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Certain edaphoecological factors for upper treeline expansion of forest vegetation in the northern parts of Kozhuf mountain massif in the Republic of Macedonia

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ABSTRACT: This paper attempts to define what changes occur with forest vegetation on the northern slopes of the Kozhuf mountain range at upper treeline. For this purpose, we defined three sub-goals: defining the current upper timberline of the forest vegetation, distribution of forest communities on Kozhuf mountain range at the upper treeline, as well as modelling of possible upper timberline of the forest according to temperature indicators. Comparative analysis method was used. The period of analysis covers 80 years. Different cartographic and written materials served as a basic material for analysis. Required sections of topographical maps were geo-referenced and digitalized as separate layers in AUTOCAD software. With layers switching, and with so-called "over-lay analysis" we got the differences in the distribution area in terms of upper treeline shifting. Forest vegetation was surveyed with recording and mapping of vegetation types. Part of it is processed by the method of Braun-Blanquet. The vegetation types development was observed, and the dynamics of populations and species movement was observed through these changes. The obtained results show that with increment of upper treeline of the forest vegetation, the most represented is forest community of Scots pine *Fago-Pinetum sylvestris* on silicate geological substrate, and relatively smaller areas are accounted to the forest communities of mixed forest of fir and beech *Abieti borisii-regis – Fagetum*, and pure fir forest *Fago-Abietetum*, while the small area accounts for *Seslerio-Pinetum nigrae* and *Fago-Abietetum* forest communities on limestone geological substrate. Regarding the treeline of the forest in 30 years of the last century and the present state, the greatest expansion is on western exposure, in this case up to maximum of 400 m. The forest vegetation expansion is smallest on eastern exposure.
Keywords: topographic maps, AUTOCAD software, treeline, forest communities, expansion

1 INTRODUCTION

Forest vegetation permanently changes its distribution limit [12]. For the current picture of the vegetation cover at the upper treeline of the Kozhuf mountain range, the primary significance has: the development of vegetation in the past, the existing life conditions and the human influence, while a decisive role belongs to climate, relief and edaphic factors.

In this regard, a major environmental factor that strongly influences on the recent geographical layout, composition and growth of the forest is the climate with its elements: air temperature, precipitation, relative humidity, winds, insolation and other.

The upper treeline in terms of relief depends on the mountain massiveness, altitude, exposure, proximity to the sea and other.

In aspect of the massiveness and stretchiness direction of mountain ranges, the continentality or oceanic position of the mountains affect the limit of upper or alpine border of the forest cover. The mountain's massiveness affect the climate. The more mountain is massive it has more continental climate, as it is quickly heated and cooled. If the mountain is smaller, it has more oceanic character, as it is slowly heated and slowly cools. Because of such a role, the mountain's massiveness influence the position of the alpine treeline, the more mountain is massive and away from the sea, this alpine treeline is on higher altitudes, and vice-versa, as the mountain is less massive or closer to the sea, the alpine treeline is on lower altitudes.

An important feature of the elevation of the upper treeline is exposure. Namely, on the northern exposures the upper treeline is higher than those on southern exposures are. Here despite of the low temperatures, the fluctuations are smaller [10].

The elevation of the alpine treeline is actually determined by the elevation at which the July isotherm of 10° C is moving. At a temperature below that, the forest does not thrive anymore. Comparisons in older literature between timberline location and certain isotherms had already indicated that temperature during the growing season plays the key role in setting the forest limits. The 10°C July-isotherm agrees relatively well with the course [2].

Although the relief affects the formation of vegetation cover almost everywhere relatively equal, in some parts of the country there are big differences in appearance and layerness of the vegetation cover. The reason for these changes is the development of vegetation in the past and geographical location (latitude and longitude). The impact of the relief is not seen only in the establishment of the recent vegetation cover, but also in the formation of vegetation cover in the past (invasions and withdrawals and survival of certain plants and plant communities that lived in different geological periods) closely related to the climate and the form of relief.

