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Natural Disaster Risk Assessments for Pine Honey Apiaries in Muğla, Turkey

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Abstract

Since Muğla province has 90% of the world's total pine honey production, ensuring efficiency and economic income requires the determination of measures for apiary locations and estimation of risks. However, ensuring development and productivity requires identifying natural disasters susceptibility such as forest fires and floods to maintain productivity. Muğla province has a high forest fire potential due to its dense forest cover and approximately 200 forest fires occur each year. Forest fires are one of the main factors that threaten apiaries, as there are a lot of apiary places (approximately 15,000) in forests for pine honey. On the other hand, due to the mountainous topography and high precipitation rate of Muğla, the province has a high rate of flood formation (20 per year), which threatens the hive sites by destroying the entire colony. In this study, Apiary Locations Risk Index (ALRI) was carried out to guide the insurance process for apiary locations by applying the Forest Fire Risk Index (FFRI) and the Flood Hazard Risk Index (FHRI). Determination of forest fire risk zones and flood hazard maps requires environmental, forestry, topographic, economic and meteorological parameters to be handled within a decision support platform. For this purpose, Analytical Hierarchy Process (AHP) technique supported by Geographic Information System (GIS) was used in the creation of sensitivity maps. As a result, 1533.40 ha (11.82%) of the study area was determined as extremely risky areas for apiary areas. The results were confirmed with 1454 forest fire sites and 20 flood hazard sites where the Eşen, Dalaman, Çine, Sarıçay, Akçay, Kamiişdere and Namnam rivers were stated to be highly susceptible to flood hazard.

Keywords
Forest Fire, Flood Hazard, Analytical Hierarchy Process, Site Suitability, Apiary

Türkiye Muğla İlindeki Çam Balı Arılıkları için Doğal Afet Riskinin Değerlendirilmesi

Özet

Muğla ili dünya toplam çam balı üretiminin %90'ına sahip olduğu için verimliliğin sağlanması, arılık lokasyonları için önlemlerin belirlenmesi ve risklerin önceden tahmin edilmesini gerektirmektedir. Orman yangını ve sel gibi doğal afetlerin önceden tahmin edilmesi, verimliliğin sürdürülmesinde ve ekonomik kayıpların tahmin edilmesinde hayati öneme sahiptir. Muğla ili, yoğun orman örtüsü nedeniyle yüksek bir orman yangını potansiyeline sahiptir ve her yıl yaklaşık 200 orman yangını meydana gelmektedir. Çam balı için ormanlarda yüksek miktarda (yaklaşık 15.000) arılık yeri bulunduğundan, orman yangınları arılıkları tehdit eden ana faktörlerden biridir. Öte yandan, ilde tüm koloniyi yok ederek arı kovanı yerlerini tehdit eden yüksek sel oluşum oranı (yılda 20 adet) bulunmaktadır. Bu çalışmada, Orman Yangını Risk İndeksi (FFRI) ve Taşkın Tehlike Risk İndeksi (FHRI) uygulanarak, arılık lokasyonları için sigorta sürecine rehberlik edecek Arılık Lokasyonları Risk İndeksi (ALRI) gerçekleştirilmiştir. Sonuç olarak, çalışma alanının 1533.40 ha (%11.82)'si arılık yerleri için aşırı riskli bölgeler olarak belirlenmiştir. Sonuçlar 1454 orman yangın yeri ve Eşen, Dalaman, Sarıçay, Akçay, Kamiişdere ve Namnam nehirlerinin sel tehlikesine yüksek derecede duyarlı olduğu belirtilen 20 taşkın tehlikesi yeri ile doğrulanmıştır.

Anahtar Sözcükler
Orman Yangınları, Sel Felaketi, Analitik Hiyerarşi Yöntemi, Uygunluk Analizi, Arıcılık

1. Introduction

Beekeeping activities are an indicator of economic development thanks to the derived products and pollinator role in agricultural crops (Estoque and Murayama 2010; 2011; Damián 2016). Approximately 33% of the agricultural crops pollination has been realized by honeybees which refer to an invisible economic income due to the increased yield of crops (Maris et al. 2008; Oldroyd and Nanork 2009). Considering the intensive agricultural activities and rich flora of Turkey, it provides a suitable environment for beekeeping activities. Moreover, 90% of the total pine honey production all around world is produced endemically in Muğla province which refers a significant national export (Miguel et al. 2014).

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On the other hand, Muğla province has high forest fire occurrence rate due to the intensive forest cover and warm climate. Additionally, Muğla province has high precipitation rate and this leads to flood hazards in several river basins which come from through high mountains to coasts. Thus, Muğla has high potential forest fires and flood hazards occurrence rates and according to the statistics (URL-1 2019), over 200 forest fires have been occurred annually which destroys approximately 500 ha forest cover and 20 flood hazards have been revealed that damages to agricultural lands. Considering 15,000 apiary locations that are located in forestry and mountainous zones for pine honey production, forest fires and flood hazards are the most important natural hazards which threaten the apiary locations.

One of the most effective ways to achieve reliable and accurate risk predicting is Geographical Information System (GIS) aided Multi Criteria Decision Analysis (MCDA) techniques approach to provide effective solutions to the complex structure of the forest fire and flood hazard susceptibilities. In MCDA concept, Analytic Hierarchy Process (AHP) is the most applied method which provides weighting each criterion via comparing them against to each other (Saaty 1977, 1980, 1994, 2001; Saaty and Vargas 1991). The AHP method includes determining the solutions within complex structure of real problems by providing a selection and assigning the importance to each criterion (Arentze and Timmermans 2000) via pairwise preference matrix (Chen et al. 2010). In recent years, a large number of MCDA methods such as AHP, ANP, COPRAS, ELECTRE, PROMETHEE, MOORA, TOPSIS, VIKOR, MABAC, MARCOS, etc. have been proposed and used to solve various problems. All the MCDA techniques have advantages and inadequacies in terms of ranking calculation and accuracy of results (Seyed and Alireza 2017). Deciding the best MCDA technique is very hard process to handle and usually differs according to the selected problem. Thus, more than one MCDA technique usage is suggested to reveal more reliable results of given problems (Løken 2007; Jahan et al. 2012; Mulliner et al. 2016; Wang et al. 2016; Seyed and Alireza 2017). In this study, only AHP method was used to determine the risk maps due to the multiple criteria existence and their different contribution value to the risk maps.

The recent studies include different criteria in the field of environmental, topographic, climatic and socio-economic and a large amount of methods to generate susceptibility maps. Although forest fire and flood hazard susceptibility are different phonema, the criteria that affect the susceptibility are quite similar to each other. Generating realistic forest fire risk maps require considering all the factors that affect the ignition risk and spread of the fire via GIS aided functions (Jaiswal et al. 2002; Chuvieco et al. 2010; Adab et al. 2013; Hernandez et al. 2006; Puri et al. 2011; Ajin et al. 2016; Pourghasemi 2016) and integration of MCDA methods (AHP) (Iwan et al. 2004; Vadrevu et al. 2010; Eugenio et al. 2016; Suryabhagavan et al. 2016; Güngöroğlu 2017; You et al. 2017) to improve prevention and prediction procedures. For flood hazards, GIS also used to provide useful information about the flood characteristics for flood risk assessment (Zhou et al. 2000; Liu et al. 2008; Wang et al. 2011; Haq et al. 2012; Pradhan et al. 2014) and MCDA techniques (Tkach and Simonovic 1997; Wang et al. 2002; Zhang et al. 2002; Thinh and Vogel 2006; Sinha et al. 2008; Wang et al. 2011; Zou et al. 2013). However, risk evaluation for apiary locations requires considering both forest fire and flood hazard risk together and the result will give valuable information about the safety of apiary locations. Thus, in this study, an Apiary Locations Risk Index (ALRI) value was realized to predict the risk rate of apiary locations by integrating forest fire and flood hazard susceptibility values which will be mentioned as Forest Fire Risk Index (FFRI) and Flood Hazard Risk Index (FHRI). 17 criteria for forest fire and 16 criteria for flood hazard susceptibility were used to determine the FFRI and FHRI separately and results are overlapped to generate ALRI for Muğla province to be able to guide insurance procedures for apiary locations.

2. Material and Methods

Generating ALRI involves determining FFRI and FHRI which requires considering all the parameters that have an effect on both forest fire and flood hazard in the field of topographic, environmental, climatic and economic factors. For the purpose of determining realistic ALRI, all the factors should be considered as much as possible and critical intervals or threshold values should be specified both for forest fire and flood hazard. Moreover, the weights of the criteria should be calculated by AHP method considering the general aspects and recent studies to increase the reliability of risk index values. At this point, the preference values in pairwise comparison matrix should be specified carefully. The implementation model of the study is given in Figure 1.

