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Land Suitability for Afforestation and Nature Conservation Practices Using Remote Sensing & GIS Techniques

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Abstract

Monitoring the locations and distributions of land cover changes is important for establishing linkages between policy decisions, regulatory actions and subsequent land use activities. Given the importance of land cover changes in conservation plans, adequate scenarios and efficient multi temporal remote sensing techniques were desired for implementation in the study area. The study is located at the south western corner of Crete Island, Greece. Two temporal Landsat images acquired in 1984 (Landsat TM-5) and 2006 (Landsat ETM-7) were used to generate Normalized Difference Vegetation Index (NDVI) change detection map. Visual interpretation of color composite Landsat images is used to obtain suitability map. To keep the concept of sustainability, the involvement of human dimension in landscape multi dimension space is considered. Spatial Decision Support System (SDSS) is then implemented to assure to guide the selection of the most satisfactory alternatives. Multi Criteria Analysis (MCA) is used for compromising conflicts and to show how two different criteria are diverge or converge according to the analysis. Different suitability maps were produced and the most suitable areas for the two different practices were conducted. Areas less than 1800 m^2 were neglected and the areas with common interest were buffered with 100 m.

Key words: Change detection, GIS, Land cover, Land suitability, MCA, NDVI and SDSS.

Introduction

Land cover composition and change detection are important factors that affect ecosystem condition and function. These factors are frequently used to generate landscape-based metrics, to assess landscape condition and to monitor the status and the trends over a specified time interval (Jones *et al*., 1997). The use of satellite-based remote sensing imagery has been widely applied to provide a cost-effective means to develop land coverage's over large geographic regions.

The calculation of Normalized Difference Vegetation Indices (NDVI's) can be very useful in the generation of a land use/ land cover classification. NDVI's can provide useful information about the health and amount of vegetative cover across the landscape. The comparison of NDVI's can show temporal variations within vegetative cover, helping to distinguish between deciduous and evergreen forest types (Lambin, 1994; Rindfuss and Stern, 1998). Comparisons can be used to show variations of vegetative cover loss over longer temporal periods.

The magnitude of change from multiple NDVI's can be tabulated in various ways. One such way would be to look at the raw difference in the NDVI values from year one to year two. However, looking at the percent change from year one to year two could be more useful in terms of the overall assessment of change detection within an area.

The percent of change was calculated for high and low in NDVI values normalized to the value of global maximum high and low between the two images.

Higher NDVI value indicates the addition of vegetation and lower NDVI value indicates the removal of vegetation. Prominent areas of high NDVI value might indicate the regeneration of a forest after an earlier harvesting and areas of low NDVI value might indicate the removal of vegetative cover for land development resulting of biodiversity loss (Cohen *et al*., 1998).

Environmental objectives used to be multiple and conflicting problems, practical applications usually present alternative solutions which have different achievement on these objectives. Since there are always more than one alternative and to mark one solution we should compromise among objectives. The selection of the most suitable solutions requires subjective weights from decision makers not through automated purely technical process.

The selected raster environment for this study included: soil-geology, precipitation, distance from river and NDVI change detection layer from the two Landsat satellite images acquired in 1984 and 2006 consequently. The Landsat images are with 30m spatial resolution and the first five bands spectral resolution. In addition, a digital elevation model (DEM) layer and one of its derivatives (slope) are important in similar studies (Dragan *et al*., 2003). The theme layers were collected from existing maps and other sources of information. Spatial and attribute data are used in a GIS database to proceed with spatial analysis. Criteria selection of suitability map is arbitrary where the decision will base on them, for this reason Malczewski (1999) proposed

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Spatial Decision Support System (SDSS) as semi-structured problems solution. SDSS was constructed with Decision Support module available in IDRISI, which is a widespread, friendly and affordable GIS software tool. Multi Criteria Decision Analysis (MCDA) was among the many possible methods and techniques of SDSS (Dragan *et al*., 2003). Land suitability classes are identified by matching the requirements of the land use against the characteristics or qualities of the land. This is the fundamental principle of land evaluation, which assesses the suitability of the land for specified kinds of land use.