The difference in latitude may be the reason for appearance of vegetation that the relief as a factor conditions somewhere.

The impact of the relief on the vegetation cover is reflected in two ways: on wider areas with joint action of mega relief, the climate of the wider area, the land configuration influence in the formation of climatogenic communities. On the smaller area with the impact of mezorelief or microrelief, the microclimate and atypical soils affect the formation of locally conditioned communities.

The Balkans and Macedonia are known for centuries – old quest to destroy the forest at the upper treeline, in order to obtain productive pastures in order to satisfy the extensive economic output in cattle breeding and manufacture operations in mountain areas over the centuries [13, 28]. The livestock in this part of Kozhuf is of semi-nomadic type. The presence of large livestock in the area of interest is insignificant. The potential for grazing the entire pasture area is about 3,500 sheep. By conquering the heaths vegetation, the number of sheep that could graze will be reduced by 50% [14]. All this, accompanied by the historical development of forest vegetation contributed to the reduction of the upper treeline in some Macedonian mountains by 400–500 meters.

In the past 50 years, a reversible process is visible. It is the process of returning of forest on places where long it has been superseded. This is due to reduction of the herds that graze in the mountains of Macedonia. On the Kozhuf mountain range in a negative direction is the existence of a sheepfold with a significant number of cattle that slows the regeneration potential of the sites where cattle grazing occurs.

In the last decades, the scenarios are present to increase the upper treeline in vertical gradient through impact in parts of the forest ecosystems. This in correlation with climate change is evident.

Analysed data for movement of the upper treeline based on research undertaken at Kozhuf mountain range in southern part in Macedonia will be presented here.

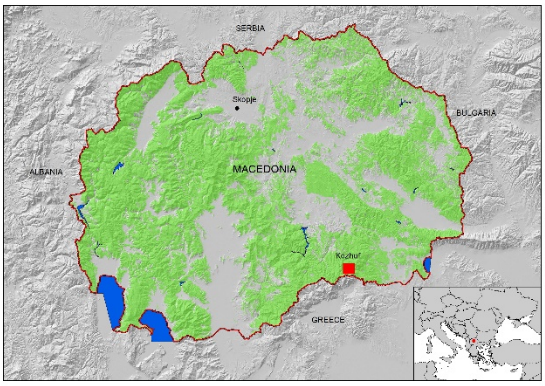

Figure 1: Investigation area – Kozhuf Mt. in the Republic of Macedonia

2 INVESTIGATION AREA

Kozhuf Mountain range is a situated in the southern part of Macedonia and northern part of Greece. It has extends in a southwest-northeast direction and has a rounded and undivided mountain ridge.

Kozuf Mountain is one of the oldest mountain massifs in Macedonia and from a regional aspect belongs to the Vardar geotectonic zone.

This research was conducted on central-southern part of the Balkan Peninsula in the northern parts of Kozuf mountain massif in the Republic of Macedonia (Figure 1). The vertical altitude of this research was in-between 1,400 and 1,800 (2,200) m in the altimontane and subalpine belt. According map of isohyets of Republic of Macedonia for Kozhuf Mt. average isohyets in subalpine belts more than 1,000 mm. According to short-term measurements made in the subalpine belt recently by the owner of the ski resort Kozhuf, the annual amount of precipitation is 1,220 mm. According to the same source, the depth of the snow cover varies depending on the altitude and the months in the winter shown on Table I. The heaviest snow cover was recorded in February [14]. Average temperature according to the Map of isotherm issued by the National Hidrometerological Service of Macedonia is 4℃ [31].

Table I: Depth of the snow cover on the Kozhuf Mt.

