Land Use Suitability Classification for the Actual Agricultural Areas within the Bartın Stream Watershed of Turkey

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Abstract

Suitability classification of the land uses particularly involves the lands' qualification based on their ecological characteristics. Hence, ecological land use serves the sustainable planning objectives which ultimately constitute the fundamentals of environmental landscape planning. Among the diverse land uses, suitable agricultural areas occupy a significant interest not only because of their scarcity but also because of their environmental vulnerability. For this purpose, in this study, the land use suitability classification was performed for the actual agricultural areas within the Bartın stream watershed. The mesoscale watershed that covers approximately 1943 km^2 is located at the Western Black Sea Region of Turkey. The watershed is mountainous with the average slope of 15° and with the altitudes ranging between 20 m and 1735 m asl. The actual agricultural areas cover almost 37% of the watershed and particularly located within the lower altitudinal gradients of the watershed. Based on the slope degree and soil depth parameters, land use suitability classification was conducted for the agricultural areas. Between the slope degrees of 0° and 25°, five categories of slope degree ranges each of which was 5°, were determined. On the other hand, the soil depth parameter was divided into two categories; "moderate deep and deep (50> cm)" and "too shallow and shallow (50< cm)". Merging the digital map values of these two parameters using the GIS (Geographical Information Systems), yielded the 10 classes of land suitability for the agricultural areas. These 10 classes of land suitability for agricultural areas were displayed on the ultimate digitized map. According to the results of this study, only 25% of the agricultural areas were within the first three land suitability classes. However, almost 32% of the agricultural areas were within the last three land suitability classes. Furthermore, these problematic agricultural areas are particularly located at the higher altitudinal gradients within the watershed. These results indicated the significant misuse of the agricultural areas within the watershed. Consequently, re-arrangement of the land use plans and programs should be proposed in order to achieve the sustainable use of the agricultural areas within the watershed. This re-arrangement and re-handling will serve the objectives of landscape planning compatible with the environmental ethics and morality.

Keywords: Environmental land use, suitability classification, agricultural areas, landscape ecology and planning, Bartın stream watershed

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1. Introduction

The use of lands deals with many aspects of natural science including particularly the ecological, hydrological and environmental issues [1]. Hence, the land use is associated with various earth and atmosphere processes involving water [2, 3] and biogeochemical cycles [4], nutrient dynamics [5], soil erosion [6] and land degradation [7], biodiversity [8] and habitat fragmentation [9].

Because of their significant roles on the environment, the land uses must be in accordance with their natural and ecological characteristics [1]. Otherwise, the misuse of lands incompatible with their creation will gradually lead to the degradation of these lands [10]. Frequently, agricultural areas constitute the major land uses together with the forests and settlements [11]. Therefore, they play fundamental role on the environmental processes and dynamics, influencing and being influenced by the overall landscape ecology [12]. In particular, during the recent decades, agricultural areas not only face abandonment but also be exposed to the urbanization and urban sprawl threats. The situation is also valid for the Western Black Sea Region (such as other regions) of Turkey which loses its' farmer population of the villages to the city centers and metropolitans [13]. Furthermore, the region suffers the conversion of agricultural lands to the forests due to the land abandonment [3] and experiences the transformation of agricultural lands to the poplar cultivation [14] and settlements due to the agricultural labor loss. Accordingly, the remaining dwellers of the villages are forced to practice cultivation at some places unsuitable for the agriculture [15].

In order to achieve and sustain comprehensive land use planning, land use suitability classification should especially be applied for the sensitive and vulnerable areas including such as the agricultural lands [16, 17]. Thus, ecological health of the agricultural land will be maintained and a control mechanism for the environment will be supplied. Bartın stream watershed at the Western Black Sea Region of Turkey have encountered the forest spread into the agricultural areas due to the land abandonment at the last few decades in the region [3]. Besides, some of the villagers have converted their agricultural areas close to the town and city centers to the settlements due to finding real estate more lucrative and due to the agricultural labor deficiency. Moreover, agriculture was performed compulsorily in some relatively steep and shallow areas due to the lack of suitable areas around some villages. Consequently, in this study, land use suitability classification was conducted for the actual agricultural areas of the Bartın stream watershed based particularly on the topography and soil physical characteristics. Thereby, the consistencies and inconsistencies within the usage of the actual agricultural lands were tried to be revealed.

