ANNEXES

to the Report on Common Methodology on Estimation of Climate Change Induced Land Use Changes and Changes in Water Quality on Test Areas

Let's grow up together

DRINK ADRIA

Adriatic IPA
Cross Border Cooperation 2007-2013

The project is co-funded by the European Union, Instrument for Pre-Accession Assistance

4.3. ESTIMATION OF CLIMATE CHANGE INDUCED LAND USE CHANGES AND THE IMPACT ON WATER QUALITY

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Date last release	30/5/2015
State of document	FINAL

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1 INTRODUCTION

The present report focuses on land use data analysis on the pilot area of Isonzo River alluvial plain (NE Italy) chosen as test site area in the framework of DRINKADRIA project.

The Isonzo Plain, about 170 km^2, is located in the eastern side of the Friuli Venezia Giulia Region. It holds a significant phreatic aquifer and many rich artesian aquifers that represents an important natural wealth, in terms of quantity, quality and ease of supply. The aquifers are used for different purposes: drinking, household, industrial, agricultural and farming. They serve more than 350.000 inhabitants.

Water analyses here presented are based on reports and data published on the subject since 1960 and updated by recent studies realized in the framework of ITA-SLO INTERREG projects in the period between 2010 and 2014: GEP and ASTIS (GEP - Joint Geo-Information System (GIS) for Emergency Protection of Drinking Water - http://www.gepgis.eu/; ASTIS - Groundwater and Transition Isonzo/Soča).

The Isonzo-Soča Plain (Figure 1) is almost made entirely by quaternary alluvial deposits of Isonzo/Soča, Torre, Judrio, and Versa rivers. It is divided in two areas: the High Plain to the North and the Low Plain to the South. The High Plain at its North edge has the Collio Hills, made up by marlstones and sandstones of the Eocene Flysch. To the South are present instead the cretaceous limestone reliefs of the Karst Plateau. Coarse and very permeable deposits that hold a well-developed phreatic aquifer mainly constitute the High Plain. The rivers have an influent character with respect to the High Plain; for this reason, Torre and Judrio rivers remain dry most of the year. Isonzo/Soča River loses about 25% of its discharge. The river losses, together with effective infiltration, run-off waters coming from the hills and karst waters, actively recharge the phreatic aquifer of the High Plain. Proceeding towards the Low Plain from North to South, the phreatic aquifer joins into a multi-layered aquifer system characterized by alternating gravel-sand and clay-silt deposits. Due to the southward permeability decrease, the High Plain phreatic waters outflow in correspondence to a NW-SE wide area displayed as a resurgence belt. Here waters are rising creating an outflow that can be identified as a water quantity and quality indicator.

The thickness of the alluvial deposits changes from site to site according to the different places in which it is calculated. It varies from few meters in proximity of the reliefs to hundreds of meters in correspondence of the depressions complicating the bedrock morphologies. The shape of the case where flood deposits are contained is complex. It is characterized by valleys and mountains generated by erosional and tectonical processes. South of Gorizia is present a depression: here the bedrock drops of approximately 100 meters. The deepening starts in Mariano municipality (-50 m) reaching, in the surroundings of Villesse area, the depth of -350 m b.g.l.

The isopach map elaborated for the Quaternary deposits, obtained by subtracting from the Digital Elevation Model the values of the isobaths, shows that the thickness of the deposits reaches 100 m in correspondence of the depression south of Gorizia and 75 m in the area between Farra and Medea. The thickness of the deposits, in the test area, reaches its maximum at Villesse (-350 m).

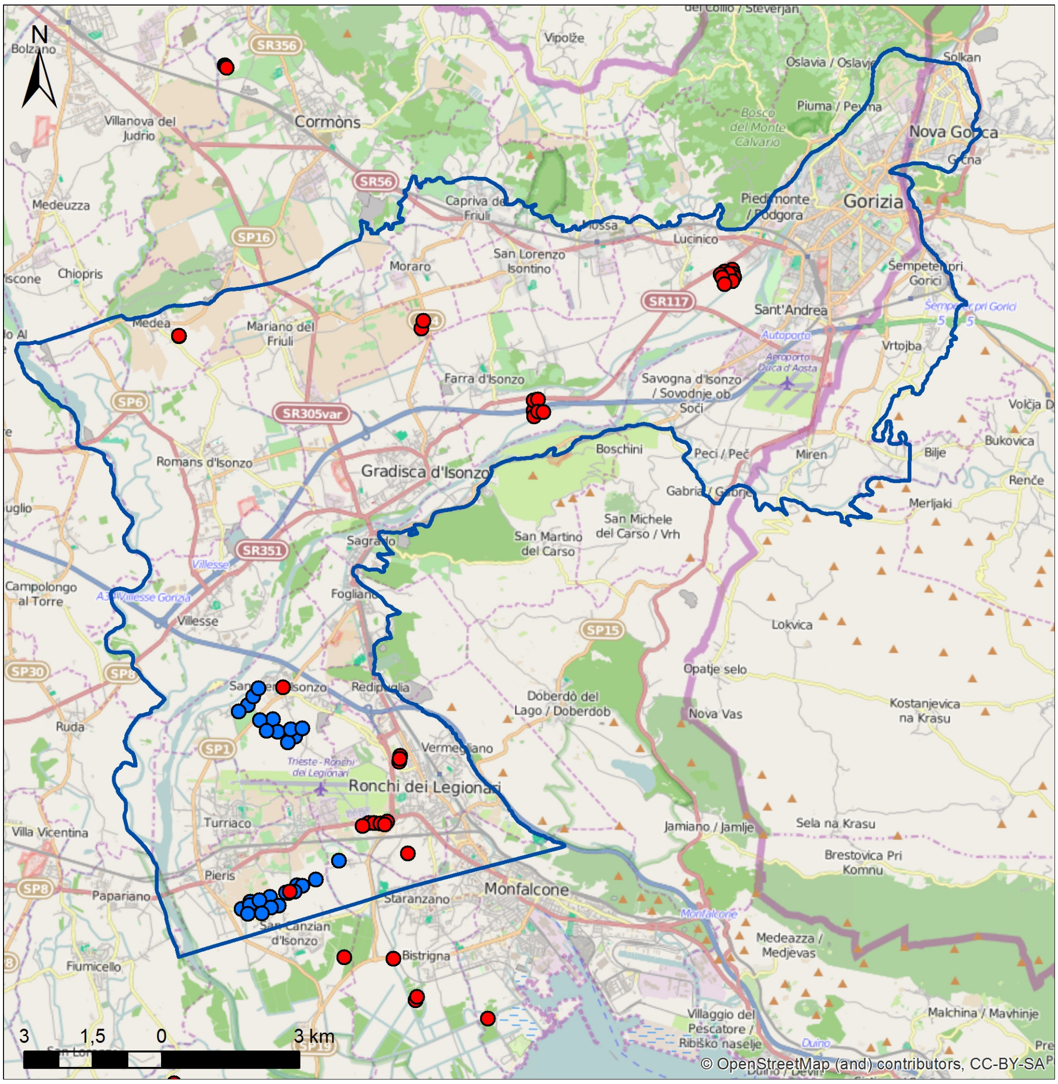


Figure 1: DRINKADRIA pilot area (in blue), the Isonzo/Soča River plain. In red IRISACQUA piezometers and pumping wells, in blue AcegasApsAmga piezometers and pumping wells.

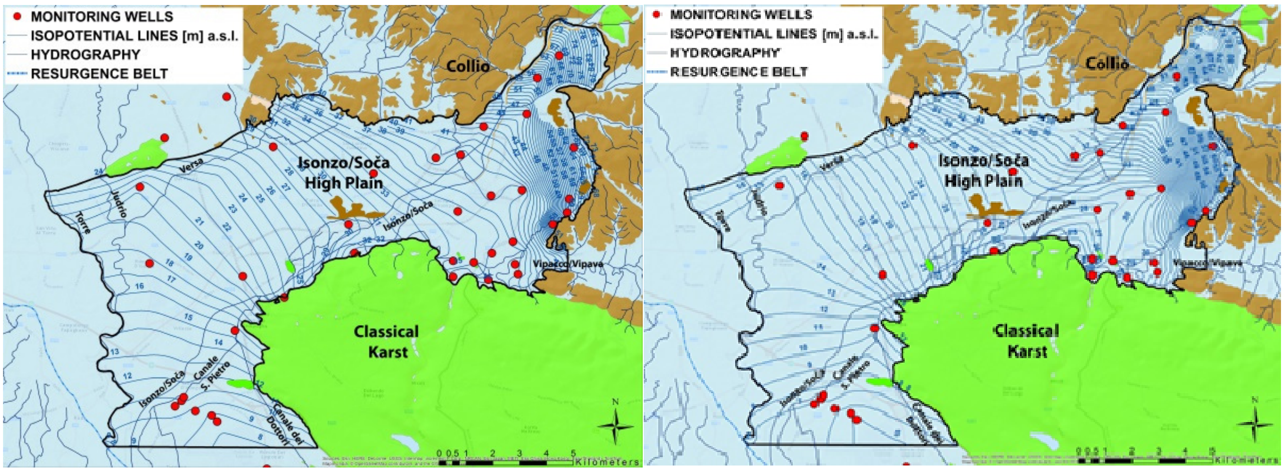


Figure 2: A) Isophreatic map during a period of very high level (first decade of February 2014); isophreatic map during a period of minimum level (8th August 2013). Red dots are the monitored points. Blue lines are the isophreatic lines. The numbers are expressing the water level in m a.s.l.

For a year, every 15 days, during the ASTIS Project, the phreatic aquifer in the High Plain has been monitored. 46 wells/piezometers have been monitored on the Italian side, manually and automatically.These data allowed the elaboration of several maps where the obtained results are summarized. *In primis* the phreatic aquifer was analyzed and different isophreatic scenarios were elaborated (high water regime, low water regime) obtaining the groundwater flow directions and the water table fluctuations. Figure 2 is one example of the obtained results. The isophreatic maps highlight a general groundwater flow partially guided by the presence of the different rivers that flows from East toward West. In the surroundings of Sagrado, the flow is veering toward South. In particular, from the maps, it is possible to identify two contributions: one due to the Isonzo/Soča and Vipacco rivers and the other derived from the runoff coming from the hills around. In the western part of the investigated area, the presence of the Torre River is also recognized: its contribution is the one that trigger and accelerate the southern veering of the groundwater flow. South of Gorizia, part of the groundwaters are drained by the karst hydrostructure contributing with approximately 10 m^3/s to the Timavo spring discharge area (Zini et al. 2011, Cucchi et al., 2015).

