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ORIGINAL PAPER

Assessment of rural community and agricultural development using geomorphological–geological factors and GIS in the Trikala prefecture (Central Greece)

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Abstract In this study, the potential land use planning for rural communities and agricultural development is examined with a multi-criteria analysis and Geographical Information System. For this purpose, geological, geomorphological and socio-economic data and natural hazard maps were chosen as major factors affecting both land uses. The Analytical Hierarchical Process method was applied to evaluate these factors and the uncertainty of their weight alterations estimated. Three scenarios were developed for each land use to examine the effect of uncertainty to the suitability assessment results, leading to the corresponding potential suitability maps. The areas of very high suitability are distributed mainly at the plain part of the study area. The proposed methodology comprises a case application concerning physical factors in conjunction with natural hazard maps in the land use planning procedure.

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1 Introduction

During the last century, rural depopulation has been observed on a global scale, resulting in the abandonment of villages and the significant reduction of certain rural activities (traditional crop, farming among others). A constant movement of the population from rural to urban areas, which are considered to provide more favourable economical and social conditions, has been recorded (United Nations Population Funds 2007). On the other hand, urban areas are frequently characterised by intense industrial activity that threatens the natural environment with a wide range of chemical contaminants, degrading the quality of life and even causing serious problems for human health (Eyles 1997). To counter the aforementioned problems, slowing down the observed trend of the population movement from rural to urban areas is required (Beauchemin and Schoumaker 2005).

To implement this ambitious goal, the necessary economic, social and environmental conditions must be created that will provide a satisfactory quality of life to the rural habitants (D'Agostini and Fantini 2008; Grgić et al. 2010).

In Greece, during the last 60 years, the rural depopulation phenomenon has been very intense. More than the 52 % of the national population is congregated in the two largest urban complexes of the broader areas of Athens (the capital of Greece) and Thessaloniki. The six biggest cities-towns of Greece host more than 70 % of the total population (NSSG 2009a). During the present economic and social conditions in Greece, further enhancement of regional development and planning should take place to protect the cultural structure of the society. Previous plans to successfully improve the quality of life of countryside population were based on economic and social factors alone (Son et al. 2008) without taking into account the natural parameters.

In most developed countries, the historical migration trend of rural-to-urban movements has largely been replaced by urban-to-rural flow and repopulation tendencies. The magnitude of this "counterurbanisation" trend has declined during recent years and is now a common feature of many countries (Beale 1977; Champion 1988; Stockdale et al. 2000). In Greece, the population of the rural areas has just increased over the last two decades (NSSG 2003).

Considering the potential for the relocation of newly relocated people to the Greek rural areas, it is necessary to define the land uses (agriculture, housing, touristic, etc.) to avoid likely social and economic frictional effects (Papadopoulos et al. 2008). For the above-mentioned reasons, the prefecture of Trikala (Central Greece), a part of which is already a part of which is already primarily used for agricultural purposes, was selected as the study area. The agriculture activities in Thessaly have a 5,000-year history since the Neolithic Era (van Andel and Runnels 1995). Additionally, tourist arrivals increased (NSSG 1999) in the region because of the presence of protected, forested areas and antiquities.

The main aim of this study is to identify suitable areas for the rural communities (villages with population less than 1,800 inhabitants) and agricultural development based on mainly physical geographical factors and hazard maps. Geological, geomorphological and socio-economic characteristics of the study area were used along with data on landslides, seismic events, floods and erosion to highlight their usage in the land use planning procedure.

Environmental planning consists of land evaluation and acquisition of the appropriate sites for various land uses that can be accomplished using different factors. Dai et al. (2001) evaluated geo-environmental factors for urban land use planning. Kalogirou (2002) analysed soil, geology, land use, flood hazard and economic factors for land suitability for agricultural crops. Svoray et al. (2005) investigated land use, soil characteristics, topographic attributes, vegetation cover and landscape heterogeneity for the assessment of the suitability of nature reserves, forest plantations, and residential and industrial areas. Baja et al. (2007) took into account land suitability, erosion, water bodies and roads for agricultural land use development. Chen et al. (2010a) investigated topography, soil and groundwater for the evaluation of land suitability for the expansion or retirement of irrigated cropland. Dai et al. (2011) combined water, atmosphere, land, geology and habitat for eco-environmental sensitivity assessment.

The Analytical Hierarchical Process (AHP) is a multi-criteria technique designed for hierarchical representation of a decision-making problem and is a useful tool for decision makers and planners (Saaty 1977, 1990, 2004; Al-Subhi Al-Harbi 2001). The AHP has gained wide application in site selection and suitability (Thapa and Murayama 2008; Zhijun et al. 2009; Tegou et al. 2010; Rozos et al. 2011; Youssef et al. 2011; Panagopoulos et al. 2012). The method is based on two specific characteristics: the construction of hierarchy structure and the pair-wise comparisons between different factors (Nekhay et al. 2009).

Moreover, Geographical Information System (GIS) is a valuable tool, providing an opportunity for rapid management and complex processing of spatial data, while the user of the GIS is capable of implementing them in the decision-making procedure (Malczewski 1999; Marinoni 2004). Additionally, the integration of the AHP in a GIS improves decision-making methodology with powerful visualisation and mapping capabilities that consecutively facilitate the creation of land use suitability maps and optimise land use planning. However, one of the important problems of AHP method is the inability to determine the uncertainty as the model predicts the point estimates only, with no estimation of error of any confidence level in the output (Benke et al. 2009; Chen et al. 2010a). The uncertainty in spatial decision-making methodology may occur from selection, comparison and ranking of multiple criteria (Christakos 2000). The greatest source of uncertainty is often criteria ranking. Several studies analyse the uncertainty of criteria ranking in the AHP method based on variation of the criteria weights (Delgado and Sendra 2004; Hill et al. 2005; Levy 2005; Levy and Hall 2005; Sadeghi-Niaraki et al. 2011) and the uncertainties of spatial and quantitative impacts in the evaluation results (Chen et al. 2010b; Su et al. 2012).

In this study, the AHP is implemented to support the evaluation of the factors used in the assessment and the selection of suitable areas for rural communities and agricultural development. The processing and the evaluation of the various thematic layers of the factors used in the suitability assessment were performed in a GIS. Furthermore, the uncertainty of factor ranking changes is considered as well as how this uncertainty affects the spatial and quantitative distribution of suitable areas.

2 Study area

The Trikala prefecture is located in the western part of the fertile plain of Thessaly in central Greece (Fig. 1). The