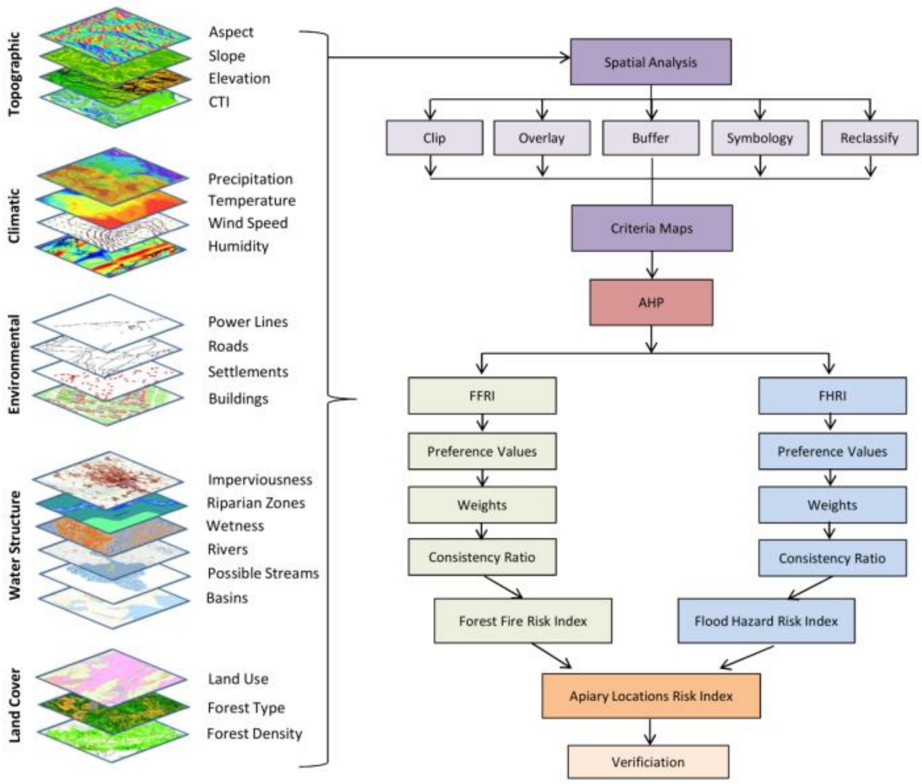

Figure 1: Implementation model of ALRI

2.1. Study Area

The study area is Muğla province is located between 27º 13’ 30’’ and 29º 41’ 00’’ W longitude and 36º 18’ 22’’ and 37º 35’ 10’’ N latitude. Muğla has vital importance thanks to the pine honey apiaries (90% of the world total production) which are located in forests. Because Muğla has high mountains and intensive forest cover, the region is quite prone to forest fires and flood hazards. The climate of Muğla is classified as warm and the rain in Muğla falls mostly in the winter, with relatively little rain in the summer with average 1200-1400 mm (URL-2 2019). The study area is given in Figure 2.

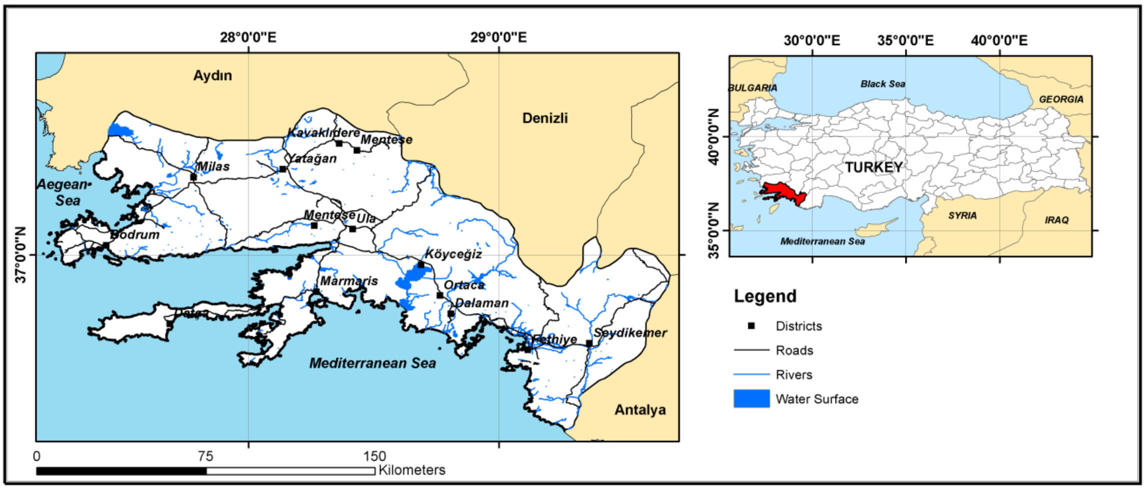

Figure 2: Study area Muğla province location

2.2. Criteria Selection

For the purpose of generating FFRI and FHRI maps accurately, all the factors should be considered which have effect on forest fire and flood hazards. Thus, topographic, environmental, climatic and economic factors should be involved in susceptibility map generation.

2.2.1. Topographic Criteria

Elevation (EL), Aspect (AS), Slope (SL) and Compound Topographic Index (CTI) criteria were included in topographic criteria category that has effect on environmental and meteorological conditions of the region. Humidity, temperature and wind are related to the elevation which define the dryness of the organic materials and increase the ignition chance (Rothermel 1983; Suryabhagavan et al. 2016). Flood hazard occurrence is also related to the elevation where lower elevations are quite prone to flood than higher elevations (Elkhrachy 2015). Slope defines the forest fire characteristics such as direction of the fire spread and preheating. When evaluating the forest fire spread, it tends to move and spread faster towards uphill than moving downhill (Rothermel 1983; Kushla and Ripple 1997). Slope defines the direction, accumulation and speed of flood because floods are tending to move faster in sloping areas (Bapalu and Sinha 2005). Aspect criterion is related to the sunlight exposure of land and also with the temperature and humidity. Because northern faces of the forests exposures to the sun less than southern faces, northern faces are less prone to forest fire due to the shortest exposure time. Thus, organic matters and soil tend to dry earlier in southern faces of the forests (Jose 2012). Floods are tending to occur in southern faces of high mountains due to the melting of snows earlier than Northern faces. CTI is an indicator of the wetness of the soil (Moore et al. 1991) which indicates the possibility of the wetness (Eq. 1).

$$CTI = \ln\left(\frac{As}{\tan\beta}\right) \quad (1)$$

Where As is catchment area in m2 unit and β is the slope in radian unit (Gessler et al. 1995). While higher values represent high potential soil moisture, lower values represent firstly dry up soils which are less prone to forest fire and highly prone to floods. The topographic criteria maps are given in Figure 3.

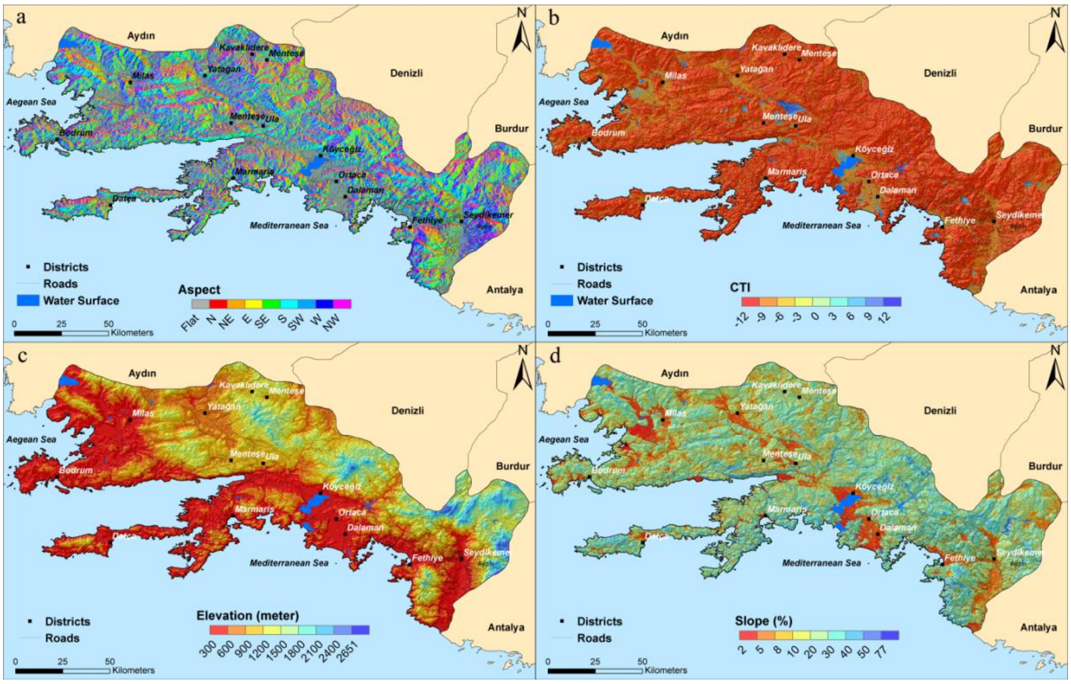

Figure 3: a) Aspect, b) CTI, c) elevation d) slope criteria maps

2.2.2. Environmental Criteria

Roads (RD), Settlements (ST), Buildings (BL) and Power lines (PL) were included in environmental criteria category which involves direct effect on forest fire and indirect effect on flood risk via manmade objects. The roads are quite prone to forest fire because of carelessly thrown objects such as bottles and cigarettes which lead forest fires very frequently (Suryabhagavan et al. 2016). The zones close to the settlements and buildings are also fire prone due to the intensive human activities and traffic movements. One of the main reasons of forest fires is contact of high voltage power lines with tree branches or any other materials which can cause arcing and ignite dry materials (Mitchell 2013). The environmental criteria maps are given in Figure 4. These data were retrieved from Open Street Map database in vector format which are belong to 2019.