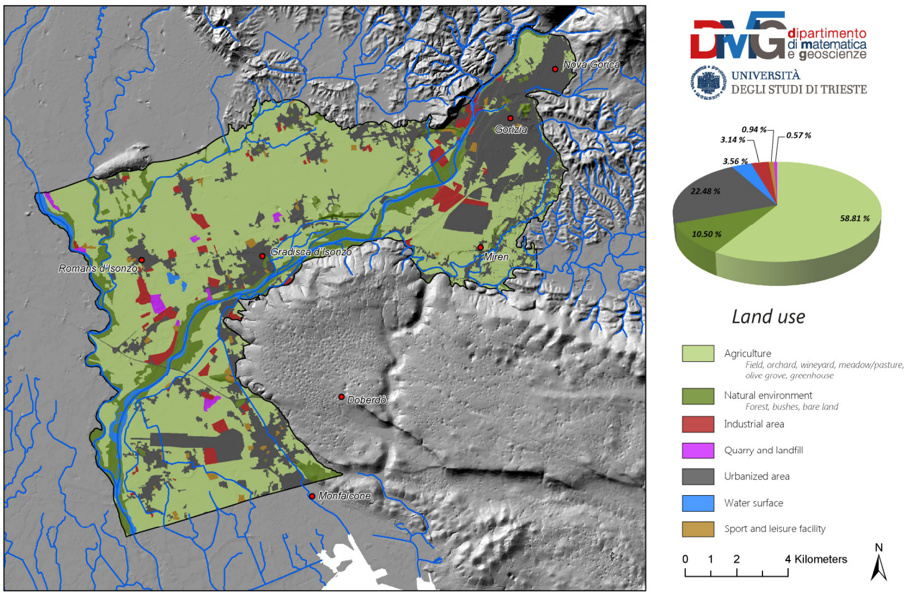
2 ANALYSIS OF THE ACTUAL LAND USE ON TEST AREAS

The spatial analysis and the proposals for a different environment management of the study area (Isonzo/Soča Plain) required the application of GIS techniques integrated to assessment systems for the estimation of environmental pressure and to decision support systems. The tool used is the ArcGIS 10.2 software.

Land use data in Italy have been obtained from the Friuli Venezia Region (http://irdat.regione.fvg.it, Moland database, JRC-IES, 2002). Land use data in Slovenia have been obtained from the Ministry of Agriculture, forestry and food of Slovenia (http://rkg.gov.si/GERK/viewer.jsp). As the original database are different, land use classes in Italy and Slovenia diverge. To analyze the land use data in a unique map a merging of the numerous original classes was necessary. We reduced their number to seven common classes (agriculture, natural environment, Industry, Quarry/landfill, urbanized area, water surface, sport and leisure facility) - Figure 3.

What emerges from a preliminary data analyses, is that the most part of the territory within the study area, is occupied by Agriculture (58,81%) followed by the Urbanized area (22,48%) and by the Natural environment (10,50%). Water surface corresponds to approximately 3,56% of the whole investigated area. Industries are the 3,14%, while for the Sport and leisure facility is dedicated 0,94%; Quarry and landfill are 0,57%.

Figure 3: Land use map for the DRINKADRIA Project test site area. Data have been partially collected and elaborated in the framework of ASTIS and GEP INTERREG Projects and later re-elaborated.



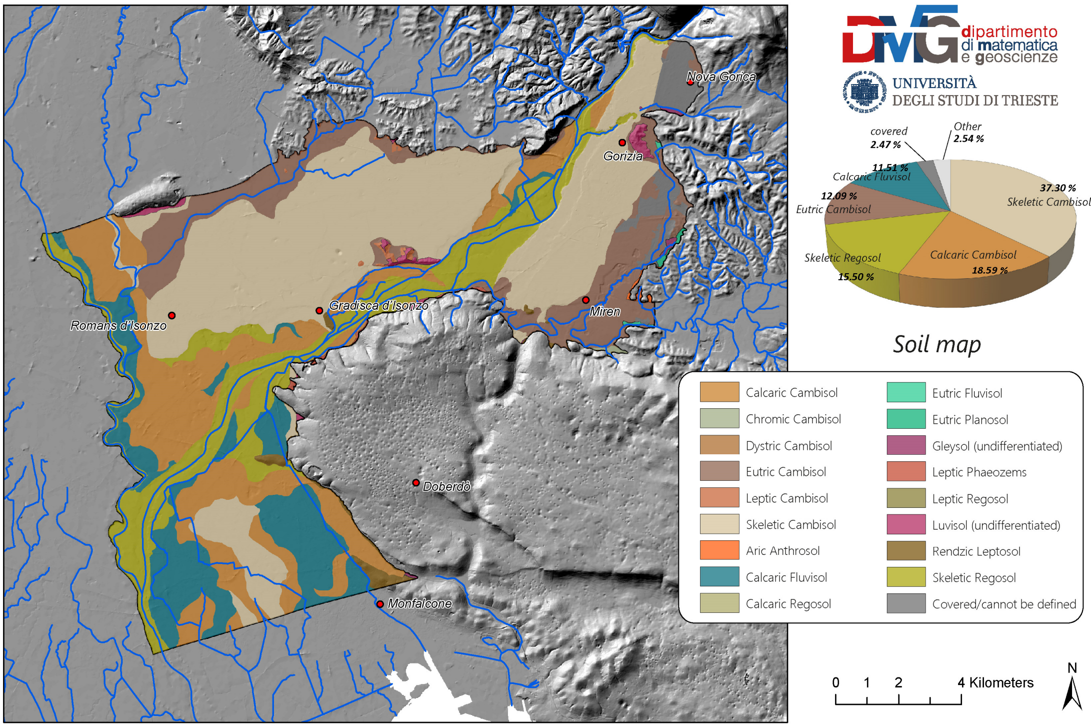


Figure 4: Soil map for the DRINKADRIA Project test site area. Data have been partially collected and elaborated in the framework of ASTIS and GEP INTERREG Projects.

If we look at the soil map, the original soil map data were provided by ERSA (Michelutti et al., 2006) and Center za pedologijo in varstvo okolja (Šporar et al., 1999). The soil type classes have been reduced for legibility and comparison purposes on both sides of the border. Original maps follow the World Reference Base for Soil (IUSS Working Group WRB. 2007). The homogenization and simplification mainly consisted in maintaining only the reference group and the main qualifier. The schematization obtained can be summarized as follows: Skeletic cambisol 37,30%; Calcaric cambisol 18,59%; Skeletic regosol 15,50%; Eutric cambisol 12,09%; calcaric fluvisol 11,51%; covered 2,47%; other 2,54%. The main percentage is represented by the skeletic cambisol, soils with beginning horizon differentiation evident from changes in colour, structure or carbonate content having a medium and fine-textured materials derived from a wide range of rocks, mostly in colluvial, alluvial or eolian deposits. In the present case, in the northern part of the study area, where is more evident the presence of the alluvial deposits due to the Isonzo/Soca River, the presence of the skeletic cambisol is dominant, while in the southern part of the investigated area, the calcaric fluvic and cambisol prevail.

3 THE IMPACT OF CLIMATE CHANGE AND PLANNED DEVELOPMENT (SPATIAL PLANS) ON THE LAND USE IN FUTURE ON TEST AREAS

The Isonzo River, in Slovenia known as Soča, has its source in Slovenia and empties into the Adriatic Sea. The basin has a pronounced mountainous character with an average elevation of about 599 m a.s.l.. Major transboundary tributaries include the rivers Natisone, Vipacco and Iudrio. Isonzo/Soča is a river shared between two countries that are trying to benefit most from its waters. In both countries dams exist along the river and they can create artificial pressures on natural river discharges. Salcano, Sottosella and Canale dams are situated in Slovenia, Crosis dam in Italy. Salcano dam is used for regulation of flow and floods; the reservoir operations have a direct influence on the downstream discharge creating conflicts mainly with Italian agricultural uses (other than possible impacts on ecosystems due to hydro-peaking). Water from the river is withdrawn for hydroelectric, industrial and agricultural purposes, creating pressure especially during drought period. Pressures arise from both anthropogenic and natural sources. Dumped mining residues of Idrija mercury mine in Slovenia cause quicksilver contamination in fluvial and marine sediments. Wastewater discharges from Nova Gorica in Slovenia are flushed into the Corno River causing organic contamination in the Italian side of the Isonzo basin. In general organic matter from wastewater discharges and heavy metals cause a transboundary impact affecting the water quality.

All the problems summarized above have a common international character, being directly related to quantitative and qualitative pressures present in the Slovenian territory; the definition of the necessary corrective measures must therefore necessarily traced by the initiatives of cross-border cooperation between Italy and Slovenia already started following the Osimo Agreement implemented in the far 1975.

In accordance with the international agreement concerning this transboundary river, the Authority who has to supervise over this precious resource is the Basin Authority that drawing up its Plans is able to minimize the pressures induced by nature and humans.
To these more legal aspects it is necessary to add to the general framework, the climate change that are occurring on the whole planet. In the Drinkadria study area the temperature increasing, with a following not well defined precipitation behaviour (Table 1) (decreasing trend 100y analysis and uncertain trend on 50y analysis), are partially compromising the recharge of the aquifers taking to an escalation of the actual problems.

Gorizia prese CBPI	ARPEGE	PROMES	ECHAM5	Observed
Temperature [°C/10y] 50y	0,18	0,19	0,14	0,28
Temperature [°C/10y] 100y	0,34	0,17	0,38	
P (50y) [mm/10y]	25	9	-19	-20
P (100y) [mm/10y]	-28	-12	-26	

Torviscosa	ARPEGE	PROMES	ECHAM5	Observed
Temperature [°C/10y] 50y	0,06	0,11	0,06	0,9
Temperature [°C/10y] 100y	0,34	0,47	0,38	
P (50y) [mm/10y]	47	4	-30	-36
P (100y) [mm/10y]	-22	-30	-11	

Alberoni	ARPEGE	PROMES	ECHAM5	Observed
Temperature [°C/10y] 50y	0,13	0,13	0,17	0,37
Temperature [°C/10y] 100y	0,34	0,47	0,38	
P (50y) [mm/10y]	38	6,6	-22	-9
P (100y) [mm/10y]	-19	-13	-6	

Table 1: Results obtained from the analysis of the experimental data and the relative trends using different Climate Change models (see Report 4.1).

If we look at possible other pressures a short digression has to be done analyzing the demographic trend in the study area. The number of inhabitants in fact creates an expectation of a better life with more comforts sometimes acting in a negative way on the natural environment.

In view of the consumption of water for drinking purposes, based on demographic data made available and analyzed in the framework of the Report WP4.2, it is observed that the situation in the Trieste and Gorizia provinces is slightly increasing with a forecast of a future stable water consumption. AcegasApsAmga in fact, estimated for the next years, a withdrawal amount of 50 million of m^3/y. According to the ISTAT FVG elaboration (Dominutti & Abatangelo, 2008), the amount of residents in Trieste Province will decrease from 236.515 in 2007 to 216.455 in 2050. In Gorizia Province instead there will be an increasing in the amount, passing from 141.229 in 2007 to 151.720 in 2050.

In Friuli Venezia Giulia Region, there are about 98.000 manufacturing companies, divided in different sectors. Among them there is a clear predominance of the agriculture, trade and building which together represent the 57.1% of the total. The decisive reference industrial risk is mainly represented by the chemical, energy, metallurgy and manufacturing sectors which sum is just over the 6% of the total (Regione Autonoma FVG, 2014).