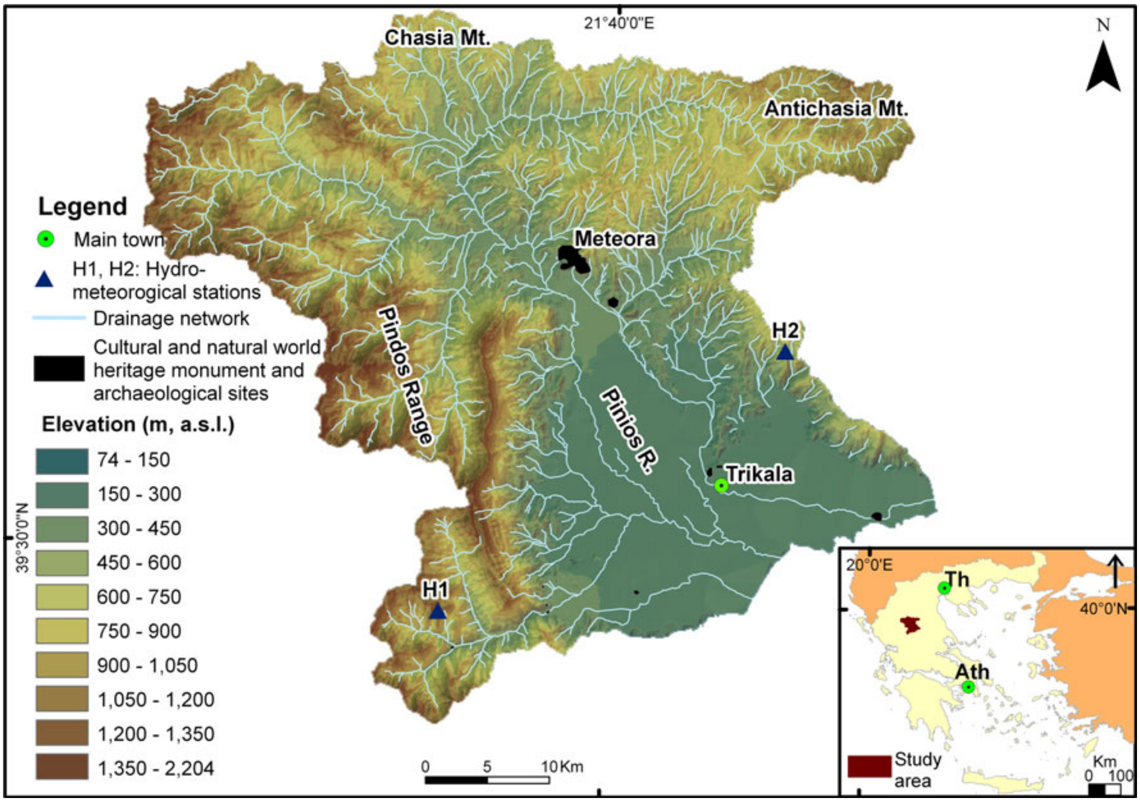

Fig. 1 Topographic map of the study area (*Ath.* and *Th.* Athens and Thessaloniki, respectively; *H1* hydrometeorological station of Stournareika; *H2* hydrometeorological station of Liopraso)

Trikala prefecture is one of the four prefectures of Thessaly, and its main characteristic is the mountainous relief. Overall, 66 % of the prefecture is mountainous, 14 % is semi-mountainous and only 20 % is plain. According to the classification of the NSSG (2006), areas are defined as follows: (a) areas having intense relief, totally or mostly located at an altitude of 800 m or more above sea level (a.s.l.) are called mountainous, (b) areas located at the feet of mountains or divided between a plain and a mountain, but always of an altitude less than 800 m a.s.l. are described as semi-mountainous, and (c) areas located on flat or gently sloping areas of an altitude not to exceed 800 m a.s.l. are characterised as plain.

The study area boundaries coincide with the boundaries of the Trikala prefecture, which shares a watershed with the Pinios (Peneus) River, a major river of Thessaly. The mountain range of Pindos and the mountains of Chasia and Antichasia form the relief of the area. The extent of the study area is 2,056 km^2, with altitudes varying from 74 to 2,204 m a.s.l.

The drainage network is well developed with a significant surface run off (Migiros et al. 2011). The mean drainage density varies from 1.214 to 5.195 km/km^2 (Bathrellos 2005). The Pinios River flows from northwest to southeast.

The climate is continental, with cold winters and hot summers with large temperature differences (Loukas et al. 2007). The rainy period begins in October and ends in May. According to the hydrometeorological data, for a time-period of 30 years (1973–2003), the mean annual precipitation of the study area that has occurred over the past 30 years is 1,633.6 mm in mountainous areas (hydrometeorological station of Stournareika) decreasing to 671.7 mm in lowlands (hydrometeorological station of Liopraso).

The geological formations that can be identified in the study area, according to the geological map of Bathrellos (2005), are crystalline schists, gneisses and amphibolites, semi-metamorphic formations, crystalline limestones, conglomerates, ophiolites, limestones, schists-cherts, cherts, marls, flysch formations, and Pliocene and Quaternary deposits.

In the study area, 153 villages or settlements exist, with populations varying between 12 and 1,617 inhabitants, based on the most recent census (NSSG 2003).

The research for the selection of the appropriate sites for rural communities and agricultural development in the Trikala prefecture is significant due to the characteristics of the study area. Specifically, a significant portion of the inhabitants is engaged in agricultural work because a large part of the study area is plain, and agricultural activities along with stock farming support the local economy. A total of 38 % of the study area is covered by agricultural areas. Most of the agricultural activities take place in soils whose behaviour, according to Christakos (2003), is a crucial component of several studies concerned with the environmental effects of dynamic conditions such as earthquakes, risk assessment and geological hazards. Furthermore, considerable areas are either covered by forests or protected by international conventions (Natura 2000 Europe-wide network given by the Council Directive 2006/613/EC UNESCO—Cultural and natural world heritage monument) and national legislation or are mountainous where the development of winter tourism is suggested.

3 Methodology

The data used in this study consist of the following:

- the 11 corresponding topographic maps (map scale 1:50,000), published by the Hellenic Army Geographical Service (H.A.G.S.);
- the geological map (scale 1:100,000) (Bathrellos 2005);
- seismological data of the Geodynamic Institute of the National Observatory of Athens for the time period from 1953 to 2009; and
- well data of the Land Improvement and Water Resource Directorate of the Trikala prefecture; and

A spatial database was created, and ArcGIS 9.3 software (ESRI 2008) was used to process the collected data.

For the suitability assessment concerning rural communities and agricultural development, we used a multi criteria model based on geological, geomorphological and social-economic factors and natural hazard maps. To determine the areas where sustainable touristic development can be developed, the boundaries of the protected areas were used instead of the multi-criteria model because the land uses in these regions are determined by international conventions and national legislation.

Several physical, social and economic factors may affect the land use suitability in the Trikala prefecture. Usually, the planners use socio-economic factors in spatial planning. In this study, the selection of factors is not exhaustive. The scope of the study is to highlight the importance of physical factors in planning.

Twelve factors were taken into account in the evaluation for the suitable locations of the two studied land uses:

- four geomorphological factors (slope, aspect, elevation and drainage network);
- two geological factors (lithology and water supply);
- four natural hazards factors (landslides, earthquakes, floods and erosion); and
- two social-economic factors (road network, towns and villages).

The selection of the factors was based on a review of the literature (FAO 1984; Bantayan and Bishop 1998; Dai et al. 2001; Kalogirou 2002; Baja et al. 2007; Thapa and Murayama 2008; Wang et al. 2008; Elaalem et al. 2011; Youssef et al. 2011), personal experience, and data availability. A description of these factors follows.

Steep slopes increase the cost of engineering constructions (Rao 2005) and the cost of land cultivation, providing the motivation for this study. Moreover, the steeper the slope of an area, the more erosion contributes to the amount of soil loss (Desmet and Govers 1996). For the production of the slope layer, a Digital Elevation Model (DEM) was used. The DEM was created by digitising the contours with the 20 m intervals of the topographic maps. According to Tudes and Yigiter (2010) and Chen et al. (2010a), the slopes (Fig. 2a) were classified into five classes for each land use (Table 1).

The aspect of the slopes was taken into account because constructions and agricultural land with southern and eastern orientation are exposed to larger amounts of sunlight and heat during the winter compared to those with northern and western orientations (Tselepis 1999; Bennie et al. 2006). The aspect map was derived from the slope map. Taking into account the above mentioned literature data, it was decided to classify the aspect (Fig. 2b), for both suitability assessment cases, into four classes: 315°–45°N, 45°–135°E, 135°–225°S, and 225°–315°W (Table 1).

