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The dynamics of land cover changes and the impact of climate change on ultramafic areas of Albania

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ABSTRACT

Ultramafics cover quite large areas in Albania. The purpose of this study was to identify land cover changes and the impact of climate scenarios on some of the plant species of ultramafic substratum in Albania. The CORINE Land Cover (2000-2018), the plant hardiness map and Map of Albania's ultramafics were used for this study. The plant hardiness zones map was used to study the impact of climate change scenarios for the ultramafics substratum. Analysis showed that the surface of ultramafic substrates in Albania containing between 10-43% MgO occupy about 11% of the total area of Albania. The majority of this area is divided among the following districts: Puke (76.54%); Fushe Arrez (31.15%); Bulqiza (28.78%); Prrenjas (28.61); Librazhd (26.51%); and Tropoja (26.39%). The major land cover categories in ultramafic area for 2000 were dominated by forest and semi natural areas with 92.22% followed by agricultural with 7.45% and artificial surfaces (0.16%), water bodies (0.15%), and wetlands (0.02%). Over an 18 year period, agricultural areas were converted to other land use categories at the rate of 202 ha year^{-1}, whereas the forests decreased by 2884 ha year^{-1}. The analysis of the impact of climate change scenarios showed that the potential area of *Alyssium murale* Waldst. and Kit and *Gentiana lutea* L. could decrease by as much as 47.7% by 2070, for the most aggressive climate scenario. The rate of change in land cover and the impact of climate change on the distribution of certain plant species are important to assess soil and plant resource degradation and plan for a sustainable management and conservation of natural resources of ultramafic ecosystems.

Keywords: land cover; serpentine soil; climate change.

INTRODUCTION

The need for monitoring and measuring changes in land cover over large areas using Geographic Information systems (GIS) has been well recognized (Rigge et al., 2013; Vogelmann et al., 2009; Cegielska, 2018). Geographic Information systems are important tools for assessing and monitoring land use and land cover (LULC) changes and their environmental impacts over time utilizing space borne imagery.

Ultramafic outcrops represent less than 1% of the terrestrial surface. 'Ultramafic' is synonymous with 'magnesium' or 'serpentine', and is used to describe igneous or metamorphic rocks that contain more than 90% mafic minerals (Le Bas and Streckeisen, 1991), with less than 45% silica (SiO_2) (Williams et al., 1954). Soils forming on either peridotite or serpentinite (ultramafic) parent materials are commonly called serpentine soils (Alexander, 2004). Ultramafic substrates share a number of chemical characteristics including a low Ca/Mg ratio with Ca at significantly lower concentrations than in other soils. They also frequently contain elevated levels of heavy metals, such as Fe, Mn, Ni, Cr and Co, which could induce toxicity for most of the plants (Brooks, 1987; Proctor and Woodell, 1975; Shallari et al., 1997; Bani et al., 2010). Ultramafic soils were studied because of their economic importance related to the genesis of nickeliferous laterites but also because of their role in trace metal geochemistry (Gleeson et al. 2003), Becquer et al., 2006; Bani et al., 2014; Kierczziak et al., 2016; Echevarria, 2018). Serpentine soil are often deficient in essential plant nutrients such as N, K and P (Brooks, 1987; Proctor and Woodell, 1975) making them unique with respect to plant biodiversity.

The vegetation of serpentine soils, adapted to the chemical, physical, and biotic components of the edaphic factor, display what Jenny (1980) coined the "serpentine syndrome," which includes resistance to Ca, K and P deficiencies and tolerance to heavy metals (Whittaker, 1954; Proctor and Woodell, 1975; Brooks, 1987). The existence of Nickel hyperaccumulator plants (Jaffré et al., 1976) is an example of Ni phytoavailability in ultramafic soils. Hyperaccumulator plants that grow in serpentine soil can be effective in phytomining from contaminated or mineralized soils (Chaney et al., 2007; Tang et al., 2012; Bani et al., 2014).

Ultramafic (serpentine) substrate covers large areas in the Balkans, more than in any other part of Europe. They extend from north east and south east Albania to the serpentine formations of Epirus and Thessalia in Greece and south west and south central Bulgaria (Stevanović et al 2003; Pavlova et al., 1998; Pavlova, 2001). Serpentine substrate, flora and vegetation of Albania has attracted the attention of many researchers, primarily because of its exceptionally rich flora, its remarkable levels of species and endemism (Stevanović et al., 2003; Cecchi et al., 2018; Echevarria et al., 2018) and the presence of extensive areas with ultramafic substrates (Massoura et al., 2006; Bani et al., 2014; Echevarria, 2018) where many species have adapted to the very special and highly selective edaphic conditions (Shallari et al., 1997; Bani et al., 2018; Chaney et al., 2018). Ultramafic substrate of Albania is characterized by a high metallogenic potential. The LULC changes in ultramafic regions of Albania are the main factors contributing of their degradation. After the 1990 the human activities in Albania have been very aggressive causing changes in the physical, biological or chemical conditions of the resources (Quentin et al., 2006; Bahrami et al., 2010; Kizilkaya and Dengiz, 2010). Most of ultramafics in Albania are covered by natural forest and grass land but due to deforestation, overgrazing, and illegal settlements significant parts of those areas have become barren (Sallaku et al., 2009). Since ultramafic environments have unique physical conditions and a specific flora, changes in land use and land cover may be irreversible.