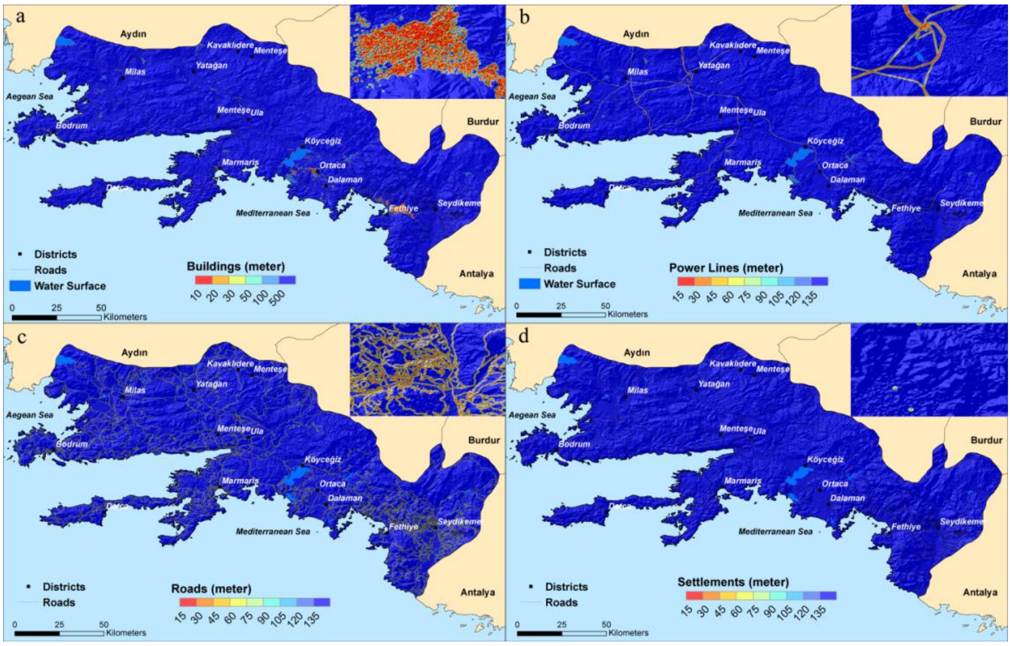

Figure 4: a) Buildings, b) power lines, c) roads d) settlements criteria maps

2.2.3. Climatic Criteria

Temperature (TM), Humidity (HM), Wind (WD) and Precipitation (PR) criteria were included in climatic criteria category and refer to the wetness of soils and fuel types which define the ignition risk (Bonora et al. 2013). Conversely, flood hazards do not occur in high temperature because of evaporation. Because higher temperature leads to faster dry up fuel types, drier climate increase the forest fire potential (Sun et al. 2014; Amraoui et al. 2015) and make fuels highly susceptible. Precipitation criterion is an indicator for humidity and water balance of forest (Vadrevu et al. 2010; Bonora et al. 2013) and one of the main indicators for flood occurrence (Elkhrachy 2015). Humidity is an indirect criterion which indicates the wetness of fuels and cumulative of water in basins. Climatic criteria maps are given in Figure 5. The climatic parameter data were retrieved from Turkish State Meteorological Service Institute records for 2019 average observations. In total, 16 station observations were used to generate the distribution maps of each variable.

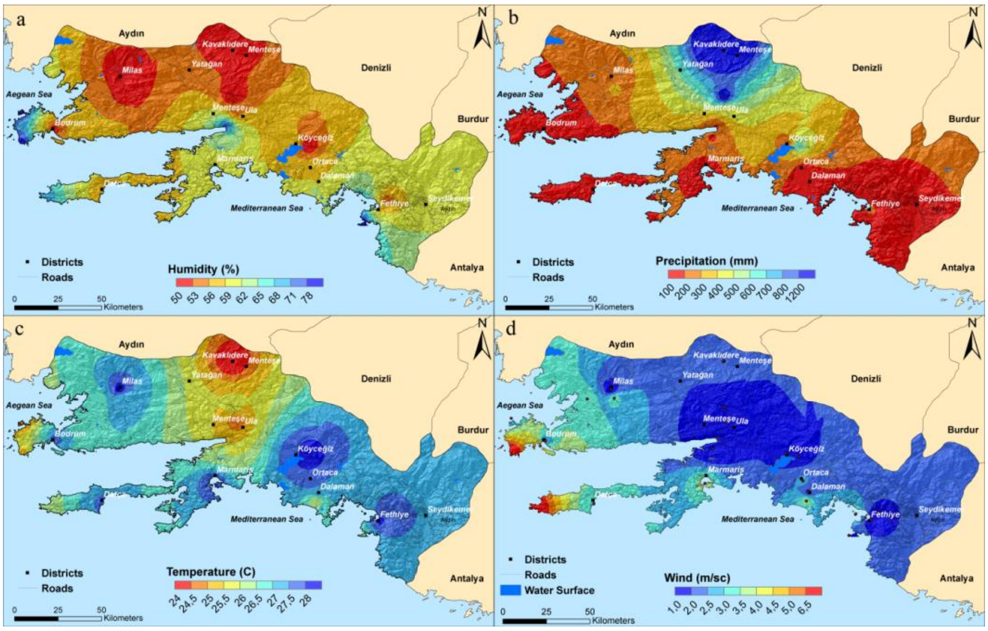

Figure 5: a) Humidity, b) precipitation, c) temperature d) wind criteria maps

2.2.4. Water Structure Criteria

Riparian zones (RZ), Wetness (WT), Imperviousness (IM), Possible Streams (PS) and Rivers (RV) were included in water structure criteria category. Although water structure criteria are the main decisive factors for flood hazards, the wetness of soil, organic matters and fuel types are related to these criteria which decrease the ignition risk. Riparian zones criterion refers to the high potential flood basins and low potential of forest fire risk. Wetness criterion includes both temporary and permanent water and wet zones which have high potential of flood risk and low potential of forest fire. Imperviousness criterion involves the potential water accumulation zones to decide the wetness and water flow directions. Possible streams were calculated via hydrology tools and include possible streams that will be revealed after rain. The river criterion involves existing water surfaces and water ways which is one of the most important criteria for flood risk. Water structure criteria are given in Figure 6. These variables were retrieved from COPERNICUS land cover project database in raster format which are belong to 2018 year. Basin and Streams variable maps were generated by using Hydrology tools in ArcGIS software using 30 x 30 meters resolution ASTER GDEM data.

