

Chapter 8

Physical Geographic Characteristics and Sustainable Development of the Mountain Area in Montenegro

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Abstract Montenegro is located in the Balkan Peninsula, which is extremely mountainous country. More than two thirds of the total area is mountainous. There are four macro relief units in the mountain area: mountain plains, valleys (canyons and gorges), basins, and mountains. A very dynamic physical geographic basis (geology, geomorphology, climate, hydrology) enabled the diversity and rich natural potential resorts to be formed in the mountain area in Montenegro. In the past 50 years, new industries have appeared: mining, metallurgy, energy production, traffic, and tourism, and their development has led to endangered, devastated, and polluted environments in the mountain area of Montenegro.

Keywords Mountain area • Physical geography • Relief • Sustainable development • Montenegro

8.1 Introduction

Montenegro occupies the southwestern part of the Balkan Peninsula. Although Mediterranean, it is mostly a mountainous country. The land portion includes 13,812 km², and that under the sea is 4800 km². Montenegro extends in meridian line approximately 200 km (between latitudes 41°39' and 43°44'N), and the distance between the easternmost and the westernmost point is 173 km (between longitudes 18°26' and 20°21'E) (Radojičić 1996). The recently conducted census in 2011 showed a population of 620,029 in Montenegro, which currently encompasses 23 municipalities, each of which is partly mountainous.

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8.2 Borders and Division of the Mountain Terrain

Determination of boundaries in the mountain area is a very difficult and complex procedure (Rasemann et al. 2004) because various qualitative and quantitative criteria have been used in their definition. Quantitative (hypsometric) criteria rely on relief and its elevation (Zevenbergen and Thore 1987), the simplest and the most applicable method. Additional criteria, besides absolute height, include slope angle, relative height, etc. (Barsch and Caine 1984).

According to the accepted division of relief based on elevation in the given part of southwestern Europe (Mladenović 1984), the altitude of 500 m a.s.l. is established as the lower boundary of the mountain area in Montenegro. The influence of Mediterranean climate is strong, also affecting the hinterland. Consequently, some mountainous regions that display such mild climate and corresponding biogeography could not be classified as mountains. However, in spite of a possible although small inconsistency, the mountain area in Montenegro is assigned to the region above 500 m a.s.l. (Table 8.1).

The mountain area encloses the largest part of Montenegro. Regions above 500 m a.s.l. include 83.8 % of the total area of this country, that is, 11,596 km². Division of the mountain area is based on hypsometric, climate, geomorphological, and biogeographical characteristics.

The mountain area is divided into three elevation regions. The lower mountain region (500–1000 m a.s.l.) occupies 32.4 % of the total mountain area and has the most appropriate climate, floral diversity, and highest population density. The mid-mountain region (1000–1500 m a.s.l.) includes 46.4 % of the total mountain area. Climate and relief in this area are unsuitable although its upper boundary represents the boundary of habitation and continual forest extent. The high mountain region (exceeding 1500 m a.s.l.) as regards climate, relief, flora, etc. is the most limited region; it covers 21.2 % of the total mountain area in Montenegro.

The biggest part of Montenegro is mountainous, excluding the narrow coastal area, Skadar Lake basin, and the Zetsko-bjelopavlička plain (Fig. 8.1). Within the mountainous area have been distinguished four macro relief units: mountain plains, valleys (canyons and gorges), basins, and mountains.

Table 8.1 Elevation regions in the mountain area (Mladenović 1984)

Elevation region	Spatial area (km ²)	Percent (%)
0–200 plains	1425	10.4
200–500 hills	791	5.8
500–1000 lower mountain regions	3763	27.1
1000–1500 mid-mountain regions	5378	38.9
>1500 high mountain regions	2455	17.8
Total	13,812	100



Fig. 8.1 Relief units of mountain area

Mountain plains are parts of the mountain area that formed in the very early geomorphological past. They occur at different elevations, from 700 m a.s.l. (Katunska plain between the Bay of Boka Kotorska and Podgorička ravine), above 1200 m a.s.l. (plain of Sinjajevina between Durmitor and Bjelasica and Pivska plain above the Piva canyon), to 1450 m a.s.l. (Jezerska plain surrounding Durmitor, etc.). They were created under fluvial-denudation processes that took part during a long and, regarding tectonics, a peaceful period since Miocene to Pliocene (Cvijić 1926).

Plains are, as a rule, intensively karstified and represent suitable area for holokarst to be developed.

Valleys are steeply incised into the mountain area in Montenegro. The least number of valleys is in areas composed of carbonate rocks. Here they are commonly very deep and narrow, considered to be canyons. Valleys are more abundant, considerably wider, and with alluvial plains transiting sporadically into basins, particularly in areas of noncarbonate rocks.

