IMPACT OF CLIMATE CHANGE SCENARIOS ON THE EXTEND OF PLANT HARDINESS ZONES OF SOUTH WEST ALBANIA

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Abstract

Albania is part of the Mediterranean region which is considered at high risk regarding climate change. The climate changes are expected to have greater impact on high relief areas like South West Albania. In this study plant hardiness zones are used to analyze the impact of different scenarios of climate change in their spatial extend. Representative Concentration Pathways (RCPs) from IPPC5 climate scenarios are used for climate modeling. The distribution and extent of plant hardiness zones was affected by the IPPC5 climate scenarios. Plant hardiness zone 10a experienced the greatest increase. In addition, a plant hardiness zone (10b) new to the current climate scenario appeared. The disappearance of some of the existing plant hardiness zones presents challenges for the survival of some plant species. On the other hand the appearance of new plant hardiness zones would affect the plant distribution in the area and presents opportunities for introducing new species.

Key words: *climate change, plant hardiness zones*

1. INTRODUCTION

The method of Plant hardiness zones is one of the most well-known methods to assess the survival and adaptability of plants to climate fluctuations. It is widely used because the maps of plant hardiness zones are simple, useful and practical (Christopher Daly et al. 2012; Daniel et al., 2007, 2014; Widrlechner et al., 2012; McKenney et al., 2014). Hardiness zone maps based on the USDA model have been developed for many parts of the world, including Australia (Dawson, 1991), China (Widrlechner, 1997), Europe (Heinze and Schreiber, 1984), Japan (Hayashi, 1990), South Africa (Pienaar, 1996), Ukraine (Widrlechner et al., 2001), and Turkey (Yilmaz and Tolunay, 2012). The wide use of this classification provides advantages in facilitating transferability of horticultural species with other countries or the region.

In a previous study we developed, for the first time, the plant hardiness zone map of Albania. We studied the climate impact on the distribution of some plant species in Albania by comparing the current climate using the WorldClim data (http://www.worldclim.org/) for the period 1950-2000, with future climate scenarios using downscaled IPPC5 Coupled Model Intercomparison Project Phase 5 (CMIP5) data (IPCC, 2013). The measured mean Tmin and absolute Tmin from climate stations were highly correlated, with a mean difference of -7.3 0C. The distribution of the mean difference did not show any spatial bias and allowed for the assessment of the influence of future climate scenarios on the distribution of plant hardiness zones. The IPPC5 climate scenarios affected the distribution and extent of plant hardiness zones. The disappearance of relatively cold plant hardiness zones and the appearance of relatively warmer plant hardiness zones under rcp2650/2670 IPPC5 climate scenarios indicated a general warming trend. The shifts in spatial distribution of plant hardiness zones related to climate change present opportunities for growing new species; however, more studies are needed to assess the interactions between climate change and management practices for the new species.

Albania is part of the Mediterranean region which is considered at high risk regarding climate change. The climate changes are expected to have greater impact on high relief areas like South West Albania. (de Dios et al., 2007). A change in climatic limits implies that new prospects and/or threats to land use changes could develop. Therefore, exploration of climate change impacts on plant hardiness zones

could identify areas where the range of land use options is expected to change and, more explicitly, whether the inherent flexibility in land use options is increasing or decreasing.

The above mentioned study gives a general overview for Albania at the national level but it is difficult to be used by farmers, traders or other end users. The objective of this study is to bring the plant hardiness zones at the village level. So firstly we develop the classification of plant hardiness zones at village level for South West part of Albania and then we assessed the impact of future climate scenarios on the distribution and extent of plant hardiness zones.

The distribution and extent of plant hardiness zones was affected by the IPPC5 climate scenarios. Plant hardiness zone 10a experienced the greatest increase. In addition, a plant hardiness zone (10b) new to the current climate scenario appeared in South West of Albania for the most aggressive climate scenario. The disappearance of some of the existing plant hardiness zones presents challenges for the survival of some plant species. On the other hand the appearance of new plant hardiness zones would affect the plant distribution in the area, especially horticultural species, and presents opportunities for introducing new species.