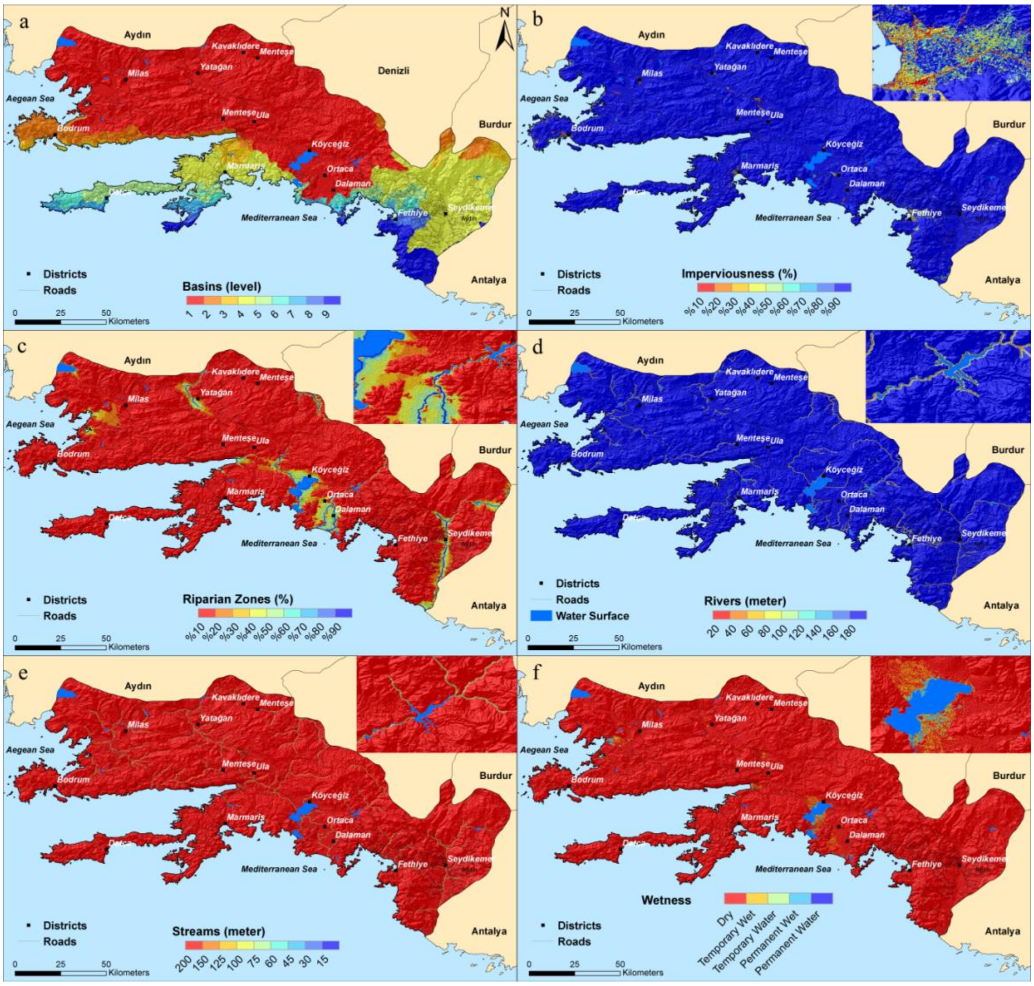

Figure 6: a) Basins, b) imperviousness, c) riparian zones d) rivers e) streams f) wetness criteria maps

2.2.5. Land Cover Criteria

Land Use (LU), Forest Density (FD) and Forest Types (FT) criteria are main decisive factors which have greatest influence on ignition risk. Shrub species and flammable vegetation types have increasing effect on forest fire risk (Güngöroğlu 2017). Densely vegetated and dry land covers have high forest fire potential comparing to moist and sparsely vegetated areas (Ajin et al. 2016). On the other hand, the types of the forests have different forest fire potential due to the fuel type (Huyen and Tuan 2008). On the other hand, forest density and land use have importance effect on flood occurrence due to the different characteristics of the land surfaces (Alexakis et al. 2014). Floods tend to be occurred on non-forest lands and bare lands because trees or land cover does not block the flow of water. Land cover criteria maps are given in Figure 7. These variables were retrieved from COPERNICUS land cover project database in raster format at 20 x 20 meters resolution.

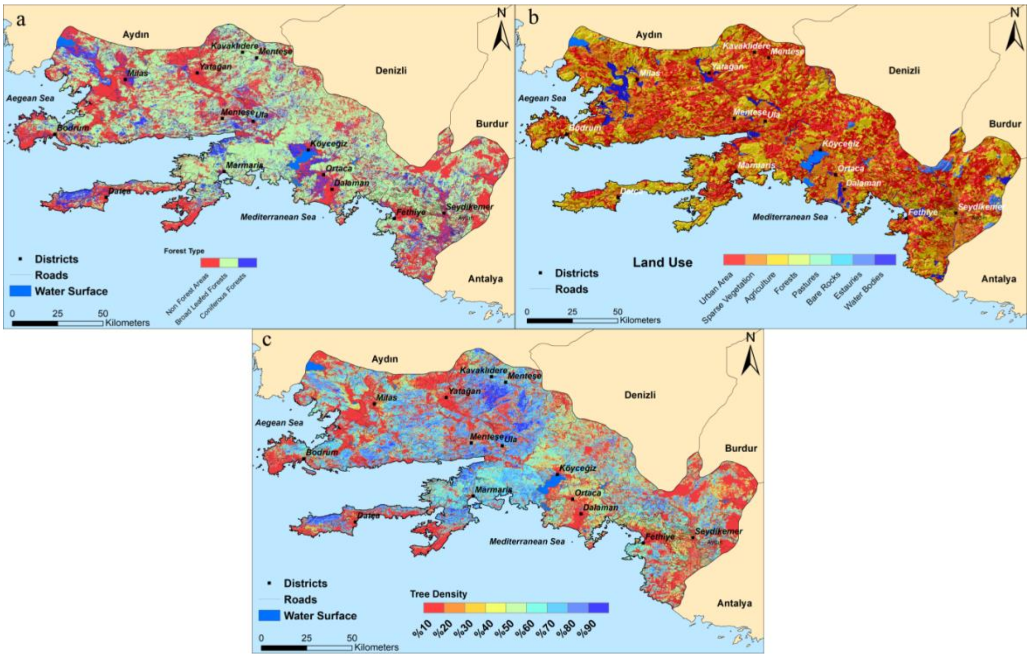

Figure 7: a) Forest type, b) land use, c) tree density criteria maps

2.3. Analytical Hierarchy Process (AHP)

The AHP method proposed by (Saaty 1977, 1980) which scales the importance of each criterion, from 1 to 9 relatively (1=Equal, 3=Moderately, 5=Strongly, 7=Very, 9=Extremely). The (a_{nn}) importance scales of each criterion involved in pairwise comparison matrix (Eq.2).

A	Criteria 1	Criteria 2	Criteria 3	…	Criteria n
Criteria 1	a_{11}	a_{12}	a_{13}	…	a_{1n}
Criteria 2	a_{21}	a_{22}	a_{23}	…	a_{2n}
…	…	…	…	…	…
Criteria n	a_{n1}	a_{n2}	a_{n3}	…	a_{nn}

(2)

Normalized matrix was determined by division of each (a_{nn}) to sum of the its own column (Eq.3).

$$a^1_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{3}$$

The average sum refers to the weights of each criterion (Eq. 4).

$$w_i = \left(\frac{1}{n}\right) \sum_{i=1}^{n} a'_{ij}\,, \;\; (i, j = 1,2,3, \ldots., n) \tag{4}$$

A consistency calculation is proposed by Saaty (1994) to decide the whether weight calculation is consistent or not. For this purpose, Consistency Index *(CI)* is used to determine the coefficient of the pairwise comparison matrix (Eq.5).

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{5}$$

CI calculation required the λ_{max} (eigen value) and Rand5om Index *(RI)* value according to the matrix order (1,59 in this study).

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \left[\frac{\sum_{j=1}^{n} a_{ij} w_j}{w_i}\right] \tag{6}$$

Consistency ratio *(CR)* is an indicator of the consistency of the calculation (Eq.7). If *CR* exceeds 0.1, based on expert knowledge and experience (Saaty and Vargas 1991), recommended a revision of the pairwise comparison matrix with different values (Saaty 1980).

$$CR = \frac{CI}{RI} \quad (7)$$

3. Generating Apiary Locations Risk Index (ALRI)

Generating ALRI requires calculating FFRI and FHRI and determining the weights of each criterion which represents the contribution rate of criterion to susceptibility separately. Then generated maps will be overlapped to calculate ALRI value as a weighted sum of FFRI and FHRI maps for Muğla province. Criteria weights were calculated with a pairwise matrix via AHP by comparing the importance of each criterion to another. The weight calculations were started with assigning Saaty from 1 to 9 preference scales to criterion classes. While 9 represent the high potential forest fire and flood hazard risk, 1 represents the non-potential areas. The criteria classifications and preference values are given in Table 1 and 2.

Table 1: Preference values for flood hazard susceptibility map

Criterion	Unit	Low risk			Moderately			High Risk		
		1	2	3	4	5	6	7	8	9
Elevation	**Meter**	0	100	300	500	1000	1500	2000	2500	2500 <
Slope	**%**	0	5	10	15	20	25	30	40	50
CTI	**Class**	-12	-9	-6	-3	0	3	6	9	12 <
Roads	**Meter**	120 <	105	90	75	60	45	30	15	0
Buildings	**Meter**	80 <	70	60	50	40	30	20	10	0
Temperature	**C^{O}**	25	25,5	26	26,5	27	27,5	28	28,5	29 <
Humidity	**%**	74 <	74	70	66	62	58	54	50	46
Precipitation	**Mm/m^2**	1800	1600	1400	1200	1000	800	600	400	200
Basins	**Class**	9	8	7	6	5	4	3	2	1
Riparian Zones	**%**	>10	20	30	40	50	60	70	80	90 <
Wetness	**%**	>10	20	30	40	50	60	70	80	90 <
Imperviousness	**%**	>90	80	70	60	50	40	30	20	10 <
Possible Streams	**Class**	120 <	105	90	75	60	45	30	15	0
Rivers	**Class**	120 <	105	90	75	60	45	30	15	0
Land Use	**Class**	Urban	-	Forests	-	Agriculture	-	Mountain	-	Water Bodies
Forest Density	**%**	>90	80	70	60	50	40	30	20	10 <

