PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.1

SET UP OF PILOT SCECIFIC MANAGEMENT PRACTICES

D.T2.1.4 DESCRIPTIVE DOCUMENTATION OF PILOT ACTIONS AND RELATED ISSUES

PILOT ACTION PAC2.4-2: *"IMOTSKO POLJE SPRINGS"*

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Lead Institution	Croatian Geological Survey
Contributor/s	Ivana Boljat, Ivona Baniček, Matko Patekar, Tihomir Frangen
Lead Author/s	Josip Terzić, Jasmina Lukač Reberski
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Contributors, name and surname	Institution
Josip Terzić	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Jasmina Lukač Reberski	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Ivona Baniček	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Ivana Boljat	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Matko Patekar	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Tihomir Frangen	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Daria Čupić	Croatian Waters

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1. Introduction

The pilot area of the spring catchment area of the Imotski field is a typical karst catchment characterized by very complex and intricate hydrogeological features. This area is faced with two basic problems, on the one hand by the flooding of certain areas, on the other hand, by the intensive agricultural activity. Since both issues are directly related to the quantity and quality of drinking water resources, managing this area is of the utmost importance.

2. Basic data about pilot action

2.1. Geographical description

Imotsko polje is a karstic field partially situated in Croatia and partly in Bosnia and Herzegovina (Figure 1). Its total surface area is 92 km^2, of which 48% is in Croatia. It is 24 km long and sloping from northwest to southeast, from 280 to 250 m a.s.l. To the south and southwest of the polje, the high mountain mass of Biokovo (1762 m a.s.l.) rises, and on the north and northwest the mountains are lower. Between the hills, smaller poljes (Studenačko polje) and valleys (Ričica) are located.

The largest settlement in this area is Imotski with 10 thousand inhabitants, which is the main administrative centre of the Dalmatian Zagora. It is also the main transport hub connecting the Republic of Croatia with Bosnia and Herzegovina. Other larger settlements include: Proložac, Vinjani, Zmijavci and Runovići.

The northern part of the Imotsko polje differs from the south due to the different rock composition. In the northern part we encounter huge pits with or without water, and in the south are dry valleys and smaller karstic occurrences - pits, caves and crags. Around the Imotsko polje and the Prološko Blato, significant karstic occurrences are lakes in pits and very large dry pits.

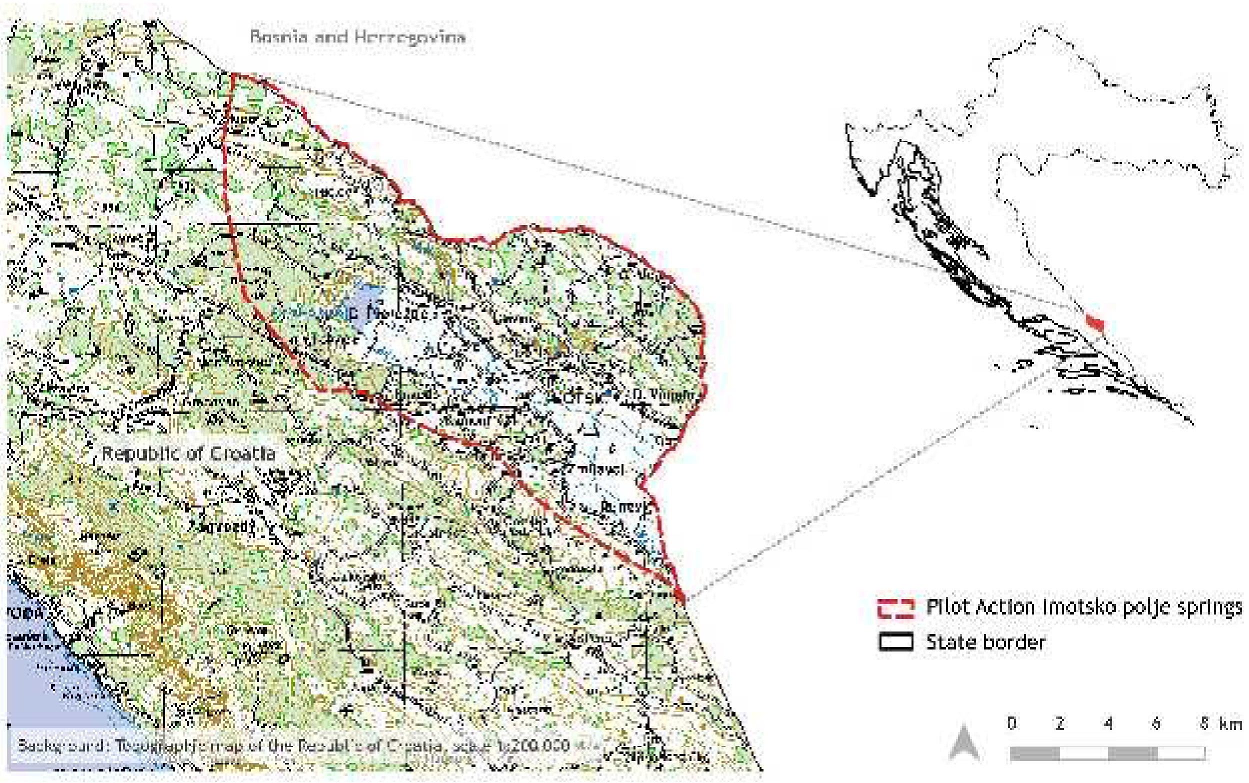

Figure 1. Topographic map of the Imotski field spring catchment area

2.2. Geological description

The geomorphological characteristics of the considered space are the result of complex geological, lithological, hydrogeological and climatological processes. Morphological forms of today's terrain are conditioned primarily by the lithological composition of deposits and their position, the tectonic movements and the influence of exogenous and endogenous factors.

Lithostratigraphic and tectonic features of the Imotsko polje are shown in **Figure 2**. The basis for the geological description was Basic geological map, sheet Imotski (Raić, V. i dr., Sarajevo-Beograd 1976).

The pilot area is largely built of limestone and dolomite of Cretaceous age. The surrounding mountains and other elevations as well as karstic plateaus are all built from the limestone, while the valleys are made in the less resilient limestone-dolomitic and dolomitic rocks or in the younger, Tertiary semi-permeable and impermeable deposits. Tertiary deposits, mostly consisting of flysch, lie transgressively on the Cretaceous base, while the Quaternary ones are deposited in the Imotsko polje. These consist of mostly alluvial deposits of sand, gravel, loam, mixed with terra rossa and humus, and in the central part of the polje Pleistocene deposits of clay, gravel and sand are located.