2. STUDY AREA CHARACTERISTICS

Albania has a diverse climate that fluctuates within short distances due to its mountainous and high-relief characteristics. The mean elevation is about 750 m and varies from 0 to 2,700 m above sea level. The South west part of Albania is mainly covered by Vlore prefecture. It is located in the south of Albania and forms the Albanian Riviera. The southeastern part of prefecture borders Greece. Vlore prefecture is one of the 12 prefectures of Albania. The population according to 2011 census was 374,168, in an area of 2706 km². Its capital is the city of Vlore. The three main cities are Vlore, Saranda and Delvina. Since the 2015 local government reform, the prefecture consists of the following 7 municipalities: Delvinë, Finiq, Himarë, Konispol, Sarandë, Selenicë and Vlorë.[Ligji] The municipalities are composed by the following 26 public administrative units: Aliko, Armen, Brataj, Delvinë, Dhivër, Finiq, Himarë, Horë-Vranisht, Konispol, Kotë, Ksamil, Livadhja, Lukovë, Markat, Mesopotam, Novoselë, Orikum, Qendër Vlorë, Sarandë, Selenicë, Sevaster, Shushicë, Vergo, Vllahinë, Vlorë, Xarrë. Vlore prefecture consists in total of 205 towns and villages.

On average, the warmest months are July and August which corresponds with dry periods also. Most rainfall is seen in January, February, October, November and December. On average, the coolest month is January, December is the wettest month (Hydro-meteorological Institute, 1988).

3. MATERIALS AND METHODS

For the classification of the territory of South West Albania the range of temperature proposed by USDA is used. This is based on the influence of low temperatures in plant community development and distribution. The temperature range is divided in plant hardiness zones and so in total there are 12 hardiness zones. Table 1 shows the temperature range for South West of Albania. The amplitude of minimum temperatures in this area is in the range of plant hardiness zones from 8 to 10. Each zone is divided in subzones “a” and “b”, where subzone “b” is wormer than “a”.

Changes in spatial distribution extent of various plant hardiness regions and their trend with climate change were assessed using ArcMap software (ESRI, 2010). The gridded maps of monthly minimum temperatures from the WorldClim data were downloaded and clipped to the extent of the study area. The grids were re-projected and classified based on plant hardiness zones. The area extent of plant hardiness zones was calculated for the current climate (1950-2000 period) and future climate scenarios (rcp 26, 45, 60 and 70) for 2041-2060 and 2061-2080 periods that were adjusted to reflect plant hardiness zones.

After creating all climate change scenarios an analysis is done to see what are the villages that are more affected by climate change. Meanwhile, to have an idea of the importance of any area regarding agriculture and plant communities in general, we analyzed the land cover for all administrative units.

Table 1. Plant hardiness zones based on absolute minimum air temperatures

Severity Class		From	To
8	a	−12.2 °C (10 °F)	−9.4 °C (15 °F)
	b	−9.4 °C (15 °F)	−6.7 °C (20 °F)
9	a	−6.7 °C (20 °F)	−3.9 °C (25 °F)
	b	−3.9 °C (25 °F)	−1.1 °C (30 °F)
10	a	−1.1 °C (30 °F)	+1.7 °C (35 °F)
	b	+1.7 °C (35 °F)	+4.4 °C (40 °F)

This is done based on the land cover prepared by the National Agency of Environment using ArcGIS. From more than 40 land use categories of land cover we created 5 most important groups: Urban and industrial areas, Urban green area, agricultural area, natural area and water bodies.

4. RESULTS AND DISCUSSION

4.1 Land cover for South West part of Albania

Table 2 gives the structure of land cover of Vlore prefecture for all its public administrative units. It is derived from the land cover map of Albania, prepared by the National Agency of Environment using ArcGIS. Land cover is organized in 5 categories: Urban and industrial areas, Urban green area, agricultural area, natural area and water bodies. Among the public administrative units that rely mainly on agriculture are: Aliko, Armen, Finiq, Novosele, Qender Vlore, Selenice, Shushice and Vllahine.

Some other public administrative units have important natural resources; Brataj, Delvine, Dhiver, Himare, Hore- Vranisht, Konispol, Kote, Livadhja, Lukove, Markat, Mesopotam, Novosele, Sarande, Vergo and Zarre.

It is seen that agricultural areas cover from 10 to 83% of the territories of public administrative units of the South West part of Albania, while natural areas cover from 3 to 86%. Both agricultural and natural areas cover most of the territory of all administrative units. Urban areas cover most of the territory just for the capital prefecture city of Vlore.