Table 2: Preference values for forest fire susceptibility map

Criterion	Unit	Low risk			Moderately			High Risk		
		1	2	3	4	5	6	7	8	9
Aspect	**Class**	N	NW	NE	W	Flat	E	SW	SE	S
Elevation	**Meter**	0	100	300	500	1000	1500	2000	2500	2500 <
Slope	**%**	0	5	10	15	20	25	30	40	50
CTI	**Class**	-12	-9	-6	-3	0	3	6	9	12 <
Roads	**Meter**	120 <	105	90	75	60	45	30	15	0
Settlements	**Meter**	120 <	105	90	75	60	45	30	15	0
Buildings	**Meter**	80 <	70	60	50	40	30	20	10	0
Power Lines	**Meter**	120 <	105	90	75	60	45	30	15	0
Temperature	**C^{O}**	25	25,5	26	26,5	27	27,5	28	28,5	29 <
Humidity	**%**	74 <	74	70	66	62	58	54	50	46
Wind Speed	**m/sn**	2 >	2,5	3	3,5	4	4,5	5	5,5	6,5
Precipitation	**Mm/m^2**	1800	1600	1400	1200	1000	800	600	400	200
Wetness	**%**	>90	80	70	60	50	40	30	20	10 <
Rivers	**Meter**	0	15	30	45	60	75	90	105	120 <
Land Use	**Class**	Water Bodies	-	Bare Lands	-	Urban	-	Agriculture	-	Forests
Forest Type	**%**	Non-Forest	-	-	-	Mixed	-	Broad Leaved	-	Coniferous
Forest Density	**%**	< 10	20	30	40	50	60	70	80	90 <

The preference values should be given carefully by considering the threshold values, general aspects and researches in the past. While riparian zones, rivers and land use are the main criteria for flood hazard; power lines, forest density and slope are the most effective criteria which should have higher weights. The preference matrices and calculated weights are given in Table 3 and 4. The consistency index was calculated as 0,078 for FHRI and 0,043 for FFRI which indicate the weight calculations are consistent. The sum of the weights must be equal to 1.

Table 3: Criteria weights for flood hazard susceptibility map

Criteria	EL	SL	CTI	RD	BL	TM	HM	PR	BS	RZ	WT	IM	PS	RV	LU	FD	Weight
EL	**1**	1,5	3	2,1	3	3	3	2,1	1,4	0,2	1,5	1,5	0,7	0,9	1,5	1,5	**0,08**
SL		**1**	2	1,5	2	2	2	1,5	1,2	0,3	1,1	1,1	0,5	0,6	1	1	**0,08**
CTI			**1**	0,9	1	1	1	0,9	0,7	0,2	0,7	0,7	0,3	0,3	0,5	0,5	**0,05**
RD				**1**	1,1	1,1	1,1	1	0,9	0,2	0,9	0,9	0,3	0,3	0,6	0,6	**0,03**
BL					**1**	1	1	0,9	0,7	0,2	0,7	0,7	0,3	0,3	0,5	0,5	**0,03**
TM						**1**	1	0,9	0,7	0,2	0,7	0,7	0,3	0,3	0,5	0,5	**0,03**
HM							**1**	0,9	0,7	0,2	0,7	0,7	0,3	0,3	0,5	0,5	**0,03**
PR								**1**	0,9	0,2	0,9	0,9	0,3	0,3	0,6	0,6	**0,03**
BS									**1**	0,3	1	1	0,5	0,5	0,9	0,9	**0,03**
RZ										**1**	3	3	1,2	1,7	3	3	**0,17**
WT											**1**	1	0,5	0,5	0,9	0,9	**0,05**
IM												**1**	0,5	0,5	0,9	0,9	**0,05**
PS													**1**	1,1	2	2	**0,05**
RV														**1**	1,4	1,4	**0,11**
LU															**1**	1	**0,10**
FD																**1**	**0,06**

Table 4: Criteria weights for forest fire susceptibility map

	AS	EL	SL	CTI	RD	ST	BL	PL	TM	HM	WD	PR	WT	RV	LU	FD	FT	Weight
AS	**1**	0,6	0,5	0,7	1	1,3	1,3	0,5	0,6	1	1,3	0,7	0,7	0,6	0,7	0,2	0,6	**0,04**
EL		**1**	0,9	1,1	1,6	2,1	2,1	0,9	1	1,6	2,1	1,1	1,1	1	1,1	0,6	1	**0,07**
SL			**1**	1,4	2	2,2	2,2	1	1,1	2	2,2	1,4	1,4	1,1	1,4	0,7	1,1	**0,07**
CTI				**1**	1,5	2	2	0,8	0,9	1,5	2	1	1	0,9	1	0,3	0,9	**0,06**
RD					**1**	1,1	1,1	0,5	1,4	1	1,1	0,6	0,6	0,6	0,5	0,3	0,6	**0,04**
ST						**1**	1	0,3	0,4	0,9	1	0,5	0,5	0,4	0,5	0,3	0,3	**0,03**
BL							**1**	0,3	0,4	0,9	1	0,5	0,5	0,4	0,5	0,3	0,3	**0,03**
PL								**1**	1,1	2	2,2	1,4	1,4	1,1	1,4	0,7	1,1	**0,08**
TM									**1**	1,6	2,1	1,1	1,1	1	1,1	0,6	1	**0,06**
HM										**1**	1,3	0,7	0,7	0,6	0,7	0,2	0,6	**0,03**
WD											**1**	0,5	0,5	0,4	0,5	0,3	0,3	**0,03**
PR												**1**	1	0,9	1	0,3	0,9	**0,05**
WT													**1**	0,9	1	0,3	0,9	**0,05**
RV														**1**	1,1	0,6	1	**0,07**
LU															**1**	0,6	0,9	**0,06**
FD																**1**	1,7	**0,12**
FT																	**1**	**0,07**

Calculated weights were used to generate FFRI and FHRI maps by multiplying each pixel value of all criteria with weights via Equation 8.

$$\boldsymbol{FHRI} = \sum_{i=1}^{n} w_i\,.r_i = W_{EL}.EL + W_{SL}.SL + W_{CTI}.CTI + W_{RD}.RD + W_{BL}.BL + W_{TM}.TM + W_{HM}.HM + W_{PR}.PR + W_{BS}.BS + W_{RZ}.RZ + W_{WT}.WT + W_{IM}.IM + W_{PS}.PS + W_{RV}.RV + W_{LU}.LU + W_{FD}.FD \quad (8)$$
$$\boldsymbol{FFRI} = \sum_{i=1}^{n} w_i\,.r_i = W_{AS}.AS + W_{EL}.EL + W_{SL}.SL + W_{CTI}.CTI + W_{RD}.RD + W_{ST}.ST + W_{PL}.PL + W_{TM}.TM + W_{HM}.HM + W_{WD}.WD + W_{PR}.PR + W_{WT}.WT + W_{RV}.RV + W_{LU}.LU + W_{FD}.FD + W_{FT}.FT$$

Although FFRI and FHRI can be used separately for susceptibilities, apiary locations could be threatened by forest fire or flood hazard together. Thus, ALRI should include both risk values to represent the reliable and accurate risk zones for apiary locations. For this purpose, instead of using FFRI and FHRI separately when locating apiaries, the spatial sum should be generated with Equation 9.

$$ALRI = FFRI + FHRI \quad (9)$$

While FFRI and FHRI values are between maximum 9 and minimum 1, the ALRI will be in an interval between maximum 18 and minimum 2 thanks to the sum of two maps. Higher values will represent the existence of forest fire and flood hazard risk together, 7-12 intervals will represent the existence of forest fire or flood hazard risk and lower values will represent the non-risk areas which will be suggested for apiaries to be located.

4. Results

The FFRI and FHRI maps were generated by using Equation 8 separately and given in Figure 8. The red zones represent the high potential forest risk and flood hazard risk zones.