The main goal of this study was to assess the status of the ultramafic (serpentine) environment regarding changes in LULC and distribution of plant species affected by these changes and climate scenarios. The specific objectives of the study were; (i) to asses changes in LULC for 2000, 2006, 2012 and 2018; and (ii) estimate the impact of climate change scenarios on the geographical distribution and abundance on some of the plant species.

MATERIAL AND METHODS

Description of study area

The Albanian ophiolites are restricted to the "Dinaride-Albanide-Hellenide" ophiolite belt and comprise mainly ultramafics. The Albanian ultramafics represents an elongated belt from south to the north, about 250 km long and 30-50 km wide (Milushi, 2015). It covers an area of about 4300 km^2 or 1/7 of the territory of Albania. The belt represents a synform structure (Nicolas et al., 1999) with two ultramafic massif ranges on the western and eastern sides, often known as western and eastern ultramafic belts, whereas in the central part the oceanic crust sequences are developed. According to our estimations, less than 18% of ultramafic soils occur at an elevation less than 500 m above sea level, about 40% of these soils occur at an elevation between 500 and 1,000 m above sea level while about 42% occurs at an elevation above 1,000 m above sea level.

The ultramafics massifs in Albania are: Tropoja; Krrabi, Puka, Kukes, Lure, Gomsiqe, Skenderbeu, Bulqize, Shpati, Shebenik, Devolli, Vallamare, Morava, Biticka, Voskopoja and Rehove. Figure 1 shows the area distribution of ultramafics in Albania.

Data Sources and Processing

The main data used in this study are: (i) CORINE Land Cover (CLC 2000-2018) data downloaded from https://land.copernicus.eu/pan-european/corine-land-cover; compiled by the European Environment Agency (EEA) as part of the European Union Copernicus programme and implemented by countries under the guidance and quality protocols of the EEA; (ii) Administrative map of Albania provided by the Ministry of Local Government in 2015; (iii) Map of Albania's ultramafic rocks 2016 (1:200,000) issue by the Albanian Geological Service. Ortho-rectified high spatial resolution satellite images provided the geometrical and thematic basis for georeferencing the maps from different sources for spatial analysis. The technical specification (i.e. 44 LULC classes; 25 hectares minimum mapping unit delineation; and 100 meters minimum mapping width) were the same for the all CLC over time (2000, 2006, 2012, and 2018), thus allowing for

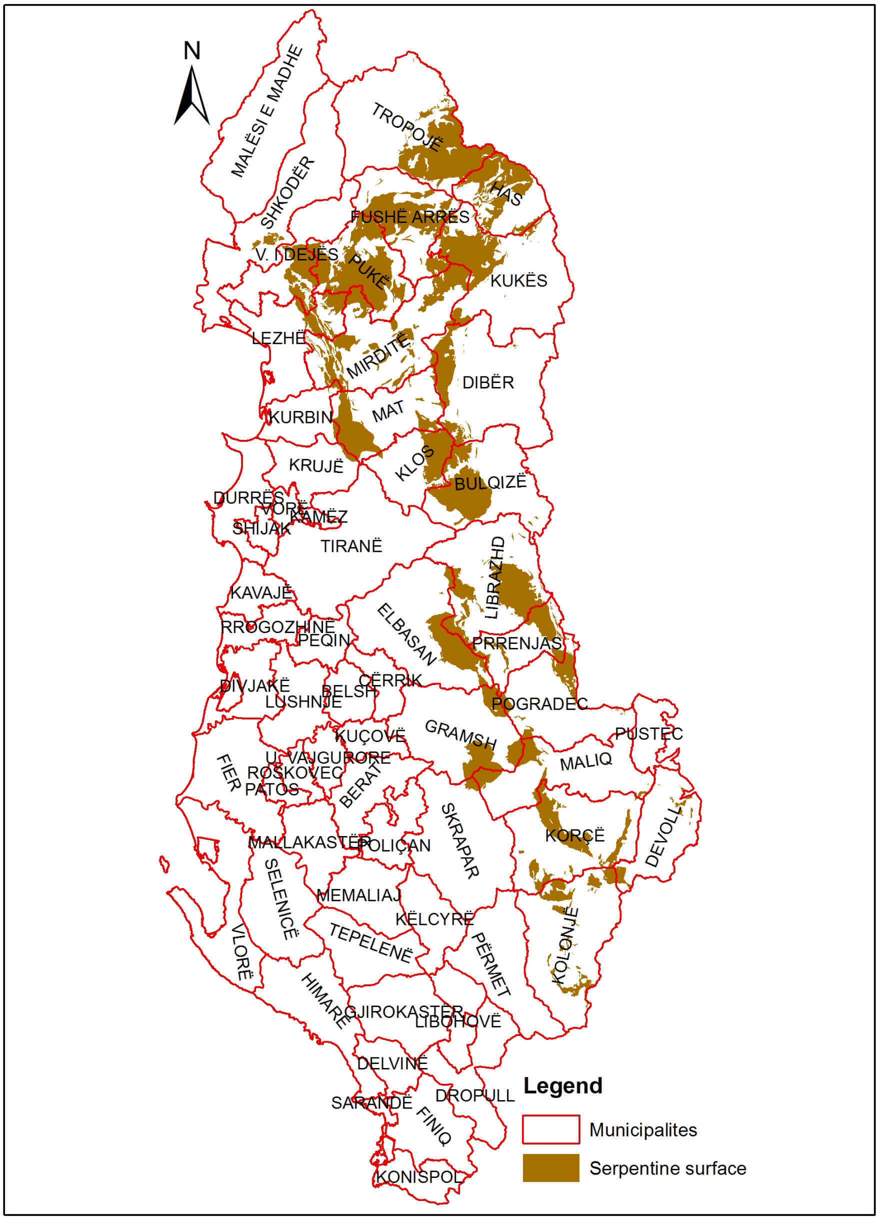

Figure 1. Distribution of ultramafics over the territory of Albania.

a spatial-temporal analysis inventories. Based in CORINE land cover nomenclature, the land cover of ultramafic area of Albania comprises three levels: the first level indicates the major categories of land cover globally; the second level is for use at 1:500,000 and 1: 1,000,000 scales; and the third level is used at 1:100,000 scale.