Month	Elevation	
	1,550–1,850 m	**1,850–2,200 m**
	Snow depth (cm)	**Snow depth (cm)**
November	35	45
December	50	60
January	70	80
February	90	110
March	40	60
April	30	40

3 METHODS

This paper attempts to define what changes occur with forest vegetation on the northern slopes of the Kozuf mountain range at upper treeline, and what the vertical distribution limit of forest vegetation is. For this purpose, we defined three sub-goals: defining the current upper treeline of the forest vegetation, distribution of forest communities on Kozhuf mountain range at the upper treeline, as well as modelling of possible upper treeline of the forest according to temperature indicators.

Comparative analysis method was used. The period of analysis covers 80 years. Different cartographic and written materials served as a basic material for analysis.

Study limitation: During the research were used various maps according to the scale and technique. Topographic maps from multiple time periods and methods of elaboration available for the Republic of Macedonia were used. Namely, the maps at a scale 1: 50,000 which were created on the basis of geodetic measurements during the thirties of the last century as a version of the same maps amended in the fifties of the last century, further topographic maps at a scale 1:25,000 created with photogrammetry in the seventies of the last century, topographic maps 1:25,000 issued by the Agency for Real Estate Cadastre of Republic of Macedonia in 2004 and latest state presented with satellite images from Google Earth as of 2014 [34]. In addition, written materials for forest vegetation from existing forest management plans elaborated for the region in different periods were used. Required sections of topographical maps were geo-referenced and digitalized as separate layers in AUTOCAD software. With layers switching, and with so-called “over-lay analysis” we got the differences in the distribution area in terms of upper treeline shifting.

Forest vegetation was surveyed with recording and mapping of vegetation types. The vegetation relevés were sampled according to the Zürich-Montpellier approach using the adapted Braun-Blanquet scale [32]. After drying and labelling the collected plant material was identified, using thereby a large number of floristic works – Flora of the (S) Republic of Macedonia [15–21]; Flora of Bulgaria [22–24]; Flora of SR Serbia [25], Mountain flora of Greece [26], Flora Helenica [27] and also some other floras and monographic works. The taxonomic nomenclature and the compliance of registered taxa of our vegetation relevés were done with the taxonomy and nomenclature of the species and lower taxa and their synonyms using the online EURO + MED PLANT BASE (database for vascular plants of Europe and the Mediterranean region – http://www.euromed.org.uk/). The vegetation type's development was observed, and from the tree measurement aspect, we provided the basic structural elements. The dynamics of populations and species movement was observed through these changes. Such data were compared with data from previous studies and management plans [33] related to the researched area.

We took soil samples from each investigated vegetation community on both mountain on different locations. Five (5) soil profiles were excavated and morphologically described on the field.

They were thereafter air-dried and taken to the laboratory at the Department of Soil Science – Institute of Agriculture, Ss. Cyril and Methodius University in Skopje, for analysis of chemical properties and some soil-forming factors.

Figure 2: Rendzinas on hard limestone and dolomites on plate limestone

4 RESULTS AND DISCUSSION

According to Mayer [2], the forest cover cannot thrive in areas, where in the period of four vegetation months (May–August) the precipitation is less than 50 mm, and relative humidity of the air is less than 50%. However, if precipitation during that period surpassed over 100 mm followed by a lower relative humidity of the air the forest cover can succeed. In this case, the relative lack of moisture in the air can be compensated if the level of groundwater is high. The forest cover does not thrive in any subpolar or alpine area where the average July temperature is less than 10°C.

In order to define up to which elevation the forest vegetation can thrive without the influence of external factors, according to temperature indicators, we designed the average July isotherm with different altitudes for the northern slopes of Kozhuf mountain range (Table IV). Regarding the July temperature in Macedonia, there are four thermally homogeneous areas differentiated with specific terms of the change in the average July temperature at different altitudes. The Kozhuf mountain range is covered in the first region according to which up to 500 meters, the mean July thermal gradient is 0.8/100, from 500 to 1,300 meters of altitude is 0.7/100 m, and over this altitude the gradient is 0,6/100 meters. For this purpose, we used data for climate monitoring stations in Gevgelija, Demir Kapija, and Kavadarci and climate data from the monitoring station at Ski resort Kozhuf open on the elevation of 1,625 meters.

