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A COMPARISON BETWEEN MONTENEGRO AND SOUTHERN ITALY ACROSS THE ADRIATIC SEA

Abstract: Altimetry is a key factor in determining water availability, as well as water shortage due to its use for purposes other than drinking. Secondary factors for the hydrologic balance are the positioning of the mountains with respect to the prevailing winds, the lithological structure of the mountains and their cover by grassland and trees. These factors will be evaluated in two regions which have many features in common, besides that of stretching along the 42° parallel, being separated by the Adriatic Sea: Montenegro (with the Croatian-Dalmatian coastline) and Molise (with the neighboring Gargano peninsula in the Foggia province of Apulia). A comparison will be made between the current climate situation in Montenegro and in Gargano, as both comprise high plains having a similar agroforestry profile. The study will focus on the Umbra Forest on one side, and the central-southern part of Montenegro overlooking Lake Skadar on the other side. Further comparisons will include the coasts of the so-called "Venetian Albania" and of Molise with the Lesina and Varano Lakes, and it will account too for the expected variations due to the rise of the sea level predicted by 2050 (1.5 and 2 cm/a). Pollution caused by the sea currents that carry material from the Po Valley area, and pollution caused by the modification of water circulation resulting from the construction of the trans-Adriatic pipeline will also be analyzed. Northern Montenegro, being a part of the climatic and hydrographic Balkan area, hence beyond comparison to the Apennines, shall be dismissed.

Key Words: *Water, Hydrology, Climate change, Forestry, Earthquake*

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1. INTRODUCTION

The 42° N-parallel stretches across the Adriatic Sea (Jadransko More) and hits the Italian peninsula in Molise at Termoli, on the western side, and the Balkan one in Montenegro (Crna Gora) at Ulcinj (Dulcigno), on the eastern side [1]. In between the two landmasses there are the two archipelagos Tremiti (Italy) and Pelagosa (Palagruža, Croatia). Montenegro has no significant islands and faces the sea directly through its mainland. Indeed, Coastal Montenegro, deeply indented by the Boka Kotorska (Bocche di Cattaro) — a series of four deep basins and narrow straits that makes the