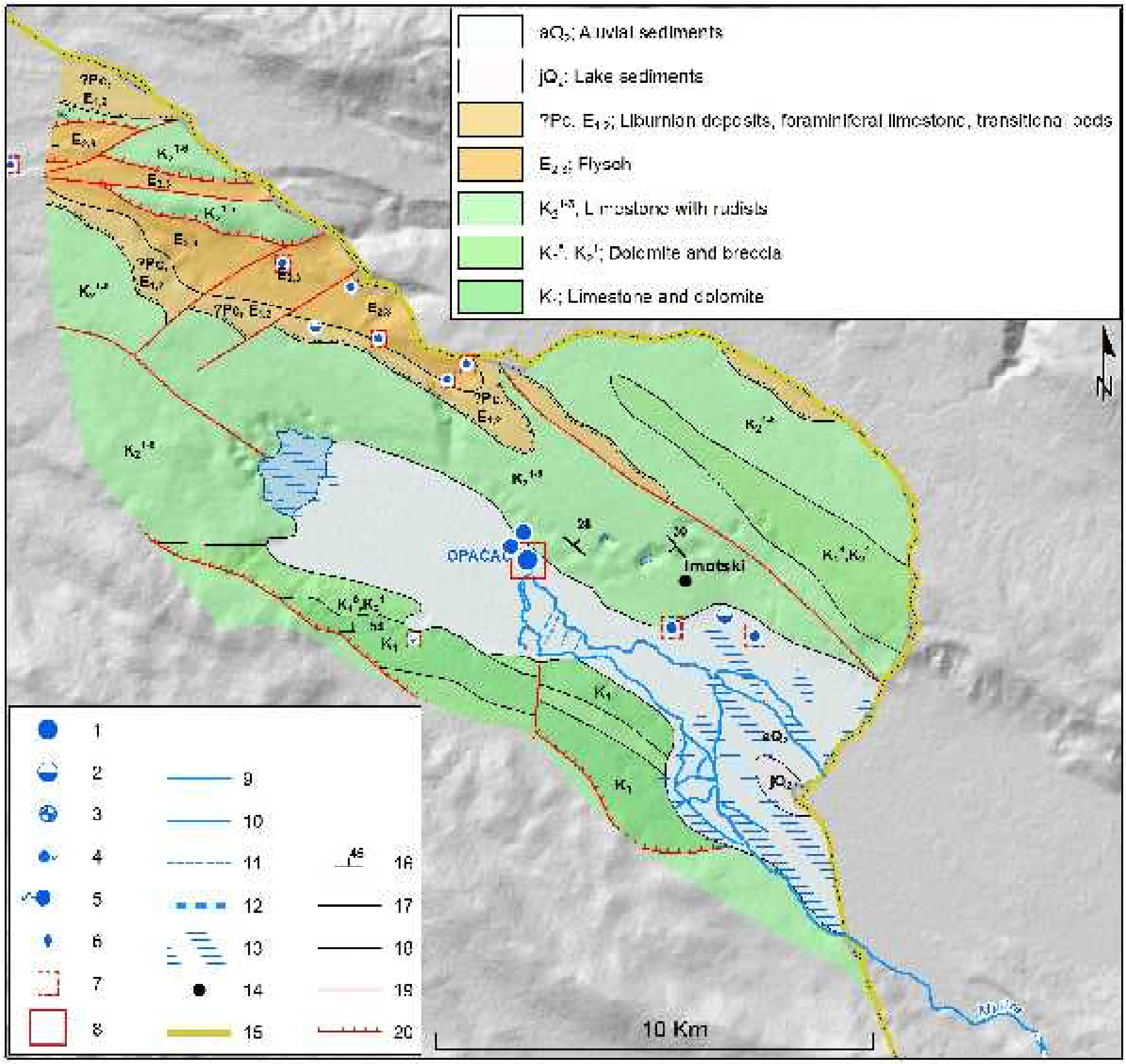

Figure 2. Geological map of the spring catchment area of the Imotski field. Legend: 1 constant spring 2 occasional spring 3 estavelle 4,5 springs of various abundance 7 primitive catchment 8 public water supply site 9-11 surface stream 13 flooding area, swamp 14 settlement 15 state border 16 position of layer 17 normal lithostratigraphic boundary 18 erosion-discordant geological boundary 19 normal fault 20 reverse fault

Given the structural-tectonic characteristics, this area belongs to the Dinaric zone (Herak, 1991). The fundamental feature of this and the surrounding terrain is the high level of tectonic disturbance of the sediments, which is manifested in intense folding, flexural stretching, breaking and shaping of crusty material. Structures have a typical Dinaric orientation, NW-SE. This area belongs to the structural subunit of Imotski within which a greater number of anticline and syncline were found, and it was overthrust on the southwestern structural unit. Structural shapes are tectonically cut into longitudinal and transverse faults, which have weakened their barrier function. Due to the stress on the faults and parts of the structure, the opening of the space is present, and along such tectonic weakened zones the groundwater flow is possible, so such faults have the most important hydrogeological function. The formation of the Imotsko polje was conditioned by the tectonics. Afterwards, the polje was shaped by erosive processes. The lateral part of the polje form Cretaceous limestones and dolomites, and the bottom is covered with loose material that is deposited by the flooding of water streams.

2.3. Pedology

As mentioned above, South Dalmatia consists mostly of limestone and dolomites. The most prevalent terrain is bare limestone karst with all members of the evolutionary series of soils on limestone, except in valleys with a large area under hydromorphic soils: fluviosol, histosol, hypogley and amphygley, both in the Neretva valley and in the karst field, as well as rendzina, regosol, anthropogenic soils of glass and plastic houses-rigosol and hortisol on flysch (Bašić, 2013). Pedological units of the area are presented in **Figure 3**.