Using ArcGIS 10.5, intersection techniques analysis was performed for the 25 Municipalities of Albania ultramafic areas occur. The study area comprises of five major categories of land cover: (1) Agricultural areas, (2) Forest and semi natural areas (3) Artificial surfaces, (4) Water bodies and (5) Wetlands.

Plant hardiness zones maps of Albania developed by Teqja et al., (2017) were also used for this study. The maps comprise of standard plant hardiness zones map based on current climate and maps based on four different scenarios of representative concentration pathways of greenhouse gas (GHG) (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) for two time periods: 2050 (average for 2041-60) and 2070 (average for 2061-80). A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report in 2014. Four pathways have been selected for climate modeling and research, which describe different climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs, namely RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5, are labeled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6.0, and 8.5 W/m^2, respectively) (Wikipedia, 2019).

However, for this study we used only the most aggressive scenario (RCP 8.5) for 2070 period. According to this scenario greenhouse gas emissions continue to rise throughout the 21st century (IPCC, 2013). The maps of plant hardiness zones are widely used because they are simple, useful and practical (Daly et al., 2012; McKenneyet al., 2007, 2014). The plant hardiness maps were overlaid with the map of ultramafic substrate distribution of Albania to assess their spatial extent. The climate change impact on plant hardiness zones for serpentine areas was assessed by comparing the current potential distribution of two plant species with the future extreme climate scenario.

Studied species

The nickel hyperaccumulator species, *Alyssium murale* Waldst. and Kit and the medical species *Gentiana lutea* L. were analyzed for this study. *Alyssium murale* (syn *Odontarrhena chalcidica* (Janka) Spaniel, Al-Shehbaz, D.A.German and Marhold (Cecchi et al., 2018) was selected because it is the most common and widely distributed species, sometimes found also on non-serpentine soils and usually forming large populations in anthropogenic habitats (Cecchi et al., 2018). Previous studies have shown that *Alyssum murale* plants can be cultivated successfully in Mg-rich soils for agromining purposes (Li et al., 2003; Bani et al., 2007, 2015a, 2019). This plant is able to accumulate trace metals from serpentine soils and transport them to the shoots (>1%), which can then be harvested as a bio-ore to recover highly valuable metals such as Ni (Li et al., 2003; Zhang et al., 2014; Bani et al., 2015b).

Yellow Gentian *(Gentiana lutea* L.*)* also known as Sanza is a native perennial plant growing in serpentine pastures for medicinal purposes, occupying an area of approximately 1000 ha. After the collapse of the communist regime, *Gentiana lutea* was harvested indiscriminately with about 150-170 tons annually (Nelaj et al., 2018) and consequently its habitat and production decreased drastically. As a result, it was included to the Red List of Threatened Species (Bani et al., 2017). Because of the increasing demand from the international market and the threatening situation recently initiatives to start *Gentiana lutea* cropping (Nelaj et al., 2018) have been undertaken.

RESULTS AND DISCUSSION

Distribution of ultramafic formation in Albania

The main Municipalities with ultramafic massifs and serpentine soils include Tropoja, Puka, Fushe Arres, Bulqize, Mat, Has, Diber, in the north east and Elbasan, Perrenjas, Librazhd, Korça, Gramsh, Pogradec, in South-East (Figure 2).

Analysis showed that the surface of ultramafic (serpentine) soils in Albania with 40-43% MgO is 8.93% of the total surface of Albania. The larger serpentine substrates are located in the following districts based on this order: Puke (41.13%) > Bulqiza (27.85%) > Prrenjas (27.65%) > Klos (26.54%) > Librazhd (26.09%) > Tropoje (26%) > Has (22.26%) > Vau i Dejes (18.27%) > Gramsh (17.12%) > Pogradec (11.45%). The municipalities areas with limited serpentine surface are: Skrapar (1.27%) < Shkoder (1.68 %) < Kruje (2.32%). The total surface area of serpentine in Albania with 10-43% MgO is 313,300 ha or 11.05% of the total surface of Albania with majority occurring in the following districts: Puke (76.54%) > Fushe Arres (31.15%) > Bulqiza (28.78%) > Prrenjas (28.61%) > Librazhd (26.51%) >Tropoja (26.39%) > Mirdita (24.54%) > Has (22.26%) > Vau i Dejes (23.17%) > Gramsh (17.12%). The analysis from our study are corroborated also by others (Stevanović 2003) showing that the serpentine areas of Albania extend towards NE and SE. Our previous studies have shown that some of these areas are populated by a rich flora among them many endemic and metal hyperaccumulator plants (Bani et al., 2009, 2013, 2018; Osmani et al., 2018). Ni-hyperaccumulators species, that accumulate in the above-ground parts at least 1000 $\mu g\ g^{-1}$ shoot dry weigh, recently have attracted a great interest for both scientific research and practical applications, especially phytoremediation and phytomining (Nkrumah et al., 2016).

