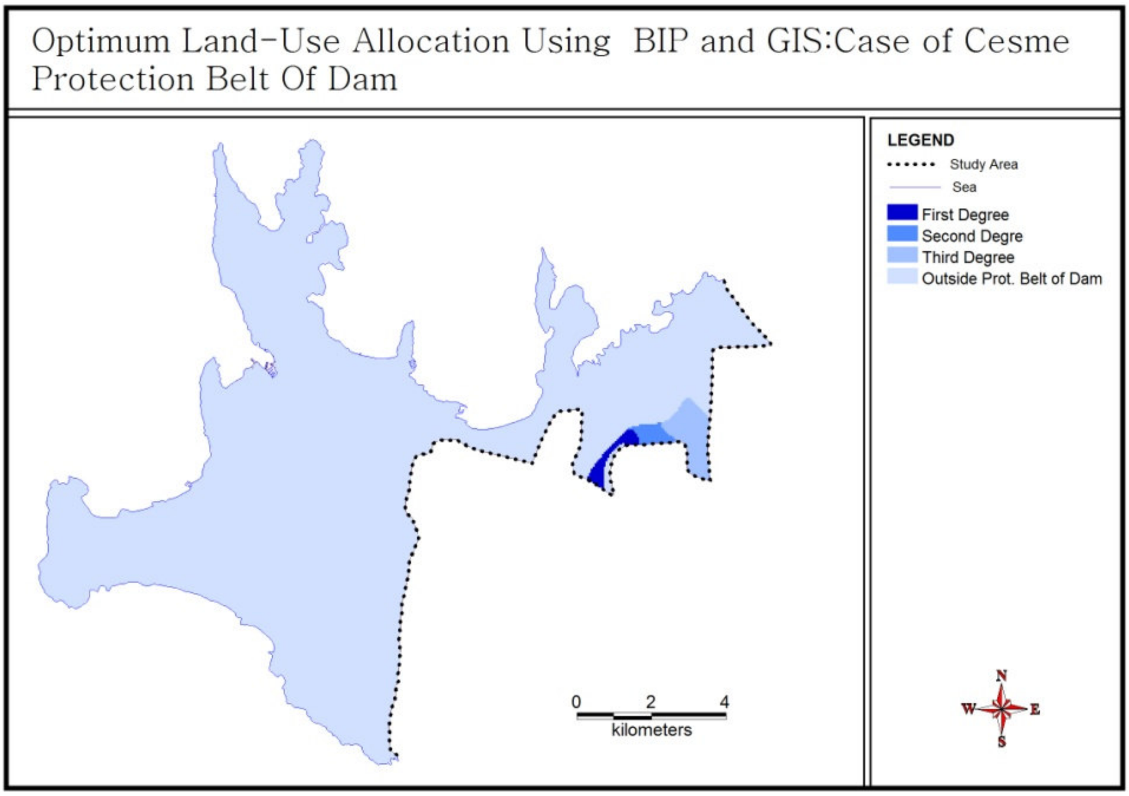

Figure 5.8. Protection belt of dam
(Source: İYTE, 2002)

5.3.2. Situation Factors

Proximity to Highway: The proximity highway map was derived from the existing land use map which was provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. The proximity highway layer was split into 6 meaningful scaling intervals. Figure 5.9 illustrates that most of the study area is covered by proximity to 2000+.

Proximity to Second Degree Road: The proximity to second degree road map was derived from the existing land use map which was provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. It was split into 6 meaningful scaling intervals. As it can be seen in Figure 5.10, most of the study area is covered by proximity to 2000+.

Proximity to City Centre of Çeşme: The proximity to city centre of Çeşme was split into 5 meaningful scaling intervals. Figure 5.11 shows that most of the study area is covered by proximity to 3000+.

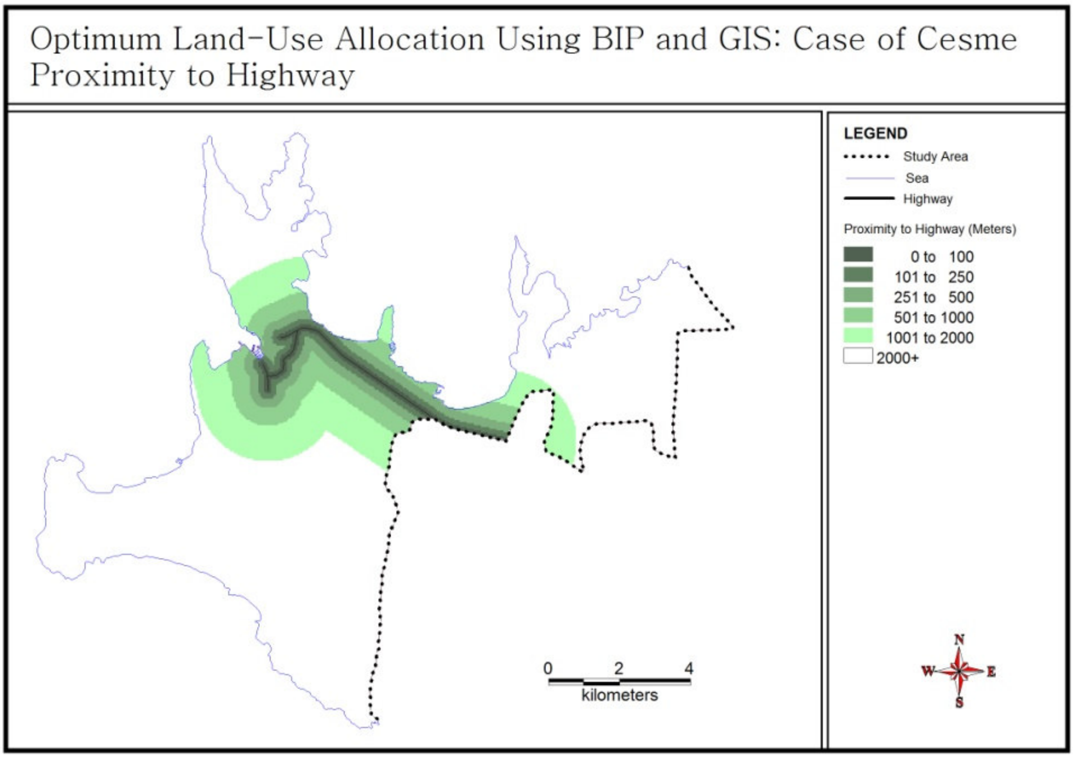

Figure 5.9. Proximity to highway

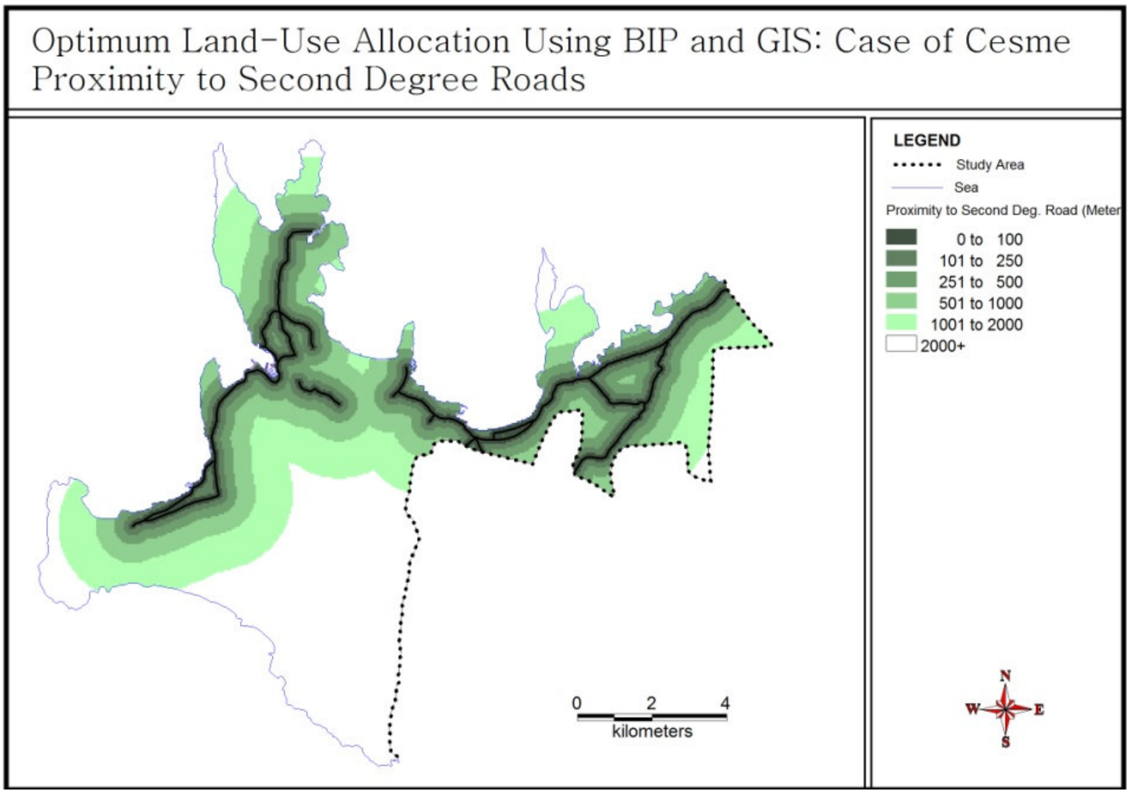

Figure 5.10. Proximity to second degree roads

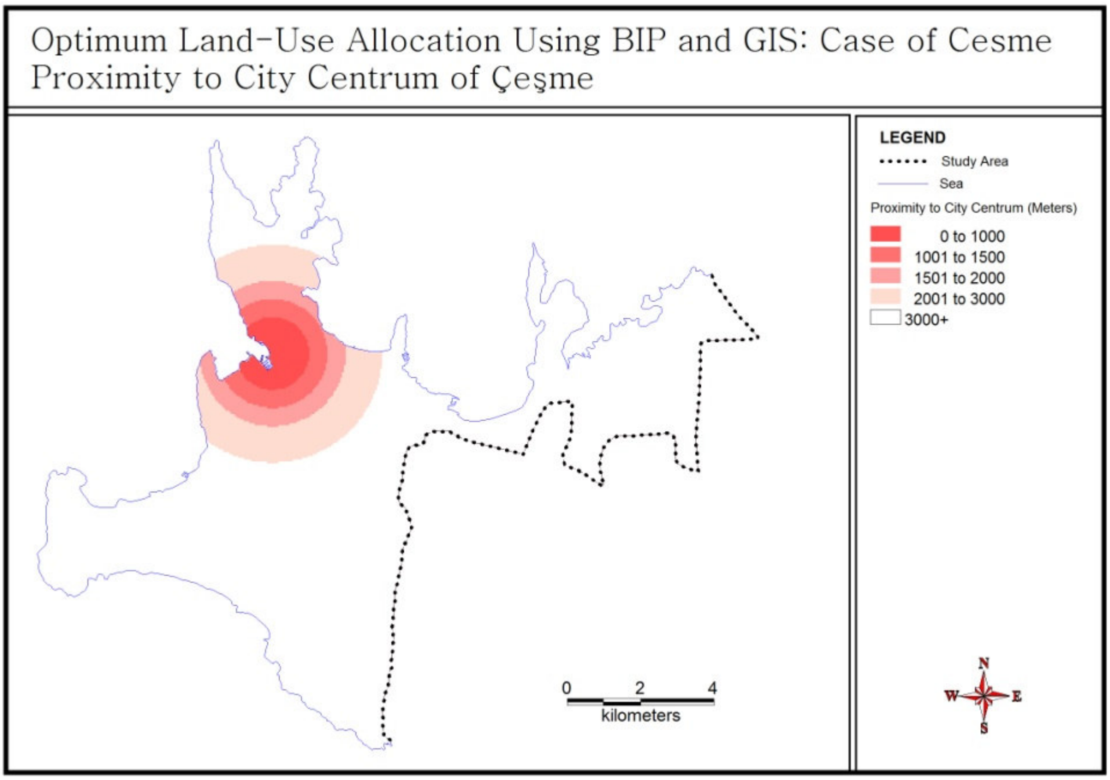

Figure 5.11. Proximity to city centre of Çeşme

Proximity to Residential Districts: In Çeşme, there are 5 residential districts which are DalyanKöy, Reisdere, Ovacık, Çiftlikköy and Ilıca. The proximity to each residential district was classified into 5 meaningful scaling intervals. As it can be seen in Figure 5.12, most of the study area is covered by proximity to 2000+.

Proximity to the Sea: The study area is a peninsula. Thus, three sides of it are surrounded by the sea. The proximity to sea layer was classified into 7 meaningful scaling intervals. Figure 5.13 illustrates that most of the study area is covered by proximity to 2000+.

Proximity to Beach: The proximity to beach map was derived from digitalizing map which was provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. It was split into 7 meaningful scaling intervals. As it can be seen in Figure 5.14, most of the study area is covered by proximity to 2000+.