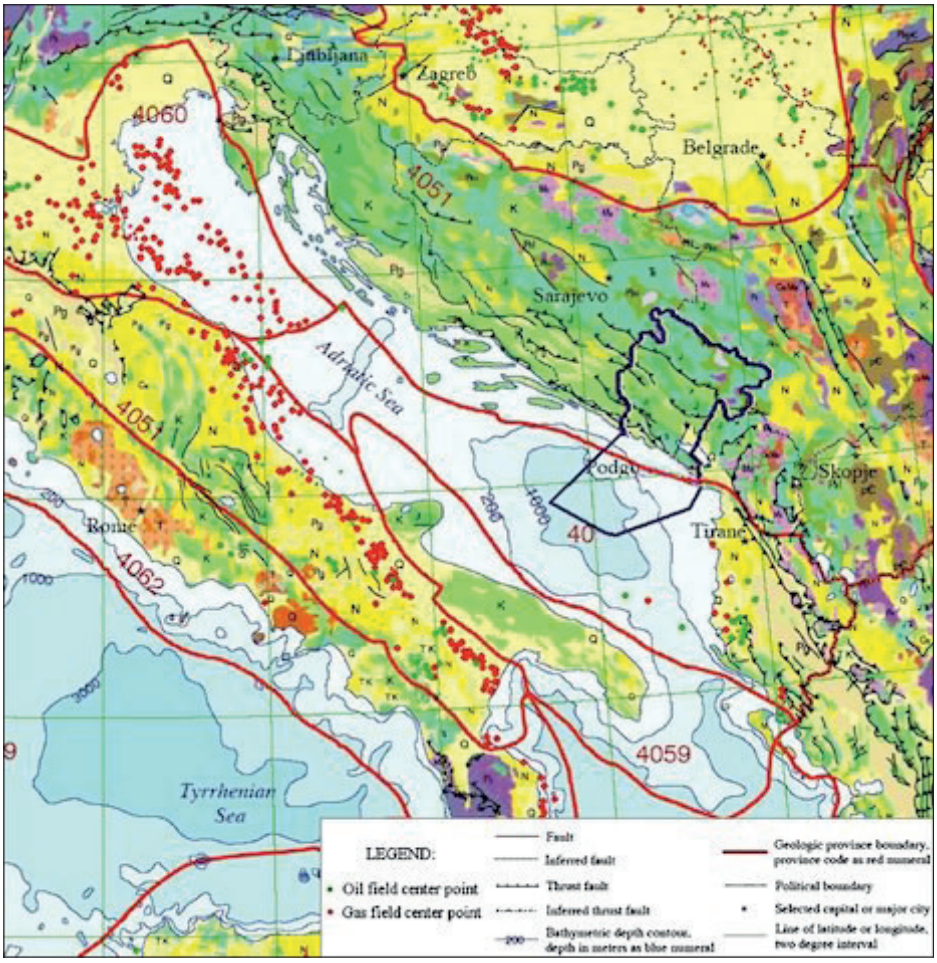

Fig. 1. The Adriatic Sea between the Italian and Balkan peninsulas. Montenegro is outlined in black, and the expected oil provinces in red.

whole of it the best natural harbour in the Mediterranean Sea — has territorial waters that project into the Adriatic Sea for only a small distance (Figure 1). By contrast, the Italian coastline is linear, but it is rather sharply interrupted by the protruding Gargano peninsula that stretches several km ahead from the coastline to form the so-called "Italian spur". Nowhere is a boundary from Montenegro towards Italy territorial waters, as the Croatian territorial waters around Palagruža, the island that Italy lost in 1947 to the Yugoslavian federation and did not reclaim when this dissolved in 1991, go across both water lines.

The two sides of the Adriatic Sea are deeply interrelated historically, since most if not all the coast that is now Croatia belonged to the Republic of Venice till 1797 (Dalmatia), as it also did a stretch of the Montenegro coast for shorter times (Albania Veneta, or Mletačka Albanija). Ethnically, there are in Italy several villages with people still speaking Slavic (the so-called "Schiavoni"); they are scattered through the Apennines not too far from the Adriatic coast. However, people there feel to be Croatians rather than Serbians or Montenegrins, as it results from both the characteristics of their language, despite the current heavy corruption by Italian, and their adherence to the Roman Catholic faith rather than to the Orthodox one.

2. GEOLOGY

Geology speaks against a close relationship between Italy and Montenegro. Indeed, the overall geological setting is very different between the Italian and Balkan peninsulas, although they both owe their origin to the northward movement of the African plate against the Eurasia plate.

The Dinarides are the continuation of the W to E oriented eastern Alps, but they bend towards SE down to Montenegro, where they still show most characteristics of the main Alpine belt. Their main structure formed over 30 million years (Ma) ago, but for the limestone and marly limestone ridges along the present Adriatic coastline, which formed later and grade into the N to S oriented uppermost Hellenic range in Albania. Folds, usually broken, verge towards the coastline and generated a series of elongated narrow valleys, the ridges in between reaching ca. 2000 m on average [2]. All limestones are affected by karst phenomena, which often go as far as to produce sinkholes (dolinas, polje), which interrupt the regular NW to SE continuity of the valleys. The Italian and Montenegrin regions have in common the occurrence of large lakes at a short distance from their coastlines: Varano in Italy, and Skodar (Scutari) crossed by the Montenegro/Albania border. The Dinarides narrow valleys have their rivers running mostly NW to flow into the Danubian plain, the unique major exception being

the Narenta river close to the Hercegovina/Montenegro border, which because of a fault crosses the ridges and flows directly into the Adriatic Sea.

The Apennines run SE-NW just as the Dinarides do, but they are much lower in average altitude and have a more complex setting that makes the rivers to cut the general direction; indeed, they mostly flow towards ENE to the Adriatic Sea. There a geological deep reason for such a different behaviour. The Adriatic coast of the Italian peninsula stretches partly along the southern Apennine belt and partly along the Apulian microplate (cf. Figure 1), both elongated from SE to NW and both pushing hard towards NE, but according to a different sequence of interrupted slices. The Apennine front line is nowhere visible, being under the Adriatic waters, but it makes itself acknowledged by frequent earthquakes. In the Molise Apennines they may reach magnitudes as high as 6.0, as in the 2002 Montecifone earthquake, as also, very recently (2018), 5.1 again at Montecifone. In the Apulian mass the highest recorded magnitude was 5.7 for the 2002 S. Giuliano di Puglia earthquake. However, much stronger events (up to magnitude 7.7) took place in the Gargano peninsula in 1627. One of them caused an imposing tsunami that affected all the lower Adriatic coastline: the sea retreated 2 miles from the Frontone River than the high waves moved back

