FUTURE VULNERABILITY ASSESSMENT OF FOREST FIRE SECTOR TO CLIMATE CHANGE IMPACTS IN CYPRUS

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Abstract

Forests of Cyprus are vulnerable to fire, primarily due to the long, hot and dry summers, mild winters, strong winds, intense relief and flammable xerophytic vegetation. These natural factors are further exacerbated by changing climatic conditions, which favour prolonged periods of drought and extreme weather events. The vulnerability of Cyprus forests to the future climatic changes is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus.]. In order to study the exposure and the sensitivity of Cyprus forests to forest fires, climatic indices and the meteorologically based Fire Weather Index (FWI) were examined for two future period: the near (2021 – 2050) and the distant (2069 – 2098). Future projections carried out using PRECIS Regional Climate Model and compared with control period (1961 – 1990). The adaptive capacity of forests to fire risk was evaluated in terms of the measures were taken by the Forestry Department of Cyprus aiming to eliminate forest fires. As for the overall vulnerability, it was found that most vulnerable regions are the mountain areas of Troodos while western forested areas present the lower vulnerability.

Keywords: Climate change, Forests, Fire Risk, Fire Weather Index, Regional Climate Modeling

1. Introduction

According to the Department of Forests of the Ministry of Agriculture, Natural Resources and Environment of Cyprus (www.moa.gov.cy/), forest fires are considered as the main threat for the forests of Cyprus. Every year, forest fires cause extensive and irreversible damages to forest ecosystems. It must be mentioned that forests consist an exceptionally important ecosystem in Cyprus which cover an area equivalent to 25% of the total area of the island. The Cypriot forests are natural and the main species are the Turkish pine (*Pinus brutia*) and the Black pine (*Pinus nigra*) which mainly covers the higher parts of Troodos Mountain. Also, many endemic species are found from which the well known are the Golden oak (*Quercus alnifolia*) and the Cyprus cedar (*Cedrus brevifolia*).

Forests of Cyprus are vulnerable to fire, primarily due to the long, hot and dry summers, mild winters, strong winds, intense relief and flammable xerophytic vegetation. These natural factors are further exacerbated by changing climatic conditions, which favour prolonged periods of drought and extreme weather events. Also, the accumulation of biomass due to the abandonment of rural areas and the increasing tourism and exodus of city residents to forested areas, are also important factors which contribute to an increased fire risk, especially during summer months.

According to IPCC Third Assessment Report, vulnerability is defined as “The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity” [7]. As a result, vulnerability consists of three components i.e. exposure, sensitivity and adaptive capacity. The first two components together represent the potential impact while the adaptive capacity represents the extent to which these impacts can be averted.

2. Methodology and results

The vulnerability of Cyprus forests to the future climate changes is assessed in terms of their sensitivity, exposure and adaptive capacity according to the aforementioned definitions. In particular, sensitivity is defined as the degree to which forests will be affected by climate changes, exposure is the degree to which forests will be exposed to future climate changes and their impacts while the adaptive capacity is defined by the ability of forests to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

2.1. Assessment of exposure

Exposure reflects both the direct danger and the extent of changes to a region's climate variables. For the Cyprus forests, which are Mediterranean-type ecosystems, fire occurrence strongly depends on the drought conditions that drastically increases flammability during summer period, on the temperature reached during this period as well as on the amount of fuel load [5]. In order to study the exposure of Cyprus forests to forest fires, climatic indices and the meteorologically based Fire Weather Index (FWI) were examined.

The Fire Weather Index system is described in detail in van Wagner [11]. Briefly, FWI is a daily meteorological-based index used worldwide to estimate fire danger in a generalized fuel type. It consists of six components that account for the effects of fuel moisture and wind on fire behavior. These include numeric ratings of the moisture content of litter and other fine fuels (FFMC), the average moisture content of loosely compacted organic layers of moderate depth (DMC), and the average moisture content of deep, compact organic layers (DC). The remaining components are fire behavior indices (ISI), which represent the rate of fire spread, the fuel available for combustion (BUI), and the frontal fire intensity (FWI); their values rise as the fire danger increases (Figure 1). Calculation of the FWI components is based on consecutive daily noon measurements of dry-bulb temperature, relative humidity, 10m wind speed and 24 h accumulated precipitation. Although FWI has been developed for Canadian forests, several studies have shown its suitability for the Mediterranean basin [6, 8]. FWI is divided into four fire danger classes:

1st Low 0 – 7 3th High 17 – 31

2nd Medium 8 – 16 4th Extreme >32

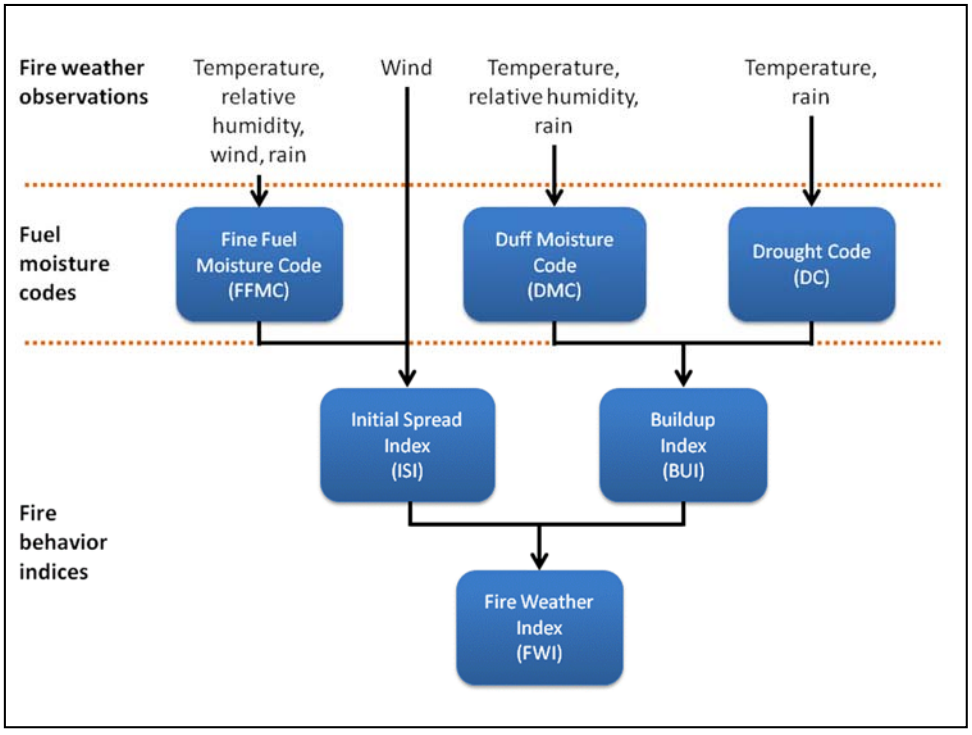

Figure 1: The Canadian Forest Fire Weather Index (FWI) System

A comprehensive analysis of FWI has been undertaken for the entire study domain. FWI is calculated using the PRECIS regional climate model provided by the United Kingdom (UK) Meteorological Office Hadley Centre for the control period (1961–1990) as well as two future periods i.e. the near future period (2021–2050) and the distant future period (2069 – 2098). The model used with horizontal resolution of 25 x 25 km, with 19 levels in the atmosphere (from the surface to 30 km in the stratosphere) and with four levels in the soil. Future projections based on the intermediate A1B scenario of the Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change [9].

Tables 1 & 2 present the mean control values as well as the changes in the near and distant future of climatic indices relevant to forest fires for Cyprus. The entire area of study was divided into five sub-regions i.e. the western area which represent the greater area of Paphos, the southern area which represent the greater area of Limassol, the eastern area which represent the greater area of Larnaca, the continental lowland area which represent the greater area of Nicosia and finally the higher elevation area which represent the mountain area of Troodos.

Table 1: Values of climatic indices with particular relevance to forest fire risk for the control period (1961 – 1990) in Cyprus.

	Western Regions	Southern Regions	Southeastern Regions	Continental Lowland regions	Higher Elevation Regions
Nb of dry days (P<0.5mm)	200	250	280	280	265
Max length of dry spell (days)	15	60	90	85	70
Nb of days with Tmax>35 °C	4	18	15	41	25
Average summer Tmax (°C)	27	30	30	34	33

Table 2: Projected future changes in climatic indices with particular relevance to forest fire risk for the near (2021-2050 – NF) and distant (2069-2098 – DF) future periods in Cyprus