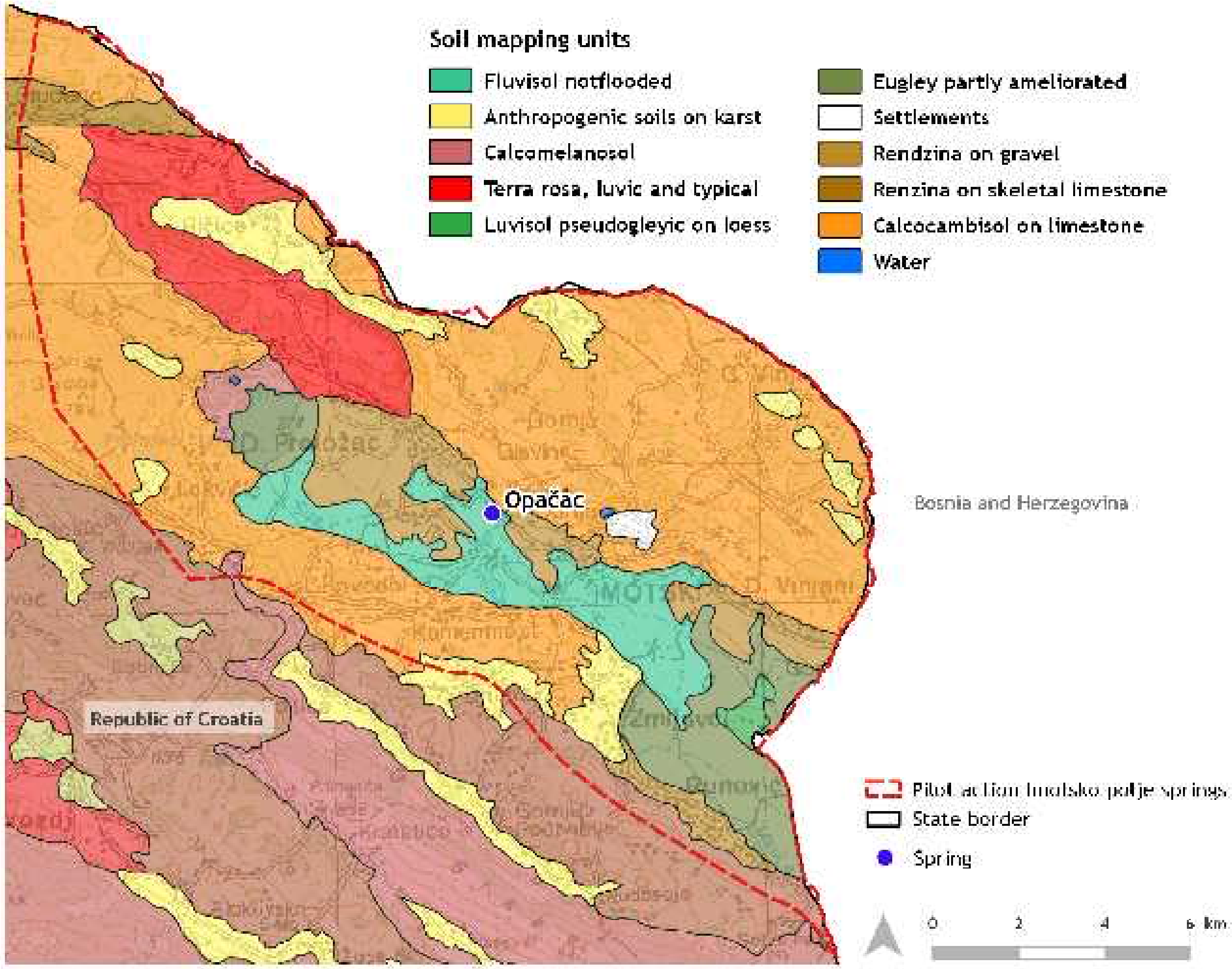

Figure 3. Pedologic map (source: Croatian Environmental Agency)

2.4. Climate characteristics

The greatest influence on climate conditions is the mountain Biokovo, which makes the topographic barrier, and also the border between the Mediterranean and Submediterranean climate. In the area of Imotsko polje the winters are cold and humid, and the summers are very dry and warm.

During the summer months of July through the end of September, drought is a significant feature of this area. The basic winds are Bura and Jugo, whose frequency and strength are greatest in the cold period of the year. The Bura is a relatively dry and cold wind, bringing clear, dry and cold weather, while Jugo is a warm and damp wind that brings warm and humid weather with rain. Mediterranean influences on the Imotski area come from the southeastern valleys of the Neretva, Trebižat and Tihaljina and they are here, due to the openness of the relief to the southeast, more pronounced than in other parts of the Imotska krajina (e.g. Vrgorac).

According to the data of the Climate Atlas of Croatia (Zaninović et al., 2008; Perčec Tadić M., 2010), the average annual temperature of the Imotsko polje ranges from 10-13°C (**Figure 4**), and the mean annual precipitation amounts from 1300-1500 mm (**Figure 5**). Evaporation ranges from 600-800 mm/year. The mean annual air temperature was analysed based on the air temperature data from 152 main and climatological stations, while the mean annual precipitation volume for the period 1961-1990 is analysed on the basis of measurements of average daily precipitation amounts from 567 main climatic and rain measuring stations.

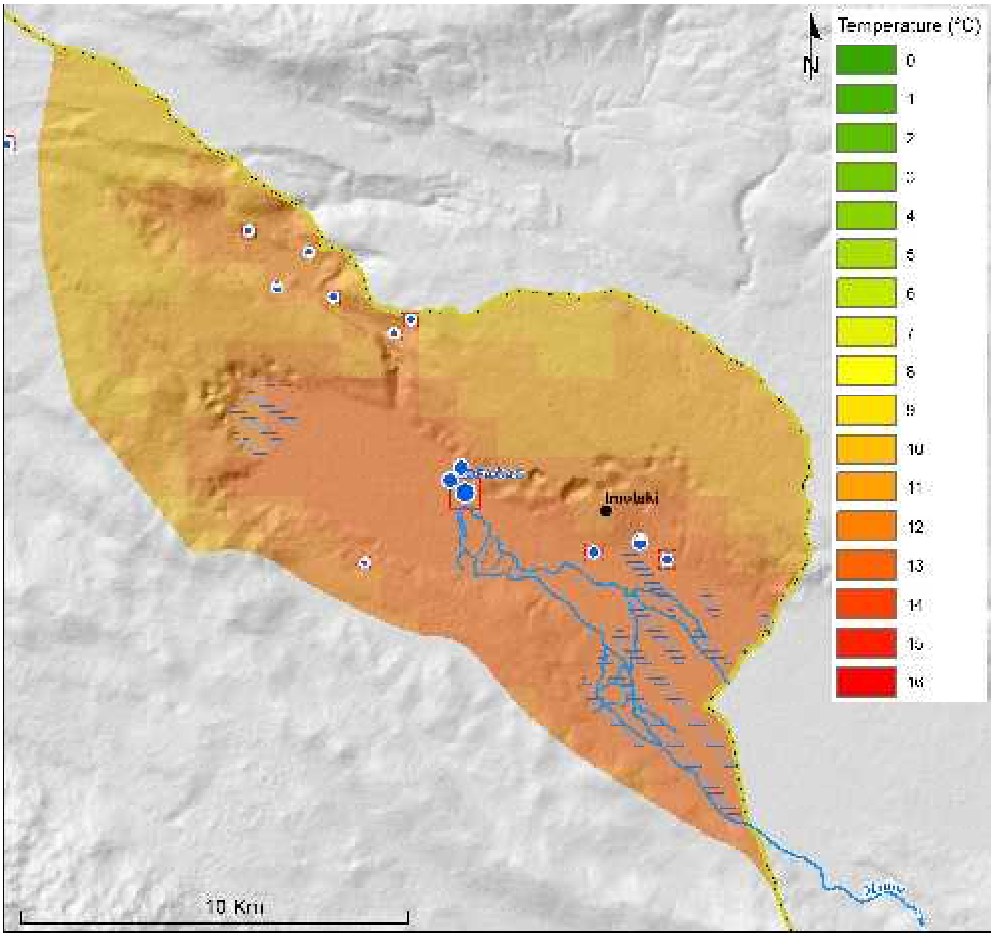

Figure 4. Map of the average annual temperatures according to the data of the Climate Atlas of Croatia (Zaninović et al., 2008; Perčec Tadić M., 2010)