For the purpose of illustrating, a case study from southern west part of Crete (Nisos Elafonisos) was selected. The evaluation of land in term of land suitability classes was based on the method as described in FAO (1984) guideline for land evaluation. The essence of land evaluation is to compare or match the requirement of each potential land cover with the characteristics of each kind of land. A land unit is obtained by overlaying of the selected theme layers, which has unique information of land qualities for which the suitability is based on.

The study aims to clarify suitable area for afforestation practices and locating area that suffers from vegetation loss to follow rehabilitation program, and to realize whether the former criteria are conflicting or complementary to each other. Finally, the study aims to visualize minimum areas of 1800 m^2 as a suitable geographical unit where nature rehabilitation program might be applied.

MATERIALS AND METHODS

Study area

The study area, Nisos Elafonisos, is located in Southern west of Crete and covers an area of about 4,317.21 hectares; the study area is enclosed by the red box illustrated in (Fig.1) and specific area show in Landsat image. The area characterized by important biotope with fragile ecosystems. The latter undergo intense human influence mainly due to tourism activities (camping, tramping, vehicles, waste dumping and plant removal).

Although degradation of the site is limited so far (due to absence of improved access to the site) it is considered top priority that strict measures must be taken in order to protect the rare sand dune bio-communities area. The site is also characterized by a variety of habitat types, most of them are fairly well conserved.

The flora of the site is rich in common species and also contains endemics, local endemics and species with geographical distribution of residual character. It is one of only 100 or less sites in the European Community where the plants *Androcymbium rechingeri* and *Ipomoea stolonifera* still exist. Endemic subspecies (*Felis silvestris cretensis, Meles meles arcalus* and *Podarcis erhardii elaphonisii*) constitute part of the fauna of the site as it is described by Turland *et al*., (1993) and Georghiou (1995).

The study area is affected by Mediterranean weather conditions, dry hot summer and rainy cold winter. The rain season starts in October and ends in April of the next year. The dry season starts in June and ends in September of the same year. The average temperature recorded from 1972 to 1992 is about 18^o C. Mean annual rainfall is about 750 mm.

Data set and Analyses

The process of evaluating the land is adopted from the framework developed by FAO (1976; 1983; 1984 and 1985). The method to be proposed is intended to design for assessing land for different practices under the present condition in Nisos Elafonisos. In order to develop a set of themes for evaluation and ultimately to produce a suitability map, the condition requirement in terms of land qualities and land topography were reviewed (Byrne *et al*., 1980). The methodological framework is demonstrated in (Fig. 2).

To proceed with the analysis, criteria need to be identified; a criterion map is a layer in GIS database representing evaluation criteria. There are two different types of criteria, factor and constrain criterion.

I - A factor is a criterion that enhancement or detract from the suitability of a specific alternative. The current study includes five factors, (Table 1) describes

Figure (1): Location of the study area.