There are many quite long and very deep canyons in the mountain area in Montenegro (Table 8.2). Some of them exceed 1000 m in depth. Various characteristics of river courses and their changes during longer periods of time have influenced the formation of three types of canyons: canyons formed directly by glacial, meltwater streams; canyons formed by river courses with glacial-nival regime; and canyons formed by torrent streams (Djurović and Petrović 2007).

Basins are located in the mountain area composed of rocks other than carbonate. Basins occur along river flows separating gorges. These are the most fertile parts of the mountain area, with a mild climate. They are intensively inhabited for reasons of the broadest agricultural fields and the best traffic infrastructure. The most important basins are in the valleys of these rivers: Lim: Gusinjsko-plavska (about 900 m a.s.l.), Andrijevica (about 740 m a.s.l.), Berane (at approximately 660 m a.s.l.), Bijelo Polje (at about 560 m a.s.l.); Ibar: Rožaje (at about 990 m a.s.l.); Tara: Kolašin (at 940 m a.s.l.), Mojkovac (at about 790 m a.s.l.); and Čehotina: Pljevalja (at about 760 m a.s.l.).

Different geologic backgrounds, intensive and long-lasting tectonic movements, and diverse geomorphological evolution of the mountain area resulted in formation of numerous and various mountains. Mountains in Montenegro are included in two extensive mountain ranges: the Dinaric Alps and Prokletije. Their boundary is yet unclear. Investigations conducted at the end of the nineteenth century (Cvijić 1899), along with later research (Bošnjak 1938; Milojević 1937; Bešić et al. 1985; Lakušić et al. 1985; Petrović 1985) indicated and confirmed the individuality of Prokletije as an independent mountain range. It stretches almost perpendicular to the direction of the Dinaric Alps and displays different geologic (diversity and age of rocks) and

Table 8.2 The most significant canyons in Montenegro

Number	Name of the canyon	River	Length (m)	Depth (m)
1	Piva canyon	Piva	31,240	1034
2	Tara canyon	Tara	79,400	1341
3	Lim canyon	Lim	3005	517
4	Djalovića canyon	Bistrica	8520	627
5	Ibar canyon	Ibar	7100	151
6	Mrtvica canyon	Mrtvica	6667	1247
7	Kruševački potok canyon	Kruševački potok	4400	1008
8	Morača canyon	Morača	31,676	1168
9	Mala Rijeka canyon	Mala Rijeka	11,391	814
10	Cijevna canyon	Cijevna	12,400	903

geomorphological features. Additionally, different floral-vegetation species and its general ecological diversity distinguish Prokletije Mt. as the distinct mountain system at the Balkan Peninsula. Prokletije is located between the Dinaric Alps in the northwest, the Šar-Pindus system on the east, and the Skadar basin in the southeast; the Kosovo-Metohija basin borders it on the northeast.

According to geologic, climate, and relief differences, in the Dinaric Alps in Montenegro were distinguished three mountain regions: coastal, middle, and outer (Fig. 8.1).

The coastal mountain region (Fig. 8.2) stretches, as do the Dinaric Alps (NW–SE), as a narrow belt parallel to the coastline. Mountains rise abruptly from sea level as rocky cliffs reaching from a few hundred meters to 1000 m in altitude. This mountain region extends from the border with Bosnia and Herzegovina to the valley of River Bojana and is about 100 km long. The region varies in width from 10 to 20 km, including several mountains: Orjen (1894 m a.s.l.), Lovćen (1749 m a.s.l.), Sozina (780 m a.s.l.), and Rumija (1594 m a.s.l.). Its northeastern part meets the mid-mountain region.

The mid-mountain region (Fig. 8.3) includes the central part of Montenegro between the coastal and the outer region, from the border with Bosnia and Herzegovina to Podgorička basin and the valley of River Morača, which separates it from the Prokletije mountain range. It stretches as do the Dinaric Alps. The broad-



Fig. 8.2 The coastal mountain region: (a) Cetinjsko polje, (b) Njeguško polje, (c) rural architecture, (d) tourist center on Mt. Lovćenu (Photographs by P. Djurović)