This is an area with relatively good water resources. They are important especially for public administrative units of Ksamil and Novolesele. These areas may be affected by expected increase in water level also. So in considering different climate change scenarios should plan changes in water level.

From the table 1 it is seen that urban green areas are evidenced just for the city of Vlore. This is because of relatively low resolution of land cover and reflects the need of a more accurate study in the future, but it reflects the need for more urban green areas also. The distribution of land cover should be considered in analyzing the risk and potential of climate change scenarios. The main areas with large share of agricultural land like Aliko, Armen, Finiq, Novoselë, Qendër, Selenicë, Shushicë belong to plant hardiness zone 9b and according to clime change scenarios analyzed in the next sections are expected to have significant shifts from plant hardiness zone 9 to 10. This change may create problems the productivity of several agricultural plants. From the other side research and experimentation should begin to test the possibility of introducing new crops also. So Pistacia vera, Acca sellowiana, and Actinidia deliciosa are currently cultivated in Albania but their potential cultivation area would increase in the future according to all climate change scenarios analyzed in this study. Musa acuminate, Persea americana, and Ananas comosus could potentially be cultivated, especially under the most aggressive climate change scenarios.

Table 2. The structure of land cover for South West part of Albania

Municipality	Structure of land cover (%)				
	Urban and industrial area	Urban Green area	Agricultural area	Natural area	Water bodies
ALIKO	7.15	0.00	63.83	27.75	1.27
ARMEN	2.99	0.00	60.76	34.71	1.54
BRATAJ	2.42	0.00	24.64	72.94	0.00
DELVINË	6.04	0.00	31.37	62.59	0.00
DHIVER	2.70	0.00	11.00	86.30	0.00
FINIQ	13.76	0.00	83.15	3.09	0.00
HIMARË	2.14	0.00	10.26	85.29	2.31
HORË-VRANISHT	0.24	0.00	14.02	85.73	0.00
KONISPOL	5.94	0.00	18.32	75.75	0.00
KOTË	1.49	0.00	19.51	79.00	0.00
KSAMIL	9.93	0.00	25.94	46.56	17.57
LIVADHJA	3.90	0.00	20.35	75.75	0.00
LUKOVË	1.52	0.00	14.39	82.77	1.32
MARKAT	3.41	0.00	11.46	83.85	1.27
MESOPOTAM	3.05	0.00	16.91	80.05	0.00
NOVOSELË	5.37	0.00	52.14	22.92	19.57
ORIKUM	1.59	0.00	13.66	81.82	2.93
QENDËR	5.99	0.00	67.60	19.23	7.18
SARANDË	18.44	0.00	23.60	54.82	3.13
SELENICË	6.26	0.00	69.49	19.86	4.39
SEVASTËR	0.00	0.00	25.14	73.90	0.96
SHUSHICË	4.21	0.00	83.37	11.31	1.11
VERGO	1.19	0.00	20.09	78.72	0.00
VLLAHINË	0.89	0.00	52.05	45.49	1.57
VLORË	52.88	1.48	29.75	10.56	5.33
XARRË	1.81	0.00	30.94	61.98	5.27

4.2 Plant hardiness zones in South west of Albania

Figure 1 shows the plant hardiness zones for South West of Albania. The white borders in this figure represent all the public administrative units of Vlore Prefecture. It is seen that most of the territory of Vlore prefecture is covered by plant hardiness zone 9. It has the majority of the areas in most of public administrative units, excluding Novosele and Shushice, where a larger presence of plant hardiness zone 10a was verified. Comparing the area different plant hardiness zones cover all over the territory of Vlore prefecture, zone 10 is followed by plant hardiness zone 8 (mainly 8 b). Plant hardiness zone 8 is verified to cover mainly hilly and maintain areas relatively far from the impact of sea zone. In fact, in the territory of Vlore prefecture we could verify some very small areas of zone 7 also. They are in the picks of the highest mountains without any interest for agriculture development but with interest for biodiversity resources of course. This zone doesn't exist in any of future scenarios of climate change and this fact may present risks for the survival of special plant species so specialized studies in this area would be of interest.