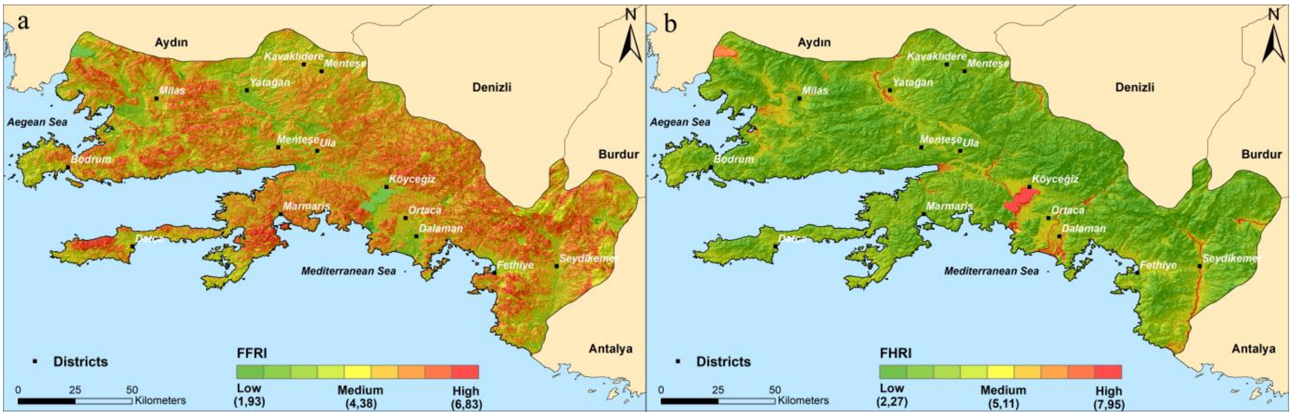

Figure 8: a) Forest fire risk index b) flood hazard risk index

The results indicated that 5556.76 ha (42,83%) of the study area is assigned as highly prone to forest fire risk according to the 7, 6 and 5 AHP and 736.92 ha (5,68%) of the study area is assigned as high potential flood area. The Marmaris, Köyceğiz, Dalaman and Fethiye districts have high forest fire potential due to the intensive forest cover. Because 41% of the weights were constituted by forest density, forest type, power lines, elevation and slope criteria, FFRI map tend to be similar to these criteria maps. Moreover, Eşen, Dalaman, Çine, Sarıçay, Akçay, Kamiişdere and Namnam rivers and their basins were calculated as high potential flood areas. The most effective criteria are calculated as riparian zones, rivers and potential streams. Thus, the flood zones and flood accumulative areas are tend to be clustered more evidently. The spatial sum of the FFRI and FHRI were calculated (Eq. 9) to generate ALRI for apiary risk values and given in Figure 9.

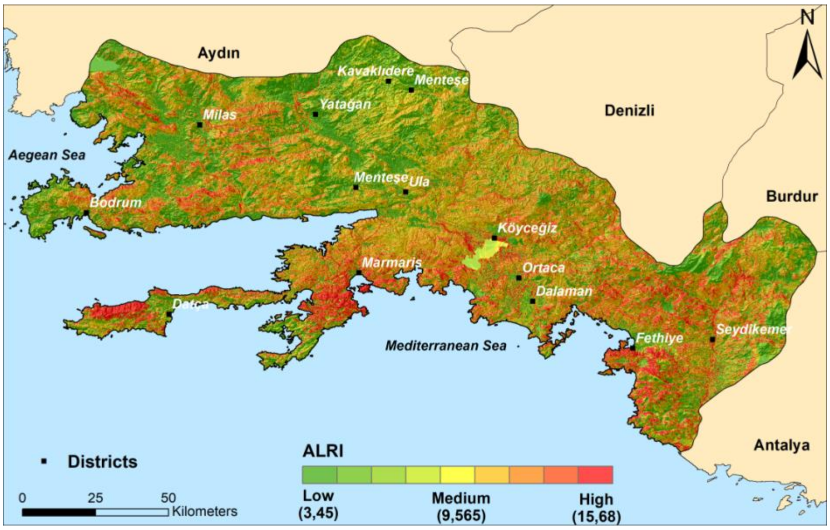

Figure 9: Apiary locations risk index

The ALRI map showed that 1533.40-ha (11,82%) of the Muğla province were calculated as extremely risk for apiary locations. The zones which are assigned as extremely risk includes both forest fire and flood hazard potential together. While maximum risk coefficient was calculated as 15.68, minimum risk coefficient was 3.45 that represent non-risk areas which will be suggested for apiaries. For the purpose of assigning non risk areas as 0 value, the following equation was applied to normalize the risk index values;

$$NALRI = ALRI - 3.45 \quad (10)$$

After this calculation, the normalized ALRI values will be equal to maximum 12.23 and minimum 0. For the purpose of classification the results according to the risk categories, the Table 5 was proposed.

Table 5: Criteria weights for forest fire susceptibility map

NALRI	Risk Category	Risk Definition
0-3	Non-Risk	Neither forest fire nor flood hazard risk
3-6	Moderately Risk	Both forest fire and flood hazard risk very low
6-8	Strongly Risk	One of the forest fire or flood hazard risk
8-10	High Risk	One of the forest fire or flood hazard risk higher than other
10-12	Extremely Risk	Both forest fire and flood hazard risk together

Considering 15,000 existing apiary locations, they tend to be clustered in forestry areas due to the pine honey production. Thus, the pine honey apiary locations have higher forest fire risk than flood hazard risk.

4.1. Verification of Susceptibility Maps

Verification of the FFRI and FHRI maps could be realized to determine the reliability and applicability of ALRI map considering the forest fire and flood hazard locations. The intersection of the forest fire and flood hazard data locations can reveal valuable information about the accuracy of ALRI. For this purpose, 1454 forest fire locations were retrieved from Republic of Turkey General Directorate of Forestry between 2013 and 2018. Moreover, the flood basins, which flood hazards mostly occurred, were retrieved from Turkish Statistical Institute. The overlap of the forest fire and flood hazard data with FFRI and FHRI are given in Figure 10.

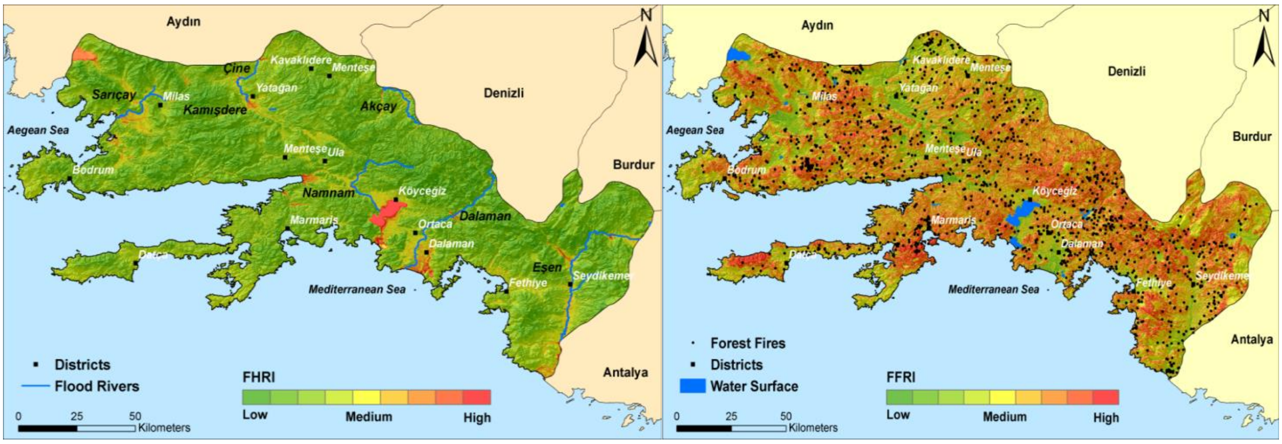

Figure 10: Intersection of forest fires and flood hazards locations with FFRI and FHRI

The results indicated that 715 forest fire locations were intersected with high potential forest fire risk zones and 589 forest fire locations intersected with moderately risk zones. However, 150 of 1454 forest fires occurred in non-risk areas. Considering the burnt area, the forest fires which destroyed the largest area overlapped with high potential forest fire risk zones. It is possible to say that 1304 (89%) of the forest fire occurred in potential forest fire locations which means FFRI reflects the forest fire risk accurately.

According to the flood statistics, Eşen, Dalaman, Çine, Sarıçay, Akçay, Kamiişdere and Namnam rivers and their basins are the main locations that flood hazards were occurred. As can be seen in Figure 10, these rivers are overlapped with the highly susceptible flood areas. There was a good correlation and overlapping determined with FHRI. Especially, the low level basins of the rivers that are located in low elevation (close to the sea) have higher flood potential than the higher elevation of the rivers. These locations can be seen in figure 10 with red polygons. For a general view of ALRI verification, the intersection of forest fires and flood hazards with ALRI is given in Figure 11. The forest fires tend to be clustered in high ALRI values.