Land cover categories on serpentine soils of Albania

The Land cover categories on ultramafic area in Albania for the year 2000 were 7.45% agricultural areas, 92.22% forest and semi natural areas, 0.16% artificial surfaces, 0.15% water bodies and 0.02% Wetlands (Table 1). The largest ultramafic area of Albania is included in the category forest and semi natural areas and a part of agricultural areas. A comparison of the land cover for each category between the years 2000 and 2006 showed that agricultural areas and artificial surfaces categories changed the most. So agricultural areas in ultramafic areas declined by 47.3 ha while that the category artificial surfaces increased almost by same amount (42 ha) from the diversion of agricultural land to construction after 2000 (Sallaku et al., 2009). Changes in other land cover categories were very small. Over the years the changes in the main land cover categories become more visible.

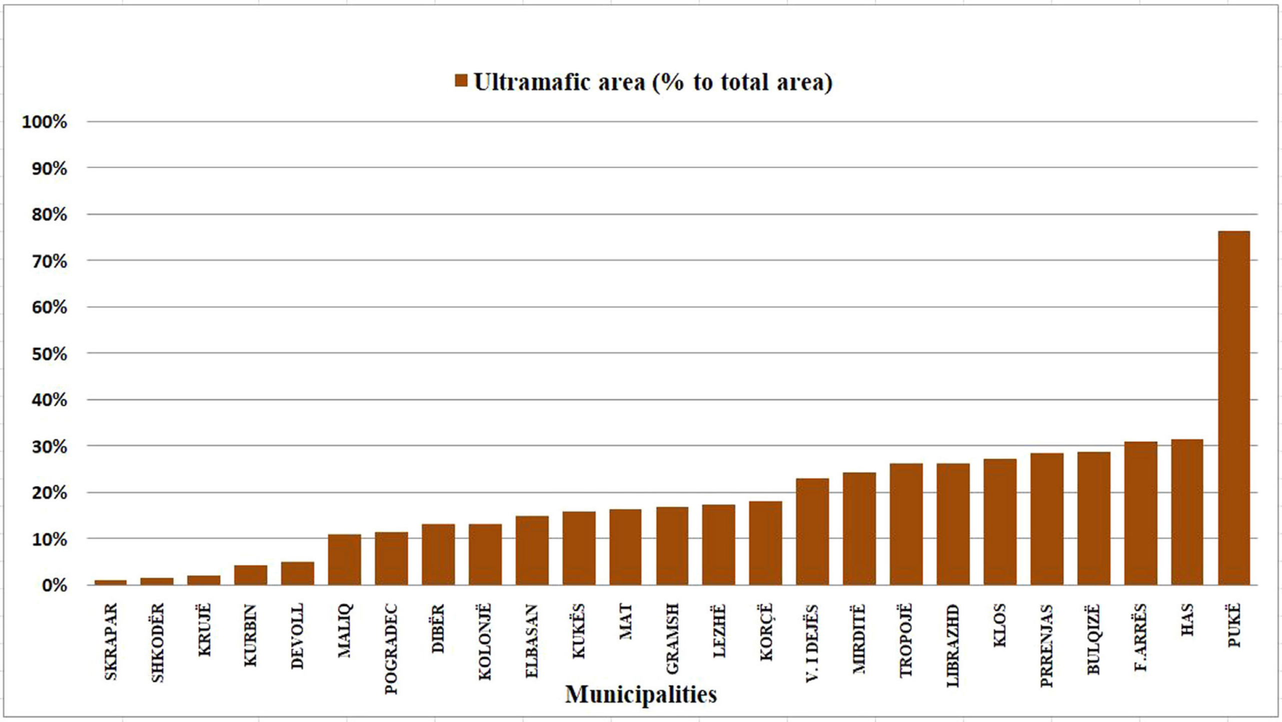

Figure 2. Area of ultramafic substrates (10-43% MgO) in Albanian municipalities (% to the total area of municipalities).

Table 1. Land cover (LC) area size (five items) and change for the major categories detected from supervised CORINE Land Cover (CLC) inventories of 2000, 2006, 2012 and 2018 for the Albanian ultramafic area (Copernicus Land site).

Level 1	2000		2006		2012		2018		Change 2000-2006		Change 2000-2012		Change 2000-2018		Rate of cover change 2000-2018
Land Cover	Area		Area		Area		Area		Area		Area		Area		ha /year
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	
1. Agricultural areas	23331.1	7.45	23283.9	7.43	22225.1	7.09	20907.4	6.67	-47.3	-0.02	-1106.0	-0.35	-2423.7	-0.77	-202
2. Artificial surfaces	502.9	0.16	544.9	0.17	846.9	0.27	1047.4	0.33	42.0	0.01	344.0	0.11	544.5	0.17	45.4
3. Forest and semi natural areas	288931.9	92.22	288930	92.22	289255.5	92.33	290562	92.74	-1.5	0.00	323.6	0.10	1630.2	0.52	135.8
4. Water bodies	458.7	0.15	465.5	0.15	906.7	0.29	727.4	0.23	6.8	0.00	448.0	0.14	268.7	0.09	22.4
5. Wetlands	75.5	0.02	75.5	0.02	65.9	0.02	55.8	0.02	0.0	0.00	-9.6	0.00	-19.7	-0.01	-1.6
Total	313300	100	313300	100	313300	100	313300	100							

Thus, a comparison of the land cover for each category between the years 2000 and 2012 and 2018 showed that agricultural areas had declined respectively by 1106 and 2423.7 ha (or 0.35 and 0.77%) while the surface increased in 2012 for other categories such as; artificial surfaces (344 ha or 0.11%), forest and semi natural areas (323.6 or 0.10%), water bodies (448 ha or 0.14 %) and in 2018 (544.5 ha or 0.17%), (1630.2 ha or 0.52%) and (268.7 ha or 0.09%). Similar trends, in decreasing agricultural land and increased forest and uncultivated land coverage have been observed in Poland and Hungary (Cegielska et al., 2018; Grešlová et al., 2019). The socio-political transformation in the 3 post-socialist countries after 1989-1991 have contributed significantly to the land cover change.