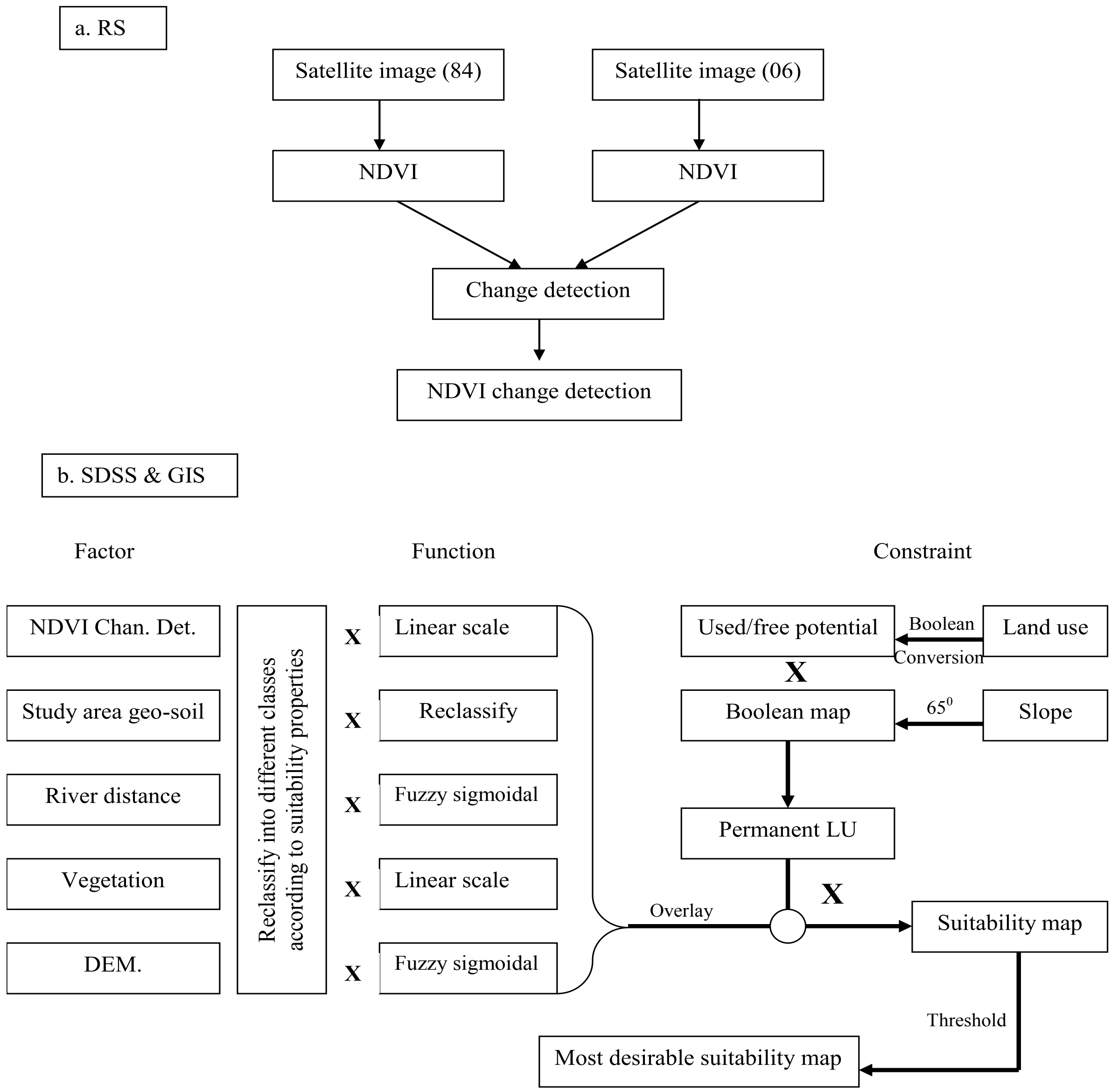


Figure (2): Methodological framework.

Table (1): List of the used factors and their deterministic transformation.

Layer	Factor	Function	Inflection Points/Classes	Score Range
River	Distance	Fuzzy sigmoidal	2 (500 and 1000 m)	Cost
Vegetation	Land cover	reclassify	5 classes	Rank
NDVI	Changes	Linear scale	2 (+ve and –ve)	Benefit
Precipitation	Rainfall	Linear scale	4 (0, 700, 1500 and 2000 m)	Benefit/Cost
DEM	Elevation	Fuzzy sigmoidal	2 (100 and 700 m, asl)	Cost

the different layers and their classification according to deterministic transformation.

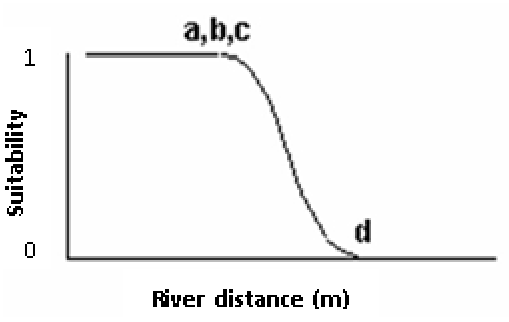
The score range of each factor used in the establishment of weighted linear combination is described in (Fig. 3).