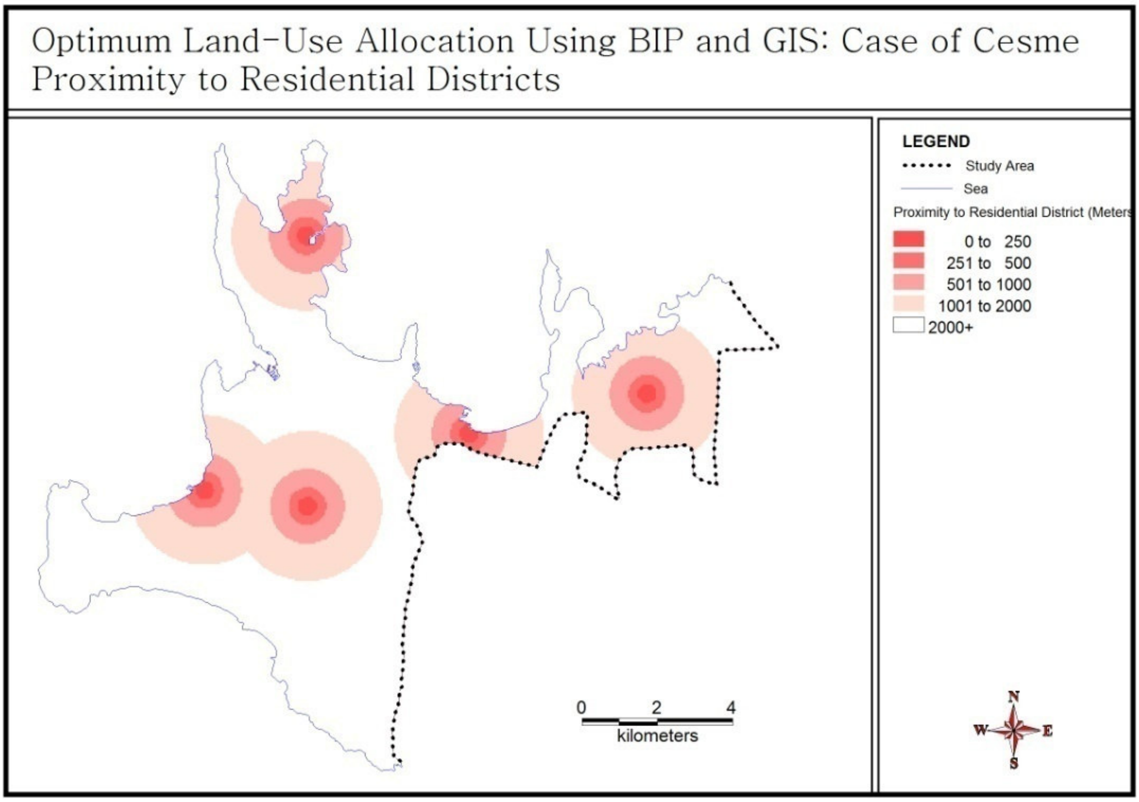

Figure 5.12. Proximity to residential districts

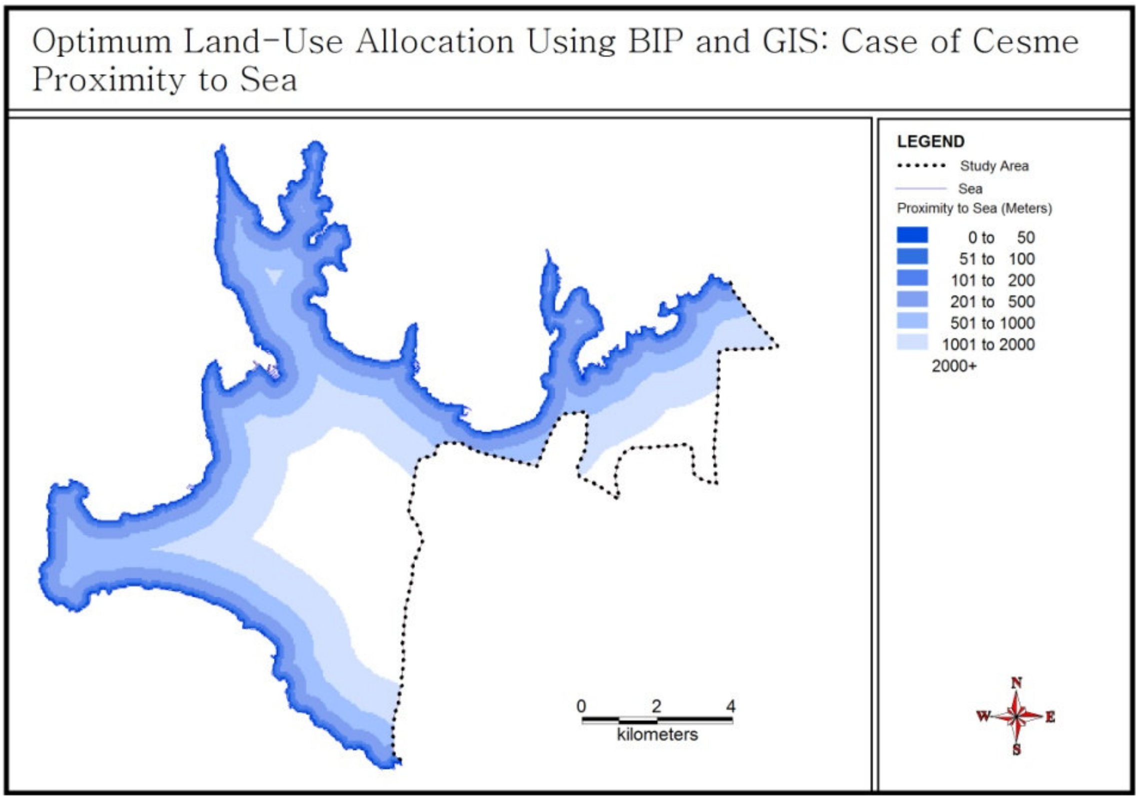

Figure 5.13. Proximity to sea

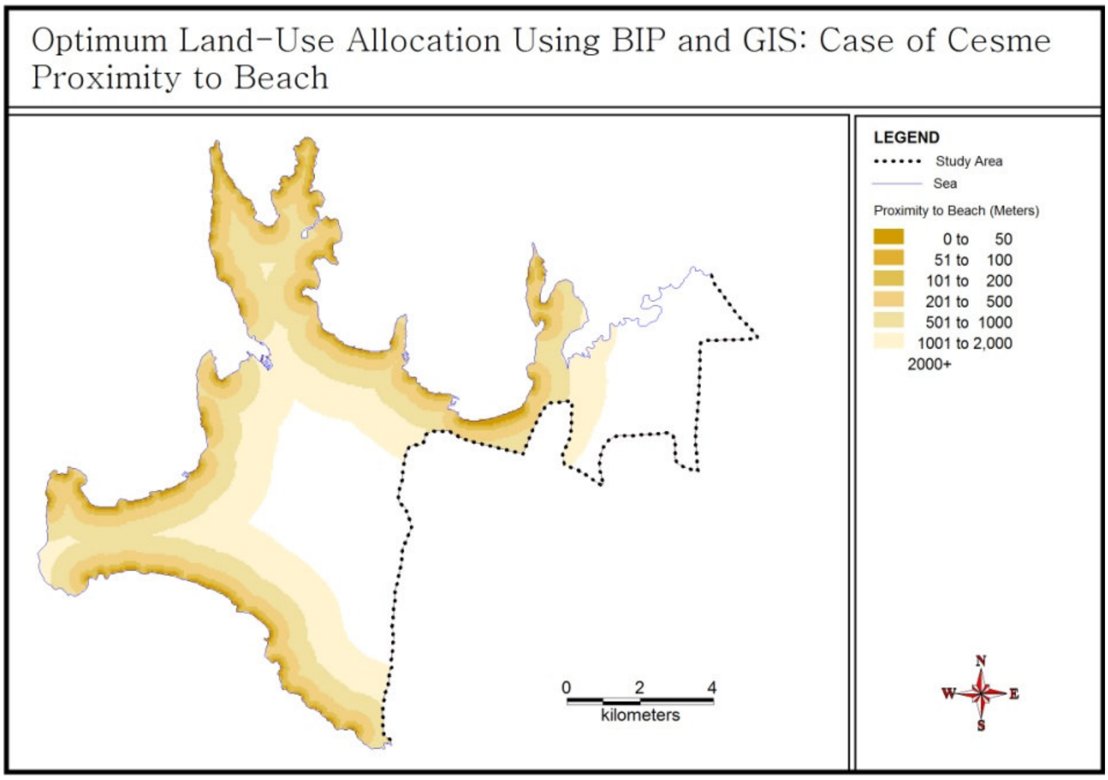

Figure 5.14. Proximity to Beach

Proximity to Thermal Spring: The thermal spring locates at the east boundary of the study area. The proximity to thermal spring map was obtained from digitalizing the existing land use map which was provided the archive of Department of City and Regional Planning of İzmir Institute of Technology. It was classified into 7 meaningful scaling intervals. Figure 5.15 shows that most of the study area is covered by proximity to 2000+.

Distance to Geographical Fault: In the study area, there are many fault lines that the case study area is in first-degree seismic zone. The map of distance to geographical fault was derived from the geological formation map which was provided from the archive of Department of City and Regional Planning of İzmir Institute of Technology. The proximity to geographical fault layer was classified into 5 meaningful scaling intervals. As it can be seen in Figure 5.16, only an area where is at the west of Çiftlikköy is far from all fault lines at a distance of 2000 meters.

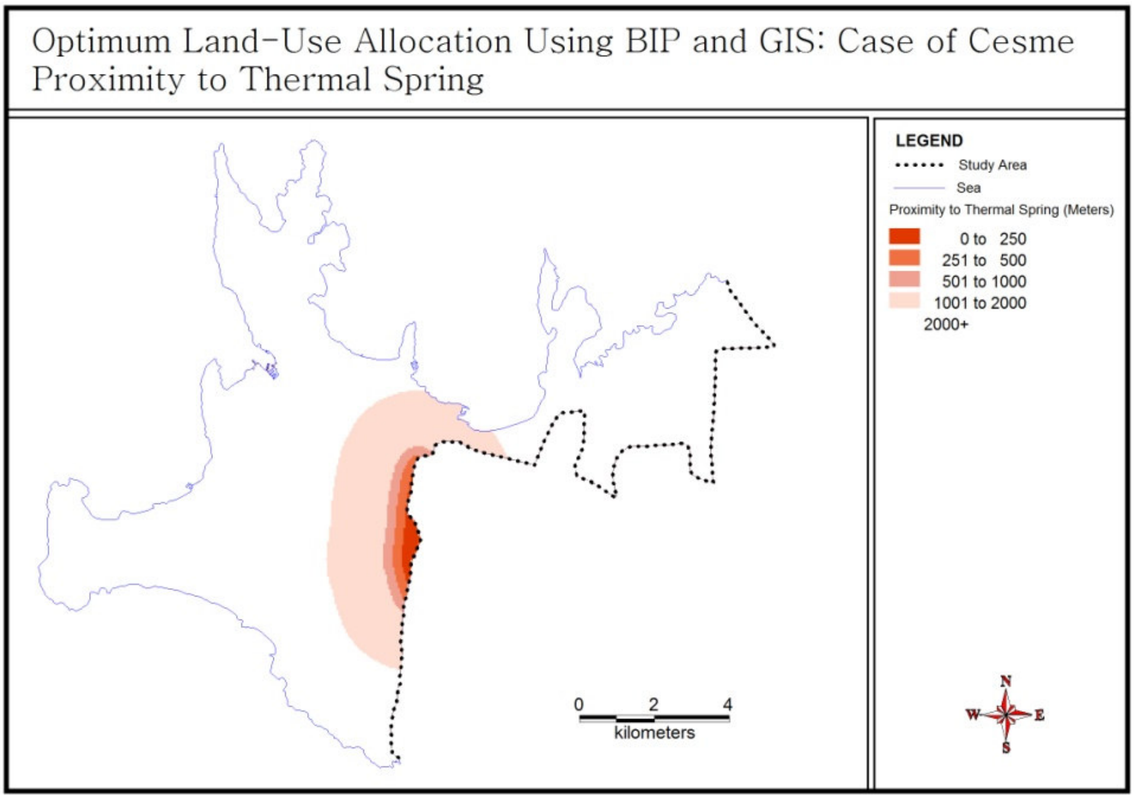

Figure 5.15. Proximity to thermal spring

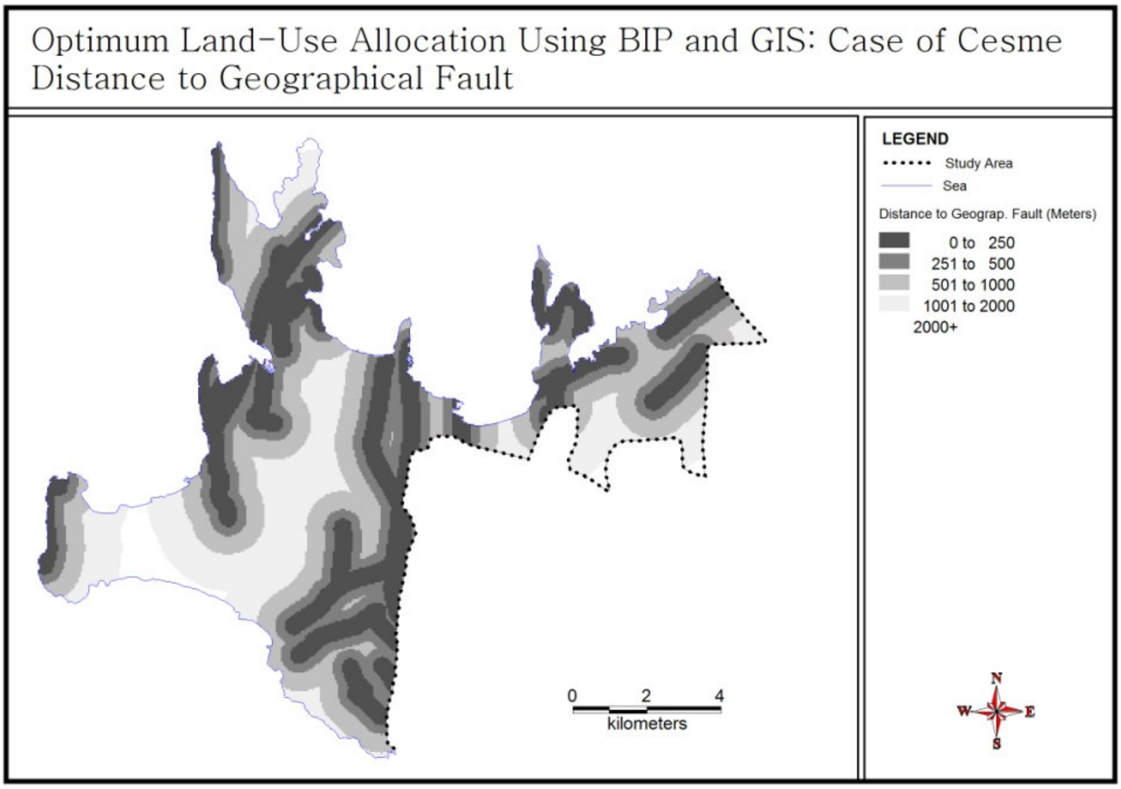

Figure 5.16. Distance to geographical fault

5.4. Scale of Measurement and Standardization of Criteria

All criterion maps hold cell values for original map codes that are nominal, binary, ordinal, ratio and interval measurement scales. These have to be categorized, measured on quantitative scales and standardized to a uniform suitability scale. Various statistical and empirical guidelines from the related national codes and literature were used to determine the scaling intervals for various land-use categories. In each criterion map, the number of categories changes between 2 and 9. The pairwise comparison technique is used to derive commensurate measurable criterion maps. The pairwise comparisons provide a way for calibrating a numerical scale, particularly in new areas where measurements and quantitative comparisons do not exist (Saaty, 1980, p.33). The pairwise comparisons were based on experiments and field observations. Outputs of pairwise comparisons are normalized values.

In MCDM process, one of the most important steps is to standardize criterion scores across all criteria considered. These measurements can be standardized with formula 5.1 developed by Voogd (1983). Where A'_{jk} is the standardized score for the *j*th land use and kth criterion map, A_{jk} is the raw score, and A_k^{max} and A_k^{min} is the maximum and minimum scores for the kth criterion map, respectively. The value of the standardized score can range from 0 to 1. And the worst standardized score is always equal to 0, and the best score equals 1. This procedure is applied to each raster criterion map. Table 5.5 shows the scaling intervals and standardized measurements employed for each criterion.

$$A'_{jk} = \frac{A_{jk} - A_k^{min}}{A_k^{max} - A_k^{min}} \quad (5.1)$$

Tablo 5.5. Standardized suitability scores for each land use and criteria

Criteria	**Category/Land Uses**	**Residential Development**	**Commerce and Administrative**	**Tourism**	**Pref. Tourism and Residence**	**Thermal Tourism**	**Public Establishment**	**Recreation**	**Agricultural**	**Afforestation**
Slope (%)	0-5	1	1	1	1	1	1			
	6-10	0.710	0.294	0.710	0.710	0.710	0.710			
	11-20	0.077	0.111	0.077	0.077	0.077	0.077			
	21-40	0.022	0	0.022	0.022	0.022	0.022			
	41-65	0	0	0	0	0	0			
Property	Private	1	1	1	1	1	0.125	0		0
	Municipality	0.378	1	0.377	0.247	1	0.295	1		0.098
	Treasury & Municip.	0.378	1	0.377	0.247	1	0.541	1		0.156
	Deserted Land	0.378	1	0.377	0.247	1	1	1		0.234
	Treasury	0.378	1	0.377	0.247	1	1	1		0.234
	Forest	0	0	0	0	0	0	0.302		1
Quality of soil	I & II	0	0	0	0	0	0	0	1	0
	III	0	0.027	0	0	0	0	0	1	0
	IV	0.208	0.147	0.159	0.207	0.207	0.207	0.231	0.428	0.190
	V	0.652	0.339	0.545	0.648	0.648	0.648	0.498	0.119	0.476
	VI &VII	1	1	1	1	1	1	1	0	1
Geological structure	Agglomerate	1	1	1	1	1	1			
	Agglomerate &Tuff	1	1	1	1	1	1			
	Limestone	0.531	0.531	0.531	0.531	0.531	0.531			
	Dolomite	0.303	0.303	0.303	0.303	0.303	0.303			
	Clay limestone marl	0.155	0.155	0.155	0.155	0.155	0.155			
	Alluvium	0.040	0.040	0.040	0.040	0.040	0.040			
	Talus	0	0	0	0	0	0			

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Table 5.5. (cont.)