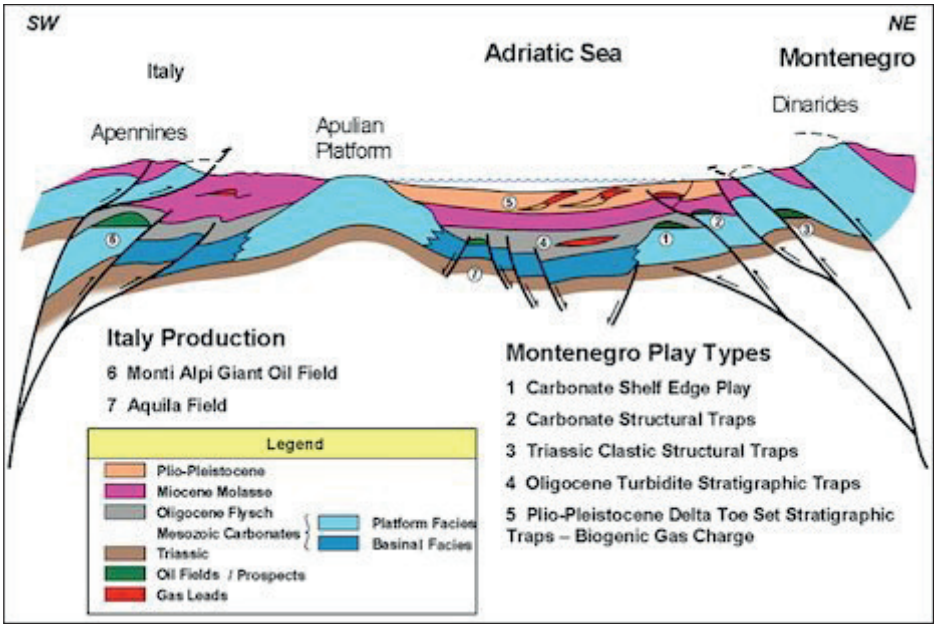

Fig. 2. Trans-Adriatic Sea profile from southern Italy to Montenegro. Note how the Apulian limestone platform divides the transect into two oil-producing sedimentary zones with different characteristics

from the Montenegro coast (where documentation is lacking) to the Molise and Apulia one. They flooded inland over most Foggia plain to the Lesina Lake, so that the Gargano peninsula for a short time was isolated as if it were an island. The first wave of the tsunami that had washed the Albania Veneta could not enter deeply into mainland, because the eastern Adriatic coast is everywhere too high and steep and because the Boka Kotorska sharp bents were transversal to the wave propagation direction.

3. GEOMORPHOLOGY

The Apennine smooth lithologies — mostly variegated Tertiary flysch of marly composition the age of which is as young as Pliocene-Pleistocene particularly along the coastline — are occasionally interrupted by elevated hard limestone massifs of much older age (Cretaceous), namely the Majella massif in Abruzzo, just north of Molise, and the Gargano peninsula in Apulia, the former one topping at 2793 m a. s. l. and the latter at 1065 m only [3]. Both limestone massifs are affected at the surface by extensive karst phenomena, and nowhere they show wide sinkholes, but in the Gargano National Park. Here the Pozzalina dolina, more than 100 m deep and with a diameter of 500 m, is the widest European single sinkhole of the karst type. However, notably, within the park there are numerous other caves, some of which decorated by the Palaeolithic man. The location of the hard limestone massif borders two basins of active sedimentation, both of potential oil production (cf. Figure 2), the western one being much smaller than the eastern one, which is super incumbent over the southern Adriatic Sea pit. Landslides are present everywhere not only because of the small resistance of the flysch to atmosphere degradation, but also because of the backerosion of the rivers due to the general Holocene upheaval of the sea level. Nevertheless, currently there is a widespread reduction of the Molise sandy coastline because of the river reduced solid capacity flow; indeed, most river waters are either regulated by dams or turned aside for irrigation purposes. Lake Lesina, the second largest lake (or — better said — lagoon) in southern Italy, formed because of a stream-driven sand barrier that in the late Glacial times locked a large bay that existed in the northern Gargano peninsula, not far from the Varano Lake. Currently, the sand barrier is being increasingly restricted by both the reduced sand feeding by the Adriatic currents and the general upheaval of the sea level induced by the climate change [4]. It is forecasted that by 2100 the lagoon will completely disappear, both because of the aeolian sand that will fill it from South and because of the demolishing effect of the wave and the currents against the barrier from the North (Figure 3).