		Western Regions	Southern Regions	Southeastern Regions	Continental Lowland regions	Higher Elevation Regions
Nb of dry days (RR<0.5mm)	NF	+4	+4	+8	+8	+11
	DF	+12	+14	+15	+18	+20
Max length of dry spell (<0.5mm) (days)	NF	-2	+7	+8	+10	+13
	DF	0	+8	+21	+22	+9-15
Nb of days with Tmax>35 °C	NF	+2	+19	+17	+34	+30
	DF	0	32	45	55	52
Average summer Tmax (°C)	NF	+1.6	+2.0	+1.8	+2.5	+2.6
	DF	+3.2	+3.8	+3.4	+4.8	+4.6

As Table 3 shows, the number of dry days in Cyprus varies from 4 to 11 days in the near future and from 12 to 20 days in the distant future. In both future periods, western and southern regions present the lower increases while the mountain areas show the higher increases. As for the maximum length of dry spell, western regions show a slight decrease of about 2 days in the near future and no change in the distant future. The remaining regions show increases which vary from 7 and 8 day in southern and southeastern regions to 10 and 13 days in

continental and higher elevation areas (near future). In distant future, increases reach 21 and 22 days in southeastern and lowland regions respectively. Regarding the number of days with maximum temperature >35°C in the near future, continental and higher elevation areas present increases of about one additional month while in distant future the increases are more higher i.e. 52-55 additional days. Western regions present a slight or no increase. Furthermore, average summer maximum temperature is expected to increase up to 2.6°C in mountain regions in the near future and up to 4.6°C in the distant future. Significant increases, up to 3°C, are shown by the remaining areas in the distant future.

To further investigate the future exposure of Cyprus forests to forest fires in near and distant future, the number of days with elevated fire risk i.e. FWI>30 (extreme fire risk) was calculated. As shown in Figure 2, Troodos Mountain shows the higher increase of about 8-10 days in near future and approximately 25 days in the distant future. In the present-day climate (not shown), the number of days with extreme fire risk varies from 50-70days in northwestern regions of Troodos to 80-100 days in southeastern areas. Other forested regions show lower increases in extreme fire risk. For example, Akamas peninsula, where the National Park of Akamas is located, presents no increase in extreme fire risk in the near and distant future.

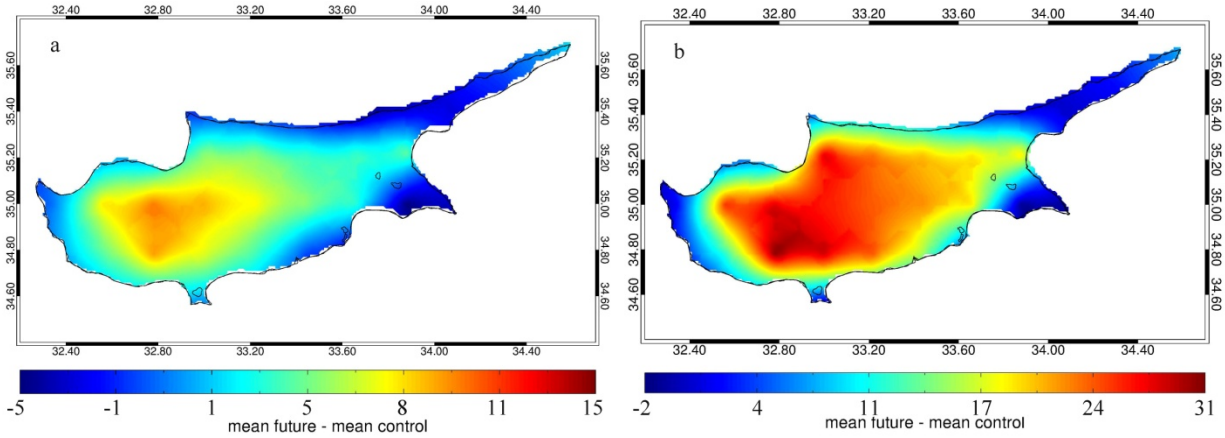

Figure 2: a) Near future changes of the number of days with extreme fire risk (FWI>30), b) Distant future changes of the number of days with extreme fire risk (FWI>30)

2.1. Assessment of Sensitivity

Forests in Cyprus are sensitive to fires because of their composition which is dominated by flammable vegetation and the topography of the forested areas, which is mostly mountainous. Moreover, urbanization increases the fire hazard because of the increase of flammable forest vegetation and decrease of human activity in the countryside as well as the availability of human and water resources in case of fires.

The area, density and distribution of the main forest tree and shrub species that are threatened by forest fires as well as the range of threat within Cyprus, are presented in Table 1 [3].