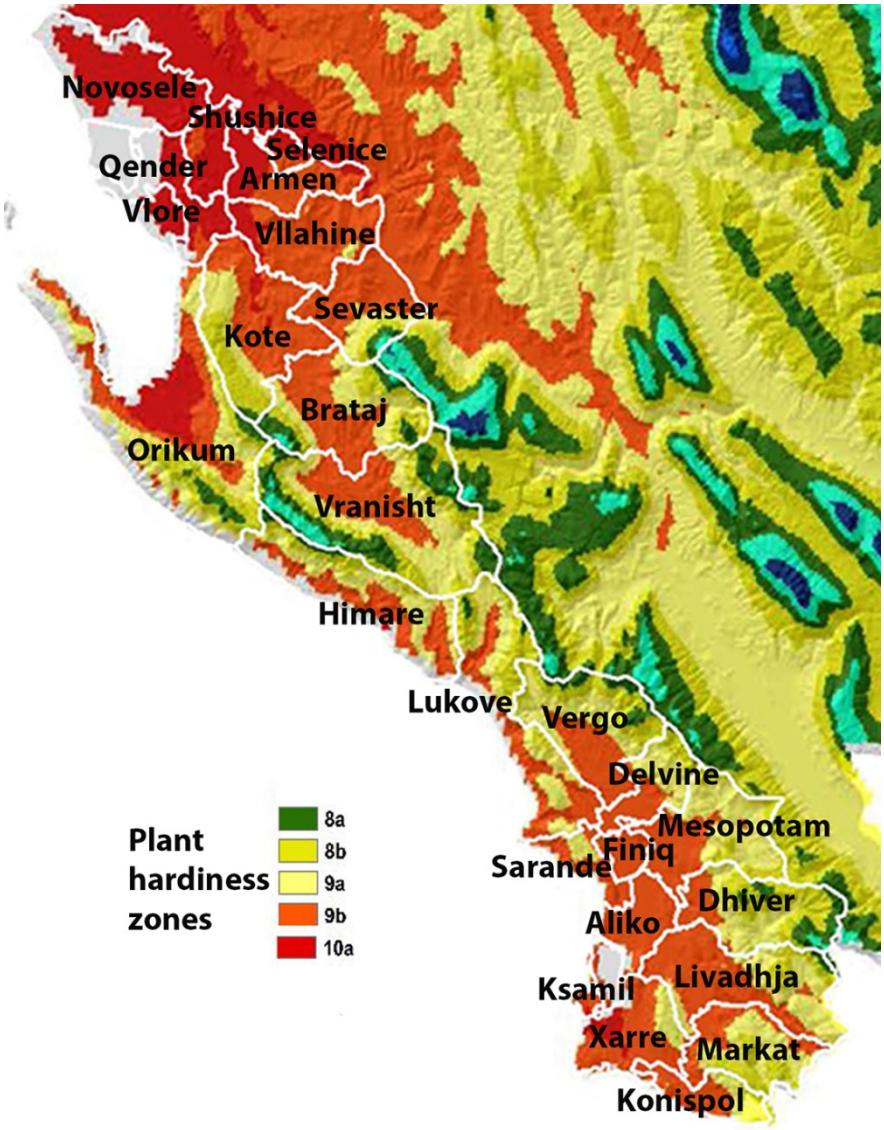


Figure 1. Plant hardiness zones of South West Albania

Table 3 gives the distribution of all villages of Vlore prefecture according to plant hardiness zones. This table can be used by anyone who is interested to know what is grown or may be grown in any village of Vlore prefecture.

4.3 The impact of climate change scenarios on plant hardiness zones of South West Albania

The impact of climate change scenarios is done by comparisons between different forcing scenarios from downscaled IPPC5 Coupled Model Intercomparison Project (CMIP5) (Moss et al., 2008). In this way four different representative concentration pathways (RCPs) greenhouse gas (GHG) scenarios (rcp26, rcp45, rcp60, and rcp85) for two time periods: 2050 (average for 2041-2060) and 2070 (average for 2061-2080) are considered (Fig. 2 and 3).

Figure 2 presents the expected changes of plant hardiness zones for the period of 2041-2060 while figure 3 shows the expected changes for the period 2061-2080. In these maps the geographic position of all villages of Vlore prefecture are shown also.

The shifts in spatial pattern distribution of plant hardiness zones present risk for the survival of some plant species but also present opportunities for introducing new horticultural plants. From the figure 2

it can be seen that for the less aggressive scenario, just few changes may be expected during the near future, but the most aggressive scenarios seem to present real challenges.