Elevation is a topographic factor that plays a crucial role in community development because areas with high elevation are usually characterised by the absence of vital infrastructure, such as modern transportation networks, while at the same time, the weather is too harsh, encumbering agricultural development. The elevation (Fig. 2c) was classified into five classes for each land use. For the suitability assessment concerning communities, the boundaries of the classes were taken from the NSSG (2009b). For the suitability evaluation of agricultural development, the boundaries of the classes were defined taking into account the Commission Regulation (2008).

The drainage network was taken into account because streams are able to contribute to the aesthetic view of a village, as recreational parks are often placed near them, while at the same time, they can be partially used for irrigation contributing to the agricultural development. Similarly, the drainage network was derived from the topographic maps, and the sixth, seventh and eighth order streams were classified by the Strahler (1964) method and

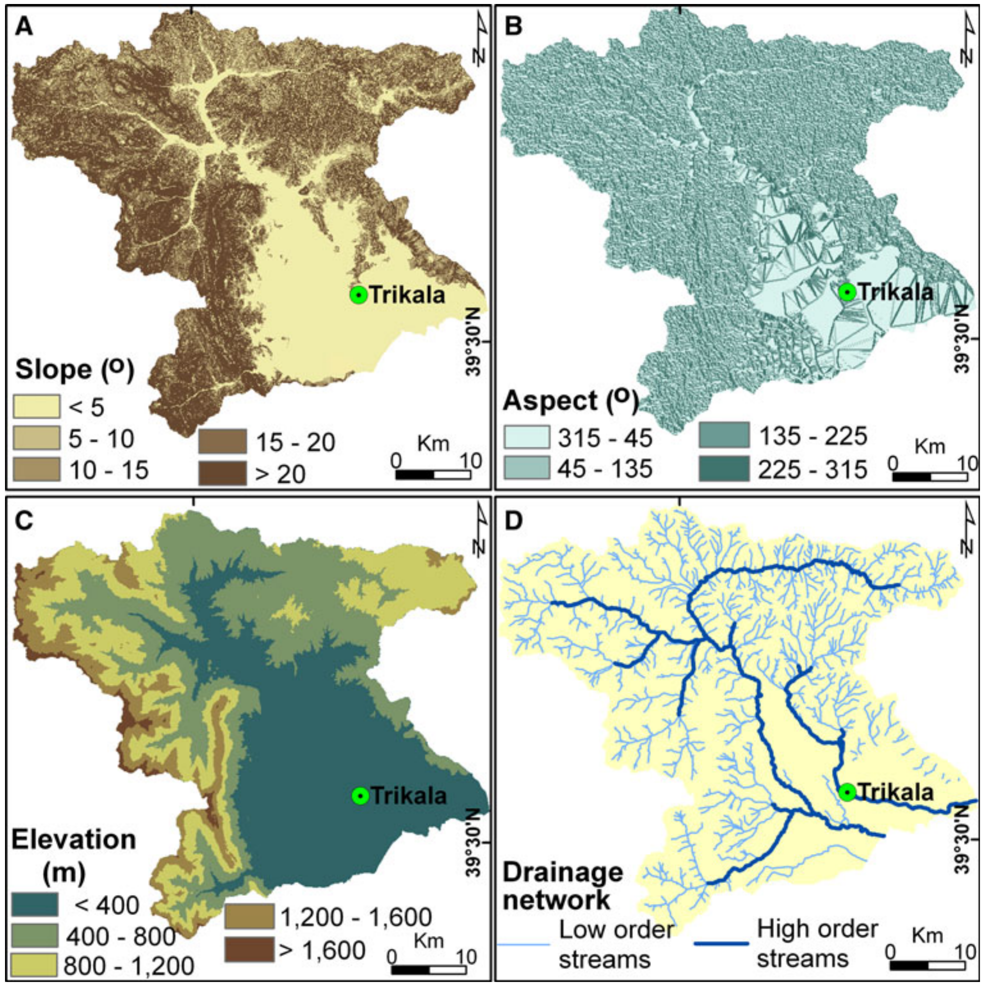

Fig. 2 The thematic layers of the topographical–geomorphologic factors involved in the analysis. **a** Slope (for development of rural communities), **b** aspect, **c** elevation (for development of rural communities), and **d** drainage network

characterised as a high order drainage network (Fig. 2d). Buffer zones were drawn around them with distance intervals from 100 to 400 m. Additionally, the fourth and fifth order streams were characterised as a low order drainage network (Fig. 2d), and buffer zones were drawn around them with a distance interval ranging from 50 to 200 m (Table 1). The threshold values of the classes for the drainage network in each land use were determined based on a literature survey (Liu et al. 2006; Baja et al. 2007; Youssef et al. 2011) and personal judgment.

Lithology is a geological factor that affects both the rural communities and agricultural development, determining the foundation features of an area for engineering constructions and designating the type of agricultural activity. The geological formations of the study area, derived from the corresponding geological map, were classified according their geotechnical engineering behaviour into three categories (Matula 1981): (i) rocks consisting of crystalline schists, gneisses and amphibolites, semi-metamorphic formations, crystalline limestones, well-cemented conglomerates, ophiolites, limestones, schists-cherts and cherts; (ii) hard soils-soft rocks comprising of marls, conglomerates with intercalations of thin-platy marly limestones, flysch formations and terrestrial deposits of Pliocene; and (iii) soils consisting of alluvial deposits (sand, clay, silt, gravels, pebbles, etc.), alluvial fans and scree, and weathering mantle (Fig. 3a; Table 1).

Concerning water use, irrigation greatly exceeds other uses (e.g., industrial and urban). Additionally, water is mainly drawn from aquifers. Hence, supply measurement data are important for planning purposes, and discharge data from 43 wells located on the plains of the study area were included in the study. The discharge data were interpolated using the inverse distance weighted (IDW) method. Taking into consideration the literature review (FAO 1984; Kalogirou 2002; Liu et al. 2006), the discharge data were grouped into four categories (Fig. 3b; Table 1).

Regarding the natural hazards, hazard maps for landslides, earthquakes, flood events and erosion were used. Landslides can cause serious damage to both construction and agricultural activities. The published landslide susceptibility map of the Trikala prefecture (Bathrellos et al. 2009) was used, dividing the study area into four sections

Table 1 The selected factors involved in the analysis, their classes and their ratings for the suitability of rural communities and agricultural development

Factors	Category	Potential rating				
		0	1	2	3	4
Slope (°)	RD	>20	15–20	10–15	5–10	<5
	AG	>10	8–10	5–8	2–5	<2
Aspect (°)	RD		315–45	225–315	45–135	135–225
	AG		315–45	225–315	45–135	135–225
Elevation (m a.s.l.)	RD	>1,600	1,200–1,600	800–1,200	400–800	<400
	AG	>650	500–650	350–500	200–350	<200
Distance (m) from high order drainage network	RD	>400	300–400	200–300	100–200	0–100
	AG	>400	300–400	200–300	100–200	0–100
Distance (m) from low order drainage network	RD	>200	150–200	100–150	50–100	0–50
	AG	>200	150–200	100–150	50–100	0–50
Lithology	RD		Soils	Hard soils–soft rocks		Rocks
	AG	Rocks		Hard soils–soft rocks		Soils
Q (m^3/h)	AG		<100	100–150	150–200	>200
Landslide susceptibility map	RD	Very high	High	Moderate		Low
	AG		Very high	High	Moderate	Low
Seismic Intensity (Mercalli scale)					>5.5	<5.5
Distance (m) from flood events	RD	<50	50–100	100–150	150–200	>200
	AG	<50	50–100	100–150	150–200	>200
Erosion hazard map	RD			High	Moderate	Low
	AG	High		Moderate		Low
Distance (m) from national roads	RD		<500	500–1,000	>1,000	
	AG	<400	400–600	600–800	800–1,000	>1,000
Distance (m) from provincial roads	RD	>400	300–400	200–300	100–200	<100
	AG	>400	300–400	200–300	100–200	<100
Distance (m) from rural roads	AG	>400	300–400	200–300	100–200	<100
Distance (m) from villages	RD	>1,500	1,000–1,500	500–1,000	250–500	<250
	AG	>1,500	1,000–1,500	500–1,000	250–500	<250