Table 3: Main tree and other woody forest species considered to be threatened by forest fires in all or part of their range in Cyprus

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Threat Category*		
				High	Medium	Low
***Cedrus brevifolia* (tree)**	367	75	Local		X	
***Juniperus excels* (tree)**	643	32	Local		X	
***Pinus nigra* ssp. *pallasiana* (tree)**	4,970	n.a.	Local		X	

***Juniperus foetidissima* (tree)**	72.7	n.a.	Local		X	
***Quercus infectoria* ssp. *veneris* (tree)**	354.7	n.a.	Widespread	X		
***Cupressus sempervirens* (tree)**	450	n.a.	Widespread			X
***Arbutus unedo* (shrub)**	1.5	53	Local	X		
***Phillyrea latifolia* (shrub)**	596	8.4	Rare	X		
***Viburnum tinus* ssp. *tinus* (shrub)**	17	60	Local	X		

**Threat categories: High – threatened throughout species range within Cyprus, Medium – threatened in at least 50% of range within country, Low-threatened in less than 50% of range within country.*

In addition, as shown in Figure 3, in all the areas that main forests of Cyprus exist, such as in Troodos the fire risk is "very high" while at maquis and garique vegetation areas found at Troodos as well as southern of Troodos the fire risk is high.

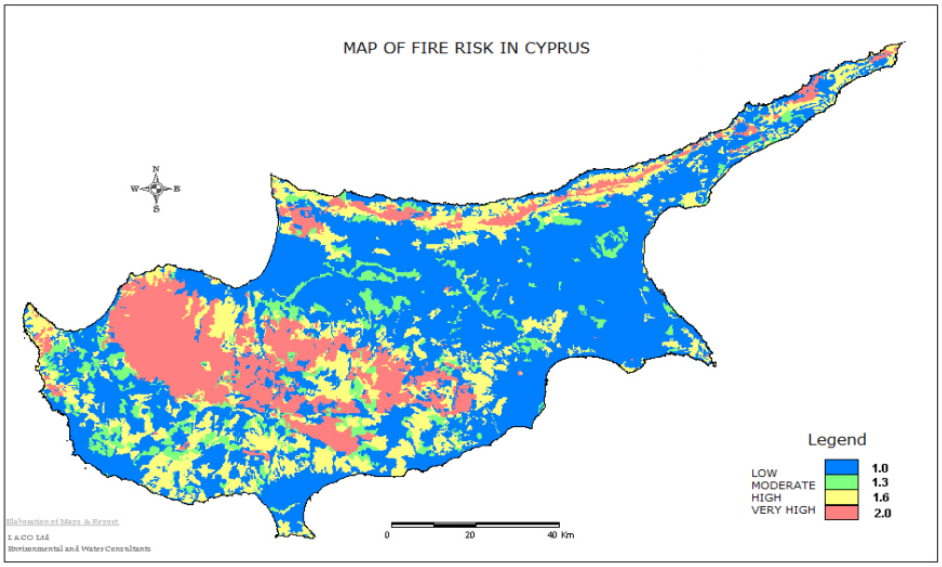

Figure 3: Map of fire risk in Cyprus [4].

The long, hot and dry summers that last from May until October increase the fire risk since they convert the pine into a dry and highly inflammable fuel mass. During the fire season the temperature fluctuates from 30° to 44°C increasing the risk of ignition to very high levels [2]. Figure 4 shows that in the present-day climate, during summer the entire forested area of Cyprus, except for western regions, presents extreme fire risk. In addition in near and distant future (Figure 5 & 6) is anticipated an increase in summer FWI of about 3 and 6 respectively in higher elevation forested areas.