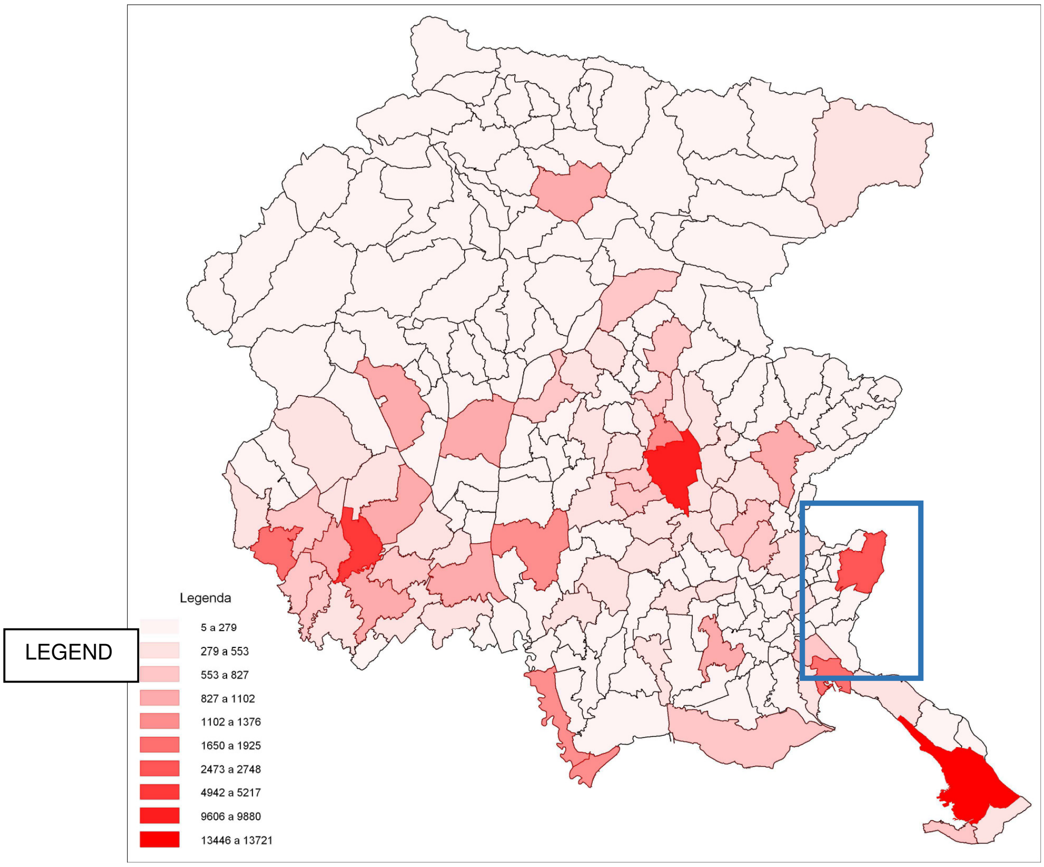


Figure 5: Number of active plants in the industrial and services sector (RAFVG, Servizio Pianificazione Territoriale, 2009).

The Figure 5 indicates that Gorizia and Monfalcone municipalities are the one that have more active plants lumped in the industrial consortium in both areas and the port in Monfalcone. From the Figure 6, instead, is possible to notice that there are no plants at high risk of major accident in the studied area.

In recent years, the manufacturing sector, in Friuli Venezia Giulia, is certainly the one that most suffered the consequences of the economic crisis together with the construction industry sector. The suffering is in terms of reduced production, depletion of the productive fabric, the heavy impact on employment and the bending in sales both in foreign markets and especially in the internal ones. The considerable weight of the manufacturing industry, combined with the strong projection to the international markets characterized by a reduction in demand, has made the regional economy particularly exposed (REGIONE FVG, 2014). This recession phase discourage the increase of new industrial sites with a potential return to the agriculture, and this is sometimes even more dangerous for the phreatic aquifers in the High Plain due to the intense use of pesticides and other substances.

Farming and the rural world in recent years are in the middle of a profound structural transformation and planning. At the end of the '90s was in fact begun to acknowledge to the agricultural activity a new role of balance and land conservation. The selected indicators outline for the regional context, the most salient characteristics of the agricultural sector and its evolution from the environmental point of view.

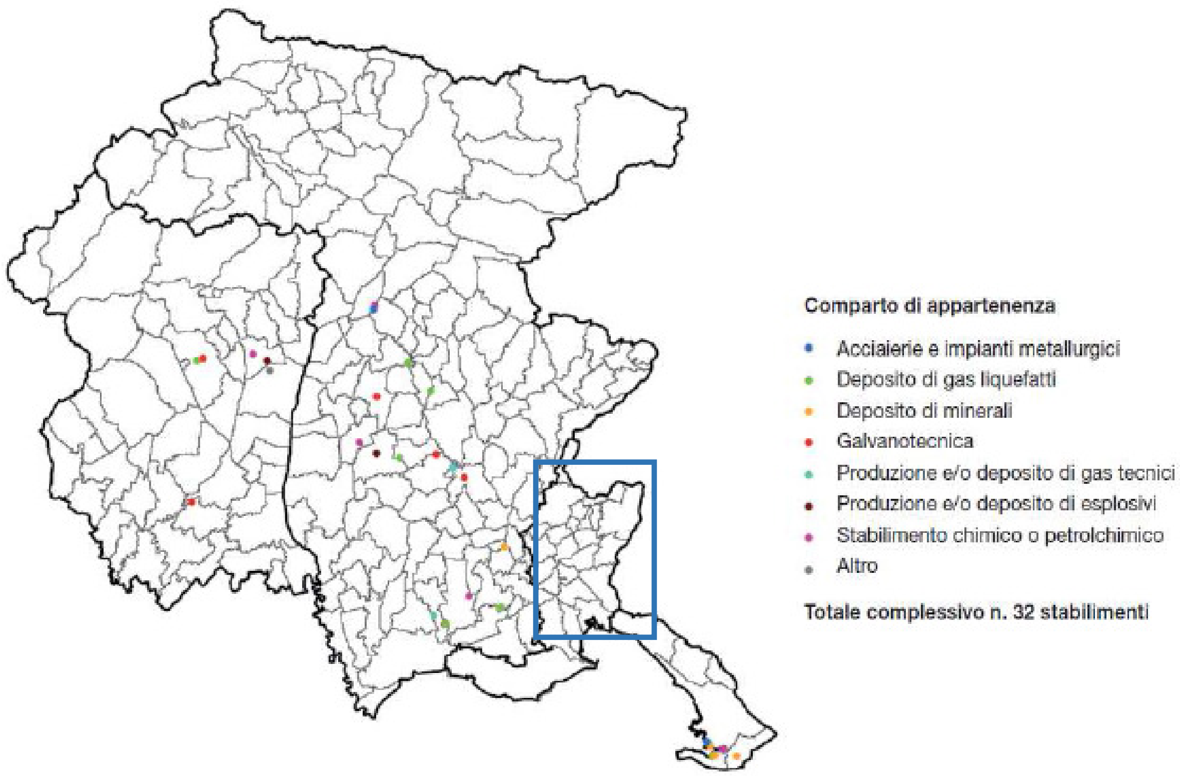


Figure 6: Areal distribution of the industrial plants at risk of major accident (ARPA FVG, 2011).

The Used Agricultural Area (UAA) has fallen by 12.6% between 1990 and 2005; the decrease in FVG was less pronounced than the national one until 2000, while it seems more pronounced in the latest five-year period. The relationship between the UAA and the total cultivated area has actually increased between 1990 and 2005. Arable crops are the most widespread in Friuli Venezia Giulia and in 2005 occupy about 71% of the UAA (Regione Autonoma FVG, 2014). According to what diffused in the Piano di Tutela delle Acque (Regione Autonoma FVG, 2014), the 2010 Census of Agriculture counts 22.327 farms in the FVG region, down compared to the census had in 2000. This decrease however occurred with a corporate restructuring that gradually reduced the family farms according to a trend which is estimated to continue in the coming years. Of these farms only a small part was biological agriculture (226 units in 2000), but in the period between 2000-2005, an increase was observed reaching to about 400 units at the end of 2005. In recent years, the number of regional biological farms has stopped growing.

In addition to agriculture and to the industries present on the regional territory, an increasing sector is the one related to the rural tourism. The number of farm businesses in 2009 stood at 524, entitled to accommodation and catering. Udine province is leading with 70% of the farms, Gorizia Province is following with 17,4%. The two mentioned provinces are indeed those that lend themselves to this type of activity, thanks to the variety of the territory and the typical agricultural food production. In particular there is a significant concentration of the agritourism in the eastern hills close to the border with Slovenia and in the Collio area. Seen the increase of this type of farms as the increased requirement of agricultural land, specific strategies have been implemented in order to limit the accumulation of detrimental substances in the soil and in the surface and groundwaters. The intention is to reduce upstream the chemical fertilizers and plant protection products introduced in the non-organic agro ecosystems.

The Regulations for agronomic use of nitrogen fertilizers and the action program in the areas vulnerable to nitrates according to the regional laws (L.R. n.16, 5 December 2008; L.R. n.17, 25 Agosto 2006; L.R. n.24, 30 Dicembre 2009) contemplate the necessity of specific action programs in order to reduce the found pollution and to prevent further pollution caused or induced by nitrates from agricultural sources. The Figure 7, is identifying, in the FVG Region, the areas vulnerable to nitrates. The Province of Gorizia, and so, also the study area, is considered not jet affected by this risk.

If we look more in detail, considering only the study area and not the whole FVG Region, for the assessment of land use evolution, we analyzed the Corine land Cover (CLC) dataset (European Environmental Agency, http://www.eea.europa.eu/publications/COR0-landcover and http://land.copernicus.eu/pan-european/corine-land-cover/).

Available data cover a 22 years range (years 1990, 2000, 2006 and 2012). Land cover data from 1990 coverage are only distributed in raster format (100*100 m grid) and cover the entire test area. Instead data corresponding to years 2000 and 2006 are provided in both raster and vectorial format. The whole test area is covered by these datasets. The 2012 dataset covers the whole Italian part of the test area in vectorial format. Unfortunately part of the Slovene territory has not yet been processed and is not available. For this relatively small area (4.7 km^2) the 2006 coverage has been used to complete the 2012 dataset (see Figure 11).