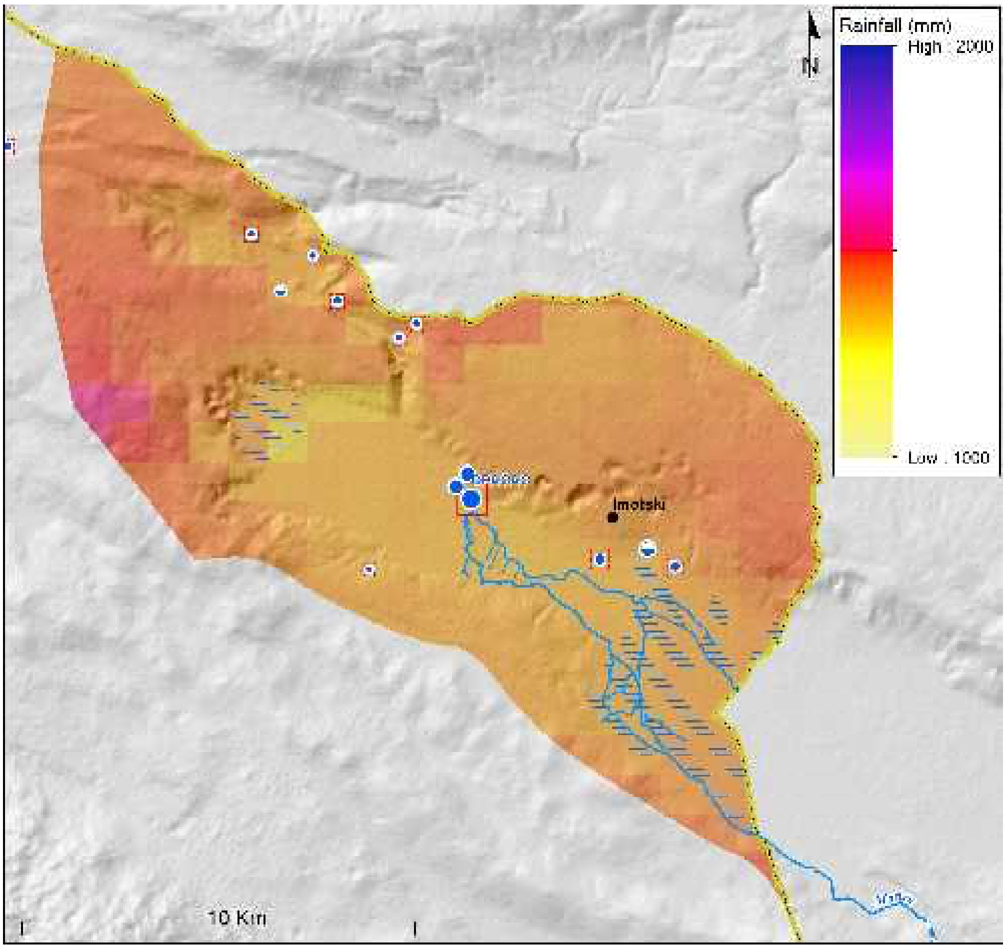

Figure 5. Map of the average annual precipitation according to the Climate Atlas of Croatia (Zaninović et al., 2008; Perčec Tadić M., 2010)

2.5. Hydrology

2.5.1. Surface waters

From the surface streams, the most important one is the only constant flow of the Vrljika River, followed by Ričina and a large part of the regulated watercourse Suvaja (forms the Prološko Blato) and the channel of Sija (the drainage of the water from the Prološko Blato) (**Figure 6**).

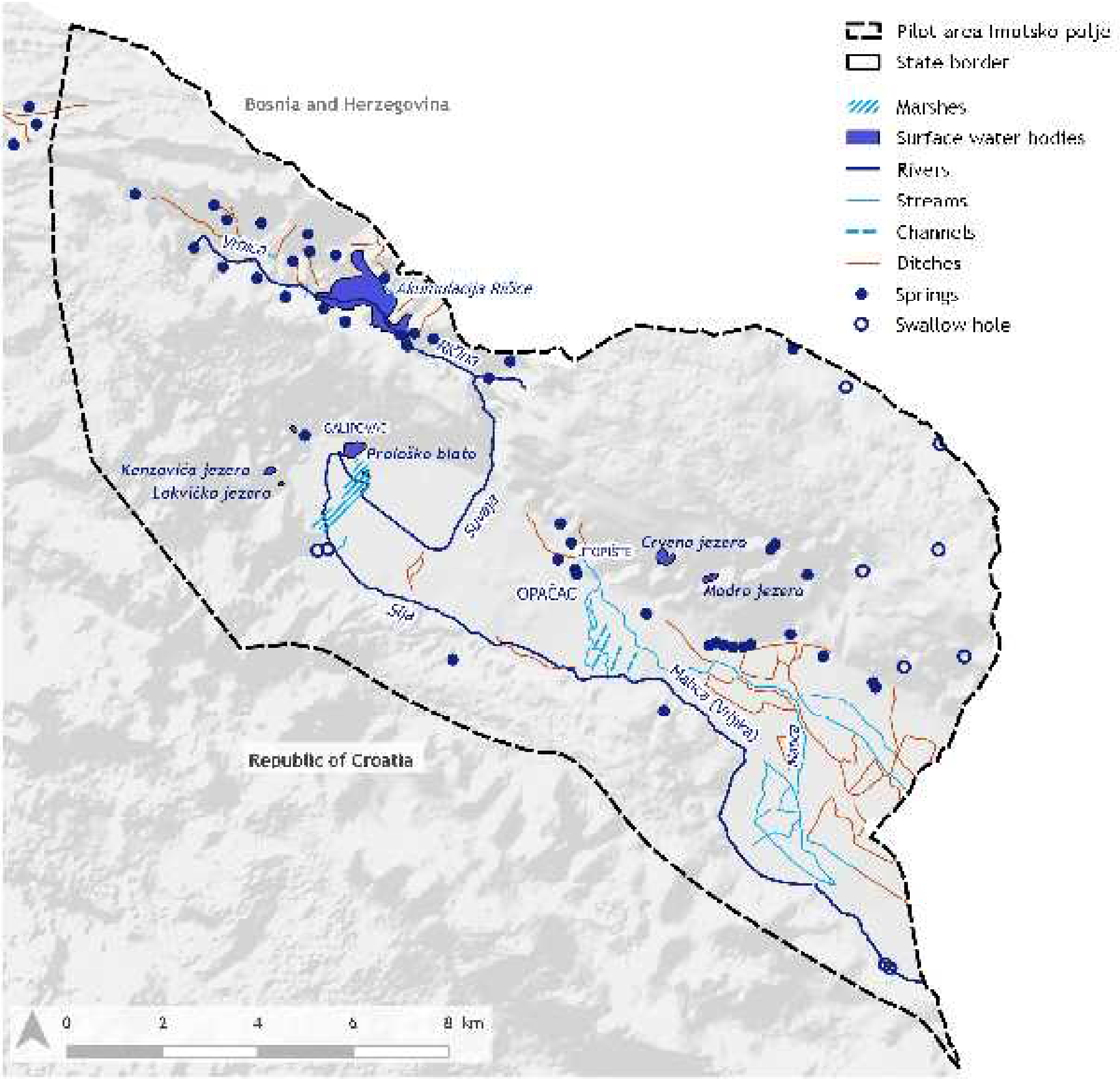

Figure 6. Surface waters at the pilot area

Vrljika River is the largest watercourse of the Imotsko polje, which is 18.3 km long and passes from the Opačac spring to the tunnel of Pećnik in Herzegovina. During its course, it changes its name five times (Vrljika-Matica-Tihaljina-Mlada-Trebižat). The Vrljika River is made up of five springs, the largest of which is Opačac (**Figure 7**). It is the main recipient of the polje and receives water from a network of drainage channels of the polje. The Opačac springs siphonally flows from a fenced lake that is 25 m in diameter. The Jauk spring is located upstream to the left of the Vrljika River, which is sometimes dry. The Utopišće spring has a minimum yield of 250 l/s. From larger springs, mention should be made of a large periodic spring of Duboka Draga with a maximum discharge of more than 5 m^3/s. In 1961 and 1962 discharge of the Vrljika spring was measured, according to which the average discharge of the river is 7.38 m^3/s and a minimum of

1.5 m^3/s (Petrik, 1962). In 1992 the specific discharges of the spring of Opačac was: Q_{MIN} = 0.971 m^3/s, Q_{AVG} = 5.63 m^3/s and Q_{MAX} = 28.7 m^3/s.