RD rural communities development, *AG* agricultural development

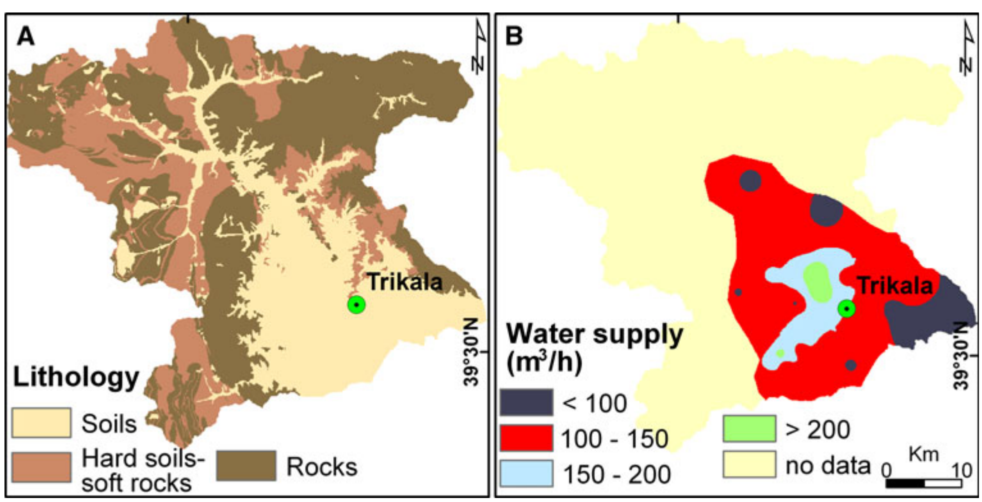

Fig. 3 The thematic layers of the geologic factors. **a** Lithology (for rural communities, and agricultural development) and **b** water supply (for agricultural development)

demonstrating very high, high, moderate and low landslide susceptibility (Fig. 4a).

Regarding earthquakes, the potential of the earthquake intensity (Papanastassiou et al. 2001, 2008) was taken into account in the study area based on the Mercalli scale but only for the case of rural community development. The earthquake intensity distribution across the area of the Trikala prefecture was mapped using a data set consisting of 30,000 intensity values from 151 earthquakes triggered since 1953 in the broader area of Greece. These values have been routinely gathered from more than 3,000 points (villages and towns) of Greece by the Institute of Geodynamics of the National Observatory of Athens and are presented in the monthly seismological bulletins of the Institute, which are available to the public. From this data set, we used all of the intensity values that have been reported from 82 towns and villages of the Trikala prefecture. These values were interpolated using the IDW method and classified into two categories (Fig. 4b; Table 1). Intensity values greater than 5.5 correspond to areas where moderate to considerable damage were reported. Following this observation, this value was chosen as a boundary to discriminate between the earthquakes causing damage and those that do not.

Flash floods cause damage in urban and rural areas (Fouache and Gaki-Papanastassiou 1997; Gaki-Papanastassiou et al. 1998, 2005, 2008; Skilodimou et al. 2003; Maroukian et al. 2005; Fernández and Lutz 2010), but they can also have positive effects through the deposition of sediment on the plough-lands. The flood hazard was taken into account for both land uses under study. In the past, drainage and irrigation works were made in the study area to protect it from flooding; however, incidents of annual flood events are reported in specific areas. For the purpose of this study the published flood hazard map (Bathrellos et al. 2012) was used, in which the areas prone to flooding were mapped and buffer zones was generated for distances of 50, 100, 150 and 200 m around them (Fig. 4c).

The erosion hazard was taken into consideration only for the delineation of the appropriate sites for agricultural development. The loss of the shallow fertile soil through erosion processes causes serious problems to cultivated land (Morgan and Rickson 1990; Kollias et al. 1999). An erosion map published by Bathrellos (2005) was used. The

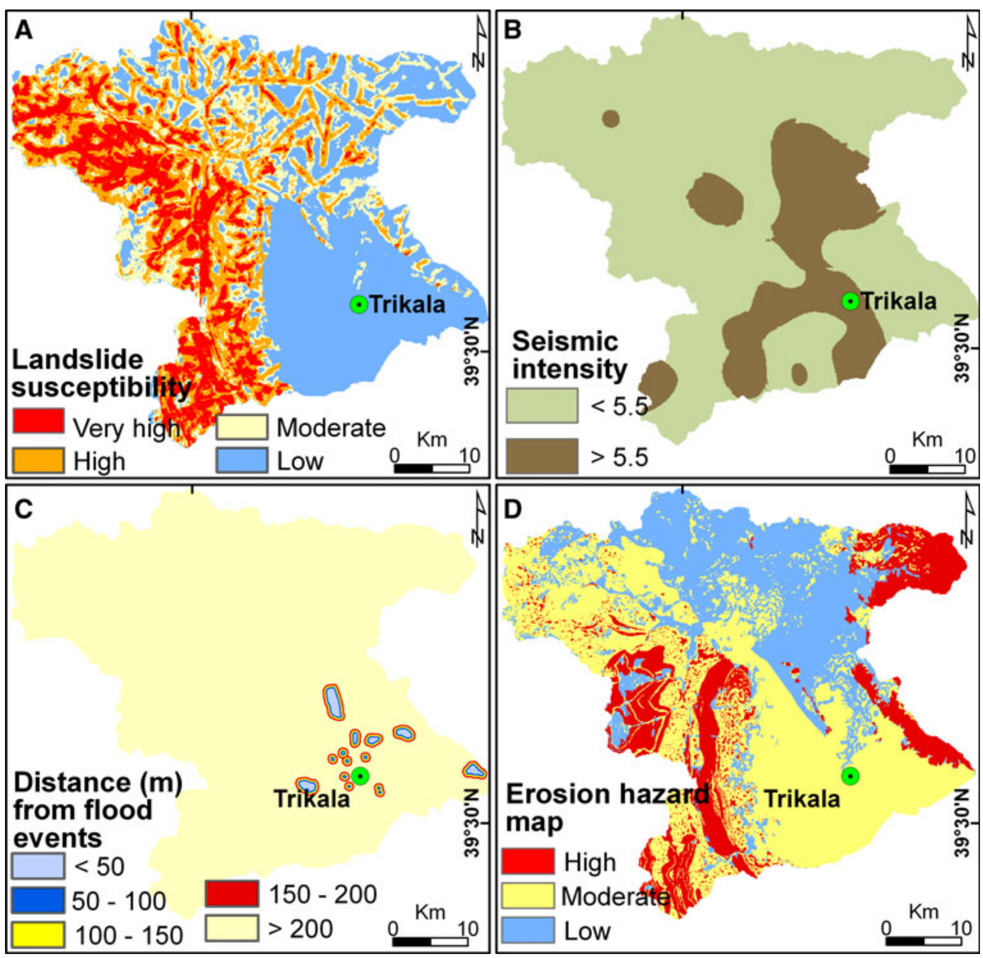

Fig. 4 The thematic layers of the natural hazard maps. **a** Landslide susceptibility, **b** seismic intensity (for development of rural communities), **c** distance (m) from flood events (for development of rural communities), and **d** erosion hazard map (for agricultural development)