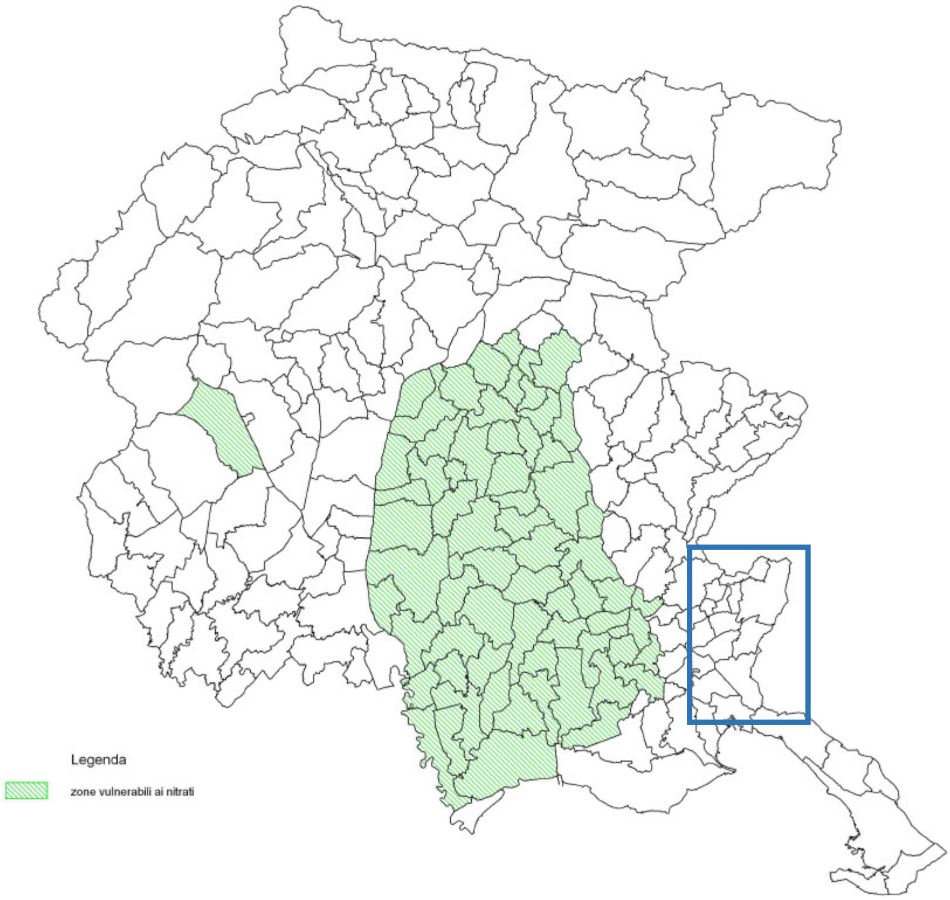


Figure 7: Areas vulnerable to nitrates from agricultural sources (RAFVG, servizio Pianificazione territoriale,2008).

For all datasets the vectorial format has been used if available. Comparison of land use variations obtained either with raster or vectorial datasets showed negligible differences. Therefore the land use variation between years 1990 and 2000 are valid even if the first dataset is in raster format and the second in vectorial format.

The CLC dataset is classified in 3 levels. Level 1 corresponds to the wider classes (five items) and level 3 being the more detailed one (44 items). For the test areas an intermediate nomenclature has been used between level 1 and level 2. Table 2 shows the equivalences between the adopted nomenclature and the level 3 nomenclature. Maps of land use for each dataset are presented in Fig 8, 9, 10 and 11. Areas and percentage of the test area surface covered by the different classes are presented in Table 2.

For the assessment of long term land use evolution a further reclassification has been performed. Three major classes have been maintained (Agricultural area / Artificial area / forest, semi natural and water). Figure 12 represents the evolution of land use between 1990 to 2012 for these three major classes. Evidently artificial areas (urban fabric, construction sites, industrial areas,…) grow at the expense of agricultural areas. Artificial areas occupied 22.3 % of the test area (37.8 km^2) in 1990 and 25.2 % in 2012 (42.6 km^2). Instead agricultural area represented 69.2 % of the test area in 1990 (117.1 km^2) and 66.2 % in 2012 (112.0 km^2). During the same period natural and semi natural areas coverage remained stable, from 8.5% to 8.7% (corresponding respectively to 14.4 km^2 and 14.7 km^2).

Table 2: Comparison of land use classes (areas and percentage) for years 1990, 2000, 2006 and 2012. Level 3 description is available and compared to the intermediate classification used in the test area (merged classes field).

CLC_CODE	Level 3 description	Merged classes	1990 raster Area (Km^2)	1990 raster %	1990 raster Merged classes %	2000 vectorial Area (Km^2)	2000 vectorial %	2000 vectorial Merged classes %
112	Discontinuous urban fabric	*Urban fabric*	27.84	***16.4***	***16.4***	28.3	***16.7***	***16.7***
121	Industrial or commercial units		4.76	***2.8***		5.3	***3.1***	
122	Road and rail networks and associated land	*Industrial, commercial and transport units*	1.25	***0.7***		1.3	***0.7***	
124	Airports		2.63	***1.6***	***5.1***	2.6	***1.5***	***5.4***
131	Mineral extraction sites	*Mine, dump and construction sites*	0.66	***0.4***		0.7	***0.4***	
133	Construction sites			***0.0***	***0.4***		***0.0***	***0.4***
141	Green urban areas	*Artificial, non-agricultural vegetated areas*	0.65	***0.4***	***0.4***	0.7	***0.4***	***0.4***
211	Non-irrigated arable land		71.33	***42.1***		70.7	***41.8***	
221	Vineyards		4.17	***2.5***		4.2	***2.5***	
222	Fruit trees and berry plantations	*Agricultural areas*	0.43	***0.3***		0.4	***0.3***	
231	Pastures		2.99	***1.8***		3.0	***1.8***	
242	Complex cultivation patterns		23.28	***13.7***		22.8	***13.5***	
243	Principally agriculture, significant areas of natural vegetation		15.04	***8.9***	***69.2***	14.7	***8.7***	***68.5***
311	Broad-leaved forest		2.71	***1.6***		2.7	***1.6***	
312	Coniferous forest		0.29	***0.2***		0.3	***0.2***	
313	Mixed forest	*Forest and semi natural areas*	1.76	***1.0***		1.8	***1.1***	
322	Moors and heathland		0.46	***0.3***		0.5	***0.3***	
324	Transitional woodland-shrub		1.81	***1.1***		1.8	***1.1***	
331	Beaches, dunes, sands		4.34	***2.6***	***6.7***	4.4	***2.6***	***6.8***
511	Water courses	*Water bodies*	2.79	***1.6***		2.9	***1.7***	
512	Water bodies		0.26	***0.2***	***1.8***	0.3	***0.1***	***1.9***
		Sum	169.5	100	100	169.3	100	100

CLC_CODE	Level 3 description	Merged classes	2006 vectorial			2012 vectorial		
112	Discontinuous urban fabric	*Urban fabric*	Area (Km^2)	%	Merged classes %	Area (Km^2)	%	Merged classes %
121	Industrial or commercial units		29.8	***17.6***	***17.6***	29.7	***17.6***	***17.6***
122	Road and rail networks and associated land	*Industrial, commercial and transport units*	5.7	***3.4***		6.3	***3.7***	
124	Airports		1.3	***0.7***		1.3	***0.7***	
131	Mineral extraction sites	*Mine, dump and construction sites*	2.7	***1.6***	***5.7***	2.7	***1.6***	***6.1***
133	Construction sites		0.7	***0.4***		1.0	***0.6***	
141	Green urban areas	*Artificial, non-agricultural vegetated areas*		***0.0***	***0.4***	1.0	***0.6***	***1.2***
211	Non-irrigated arable land		0.7	***0.4***	***0.4***	0.7	***0.4***	***0.4***
221	Vineyards		65.4	***38.7***		63.5	***37.5***	
222	Fruit trees and berry plantations	*Agricultural areas*	5.9	***3.5***		6.2	***3.7***	
231	Pastures		0.4	***0.3***		0.4	***0.3***	
242	Complex cultivation patterns		3.0	***1.8***		3.0	***1.8***	
243	Principally agriculture, significant areas of natural vegetation		24.3	***14.3***		24.2	***14.3***	
311	Broad-leaved forest		14.7	***8.7***	***67.2***	14.6	***8.6***	***66.2***
312	Coniferous forest		2.7	***1.6***		2.5	***1.5***	
313	Mixed forest	*Forest and semi natural areas*	0.3	***0.2***		0.3	***0.2***	
322	Moors and heathland		1.8	***1.1***		1.8	***1.1***	
324	Transitional woodland-shrub			***0.0***			***0.0***	
331	Beaches, dunes, sands		2.7	***1.6***		2.8	***1.6***	
511	Water courses	*Water bodies*	4.0	***2.4***	***6.8***	4.1	***2.4***	***6.8***
512	Water bodies		2.9	***1.7***		2.9	***1.7***	
		Sum	0.3	***0.1***	***1.9***	0.3	***0.1***	***1.9***
			169.3	100	100	169.3	100	100

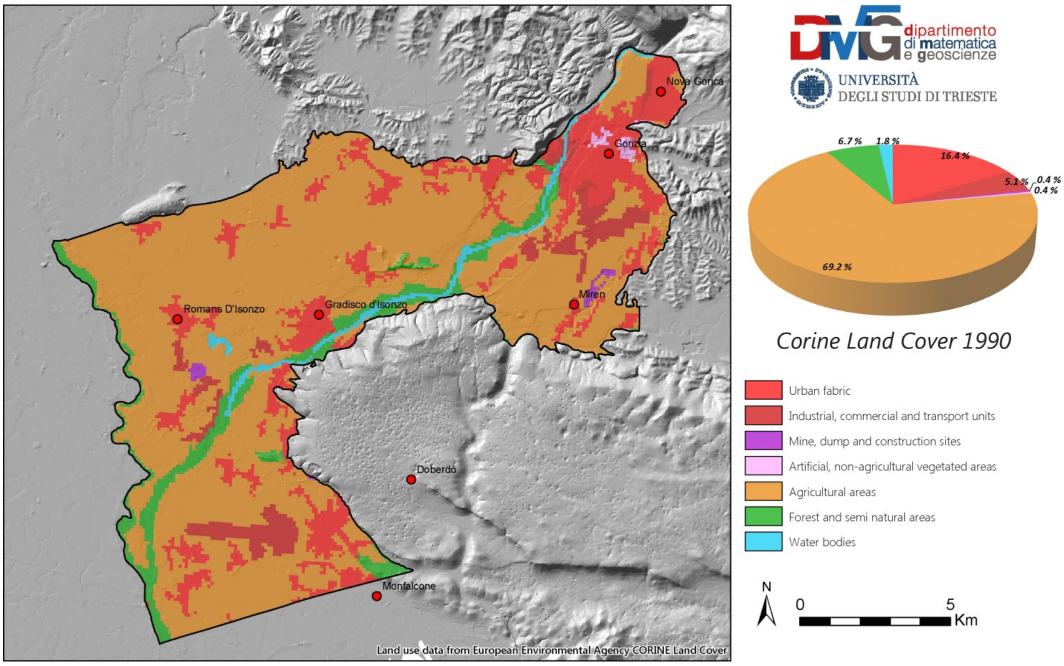


Figure 8: Land use from CLC 1990.