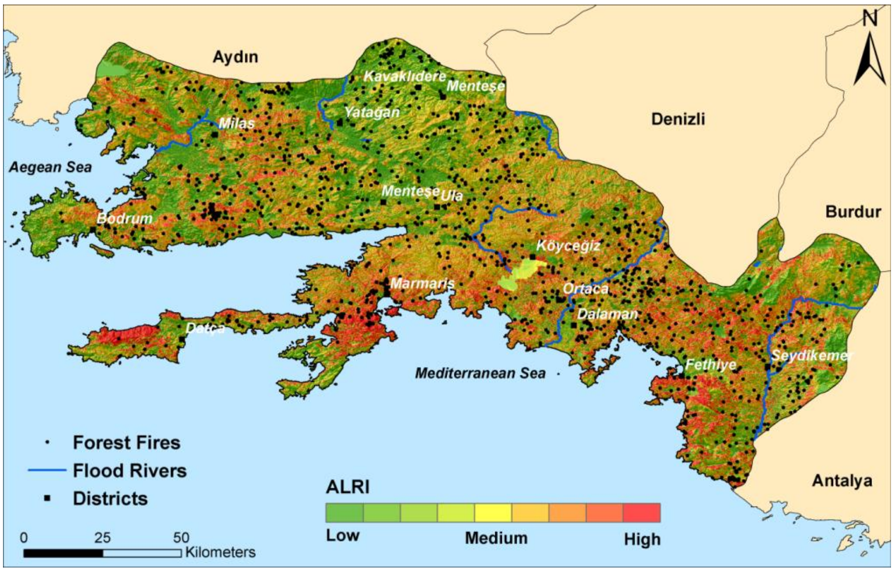

Figure 11: Intersection of forest fires and flood hazards locations with ALRI

5. Conclusions

This study presents an integrated natural hazard risk for apiaries located in Muğla province which are highly prone to forest fire and flood hazards. Although several criteria were used to detect forest fire susceptibility (Iwan et al. 2004; Vadrevu et al. 2010; Eugenio et al. 2016; Suryabhagavan et al. 2016; Güngöroğlu 2017; You et al. 2017; Sarı 2021; Sivrikaya and Küçük 2022), buildings, power lines and forest density criteria were included in this study to generate forest fire susceptibility. Additionally, for flood hazard susceptibility mapping, imperviousness, riparian zones, basins and possible streams criteria were included addition to recent studies (Tkach and Simonovic 1997; Wang et al. 2002; Zhang et al. 2002; Cheng and Wang 2004; Simonovic and Nirupama 2005; Thinh and Vogel 2006; Sinha et al. 2008; Wang et al.2011; Zou et al. 2013). The main contribution of this study is generating ALRI map which indicates a natural hazard occurrence probability combination for the study area. However, the ALRI map should be evaluated together with suitability maps for apiary locations to evaluate both suitability and risk for apiaries. The best apiaries should have high suitability and low risk to be able to increase the productivity and yield (Maris et al. 2008; Estoque and Murayama 2010; Abou-Shaara et al. 2013; Fernandez et al. 2016; Zoccali et al. 2017; Sarı et al. 2020; Sarı 2020).

This study is important for being a conceptual model for apiary risk assessment and can be applied to whole Turkey. Because Muğla province topography and climate reflects the Mediterranean characteristics, the model can be applied to Turkey both Aegean and Mediterranean zones directly. Due to the risks for apiary locations differ considering the different regions in Turkey, additional risk factors could be added for risk assessment such as land slide, earthquake, hurricane and frost. Special risk issues as like sinkholes or volcanic activities could be also added for risk assessment considering the regions.

The result ALRI map also indicates the prevention procedures for forest fire such as early intervention systems or locating the fire stations. Fire station locations could be examined or new station locations could be determined considering the intensive apiary locations which are located in higher ALRI values. Thus, effective intervention could be realized considering the risk values. The ALRI values also could be used as an insurance coefficient to predict the risk values according to the hive count.

References

Abou-Shaara H.F., Al-Ghamdi A.A., Mohamed A.A., (2013), *A suitability map for keeping honey bees under harsh environmental conditions using geographical information system*, World Applied Science Journal, 22, 1099–1105.

Adab H., Kanniah K.D., Solaimani K., (2013), *Modeling forest fire risk in the northeast of Iran using remote sensing and GIS techniques*, Natural Hazards, 65(3), 1723–1743.

Ajin R.S., Loghin A.M., Jacob M.K., Vinod P.G., Krishnamurthy R.R., (2016), *The risk assessment of potential forest fire in Idukki Wildlife Sanctuary using RS and GIS techniques*, International Journal of Advanced Earth Science and Engineering, 5, 308-18.

Alexakis D.D., Grillakis M.G., Koutroulis A.G., Agapiou A., Themistocleous K., Tsanis I.K., Michaelides S., Pashiardis S., Demetriou C., Aristeidou K., Retalis A., Tymvios F., Hadjimitsis D.G., (2014), *GIS and remote sensing techniques for the assessment of land use changes impact on flood hydrology: the case study of Yialias Basin in Cyprus*, Natural Hazards and Earth System Sciences, 14, 413–426.

Amraoui M., Pereira M.G., DaCamara C.C., Calado T.J., (2015), *Atmospheric conditions associated with extreme fire activity in the Western Mediterranean region*, Science of The Total Environment, 524, 32–39.

Arentze T.A., Timmermans HJP., (2000), *ALBATROSS: A Learning-based Transportation Oriented Simulation System. EIRASS*, Eindhoven University of Technology, The Netherlands.

Bonora L., Conese C., Marchi E, Testi E., Montorselli N.B., (2013), *Wildfire occurrence: Integrated model for risk analysis and operative suppression aspects management,* American Journal of Plant Sciences, 4, 705–710.

Bapalu G.V., Sinha R., (2005), *GIS in flood hazard mapping: a case study of Kosi River Basin, India*, http://www.gisdevelopment.net/application/natural_hazards/floods/floods001pf.htm [Accessed 17 January 2014].

Cheng S.P., Wang R.Y., (2004), *Analyzing hazard potential of typhoon damage by applying grey analytic hierarchy process,* Natural Hazards, 33(1), 77-103.

Chen Y., Yua J., Khan S., (2010), *Spatial sensitivity analysis of multi-criteria weights in GIS-based land suitability evaluation,* Environmental Modelling & Software, 25, 1582-1591.

Chuvieco E., Aguado I., Yebra M., Nieto H., Salas J., Martín M.P., Zamora R., (2010), *Development of a framework for fire risk assessment using remote sensing and geographic information system technologies*, Ecological Modelling, 221(1), 46–58.

Damián G.C., (2016), *GIS-based optimal localisation of beekeeping in rural Kenya,* Master degree thesis, Master in Geographical Information Sciences Department of Physical Geography and Ecosystems Science, Lund University.

Elkhrachy İ., (2015), *Flash Flood Hazard Mapping Using Satellite Images and GIS Tools: A case study of Najran City, Kingdom of Saudi Arabia (KSA),* The Egyptian Journal of Remote Sensing and Space Sciences, 18, 261–278.

Estoque R.C., Murayama Y., (2010), *Suitability Analysis for Beekeeping Sites in La Union, Philippines, Using GIS and Multi-Criteria Evaluation Techniques,* Research Journal of Applied Sciences, 5(3), 242-253.

Estoque R.C., Murayama Y., (2011), *Suitability Analysis for Beekeeping Sites Integrating GIS & MCE Techniques,* In Spatial Analysis and Modeling in Geographical Transformation Process (Murayama Y., Thapa R.B., Ed.), Springer, Netherlands, ss.215-233.

Eugenio F.C., Dos Santos A.R., Fiedler N.C., Ribeiro G.A., Da Silva A.G., Dos Santos Á.B., Paneto G.G., Schettino V.R., (2016), *Applying GIS to develop a model for forest fire risk: a case study in Espírito Santo, Brazil*, Journal of Environmental Management, 173, 65–71.

Fernandez P., Roque N., Anjos O., (2016), *Spatial multicriteria decision analysis to potential beekeeping assessment. Case study: Montesinho Natural Park (Portugal)*, Proceedings 19th AGILE International Conference on Geographic Information Science—Geospatial Data in a Changing World, Helsinki, Finland.

Gessler P.E., Moore I.D., McKenzie N.J., Ryan P.J., (1995), *Soil-landscape modelling and spatial prediction of soil attributes,* International Journal of GIS, 9(4), 421-432.

Güngöroğlu C., (2017), *Determination of forest fire risk with fuzzy analytic hierarchy process and its mapping with the application of GIS: The case of Turkey/Çakırlar,* Human and Ecological Risk Assessment: An International Journal, 23(2), 388-406.

Haq M., Akhtar M., Muhammad S., Paras S., Rahmatullah J., (2012), *Techniques of remote sensing and GIS for flood monitoring and damage assessment: a case study of Sindh province, Pakistan,* The Egyptian Journal of Remote Sensing and Space Science, 15, 135–141.

Hernandez-Leal P.A., Arbelo M., Gonzalez-Calvo A., (2006), *Fire risk assessment using satellite data*, Advances in Space Research, 37(4), 741–746.

Huyen D.T.T., Tuan V.A., (2008), *Applying GIS and Multi Criteria Evaluation in Forest Fire Risk Zoning in Son La Province, Vietnam*, International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences (GIS-IDEAS) 2008, 4-6 December, Hanoi, Vietnam.

Iwan S., Mahmud A.R., Mansor S., Mohamed Shariff A.R., Nuruddin A.A., (2004), *GIS-grid-based and multi-criteria analysis for identifying and mapping peat swamp forest fire hazard in Pahang, Malaysia*, Disaster Prevention and Management: An International Journal, 13(5), 379-386.