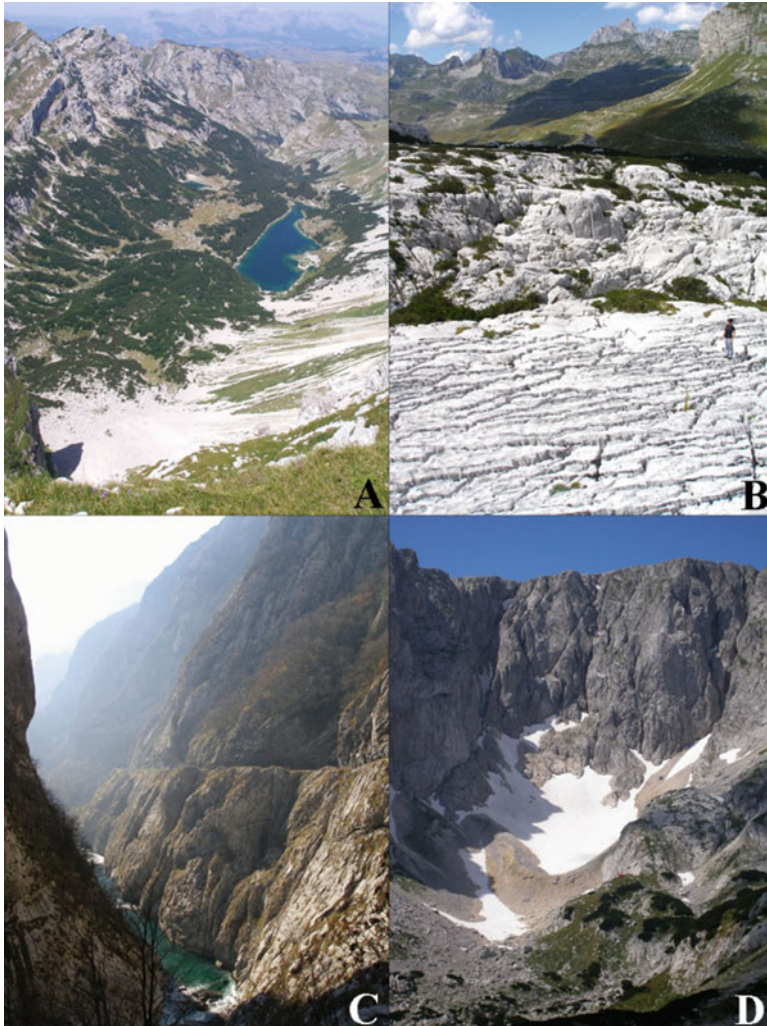


Fig. 8.3 The mid-mountain region: (a) glacial relief on Durmitor Mt., (b) high mountain karst on Durmitor Mt., (c) the River Morača canyon, (d) the Debeli Namet glacier (Photographs by P. Djurović)

est mountain region, it includes mountains that rise from old Mio-Pliocene plains and has been referred to by Cvijić as the region of “plains and hills”(Cvijić 1926). It is dominantly built of carbonate rocks that support intensive karst processes with features of holokarst. Mountains in this region are Prekornica (1927 m a.s.l.), Maganik (2139 m a.s.l.), Vojnik (1998 m a.s.l.), Sinjajevina (2277 m a.s.l.), Golija (1935 m a.s.l.), and Durmitor (2523 m a.s.l.). Deeply incised canyons occur sporadically (such as Tara, Mrtvica, Morača, Komarnica, and Piva).

The outer mountain region encloses the region from the River Tara Canyon to the border of Montenegro and Serbia, and from the border with Bosnia and Herzegovina to the Bijelo Polje basin and the River Ibar canyon. The most remarkable mountain in this region is Ljubišnja (2238 m a.s.l.); the others are of moderate height (about 1500 m a.s.l.). The valley of River Čehotina is a remarkable fluvial form in this region; here is located Pljevlja's basin.

The Prokletije mountain range (Fig. 8.4) in Montenegro encloses the region between the River Morača canyon, Kolašin and Mojkovac basin, Bijelo Polje basin, and the River Ibar canyon to the border of Montenegro with Albania. The River Lim valley divides this region into two parts. The northwestern part consists of mountains: Žijovo (2131 m a.s.l.), Komovi (2487 m a.s.l.), Visitor (2211 m a.s.l.), and Bjelasica (2139 m a.s.l.), and the southeastern part comprises Karanfili (2119 m a.s.l.), Bjelič (2556 m a.s.l.), Bogičevica (2374 m a.s.l.), Zeletin (2126 m a.s.l.), Mokra planina (1968 m a.s.l.), Hajla (2403 m a.s.l.), and Žljeb (2356 m a.s.l.).



Fig. 8.4 The Prokletije mountain region: (a) Lake Hridsko, (b) the Skakavac waterfall, (c) Komovi Mt., (d) Kotlovi on Karanfili Mt. (Photographs by P. Djurović)

8.3 Geologic Background

The geologic background of the mountain area in Montenegro is complex. Some parts are dominantly built of carbonate complexes and others are built of noncarbonate rocks. These differences have had, and still have, significant influence on geomorphological processes and the type of relief. The mountain area in Montenegro mostly contains different rocks of Mesozoic age. Cenozoic rocks are less abundant, and rocks of Paleozoic age occur only sporadically. In the sense of petrology, carbonate rocks dominate (limestone and dolomite); clastic sedimentary rocks (sandstone) and schists are less abundant, and igneous rocks (andesite, dacite) occur sporadically (Radojičić 1996).