Figure 7. Opačac spring - Vrljika River

In the karstic hinterland, along the northwestern edge of the Imotsko polje there are several lakes in deep pits. The most notable are the rare karst phenomena Crveno and Modro Lake near Imotski (declared a cultural monument in 1964), and to the west of the Prološko Blato there are also Knezović lake, Mamić lake and Galipovac.

In the northwestern part of the pilot area, near the border with the neighbouring Bosnia and Herzegovina, the reservoir of Ričica, known as "Zeleno jezero" is located. The lake was completed in 1985 with the purpose of irrigation of the surrounding area. Accumulation of Ričica is a multifunctional object. The dam was built in order to contain the sudden water breakthrough and thus protects the downstream villages and the Imotsko polje from the flooding of the water of Ričina or Suvaja. Retention space that accepts high water and controlled water flow into the Suvaja riverbed enables irrigation part of the Imotsko polje during the vegetation period.

The plan was to build a large irrigation and melioration system that would drain the water from the reservoir, but it has not yet been constructed to date, so the water stopped by the dam created a new lake, the reservoir of Ričica as well as Prološko Blato. In recent years, the idea of building this system has been restarted and is currently under development of a study of the impacts of the irrigation system of Imotski-Bekijsko polje (Bekijsko polje is the BiH part of the Imotsko polje). For irrigation, 2,580 ha are planned, which makes 77% of agricultural areas, or 68% of the Imotsko polje. Wine cultivars, which need not be irrigated, will be grown on a surface of 1,050 ha. Water for irrigation would be taken from the existing reservoir of Ričica. It was estimated that the irrigation system will have a significant negative impact on both water quantity and water quality in the area, so the final impact will be assessed after completion of the impact study.

In the western part of the Imotsko polje, there is a wetland area of Prološko Blato, protected since 1971, covering a surface of 10.24 km^2. It is a spacious flood area, which during the part of the year is under water, and only a small part is under water all year long (Prološko Blato lake is 35 m deep). Prološko Blato is a typical example of the floodplain karst fields in Dalmatia, which are now largely destroyed due to drainage that expanded the agricultural land. Prološko Blato is fed by the Ričina River, which flows into Bosnia and Herzegovina, which under the village of Ričica changes its name to Suvaja and reaches the karst field near Prološko Blato. Prološko Blato and a small lake beside it called Krenica, and the lakes in the large and deep pits, Galipovac, Lokvičići and Knezovići, make up a singular system on 261 m a.s.l. up to 266 m a.s.l. Prološko Blato oscillates up to 5 m and partially flows into Vrljika. During the dry season, Prološko Blato, as well as other nearby lakes, is drained very slowly through the swallow holes that lie at the bottom of the lake.

According to the hydrological balance (Žugaj, 2000), the flow of water into the Imotsko polje is about 17 m^3/s. The measured mean flow on the Vrljika River at the Šalnovci stream gauge point is 12 m^3/s. This suggests that about one quarter of the water is lost in the Vrljika and Prološko Blato riverbeds.

2.5.2. Flood issues

An important feature of the Imotski polje is the regular seasonal floods that limit its agricultural potentials, but at the same time maintain the fertility of the soil. Out of the total available area, about 70% is exposed to periodic flooding of lower or higher intensity and duration, and excessive moisture during winter and spring (**Figure 8**). Apart from the drainage of water from the northwestern part of the polje, in the southeastern part of the polje, all the water that discharges on the area from the Grudsko vrelo spring (average flow 3,55 m^3/s) to the town of Grude and continue to flow towards the springs in the valley of Tihaljina.

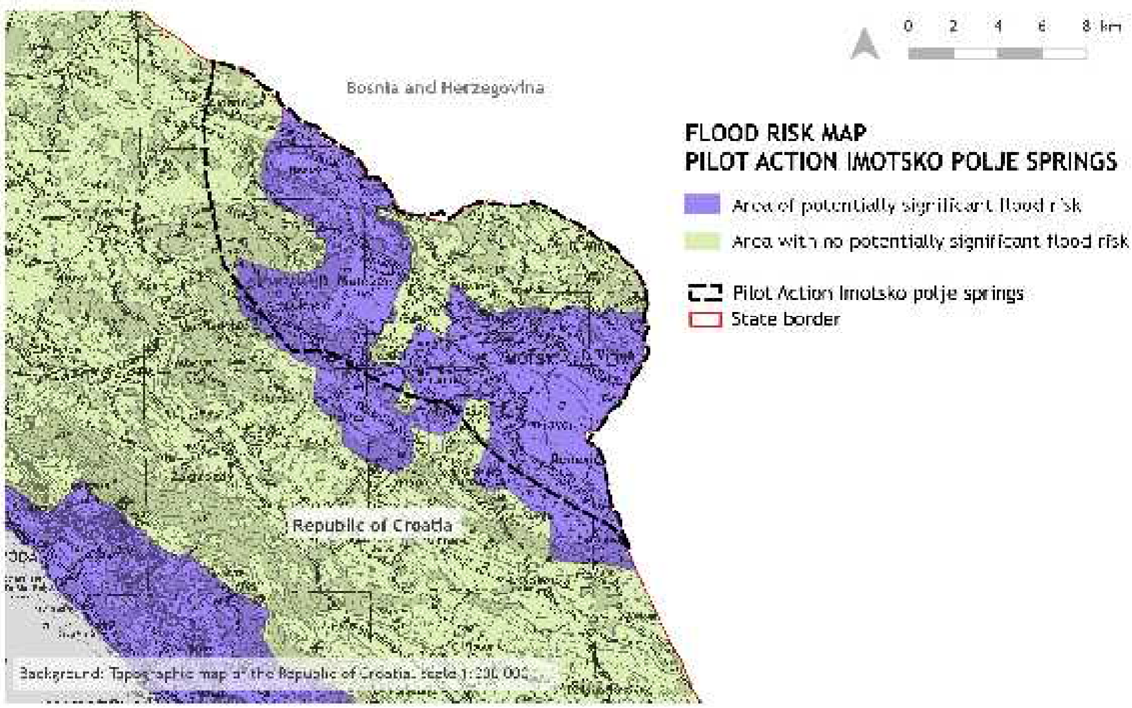

Figure 8. Flood risk map

With the construction of the Ričica reservoir, the Imotsko polje is protected from the outside flood waters, but the biggest problem remains, the internal water of Imotsko polje, i.e. the recipients who should receive them.