According to own research on soil, in this locality there are more prevalent following soil types: rendzinas on hard limestone, brown forest soils and swampy gley soil. Three soil profiles were under forest vegetation of Austrian pine (*Pinus nigra*) and describe as rendzinas on hard limestone. One profile was under Scots pine (*Pinus sylvestris*) as a brown forest soils and one soil profile was excavated as swampy gley soil.

Figure 3: Brown forest soils (cambisol) on micashist

Table II: Chemical properties of the soils on Kozhuf Mt.

Number of samples	Locality	Type of soil	Horizon	Depth	$CaCO_3$	Humus	pH	
				(cm)	(%)	(%)	H_2O	MKCl
1	Chichi Kaja	Rendzinas on hard limestone and dolomites	A	5–15	31.94	21.22	7.6	7.2
			R					
2	Chichi Kaja	Rendzinas on hard limestone and dolomites	A	0–5	46.9	22.52	7.70	7.30
			R					
3	Adžibarica	Swampy gley soil	Gr	27–42	0	5.75	4.8	4
			R					
4	Adžibarica	Brown forest soils (cambisols)	A	2–20	0	11.91	4.6	3.6
			(B)v	20–78	0	1.84	5.25	4.3
			R					
5	Mala Rupa	Rendzinas on hard limestone	O	0–8	0	77.00	5.7	4.9
			A	8–25	1.49	4.79	6.3	5.7
			R					

Table III: Some soil-forming factors

Number of samples	Horizon	Depth (cm)	Vegetation	Altitude (m)	Parent material	Exposure	Inclination (%)	Occurrence of outcrops (%)	Stoniness (%)
1	A	5–15	*Seslerio-Pinetum nigrae*	1,670	plate limestone	West	30–40	0	0
	R								
2	A	0–5	*Seslerio-Pinetum nigrae*	1,670	plate limestone	West	40–50	13	0
	R								
3	Gr	27–42	*Fago-Pinetum sylvestris*	1,480	phyllite	0	0	3–5	3–5
	R								
4	A	2–20	*Fago-Pinetum sylvestris*	1,550	micashist	South	30–40		
	(B)v	20–78							
	R								
5	O	0–8	*Seslerio-Pinetum nigrae*	1,590	marbles	Northwestern	30–40	0	0
	A	8–25							
	R								

Figure 4: Upper treeline consist of Scots pine (*Pinus sylvestris*)

Figure 5: Initial stage of regeneration of *Pinus sylvestris* in heaths

After processing the collected soil samples, we obtained data for chemical properties shown on Table II, and of soils from the investigated forest communities and data for some soil-forming factors of soils in Table III.

From the data from the Table II, it can be seen that the soil samples in profile number 1 and 2 are very carbonate. Profile 3 and 4 are non-carbonate, except profile 5 that is less carbonate. The reaction of the soil is not high. Even in profile 1 and 2 the reaction is high in other profile is low. The reaction of the soil is very strongly acidic in profile 3 and 4 that is developed on silicate parent material. These are also the most favourable habitats for development of forest, mainly due to the deep solum and the physiologically active profile, i.e., the root of the tree penetrates deeper in the soil. The humus content in the examined soils is highest on profile 5 that is developed on marbles.

The presented soil properties show that the upper treeline of the forest conquers the terrains on a silicate parent material and brown forest soils (cambisols) faster than those on a carbonate one representing on rendzinas on hard limestone and dolomites.

The obtained results show that with increment of upper treeline of the forest vegetation, the most represented is forest community of Scots pine, *Fago-Pinetum sylvestris*, developed on silicate geological substrate and brown forest soils (cambisols), and relatively smaller areas are accounted to the forest communities of mixed forest of fir and beech, *Abieti borisii-regis - Fagetum*, and pure fir forest *Fago-Abietetum* also under brown forest soils (cambisols) and swampy gley soil, while the small area accounts for *Seslerio-Pinetum nigrae* and *Fago-Abietetum* forest communities on limestone geological substrate, which are developed on rendzinas on hard limestone and dolomites.