The Dinaric Alps mountain range is mostly built of rocks of Mesozoic age (Bešić 1975, 1980, 1983). The lowest levels of the coastal mountain region are of Cretaceous-Eocene rocks (flysch, limestone), and its medium level and the highest parts are of Mesozoic limestones. Limestones range in thickness from a few hundred meters to more than 1500 m. Mesozoic carbonate rocks (limestone and notably less abundant dolomite) dominate in the mid-mountain region, exceeding 2000 m in thickness. Carbonate complex has been cut in places (thrust sheets zone) by narrow and long belts of Paleogene flysch. Igneous rocks are exposed sporadically, commonly in the piedmont of mountains (e.g., Sinjajevina, Durmitor, Volujak, Pivska planina). The outer mountain zone comprises rocks of various age and composition. Carbonate rocks are not exposed as much as in the previous two zones. They are still abundant, but the very large, wide complexes are lacking. Limestone outcrops exceed 1000 m only locally (proximity of the River Tara canyon). The alternation of carbonate and noncarbonate complexes is common (“mosaic structure”). The latter includes Triassic sandstones, andesite and dacite, Paleozoic schists and sandstones, as well as Neogene sediments. In the southeastern parts of this region (toward the Prokletije mountain range) occur larger complexes of Permian sandstones, schists, and marlstones.

The Prokletije mountain system is the most diverse mountain area in Montenegro as regards geology. Mountains are largely built from rocks other than Mesozoic carbonate rocks. In most of the mountains, carbonate rocks build their highest levels (Bjelasica, Komovi, Visitor). Marginal parts of mountains are composed of Jurassic schists, diabase, and marlstone together with Triassic dacite, andesite, and tuffs. Carbonate rocks vary in width, but in the most cases attain a few hundred meters. Hence, they are not wide as in the mountains in the Dinaric Alps. The Bjelič Mt. is prominent with the noteworthy thickness (1000–1500 m) of the dominant carbonate rocks. Recall the mountains, which lack carbonate rocks: Greben 2196 m a.s.l., with Jurassic schists, diabase, and marlstone with Triassic dacite, andesite, and tuffs, and Bogićevica from Paleozoic phyllite, and Permian–Triassic conglomerate.

8.4 Climate Conditions

The mountain area in Montenegro exhibits extraordinary climate diversity as the consequence of variable elevation, distance from the sea, and desiccation of the mountain area. It has not been uniformly monitored instrumentally. Monitoring takes place up to about 1500 m a.s.l.; thus, the higher elevations require calculations and various modeling.

The greatest importance for air temperature differences is the difference in elevation, reaching almost 2000 m (from the lowermost point to the highest summit). In Žabljak meteorological station (eastern foothill of the Durmitor Mt., 1450 m a.s.l.), the average annual temperature of 4.6 °C for the period 1961–1990 of 4.7 °C was determined (Djurović 1996, 2011; Burić et al. 2011, 2012). The average annual temperature of the air has been decreasing since 1960 until the end of 1970 and at the beginning of the 1980s when the lowest value of 3.7 °C was recorded (Djurović 2011). Since then, an increasing trend of average annual temperature has occurred. Within the period of instrumental measuring (1958–2014), the average annual temperature reached a maximum of 7.1 °C in 2014 (Republic Hydro-meteorological Service of Montenegro).

The average annual temperature of air for the high mountain elevations in the Durmitor Mountain was established in terms of their vertical temperature gradients during 1958 to 1993 (Djurović 2011). Such value obtained at 2050 m a.s.l. altitude is 1.6 °C, and for 2550 m a.s.l. is 0.1 °C (Djurović 2011). The average annual temperature of air at other higher elevations of the mountain area in Montenegro has also been calculated.

Annual precipitation rate for the whole Montenegro is approximately 1798 mm/year; during winter (October–March) it is 1223 mm (68 %), and in summer (April–September) it is 575 mm (32 %). The absolute value for average precipitation in Montenegro is $24,834 \times 10^6$ m³/year (Radojičić 1996).

The annual amount of precipitation in mountain areas is significantly influenced by the distance from the sea, elevation, and orography. Lack of precipitation stations at higher elevations also caused problems in this region. Therefore, the average precipitation at elevations exceeding 1500 m was calculated concerning the precipitation coefficient. The highest annual precipitation rates occur in mountain regions that are nearest to the Adriatic Sea.

In the coastal mountain region of the Dinaric Alps is recorded an annual precipitation of 4604 mm (1961–1990) on Crkvice (937 m a.s.l.) (Krivošije). The highest annual precipitation rate, 7067 mm, was recorded in 1979 (Republic Hydro-meteorological Service of Montenegro). In the same period, Cetinje (640 m a.s.l.) received 3236 mm (Burić et al. 2012).

An average annual precipitation rate of 1453 mm (1958–1993), that is, 1473 mm (1961–1990), has been instrumentally determined at the meteorological station Žabljak (Djurović 1996, 2011; Burić et al. 2012). According to results obtained in 11 stations (located from 446 m a.s.l. to 1450 m a.s.l.) the precipitation gradient was calculated, and afterward, an isohyetal map based on it was prepared for Durmitor.