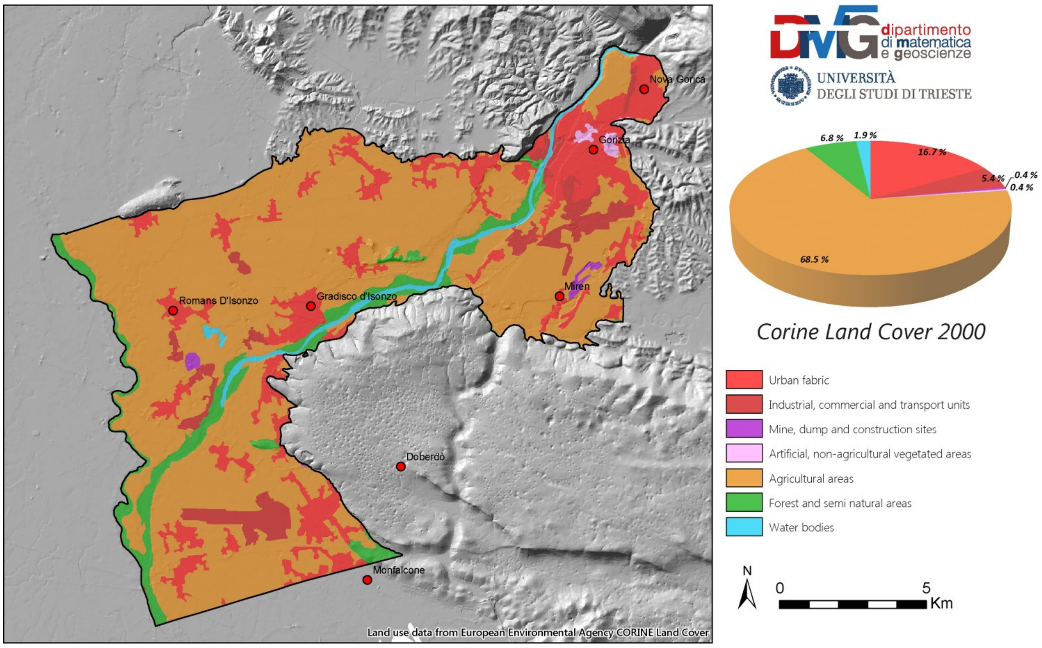


Figure 9: Land use from CLC 2000.

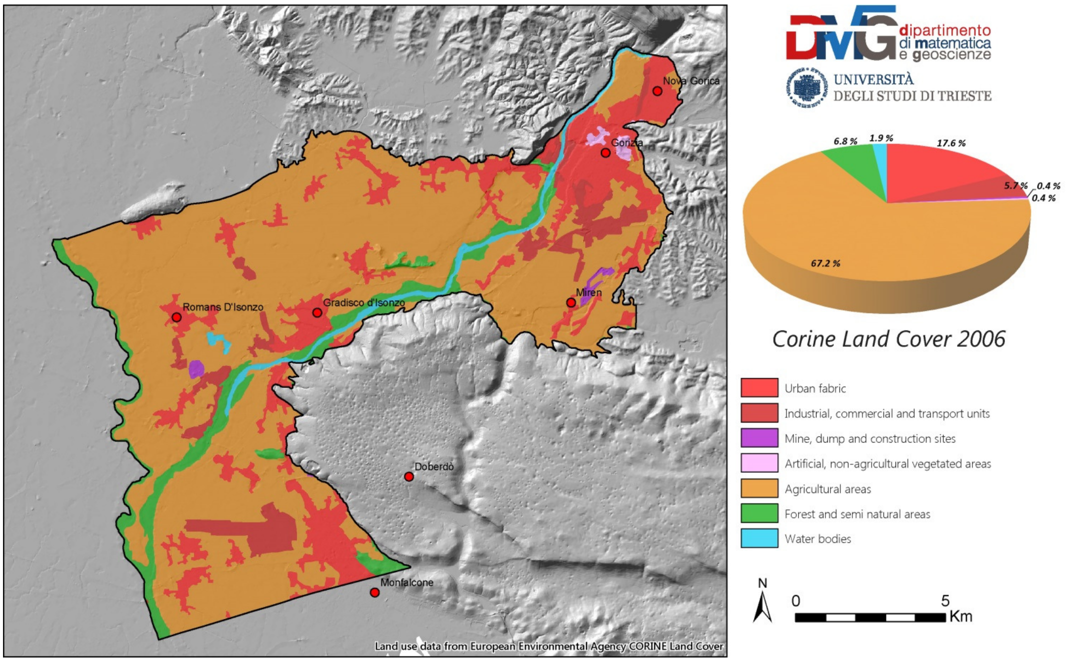


Figure 10: Land use from CLC 2006.

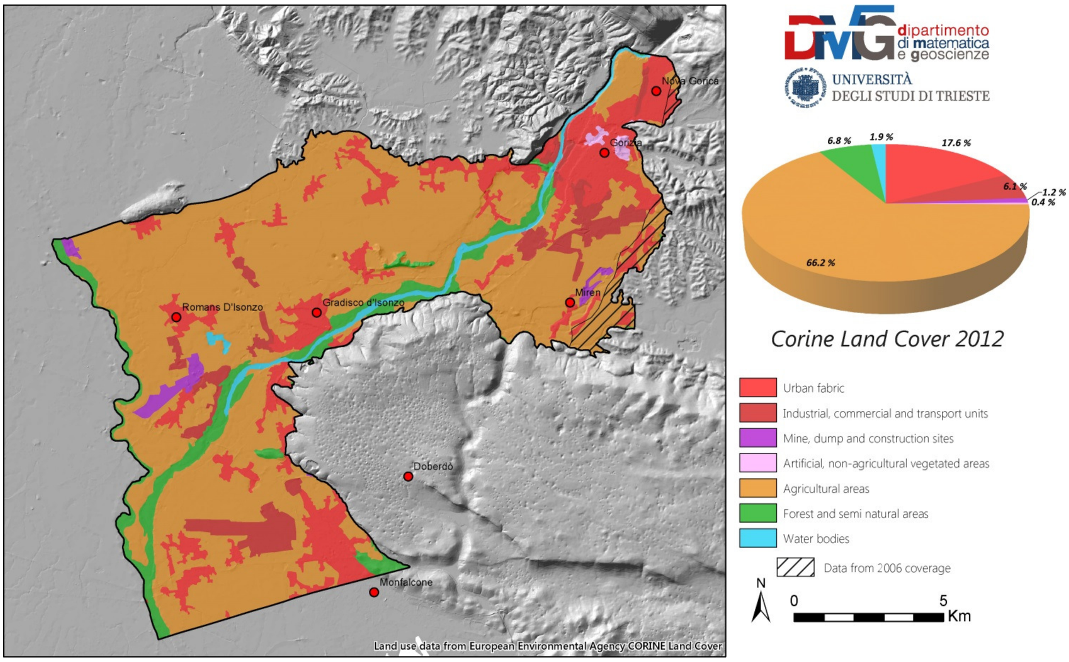


Figure 11: Land use from CLC 2012.

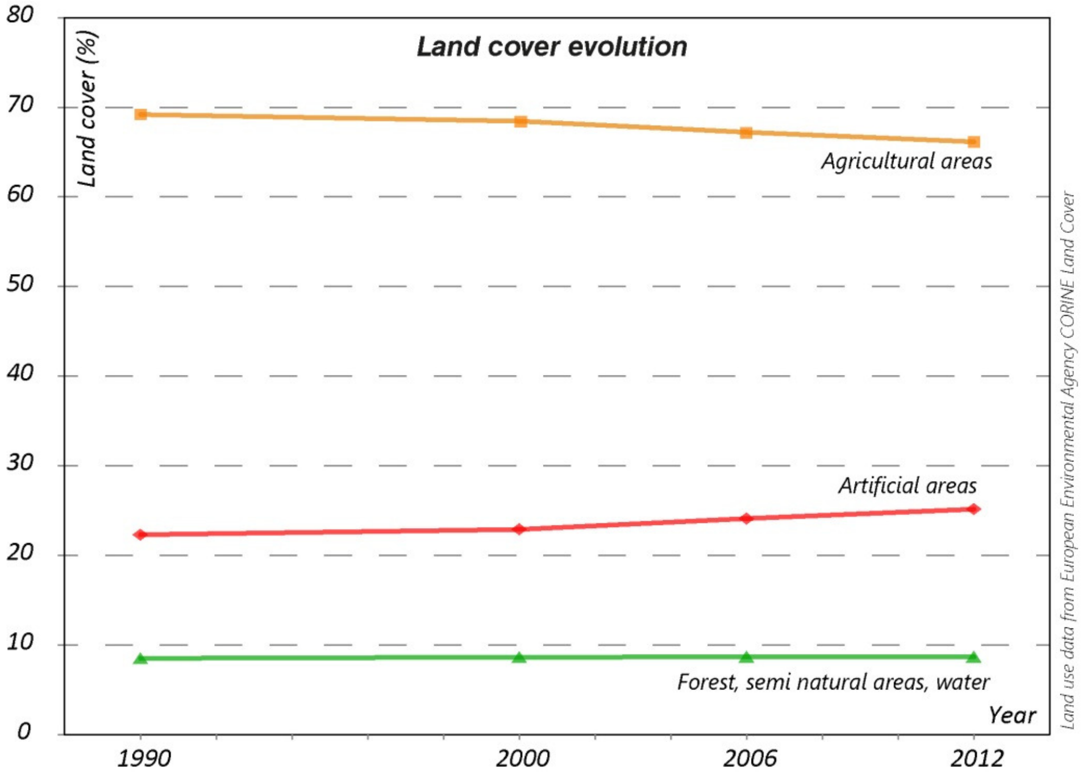


Figure 12: Land use evolution from CLC between 1990 and 2012 for the three major classes.

4 IMPACT OF LAND USE ON WATER QUALITY

Within the framework of GEP INTERREG project (A.A.V.V., 2014), a specific study started for a part of the actual study area and a specific methodology was used in order to assign to the different soil categories a different score resulting from human activities that produce pressures on the quality of the aquifers.

The groundwater pollution, in space and time, is connected in almost all cases, directly or indirectly to human activity. The pollution sources are in fact associated with a wide range of industrial, agricultural, commercial and domestic activities. Land use activities having the potential to impact on groundwater quality are described as either point or non-point source discharges (Figure 13 and 14).

Point source discharges can be defined as discharges from specific and identifiable sources (such as pipes or drains) concentrated at a given point, whereas non-point source discharges can be described as water contamination derived from diffuse sources where there is no single identifiable discharge point. Point source discharges can include tanks, offal holes, silage pits, landfills, leaking effluent ponds, underground storage tanks and wastewater application systems.

Non-point source discharges relate to the infiltration of water over a widespread area are often associated with agricultural or horticultural land use. Contaminants applied to land, including animal wastes and fertilizers, can leach through the soil profile to groundwater. The potential magnitude of non-point source discharges can also be exacerbated by land management practices such as the timing of soil cultivation. The effects of point source discharges on groundwater quality are typically localized but may be of significant magnitude and can involve a range of potential contaminants depending on the nature of the specific discharge.

For the project, within the test site area, was followed the analysis done for the GEP project. Were therefore collected and digitized point and non-point discharge areas. In particular: civil waste waters, urban solid waste, liquid storage, traffic and transportation, recreational services, mining operational and abandoned, industrial plants, electric power generators, industrial warehouses, animal husbandry, agriculture and other generic hazards.

The mapping provides an updated overview of the hazard points assessing the hazard of each hazard point in order to evaluate its compatibility with the protection of the groundwater resources.

Among the available different methods relative weight assignment scoring systems were used. These methods offer a quick preview of the scenario that can be caused by a pollution point source (Trevisan et al., 1998; Civita & Zavatti, 2006).