Degree and type of conservation	1st Natural	0	0	0	0	0	0	1		1
	2nd Natural	0	0	0.187	0.187	0.215	0	1		0.698
	3rd Natural	0.216	0.216	0.456	0.456	0.504	0.216	1		0.284
	1st Archaeological	0	0	0	0	0	0	0		0
	3rd Archaeological	0.229	0.226	0.477	0.477	0.533	0.229	1		0.254
	Urban Cons. Area	0.394	0.339	0.456	0.456	0.041	0.394	1		0
	Not conserved Area	1	1	1	1	1	1	1		0.355
Existing land use	Unsuitable land	1	1	1	1	1	1	1	0.250	0.318
	Forest	0	0	0	0	0	0	0.200	0	1
	Agriculture	0.332	0.282	0.282	0.283	0.155	0.268	0.200	0	0.079
	Others	0.332	0.229	0.229	0.099	0.392	0.219	0	1	0
Aspect	North	0		0	0	0		1		
	West	0.348		0.348	0.348	0.348		0		
	East	0.348		0.348	0.348	0.348		0		
	South	1		1	1	1		1		
Vis. of sea	Yes	1		1	1			1		
	No	0		0	0			0		
Location wrt. potable water dam	First degree	0	0	0	0	0	0	0		
	second degree	0	0	0	0	0	0	0		
	third degree	0	0	0	0	0	0	0.442		
	Out of protection belt of dam	1	1	1	1	1	1	1		
Prox. to highway (m)	0-100	1	1	1	0.504		1			
	101-250	0.509	0.367	0.730	1		0.580			
	251-500	0.230	0.171	0.339	0.546		0.312			
	501-1000	0.079	0.072	0.116	0.162		0.147			
	1001-2000	0.029	0	0.041	0.050		0.050			
	2000+	0	0	0	0		0			
Proximity to second degree road (m)	0-100	1	1	1	1	1	1			
	101-250	0.396	0.367	0.564	0.396	0.367	0.580			
	251-500	0.214	0.171	0.312	0.214	0.171	0.312			
	501-1000	0.102	0.069	0.144	0.102	0.069	0.147			
	1001-2000	0.037	0.002	0.052	0.037	0.002	0.050			
	2000+	0	0	0	0	0	0			
Proximity to centrum of Çeşme (m)	0-1000	1	1		1		1			
	1001-1500	0.349	0.534		0.349		0.537			
	1501-2000	0.165	0.254		0.165		0.262			
	2001-3000	0.082	0.094		0.082		0.122			
	3000+	0	0		0		0			
Proximity to residential district (m)	0-250	1	1				1			
	251-500	0.349	0.365				0.349			
	501-1000	0.165	0.178				0.165			
	1001-2000	0.082	0.064				0.082			
	2000+	0	0				0			

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Table 5.5. (cont.)

Proximity to sea (m)	0-50	0		0	0			1		
	51-100	0		0	0			1		
	101-200	1		1	1			0.561		
	201-500	0.428		0.672	0.777			0.309		
	501-1000	0.234		0.426	0.535			0.141		
	1001-2000	0.109		0.176	0.395			0.056		
	2000+	0.042		0.064	0.188			0		
Proximity to beach (m)	0-50	0		0	0					
	51-100	0		0	0					
	101-200	1		1	1					
	201-500	0.536		0.737	0.738					
	501-1000	0.261		0.438	0.487					
	1001-2000	0.101		0.214	0.287					
	2000+	0.027		0.084	0.168					
Proximity to thermal spring (m)	0-250			1		1				
	251-500			0.510		0.596				
	501-1000			0.248		0.404				
	1001-2000			0.093		0.143				
	2000+			0		0				
Distance to fault line (m)	0-250	0	0	0	0	0	0			
	251-500	0.117	0.132	0.117	0.117	0.132	0.132			
	501-1000	0.271	0.301	0.271	0.271	0.301	0.301			
	1001-2000	0.463	0.560	0.463	0.463	0.560	0.560			
	2000+	1	1	1	1	1	1			

5.5. Determination of Evaluation Criteria Weights

The subsequent task was to determine the criterion combinational weights for estimating suitability scores as it was stated in equation 3.1. To do that, a new questionnaire was conducted with 5 city planners. Three of them who are academicians in the Department of City and Regional Planning of İzmir Institute of Technology participated in the master plan of 2002. Two of the five participants who are professional planners in Ege Plan participated in the environment plan of 2007. In this questionnaire, the weights were estimated again using pair-wise comparison. The participants were asked to make their individual pair-wise comparisons. The estimated weights for each criterion with respect to each land use were given in Table 5.6. Each column demonstrates the given relative weights for each land use by each participant.

Tablo 5.6. Combination weights of the selected criteria

Criteria/ Planner	Residential Development					Commerce and Administrative					Tourism				
	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner
Ratio of Slope	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.02
Property	0.05	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.05	0.01	0.01	0.01	0.01	0.01
Quality of Soil	0.08	0.03	0.11	0.08	0.12	0.08	0.06	0.14	0.11	0.10	0.04	0.04	0.10	0.08	0.08
Geological Structure	0.08	0.03	0.01	0.02	0.08	0.08	0.12	0.02	0.08	0.10	0.04	0.07	0.01	0.08	0.08
Conservation degree	0.12	0.19	0.17	0.13	0.12	0.16	0.13	0.14	0.16	0.10	0.12	0.12	0.10	0.11	0.13
Existing Land Use	0.05	0.07	0.03	0.05	0.01	0.01	0.02	0.02	0.01	0.05	0.04	0.03	0.02	0.01	0.01
Aspect	0.05	0.03	0.01	0.01	0.01						0.04	0.07	0.04	0.05	0.05
Visibility of Sea	0.01	0.02	0.02	0.05	0.01						0.07	0.07	0.10	0.08	0.05
Degree of Protection Belt of Dam	0.05	0.11	0.11	0.13	0.12	0.12	0.13	0.14	0.11	0.10	0.12	0.08	0.10	0.09	0.08
Proximity to Highway	0.02	0.04	0.02	0.03	0.05	0.10	0.03	0.02	0.06	0.06	0.02	0.02	0.03	0.03	0.03
Proximity to Second Degree Road	0.07	0.10	0.08	0.09	0.02	0.03	0.07	0.02	0.02	0.02	0.02	0.05	0.01	0.13	0.01
Proximity to City Centre Of Çeşme	0.07	0.09	0.14	0.09	0.16	0.03	0.14	0.16	0.02	0.20					
Proximity to Residential District	0.13	0.04	0.08	0.09	0.02	0.03	0.13	0.16	0.16	0.02					
Proximity to Sea	0.07	0.09	0.02	0.03	0.02						0.14	0.11	0.15	0.07	0.13
Proximity to Beach	0.02	0.04	0.02	0.03	0.02						0.22	0.11	0.15	0.07	0.13
Proximity to Thermal Spring											0.02	0.10	0.01	0.07	0.08
Distance to Geo. Fault	0.13	0.10	0.14	0.16	0.21	0.30	0.13	0.15	0.24	0.20	0.07	0.11	0.15	0.13	0.13
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Criteria/ Planner	Preferential Tourism and Residence					Thermal Tourism					Public Establishment				
	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner
Ratio of Slope	0.02	0.02	0.03	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
Property	0.06	0.01	0.01	0.06	0.01	0.04	0.02	0.01	0.06	0.01	0.06	0.09	0.06	0.11	0.07
Quality of Soil	0.06	0.09	0.11	0.09	0.08	0.04	0.06	0.10	0.11	0.11	0.06	0.03	0.12	0.06	0.10
Geological Structure	0.10	0.09	0.03	0.06	0.07	0.11	0.11	0.02	0.12	0.11	0.12	0.09	0.02	0.11	0.09
Conservation degree	0.10	0.13	0.17	0.13	0.11	0.11	0.13	0.18	0.06	0.11	0.12	0.16	0.15	0.11	0.14
Existing Land Use	0.01	0.02	0.01	0.02	0.01	0.04	0.02	0.02	0.01	0.01	0.06	0.02	0.02	0.02	0.01
Aspect	0.01	0.02	0.01	0.01	0.06	0.04	0.02	0.02	0.02	0.07					
Visibility of Sea	0.10	0.04	0.03	0.06	0.06										
Degree of Protection Belt of Dam	0.06	0.09	0.11	0.08	0.09	0.11	0.12	0.12	0.11	0.07	0.06	0.09	0.12	0.06	0.06
Proximity to Highway	0.02	0.02	0.01	0.03	0.03						0.05	0.04	0.04	0.05	0.04
Proximity to Second Degree Road	0.06	0.08	0.07	0.09	0.01	0.04	0.10	0.03	0.05	0.04	0.02	0.02	0.01	0.05	0.01
Proximity to City Centre Of Çeşme	0.06	0.08	0.07	0.03	0.08						0.15	0.12	0.12	0.02	0.17
Proximity to Residential District											0.15	0.12	0.15	0.15	0.10
Proximity to Sea	0.11	0.08	0.12	0.09	0.13										
Proximity to Beach	0.16	0.08	0.12	0.09	0.13										
Proximity to Thermal Spring						0.35	0.20	0.23	0.23	0.30					
Distance to Geo. Fault	0.10	0.16	0.12	0.17	0.13	0.12	0.20	0.25	0.23	0.17	0.15	0.20	0.19	0.24	0.17
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Criteria/ Planner	Recreation					Agriculture					Afforestation				
	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner	First Planner	Second Planner	Third Planner	Fourth Planner	Fifth Planner
Ratio of Slope															
Property	0.09	0.29	0.14	0.05	0.05						0.61	0.19	0.73	0.13	0.13
Quality of Soil	0.03	0.11	0.05	0.05	0.02	0.83	0.88	0.90	0.75	0.83	0.12	0.06	0.09	0.52	0.38
Geological Structure															
Conservation degree	0.22	0.12	0.39	0.25	0.16						0.21	0.56	0.09	0.32	0.38
Existing Land Use	0.22	0.10	0.05	0.02	0.02	0.17	0.13	0.10	0.25	0.17	0.07	0.19	0.09	0.04	0.13
Aspect	0.02	0.11	0.14	0.15	0.26										
Visibility of Sea	0.02	0.05	0.05	0.05	0.16										
Degree of Protection Belt of Dam	0.22	0.05	0.03	0.25	0.16										
Proximity to Highway															
Proximity to Second Degree Road															
Proximity to City Centre Of Çeşme															
Proximity to Residential District															
Proximity to Sea	0.17	0.17	0.17	0.17	0.17										
Proximity to Beach															
Proximity to Thermal Spring															
Distance to Geo. Fault															
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

5.6. Determination of Trade-Off Weight Values of Land-Uses

The last piece of information to formulate the mathematical program is to obtain the trade-off weights, W_j in formula 3.2. These weights are the key to land allocation since land-uses deemed to be more important can occupy their most suitable sites. At the same time, this is a proxy to relative valuation of land-uses in that city and it was not an issue of technicality. For that reason, with the same planners who estimated criteria suitability weights, a new questionnaire was made to determine the trade-off weights of each land use according to economic, social and environmental benefits using AHP technique. In calculating the trade-off weights, each participant planner compared every pairing of benefits with respect to total benefit and then he/she compared every pairing of land uses depending on each benefit separately and entered the rating into a comparison matrix. Expert choice 2000 software was also used in the questionnaire. The resultant trade-off values are presented in Table 5.7. As it can be seen from the table, the first planner thought that economic benefit is equal to environmental benefit and both of the benefits are bigger than social benefit. The second planner thought that the economic, social and environmental benefits are equal. The third planner thought that the social benefit is bigger than the environmental benefit which is bigger than the economic benefit. The fourth planner thought that the environmental benefit is bigger than the economic benefit which is bigger than the social benefit. The fifth planner thought that the economic benefit is bigger than the social benefit which is bigger than the environmental benefit. The highest trade-off weight in total benefit is given as thermal spring land use by the first planner; recreation land use by the second planner; thermal spring land use by the third planner; agricultural land use by the fourth planner and recreation land use by the fifth planner.

After W_j were estimated, formula 3.2 was used to compute each parcel suitability score with respect to each land use. As a result of the last computation, the date bases are ready to compute optimum land use allocations.

Tablo 5.7. Trade-off weights

	First Planner				Second Planner				Third Planner				Fourth Planner				Fifth planner			
	Economic Benefit	Social Benefit	Environmental Benefit	**Total Benefit**	Economic Benefit	Social Benefit	Environmental Benefit	**Total Benefit**	Economic Benefit	Social Benefit	Environmental Benefit	**Total Benefit**	Economic Benefit	Social Benefit	Environmental Benefit	**Total Benefit**	Economic Benefit	Social Benefit	Environmental Benefit	**Total Benefit**
Land use/ Benefit weights	**0.429**	**0.142**	**0.429**		**0.333**	**0.333**	**0.333**		**0.163**	**0.540**	**0.297**		**0.231**	**0.077**	**0.692**		**0.634**	**0.192**	**0.174**	
Residential Development	0.093	0.066	0.034	**0.066**	0.077	0.038	0.026	**0.047**	0.091	0.016	0.022	**0.026**	0.212	0.031	0.030	**0.061**	0.079	0.087	0.049	**0.075**
Commerce and Administrative	0.238	0.025	0.034	**0.127**	0.033	0.022	0.026	**0.027**	0.166	0.093	0.022	**0.082**	0.098	0.083	0.056	**0.066**	0.182	0.210	0.032	**0.160**
Tourism	0.238	0.025	0.093	**0.150**	0.268	0.079	0.083	**0.141**	0.244	0.121	0.107	**0.130**	0.098	0.083	0.086	**0.088**	0.260	0.028	0.020	**0.178**
Preferential Tourism and Residence	0.093	0.025	0.034	**0.060**	0.252	0.079	0.026	**0.116**	0.145	0.093	0.073	**0.093**	0.353	0.031	0.018	**0.077**	0.182	0.028	0.049	**0.132**
Thermal Tourism	0.238	0.256	0.165	**0.212**	0.268	0.079	0.108	**0.150**	0.269	0.145	0.163	**0.162**	0.098	0.164	0.088	**0.097**	0.205	0.079	0.121	**0.168**
Public Establishment	0.022	0.256	0.034	**0.060**	0.021	0.226	0.026	**0.086**	0.017	0.145	0.022	**0.100**	0.034	0.216	0.082	**0.086**	0.019	0.300	0.043	**0.071**
Recreation	0.022	0.256	0.165	**0.112**	0.021	0.280	0.235	**0.180**	0.017	0.145	0.197	**0.145**	0.041	0.216	0.164	**0.148**	0.027	0.220	0.212	**0.093**
Agricultural	0.034	0.025	0.276	**0.129**	0.040	0.022	0.235	**0.106**	0.034	0.121	0.197	**0.131**	0.038	0.100	0.248	**0.199**	0.027	0.028	0.212	**0.061**
Afforestation	0.022	0.066	0.165	**0.084**	0.020	0.175	0.235	**0.147**	0.017	0.121	0.197	**0.131**	0.028	0.076	0.228	**0.178**	0.019	0.020	0.262	**0.062**

CHAPTER 6

EMPIRICAL LAND ASSIGNMENT AND RESULTS

As stated earlier, the aim of the thesis is to analyze the effects of conservation decisions on optimum land use allocation and to give a more rational answer to a subjectively discussed matter. Namely, given seven alternative conservation schemes together with no conservation area, eight land-use types and their respective predetermined demand levels, which one of the conservation schemes would maximize the total benefit? To find an answer, the mathematical formulation given by equations 3.3 to 3.6 was used. During data preparation, seven different sets of suitability scores were computed for each participant planner since the changing schemes would change the suitability scores of land parcels for certain land-uses. With these different suitability scores, the mathematical program was run seven times for each planner one for each scheme. Since this is a maximization problem, the scheme achieving the highest objective function value would then mean the most preferable scheme in terms of conservation and use equilibrium giving an explicit answer to the research question depending on planner's view point.