Vrljika's regulation was carried out at the beginning of the 1960s and neither system reconstruction nor cleaning of the basin has been done since. Such a situation requires urgent intervention, but any major action on the Vrljika River can be done only after repairing the condition in the downstream section of the watercourse in the Herzegovinian part of the polje. The largest impact on the flood level of the Imotsko polje is the manner of evacuation of high waters from the area of the natural retention of Nuga in the southeastern part of the catchment area. Until 1950, the discharge of the Imotsko polje was carried out by drainage and seepage through swallow hole zones from the wider area of Nuga Lake in the northeastern part of the Imotsko polje. In order to reduce the duration of the flood and the rapid evacuation of the water, the tunnel of Pećnik was built, which controlled the discharge of water into the Tihaljina River. The construction of HPP Peć Mlini has changed the conditions of retention of inflow and evacuation of water. A part of the retention space was arranged as a pool for the needs of balancing inflows for HPP purposes. For the evacuation of water from the lower part of the Imotski-Bekijsko polje, apart from the swallow holes and sloping zones, the water tunnel of Pećnik is used as well as the tunnel Peć Mlini HPP.

In order to solve the problem with the flood water reception, a regulation of the Vrljika segment, reconstruction of the Pećnik tunnel and regulation of the Trebižat River (downstream of Imotsko polje) are required. The problematic part of the system is situated on the territory of the Federation of Bosnia and Herzegovina, which outlines the need and obligation to negotiate and harmonize the actions with the relevant institutions of the other country. Recommendations are that areas designated as floodplain should be employed for non-sensitive flood uses, so they would not suffer any great damage due to high water (Hrvatske vode, 2012).

The amount of water evacuation through swallow holes and constructed devices apart from their capacity depends largely on the flow of the Tihaljina River (downstream of Imotsko polje) on the Humac hydrological station profile. The discharge limit is set to prevent flooding in the downstream area so that the amount of water evacuated from the Nuga pool area is equal to or lesser the capacity of evacuation structures and slopes depending on the downstream hydrological situation.

It is important to highlight the results of research related to the climate change we are facing in the last decades. Based on three different climate models (RegCM3, Aladin and Promes) assessment of impact of projected climate change on water resources in catchment area in southern Dalmatia has been done. Identified changes in the main water balance of Prud spring for the period 2021-2050 in relation to the period 1961-1990 ranging from -1.4 % to, as much as -52.3 % (Lukač Reberski et al., 2015). Despite uncertainties arising from climate models, it is very important to take into account such high values of scenarios and serious and urgent consider the measures that should

be taken in case of future realization of these predictions.

2.6. Hydrologeology

The pilot area is largely made of porous carbonate deposits that are characterized by fracture-cavernous porosity (**Figure 9**). The geological basis for the creation of the basic hydrogeological map M 1:100.000, sheet Imotski, was the Basic geological map (Raić, V. et al., Sarajevo-Belgrade 1976).The greatest influence on the hydrogeological characteristics of the pilot area is the Imotsko polje, which is made of intergranular Quaternary deposits of medium to low porosity. The Imotsko polje is slightly sloping from northwest to southeast and from northeast to southwest. It is a typical karst field (polje) on whose northeast edge there are numerous occurrences of permanent and intermittent springs that form the hydrographic network with the main flow of the Vrljika River, while the southeastern part has numerous swallow holes of different capacities. Quaternary deposits of the polje, up to 150 m thick, of a clay-sandy composition in the part of the polje around the source of Opačac, have the function of a complete barrier and cause the drainage of the groundwater that gravitate towards the polje from the carbonate hinterland in the north and northeast. Deposits in the Imotsko polje form a hinged (partial) barrier and the water flow underground towards a lower erosion base, while on some places they form a complete barrier causing the groundwater discharging on numerous springs in the northern part of the polje. The springs in the northern part of the pilot area have low discharges, 0.1-1 l/s, and occur in the area of the Eocene flysch in the Studenačko polje and in Ričica. Only on the northwestern side of the Imotsko polje there are large permanent and occasional springs, the largest of which is Opačac.