The analyses between the years 2000 and 2018 showed that over the 18 year period agricultural areas and wetlands were converted to other land use categories on average at the rate of 202 ha year^{-1} and 1.6 ha year^{-1} whereas artificial surfaces, forest and semi natural areas and water bodies increased by 45, 135.8, and 22.4 ha year^{-1} respectively (Table 1). This study shows that the agricultural area suffered the greatest decline mostly due to anthropogenic activities such as distribution of agricultural land to farm households in 1991 associated with illegal activities of citizens like dividing and building on land without legal authorization (Sallaku et al., 2009). The population pressure together with the unwise land management system were the major factors for land use and land cover change in the study area (Sallaku et al., 2009).

Within the category of agricultural area, arable land and heterogeneous agricultural areas were the main sub-categories that contributed to the decrease in ultramafic area of Albania (Table 2). Thus, between the years 2000 and 2012 or 2018, arable land declined by 49 and 168 ha respectively while heterogeneous agricultural by 1744 and 3213 ha. The rate of change in ultramafic areas of Albania for 2000-2018 period showed that arable land and heterogeneous agricultural areas were converted to other land use categories at the rate of 14 ha year^{-1} and 167.7 ha year^{-1}. At the same time, permanent crops and Industrial, commercial and transport units increased by 78.2, and 1.6 ha year^{-1}.

Under the forest and semi natural areas category, forested areas decreased in the following order: 7474 ha (2000-2006) < 10383 ha (2012-2018) < 16752 ha (2006-2012) with a mean rate of 2884 ha year^{-1}. The current situation is characterized by rapid deforestation of standing timber stocks and degradation in the productive potential of the forest and pastoral ecosystems. Forest resources have

Table 2. Land cover (LC) area size and change (12 items included in major categories). Scales of 1:500,000 and 1: 1 000,000. Detected from supervised CORINE Land Cover (CLC) inventories of 2000, 2006, 2012 and 2018 for the Albanian ultramafic area (Copernicus Land site).

Level 2	2000		2006		2012		2018		Change 2000-2006		Change 2000-2012		Change 2000-2018		Rate of cover change
Land Cover	Area		Area		Area		Area		Area		Area		Area		2000-2018
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha/ year
1.1 Arable land	1552.5	0.50	1553.5	0.50	1503.3	0.48	1384.5	0.44	1	0.00	-49	-0.02	-168.0	-0.05	-14
1.2 Heterogeneous agricultural areas	20121.1	6.42	20072	6.41	18377.5	5.87	16908	5.4	-49	-0.02	-1744	-0.56	-3213	-1.03	-267.7
1.3 Pastures	1410	0.45	1407.5	0.45	2107	0.67	2348	0.75	-3	0.00	697	0.22	938	0.30	78.2
1.4 Permanent crops	247.4	0.08	250	0.08	233.8	0.07	267	0.09	3	0.00	-14	0.00	19.2	0.01	1.6
2.1 Industrial, commercial and transport units	2.9	0.00	2.9	0.00	211.5	0.07	376.3	0.12	0	0.00	209	0.07	373	0.12	31.1
2.2 Mine, dump and construction sites	102.8	0.03	100.6	0.03	229.2	0.07	336.8	0.11	-2	0.00	126	0.04	234	0.07	19.5
2.3 Urban fabric	397.2	0.13	441.5	0.14	406.2	0.13	334.3	0.11	44	0.01	9	0.00	-62.9	-0.02	-5.2
3.1 Forests	145411	46.41	137937	44.03	121185	38.68	110802	35.37	-7474	-2.39	-24226	-7.73	-34609	-11	-2884
3.2 Open spaces with little or no vegetation	16205.7	5.17	16196	5.17	20427	6.52	27285	8.71	-10	0.00	4221	1.35	11079	3.54	923.3
3.3 Scrub and/ or herbaceous vegetation associations	127315.2	40.64	134799	43.03	147646	47.13	152475	48.67	7483	2.39	20331	6.49	25160	8.03	2097
4.1 Inland waters	458.7	0.15	465.5	0.15	906.7	0.29	727.4	0.23	7	0.00	448	0.14	268.7	0.09	22.4
5.1 Inland wetlands	75.5	0.02	75.5	0.02	65.9	0.02	55.8	0.02	0	0.00	-10	0.00	-19.7	-0.01	-1.6
Total	313300	100	313300	100	313300	100	313300	100							

decreased significantly over the last 10 years because of the country's transition to a market economy. One of the main reasons is the illegal logging of wood for timber and for firewood (Sallaku et al., 2009). However, at the same time under the forest and semi natural areas category the items that have been increased the most were: open spaces with little or no vegetation (923.3 ha $year^{-1}$) and scrub and/or herbaceous vegetation associations (2097 ha $year^{-1}$).