There were 36.270 parcels, each one of them being a decision variable in the program. The number of the equations expressed both in 3.4 and 3.6 were 36.270 each, and it was nine for equation 3.5. The right hand side values, the level of demand for these equations were given in Table 5.1 as number of parcels. All computations were made with the branch and bound algorithm of GAMS solver. One computation took 41 minutes on a PC with a microprocessor of Intel Core 2 Duo 2.4.

Changes in total benefits with respect to changes in conservations schemes and weighting of planners are given in Figure 6.1. The figure shows that the total benefit lines of planners are different from each other but they are nearly parallel. The total benefits of the fourth planner who has the highest total benefits are twice the total benefits of the fifth planner who has the lowest total benefits in all conservation schemes. The cause of the difference between planners' total benefits is concerned with predetermined number of parcels allocated to land uses and the trade-off weights of planners. Namely, the fourth planner gave the maximum trade-off weights to agriculture, afforestation and recreation land uses that covers 57% of study area. On the other hand, the fifth planner gave the maximum trade-off weights to tourism, thermal tourism and commerce and administrative land uses that cover only 12% of the study area.

According to the results, the highest objective value is associated with the conservation schemes for all planners ruled in 1996 or 1998. As stated earlier, conservation schemes of 1996 and 1998 are very similar that the planners' objective function values in 1996 and 1998 are equal or there are differences only at few points. Before 1991, there was no conservation area so that the criterion of conservation degree must be excluded when each parcel's suitability scores with respect to land uses were computed at the no conservation area. To exclude the criterion of conservation degree, the weights of other criteria were increased. Thus, the objective functions at no conservation area for each planner are relatively high compared with the conservation schemes of 1991 and 1992. Objective value is the lowest in 1991 when the conservations geography was real low. Extending the coverage of conservation increased the value of the objective function in 1992 and 1995. Even though the coverage of first degree conservation area was decreased in 1996 and 1998, the value of the objective increased. In 2007, while the amount of first degree conservation was further decreased, the value of objective function decreased this time indicating under conservation for the first degree conservation areas.

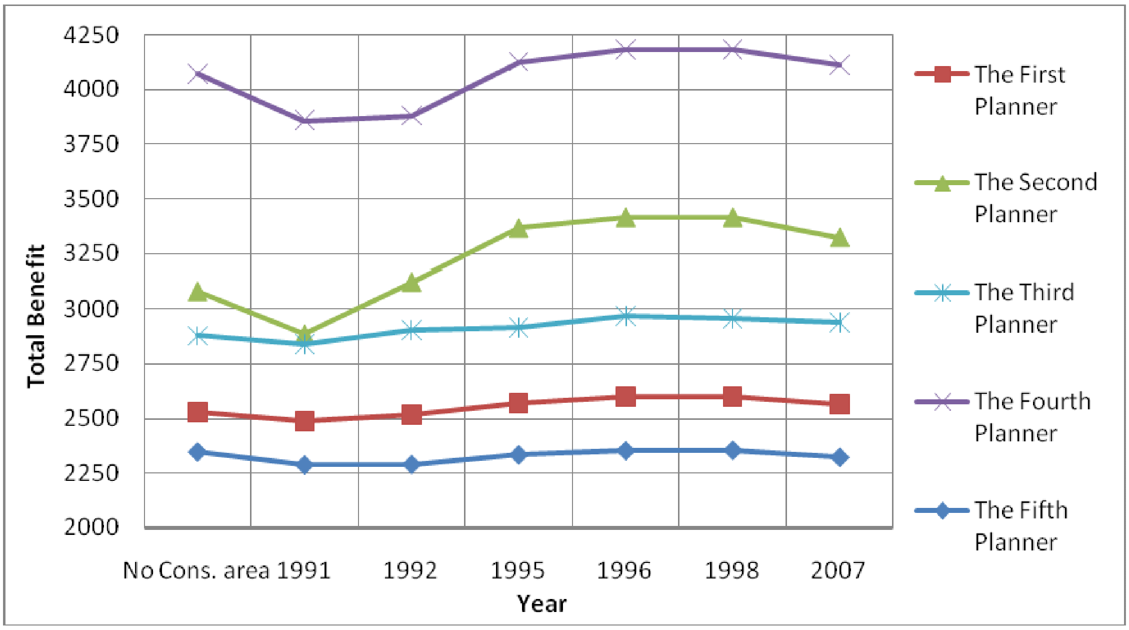

Figure 6.1. Objective functions (Total benefits) of each planner

One of the Gams solver output is the shadow prices (marginal prices) of land-uses of each planner in time series. The shadow prices associated with land-use demand constraints also reflect the changes in conservation schemes. As a general comment, it is possible to say that the shadow prices were not changed drastically since both total area of planning (number of decision variables) and the right hand side of land-use constraints remained unchanged. In any case, all being positive indicates that all the land-uses are positively valued since the shadow prices associated with the resource constraints indicate the amount of increase in the objective function when one unit of that resource is increased.

As a general consequence, the figures of shadow prices of land-uses show that first, there is a correlation between planner's trade-off weights and shadow prices of land-uses but the shadow prices of some land-uses change considerably in time; second, the shadow prices of afforestation, recreation and agriculture land uses are positively affected from the increasing natural conservation area while increasing the natural conservation area decreased the shadow prices of other land uses. In addition, when overall shadow prices of planners are compared, the fourth planner has the highest shadow price with agriculture land-use which is 0.14 and the third planner has the lowest shadow price with residential development which is 0.006. Each planner's figure of shadow prices of land-uses is examined individually below.

The first planner gave the highest trade-off weights to thermal tourism, tourism, agriculture, commerce and administrative land-uses respectively. It can be seen from Figure 6.2 that these land-uses have the highest shadow prices respectively. Changing conservation scheme did not change considerably the shadow prices of agriculture, commerce and administrative and tourism. The shadow prices of thermal tourism, residential development, public establishment, preferential tourism and residence and afforestation increased but the shadow price of recreation decreased for 1991 and increased for 1992 in comparison to those of no conservation area. For 1995, the shadow prices of thermal tourism, residential development, public establishment, and preferential tourism and residence decreased while the shadow prices of the others either increased or did not change. For 1996, 1998 and 2007, all shadow prices except for thermal tourism did not change considerably but the shadow price of thermal tourism increased for 1996, decreased for 1998 and 2007. In summary, it can be said for the shadow prices of land-uses of the first planner that changing conservation schemes did not change drastically the shadow prices of agriculture, commerce and administrative and tourism land uses. Nevertheless, increasing natural conservation areas decreased the shadow prices of forestation and increased the shadow prices of other land uses with varying amounts.

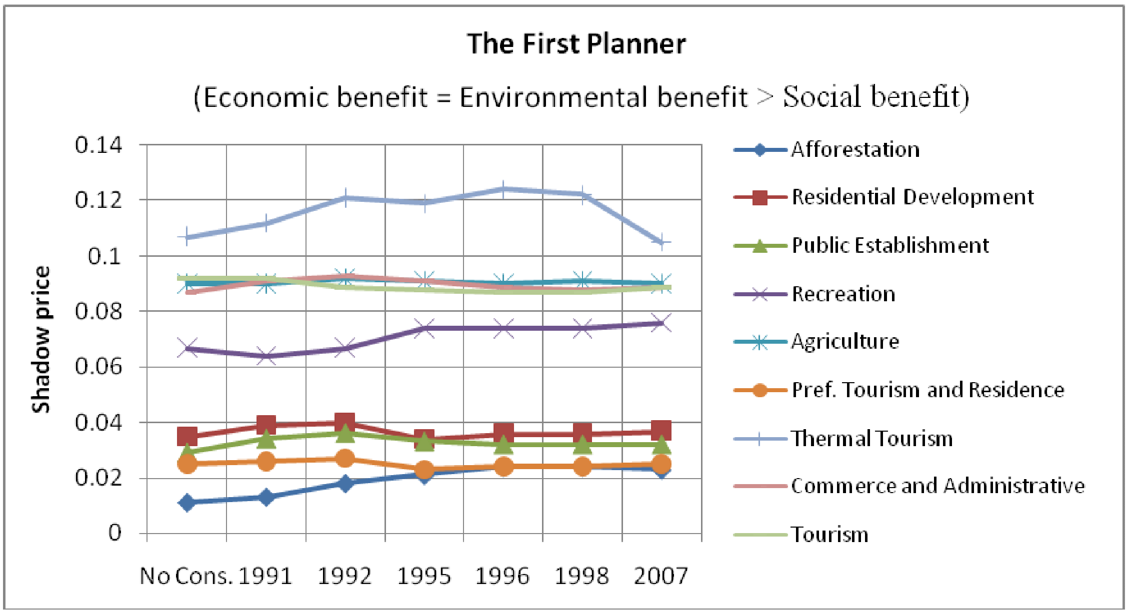

Figure 6.2. Shadow prices of each land-use of the first planner

The second planner gave the highest trade-off weights to recreation, thermal tourism, afforestation, and tourism land-uses respectively. It can be seen from Figure 6.3 that these land-uses have the highest shadow prices respectively. Changing conservation schemes did not change considerably the shadow prices of agriculture. All shadow prices except for afforestation either increased or did not change for 1991 and 1992 in comparison to those of no conservation but the shadow prices of afforestation decreased for 1991 and increased for 1992. For 1995, the shadow prices of recreation and agriculture did not change while the shadow prices of the others decreased. For 1996, the shadow prices of thermal tourism, tourism, preferential tourism and residence and residential development decreased while the shadow prices of the others either increased or did not change. For 1998, all shadow prices were same as 1996. For 2007, the shadow prices of recreation and afforestation decreased but the shadow prices of the others did not change. In summary, the shadow prices of afforestation, recreation and agriculture land uses are positively affected from increasing natural conservation area. On the other hand, increasing the natural conservation area decreased the shadow price of other land uses.

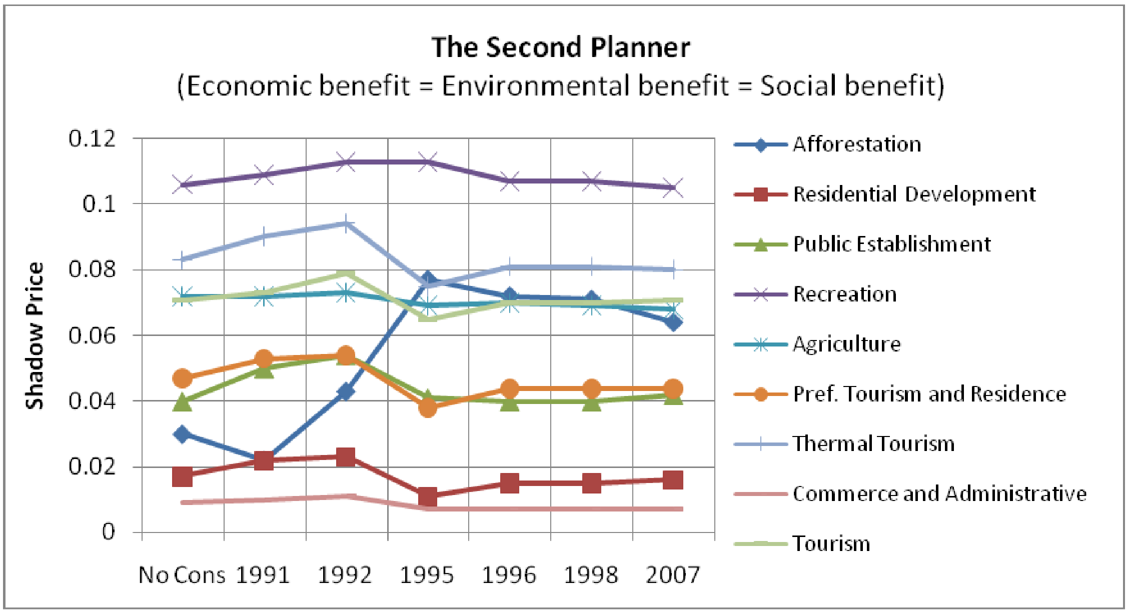

Figure 6.3. Shadow prices of each land-use of the second planner

The third planner gave the highest trade-off weights to thermal tourism, recreation, agriculture, afforestation and tourism land uses respectively. The figure 6.4 depicts that these land-uses have the highest shadow prices but there are some changes in order. All shadow prices except for recreation and agriculture either increased or not changed for the scheme of 1991 and 1992 in comparison to those of no conservation. On the other hand, the shadow prices of agriculture decreased for the schemes of 1991 and 1992 and the shadow price of recreation decreased for 1991 and increased for 1992. For 1995, the shadow prices of recreation and afforestation increased whereas the shadow prices of the others either decreased or did not change. For 1996, all shadow prices except for residential development increased and the shadow price of residential development did not change. For 1998, the shadow price of thermal tourism decreased but the shadow prices of other land uses did not change in comparison to those of 1996. For 2007, all shadow prices decreased. In summary, shadow prices of recreation and afforestation land uses are positively affected from the increasing natural conservation area. On the other hand, increasing the natural conservation area is decreased shadow price of other land uses.