Regarding the treeline of the forest in 30 years of the last century and the present state, the greatest expansion is on western exposure, in this case up to maximum of 400 m. The forest vegetation expansion is smallest on eastern exposure.

The expansion of the western exposure is associated with topographic conditions prevailing on Kozhuf mountain range. Namely, these are flattened areas with deeper soils and with reduced impact human and animals where seeds of Scots pine committed a strong expansion, and as a heliophyte species, it expands its maximum limit (Figures 5 and 6).

The terrains on eastern exposure are steeper and rocky, and in combination with strong winds, they are slowing natural regeneration and suppress the greater increase of the upper treeline.

The southern exposure is covered the most difficult terrains, on shallow soil in its initial stage, where the Austrian pine as a pioneering species extend its upper limit.

It is important to note that progressive succession goes in the direction of deterioration of pastures with appearance of heaths of ass. *Bruckenthalio-Juniperetum*, and further connection of the heaths with high altitude forest communities.

On the surveyed sites there was no afforestation done in the past. The overall regeneration, and thus expansion of the upper treeline is of natural origin (Figure 4).

Based on a mean July isotherm constructed from the closest climate station, according to Mayer [2], the forest vegetation in the north parts of Kozhuf mountain massif can conquer the entire array, i.e., up to 2,250 meters elevation in our case for Kavadarci climate station shown in Table IV.

The current upper treeline is approximately 1,900 meters elevation. This is in addition to the size of the range, its northern orientation and the relative distance from the Aegean Sea.

Table IV: Mean July air temperature at 4 (four) monitoring stations

Climate monitoring stations							
Gevgelija		**Demir Kapija**		**Kavadarci**		**Ski Kozhuf**	
Elevation (m)	**°C**	**Elevation (m)**	**°C**	**Elevation (m)**	**°C**	**Elevation (m)**	**°C**
59	27.2	110	26	265	24.6		
159	26.4	210	25.2	365	23.8		
259	25.6	310	24.4	465	23		
359	24.8	410	23.6	565	22.2		
459	24	510	22.8	665	21.4		
559	23.2	610	22	765	20.6		
659	22.5	710	21.3	865	19.9		
759	21.8	810	20.6	965	19.2		
859	21.1	910	19.9	1,065	18.5		
959	20.4	1,010	19.2	1,165	17.8		
1,059	19.7	1,110	18.5	1,265	17.1		
1,159	19	1,210	17.8	1,365	16.4		
1,259	18.3	1,310	17.1	1,465	15.7		
1,359	17.6	1,410	16.4	1,565	15		
1,459	17	1,510	15.8	1,665	14.4	1,425	16.8
1,559	16.4	1,610	15.2	1,765	13.8	1,525	16.3
1,659	15.8	1,710	14.6	1,865	13.2	1,625	15.8
1,759	15.2	1,810	14	1,965	12.6	1,725	15.3
1,859	14.6	1,910	13.4	2,065	12	1,825	14.8
1,959	14	2,010	12.8	2,165	11.4	1,925	14.3
2,059	13.4	2,110	12.2	**2,265**	**10.8**	2,025	13.8
2,159	12.8	2,210	11.6	**2,365**	**10.2**	2,125	13.3
2,259	12.2	2,310	11	2,465	9.6	2,225	12.8
2,359	11.6	2,410	10.4	2,565	9	2,325	12.3
2,459	11	2,510	9.8			2,425	11.8
2,559	10.4					2,525	11.3