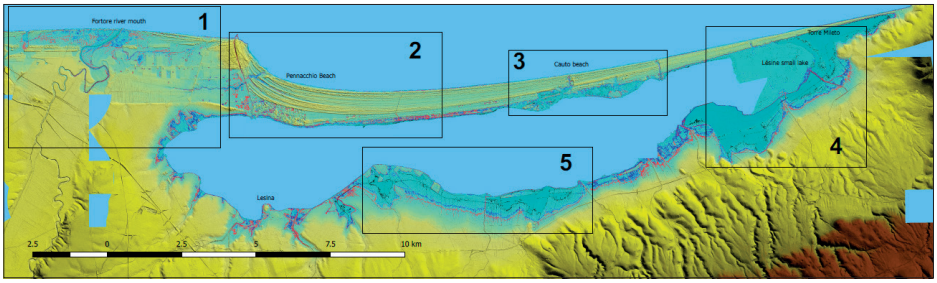

Fig. 3. Present extension of the Lesina Lake and location of the five main points where indications of its sand filling occur that will eventually lead in 2100 to its disappearance, as forecasted by the sea upheaval induced by the climate change (reproduced from [4])

While the rivers of the Italian peninsula flow down slowly in their wide valleys, often with an intermittent discharge due to summer draught, those in the Balkan peninsula steep valleys have rapid and constant flow regimes and are very cold, just as the Alpine streams are. Indeed, in Montenegro there is the deepest gorge in Europe, which was carved by the Tara river into the limestones as deep as 1300 m (Kanjon rijeke Tare). The narrow but steep profile of the Montenegro valleys makes them suitable of being barraged by arch dams and fill elongated reservoirs to catch water and produce hydroelectric power, whereas the Italian ones, even where they are regulated, are mainly used as reservoirs to catch rainfall during winter and spring, which shall then be distributed for irrigation during the dry summer season.

4. WATER RESOURCE

Water is Montenegro's biggest natural resource. Regarding precipitation, the mountainous area north of Boka Kotorska is the rainiest area of Europe, with annual precipitation levels of 4600 mm, which locally may reach values as high as 6000 mm [5]. Furthermore, in addition to the high rainfall due to altimetry, climate is significantly affected by *Genoa Lows*: cyclonic systems which form south of the Alps and bring additional rainfall, very local and intense but lasting just a few days. Longer periods of rainfall are the result of strong high-altitude SW air flow associated with the passage of depressions across Western Europe. Where the precipitation regime (rain and snow) is affected by Mediterranean influences, the areas tend to experience dry summers, with only 10% of annual rainfall quantities recorded in the summer.

Most rivers have their source within Montenegro and more than half of them (52%) fall within the Danube Catchment (Figure 4). All rivers have

a rather constant outflow that can be easily regulated by dams, reservoirs and large power stations thus being potentially suitable to produce significant amounts of electricity. However, only two rivers (Moraca and Komarnica, namely only 17% of the full potential) are being exploited, thus Montenegro is an importer rather than an exporter of electricity. Italy is a major partner in this application; in fact, the two largest power stations on the above rivers (at Perućica and at Piva) are financially and technically controlled by Italian companies. In addition, Italy and Montenegro are jointly involved in a project that would lay a 1000 MW power high-voltage direct current (HVDC) submarine trans-Adriatic interconnector cable having Villanova and Lastva as terminals and Kotor as its main distribution point [6]. Therefrom, the project has access to the entire Balkan electricity system. The Montenegro authorities now plan to open the market of hydroelectricity to other foreign investors, by allowing employment of two more rivers (Bukovica and Stiticarka) and by promoting the private building of mini-generating power stations on five more rivers (Ljestanica, Bistrica, Bjelojevicka, Sjevernica and Bukovica). Despite the frequent occurrence of waterfloods, particularly in the industrial area around Lake Skodar, Montenegro water resource will not undergo shortage because of pollution. The water used to produce electricity may be immediately re-used for irrigation, if needed, or even for drinking via some simple process of potabilization. Nevertheless, it should be noted that there is a future possibility of additional, even more restricted supply, because developing of a touristic economy will in future require increasing electricity, both during summer for air conditioning and during winter to adjust the snow fields, which moreover will require artificial snow and ice that can only be produced from water stored during the summer season. Unfortunately, current technique makes such an artificial ice polluted to a point of no longer being able to any other use but for the irrigation of marginal pasturing areas. A different story concerns the thermoelectric station at Pljevlja, at the NW corner of the country, also managed by an Italian company, the negative impact of which on the Montenegro environment is largely debated because it burns locally excavated lignite that releases sulphur to the atmosphere.