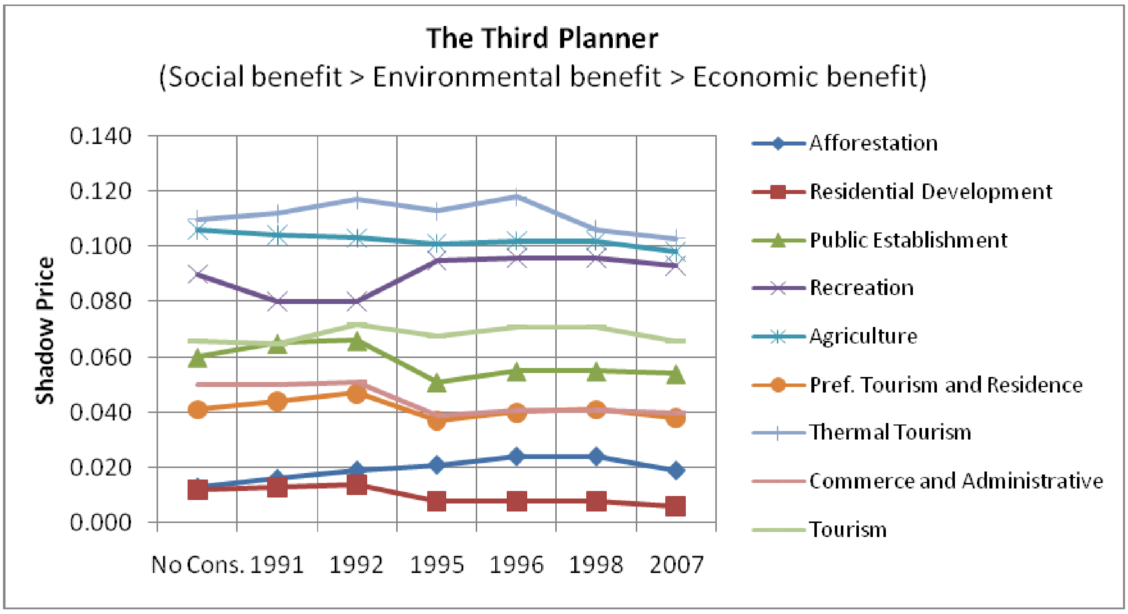

Figure 6.4. Shadow prices of each land-use of the third planner

The fourth planner gave the highest trade-off weights to agriculture, afforestation and recreation land-uses respectively. The figure 6.5 shows that these land-uses have the highest shadow prices respectively. For 1991 and 1992, the shadow prices of agriculture, afforestation and recreation decreased while the shadow prices of the others either increased or not changed in comparison to those of no conservation. For 1995, the shadow prices of afforestation and recreation increased but the others decreased. For 1996, all shadow prices except for afforestation increased but the shadow price of afforestation did not change. For 1998, the shadow prices of afforestation, agriculture and thermal tourism decreased whereas the shadow prices of other land uses did not change. For 2007, the shadow prices of all land-uses either increased or did not change. In summary, shadow prices of afforestation and recreation are positively affected from increasing natural conservation area. On the other hand, increasing the natural conservation area decreased the shadow price of other land uses. The first three highest shadow prices of land-uses of the fourth planner are bigger than 0.1 whereas the other planners do not have.

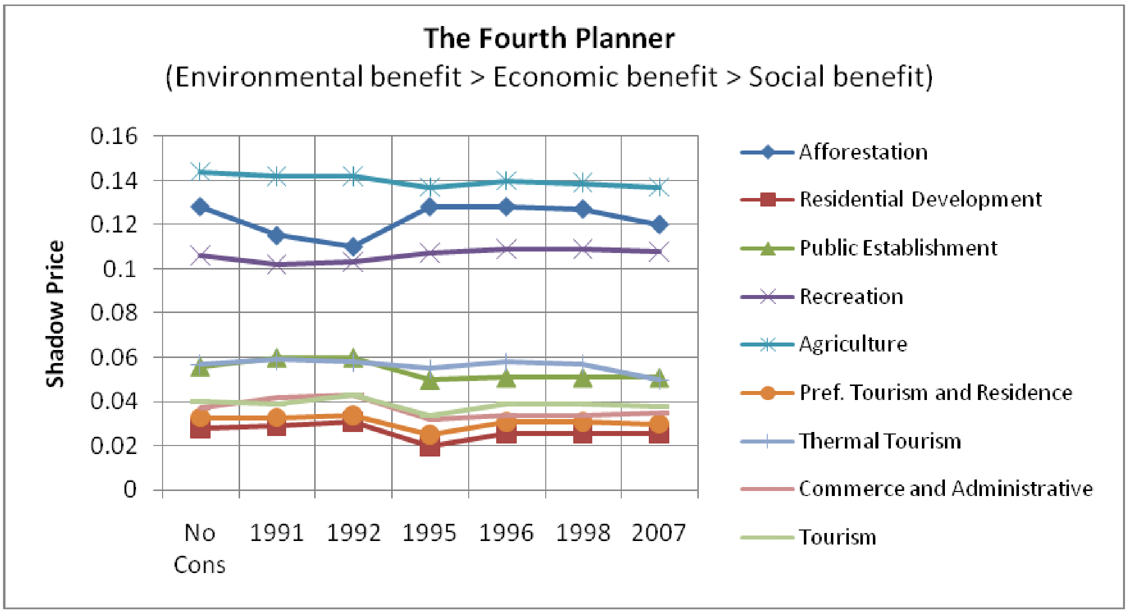

Figure 6.5. Shadow prices of each land-use of the fourth planner

The fifth planner gave the highest trade-off weights to tourism, thermal tourism and commerce and administrative. It can be seen from in figure 6.6 that these land-uses have the highest shadow prices respectively. For 1991, the shadow prices of afforestation, recreation and agriculture decreased while the shadow price of other land uses increased. For 1992, the shadow prices of afforestation, recreation, thermal tourism and commerce and administrative increased but the others either decreased or did not change. For 1995, the shadow prices of afforestation and recreation increased but those of the others decreased or did not change. For 1996, the shadow prices of thermal tourism and commerce and administrative increased whereas the others decreased or did not. For 1998, all shadow prices except for recreation did not change but the shadow price of recreation decreased. For 2007, the shadow prices of residential development, public establishment, preferential tourism and residence and tourism increased while the shadow prices of other land uses decreased or did not change. In summary, shadow prices of afforestation and recreation land uses are positively affected from increasing natural conservation area. On the other hand, increasing the natural conservation area decreased the shadow price of other land uses or did not change. The highest shadow prices of land uses of the fifth planner are lower than the other planners.

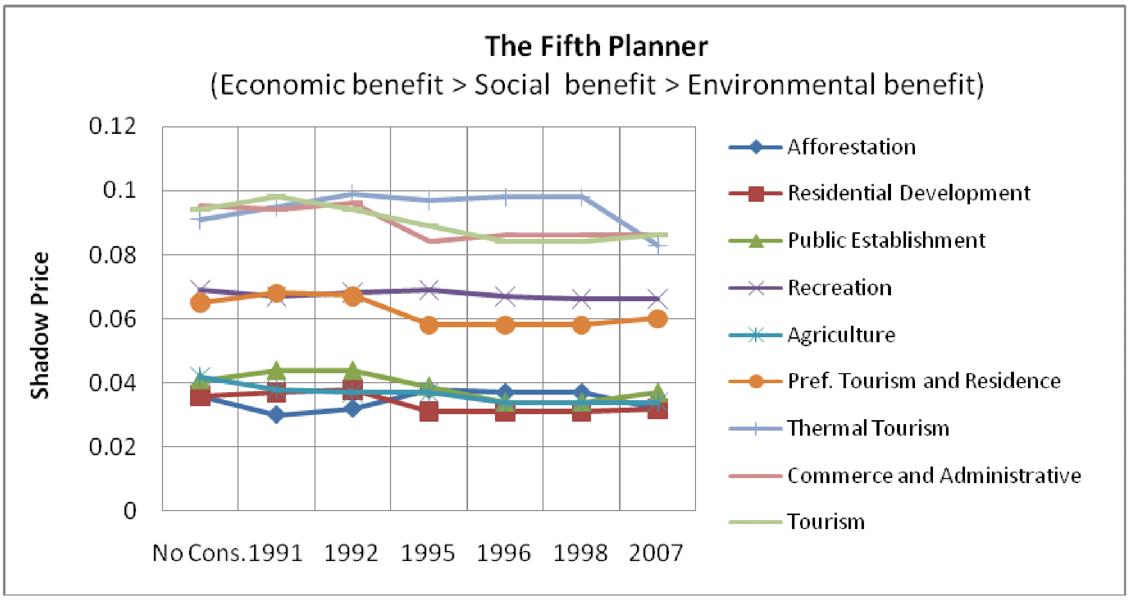

Figure 6.6. Shadow prices of each land-use of the fifth planner

Another standard Gams software output is an optimum land use allocation pattern for each conservation scheme which provides a solution that maximizes the total benefit. The outputs show that changing boundary, degree and type of conservation area affect the land use allocation pattern considerably. On the other hand, the land use allocation of agriculture is not affected like other land uses because the criterion of conservation decision was not a criterion for allocation of agriculture and agricultural land use which has the highest trade-off weight in all planners' weighting. All optimum land-use allocation patterns of the planners, the 1st, 2nd, and 3rd quality of the soil for agricultural use was allocated only agricultural land use. Each planner's land use allocation patterns in time series are examined below.

Land-use allocation patterns of the first planner (see Figure 6.7)**:** According to coastal law of 3621, parcels in the coastal band cannot be allocated to constructive land uses such as tourism, residence, commerce etc. so that these parcels can be allocated only recreation and afforestation land uses. It can be seen in the figure that parcels at the coastal band were assigned to recreation and afforestation and parcels at the back of the coastal band were assigned to tourism such as a band since the planner gave high weights to the criteria of proximity to the sea and beach for location selection of tourism. 1st degree natural conservation areas were assigned only to afforestation or recreation and 2nd degree natural conservation areas were assigned to tourism, recreation or afforestation land uses in all land use allocation patterns except in 1995. In 1995, while according to the resolutions of the High Committee it is impossible, first degree natural conservation areas were assigned to tourism and preferential tourism and residence, second degree natural conservation areas were assigned to preferential tourism and residence and first and second degree archaeological areas were assigned to tourism and preferential tourism and residence.

When the others' land-use allocation were examined; public establishment was assigned to not conserved areas near the residential districts of Reisdere, thermal tourism was assigned to only near of the thermal spring water before 1995. However, after 1995 a part of it was assigned to the southwest of residential district of Reisdere, residential development was assigned dispersedly to the residential districts of Reisdere and Ovacık and the city centre of Çeşme and commerce and administrative land-use was assigned to not conserved areas near the residential districts of Reisdere and an isthmus at the far west of study area before 1995 but after 1995 it was assigned only to the southwest of residential district of Reisdere.

Land-use allocation patterns of the second planner (see Figure 6.8.)**:** The planner gave the highest criterion weights to the criteria of conservation degree with respect to afforestation thus the impacts of conservation decision changes can be seen easily in comparison to other planners. 1st degree natural conservation areas were assigned only to afforestation or recreation, 2nd degree natural conservation areas were assigned to tourism, recreation or afforestation in the land use allocation map of 1991, 1992, 1996, 1998 and 2007. In 1995, on the other hand, 1st degree natural conservation areas were assigned to tourism and preferential tourism and residence, 2nd degree natural conservation areas were assigned to preferential tourism and residence and 1st degree archaeological areas were assigned to tourism and preferential tourism and residence that these assignments are contrary to the resolutions of the High Committee. Generally, parcels at the coastal band were assigned to afforestation and recreation but the north of coastal band of study area were assigned to preferential tourism and residence and tourism that was legally impossible, as stated earlier.

When the others' land-use allocations are examined; public establishment and commerce and administrative land uses were assigned dispersedly to not conserved areas near the residential districts of Ovacık and Reisdere. In land use allocation patterns of no conservation, 1991 and 1992, development residential areas were assigned disorderly to parcels at the north and south of the town centre of Çeşme. However, in and after 1995 the north of the town centre of Çeşme was determined as a natural conservation area so that residential development activity was assigned to the north and south of Ovacık residential district. Thermal tourism was assigned to the vicinity of thermal spring water and southwest of residential district of Reisdere.

Land-use allocation patterns of the third planner (see Figure 6.9.)**:** The parcels at the coastal band were assigned to recreation and afforestation. First degree natural conservation areas were assigned only to afforestation or recreation, second degree natural conservation areas were assigned to tourism, recreation or afforestation in all land use allocation maps except in 1995. In 1995, while it is not possible according to the resolutions of the High Committee, first degree natural conservation areas were assigned to tourism and preferential tourism and residence, second degree natural conservation areas were assigned to preferential tourism and residence and first degree archaeological areas were assigned to tourism, preferential tourism and residence and residential development.

When others' land-use allocation are examined; public establishment, commerce and administrative and residential development land-uses were assigned dispersedly to the vicinity of residential districts of Reisdere and Ovacık and the city centre of Çeşme. Unlike the other planners, this planner gave the highest trade-off weight to thermal tourism and the most important criterion with respect to the thermal tourism was the distance to fault lines but this weighting was a dilemma. Thus, thermal tourism areas were allocated to the vicinity of the thermal spring water, southwest of residential district of Reisdere and on isthmus at the far west of study area. The first area is adjacent of the thermal spring water and the last two areas are the most remote areas from the fault lines so that they are remote from thermal spring water. This allocation violates the rationality.

Land-use allocation patterns of the fourth planner (see Figure 6.10.)**:** Parcels at the coastal band were assigned to recreation and afforestation. First degree natural conservation areas were assigned only to afforestation or recreation, second degree natural conservation areas were assigned to preferential tourism and residence, recreation and tourism in all land use allocation patterns except in 1995. While it is not legally possible, second degree natural conservation areas are assigned to preferential tourism and residence land-use. In 1995, first degree natural conservation areas were assigned to preferential tourism and residence and tourism, second degree natural conservation areas were assigned to preferential tourism and residence and first degree archaeological and natural conservation areas were assigned to preferential tourism and residence. Yet this breaks the resolutions of the High Committee. Unlike the patterns of the other planners, tourism was allocated especially to the vicinity of the residential district of Reisdere, the west of Ilıca district and the north of the city centre of Çeşme in all patterns because the planner gave the lowest trade-off weight to tourism within all planners. However, these areas are very far from the sea and beach.

When the others' land-use allocation are examined; public establishment were assigned to only the vicinity of the residential districts of Reisdere. Thermal tourism was assigned to near of the thermal spring water and southwest of residential district of Reisdere. Residential development was assigned dispersedly to the residential district of Ovacık and Reisdere and city centre of Çeşme in the patterns of no conservation, 1991 and 1992 but after 1995, it was assigned compactly north and south of the residential district of Ovacık. Like the allocation of residential development, commerce and administrative was assigned the residential district of Ovacık and Reisdere in no conservation, 1991, 1992 and 1995 but after 1995 it was agglomerated to the residential district of Reisdere.

Land-use allocation patterns of the fifth planner (see Figure 6.11.)**:** Parcels at the coastal band were assigned to recreation and afforestation. First degree natural conservation areas were assigned generally to afforestation and a small amount of recreation and preferential tourism and residence, second degree natural conservation areas were assigned to preferential tourism and residence, afforestation, recreation and tourism in all land use allocation patterns except in 1995. Whereas, according to the resolutions of the High Committee it is impossible, first degree natural conservation areas were assigned to tourism and preferential tourism and residence, second degree natural conservation areas were assigned to preferential tourism and residence and first degree natural and first and second degree archaeological conservation areas were assigned to preferential tourism and residence. In 1995, first degree natural conservation areas were assigned to preferential tourism and residence and tourism, second degree natural conservation areas were assigned to preferential tourism and residence and first degree archaeological and natural conservation areas were assigned to preferential tourism and residence but this breaks the resolutions of the High Committee. Especially, allocation of preferential tourism and residence violates the resolutions of the High Committee because the planner gave a high trade-off weight to preferential tourism and residence. Tourism was assigned to coastline and between Çeşme city centre and the residential district of Ilıca before 1995 but after 1995 tourism at the coastline decreased and agglomerated to west and north of the residential district of Reisdere.

When the others' land-use allocation are examined; public establishment were assigned dispersedly to the vicinity of the residential districts of Reisdere and between the residential districts of Ovacık and the city centre of Çeşme in all patterns except in 1995. In 1995, it was assigned to as a compact shape at the south-east of Reisdere. Thermal tourism was assigned to near of the thermal spring water and the southwest of residential district of Reisdere. Residential development was assigned to the south-east of the city centre of Çeşme in no conservation, 1991 and 1992. But after 1995, it was assigned dispersedly to the residential district of Ovacık and Reisdere. Commerce and administration was assigned to the vicinity of the existing residential area of Çeşme and the south-west of Reisdere.