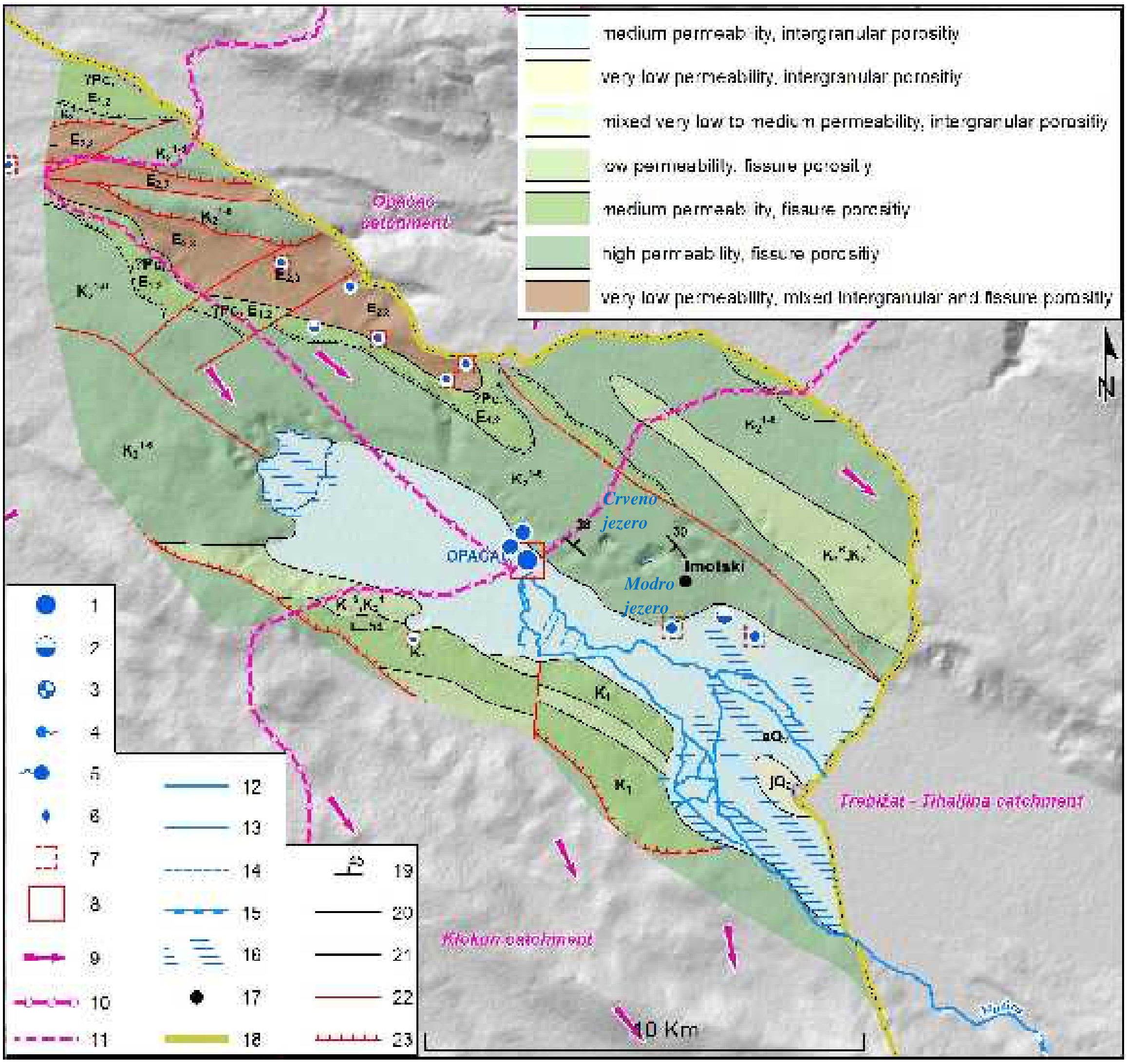

Figure 9. Hydrogeological map of the catchment area of the Imotsko polje springs. Legend: 1 constant spring 2 occasional spring 3 estavelle 4,5 springs of different abundance 7 primitive catchment 8 public water supply site 9 groundwater flow 10 watershed 11 presumed watershed 12-14 surface flow 16 flood area, wetland 17 settlement 18 state border 19 layer position 20 Normal lithostratigraphic boundary 21 erosion-discordant geological boundary 22 normal fault 23 reversal fault

The most complicated hydraulic relationships are observed in the northwestern part of the Imotsko polje, where there are several hydrogeological phenomena of different hydraulic mechanisms at relatively low distances (Slišković, 2014). Investigations have found that the springs of the Vrljika River (Opačac and others) are completely independent of nearby lakes. Complex hydrogeological relations are conditioned by complex tectonic relations in the Vrljika River (Petrik, 1960).

The water in Modro jezero is situated in a deep pit and is occasionally dry, while the Crveno jezero is in a large hole whose bottom is about 6 m below sea level. At the bottom of the lake there is a drainage gallery (channel) (Garašić, 1999). Modro and Crveno Lake are located at a distance of 1 km and are formed in the rocks of the same hydrogeological environment and yet the fluctuation of the level of the Modro jezero (103 m) is five times larger than that of the Crveno jezero (21.6 m). The highest lake level oscillations are recorded in Modro jezero, and the lowest in the lake Krezović (1.5 m). Such differences in hydraulic relationships at such a small distance reflect the very complex nature and intricate connections in the karstic terrains. All the lakes located in the karstic sediments on the very edge of the Imotsko polje lose their water only via the underground.

2.7. Land use

On the Corine land cover map it is visible that about half of the pilot area is covered with forests, while the other half is belongs to agricultural land and vineyards (**Figure 10, Table 1**). In the area of the Imotsko polje there are almost no unarable surfaces. Planned irrigation system construction will significantly change agricultural production, which implies intensification of production, particularly fruit, vegetable and arable crops, which, unlike wine cultivars, require irrigation.

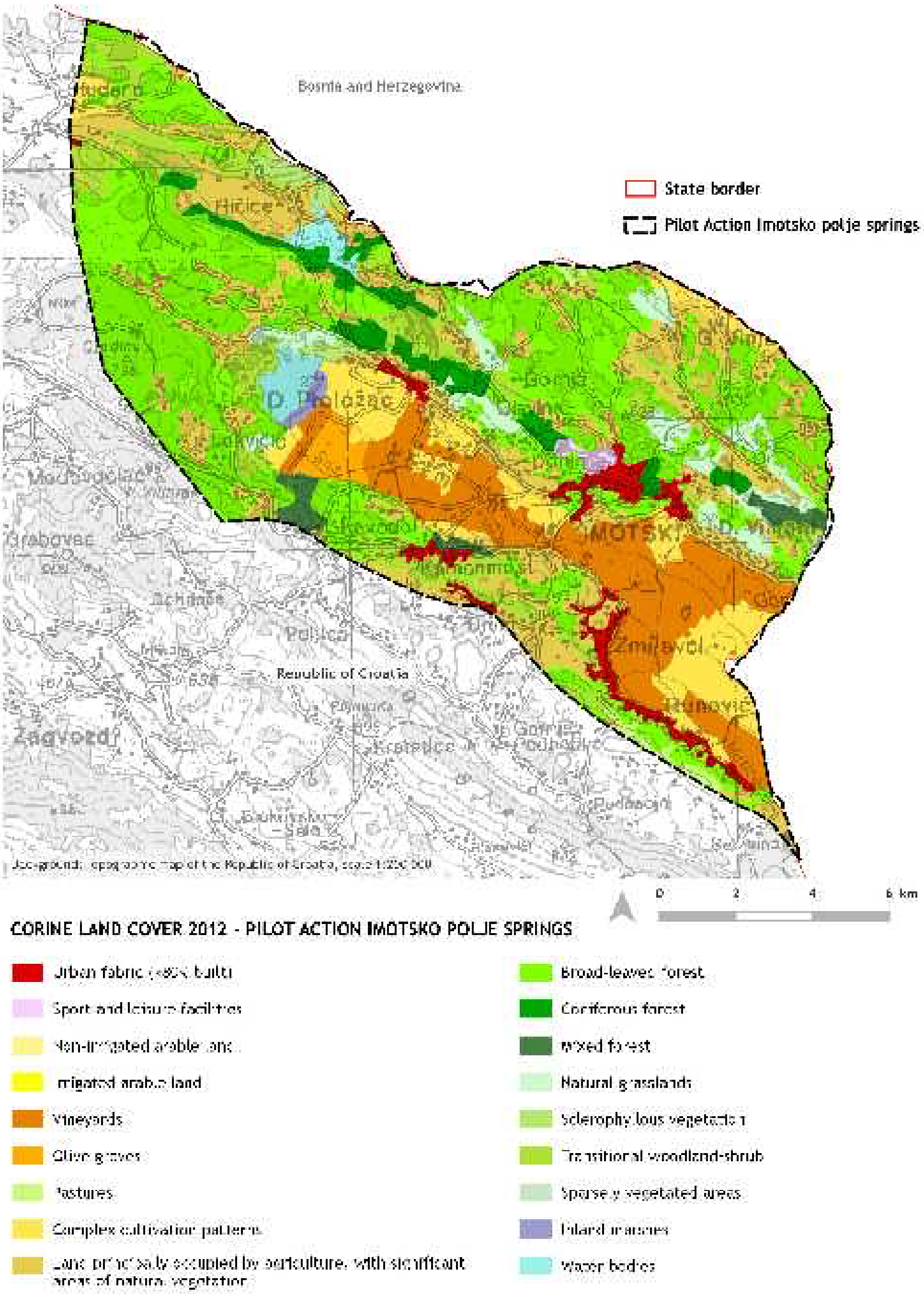

Figure 10. Land cover based on CORINE 2012

Table 1. Percentages of particular land use of the pilot action

Corine Land Cover in the Pilot Action Imotsko polje springs			
CLC code	CLC category	Area (km^2)	%
311	Broad-leaved forest	66.52	34.45
243	Land principally occupied by agriculture. with significant areas of natural vegetation	37.16	19.24
221	Vineyards	23.06	11.94
324	Transitional woodland-shrub	17.44	9.03
242	Complex cultivation patterns	16.39	8.49
321	Natural grasslands	7.54	3.90
312	Coniferous forest	6.79	3.51
112	Urban area (<80% constructed)	5.98	3.09
512	Water bodies	3.13	1.62
313	Mixed forest	2.53	1.31
223	Olive groves	2.14	1.11
323	Sclerophyllous vegetation	1.75	0.91
231	Pastures	1.12	0.58
142	Sport and leisure facilities	0.74	0.38
411	Inland marshes	0.63	0.32
333	Sparsely vegetated areas	0.14	0.07
212	Permanently irrigated land	0.07	0.03
211	Non-irrigated arable land	0.01	0.01

2.8. Protected areas

The Republic of Croatia has numerous diverse and preserved natural and semi-natural habitat types with the abundance of species. Some of these valuable natural assets are protected either by national legislation or in accordance with international agreements, conventions and legislation of the European Union. In the pilot action area Imotsko polje springs, areas protected with Nature Protection Act (OG 80/13) that also correspond with the IUCN categories, are presented in the Table 2 and Figure 11.