This map indicated annual precipitation from 2200 to maximally 2600 mm in the highest elevations on the Durmitor Mt. (Djurović 2012).

The largest distance from the sea and the highest elevations of mountains exposed between the outer mountain region and the Adriatic Sea caused the lowest annual precipitation. In the Pljevlja basin (784 m a.s.l.) annual precipitation is 802 mm (1961–1990), whereas in the Cetinjsko polje (640 m a.s.l.) synchronous precipitation is 3236 mm.

The mountainous region in the Prokletije mountain range, for the same reasons, has a lower precipitation rate despite the highest altitudes. Annual precipitation in the Bijelo Polje basin (606 m a.s.l.) is 908 mm and 1985 mm in Nikšićko polje (647 m a.s.l.). Average annual precipitation ranges from 1000 to 1400 mm (Burić et al. 2012).

8.5 Hydrologic Characteristics

The hydrologic characteristics of the mountain area in Montenegro are complex and include numerous hydrologic events. Such characteristics arose from the geologic background, climate differences, and relief features.

The coastal mountain region is lacking in big rivers. A small number of river flows discharge directly into the Adriatic Sea or the Skadar Lake. High slopes give a torrential character to water flows, whereas the carbonate basement slows water to be retained during the year. Disappearing rivers occur sporadically in karst poljes (Grahovsko, Dragaljsko, Njeguško, and Cetinjsko).

Rivers from the mid-mountain region empty into two sea drainage basins: Adriatic (Morača with Zeta) and the Black Sea (Tara and Piva). The mean annual discharge of the River Morača (1961–2001) was 156 m³/s (from 95 m³/s in 1983 to 255 m³/s in 1979) (Knežević 2009). The mean annual discharge of the River Piva is 75 m³/s, and that of Tara 79 m³ (Prohaska et al. 2004). Specific spatial distribution of carbonate rocks causes the lack of surface flows and the domination of underground flows. The powerful karst springs Vukovo vrelo, Vidrovana, Gornjopoljski vir (Nikšićko polje), Ljutica (Canyon Tara), and Pivsko (about 20 m³/s; Canyon of Piva) emerge in such areas (Prohaska et al. 2004). Hydrologic curiosities include intermittent springs (Vidov potok, Šavnička glava, and Zaslavnica), as well as estavelles (Gornjopoljski vir).

Lakes in mountain area were formed either inside the Pleistocene cirques (Lake Manito jezero on the Moračke mountains, Trnovačko Lake in the base of the Volujak Mt. and Bioč, Jablan Lake, Zeleni vir, Veliko and Malo Škrčko Lake on Mount Durmitor, etc.) or in glacier valleys (Crno, Modro, Valovito, and Zminje Lake on Mount Durmitor, Veliko and Malo Stabanjsko Lake on the Bioč, Kapetanovo Lake on the Moračke mountains, etc.) (Stanković 1975). Artificial lakes were formed by dams in river valleys (such as Pivsko Lake in the River Piva canyon: the dam is 220 m in height and volume is 800 million m³) (Prohaska et al. 2004), or in karst poljes (Lakes Krupac, Slano, and Vrtac in Nikšićko polje). The most distinctive

property of this area is the existence of the Debeli Namet glacier (Djurović 1996, 2012; Hughes 2007, 2008). It is situated on the Durmitor Mt., at elevations from 2050 to 2150 m a.s.l., and covers an area of 1.8 to 2.6 ha.

In the outer mountain region are most of the water draining rivers: Čehotina (average annual discharge, 18 m³) (Prohaska et al. 2004) and Tara, and to a lesser extent the River Lim. When compared with the two previous regions, as the consequence of less exposed carbonate rocks, the river catchments are better developed. Otilovića Lake was formed by enclosing the valley of the River Čehotina for the purpose of of thermoelectric power (“Pljevlja”).

River catchments are better developed in the Prokletije mountain range than in the Dinaric Alps. The Rivers Lim (average annual discharge, 112 m³/s) and Ibar drain into the Black Sea and the River Cijevna empties into the Adriatic Sea. Powerful springs create the Rivers Vruja (Alipašini springs) and Ibar (Glava Ibra). Not less powerful springs come from caves (Glava Bistrice) (Djurović and Lješević 1994). Glacial lakes on the Prokletije Mt. include Ridsko, Ropojansko, and Rikavičko. Lakes form in basins left by accumulation of glacial material; such are Plavsko (the largest lake in the mountain area of Montenegro, ~2 km²) and Biogradsko Lakes.

8.6 Geomorphological Characteristics

The relief in the mountain area in Montenegro has been created from different geologic backgrounds and under different climate impacts. Karst processes dominate in the largest area, and fluvial processes are important in terrains composed of non-carbonate rocks. The area above 1800 m a.s.l. is under the influence of cryo-nivation processes (Milivojević and Djurović 2010). In the mountain area, preserved forms of Pleistocene glacial relief remain. They are presented in terms of their genesis instead of their location within a certain mountain region with the aim of better insight.