In conclusion, in all land-use allocation patterns of all planners, first degree natural conservation areas were assigned generally to afforestation and recreation, second degree natural conservation areas were assigned to tourism, recreation or forestation except in 1995. In 1995, while it is not legally possible, first degree natural conservation areas were generally assigned to tourism, second degree natural conservation areas were assigned to preferential tourism and residence, and first degree natural and archaeological areas were assigned to tourism and residence. Generally, the isthmus at the far west of the study area was determined as first degree conservation area in 1995, in almost all planners' land-use patterns this area was assigned to tourism or preferential tourism and residence or the other constructive land-uses because it is near the sea, beaches and the most remote areas from the fault lines in 1995. Thus, it is possible to say that the optimum land use allocation patterns/plans are designated by conservation decisions but the conservation scheme of 1995 caused legal violations in all planners' patterns.

The optimum land-use allocation patterns of the second planner was the most sensitive to changing conservation decision because he gave the highest criterion weight to the criterion of conservation decision with respect to afforestation. On the other hand, the land-use patterns of the fifth planner was the most insensitive to changing conservation decision because he gave the highest trade-off weights to constructive land-uses such as tourism, preferential tourism and residence etc. Therefore, these land-uses allocated first and second degree natural and archaeological conservation areas although it is not legally possible.

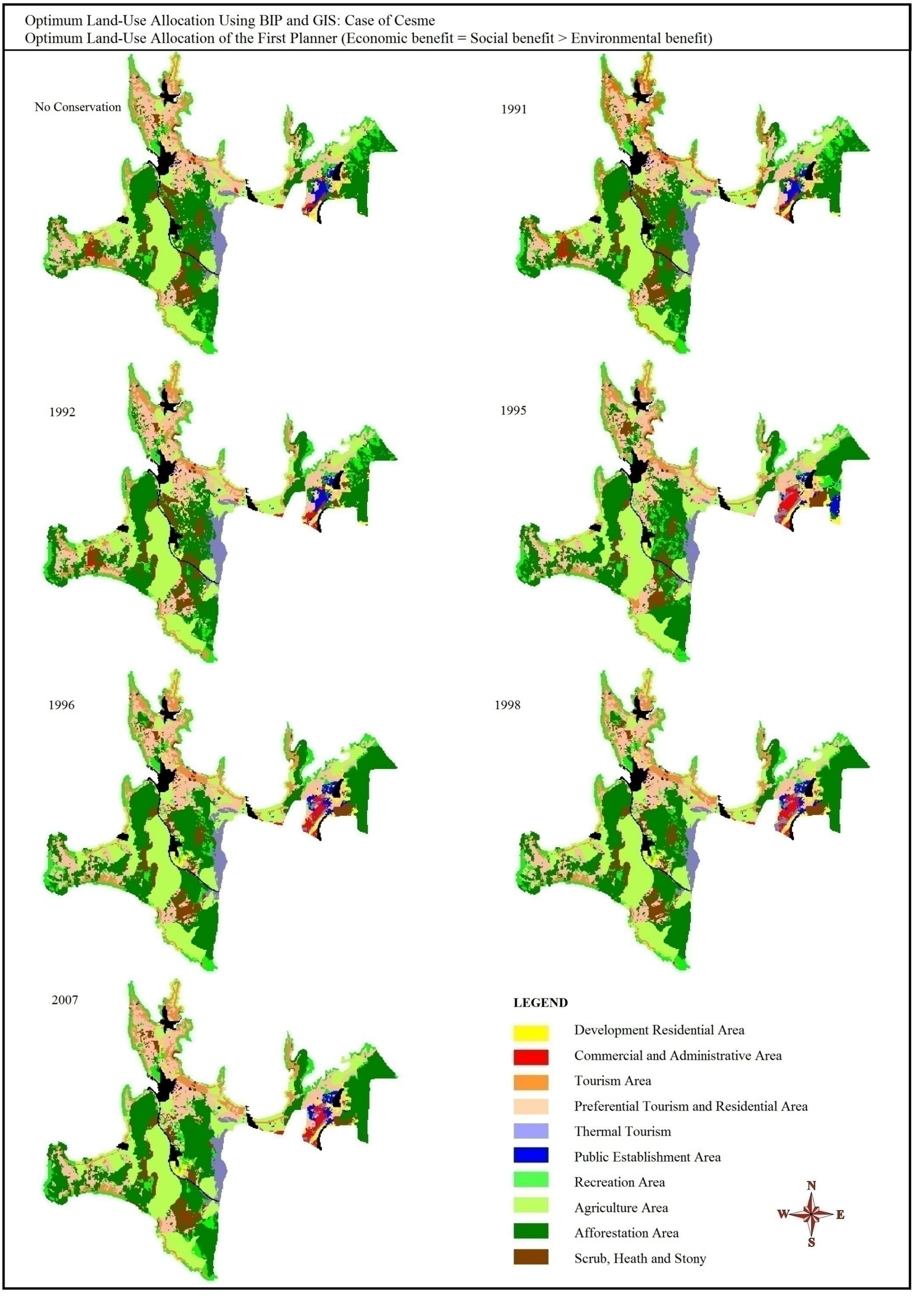

Figure 6.7. Optimum land-uses allocations of the first planner by the mathematical program

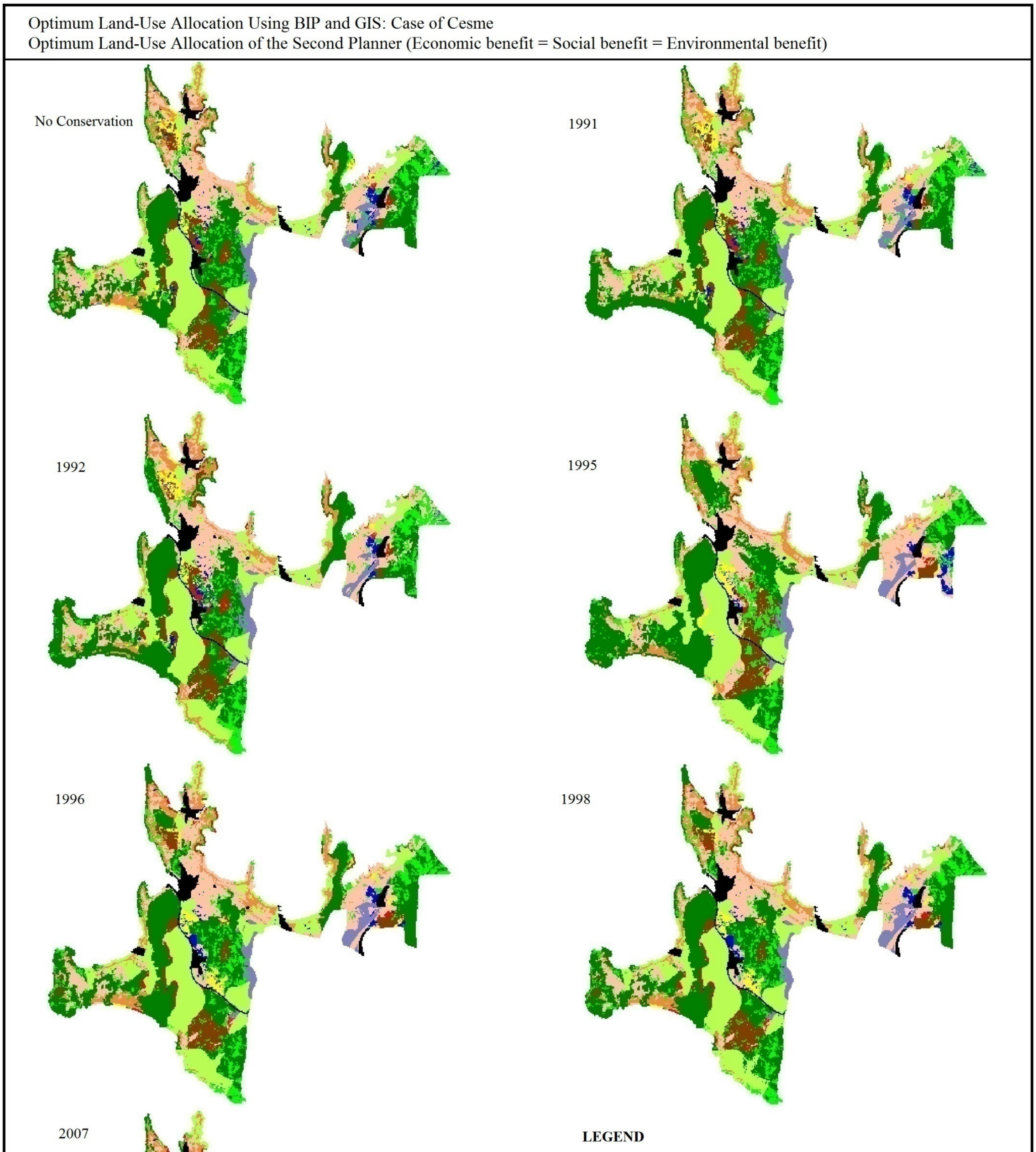

Figure 6.8. Optimum land-uses allocations of the second planner by the mathematical program

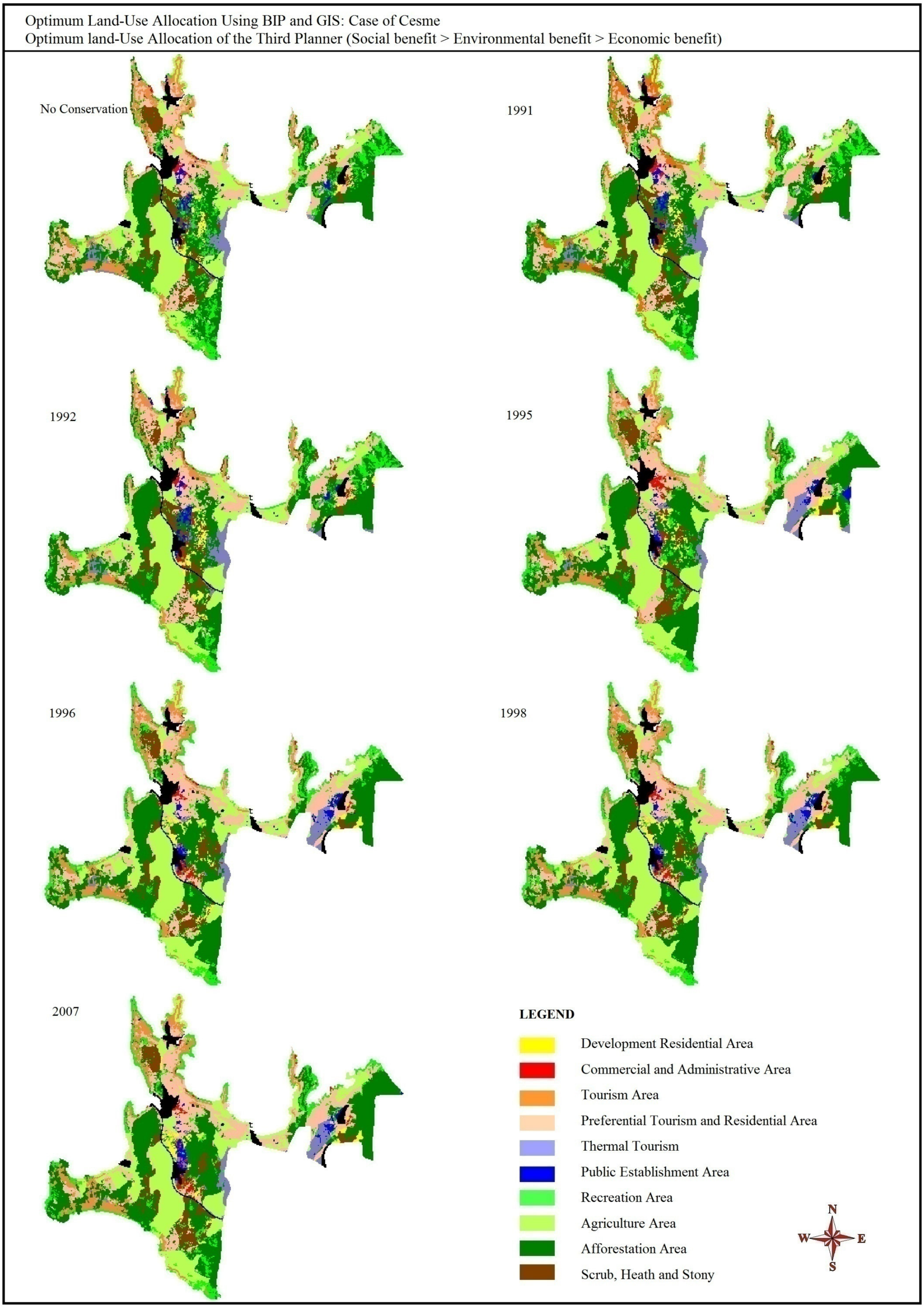

Figure 6.9. Optimum land-uses allocations of the third planner by the mathematical program

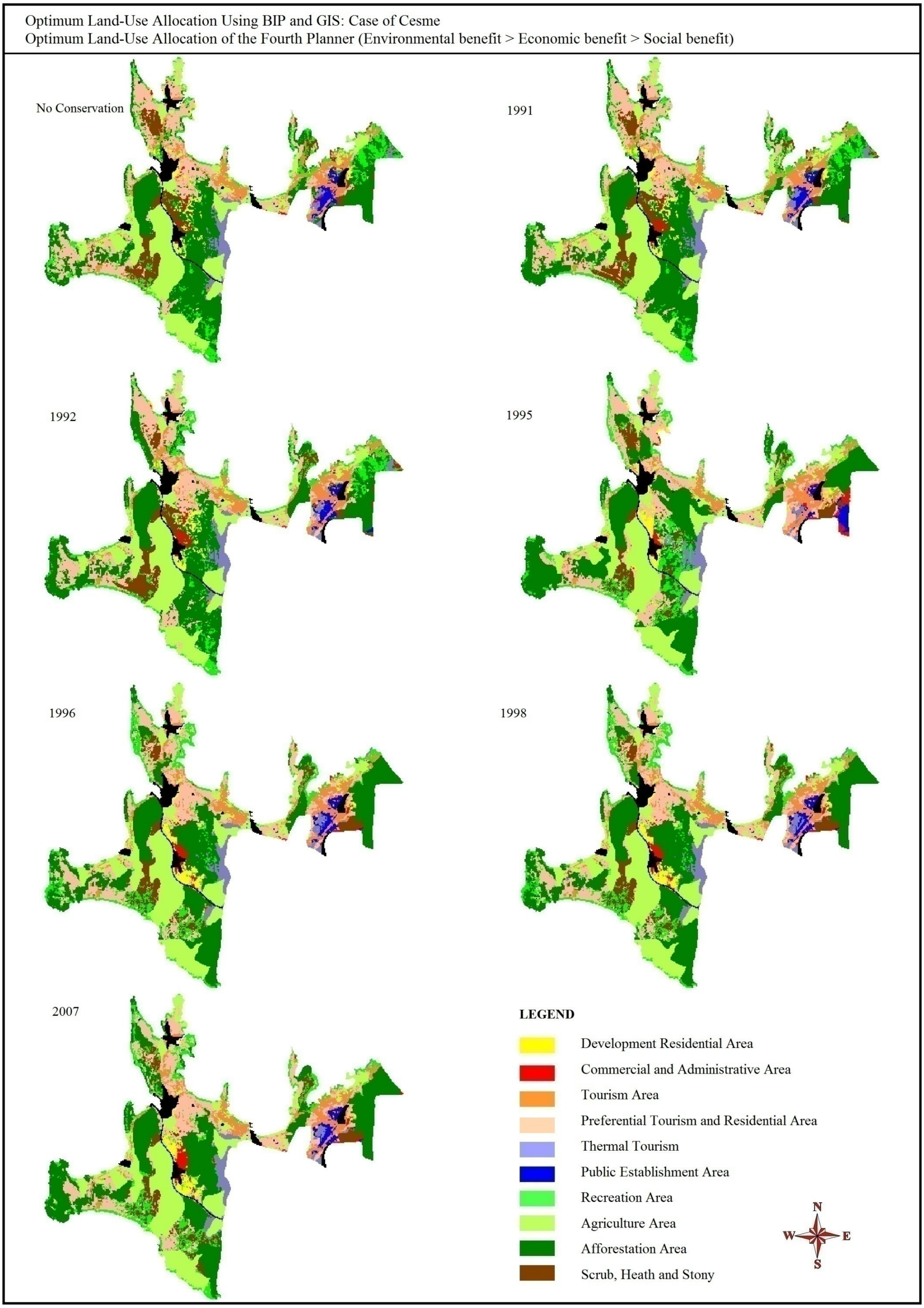

Figure 6.10. Optimum land-uses allocations of the fourth planner by the mathematical program