2. Material and Method

2.1. Study Area

The mesoscale watershed covers approximately 1943 km^2 at the Western Black Sea Region of Turkey [18] (Figure 1). The watershed is located within the 41°17' and 41°45' northern latitudes and 32°13' and 32°60' eastern longitudes (Figure 1). The altitude of the watershed ranges between 20 and 1735 m asl. [19] whereas the mean altitude is 517 m asl. (Figure 1). Almost 2/3 of the watershed is within the first 600 m asl. altitudinal gradients. About 71% of the rest of the watershed has the altitudinal gradients between 600 m asl. and 900 m asl. The average slope of the watershed is 15°. Almost 10% of the watershed constitutes relatively the plain areas with the average slope of 5°. These plain areas are particularly concentrated at the lowest altitudes of the watershed. There is no definite dominant aspect within the watershed. In other words, the exposure of the watershed is directed evenly towards all aspects.

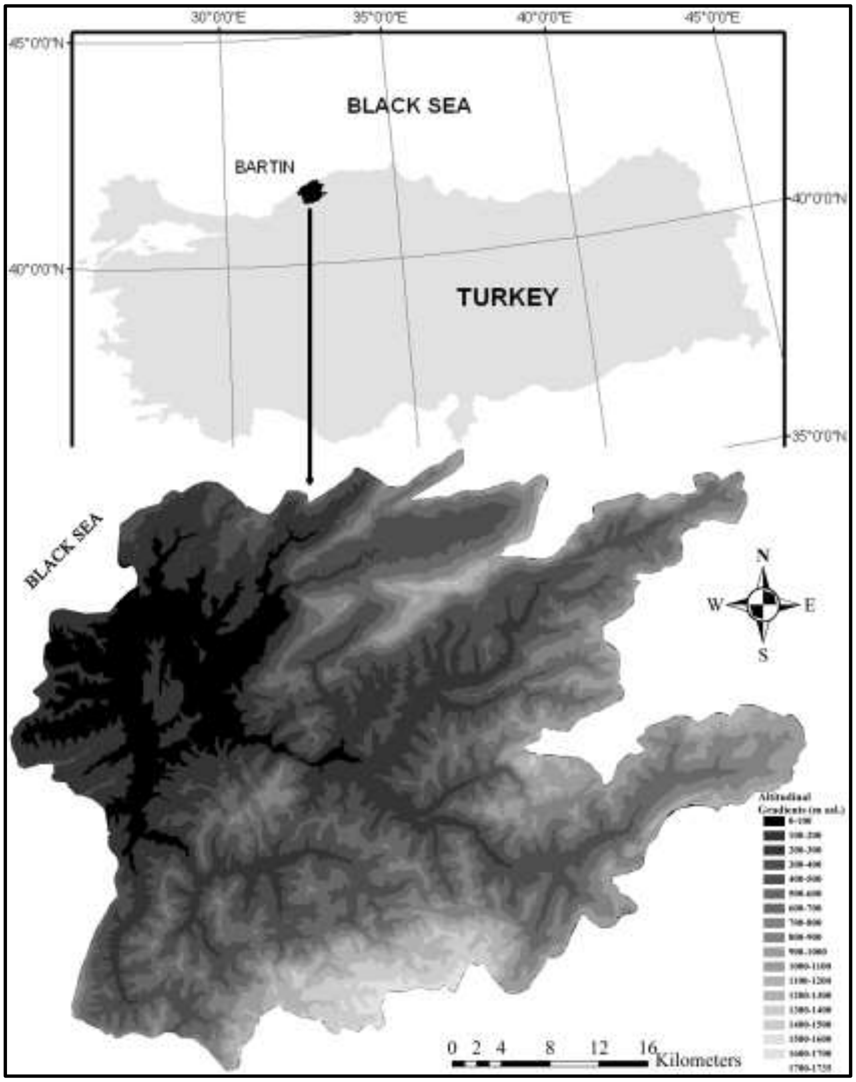

Figure 1. Altitudinal gradients of Bartın stream watershed at Western Black Sea Region of Turkey