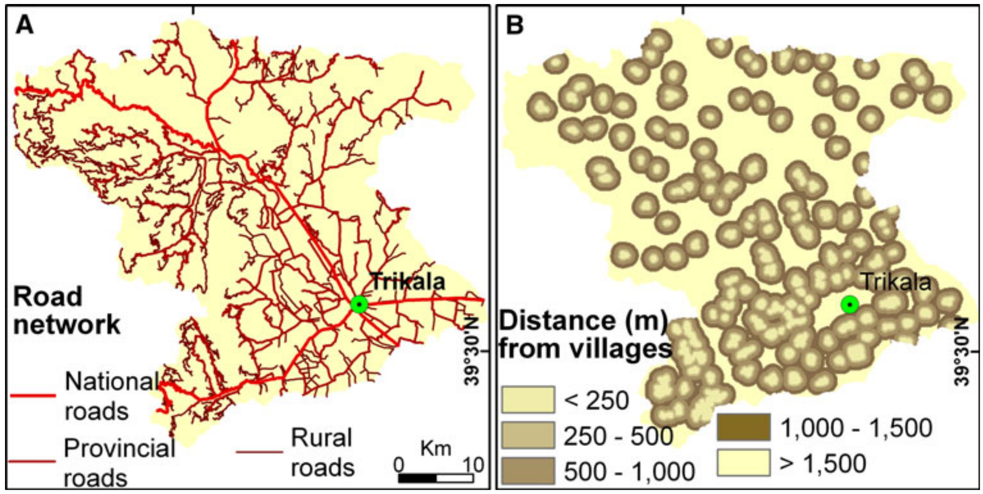

Fig. 5 The thematic layers of the geographic factors. **a** The road network and **b** distance from villages (for development of rural communities and agriculture)

map classifies the study area into three sections of high, moderate and low erosion hazard level (Fig. 4d; Table 1).

Finally, regarding socio-economic factors, the road network and the towns and villages of the study area were taken into consideration. According to Gutierrez and Urbano (2002), the road network was divided into three categories: (i) national roads, (ii) provincial roads and (iii) rural roads. Distance maps were created around these three classes, and the corresponding categories are presented into Table 1. The determination of the class boundaries for the socio-economic factors was based on the literature survey (Baja et al. 2007; Papadopoulos et al. 2008). The thematic layers of the socio-economic factors involved in the analysis are presented in Fig. 5a, b.

A primary step in the process of the suitable site evaluation for rural communities and agricultural development is to standardise (classify) all of the factors considered. Each factor was separated into classes, and every class represents specific suitability conditions. Therefore, the classes of the involved factors have to be standardised to a uniform suitability rating scale. The standardisation method used in the analysis was consistently based on a five-grade scale. Integer numbers, ranging from 0 to 4, were assigned to every class. Thus, the class, which was rated as 0, represented low suitability, and the one rated as 4 represented very high suitability.

The suggestions of engineers, geologists and agronomists working in the Public Services of the Trikala prefecture and personal experience were used to determinate the assigned values for each class of the factors. The eight experts, independently of one another, were asked to assign a value ranging from 0 to 4 on each class. The same procedure was followed by the authors. The average was used as the final rating. In Table 1, the classes and their ratings are shown for the selected factors.

A basic issue in the evaluation of the suitable sites for the two studied land uses is to assign weights to each factor separately. The selected factors were correlated with the AHP method, which was proposed by Saaty (1977). An advantage of this technique is the consistency test, which can indicate inconsistent judgments. The application of the AHP implements a correlation of the factors involved, while the weighting coefficients are revealed via pair-wise comparison from a matrix with the relevant values. The pair-wise comparison process is performed using a nine point scale, and the numerical values and the corresponding levels of importance are the following: 1 = equal, 3 = moderately, 5 = strongly, 7 = very strongly, 9 = extremely, 2,4,6,8 = intermediate values between the following levels indicated above. During the construction of the matrix, every factor is rated in relation to any other with a value from 1/9 to 9. These numerical values represent the relevant significance of a factor to the others.

In this study, two table-matrixes were constructed: one for the evaluation of suitable sites for rural communities' development and one for the agricultural development. The factors were set in the vertical and horizontal axes of each table-matrix, which are considered responsible for controlling the potential suitability of the respective land use. A set of questionnaires within the two matrixes was created. The corresponsive should decide the relative importance amongst the factors. For example, if the corresponsive judges that the slope is moderately important relative to landslide susceptibility in determining suitability of the land for rural community development, the corresponsive would assign the value of 3 to the corresponding matrix position. If the inverse were the case (landslide susceptibility is moderately important relative to slope), the corresponsive would enter 1/3 (e.g., Table 2, comparison of F1 and F6). The questionnaires were assigned to eight experts working in the Public Services of the Trikala prefecture and to the authors. From the questionnaires, 12 separate matrixes were generated, which were further linearly combined using the average mean to prepare the final matrix. The rules of the AHP

Table 2 The weighting coefficient (W_i), the change of their values (ΔW_i) of every factor and the consistency ratio (CR) for the suitability of rural community development

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	W_i	ΔW_i
F1	1	3	2	5	1	1/3	1	1/3	1/3	1/3	5	1	0.081	0.016
F2		1	1/5	1/2	1/5	1/5	1/5	1/5	1/4	1/4	1/5	1/4	0.018	0.004
F3			1	1	1/3	1/5	1/5	1/6	1/3	1/3	1/2	1/3	0.031	0.006
F4				1	1/3	1/5	1/3	1/5	1/2	1/2	1	1/3	0.030	0.006
F5					1	1/3	1/3	1/4	3	3	2	2	0.097	0.019
F6						1	1	2	3	3	2	3	0.174	0.035
F7							1	1	2	2	2	2	0.129	0.026
F8								1	2	2	1	3	0.151	0.030
F9									1	1	1	1/3	0.068	0.014
F10										1	2	1/3	0.072	0.014
F11											1	1/4	0.054	0.011
F12												1	0.095	0.019
CR = 0.09														

F1 Slope, *F2* aspect, *F3* elevation, *F4* distance from high order drainage network, *F5* lithology, *F6* landslide susceptibility, *F7* flood hazard, *F8* seismic hazard, *F9* distance from national roads, *F10* distance from provincial roads, *F11* distance from low order drainage network, *F12* distance from villages

method were applied to get the final weights for each factor. More specifically, when the pair comparison is applied vice versa, the numerical value is the reciprocal of the first one. The numerical values were then normalized by dividing each entry in every column by the sum of all the entries in that column, so that they sum up to 1. Following the subsequent normalization, the values were averaged across the rows to give the relative importance weight for each factor (Saaty 2006). The method requires all factor weights to normalise by the following equation:

$$\sum_{i=1}^{n} W_i = 1 \tag{1}$$

It is important to verify the consistency of each table matrix after the calculation of the weight values. The reliability of each table matrix was checked with the consistency ratio (CR):

$$CR = CI/RI \tag{2}$$

where RI is the random index which was developed by Saaty (1977) and it is a constant which depending on the order of the matrix. The CI is calculated by the formula:

$$CI = \lambda_{\max} - n/n - 1 \tag{3}$$

where $\lambda_{\max}$ is the largest eigenvalue of the matrix, and n is the order of the matrix. This ratio is used in order to avoid the creation of any incidental judgment in the matrix and when $CR < 0.1$ as an acceptable level of consistency has been achieved. The CR values are less than 0.1, which means that the corresponding matrixes have an acceptable level of consistency. The Expert Choice 11 software (ECI 2004) was used for the pair-wise comparisons and the calculations of the weights and the CR. The calculations of the weighting coefficient of every adopted factor and the CR are given in Tables 2 and 3.