Karst relief in mountain area is well developed and is represented by surface as well as underground karst landforms. The former includes from the smallest (kamenitze) to the largest (polje) forms. Kamenitzes with diameter exceeding 2 m are found on the Durmitor Mt. (Bolj) at about 1800 m a.s.l. (Djurović 1996). Widespread karrens often reveal impassable terrains; the most remarkable karrens are on the Orjen, Lovćen, Durmitor (Bolj), Maganik, and Bjelič mountains. The most abundant karst forms are sinkholes, found at different elevations, displaying a variety of forms and sizes. They are referred to as limestone pavement when densely clustered (Pivska Mountain, Komarnica). Uvalas are also very common. Their bottoms, covered by sediments, make them larger agricultural karst surfaces. Most frequently they represent karstified dolinas, whereas those at higher elevations represent transformed Pleistocene cirques and glacier valleys (Djurović 2011; Djurović et al. 2010). Karst pedestals are characteristic for this region. According to results

obtained during their research on the Durmitor (Bolj), a decrease of spatial distribution of limestones of 0.014 mm per year was deduced (Djurović and Djurović 2011).

The majority of poljes are located in the mountain area. They are, excluding Nikšićko polje, of small dimensions. The most frequent are in the River Zeta watershed. Their bottoms are flattened and covered with gravelly-sandy sediments. Pleistocene glaciation is the most responsible for such patterns. Glaciers advanced until certain poljes and deposited moraines: Dragaljsko, Njeguško, Ivanjsko, Drobњаčko (Menković and Djurović 1993). Most poljes survived the shrinking of bottoms during retransporting moraine material from poljes from higher elevations into the lower ones (Lukovsko, Nikšićko). Accumulation was not so significant where the influence of glaciation was not prominent (Velimsko polje) or was related to fluvial processes (Bitinsko polje). Significant amounts of sediments and water caused certain poljes to be flooded (Nikšićko, Dragaljsko, Grahovsko, etc.).

Underground karst relief includes a few thousand caves, with some reaching the depth of a few hundred meters. They vary in shape, dimension, and origin. In the mountain area, vertical objects dominate and horizontal formations are less abundant. The significant thickness of limestone, along with tectonic susceptibility, deep canyons, large amounts of precipitation, and Pleistocene glaciation, created ideal conditions for cave formation. Caves at lower elevations were formed by past rivers that represented surface flows before karstification (Jama Duboki do, the River Njeguška; cave Lipska pećina, the River Cetinjska (Djurović et al. 2002). The deepest cave, Iron Cave on Maganik, is 1162 m deep.

Fluvial relief in the mountain area is represented by different dolines. The deepest canyons are in regions built of carbonate rocks. Such canyons were incised by allothigenous flows that come from non-carbonaceous water-rich terrain. In such regions dolines are shallower, but more abundant and diverse. Huge accumulations of fluvial material apart from the erosion landforms should be mentioned. These materials were deposited in basins (reaching in thickness a few tens of meters: Andrijevića, Berane, Bijelo Polje, etc.) in which the rivers have incised two series of terraces. Accumulation of fluvial material also occurred in the canyons themselves (up to 120 m thick: canyons of Tara, Morača).

Periglacial relief is developed only in the highest parts in the mountain area, that is, above 1800 m a.s.l. (Milivojević and Djurović 2010). The arc ridges, the protalus rampart, forms by rock falls that are produced by long-retained snow on carbonate material, whereas rock glaciers form in non-carbonate rocks.

Pleistocene glacial relief is well preserved (Cvijić 1903; Djurović 2009; Stepišnik and Žebre 2011; Hughes et al. 2010, 2011) and is related to the highest mountain area. It commonly includes cirques, glacier valleys, glacial shoulders, roche moutonnée, etc. Accumulation landforms, such as moraine, also stayed preserved apart from the erosion forms. These forms are highly transformed, even destroyed, on being exposed to deluvial and fluvial processes during the postglacial stage.

Coluvial processes are the most intensive in the highest parts in the mountain area resulting from the strong impact of low temperatures and increased precipitation. The most impressive talus cone, approximately 1.5 km in length, occurs at Komovi Mt. The coluvial process is important at lower altitudes and may be of

significant intensity. In 2006, in the beginning of the canyon Tara (Bistrica locality), a severe landfall caused partition of the canyon. A lake 2 km long formed above the dam, and the River Tara has stopped flowing downstream from the dam. After digging, the lake has mostly disappeared.