Weight Linear Combination formula:

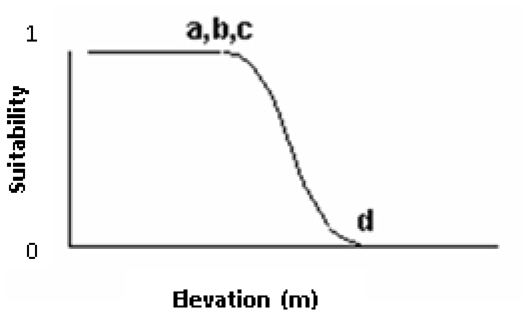
$$\text{Suitability} = \sum w_i x_i * \prod c_j$$

Where: Wi = weight of factor I, Xi = criterion score of factor I, and Cj = criterion score of constraint j

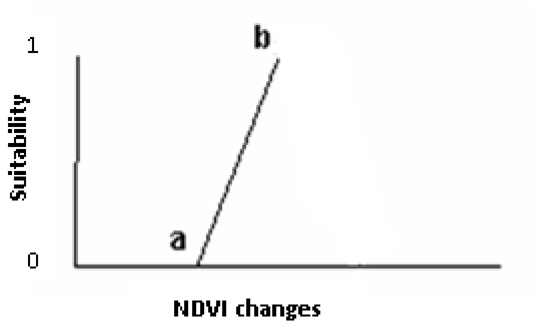
Two different sets of weighting according to two different criteria that the study suggests have assigned the former table in order to set the priority of criteria adoption. Layers weighting have been done through weight in SDSS under IDRISI environment following pairwise analysis.



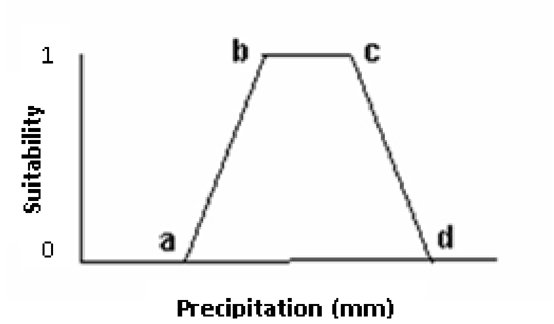
Where, a,b,c = 500, d = 1000



Where, a,b,c = 100, d = 700



Where, a = 0, b = 1



Where, a = 0, b = 700, c = 1500, d = 2000

Figure (3): The score range of each factor used in the establishment of weighted linear combination.

For the "Land use" layer, different land use/ land cover classes were ranked in (Table 2).

Table (2): Land use/ land cover rank.

Layer	Factor	Rank
Land use/ Land cover	Natural grassland	5
	Complex cultivation pattern	4
	Sclerophyllus vegetation	3
	Olive groves	2
	Beaches and sand dunes	1

II – A constraint serves to limit alternative under consideration. There are two different constraints considered according to (Table 3).

Table (3): List of the used constrains and their deterministic transformation.

Layer	Factor	Function	Inflection Points/Classes	Score Range
Land use	Distance	reclassify	2 classes	Boolean
Slope	Degree	reclassify	< 65^o	Boolean

Simple aggregation method was then applied to the factors and constraints for further analyses using moderate suitability as a threshold then followed by delineation the afforestation and nature rehabilitation suitability areas. Minimum area calculation takes place to find out the suitable area for nature conservation practices.

RESULTS

The study provides an approach to identify parametric values in modelling the land suitability according to Multi Criteria Analysis (MCA). In absence of original method of some guidelines for establishing priorities or aggregation rule, the need for MCA become essential which requires information on the relative importance of each criterion. Weight in Spatial Decision Support System (SDSS) provides the weight for the two different criteria that study adopt to proceed with Weight Linear Combination (WLC) formula as it described previously. (Table 4) describes the different weights sets with Consistency ratio = 0.09 for both of them.

Individual preference maps and corresponding individual weighting maps where produced. Four classes of suitability ranging from not suitable to highly suitable are visually illustrated for the nature conservation practices and afforestation suitability map as it is shown in figure 4 and 5 respectively.

To find out whether the two suitability maps are conflicting or complementary to each other and where they intersect, Multi Criteria Evaluation (MCE) analysis was carried out. The area highlighted by legend 110 in (Fig. 6) visualize that the two criteria representing the afforestation practices and nature conservation programs are highly related and only a few area could be serve for only afforestation purpose.

There are some additional areas that suffer from vegetation loss and are not in common with afforestation practices as it is highlighted by legend 10 in (Fig. 6).

Table (4): The assigned weight for each factor for the two different practices.