The overall score of the basic suitability assessment for the study area was calculated with the correlation of the factors estimated. This correlation was performed using the weighted linear combination method, according to the following mathematical operator:

$$S = \sum_{i=1}^{n} W_i X_i \tag{4}$$

where S is suitability degree, n is the number of the factors, Wi is the weight of the factor i and Xi is the rating of the factor i. Equation (4) was applied in order to create the basic suitability maps of the both land uses.

Finally, the influence of uncertainty of the adopted factor weights on the suitability assessment of both land uses examined.

According to Burrough and McDonnell (1998) the error ΔS produced by independent errors ΔW_i in the weighting coefficient values of the factor is given by:

$$\Delta S = \sqrt{\sum_{i=1}^{n} (\Delta W_i X_i)^2} \tag{5}$$

According to Chen et al. (2010b) each weighting coefficient value was altered 20 % from the original factor weights used for the basic suitability assessment. The alterations of the weight values are shown in Tables 2 and 3. Since the weighting coefficients are normalized ($\sum_{i=1}^{n} W_i = 1$), a considerable negative correlation P_{ij} between W_i and W_j exists. In such a case, a term

Table 3 The weighting coefficient (W_i), the change of their values (ΔW_i) of every factor and the consistency ratio (CR) for the suitability of agricultural development

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	W_i	ΔW_i
F1	1	4	3	2	2	1/4	3	1/4	3	1/3	4	5	4	0.140	0.028
F2		1	1/4	1/3	1/3	1/5	1/3	1/4	1/2	1/5	2	2	2	0.030	0.006
F3			1	1/2	1/2	1/4	1/2	1/3	2	1/3	2	2	3	0.051	0.010
F4				1	1	1/4	1/2	1/2	3	1/2	3	3	2	0.067	0.013
F5					1	1/5	1/2	1/3	2	1/3	3	3	2	0.060	0.012
F6						1	4	2	4	1/2	4	44	3	0.188	0.038
F7							1	1/2	3	1/3	3	4	3	0.079	0.016
F8								1	3	2	3	4	4	0.149	0.030
F9									1	1/3	2	2	2	0.039	0.008
F10										1	3	3	3	0.150	0.030
F11											1	1/2	2	0.028	0.006
F12												1	2	0.029	0.006
F13													1	0.026	0.005
CR = 0.07															

F1 Slope, *F2* aspect, *F3* elevation, *F4* distance from high order drainage network, *F5* distance from low order drainage network, *F6* water supply, *F7* flood hazard, *F8* erosion hazard, *F9* landslide susceptibility, *F10* lithology, *F11* distance from provincial roads, *F12* distance from rural roads, *F13* distance from villages

$\sum_{i=1}^{n} \Delta W_i \Delta W_j P_{ij}$ has to be added on the right part of Eq. (5) inside the square root. The P_{ij} values cannot be accurately determined however the error ΔS for negatively correlated W_i values is expected to be smaller than that for independent W_i's (Burrough and McDonnell 1998). Therefore, relation (5) gives a reasonable measure of the maximum expected error produced by uncertainties of W_i values.

The equation (5) was applied to calculate the error (ΔS). Then, it was multiplied by 1.96 to compute 95 % confidence level of the suitability values S. This process led to the creation of a map which was successively added and subtracted from the basic suitability map to estimate respective upper and lower S values at 95 % confidence level. Thus, two maps representing two extreme scenarios of maximum and minimum S values were produced for each land use.

4 Results

The results for the suitability assessment of rural community development are given in the maps of Fig. 6. Three alternative maps were derived for different scenarios. The first scenario was the application of AHP method, leading to the basic suitability assessment map (S_b). The second map (S_{max}) represents the maximum value of the suitability assessment of each pixel, while the minimum value scenario is expressed in the third map (S_{min}).

The study area was classified, using the Natural Breaks method, into five sections corresponding to very high, high, moderate, low and very low suitability. The percentages of these classes, in relation to the entire extent of the study area, for the S_b map, are the following: 16.4 % for "very low", 26.8 % for "low", 23.6 % for "moderate", 23.3 % for "high", and 9.9 % for "very high" suitability (Table 4).

The percentages of the suitability classes for the S_{max} map have changed in comparison to the S_b map. The very low and low suitability areas have decreased to 13.0 %, and 24.3 % of the area, respectively, while 21.4, 25.8 and 15.5 % of the region are moderately, highly and very highly suitable, respectively. The percentages of these classes have increased and the very high suitable area represents the maximum variation of increase (5.6 %) as shown in Table 4. This class has the highest variation of percentage among the others.

For the S_{min} map, the percentages of the suitability classes fluctuate less than those of the S_{max} map (Table 4). The areas of very low, low and high suitability have slightly decreased while moderately and very highly have increased in relation to those of S_b map. The highest variation of the area is observed in the moderate class. It could be considered that the remaining suitability classes are relative stable.

The application of the proposed methodology for suitability evaluation of agricultural development produced the basic map (S_b) shown in Fig. 7. As in the previous case, a map (S_{max}) corresponding to the maximum values of the suitability estimation and another (S_{min}) representing the minimum values were generated. The study area was also classified, using the Natural Breaks method, into five