The major land uses are the forests, agricultural areas and the settlements respectively. Forests cover almost 58% of the watershed [20]. Approximately 14% of these forests are handicapped [20]. On the other hand, agricultural areas constitute about 37% of the watershed [21, 20]. Urban settlements spread especially at the lower altitudes covering about 2% of the watershed. However, rural settlements exist at the 2% of the watershed in the form of scattered villages. The arable lands that belong to the land capability classes of I, II, and III. intensively occur at the lower parts of the watershed and at the riparian zones of the stream and tributary channels [21]. These areas that belong to the first three land capability classes cover only 10% of the watershed. However, the rest of the lands that belong to the capability classes up to VIII, and that are able to be used for forest, pasture and recreation are particularly located at the higher and mountainous parts of the watershed. Furthermore, more than half of the watershed belong to the land capability class of VII. Brown forest soils and grey-brown podsolic soils [21] have formed on sandstone-mudstone formation in particular [22]. These two soil groups cover approximately 80% of the watershed [21]. The remaining lands are covered by red-yellow podsolic soils, alluvial and colluvial soils respectively [21]. More than half of the watershed has the shallow soils with the depth ranging between 20 cm and 50 cm. Limestones and vulcanite-sedimentary rocks are the second and third major geological formations after the sandstone-mudstone formation within the watershed [22].

According to the 30 years (between 1982 and 2011) of meteorological data based on the measurements of meteorological station in the city center of Bartın Province, the average annual total precipitation is 1033 mm whereas the average annual temperature is 12.6°C [23]. The region drops into the humid mesothermal climate regime [24]. Nominately, October is the wettest month with the 123 mm mean monthly total precipitation. May is the driest month with the 49 mm mean monthly total precipitation [23]. The warmest month is July with the mean monthly temperature of 22.2°C. On the other hand, the coldest month is January with the mean monthly temperature of 4.1°C [23]. Dependent upon the blowing durations, the dominant winds are from western-northwestern and north-northeastern directions where Black Sea is located [23].

Table 1. Based on slope degree ranges and soil depth, land use suitability classification for actual agricultural areas

Slope Degree Ranges	Soil Depth Categories		Suitability Class
0-5°	50> cm	Moderate and Deep	1
0-5°	50< cm	Shallow and Too Shallow	2
5-10°	50> cm	Moderate and Deep	3
5-10°	50< cm	Shallow and Too Shallow	4
10-15°	50> cm	Moderate and Deep	5
10-15°	50< cm	Shallow and Too Shallow	6
15-20°	50> cm	Moderate and Deep	7
15-20°	50< cm	Shallow and Too Shallow	8
20-25°	50> cm	Moderate and Deep	9
20-25°	50< cm	Shallow and Too Shallow	10

2.2. Method

The slope degree and soil depth parameters were referred for the land use suitability analysis of the actual agricultural areas in Bartın stream watershed (Table 1). Although the slope degree extends up to values higher than 30° within the watershed, the areas steeper than 25° were not included into the land use suitability classification. Because, the agricultural areas do not exist at these steeper areas. Initially, the slope degrees between 0° and 25° were categorized into 5° ranges (Figure 2). The areas with 0° to 5° slope were assumed as relatively plane (Table 1). In some places particularly close to the stream and tributary channels, the depth of the soil reaches down to the levels lower than -90 cm (Figure 3). The soil depth was grouped under “impervious (0 cm)”, “too shallow (0-20 cm)”, “shallow (20-50 cm)”, “moderate deep (50-90 cm)” and deep (90+ cm)” (Figure 3). In order to simply incorporate this soil depth parameter into the suitability classification, the "shallow" and "too shallow" soils were categorized together as soils below 50 cm depth whereas "moderate deep" and "deep" soils were categorized together as soils above 50 cm (Table 1).