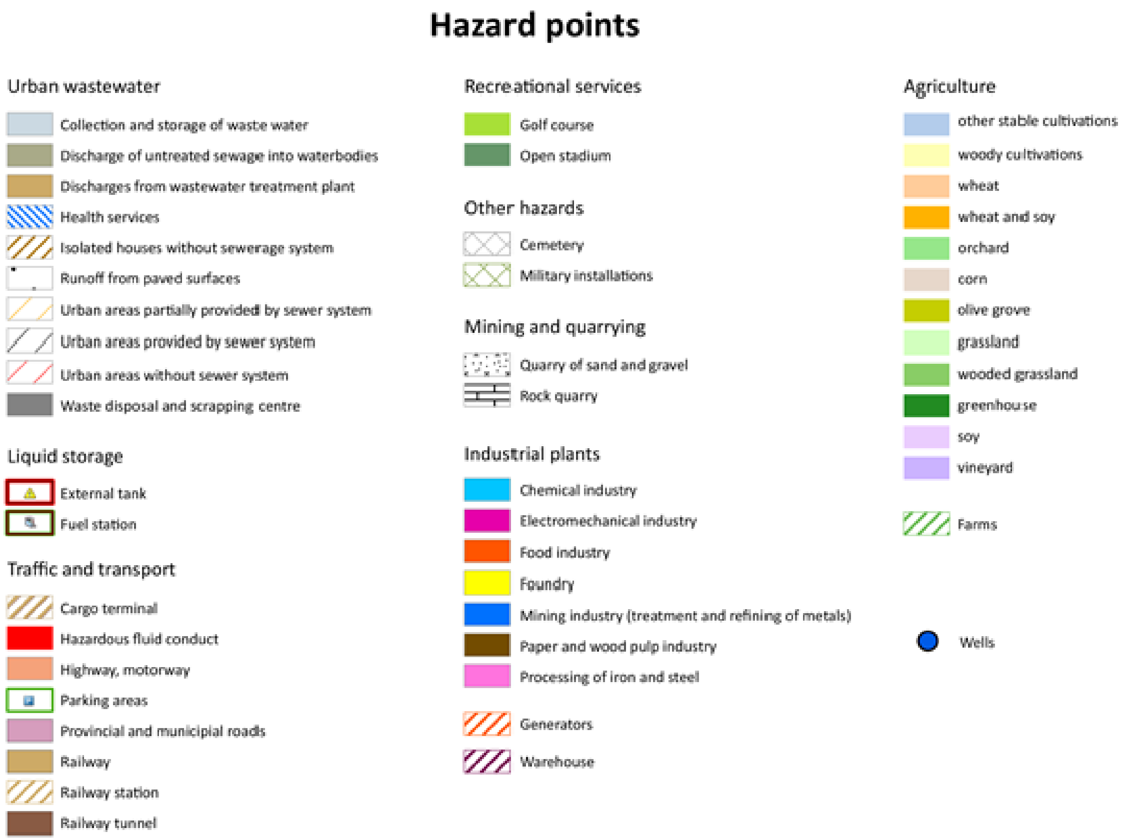


Figure 13: Legend of the hazard points identified in the analyzed study area.

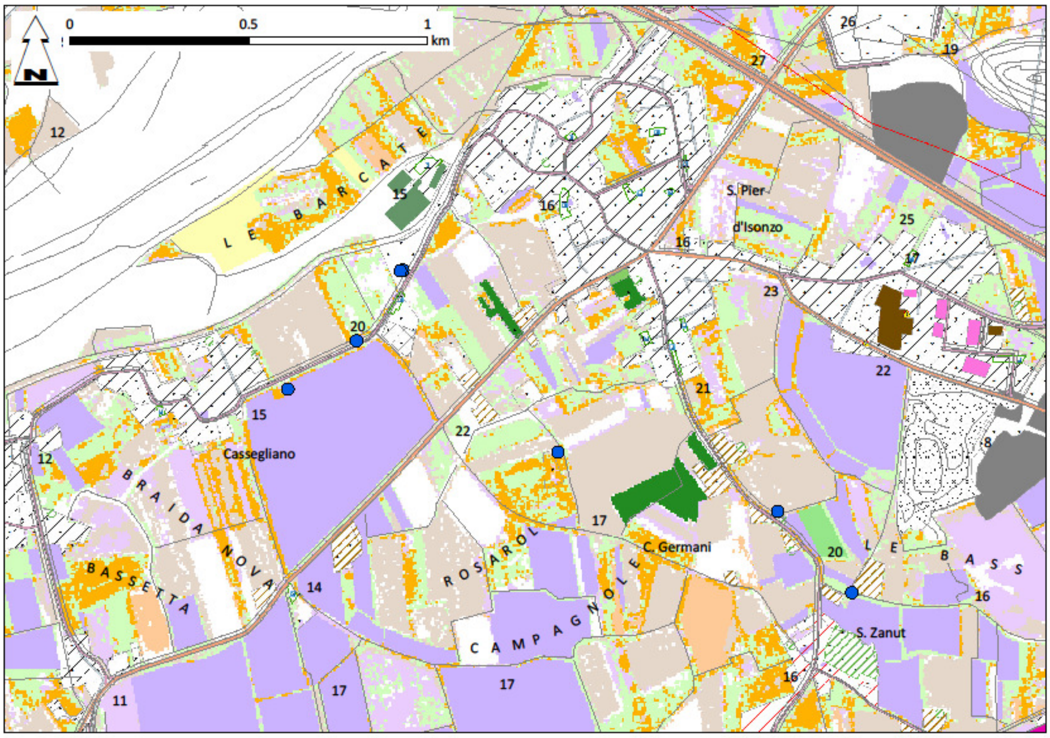


Figure 14: Hazard points legend and sketch of the hazard points digitized for the study area. The map focused on the AcegasApsAmga pumping wells of the northern line (blue dots). Vineyards and corns are the more prevalent cultures in this area.

According to the DPSIR method, in the test area DRIVERS are important and are defined in the Table 3.

Table 3: Drivers and pressures present in the Isonzo/Soča River study area.

DRIVERS	PRESSURES
INDUSTRY	
Paper and wood pulp industry	Emissions of heavy metals, Cr and organic pollutants into groundwaters
Chemical industry	
Electromechanical industry	
Food indusry	
Foundry	
Mining industry (treatment and refining of metals)	
Processing of iron and steel	
TRAFFIC AND TRANSPORT	
Cargo terminal	Emissions from roads (statal, municipal and highways) and from railways of heavy metals (cd, Zn, Pb), salt (Cl, Br), spills (oils, chemical), oil and grease, pesticides, litter, and pollutants from vehicles
Hazardous fluid conduct	
Highway, motorway	
Parking areas	
Provincial and municipal roads	
Railway	
Railway station	
Railway tunnel	
URBAN WASTEWATERS	
Runoff form paved surfaces	Emissions of microbiological pollutants, pathogens, pharmaceutical, chemical, heavy metals
Collection and storage of waste water	
Health service	
Isolated houses without sewrage system	
Urban areas partially provided by sewer systems	
Urban areas provided by sewer systems	
Urban areas without sewer system	
Waste disposal and scrapping centre	
MINING AND QUARRYING	
Rock quarry	Mainly quarry of gravel, can higher the vulnerability due to the decreased unsatured thickness
Quarry of sand and gravel	
INDUSTRIAL WAREHOUSE	
Storage for raw and semifinished materials	
RECREATIONAL FACILITIES	
Golf course	Emissions of pesticides and oils
Motopark	
Open stadium	
ZOOTECHNIC INDUSTRY	
Farms	high concentrations of pathogenic animal waste
ELECTRICITY GENERATORS	
Biomasses energy plant	Emissions of carbon monoxide, nitrogen oxides, volatile organic compounds (VOCs), particulate matter and other pollutants
LIQUID STORAGE	
External tank	Fuel leakeges to soil and groundwater
Fuel station	
OTHER HAZARDS	
Cemetery	Emissions to groundwaters of pesticides to the paths
Military installations	

DRINK ADRIA

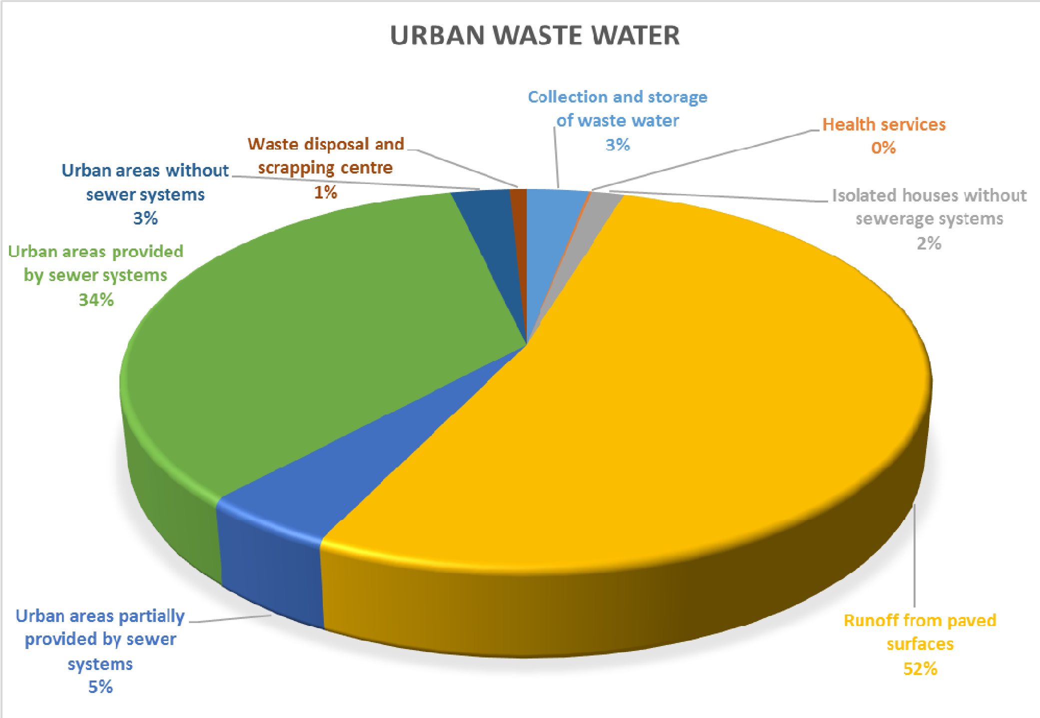


Figure 15: In particular, concerning the Urban Waste Water topic, a more detailed analysis has been done and the figure is summarizing the percentages of the different activities insisting on the territory.