Water supply for drinking in Montenegro is usually at the good level, publicly managed and cheap but for some secluded areas. The main problems are: (a) insufficient water quantity for the coastal cities during the summer tourist season, when the population doubles or event increases three times; and (b) pollution by municipal and industrial waste-water discharges. Operationally, the water supply sector suffers from huge leakages, lack

Fig. 4. Altimetric map of Montenegro, with the Tara River Gorge (above) and Skodar Lake (below) outlined

of governance, inadequate pricing policies and misuse of drinkable water for non-household activities.

In Molise and Apulia the amount of rainfall is very low (indeed Capitanata i. e, the centre of northern Apulian flats, has the lowest rainfall value in all Europe: less than 500 mm/a). However, restriction of electricity power as it occurred in the past is no longer to be expected, due to the extensive supply by the Italian electroduct network derived from thermoelectric power plants. On the long run, a greater energy supply will be received when the South-Anatolian Pipeline, which will cross both regions, shall start operating at the main thermoelectric plants, which are in the Po delta area. Shortage of water supply, anyway, is a risk to be coped with on the short run particularly in summer, because the "Acquedotto Pugliese"

(planned before WWII and built shortly afterwards) is undersize for the current needs, particularly for the irrigation of the Manfredonia plain and the nearby Capitanata, which are the largest agricultural crop producers in Italy [6]. Inadequate water supply has already compelled agricultural entrepreneurs to restrict to marginal areas near the hillside the growth of durum wheat (which is essential for pasta making i. e, for Italy's traditional food, which is now largely exported after treating imported durum). They now reserve the best sector of the flat land to growing vegetables, mainly tomatoes (i. e, another major ingredient of the so-called "Mediterranean food", highly appreciated everywhere and by now already mostly imported as ready-made juice for low-quality cooking). Unfortunately, the supply of fresh, clean and drinkable water is so short that other traditional manufacturers such as those growing bovine and ovine stocks to transform milk to cheese (both a dairy one as "burrata" as well as a seasoned one such as "caciocavallo") are already suffering, and cope with their needs using imported cow milk.

5. FORESTRY

Water natural supply though rains is an essential factor for forest best growth [7]. Forests cover some 60% and forest land (which under the international definition also includes brushwood, bushes, maquis and stone steppes) additional 10% of Montenegro. Such a large coverage places Montenegro third in Europe after Finland and Sweden and is going to increase further because of different factors. One of them is that most forests are state-owned and only recently open to acquisition by private companies, but prominent is also the trend of reducing the number of populations, primarily in rural areas of hilly and mountainous areas, which leads to the spontaneous spreading of forest vegetation on potentially productive agricultural land that is no longer being cultivated. Coniferous forests mainly dominate on higher altitudes and cover a wide mountainous area in the north of Montenegro, whereas in the areas closer to the Adriatic coast broadleaved species are the dominant ones. The biodiversity is rather large: 68 broadleaved species and 10 conifer species have been reviewed, beech (*Fagus moesiaca*) prevailing among broadleaves, while spruce (*Picea abies*) among conifers. The extimated volume of wood is 118 million m3, the share of broadleaves being 59.8%, and that of conifers 40.2%. Most volume of Montenegrin forests is concentrated on thin to medium strong trees, while the share of strong dimensioned trees, especially those above 70 cm in diameter, barely reaches 8,6%. These results classify forestry as being the second