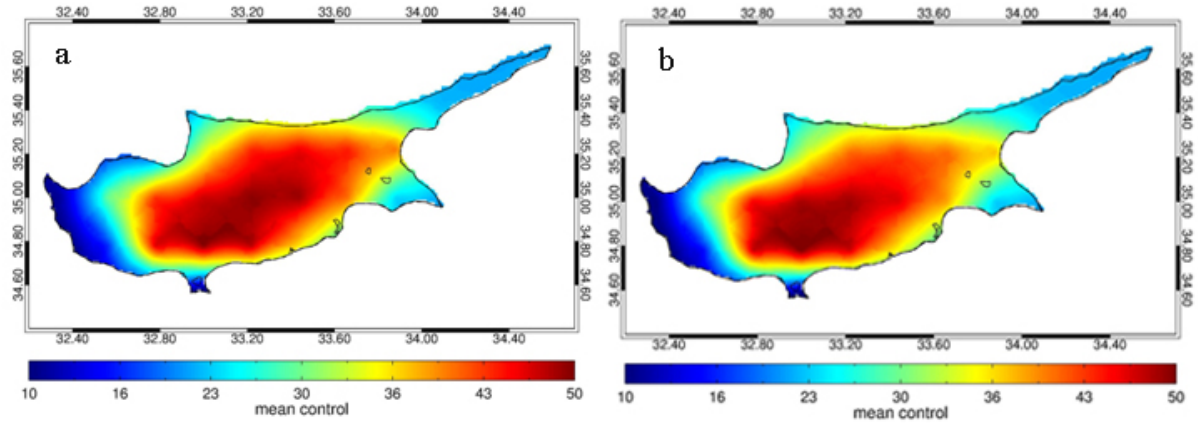

Figure 4: July (a) and August (b) average FWI for the control period (1961 – 1990).

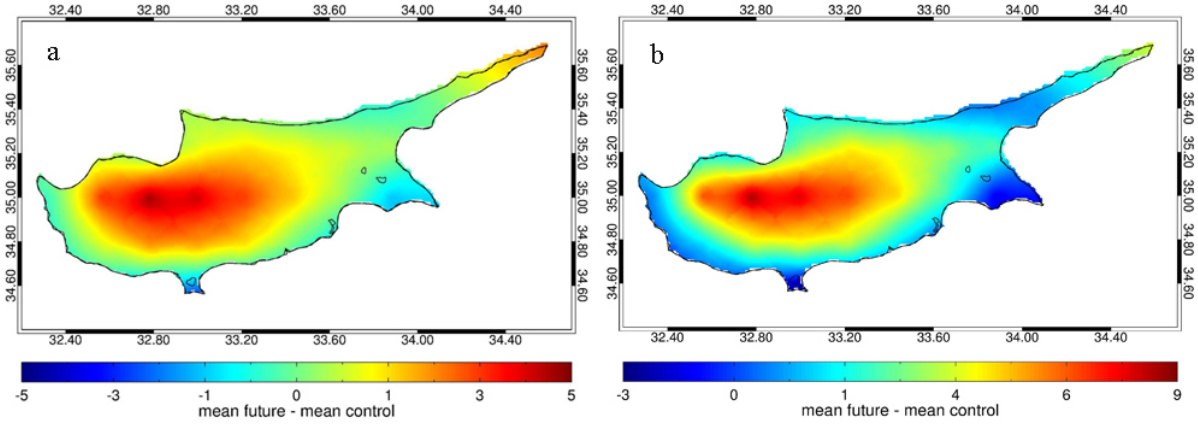

Figure 5: Changes in July average FWI in the near (a) and the distant (b) future.

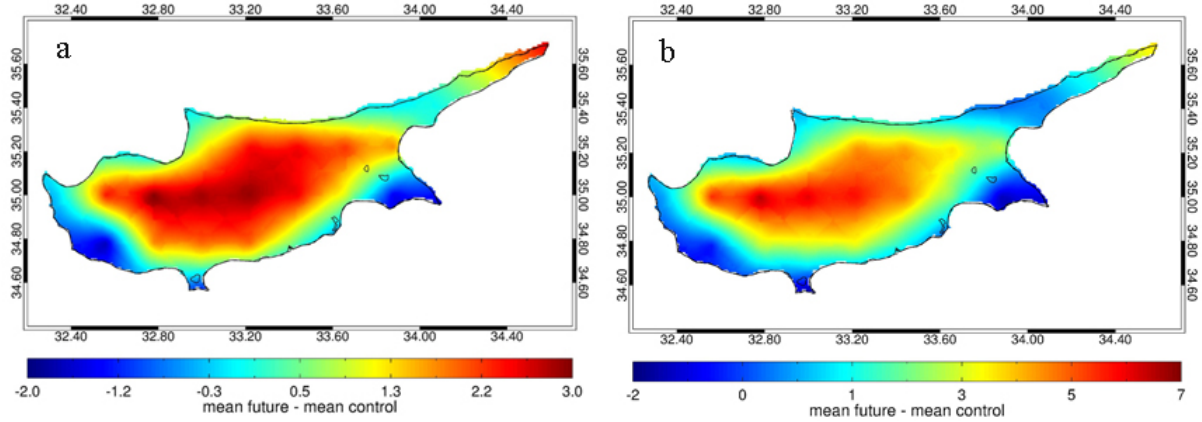

Figure 6: Changes in August average FWI in the near (a) and the distant (b) future.