Table 3. Alphabetic list of Vlore prefecture villages according to actual plant hardiness zones

Zone 8a	Çorraj
Zone 8b	Tërbaç, Brataj, Kuç, Buronjë , Kuç, Vërmik, Bashaj, Matogjin, Tatzat, Leshnicë e Sipërme, Llupsat, Dishat, Vërvë, Shalës, Markat, Ninat, Janjar
Zone 9a	Bistricë, Borsh, Cerkovicë, Çiflik, Dhërmi, Dhivër, Dhrovjan, Dhrovjan, Fterrë, Fushë, Gjilekë, Grazhdan, Iliaz, Janicat, Kakodhiq, Karroq, Konispol, Kostar, Krongj, Kudhës, Lapardha, Lefterhor, Lepenicë, Leshnicë e Poshtme, Lukovë, Malas, Malcan, Mazhar, Mazhar, Nivicë, Palasë, Pilur, Piqeras, Ploçë, Qazim Pali, Qeparo, Qeparo fshat, Ramicë, Rumanxë Sasaj, Shëndre, Shënvasil, Sirakat, Sirakat, Vagalat, Velahovë, Velahovë, Vodicë, Vranisht, Vuno, Zminec, Sopot
Zone 9b	Aliko, Amonicë, Ardhasovë, Bajkaj, Bamatat, Bistricë, Blerimas, Bolenë, Brajlat, Brajlat, Bregas, Bunavi, Buronjë, Çlirim, Çukë, Dermish, Drashovicë, Dritas, Drithas, Dukat Fshat, Dukat, Dushkarak, Finiq, Fitore, Fushë Vërri, Gërnec, Gjashtë, Gjorm, Golimbas, Gravë, Gumenicë, Hadëraj, Halo, Hysoverdhë, Jermë, Kalasë, Kalcat, Kallarat, Kaninë, Karahaxhë, Karbunarë, Kardhikaq, Kocul, Kodër, Komat, Kopaçez, Kostar, Kotë, Krane, Krane, Kropisht, Ksamil, Kulluricë, Lefter Talo, Lezhan, Livadhja, Livinë, Livinë, Llazat, Mallkeq, Mavrovë, Mavrovë, Mekat, Memoraq, Mërtiraj, Mesaplik, Mesopotam, Metoq, Mursi, Muzinë, Navaricë, Neohor, Pandalejmon, Pecë, Penkovë, Petë, Pllakë, Qafë Dardhë, Qesarat, Rahullë, Rexhepaj, Rromës, Rusan, Selenice, Sevaster, Shelegar, Shkallë, Shkozë, Sopik, Stjar, Tremul, Vajzë, Vanë, Velçë, Vezhdanisht, Vllahat, Vllahinë, Vrion, Vurgu i Ri, Xarrë, Llakatund.
Zone 10a	Akërni, Aliban, Armen, Babicë e Madhe, Babicë e Vogël, Beshisht, Bestrovë, Bishan, Çeprat, Cerkovinë, Delisuf, Dëllenjë, Dhërmi, Fitore, Grabian, Himarë, Hoshtimë, Iliaz, Kërkovë, Lubonjë, Mesarak, Mifol, Nartë, Novoselë, Orokum, Panaja, Peshkëpi, Picar, Poro, Risili, Shëndëlli, Sherishtë, Shushicë, Skrofotinë, Tragjas, Treblovë, Trevllazër, Vrinë, Xhyherinë, Zvërnec.

Table 4 shows haw the number of villages for specific plant hardiness zones is expected to change if the moss aggressive scenario happens. In this case, even in the near future, zone 8 may disappear completely. It would be a really dramatic change with serious consequences for the productivity of agricultural plants and for biodiversity resources.