Figure 6: Upper stage of regeneration of *Pinus sylvestris* in heaths

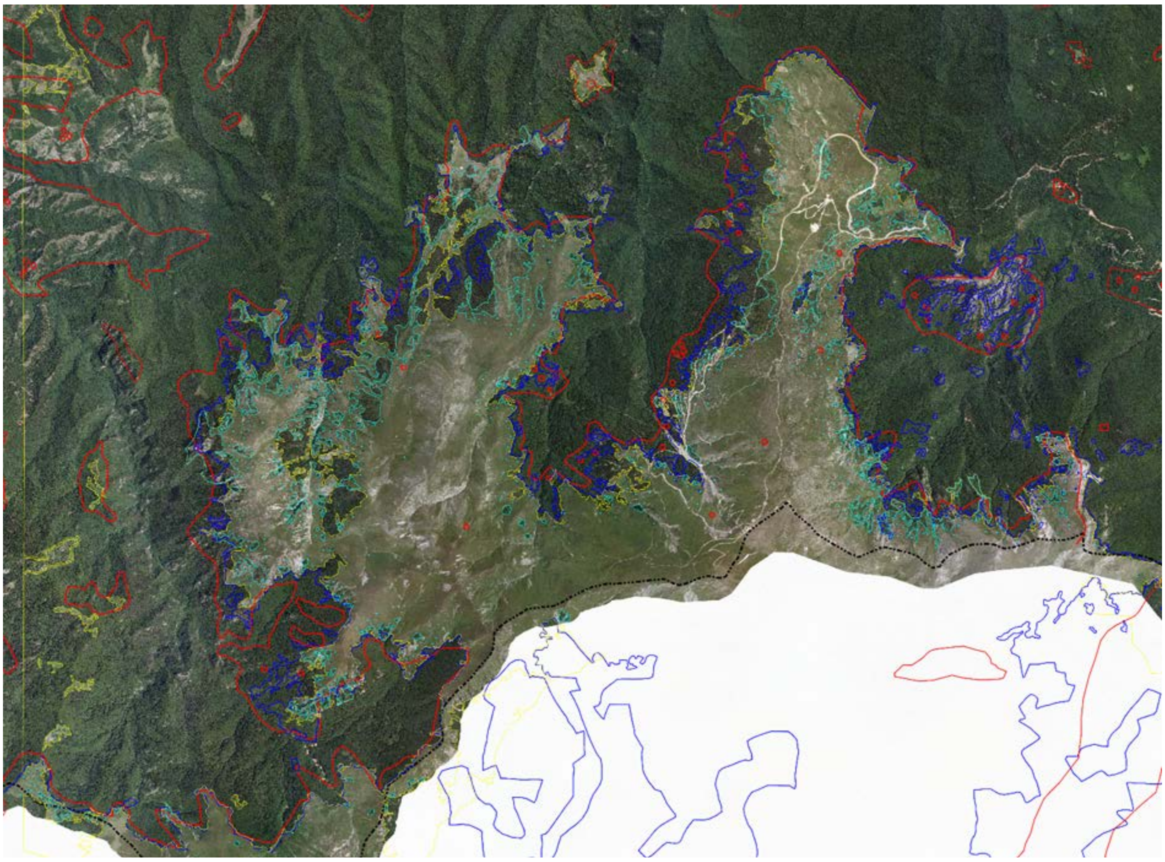

Figure 7: Expansion of forest vegetation at upper treeline in the north parts of Kozhuf mountain range through comparison of maps with time distance of 80 years on base of satellite images from Google Earth

The red line on the map shows a border line from map at a scale 1:50,000, which were created on the basis of geodetic measurements during the thirties of the last century as a version of the same maps amended in the fifties of the last century; Blue line represent a border line from a topographic maps at a scale 1: 25,000 created with photogrammetry in the seventies of the last century; Open blue line represent, a border of a line of the topographic maps 1:25,000 issued by the Agency for Real Estate Cadastre of the Republic of Macedonia in 2004, and latest state presented with satellite images from Google Earth as of 2014.