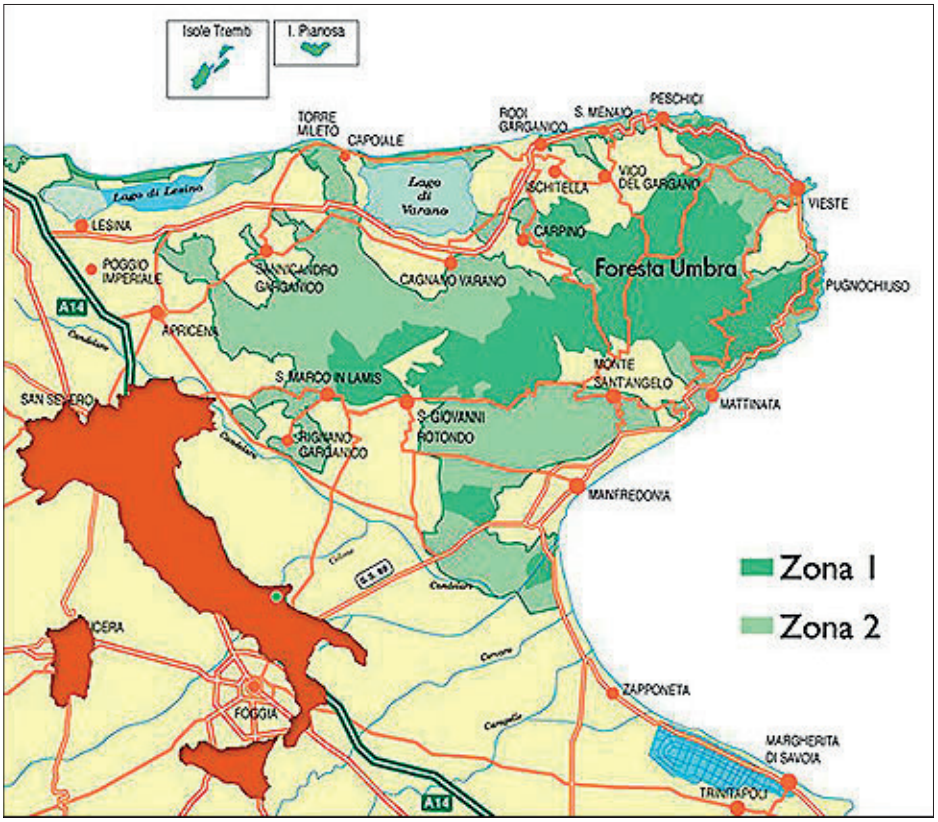

Fig. 5. Map of the Gargano National Park showing the "Foresta Umbra" (zone 1, protected area A) and the discontinuous zone 2 (which includes the B and C protected areas)

best potential natural factor creating income to Montenegro. Additional income would come from the heavily forested natural parks, which attract visitors and hunters.

Molise and Apulia are very poor of trees due to the dryness of their climate (only 1300 mm of rainfall a year, mostly in winter, when the Northeastern wind "Bora" blows) and to the usage of all flat land for agricultural purposes. However, the only natural park in this area, the Gargano National Park (Figure 5), includes a large forest (Foresta Umbra), which is a rare but highly representative example of the flora that covered all Mediterranean warm lands before man started destroying them for colonization.

Foresta Umbra extends over a nearly flat limestone hilltop surficially attacked by karst at 800 m a. s. l. It includes three zones: A) a upper zone where the most common tree species is beech (over 84%), followed by maple;

B) a middle one dominated by several types of oaks, but also including some 20% of beech and C) a lower one that at places reaches as far down as the Adriatic sea through steep valley ("valloni") where the dominating flora assemblage is the Mediterranean brushwood with holm oak intermixed with other minor bush. As the Foresta Umbra is a national park there is no permission of using it for forestry, but it produces income anyway because of tourism. A particularly attended locality is "Zappino dello Scorzone": a single 700 years' old, 5 m in diameter pine (*Pinus halepensis*), which is not far from Peschici and Vieste, the two most touristic villages in the "spur of Italy".

6. CONCLUSION

From the tip of Gargano peninsula in Apulia to the coastline of Montenegro there are ca. 200 km of Adriatic Sea, and yet the areas are utterly different as for climate, water, forestry and expected evolution during the incoming climate change. Montenegro is made up by narrow and deep valley carved into limestones by rapidly flowing cold rivers that run all the year through because of a rainfall that is the heaviest ever recorded in Europe. By contrast, Molise and upper Apulia, although lying at the same latitude, are among the driest areas in Europe, with less than a tenth rainfall than Montenegro has. Consequently, their rivers run slowly, and are often water-free; their valleys are wide, and the general landscape is fit for agriculture rather than forestry. Indeed, Montenegro has one of the largest potential economy for timber (mostly beech and spruce) and electricity within Europe, whereas Molise and Apulia are among the largest crop producers fit for the Mediterranean diet. The Parco Nazionale del Gargano, the "spur of Italy", has an intermediate setting among these two opposite Adriatic regions. At a moderate height it includes a forest (Foresta Umbra) that receives enough rainfall to grow beech and oak, but it cannot represent a potential resource because it is protected as one of the last remaining testimonies of the original Mediterranean warm climate environment. Tourism, in both regions, is likely to be the future major resource, while waiting for the climate change to stabilize.

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