Table 2. Areas protected with Nature protection Act within the pilot action Imotsko polje springs

Protected areas			
Category	**Subcategory**	**Name**	**Area (ha)**
Special reserve	Ichtiological-ornithological	Vrljika izvor	50.335
Nature monument	Geomorphological	Crveno jezero	21.63
Nature monument	Geomorphological	Modro jezero	54.89
Significant landscape		Prološko blato	994.44
Significant landscape		Imotska jezera - Gaj	420.04

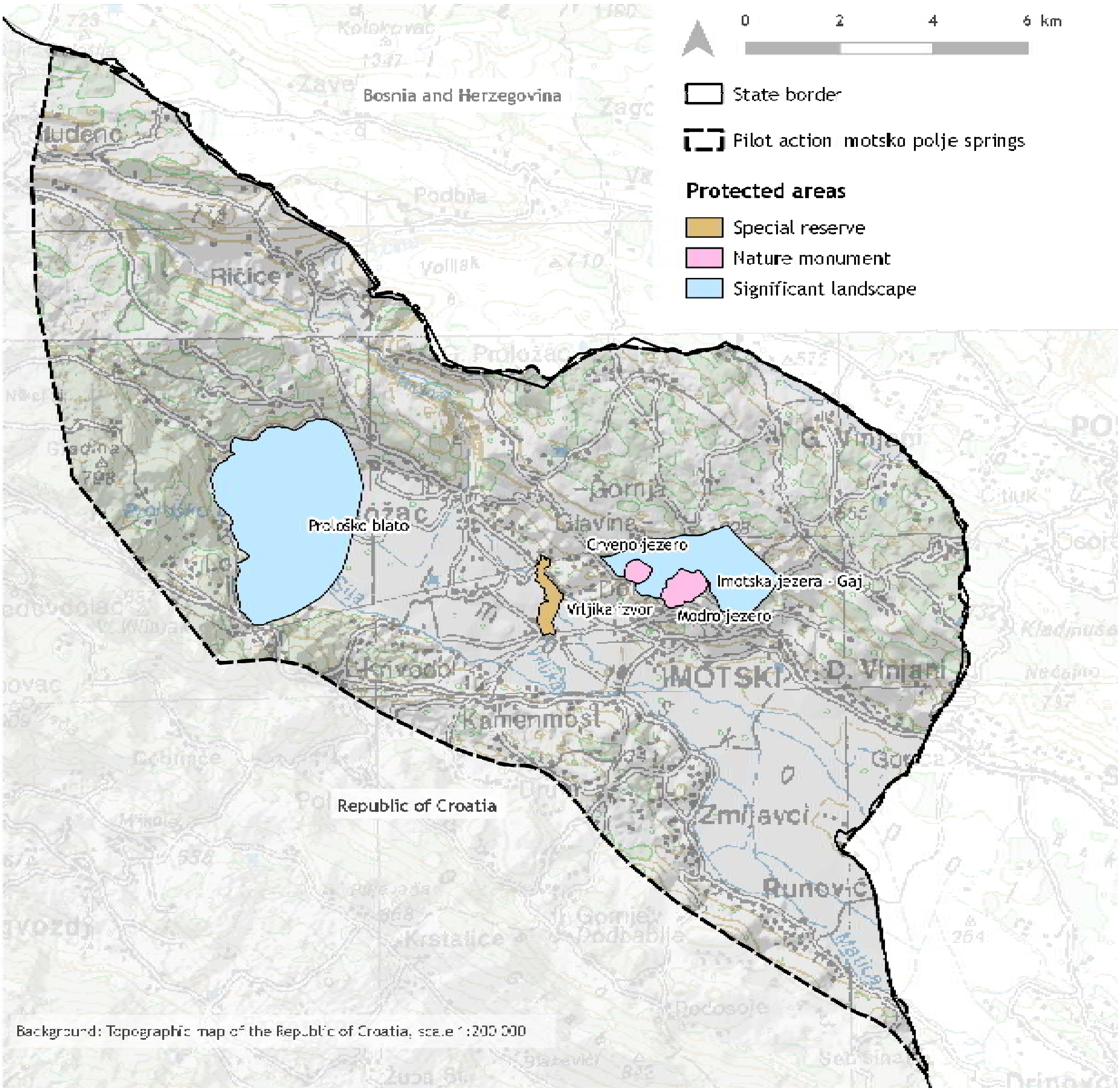

Figure 11. Protected areas within pilot action Imotsko polje springs (source: Bioportal)

Category special reserve refers to part of land and/or sea of special hour of special significance for its uniqueness, rarity or representatively, or habitat of endangered wild species and it is of particular scientific significance and purpose. Special reserve Vrljika izvor includes the area around the spring of karstic Vrljika River and a 100 m buffer along the river (from spring to bridge on Perinuša). The area is protected in order to preserve its significant water quality and fauna.

Nature monument is a single unaltered part or group of living or non-living nature that has an ecological, scientific, aesthetic or educational value. There are two areas of this category present within the pilot action Imotsko polje springs and both of them are protected in subcategory geomorphological monument. Crveno jezero and Modro jezero are unique natural phenomenons with specific hydrography and karst morphology (**Figure 12** and **13**). Crveno jezero is a sinkhole containing a karst lake (287 m deep) located near the city of Imotski. It is known for its high cliffs, reaching over 241 metres above normal water level and continuing below the water level. The total explored depth of this sinkhole is approximately 530 metres with a volume of roughly 25–30 million cubic meters. The sinkhole is named after the reddish-brown color of the surrounding cliffs, colored by iron oxides. Modro jezero is a karst lake located near Imotski. It lies in a deep sinkhole possibly formed by the collapse of an enormous underground cave. The total depth from the upper rim is around 220 meters, while water depth varies with season. Maximum dimensions of the lake are around 800×500m, but they significantly vary due to big changes in the water level. At the end of the summer the lake may completely disappear.

Figure 12. Crveno (source: Dalmatian Nature)

Figure 13. Modro jezero (source: Dalmatian Nature)

Significant landscape Prološko blato is a vast floodplain in the western part of Imotsko polje, northeast of the village Lokvičići and southwest of the Imotski town (**Figure 14** and **15**). It is only one part is flooded during the whole year (several lakes including Prološko Lake) and the entire surrounding area becomes flooded only in the period of high water (in winter).

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