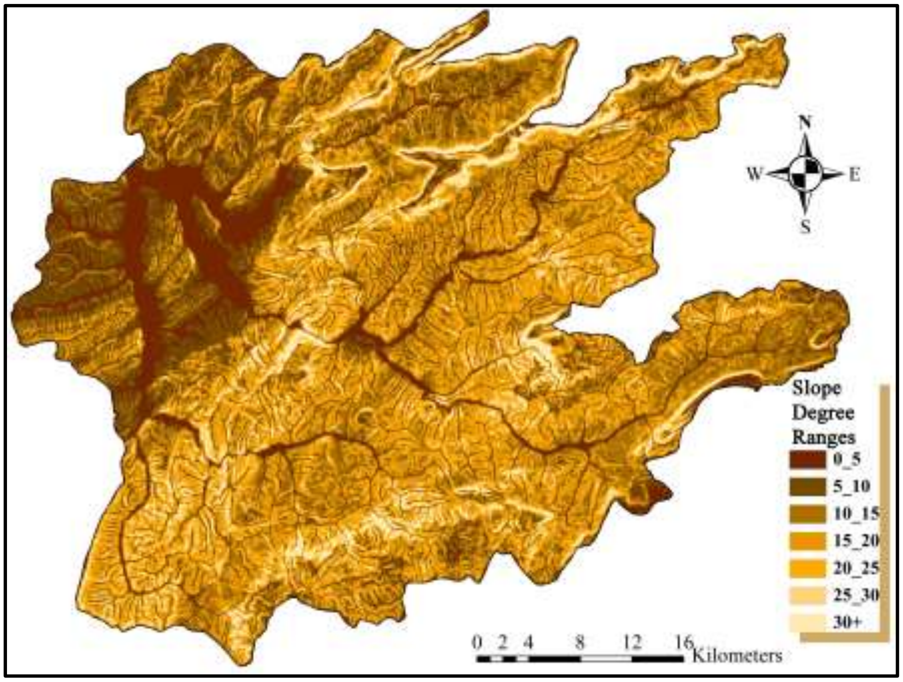

Figure 2. Slope degree ranges within Bartın stream watershed

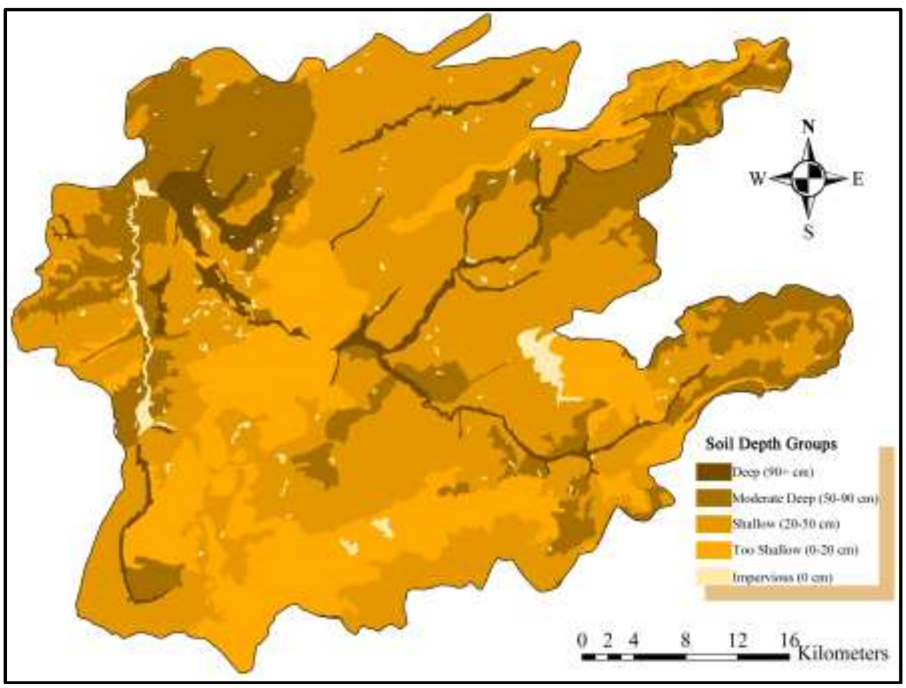

Figure 3. Soil depth groups within Bartın stream watershed

Accordingly, the first two suitability classes represent the relatively plane (0-5° slope) actual agricultural areas with soils above and below 50 cm depths respectively (Table 1). The third and fourth classes represent areas of 5-10° slope and with soils above and below 50 cm respectively (Table 1). The fifth and sixth classes represent areas of 10-15° slope and with soils above and below 50 cm respectively (Table 1). The seventh and eighth classes represent areas of 15-20° slope and with soils above and below 50 cm respectively (Table 1). The ninth and tenth classes represent areas of 20-25° slope and with soils above and below 50 cm respectively (Table 1). Ultimately, the distribution of the ten land use suitability classes for the actual agricultural areas were plotted on the Bartın stream watershed map (Figure 4) which was generated by merging these definite slope degree ranges and soil depth categories via GIS.