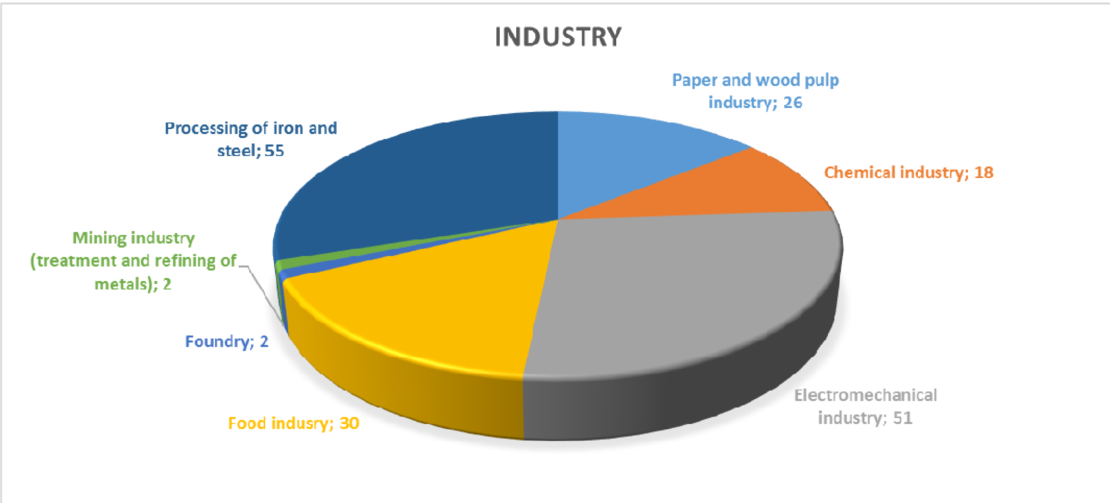


Figure 16: The same analysis has been done on the industry, subdividing the main category into more detailed ones that can have a potential different impact on the groundwater pollution. The number is representing the number of sites present in the study area.

If we look at the agriculture topic, the Regional Authority approved by Decree of the President of the region (R.D. n.3, 11 January 11 2013) as implementation of the DGR 2366 of 28 December 2012, the RFA, result of the transposition of the National Directive 91/676/EEC (the so-called Nitrates Directive), where are defined the

"Criteria and general technical standards for the regional discipline on agronomic use of the breeding effluent, referred to in Article 38 of Legislative Decree 11 May 1999, n. 152 ".

According to the directive the water bodies of the entire regional territory were analyzed within the drafting of the Piano di Tutela delle Acque (Water protection plan). The Isonzo/Soča River High Plain has a good quality chemical status as the artesian aquifers in the Low Plain (A, B, C, D and the deeper ones). As visible also from Figure 17, the study area is characterized by a low concentration of nitrates ranging between 5.1 – 10.0 mg/l.

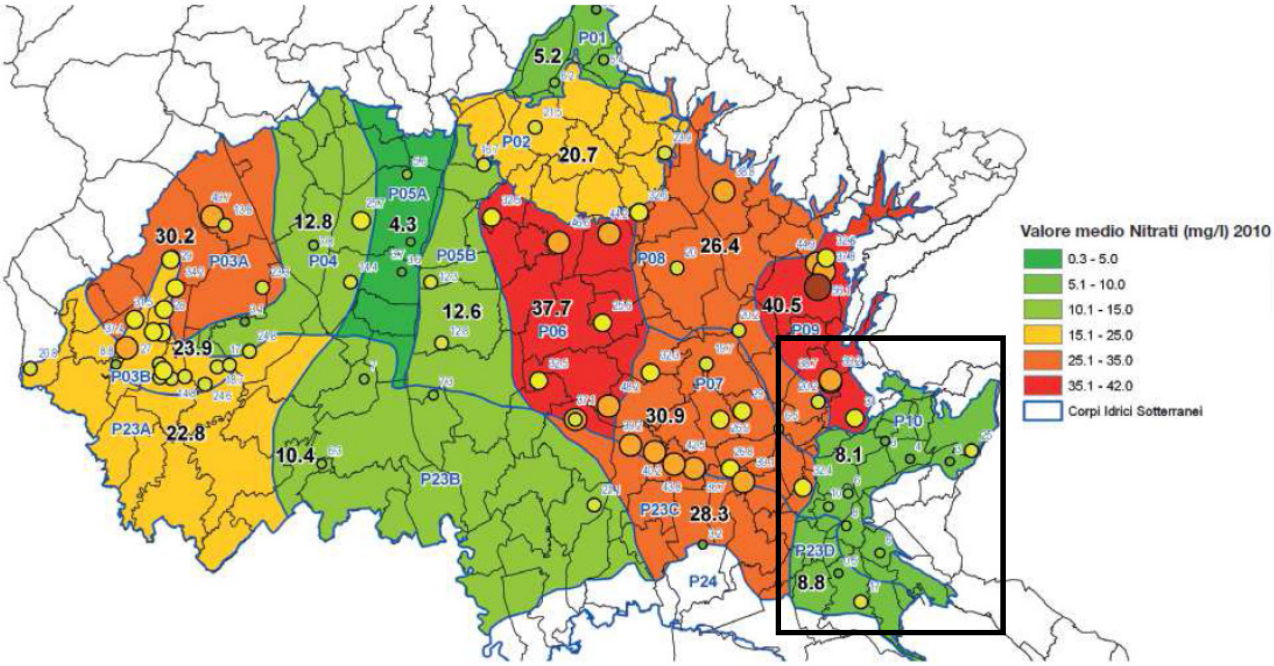


Figure 17: Mean value of the nitrates concentration (elaborated by ARPA FVG, 2010 in the framework of PTA, 2014).

Table 4: Drivers and pressures for agriculture.

STAGE	POSSIBLE INDICATORS
Driving forces	Climate Changes and demographical aspect were identified as primary driving forces. The agricultural sector is one of the secondary driving forces defined.
Pressures	In the Piano di Tutela delle Acque Plain, not jet approved, but since December 2014 under review, the following pressures were identified: water sources withdrawals and pollutant emissions mainly due to point and diffuse sources of nitrogen compound and plant protection products.
Status/Impact	The PTA is considering the actual status of the pressures insisting on the environment of the FVG Region producing a general overview on which the actions need to be applied, working on air, water, soil, biodiversity landscape and health.
Response	The PTA Technical standards contain all the specification on the action that are necessary to define sustainable the way of living and to preserve and improve the quality of the surface waters and groundwaters. One of this is the National Directive 91/676/EEC (the so-called Nitrates Directive).

The dominant climate drivers for water availability are precipitation, temperature and evapotranspiration caused by net radiation at the ground, atmospheric humidity and wind speed, and temperature. Projected changes in these components of the water balance are described in the previous report on Climate Change in the pilot area (Report WP4.1). In short, more intense rainfall events will lead to an increase in suspended solids (turbidity) in rivers, lakes and reservoirs due to soil fluvial erosion (Leemans and Kleidon, 2002) and pollutants will be introduced (Booth and Zeller, 2005; Fleury et al., 2005; Nicholls, 1999; Committee on the Environment and Natural Resources National Science and Technology Council (2008). The projected increase in precipitation intensity is expected to lead to a deterioration of water quality, as it results in the enhanced transport of pathogens and other dissolved pollutants (e.g., pesticides) to surface waters and groundwater and in increased erosion, which in turn leads to the mobilization of adsorbed pollutants such as phosphorus and heavy metals. In addition, more frequent heavy rainfall events will overload the capacity of sewer systems and water and wastewater treatment plants more often. An increased occurrence of low flows will lead to decreased contaminant dilution capacity, and thus higher pollutant concentrations. In particular, in the study area, the occurrence of this scenario will take a while to verify due to the huge amount of available water (Zini et al. 2011), even if the path we are on is the one just described. In the Isonzo/Soča Plain area, the analyzed chemical trends (see Report WP4.2) remain always well below the legal limits with not worrying fluctuations. What is worrying instead is the increased precipitation variability that may decrease the groundwater recharge due to the decreased effective infiltration capacity of the soil being exceeded more often. Anyway, the hydrologic changes associated with climate change cited thus will impact freshwater availability from both groundwater and surface water sources even in an area like the study site where freshwaters are abundant. Shallow, unconfined aquifer levels will be impacted most drastically.

On the deep confined aquifers in the Low Plain the depressurization will take to the loss of humid environments and to the decreased discharge of the withdrawing wells. This is a general consideration, luckly in the study area, due to the presence of the Osimo international agreement there is the guarantee of the minimum amount of water discharged from Isonzo/Soča downstream Salcano dam (Siché and Arnaud-Fassetta, 2014). Here the hydro-picking withdrawals are the ones that regulate the amount of waters released from Slovenia to the Italian Plain with discharge problems. From a natural point of view, what will change will be the effective infiltration on the Italian territory that will decrease in the future not allowing the important recharge contribution to the groundwaters of the Isonzo/Soča River plain.

This allow saying that in the study area the water quantity present in the alluvial deposits is significant, but the ever-increasing demand requires careful withdrawal planning to maintain the sustainability. Now, the water quality is good. AcegasApsAmga within the years (1970s till now) had to face with atrazine and its metabolites issues that are visible on data analysis but with few criticisms (up to 0,05-0,06 µg/l of disetilatrazine). Also ARPA FVG (2015) referring to the groundwater data of 2010 and on phreatic ones (2013), is declaring the good quality of the groundwater bodies. Regarding the residues of plant protection products, after many years from the prohibition of use of atrazine (1990), its degradation products (metabolites) are still present in the aquifers of large areas of the plains also in the groundwaters (Distretto Idrografico delle Alpi Orientali, 2014). This is less visible in the concentrations analysed in the AcegasApsAmga wells, also because their wells reach important depths (-200 m). The problem is more felt by IRISACQUE that has its wells in the northern sector of the Isonzo/Soča High Plain (Figure 1). Here the wells are reaching risible depths (-40 and -25/-30 m) in the phreatic aquifer being more vulnerable to all the pollutants due to the fertilizers used in agriculture and to the cross-border contamination (Slovenian waste waters).

As known, in the groundwaters, within the 1990s, atrazine and desethylatrazine were identified. To date, the groundwater quality is still influenced by the presence of herbicides. In the Isonzo/Soča river basin, atrazine metabolites have been detected in concentration higher than 0,10 µg/l (drinkable limit according to D.Lgs. 31/2001) only in Povoletto municipality in the period 2000-05. It has long been started to detect, northern of Udine, the presence of other herbicides: terbuthylazine and in particular, its metabolite, the terbuthylazine-desethyl. This herbicide had been found also in a well (agricultural use) sited in the village of Cormons (Province of Gorizia). In some wells of the network, sporadic exceedances of the limit of 0.10 µg/l were detected in recent years, also for herbicide Alachlor (Comune di Premariacco) and Metolachlor (Cormons, the whole period within 2003-07). The terbuthylazine-desethyl is present in significant concentrations, equivalent to more than 0.10 µg/l in the previously mentioned well (Angoris well in Cormons municipality) (Autorità di Bacino, 2010). For this reason, especially in the northern part of the study area, it is very important to follow a monitoring program able to verify the quality of the groundwaters.

5 PROBLEMS OF SALT WATER INTRUSION

One of the sources of pollution, in addition to organic matter, pathogens and microbial contaminants, nutrients, acidification (precipitation and runoff), heavy metals, toxic organic compounds and micro-organic pollutants, silt suspended particles, that impact water resources at local scale, is the salinization due to salt water intrusion. The natural balance between freshwater and saltwater in coastal aquifers is disturbed by groundwater withdrawals and other human activities that lower groundwater levels, reduce fresh groundwater flow to coastal waters, and ultimately cause saltwater to intrude coastal aquifers.

The chloride concentration of groundwater samples has been the most commonly used indicator of saltwater occurrence and intrusion in coastal aquifers (Reilly and Goodman, 1985; Bear et al., 1999). In the study site area, the wells close to the coast areas were analyzed to face this problem. Chlorides were taken into account and the results are visible on Figure 18.