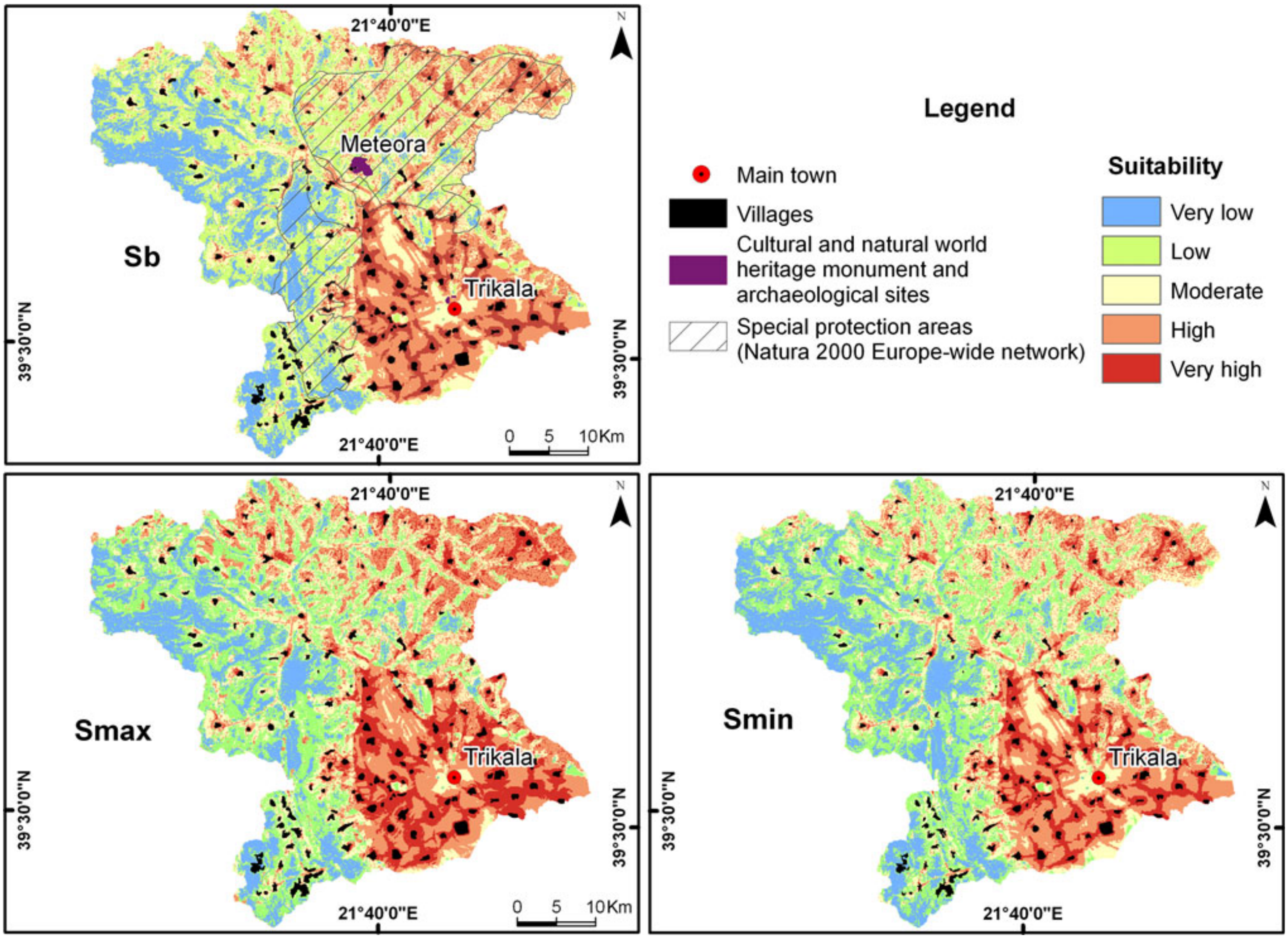

Fig. 6 Potential suitability maps for the development of rural communities. S_b the basic suitability assessment, S_{max} the maximum value of suitability assessment, S_{min} the minimum value of suitability assessment

Table 4 Percentage areas of suitability classes derived from the three scenario maps for each land use

Suitability class (%)	Rural community development					Agricultural development				
	S_b	S_{max}	Changes ($S_{max} - S_b$)	S_{min}	Changes ($S_{min} - S_b$)	S_b	S_{max}	Changes ($S_{max} - S_b$)	S_{min}	Changes ($S_{min} - S_b$)
Very low	16.4	13.0	−3.4	16.0	−0.40	20.5	17.8	−2.8	19.9	−0.6
Low	26.8	24.3	−2.5	26.4	−0.43	30.5	27.7	−2.7	28.8	−1.7
Moderate	23.6	21.4	−2.2	24.7	+1.11	17.2	17.9	+0.7	17.3	+0.1
High	23.3	25.8	+2.5	22.7	−0.56	18.3	10.9	−7.4	11.4	−7.0
Very high	9.9	15.5	+5.6	10.2	+0.28	13.5	25.6	+12.2	22.7	+9.2

S_b the basic suitability assessment map, S_{max} the maximum value of suitability assessment, S_{min} the minimum value of suitability assessment. (+) represents the increase of the suitability class area while (−) the decrease

sections. The percentages of these classes, in relation to the entire extent of the study area, for the S_b map are the following: 20.5 % for "very low", 30.5 % for "low", 17.2 % for "moderate", 18.3 % for "high", and 13.5 % for "very high" suitability.

The area of suitability classes for the S_{max} map has changed in relation to those of S_b map. The highest variation occurs in a very high suitability class, which reaches up to 25.6 % of the total area (Table 4). The very low and moderate classes for the S_{max} map have been relatively stable compared to those of S_b map. As in the previous case, the very high suitability class of the S_{min} map has increased to 22.7 % of the area and it shows the highest variation among the other classes (Table 4).

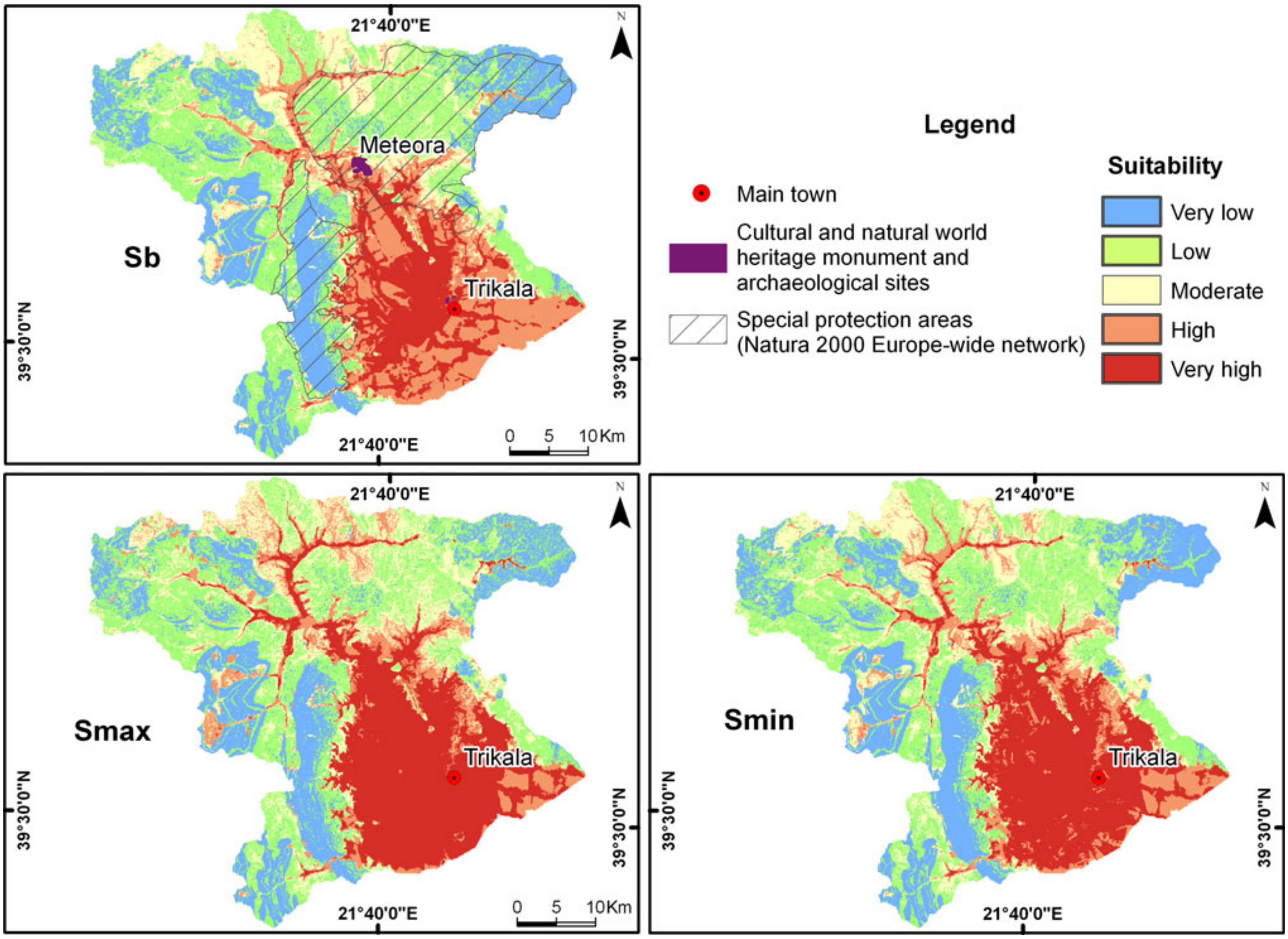

Fig. 7 Potential suitability for agricultural development. S_b the basic suitability assessment, S_{max} the maximum value of suitability assessment, S_{min} the minimum value of suitability assessment

The study area is of great tourist interest, which may contribute to the rural development. Meteora, a Cultural and Natural World Heritage Monument protected by UNESCO, where the unique geomorphology is combined with the Byzantine monasteries (fourteenth century AD), is situated inside the study area. In the Theopetra cave (near Trikala), habitation marks from the Palaeolithic Era (49,000 BP) have been discovered. Furthermore, in the Trikala prefecture, habitation marks from the Neolithic Era (Pelineo, 10,500–3,200 BC) and monuments from the Archaic Era (Asklipiio, 675–480 BC) and the Byzantine Era (900–1,600 AD) have been found. These archaeological findings ascertain the continuous habitation of the plain of Thessaly since the Palaeolithic Era. These sites of interest in combination with the natural beauties of the Trikala prefecture, such as forested and mountainous areas and the special protected areas of the Natura 2000 Europe-wide network, are ideal for light touristic development (winter activities, ecosystem visits, religious and archaeological tourism, and agro-tourism).