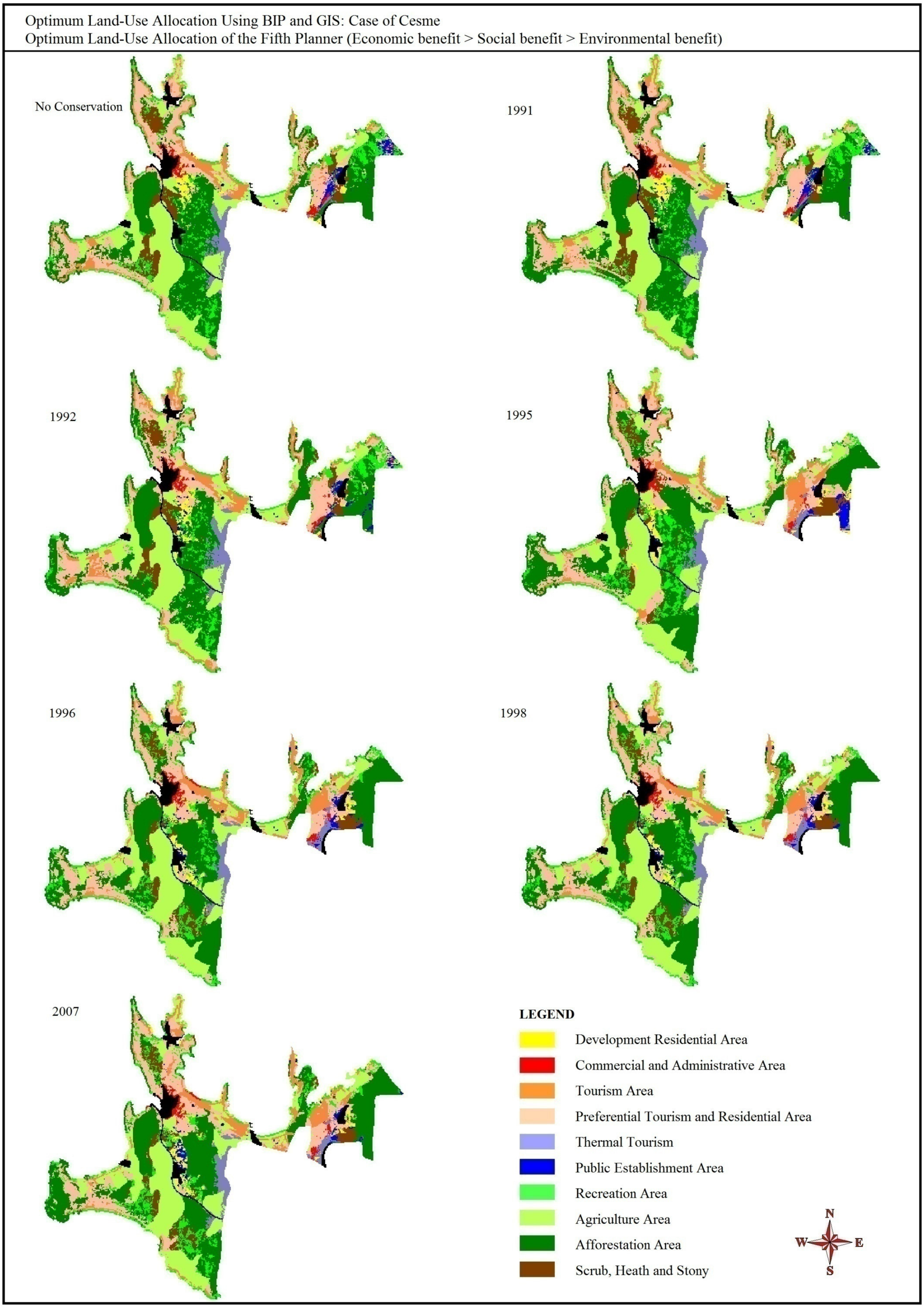

Figure 6.11. Optimum land-uses allocations of the fifth planner by the mathematical program

Another standard output of GAMS Solver was the shadow prices of parcels associated by the decision variables (i.e. site values of the parcels). The prices were expressed in the same interval and they were comparable. Hanink and Cromley (1998) interpreted parcels' shadow price as a land rent and activity consumer surplus. It is possible to say that the spatial distributions of shadow prices of all planners at the same conservation scheme are similar (see Figures 6.12-6.13-6.14-6.15-6.16). However, changing the conservation scheme affected significantly the shadow price of parcels. The shadow prices in 1991 and 1992 were generally lower than others since coverage of conservation was the lowest. In 1995, almost all areas were announced as either natural or archaeological conservation area leading to highest prices in unconserved areas. These areas were mostly agricultural land at the south of the town centre. While the aim was to conserve Çeşme from excessive construction, this conservation scheme, this time, caused a pressure on agricultural land endangering another natural resource. In 1996, 1998 and 2007 changing conservation areas decreased the pressure on the agricultural land.

In all schemes, shadow prices of parcels in coastal land were generally high as expected. Besides, the high-shadow priced parcels are collected in three areas which are at the south-west of Reisdere, between the town centre of Çeşme and Ilıca through coastline and isthmus at the far west of study. The parcels at the south-west of Reisdere are not conserved area, 6th degree agricultural land, near first and second degree roads and neighborhood of residential district area so that they have high suitability score for many land-uses. The parcels between town centre of Çeşme and Ilıca through coastline are at the periphery of town centre, near the sea, beach and 1st degree road thus they are very attractive for tourism, preferential tourism and residence, residence, commercial and administrative and public establishment land-uses. The parcels in isthmus at the far west of the study are the most remote distance from fault lines that the criterion of distance the fault line has a high weight for great deal of land uses.

Each planner schemes showed that determining an area as a first or second degree natural conservation area decreased its shadow price. Since determining an area as a first and second degree natural conservation area decreased its suitability score with respect to constructive land-uses such as residential development, tourism, preferential tourism and residence etc.

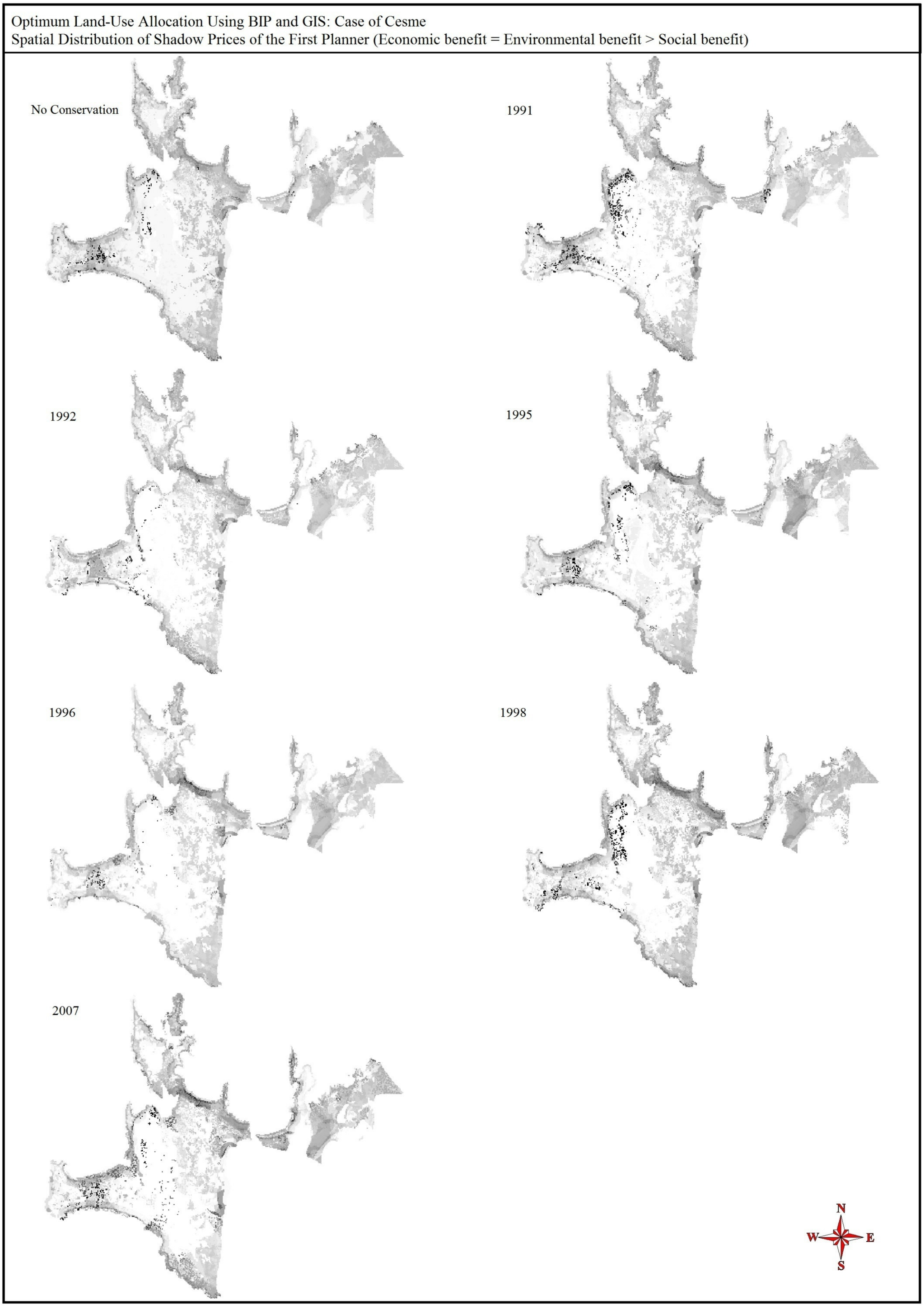

Figure 6.12. Spatial distribution of shadow prices of the first planner (Darker gray indicate a higher prices)

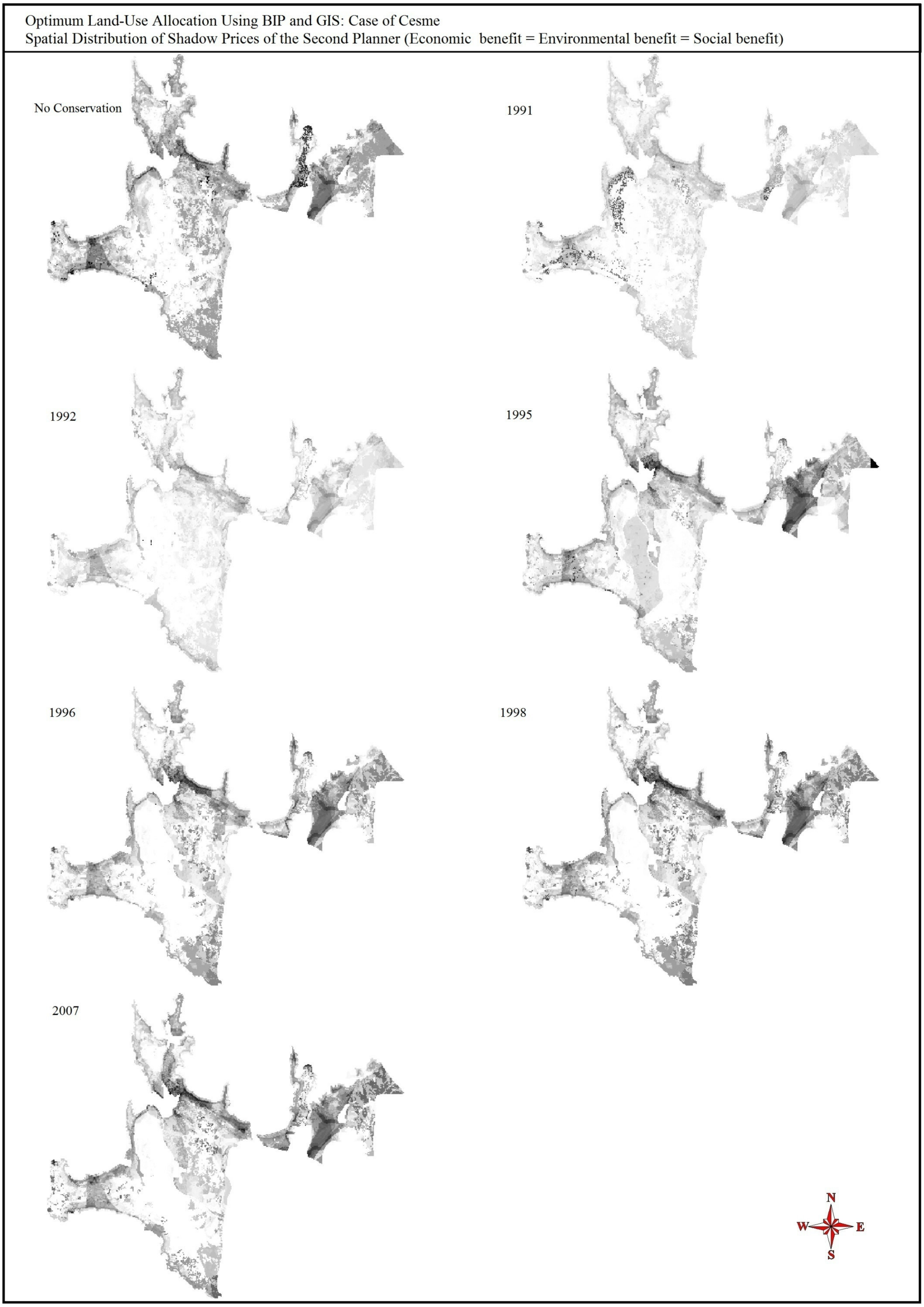

Figure 6.13. Spatial distribution of shadow prices of the second planner (Darker gray indicate a higher prices)