Factor	Afforestation practice	Nature conservation
Precipitation	0.0475	0.6227
DEM	0.0305	0.1603
NDVI	0.0762	0.1395
Vegetation	0.5278	0.0420
River	0.3180	0.0355

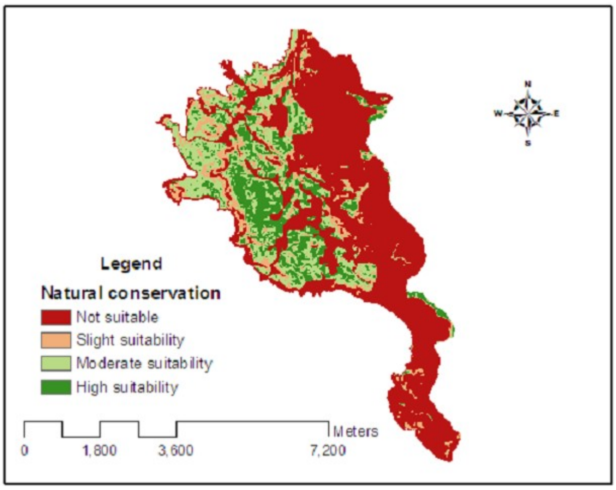


Figure (4): Natural conservation suitability map.

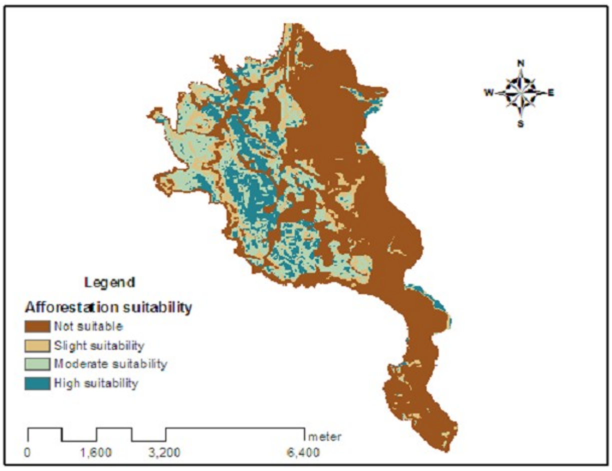


Figure (5): Afforestation suitability map.

In order to decide the effectiveness of conservation program, area calculation should be taken into consideration. Area less than 1800 m^2 (as a threshold) are considered small enough to be neglected for any further analysis. Due to area sensitivity that the conservation program shall focus on as it is considered as hotspots, buffer areas with 100 m diameter (as threshold) are added to the hotspot as it is shown in figure 7. The idea behind the buffer is to assure that the hotspot is secured from the changes that may take place in the surrounding area.

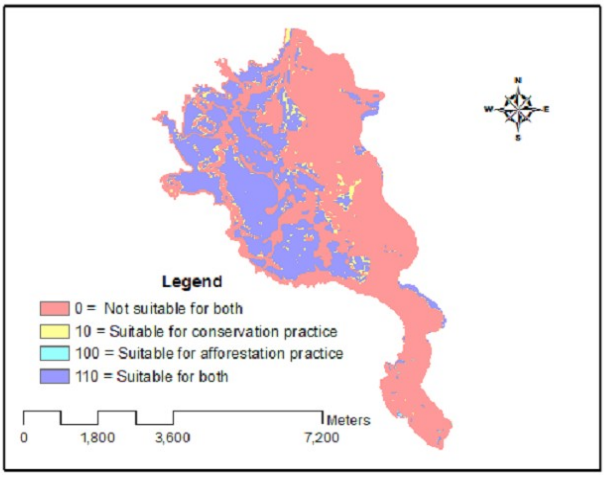


Figure (6): Common area of the different two practices.

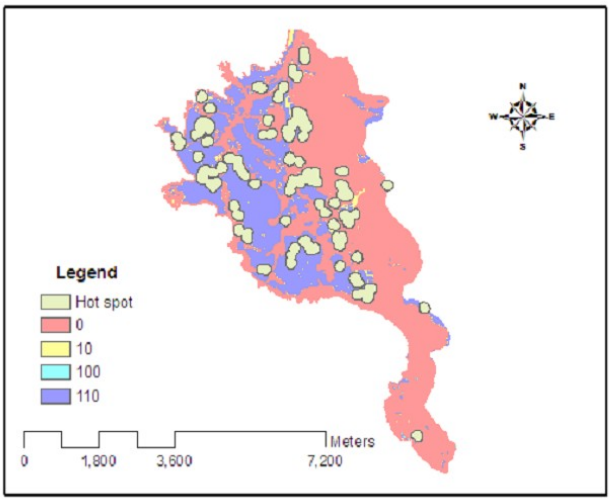


Figure (7): Hotspots with 100 m buffer.