3. Results

After delineating the map of land use suitability classes for the actual agricultural areas, the distribution of these classes based on altitudinal gradients was calculated. Almost 11% of the watershed belong to the suitability class of “1”. (Table 2). The cultivated areas are about half of the “1” class for the “2” class agricultural areas which have the similar slope and soil characteristics except the shallower soil depth (Table 2). These “1 and 2” classes of agricultural areas are concentrated intensively on the plains at the lower altitudes of the watershed (Figure 4). These plains have productive and deep alluvium soils. The “3” class agricultural areas where the average slopes are 5° higher than that of the former two classes, constitute almost only 9% of the total actual agricultural areas. These “3” class agricultural areas especially extend to 300 m asl. (Figure 4). The shallower “4” class agricultural areas constitute eighth of the total actual agricultural areas and reach to 500 m asl. in the watershed (Table 2 and Figure 4).

Table 2. According to altitudinal gradients, distribution of land use suitability classes for actual agricultural areas

Altitudinal Gradient (m asl.)	**Land Use Suitability Classes for Actual Agricultural Areas (%)**									
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
20-100	**8.14**	**2.74**	**3.88**	**3.17**		0.86	0.15	0.17	0.04	0.05
100-200	0.78	0.88	**2.27**	**2.80**	**1.27**	**2.73**	0.40	**1.27**	0.12	0.47
200-300	0.82	0.53	**1.06**	**1.53**	**1.07**	**2.54**	0.51	**2.48**	0.14	**1.28**
300-400	0.47	0.38	0.61	**1.24**	0.92	**2.67**	0.70	**3.21**	0.21	**1.88**
400-500	0.33	0.28	0.41	**1.18**	0.82	**2.95**	**1.06**	**3.61**	0.33	**2.08**
500-600	0.14	0.19	0.27	0.88	0.64	**2.77**	0.84	**3.23**	0.28	**2.19**
600-700	0.02	0.18	0.06	0.56	0.38	**2.07**	0.52	**1.97**	0.18	**1.79**
700-800	0.01	0.08	0.06	0.31	0.31	**1.22**	0.32	**1.19**	0.15	**1.34**
800-900	0.01	0.17	0.03	0.44	0.16	0.92	0.19	0.63	0.08	0.75
900-1000	0.02	0.10	0.09	0.23	0.16	0.41	0.08	0.30	0.04	0.43
1000-1100	0.02	0.04	0.06	0.09	0.04	0.07	0.03	0.07	0.01	0.34
1100-1200		0.001	0.001	0.006		0.008		0.016		0.19
1200-1300		0.001		0.007		0.009		0.011		0.06
1300-1400				0.002				0.002		0.01
Total	**10.8**	**5.6**	**8.8**	**12.4**	**5.8**	**19.2**	**4.8**	**18.2**	**1.6**	**12.9**

The "5" class agricultural areas where the average slopes are about 12.5°, constitute almost only 6% of the total actual agricultural areas. The shallower "6" class agricultural areas cover the highest portion of the total actual agricultural areas with about 19% (Table 2). Hence, they reach up to 800 m asl. (Figure 4). The "7" class agricultural areas where the average slopes are about 17.5°, constitute almost only 5% of the total actual agricultural areas. The shallower "8" class agricultural areas cover the second highest portion of the total actual agricultural areas with about 18% (Table 2). Together with "6 and 10" class agricultural areas, they climb up to 800 m asl. (Figure 4). The "9" class agricultural areas where the average slopes are about 22.5°, constitute the lowest portion of the total actual agricultural areas with almost only 2%. The shallower "10" class agricultural areas cover the third highest portion of the total actual agricultural areas with almost 13% (Table 2).