Within the category of agricultural area, complex cultivation patterns and land principally occupied by agriculture, with significant areas of natural vegetation were the main items that contributed to the decrease of heterogeneous agricultural areas. The abandonment of agricultural land is related to the fact that the soils formed on serpentine are poor in nutrients, thus do not support high yields, and furthermore are rich in heavy metals often at toxic levels (Whittaker, 1954; Proctor and Woodell,1975; Brooks, 1987; Bani et al., 2007, 2015a, 2019) These items were replaced mainly with pasture (78.2 ha $year^{-1}$), or artificial surface; road and rail networks and associated land (28 ha $year^{-1}$), industrial, commercial and transport units (3.1 ha $year^{-1}$) and construction sites (16.2 ha $year^{-1}$). The decrease of agricultural areas has a negative impact for natural vegetation of ultramafic substrate (Bani et al., 2009, 2013) and has resulted in decreases of the agromining land for which the albanian ultramafic (serpentine) soils are very effective (Bani et al., 2007, 2015a, 2019).

Broad-leaved forest and coniferous forest under the forest and semi natural areas category were the main items that decreased by 1942.7 ha $year^{-1}$ and 1024.8 ha $year^{-1}$ (Table 3). On the other hand, mixed forest, bare rocks, sparsely vegetated areas, moors and heath land, grasslands, sclerophyllous vegetation, and transitional woodland-shrub under the forest and semi natural areas category increased. The adjacent steep or rocky slopes in ultramafic landscapes host a high biodiversity, including many endemic species and hyperaccumulators plant, which can accumulate extremely high concentrations of Ni, and sometimes Co, in their aerial biomass (Bani et al., 2009, 2010).

Impact of climate change on the flora of ultramafic soils of Albania

The nickel hyperaccumulator species. *Alyssium murale* Waldst. and Kit and the medical species *Gentiana lutea* L. are native to Albania and are grown naturally in ultramafic soils thus can be used to illustrate effect of climate change on their habitat. Plant hardiness zones (USDA model: Widrlechner et al., 2012) are used in this study to estimate the actual potential habitat of these species and how it could be altered because of climate change (Teqja et al., 2014). Plant hardiness zones are based on absolute annual minimum temperatures. They are widely adopted in temperate regions because reflect the long-term survival of perennial plants and the degree to which they can endure low winter temperatures. Based on the influence of low temperatures on plant community development and distribution, the mean annual temperature values determine plant hardiness zones with a range of 5.6 °C. The regular zones are divided into subzones a and b (Widrlechner et al., 2012). According to a 2016 study (Teqja et al., 2017) Albania is under plant hardiness zones 6 to 10 (Minimum annual temperatures from -23.3 to -1.1 °C). Zones 9b and 10a lay to western Albania and coincide mostly with the western low plains and western mid plains. The mildest zones (9b and 10a) together cover approximately 22% of the country. Plant hardiness zones 9a, 8a, and 8b are the most dominant (15.600 km^2) and cover approximately 56% of the country. Plant hardiness zones 7a and 7b cover approximately 21% of the country, an area of 5.500 km^2. These zones, along with plant hardiness zones 6a and 6b, (which have a very limited extent of 2.2% or 620 km^2) coincide with the mountain physiographic region.

Figure 3 shows the distribution of ultramafic soils according to plant hardiness zones of Albania and how this distribution could change in 2070 under the most aggressive climate changes scenario. The majority of serpentine soils of Albania (94%) are under plant hardiness zones 7 and 8 but under the most aggressive climate change scenario (Teqja et al., 2017), around 50% of these soils may shift to plant hardiness zones 9 and 10. Such a change is likely to impact all flora of these areas. *Alyssium murale* belongs to plant hardiness zones 6-8 (http://www.missouribotanicalgarden.org) while *Gentiana lutea* belongs to plant hardiness zones 4-8 (https://pfaf.org/). Though *Gentiana lutea* has a wider habitat, because the plant hardiness zones 4-6 practically do not exist in Albania (Teqja et al., 2017) it makes this plant more vulnerable to climate change.

Figure 4 shows the actual potential and the forecast distribution of these native plant species. The potential area of these species would likely decrease by approximately 47.7% (Figure 4 a,b) under the most aggressive climate change scenario. However, other factors can determine the distribution and the future spatial extent of these plant species and need to be considered.

CONCLUSIONS

The analysis of ultramafic substrate in Albania showed that the substrate with 10-43% MgO comprises 313300 ha or 11.05% of the total area. Between 2000 and 2018 agricultural areas and wetlands decreased, whereas forest and semi natural areas, artificial surfaces and water bodies increased. Under the agricultural area category, arable land and heterogeneous agricultural areas decreased the most in ultramafic area of Albania. Complex cultivation

Table 3. Level 3-Land cover (LC) area size and change (27 items). Scale of 1: 100,000 detected from supervised CORINE Land Cover (CLC) inventories of 2000, 2006, 2012 and 2018 for the Albanian ultramafic area (Copernicus Land site).