8.7 Geoheritage and Environmental Protection

According to the classification proposed by ProGeo (Wimbledon 1996, 1999), a preliminary list of the geoheritage objects of Montenegro was made (Djurović and Djurović 2010a). The list includes nine main categories: objects of historical-geologic and stratigraphic heritage, structural objects, petrological objects, objects of geomorphological heritage, objects of neotectonic activity, speleological objects of geoheritage, objects of hydrologic-hydrogeologic importance, pedological objects, and archeological geoheritage objects. The majority of 217 distinguished geoheritage objects is located in mountain area 170 (Djurović and Djurović 2010b).

The most valuable regions in the mountain area are designated by law as areas of extraordinary natural worth areas and put under various protection regimes. Four of five National Parks are in the mountain area (NP “Lovćen,” “Durmitor,” “Biogradska gora,” and “Prokletije”).

8.8 Potentials and Limitations for the Application of the Concept of Sustainable Development

Agriculture and forestry are traditional economic activities in mountain areas. However, in the past 50 years some new industries have occurred: mining, metallurgy, energetics, traffic, and tourism (Fig. 8.5). Their development led to an endangered, devastated, and polluted environment. The concept of sustainable development, which looks for the balance between economic, social, and ecological requirements, that is, to satisfy needs of the present generation without putting them in danger for the future generations, arose as the solution for problems caused by economic and social development (Brundtland Commission WCED 1987). The main task of sustainable development is continual social development in accordance with environmental protection.

The state of Montenegro has determined the strategy for future development in accordance with principles and rules of sustainable development with the “Declaration of ecological country Montenegro” in 1991. Montenegro has been an ecological state since the Constitution in 1992. The strategic document “Directions for development of Montenegro as an ecological state,” from 2000, established basic criteria for realization of sustainable development. “National Strategy of sustainable development” has to guide the proposed tasks of the “Declaration of



Fig. 8.5 Protected, potentially endangered, and endangered areas in the mountain area

ecological country Montenegro,” as well as its principles for progress. This strategy is one of the elements of implementation of the “Mediterranean strategy of sustainable development”; hence it is a part of the world’s national strategies in sustainable development, which are supported by the UN Commission for Sustainable Development.

“National strategy for sustainable development in Montenegro” is based on generally established principles on sustainable development that were proclaimed by the “Declaration in Rio” and by “Agenda 21,” “Declaration and Plan for implemen-

tation from Johannesburg,” and “Millennium declaration of UN.” Montenegro is decisive in following the National Strategy for sustainable development, but similar to many countries in Southeast Europe meets with numerous complex problems. Some of the most important problems are balanced economic development, improvement of life standards, and poverty reduction, as well as the increased awareness of the inevitability and necessity of the sustainable development concept (Nacionalna strategija održivog razvoja Crne Gore 2007).

The spatial plan for Montenegro up to 2020 established priorities. Based on available resources and potentials on one side and limitations and conflicts on another, the main development paths were recognized, considering the principles of sustainable development; regardless, conflict has remained between economic development and environmental protection (Fig. 8.6).

The proximity of coastal tourist centers directly impacts the number of visitors, increasing it in the coastal mountainous region (complementary tourism). Expansion of tourist centers within the mountain area (Ivanova korita and Njeguši on Lovćen), the construction of the new magistral road Nikšić–Risan and the planned Adriatic–Ionian highway will additionally affect nature and the environment in the mountain areas. Considering the carbonate basement in this area, elevation, and the lack of wastewater treatment plants, the possibility of permanent pollution of underground karst features becomes real. One of the main tasks of environmental protection is



Fig. 8.6 Endangered areas: (a) tourism development (Žabljak), (b) mining (Pljevlja), (c) hydro-power (Piva), (d) unregulated landfill (dump) (Tara) (Photographs by P. Djurović P.)

the solution of temporary floods in the Cetinjsko polje, adequate carrying away of atmospheric waters and wastewaters, and implementation of wastewater treatment. Considering the main courses of groundwater (Lovćen–Njeguši–Bay of Boka Kotorska, Lovćen–Cetinjsko polje–Skadar Lake), the pollution of a wide area is inevitable. The construction of ski centers is planned on mounts Orjen and Lovćen where conditions for winter sports are favorable. The foundation of the second national park (on Mount Orjen), the declaration and protection of the Rumija mountain (regional park), and its planned connection with the National Park Skadar Lake will considerably contribute to the quality and improvement of environmental protection (Prostorni plan Crne Gore do 2020 2008).