Considering the above, it can be inferred that Cyprus forests are relatively sensitive to forest fires since the majority of forested area, in particular Troodos Mountain, is characterised as highly threaten to fires. Conversely, western forested areas, especially Akamas peninsula, present considerable lower fire risk.

2.2. Assessment of adaptive capacity

Several measures are taken by the Forestry Department of Cyprus aiming to eliminate forest fires. Particularly, the (a) prevention, (b) pre-suppression, (c) detection and suppression measures are presented as follows:

(A) Fire Prevention measures. Fire Prevention measures include all actions and measures aimed at reducing or eliminating the potential for a fire outbreak. The main prevention measures taken are Law enforcement,

Information campaigns, establishment of Picnic and camping sites, organization of patrolling and Fire danger mapping [1].

(B) Fire Pre-suppression measures: Include all actions and measures aimed at reducing the likelihood of spread of a potential fire and at facilitating the efforts of effective fire suppression. The main pre-suppression measures taken are Fire breaks, Forest roads, Forest telecommunications, Forest Stations, Silvicultural treatments, Detection and reporting of forest fires, placement of Fire lookout stations, placement of automatic fire detection system and Reporting of forest fires.

(C) Suppression measures: The suppression of forest fires is a complex, difficult and dangerous work that requires specialized knowledge, education and organization. Suppression includes all actions and measures aimed at facilitating rapid intervention and effective suppression of a potential fire. The main suppression measures taken are Forest fire fighting task force, Stand-by of forest officers, establishment of The Cyprus Forestry College, Fire engines, Personnel vehicles, Tractors, Warehouses, Fire protection systems, Water tanks and hydrants, Heliports, Aerial means and Cooperation with other agencies and the public.

Furthermore, in the framework of the Rural Development Programme 2007-2013 of Cyprus, economic incentives are provided to individuals through the Measure 2.5 “Protection of forests from fires and reforestation areas”. The main purpose of the measure is to improve the existing protection system of forests and other forest areas from fire as well as the restoration of burned areas. The measure includes the following two actions: (i) fire prevention, (ii) reforestation of burnt areas. This measure enhances the protection of private forests which are not covered by the national forest protection programme. Despite the great efforts and the good results of recent years, the problem of fires still exists and will always constitute a permanent threat for the forests of Cyprus.

2.3. Assessment of overall future vulnerability

In order to quantify the vulnerability potential of forests against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as Table 4 shows.

Table 4: Degree of sensitivity, exposure & adaptive capacity

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

"Impacts" and "Adaptive capacity" should be evaluated on the same scale (1-7). For this to be achieved, the square root of "Sensitivity x Exposure" is used. The results of the vulnerability assessment for the forest sector for each sub-region in Cyprus are summarized in Table 5.

Table 5: Overall vulnerability assessment of forests to fire risk due to climate changes in Cyprus

	Western areas	Eastern areas	Southeastern areas	Continental lowland areas	Higher elevation areas
Sensitivity	Limited to moderate (2)	High (5)	High (5)	High to Very high (6)	Very high (7)
Exposure	Limited to moderate (2)	High (5)	High (5)	High to Very high (6)	Very high (7)
Adaptive Capacity	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Vulnerability	None	Limited to Moderate (2)	Limited to Moderate (2)	Moderate (3)	Moderate to high (4)

3. Conclusions

From the abovementioned analysis, it can be inferred that Cyprus forests are sensitive to fires because of their composition which is dominated by flammable vegetation and the topography of the forested areas, which is mostly mountainous. Also, the decrease in rainfall as well as the increase in temperature and in dry spells constitute an pressure which elevate the exposure of forests to fire risk. The further investigation of the forest fire risk using FWI, shows that during summer months, especially during July and August, Troodos Mountain and the majority of the forested areas of Nicosia, Larnaca and Limassol present extreme fire risk. Concerning the overall vulnerability, higher elevation areas, especially central and southeastern parts of Troodos (Nicosia and Limassol Districts), present the higher vulnerability. On the contrary, western areas i.e. fostered areas of Paphos District show the lower fire risk.

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