Level 3	2000		2006		2012		2018		Change 2000-2006		Change 2000-2012		Change 2000-2018		Rate of cover change
Land Cover	Area		Area		Area		Area		Area		Area		Area		2000-2018
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha/ year
1.1.1 Non-irrigated arable land	1552.5	0.50	1552.5	0.50	1503.3	0.48	1384.5	0.44	0	0.00	-49.2	-0.02	-168.0	-0.05	-14.0
1.2.1 Complex cultivation patterns	6900.5	2.20	6860.3	2.19	5835.1	1.86	5905.9	1.89	-40.19	-0.01	-1065.41	-0.34	-994.6	-0.32	-82.9
1.2.2 Land principally occupied by agriculture. with significant areas of natural vegetation	13220.6	4.22	13212.7	4.22	12543.4	4	11002.5	3.51	-7.9	0.00	-677.2	-0.22	-2218.1	-0.71	-184.8
1.3.1 Pastures	1410	0.45	1407.5	0.45	2107	0.67	2348.0	0.75	-2.5	0.00	697	0.22	938.0	0.30	78.2
1.4.1 Fruit trees and berry plantations	216.1	0.07	216.2	0.07	200	0.06	238.5	0.08	0.1	0.00	-16.1	-0.01	22.4	0.01	1.9
1.4.2 Olive groves	31.3	0.01	33.9	0.01	33.9	0.01	28.1	0.01	2.6	0.00	2.6	0.00	-3.2	0.00	-0.3
1.4.3 Vineyards	0	0.00	0.01	0.00	0.012	0.00	0.0	0.00	0.01	0.00	0.012	0.00	0.0	0.00	0.0
2.1.1.Road and rail networks and associated land	0	0.00	0	0.00	193	0.06	336	0.11	0	0.00	193	0.06	336.0	0.11	28.0
2.1.2 Industrial. commercial and transport units	2.9	0.00	0.6	0.00	18.5	0.01	40.2	0.01	-2.3	0.00	15.6	0.00	37.3	0.01	3.1
2.2.1 Construction sites	0	0.00	0	0.00	128.6	0.04	194	0.06	0	0.00	128.6	0.04	194.0	0.06	16.2
2.2.2 Dump sites	0.6	0.00	0.6	0.00	0.6	0.00	0	0	0	0.00	0	0.00	-0.6	0.00	-0.1
2.2.3 Mineral extraction sites	102.3	0.03	99.98	0.03	100	0.03	142.7	0.05	-2.32	0.00	-2.3	0.00	40.4	0.01	3.4
2.3.1 Discontinuous urban fabric	397.2	0.13	443.6	0.14	406.2	0.13	334.3	0.11	46.4	0.01	9	0.00	-62.9	-0.02	-5.2
3.1.1 Broad-leaved forest	97657.8	31.17	93705.3	29.91	77081	24.60	74345.5	23.73	-3953	-1.26	-20576.8	-6.57	-23312.3	-7.44	-1942.7
3.1.2 Coniferous forest	34184.2	10.91	30919.6	9.87	30498.9	9.73	21886.7	6.99	-3265	-1.04	-3685.3	-1.18	-12297.5	-3.93	-1024.8
3.1.3 .Mixed forest	13569.1	4.33	13311.4	4.25	13605.4	4.34	14569.9	4.65	-257.7	-0.08	36.3	0.01	1000.8	0.32	83.4
3.2.1 Bare rocks	126.4	0.04	126.4	0.04	126.4	0.04	561.1	0.18	0	0.00	0	0.00	434.7	0.14	36.2
3.2.2 Beaches, dunes, sands	214.5	0.07	204.8	0.07	317.5	0.10	405.2	0.13	-9.7	0.00	103	0.03	190.7	0.06	15.9
3.2.3 Burnt areas	0	0.00	0	0.00	131.1	0.04	28.9	0.01	0	0.00	131.1	0.04	28.9	0.01	2.4
3.2.4 Sparsely vegetated areas	15864.8	5.06	15865.3	5.06	19851.1	6.34	26289.7	8.39	0.5	0.00	3986.3	1.27	10424.9	3.33	868.7
3.3.1 Moors and heathland	1376.6	0.44	1376.6	0.44	1149.4	0.37	4966.5	1.59	0	0.00	-227.2	-0.07	3589.9	1.15	299.2
3.3.2 Natural grasslands	33102.7	10.57	33085.1	10.56	36516	11.66	35799.3	11.43	-17.6	-0.01	3413.3	1.09	2696.6	0.86	224.7
3.3.3 Sclerophyllous vegetation	28790.2	9.19	28884	9.22	34057.3	10.87	35868.3	11.45	93.8	0.03	5267.1	1.68	7078.1	2.26	589.8
3.3.4 Transitional woodland-shrub	64045.7	20.44	71452.9	22.81	75923.5	24.23	75841.1	24.21	7407.2	2.36	11877.8	3.79	11795.4	3.76	983.0
4.1.1 Water bodies	251.7	0.08	136.5	0.04	617.7	0.20	624.3	0.20	-115.2	-0.04	366	0.12	372.6	0.12	31.0
4.1.2 Water courses	207	0.07	329	0.11	289	0.09	103.2	0.03	122	0.04	82	0.03	-103.8	-0.03	-8.7
5.1.1 Inland marshes	75.5	0.02	75.5	0.02	65.9	0.02	55.8	0.02	0	0.00	-9.6	0.00	-19.7	-0.01	-1.6
Total	313300		313300	100	313300	100	313300	100							

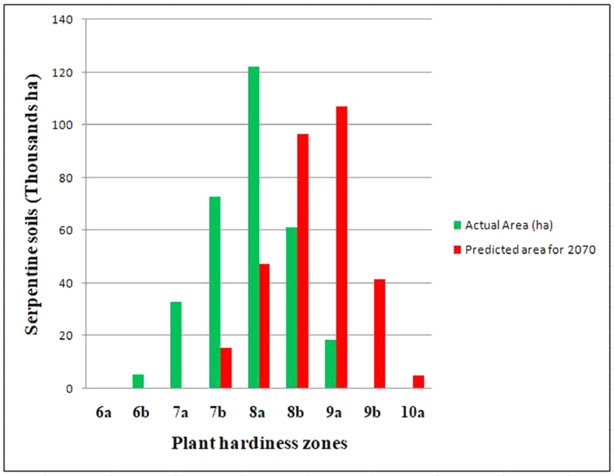

Figure 3. Distributions of ultramafic substrates of Albania according to plant hardiness zones (green color = actual area distribution; red color = predicted impact of climate change scenario).