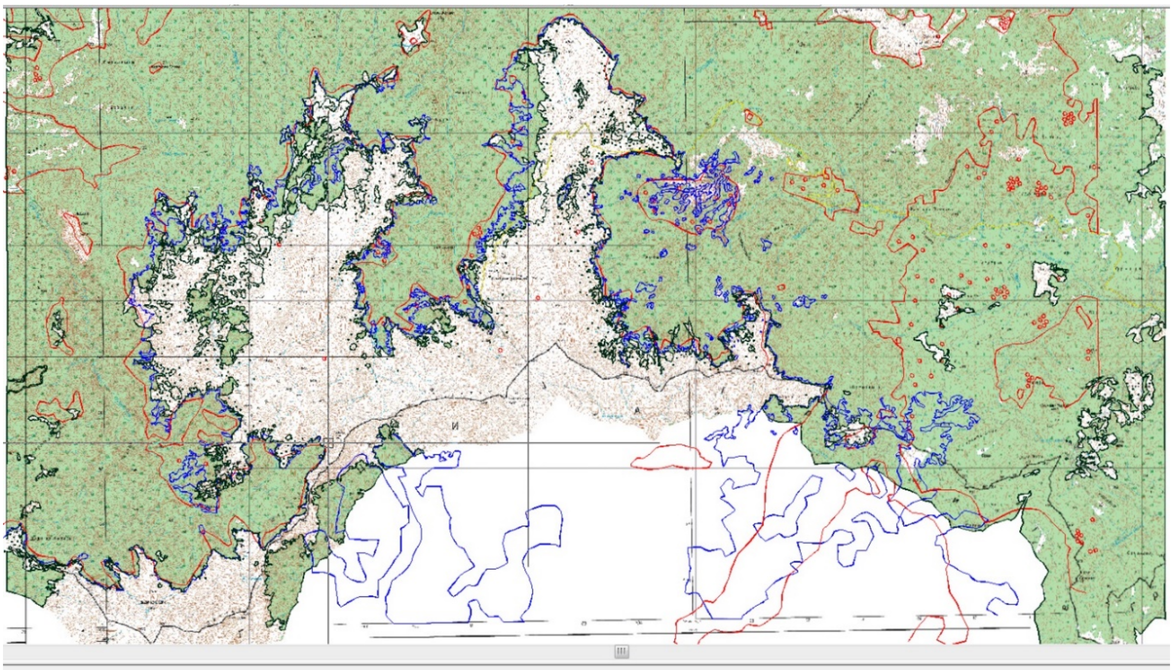

Figure 8: Expansion of forest vegetation at upper treeline in the northern parts of Kozhuf mountain range through comparison of maps with time distance of 80 years shown on topographic maps at a scale 1:25,000

5 CONCLUSIONS

According to own research on soil and studies presented in the soil map of Macedonia, in this locality there are more prevalent following soil types: rendzinas on hard limestone, brown forest soils and swampy gley soil.

Three soil profiles were under forest vegetation of *P. nigra* and describe as rendzinas on hard limestones. One profile was under *P. sylvestris* as a brown forest soils and one soil profile was excavated under *P. sylvestris* as swampy gley soil.

The obtained results show that with increment of upper treeline of the forest vegetation, the most represented is forest community of Scots pine *Fago-Pinetum sylvestris* developed on silicate geological substrate and brown forest soils (cambisols), and relatively smaller areas are accounted to the forest communities of mixed forest of fir and beech *Abieti borisii-regis – Fagetum*, and pure fir forest *Fago-Abietetum* also under brown forest soils (cambisols) and swampy gley soil, while the small area accounts for *Seslerio-Pinetum nigrae* and *Fago-Abietetum* forest communities on limestone geological substrate which are developed on rendzinas on hard limestone and dolomites.

Regarding the treeline of the forest in 30 years of the last century and the present state, the greatest expansion is on western exposure, in this case up to maximum of 400 m (Figures 7 and 8). The forest vegetation expansion is smallest on eastern exposure.

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