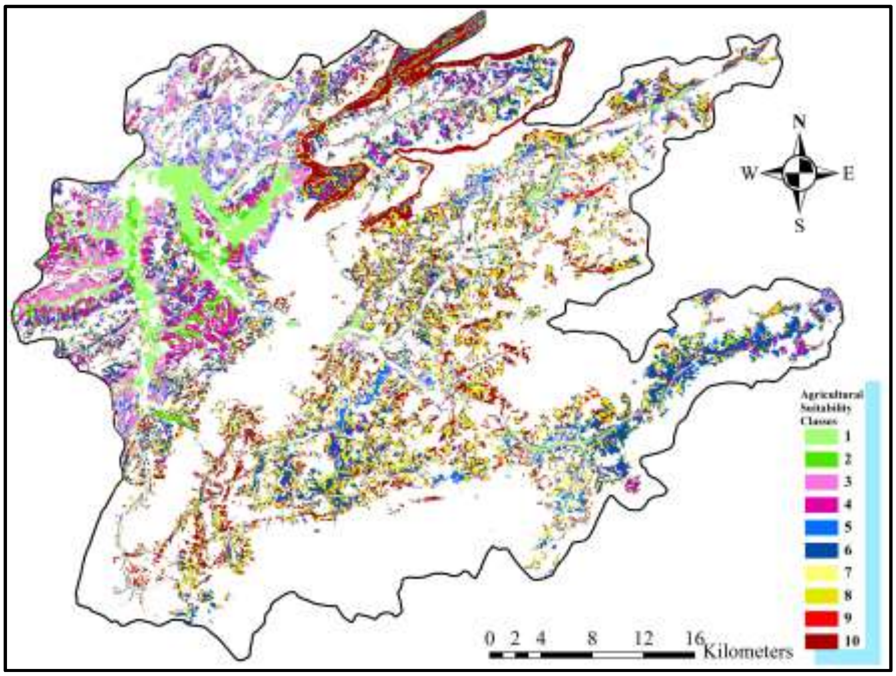

Figure 4. Land use suitability classes for actual agricultural areas within Bartın stream watershed

4. Discussion

According to the results of the land use classification for the actual agricultural areas in the Bartın stream watershed, the lands with slope degrees lower than 10° cover almost only 38% (Table 2 and Figure 4). Yet these lands belong to the first four suitability classes which are relatively more suitable for agriculture compared to the subsequent six classes. The lands of the subsequent six classes that have slope degrees higher than 10°, constitute about 62% of the total actual agricultural areas (Table 2 and Figure 4). The soils of these relatively steep lands; particularly the shallower ones are susceptible to erosion and degradation. Also taming these soils are more difficult compared to the ones at the plains. Bakker et al. [25] emphasized that the increasing slope degree had triggered soil erosion which then had led to decrease in soil depth and consequently to land abandonment.

Moreover, these last six classes of agricultural lands that belong to the suitability classes from "5 to 10" are mostly widespread at the higher altitudes compared to the previous four classes. Such that they intensely occur at the altitudes up to 900 m asl. (Table 2 and Figure 4). Agricultural cultivation is practiced particularly at the lowlands with the lower slope degrees rather than upland. In their study, Gautam et al. [26] indicated that the agricultural areas at the lowland had been more susceptible to settlement expansion whereas upland agriculture had been susceptible to forest vegetation invasion. The agricultural areas that belong to the last two land suitability classes (9 and 10) have steep slopes higher than 20° which severely threaten the stability of the soil. These lands constitute considerable portion of the total actual agricultural areas with 14% most of which has "shallow" and "too shallow" soils.

Despite agriculture was practiced at the problematic lands at the higher altitudinal gradients with high slope degrees and shallow depths, the lands at the lower altitudinal gradients with relatively plain, productive and deep soils are sealed by settlements. Furthermore, these soils sealed by buildings pertain to the first three land capability classes. According to Öztürk et al. [27], about 37% of all the housing in the watershed have been settled on these productive and deep soils pertaining to I., II., and III. land capability classes.

Conclusion

Even though the referred slope degree and soil depth parameters significantly serve the construction of land use suitability classification for the actual agricultural areas, more advanced classification supported by multiple other components will be essential for the watershed. These components should involve geological, topographical, hydrological ecological, meteorological, environmental and management parameters [28]. In consequence of the integrated analysis of these parameters, a comprehensive land use suitability classification will build up fundamentals in order to achieve sustainable landscape planning.

Due to the settlements constructed on the productive and deep alluvial soils particularly at the lower altitudinal gradients of the watershed, the agricultural areas lost a potential to expand on. Beyond that, current development and sprawl of the town and city centers over the actual productive soils, pose considerable threat and handicap for the sustainable agriculture. Besides, such that urban sprawl may trigger possible silent climate change which directly or indirectly would threaten agricultural biodiversity. Alteration in the agricultural crop ranges may lead to leave the existing cultivated area which ultimately put pressure on other natural and reserved areas [29].

Because of the more frequent human intervene, agricultural areas are very sensitive and vulnerable landscapes prone to the anthropogenic disturbances rather than forests and natural reserves. Therefore, they require exclusive attention and protection against external constraints. For this purpose, an environmental land use model that is established on ecological basis and that inquire spatial and temporal dynamics can project and serve for the respond to the unplanned urbanization, flood disaster and climate change impacts on the agricultural areas of the Bartın stream watershed.

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