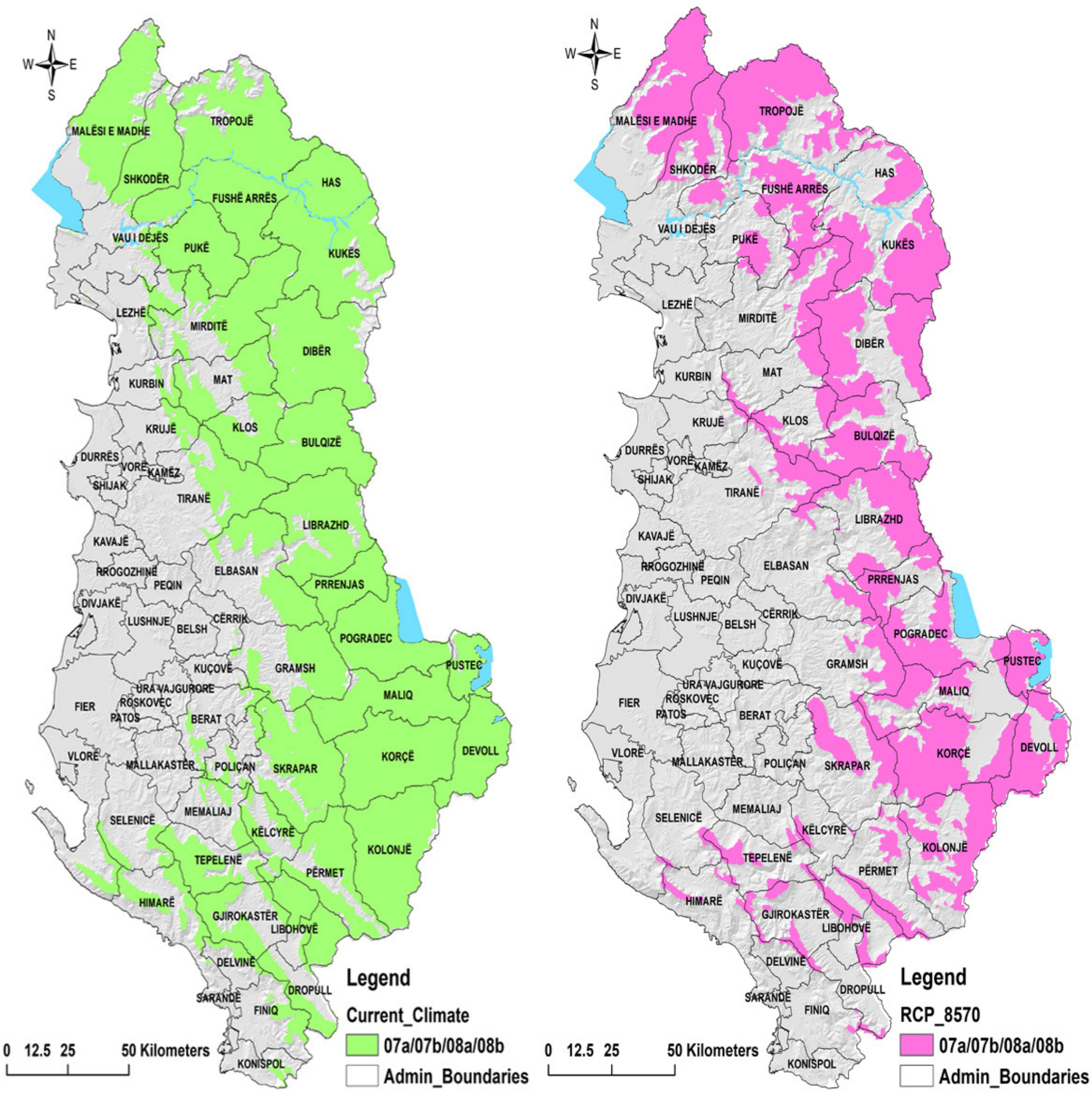

Figure 4. a) Map of the actual potential distribution of *Gentiana lutea* and *Alyssum murale* in Albania (green color). b) Map of the predicted potential distribution of *Gentiana lutea* and *Alyssum murale* for 2070 in an extreme climate change scenario in Albania (purple color).

patterns and Land principally occupied by agriculture with significant areas of natural vegetation contributed the most to the decrease of heterogeneous agricultural areas, which were replaced mainly with pasture or artificial surface. The increasing of artificial areas was mainly from Industrial, commercial and transport units and mine, dump and construction sites. Under forest and semi natural areas category, forests decreased the most over the years. Under the current climate, the majority of ultramafic soils (94%) are under plant hardiness zones 7 and 8. However, under the most aggressive climate change scenario around 50% of these soils may shift to plant hardiness zones 9 and 10. Such a change will likely impact the extent and distribution of natural flora of these areas. The continued trends of decreasing of natural vegetation, agricultural areas and forest will likely affect the native hyperaccumulator and native flora of serpentine soils. Climate change impact coupled with land use land cover changes will likely affect significantly the equilibrium of the ecosystems of these areas.

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