A few factors in the mid-mountainous region limit sustainable development, as particularly concerns the steel industry, food industries, wastewaters, and communal waste in Nikšićko polje. In three municipalities in this area (Nikšić, Plužine, Šavnik: 82,501 inhabitants), 18,200 tons of communal waste was produced in 2004 (Mapa resursa 2011). The construction of five artificial lakes led to significant environmental changes in this part of the mountain area. Many open and underground bauxite pits have severely devastated the environment. The construction of hydro-power dams, planned on the Rivers Komarnica (1) and Morača (4), will also have harmful environmental impacts. Hydroelectric plants on Morača would produce annually 706 GW. In the hydroelectric plant Andrijevo (height of dam, 150 m; capacity, 250,000,000 m³) is planned a 10-h average workday with the installed stream flow of 120 m³/s. Minimal stream flow down of the dam is calculated as 10 m³/s. The construction of 11 accumulation-derivation electric plants is additionally planned on tributaries of the River Morača (height of dams, 39–140 m) with total annual production of 520 GW (DPP za prostor visenamjenskih akumulacija na rijeci Morači 2010). Their construction will undoubtedly have a serious environmental impact on this part of the mountain terrain. Natural diversity allows many kinds of sport to develop throughout the year (mountaineering, canyoning, skiing). Ski centers Durmitor and Vučje are the base for further development of winter sports. Suggested declaration of the regional parks Bioč, Maglić, and Volujak will provide, along with their connection with the National Park “Sutjeska” in Bosnia and Herzegovina, support for the foundation of overbordered protected areas. Formation of a regional park on Mount Sinjajevina is also planned.

Disposal of the waste from the lead-zinc mine Brskovo, as well as its possible reactivation, are serious challenges for water quality in the River Tara (Prostorni plan Crne Gore do 2020 2008).

The outer mountain region has well-developed mining (exploitation of coal and lead-zinc ore) and energy production (thermoelectric power plant Pljevlja), including the earlier cement production. All together contributed to significant environmental degradation of surface water and groundwater and resulted in polluted air in Montenegro (Pljevlja City). The exploitation of various mineral resources in Montenegro annually leaves behind about 25,000 m³ of tailings. The largest part is disposed in the mountain area (Nacionalna strategija održivog razvoja 2007). The obtained annual waste is from 1,084,000 t, whereas the energy production release is 350,000 t. (lit. 14). In the municipalities Pljevlja and Žabljak (40,010 inhabitants)

7100 t of communal waste was produced in 2004. The planned protection of the Ljubišnja Mountain as a Regional Park will contribute to environmental protection in the given area (Prostorni plan Crne Gore do 2020 2008).

The Prokletije mountain system has remained preserved because of weakly developed industry and its distance, that is, its isolation. Lack of an efficient system for waste control and a number of wild deponies in lower as well as in higher elevated areas at this mountain have considerably environmental impact, affecting human health. In Berane, Plav, Andrijevica, and Rožaje (77,351 inhabitants) in 2004 8350 tons of municipal waste were inadequately deposited. Exploitation of brown coal and the construction of thermoelectric power in the middle of the River Lim valley (Berane) will significantly degrade the human environment. The planned route of the highway Bar–Boljare passes for most of its length through the mountain area; hence, growing pollution of the air and water, devastated relief, and noise is expected. The formation of the regional park Komovi and its connection with the National Park Biogradska gora, with the newly declared National Park Prokletije and the regional park Turjak with Hajla, provides a basis for better environmental protection and preservation of this part of the mountain area. Diverse protection grades are adequate issues for the harmful impacts of increasing numbers of visitors (Prostorni plan Crne Gore do 2020 2008).

The development of mountain tourism offers one of the best solutions for the concept of sustainable development in the mountain area. Following the promoted program for benefits, an increasing number of night stays from 160,000 in 2005 to 4,200,000 in 2020 is inferred. The number of accommodations in family hotels, pensions, and apartments, increasing from 3500 in 2005, is planned to reach 35,500 in 2020. The number of employees, from 1500 in 2005, is expect to increase to 11,100 in 2020. Such large changes in the number of tourists inevitably will affect the mountain environment (Program razvoja planinskog turizma 2005).

8.9 Conclusion

A diverse physical-geographic basis (geology, geomorphology, climate, hydrology) enabled the diversity and rich natural potential resorts to be formed in the mountain terrain in Montenegro. Two mountain systems (Dinaric Alps and Prokletije Alps) include several naturally distinguished mountain regions. The outstanding geomorphological diversity resulted from the dominantly carbonate basement, which occasionally alternates with noncarbonate rock complexes. High mountains, deep valleys (canyons), broad mountain plains, and basins give this area astonishing dynamics. High precipitation (particularly as snow) allowed creation of specific landscapes (high-mountain karst, long-lasting snow, as snow pack and ice sheets), including various hydrologic occurrences (streams, disappearing rivers, rivers, lakes). A conflict between the highly vulnerable mountain area and necessary economic and social development should be overcome by implementation of the sustainable development concept. In spite of all efforts, certain economic activities are

still unsolved problems, particularly as concerns the exploitation and use of mineral resources (lead-zinc ore, bauxite, coal) and energy resources (thermoelectric power plants). Inadequate disposal of communal and other waste is still a large and significant problem. Unlimited and unplanned tourism development, although one of the least harmful and in terms of ecology the most acceptable economic activities, may in the future considerably impact and devastate the most important and the most valuable places in the mountain areas of Montenegro.

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