Table 4. Distribution of the number of villages for the most aggressive scenario

Period	Plant Hardiness zones					
	Zone 8a	Zone 8b	Zone 9a	Zone 9b	Zone 10a	Zone 10b
Actual	1	17	47	100	40	0
2041-2060	0	0	10	47	108	40
2061-2080	0	0	1	42	78	84

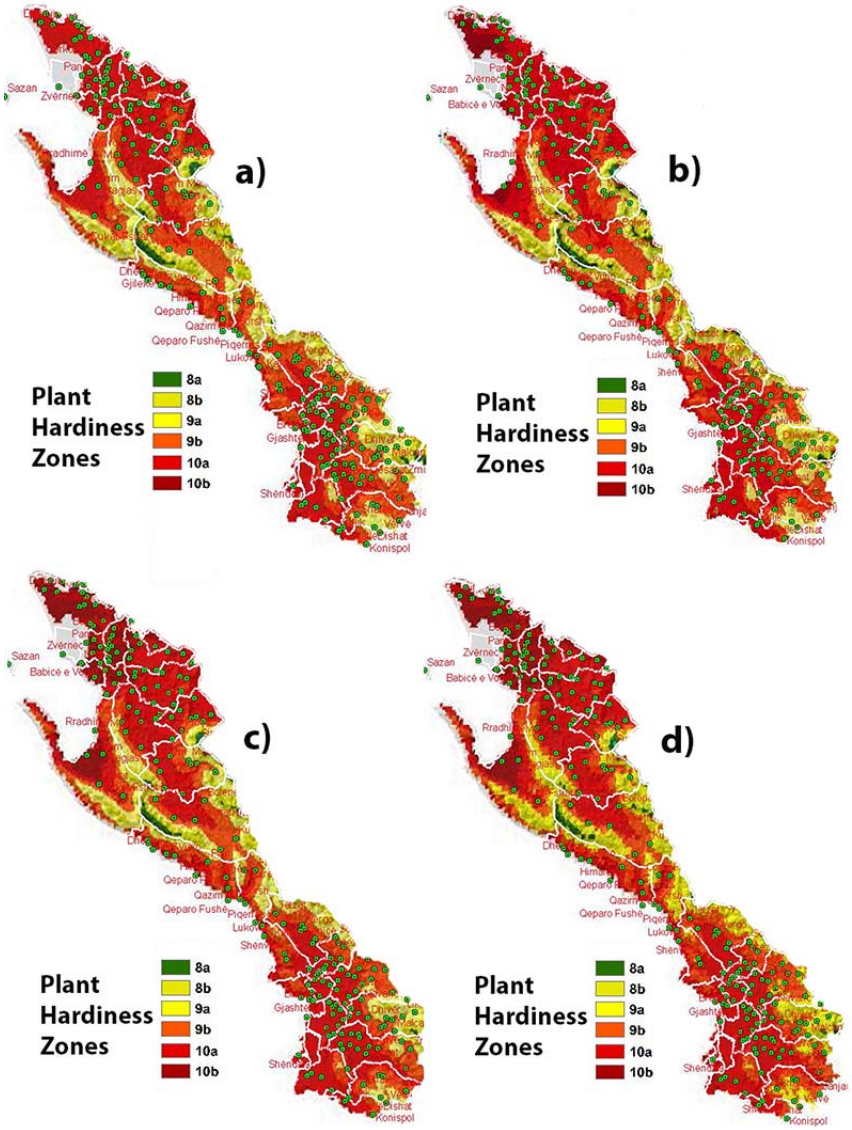


Figure 2. Expected changes of plant hardiness zones for the period of 2041-2060 for four different representative concentration pathways (RCPs) greenhouse gas (GHG) scenarios (a- rcp26, b- rcp45, c- rcp60, and d- rcp85).

If the most aggressive scenario of climate change continues in the long period (2080) the above mentioned changes will go deeper. If we see Figure 3 and table 4, it is easy to verify that in this case, complete public administrative units shift from a lower plant hardiness zone to a higher plant hardiness zone. Actually the villages of South western part of Albania that belong to zone 9, represent more that 70% of the total number. In the near future of the most aggressive scenario of climate change (rcp85) this number may drop to less than 30 % and until 2080 it may go down to 20%.

Meanwhile a significant increase of plant hardiness zone 10 was verified both periods of study (2041-2060 and 2061-2080). Actually this zone is just in less than 20% of all villages, (just the cooler subzone 10a), but in the period 2041-2060 the villages under sub zone 10a may represent more than 50% and the appearance of sub zone 10b is verified. More over sub zone 10b may become dominant if the most aggressive scenario continues until 2061-2080. In this case more than 75% of the villages of Vlore prefecture would be under plant hardiness zone 10.

This would present very dramatic challenges for the sustainability of ecosystems.