DISCUSSION

The use of NDVI change detection map pointed out the area that subjected to change in vegetation cover and to exclude the area that is permanently changed. Land use potentiality should be taken into consideration. The finding of the suitability maps is to show different classes of the suitability that we might result from the SDSS analysis where it consolidate the reality in the form that could be easily transmitted to the decision maker, stakeholder and for the public.

The theme layers to be input in the modelling have assigned the rating value as attribute data. Overall insight into the factors and constraints affecting the suitability of land can be provided spatially and quantitatively. It has become increasingly apparent that computer Spatial Decision Support System in IDIRSI and GIS can provide the means to model land suitability effectively.

According to the suitability map classes and the use of NDVI change detection map, the resulted classes Provide useful information in the context of management plan for the study area. The areas where the NDVI shows increase in change are suitable for forestation and forest regulation activities (Kristensen *et al*., 1997). The areas that remain with no change should have different scenarios to be developed and to enhance grazing practices (Bastin, 1993). Nature conservation and biodiversity protection should be the core of the management plan for the areas that suffers from vegetation decrease as the loss of biodiversity would be the result (Hegazy and Elhag, 2006).

In conclusion, analyses using spatial model and Spatial Decision Support System are able to assess the land suitability with higher accuracy. In addition the modeling provided an approach to the improvement of yield by enhancing the component of modeling input. Further attention should be paid to grazing capacity in the area and for endangered species as well. Afforestation practices should be taken into consideration for further incoming research.

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قياس قابلية الأرض لأنشطة التشجير والصون الطبيعى بإستخدام تقنية الأستشعار عن بعد ونظم المعلومات الجغرافية

محمد الحاج
قسم المعلومات الجيولوجية – معهد المحاصيل المتوسطية – اليونان

الملخص العربى

يعتبر رصد المواقع والتوزيعات لتغيرات الغطاء الأرضي مهم لإقامة الروابط بين القرارات المتعلقة بالسياسات والإجراءات التنظيمية والأنشطة اللاحقة لإستخدام الأراضي. ونظراً لأهمية تغيرات تغطية الأراضي في خطط الحفاظ على البيئة وجدت سيناريوهات مناسبة وفعالة لتقنيات الإستشعار عن بعد متعددة الأزمنة والمطلوب لتنفيذها في منطقة الدراسة. تقع الدراسة إلى الزاوية الجنوبية الغربية من جزيرة كريت، اليونان. استخدمت صورتان زمنيتان من القمر الاصطناعي لاندسات في عام 1984 (Landsat 5) واستخدمت في عام 2006 (Landsat 7) لتوليد خريطة التغيير في المؤشر الموحد لفرق الغطاء النباتي. تستخدم التفسيرات المرئية لصور القمر الاصطناعي لاندسات مركبة الالوان للحصول على خريطة ملاءمة. للحفاظ على مفهوم الإستدامة و يعتبر إشراك البعد الإنساني في الفضاء البعد المناظر لطبيعة المتعددة. ثم يتم تطبيق نظام دعم القرارات المكانية لتأكيد الاسترشاد بها في اختيار بدائل مُرضية. يستخدم التحليل متعدد المعايير لمقارنة أوجه الاختلاف وإظهار درجة التقارب أو التباعد بين اثنين منها وفقا للتحليل تم إنتاج خرائط ملائمة مختلفة وأجريت في المناطق الأكثر ملائمة لممارسة أنشطه مختلفة. وأهملت مناطق أقل من 1800 م^2 وأضيفت مساحة 100 م ^{2} للمناطق ذات الأهتمام المشترك والمناطق الأكثر ملائمة لممارسة أنشطة مختلفة. أهملت مناطق أقل من 1800 ^{2}م وأضيفت مساحة 100 ^{2}م للمناطق ذات الاهتمام المشترك.