Jahan M., Bahraminasab K.L., Edwards A., (2012), *Target-based normalization technique for materials selection*, Materials & Design, 35, 647-654.

Jaiswal R.K., Mukherjee S., Raju K.D., Saxena R., (2002), *Forest fire risk zone mapping from satellite imagery and GIS*, International Journal of Applied Earth Observation and Geoinformation, 4(1), 1–10.

Jose K.S., (2012), *Geospatial characterization and conservation potential for Agasthyamala Biosphere Reserve, Western ghats, India*, PhD thesis, School of Environmental Sciences, Mahatma Gandhi University.

Kushla J.D., Ripple W.J., (1997), *The role of terrain in a fire mosaic of a temperate coniferous forest,* Forest Ecology and Management, 95, 97–107.

Liu J.F., Li J., Liu J., Cao R.Y., (2008), *Integrated GIS/AHP-based flood risk assessment: a case study of Huaihe River Basin in China*, Journal of Natural Disasters, 17(6), 110–114.

Løken, E., (2007), *Use of multicriteria decision analysis methods for energy planning problems*, Renewable and Sustainable Energy Reviews, 11(7), 1584-1595.

Maris N., Mansor S., Shafri H., (2008), *Apicultural Site Zonation Using GIS and Multi-Criteria Decision Analysis,* Pertanika Journal of Tropical Agricultural Science, 31(2), 147 – 162.

Miguel S., Pukkala T. Yeşil A., (2014), *Integrating pine honeydew honey production into forest management optimization*, European Journal of Forest Research, 133(3), 423-432.

Mitchell J.W., (2013), *Power line failures and catastrophic wildfires under extreme weather conditions*, Engineering Failure Analysis, 35, 726–735.

Moore I.D., Grayson R.B., Ladson A.R., (1991), *Terrain based catchment partitioning and runoff prediction using vector elevation data,* Water Resources Research, 27, 1177–1191.

Mulliner E., Malys N., Maliene V., (2016), *Comparative analysis of MCDM methods for the assessment of sustainable housing affordability*, Omega, 59, 146–156.

Oldroyd P.B., Nanork P., (2009), *Conservation of Asian honey-bees,* Apidologie Bee Conservation, 40, 296-312.

Pourghasemi H.R., (2016), *GIS-based forest fire susceptibility mapping in Iran: a comparison between evidential belief function and binary logistic regression models,* Scandinavian Journal of Forest Research, 31(1), 80–98.

Pradhan B., Hagemann U., Shafapour Tehrany M., Prechtel N., (2014), *An easy to use ArcMap based texture analysis program for extraction of flooded areas from TerraSAR-X satellite image*, Computers & Geosciences, 63, 34–43.

Puri K., Areendran G., Raj K., Mazumdar S., Joshi P.K., (2011), *Forest fire risk assessment in parts of Northeast India using geospatial tools*, Journal of Forestry Research, 22, 641, doi: 10.1007/s11676-011-0206-4.

Rothermel R.C., (1983), *How to predict the spread and intensity of forest and range fires*, USDA Forest Service Intermountain Forest and Range Experiment Station General Technical Report INT-143.Ogden, UT, USA, 161ss.

Saaty T.L., (1977), *A scaling method for priorities in hierarchical structures*, Journal of Mathematical Psychology, 15, 234–281.

Saaty T.L, (1980), *The Analytical Hierarchy Process*, New York: McGraw-Hill.

Saaty T.L., (1994), *Fundamentals of Decision Making and Priority Theory with The Analytical Hierarchy Process*, RWS Publ. Pittsburg, ss.69-84.

Saaty T.L., (2001), *Decision Making with Dependence and Feedback: The Analytic Network Process*, 2nd edition, PRWS Publications, Pittsburgh PA.

Saaty T.L, Vargas, L.G., (1991), *Prediction, Projection and Forecasting*, Kluwer Academic Publishers, Dordrecht, 25ss.

Sarı F., (2020), *Assessment of Land Use Change Effects On Future Beekeeping Suitability Via Ca-Markov Prediction Model,* Journal of Apicultural Sciences, 64(2), 263-276.

Sarı F., Ceylan D.A., Özcan M.M., Özcan M., (2020), *A comparison of Multi Criteria Decision Analysis Techniques for Determining Beekeeping Suitability,* Apidologie, 51(4), 481-498.

Sarı F., (2021), *Forest Fire Susceptibility Mapping Via Multi-Criteria Decision Analysis Techniques For Mugla, Turkey: A Comparative Analysis of VIKOR and TOPSIS*, Forest Ecology and Management, 480(2), 118644, doi: 10.1016/j.foreco.2020.118644.

Seyed H.M., Alireza S.A., (2017), *A comprehensive MCDM-based approach using TOPSIS, COPRAS and DEA as an auxiliary tool for material selection problems*, Materials & Design, 121, 237-253.

Simonovic S.P., Nirupama N., (2005), *A spatial multi-objective decision-making under uncertainty for water resources management,* Journal of Hydroinformatics, 7(2), 117–133.

Sinha R., Bapalu G.V., Singh L.K., Rath B., (2008), F*lood risk analysis in the Kosi river basin, north Bihar using multi-parametric approach of analytical hierarchy process (AHP),* Journal of the Indian Society of Remote Sensing, 36(4), 335-349.

Sivrikaya F., Küçük Ö., (2022), *Modeling forest fire risk based on GIS-based analytical hierarchy process and statistical analysis in Mediterranean region,* Ecological Informatics, 68, 101537, doi: 10.1016/j.ecoinf.2021.101537.

Sun L., Wang Q.X., Wei S.J., Hu H.Q., Guan D., Chen X.W., (2014), *Response characteristics and prospect of forest fire disasters in the context of climate change in China*, Journal of Catastrophology, 29(1), 12–17. In Chinese.

Suryabhagavan K.V., Alemu M., Balakrishnan M., (2016), *GIS-based multi-criteria decision analysis for forest fire susceptibility mapping: a case study in Harenna forest, southwestern Ethiopia*, Tropical Ecology, 57(1), 33-43.

Tkach R.J., Simonovic S.P., (1997), *A new approach to multi-criteria decision making in water resources,* Journal of Geographic Information and Decision Analysis, 1(1), 25–44.

Thinh N.X., Vogel R., (2006), *GIS-based multiple criteria analysis for land-use suitability assessment in the content of flood risk management,* InterCarto-InterGIS 12, August 28-30, Berlin, Germany.

URL-1, (2019), *Turkish Statistical Institute Web Page*, http://tuik.gov.tr/UstMenu.do?metod=kategorist, [Accessed 17 January 2019].

URL-2, (2019), *Turkish State Meteorological Service Web Page*, https://www.mgm.gov.tr/ [Accessed 17 January 2019].

Vadrevu K.P., Eaturu A., Badarinath K.V., (2010), *Fire risk evaluation using multicriteria analysis--a case study,* Environ Monitoring and Assessment, 166(1-4), 223-239.

Wang R.Y., Huang H.Y., Cheng S.P., (2002), *The study of fuzzy analytic hierarchy process and grey system theory for analyzing the damage potential of inundation effect*, Taiwan Water Conserv, 50, 1-23.

Wang Y., Li Z., Tang Z. Guangming Z., (2011), *A GIS-Based Spatial Multi-Criteria Approach for Flood Risk Assessment in the Dongting Lake Region, Hunan, Central China*, Water Resources Management, 25, 3465, doi: 10.1007/s11269-011-9866-2.

Wang P, Zhu Z, Wang Y., (2016), *A novel hybrid MCDM model combining the SAW, TOPSIS and GRA methods based on experimental design*, Information Sciences, 345, 27–45.

You W., Lin L., Wu L., Ji Z., You J., Zhu J., Fan Y., He D., (2017), *Geographical information system-based forest fire risk assessment integrating national forest inventory data and analysis of its spatiotemporal variability*, Ecological Indicators, 77, 176–184.

Zhang J, Okada N, Tatano H., Hayakawa S., (2002), *Risk assessment and zoning of flood damage caused by heavy rainfall in Yamaguchi prefecture, Japan,* In Flood Defence (Wu B.S., Ed.), Science Press, New York Ltd., ss.162-169.

Zhou C.H., Wan Q., Huang S.F., Chen D.Q., (2000), A *GIS-based approach to flood risk Zonation,* Acta Geographica Sinica, 55(1), 15–24.

Zoccali P., Malacrin A., Campolo O., Laudani F., Algeri G.M., Giunti G., Palmeri V., (2017), *A novel GIS-based approach to assess beekeeping suitability of Mediterranean lands,* Saudi Journal of Biological Sciences, 24(5), 1045–1050.

Zou Q., Zhou J., Zhou C., Song L., Guo J., (2013), *Comprehensive flood risk assessment based on set pair analysis-variable fuzzy sets model and fuzzy AHP,* Stochastic Environmental Research and Risk Assessment, 27, 525-546.