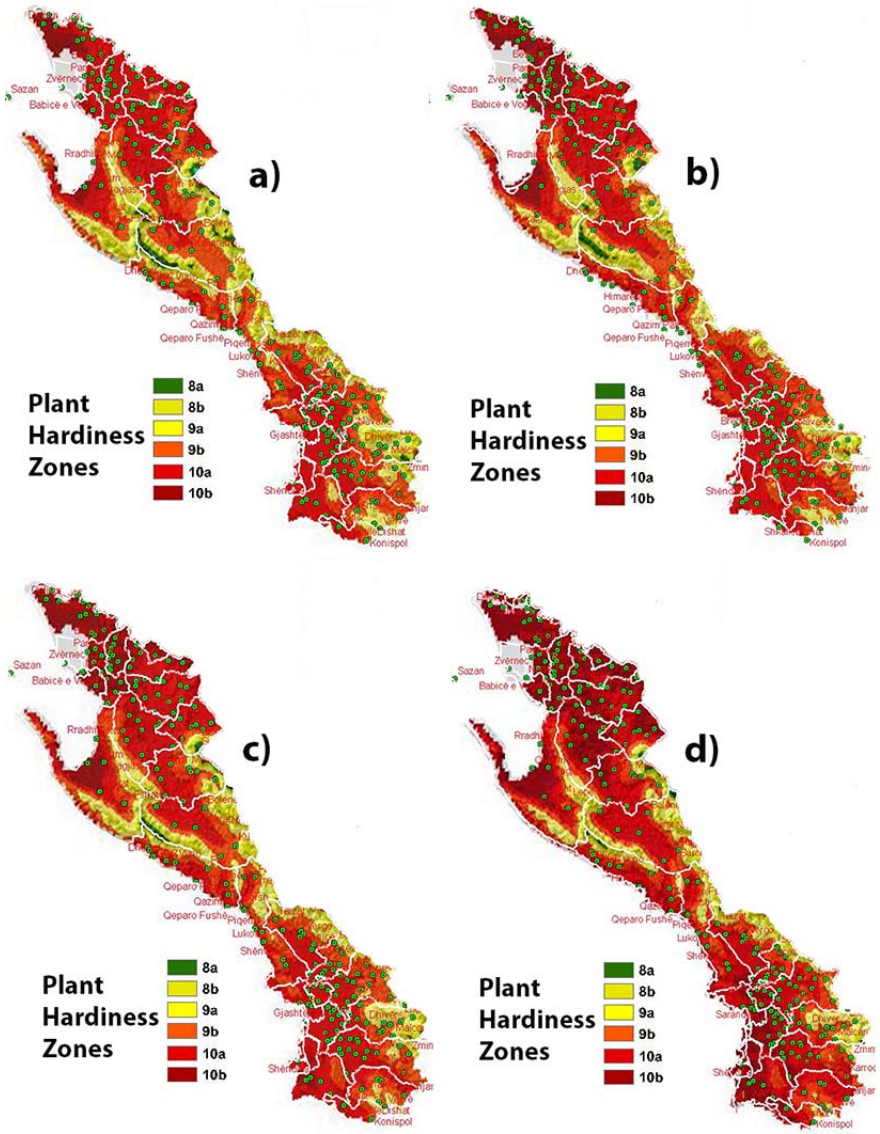


Figure 3. Expected changes of plant hardiness zones for the period of 2061-2080 for four different representative concentration pathways (RCPs) greenhouse gas (GHG) scenarios (a-rcp26, b-rcp45, c-rcp60, and d- rcp85).

5. CONCLUSIONS

The climate changes are expected to have great impact in South West of Albania. This is illustrated by the distribution and extent of plant hardiness zones. Plant hardiness zone 10a experienced the greatest increase. In addition, a plant hardiness zone (10b) new to the current climate scenario appeared in South West of Albania for the most aggressive climate scenario. The disappearance of some of the existing plant hardiness zones presents challenges for the survival of some plant species. On the other hand the appearance of new plant hardiness zones would affect the plant distribution in the area, especially viticulture and presents opportunities for introducing new species. If the most aggressive scenario of climate change continues in the long period (2080), complete public administrative units would shift from a lower plant hardiness zone to a higher plant hardiness zone. Actually the villages of South western part of Albania that belong to zone 9, represent more that 70% of the total number. In the near future of the most aggressive scenario of climate change (rcp85) this number may drop to less than 30 % and until 2080 it may go down to 20%.

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