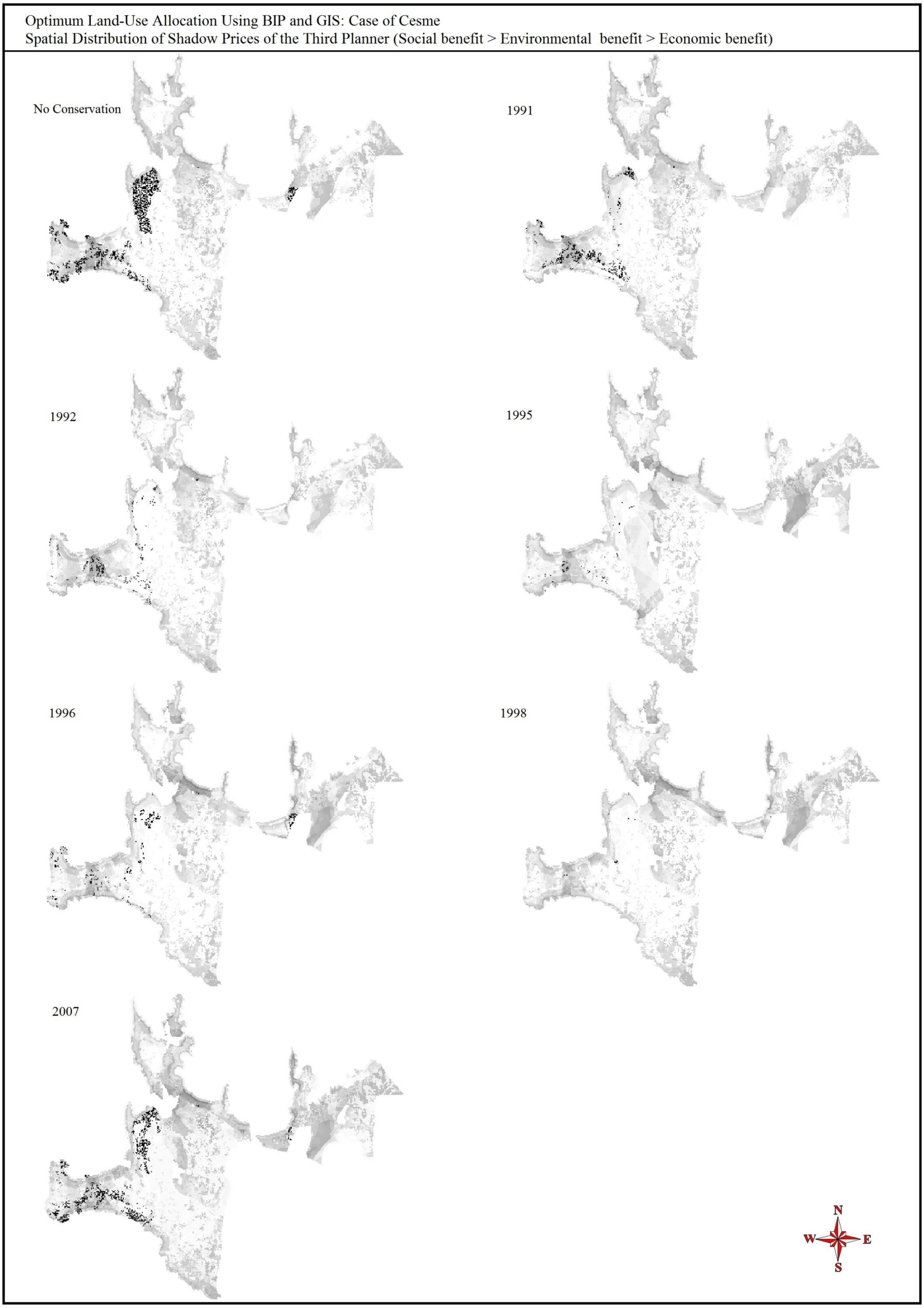

Figure 6.14. Spatial distribution of shadow prices of the third planner (Darker gray indicate a higher prices)

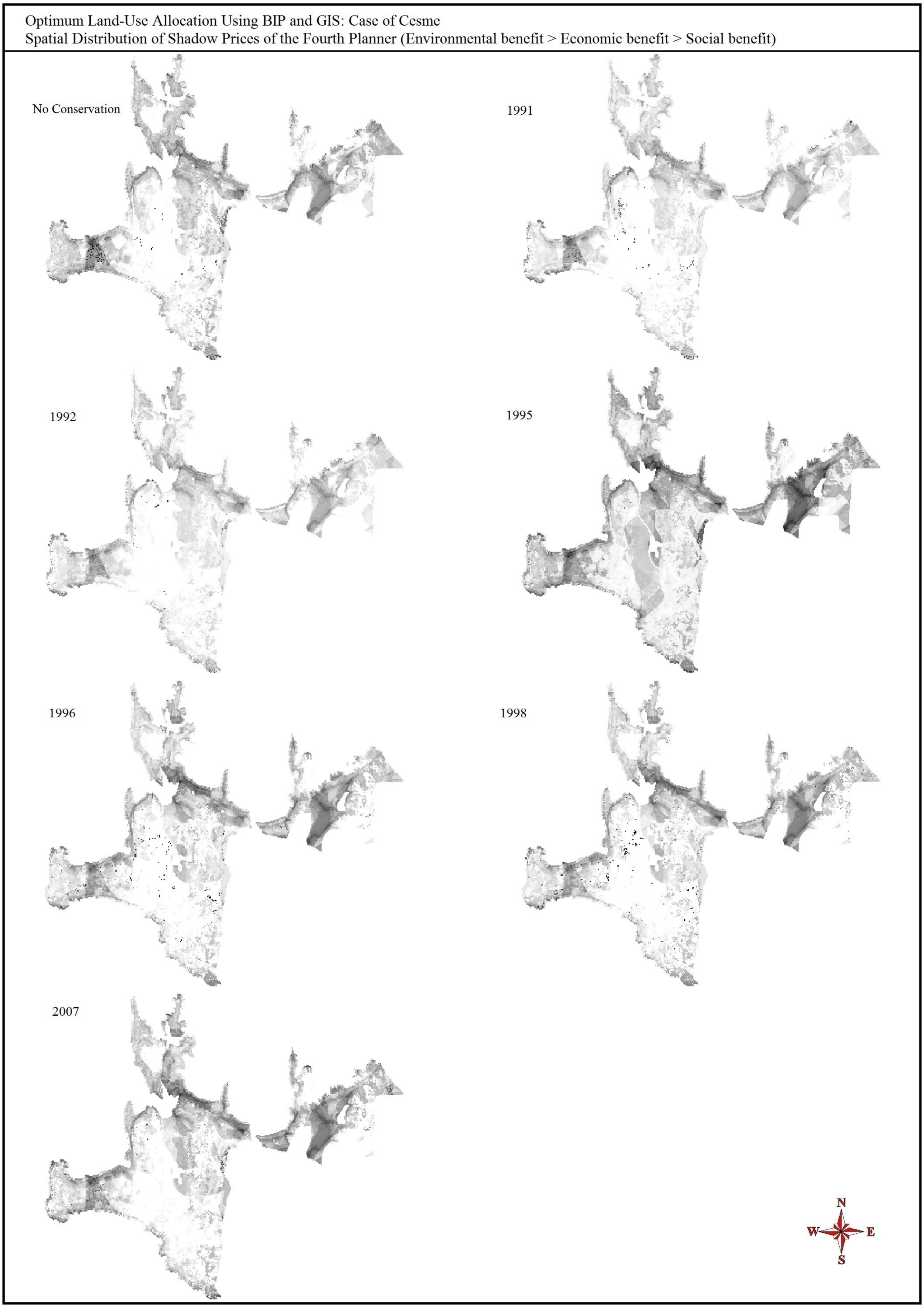

Figure 6.15. Spatial distribution of shadow prices of the fourth planner (Darker gray indicate a higher prices)

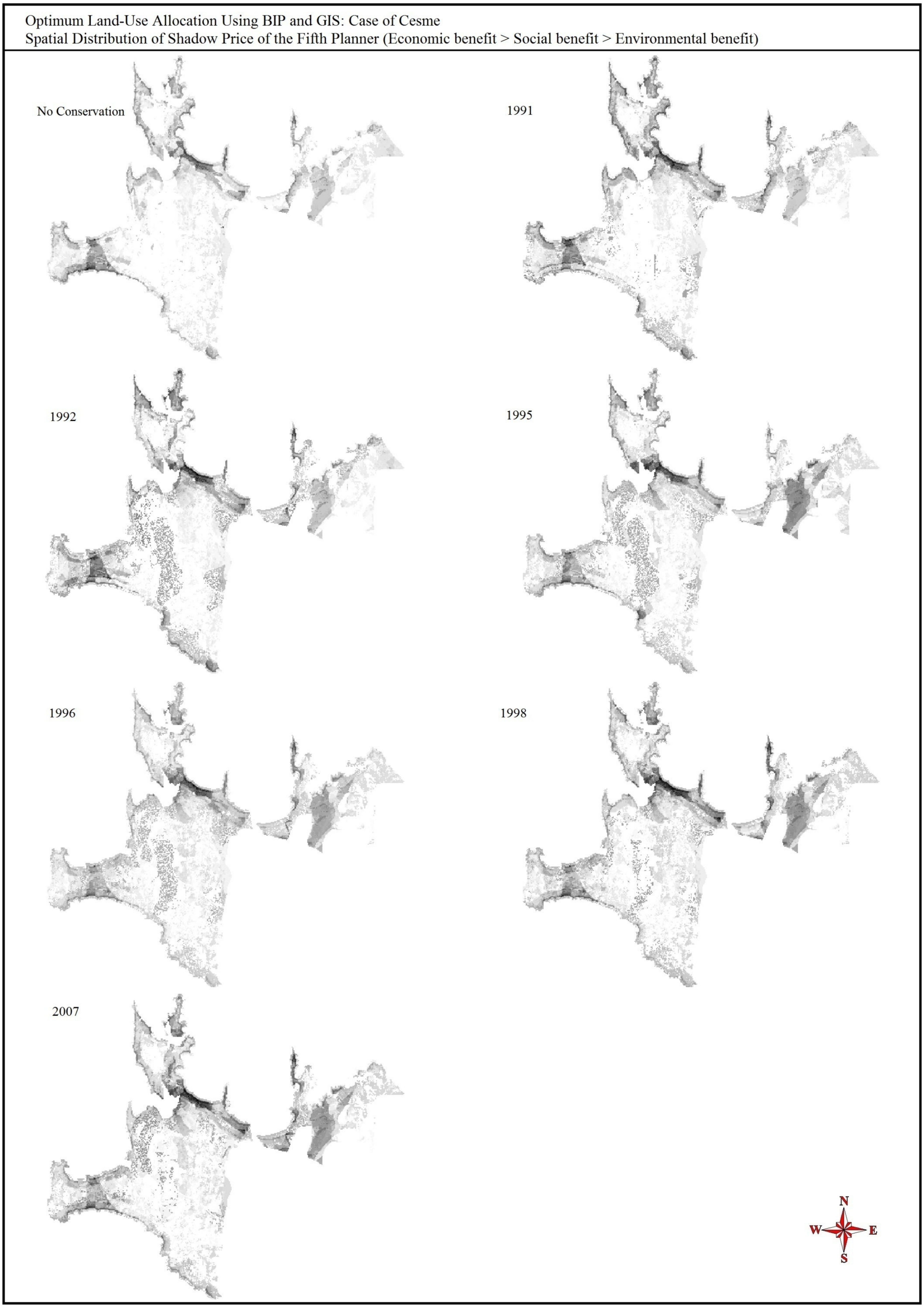

Figure 6.16. Spatial distribution of shadow prices of the fifth planner (Darker gray indicate a higher prices)

CHAPTER 7

CONCLUSION

The advances in information technology have been making many analytical tools that can be used in answering real life argumentative practical and professional decision making and planning issues. These tools can be used by academicians, professionals, and decision makers. One of them is MCDM that has a set of systematic procedures for analyzing complex decision problems by dividing the decision problem into small understandable parts; analyzing each part; and integrating the parts in a logical manner to produce a meaningful solution. MCDM techniques integrated with GIS have been used as a decision making tool in resource allocation problems of environment/ecology, transportation, urban/regional planning, waste management, hydrology, agriculture, forestry etc. (Malczewski, 2006). In city planning, they were used only in preparation of a land suitability evaluation map for a given land use/s or facility and in determination of facility locations.

MODM which is a branch of MCDM techniques were used widely in determination of facility locations, the land allocation problem with a shape constraint such as compactness, convexity and contiguity and in environmental conflict analysis. On the other hand, MODM were used for optimum land uses allocation in the scale of master plan only by Bammi and Bammi (1979) and Hanink and Cromley (1998). It should be noted that Bammi and Bammi (1979) illustrated a model with a real case while Hanink and Cromley (1998) illustrated a model with a hypothetical example.

Spatial decision making is even more complex since it is not value free and a totally objective domain. You can not quantify every factor and you cannot simply abstract all spatial entities to geographic or urban model representations. However, GIS integrated MODM techniques have provided new opportunities in city planning and spatial decision making. They should be applied also in analyzing results and effects of spatial decision making.

In Turkey, conservation decisions as a spatial decision making problem are relative and controversial that conservation scheme is changed frequently. On the other hand, the conservation scheme legally dictates which kind of land-uses that can and cannot be allocated in a conservation area in the planning process. In this context, the aim of this dissertation is to analyze the effects of various conservation decisions on optimum land use allocation when all other criteria are constant and try to find out whether an integrated model which is employing MODM&GIS could support human decision making to determine optimum conservation scheme in the concept of "conservation and usage equilibrium" as a sustainable planning approach in city planning.

The land assignment model proposed by Hanink and Cromley (1998) is indeed a very promising one among MCDM tools for the land use planners and decision makers. The thesis has shown that the land assignment model which integrated GIS and MCDM techniques can be used in answering argumentative practical and professional issues. In other word, the thesis produced a more rational answer to determine an optimum conservation scheme, given planners' weighting valuation, conservation schemes and the predetermined level of land-uses. This is accomplished using the binary integer programming in the context of MODM process.

One major contribution of this dissertation is to fulfill a knowledge gap generally with MODM but especially with a land assignment model implementation locally. This dissertation is trying to differ from other studies by integrating MODM and GIS for providing a geo-spatial planning support in decision making practice through a real-life example. Another contribution is that the model was used suitability scores in place of monetary value that gave an opportunity to meet social, environmental and economic criteria and benefits. This made it possible that the programming outputs also provided shadow prices of land uses and parcels that can be interpreted as a land rent which included all benefits.

As the study states, first, the highest objective value is associated with the conservation schemes for all planners ruled in either 1996 or 1998 in Çeşme. Second, extending the coverage of conservation increases the value of the objective function. Third, extending the first degree conservation areas increases the shadow price of agricultural land that cause pressure on agricultural land for assignment of constructive land uses and may results in legal violations for land-use allocation. Finally, the shadow prices of afforestation, recreation and agriculture land uses are positively affected from the increasing natural conservation area while increasing the natural conservation area decreased the shadow prices of constructive land uses.

The model outputs are to provide assistance to planners and decision makers for optimal development of an area while conserving the environment. In addition, the outputs can assist planners in making decision on land–use alternatives for specific land use since the model allows for making changes on the evaluation criteria or trade-off weights that explore diverse scenarios. However, it should be kept in mind that the modeling outputs are highly sensitive to the weights applied. And, in practice, master planning studies may be much more complicated, as compared to the factors employed in this study.

In conclusion, this technique can be successfully used in some other practical areas of urban land-use planning. Most important of them would be to determine the optimum level of land-uses, especially urban social and technical facilities. In Turkey, the minimum standard of urban facilities has been determined and they are uniformly enforced across all cities within the country since there is no explicit or implicit price for these usages. The land assignment model is a promising tool to analyze and determine the optimum level of urban facilities via the resource shadow price. If the constraint of land-use demand level is cancelled, the model will give the land uses' optimum levels where shadow prices associated with these land-uses are zero meaning that the city-wide utility obtained from that specific land-use is satisfied, and thus different urban facilities standards according to cities' features might be set at that point. Moreover, this technique will give the best allocation of land uses and population density in residential areas.

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