Because of the restrictions in land use due to the international conventions and national legislation, there is a limited potential for planning inside this region. Consequently, at these areas, only limited and sustainable development can take place (Figs. 6, 7). For example, there are restrictions regarding engineering and construction (i.e., multi-storey buildings), whereas some activities, such as industrial development, are prohibited.

5 Discussion

The balanced development of the main cities and agricultural districts, especially that of villages, is of great importance to avoid creating enormous urban areas, to conserve the geo-environment, to enhance of the quality of life of inhabitants, and to promote sustainable growth. Villages should obtain the necessary modern infrastructure for the resident population and visitors. The reverse of rural depopulation and the return of the residents from towns to rural areas should be based on and connected to the employment opportunities at these areas and the enhancement of the quality of life (safety, sustainable environment, and infrastructures). This can be accomplished with the improvement and/or development of old and new activities, including agricultural and touristic, that are compatible with the protection of the environment of each area.

In the present work multi-criteria decision analysis and GIS techniques were employed to estimate the suitable sites for rural community and agricultural development. Twelve factors were taken into account as the most influential parameters in the process of suitability assessment. The AHP method was applied to cross-relate the factors and to derive the weights which were subsequently assigned to each one separately. Like other systems analysis techniques, AHP has its limits for application such as the inability to determine the uncertainty (Benke et al. 2009; Chen et al. 2010b). For this reason, the uncertainty produced by changes in factor ranking was estimated using a well known formula of error theory (Eq. 5). Three scenarios were developed to examine the influence of the uncertainty to the suitability assessment results for each land use.

The uncertainty analysis of the proposed methodology showed that the landslide susceptibility has the highest value of the variation of weighting coefficients, while the aspect has the lowest one among all the involved factors for the suitability of rural community development. It follows the order of the original weighting coefficients of every factor (Table 2). For the suitability of agricultural development the water supply is the factor which has the highest value of the variation of weighting coefficient, while the distance from villages the lowest (Table 3). The variation of the weighting coefficients affected the spatial and quantitative distribution of the suitability classes. The highest variation of the percentage area is observed in the very high and moderate suitability classes for rural community development. In the case of suitability assessment for agricultural development the highest variation has occurred in the area of very high class.

Even though the variation of weighting coefficients of the adopted factors has an effect on the suitability classes spatially and quantitatively, the very high zone area derived from the basic suitability both assessment for the both land uses is smaller. So this estimation could be used to evaluate the potential expansion of rural community and agricultural development since the very high and high suitability classes have the highest possibility to be expanded.

Regarding the S_b map of the suitability for the of rural community development, the areas of very high suitability are distributed mostly on the plain, particularly to the SE and to the NNW part of the study area. On the contrary, at the mountainous part of the study area, very few regions of limited area are classified into areas of high and very high suitability. Comparing the location of the existing villages to the proposed areas for development of rural communities, it can be observed that 28 villages and settlements are situated in areas of high and 72 are in areas of very high suitability because they are built in the less vulnerable areas concerning the physical processes. However, 7 villages and settlements are situated in areas of low and 2 in very low suitability. This is because some villages are built in susceptible areas regarding natural hazards. Landslides are a regular phenomenon, especially for the villages of the western part of the study area, whereas some villages on the plain are affected by floods events.

At least two centuries ago, before the Greek Revolution in 1821 and the Independence of Thessaly in 1881 from the Turkish Occupation, the first inhabitants, looking for refuge in the mountainous and less accessible areas, built their residences in the mountainous villages of the study area (Arseniou 2010). Social criteria only were taken into account for choice of their settlement. These villages have recorded high emigration in the last decades (NSSG 2009a, b).

On the other hand, the lowland villages were mainly built close to the drainage network. Therefore, the inhabitants exploited the irrigated cultivable land nearby. In this case, the basic criterion for the inhabitants' installation was the economic factor.

Considering the physical process parameters along with the socio-economic factors during the planning of various land uses, the protection of the environment, the safety of the local population and the quality of human life, are ensured.

Concerning the S_b map of the potential suitability for agricultural development, the areas of high and very high suitability are spotted on the plain regions of the Trikala prefecture. After comparison, it was observed that 76 % of the areas of high and very high suitability zones for agricultural development are already under intensive agriculture.

At these areas, the landslide hazard is at a low level, while the erosion hazard is at a moderate one. Locally, the flood hazard is very high. Although the floods cause serious damage to agricultural production, in the long-term, they have positive effects on soil fertility because new soil, rich in trace elements, is added. On the plain, favourable conditions for cultivation development are present because of the combination of soils, the existence of groundwater reservoirs and low and smooth relief, which are factors that were taken into account during the implementation of the model.

On the other hand, favourable conditions for agricultural development can lead to extensive and intensive agriculture, both of which are able to cause serious environmental problems, such as groundwater over-pumping and the contamination of surface-water, ground water and soil. These factors should be taken into account during the crop type selection, along with crop viability.

The areas of very low and low suitability for agricultural development are observed on the mountainous part of the Trikala prefecture. The intensive morphology, the mountainous relief, and the extensive areas occupied by rocks represent the less favourable conditions for cultivation.

The proposed methodology constitutes an example of the utilisation of geological, geomorphological and socio-economic data in combination with natural hazard maps in the land use suitability assessment procedure. The incorporation of these factors assists decision makers, engineers, policy-makers and planners in the evaluation and the selection of suitable areas for sustainable development, with fundamental concern for the protection of the environment and human life.

6 Conclusions

In this study, the appropriate sites for rural community and agricultural development were selected using a multi-criteria decision analysis and GISs. The development framework was implemented in the Trikala prefecture (Central Greece).

Usually, planners use socio-economic factors for the spatial design. The present study exemplifies an alternative and additional proposal, by incorporating the usage of physical processes in spatial planning. The proposed methodology constitutes an example of the utilisation of geological, geomorphological and socio-economic data in combination with natural hazard maps in the land use suitability assessment procedure.

The uncertainty involved in the method used was determined by introducing an uncertainty in weighting the coefficient of the adopted factors. This uncertainty primarily increased the area of very high suitable locations for both land uses.

The results identified suitable sites for rural community development, where the areas with the highest scores occupy 33.8 % of the studied area. The most suitable areas are observed on the plain, while their appearance is limited in the mountainous part. The comparison between the locations of the existing villages with the proposed suitable sites showed that nine villages are situated in areas of low and very low suitability because many villages are built in susceptible areas regarding natural hazards such as landslides and floods.

For agricultural development, the most suitable locations are found on the plain and cover 31.8 % of the total area. The combination of soils, the existence of groundwater reservoirs and the low and smooth relief are factors that were taken into account during the implementation of the model and present favourable conditions for cultivation development.

Decision makers, engineers, policy-makers and planners may utilise the previously mentioned factors, accompanied by socio-economic parameters, in the evaluation and the selection of suitable areas for sustainable development with fundamental concern for the protection of the environment and the human life.

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