Figure 18: Chloride concentration evaluated for the surface and groundwaters. The red line represents the maximum ingression of the salt wedge measured in correspondence of the surface waters (rivers and channels).

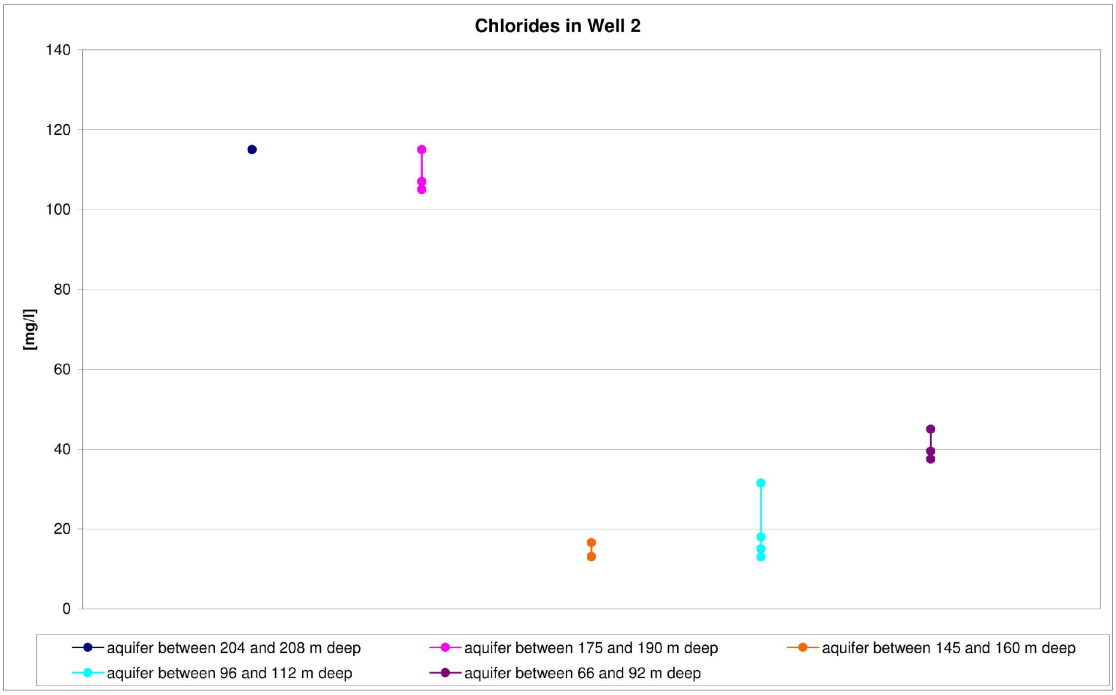


Figure 19: Well 2, chlorides concentration measured while drilling. Values correspond to the different exploited aquifers.

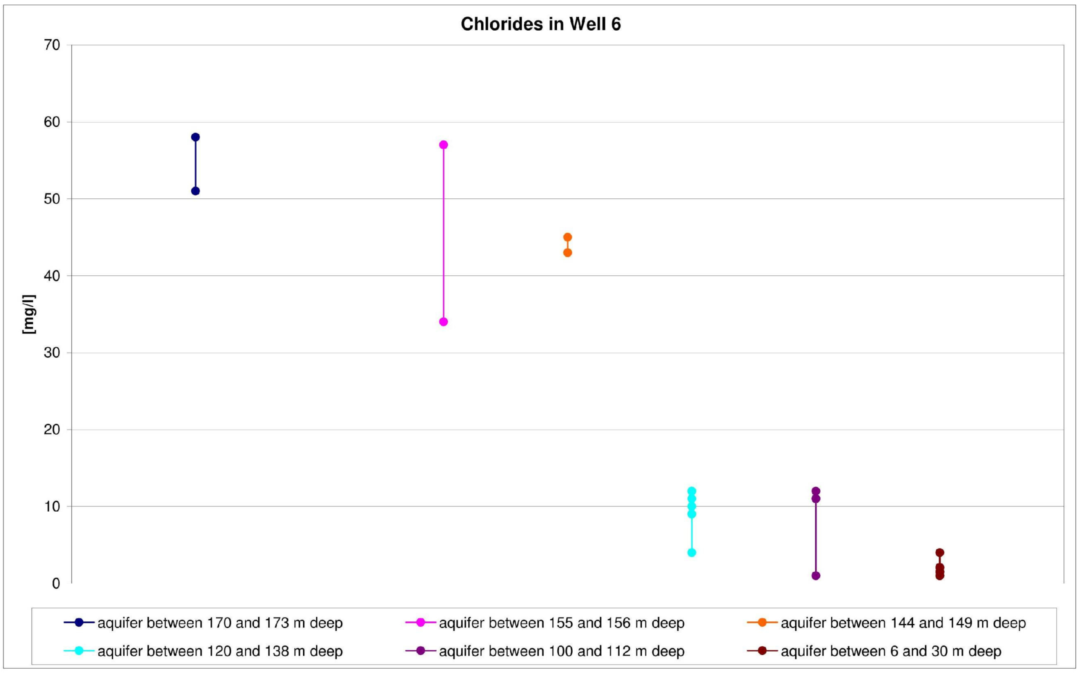


Figure 20: Well 6, chlorides concentration measured while drilling. Values correspond to the different exploited aquifers.

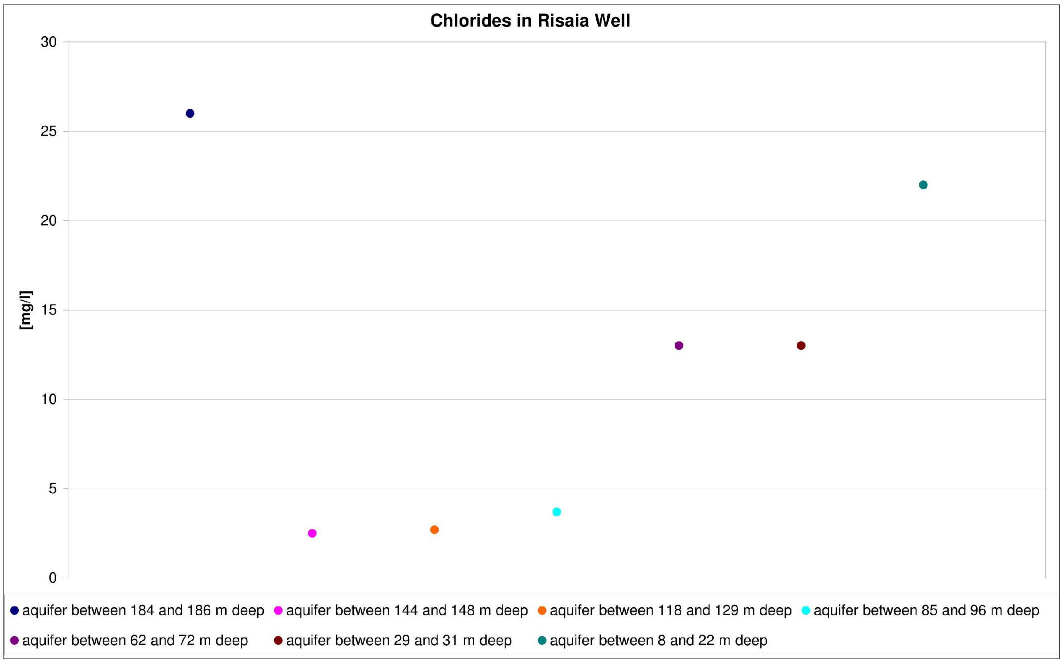


Figure 21: La Risaia well, chlorides concentration measured while drilling. Values correspond to the different exploited aquifers.

To understand if in the study area there can be the evidence to face with salt water intrusion problems, were taken into account the data coming from the deepest wells and the ones were chemical analyses for each single different aquifer were available.

Analyzing singly the different exploited wells, emerges that in the Well 2 the higher chloride concentrations are identified at depths higher than 170m with values greater than 100 mg/l. The other aquifer among 60 and 170m presents values ranging between 10 and 50 mg/l.

In the Well 6, have been measured values ranging between 30 and 60 mg/l at depth of 140-180m. The shallower part (6 – 140 m) presents instead always lower values of about 15 mg/l.

The La Risaia well, located in the area where the salt wedge is present (Figure 18), has "high" chloride values of 20-30 mg/l in the shallower (8 – 22 m) and in the deeper (184 – 186 m) exploited aquifer. All the other aquifers present values lower than 15 mg/l.

The three wells reach approximately the same depths and the same aquifers, so the data are comparable. They indicated that in the area is clear that the southern well has definitively lower chloride values than the northern ones (2 and 6). The higher recorded values were found within the limestones at depths exceeding the 200 m. Is known (Petrini et al., 2013) that a fossil marine aquifer is present in the depths in the carbonates. This aquifer supplies the Monfalcone thermal springs and has been exploited also at Grado (Grado-1 well) beneath 700m (Cimolino et al., 2010). Therefore the high chloride values identified in the northern well (2 and 6) can be linked to this resource and not to the salt water intrusion. This contamination interests only the deeper aquifers and not the shallower ones (Figures 19 and 20).

6 MEASURES TO IMPROVE THE QUALITY OF DRINKING WATER ON TEST AREAS

Fresh water is essential for human life and in general, it is an essential input to human production and to the economic development. Unfortunately, in many countries around the world, some drinking water supplies become polluted and the deteriorated quality is becoming a grave issue. Water pollution is not only a serious environmental issue but also an economic and human health problem. So this requires a monitoring adaptation based on **community-based monitoring programs.** This will play a central role in keeping communities abreast of the state of their waters. Information gathered from monitoring water (this could include water quality parameters, water levels ….) can be used in source water protection plans and water management decision-making at local, regional and national levels. Community-based water monitoring programs have the potential to provide essential localized information to support community decision-making and community participation in regional watershed governance partnerships. They will often require initial training and capacity support to ensure quality control, maintain complete community data collections, and a usable database up-to-date.

Water quality monitoring data collected regularly throughout the year, over a number of years will contribute to reveal seasonal water quality fluctuations and trends over time. This pays an important role in the development of more effective contextual community water treatment regime and source water protection plans. Monitoring water quality and quantity parameters over the long-term will make communities more conscious on the ongoing changes. Such information provides powerful leverage to support decision-making in favor of water stewardship.

Community outreach and education will be required to support watershed stewardship initiatives and to raise overall awareness not only of climate change impacts but also on land use changes impact so that community members clearly understand the importance of water conservation in the broader attempt to nourish watershed health.

Community is important, but not sufficient. It is necessary in fact to guarantee the safeguard of the resource introducing an Authority dedicated. The combined provisions of art. 13, paragraph 3 and article 3, paragraph 6 of the Water Framework Directive 2000/60/EC allows to identify in a mixed international Italian-Slovenian Commission the institutional entity that most likely could ensure the mutual harmonization between the management plans being drawn up by the Italian and Slovenian authorities (Distretto Idrografico delle Alpi Orientali, 2014). Eastern Alps Hydrographic District Management Plan has individuated the stakeholders necessary to be part of the Permanent Italian Slovenian Commission for Hydro-economy as an official public organism to discuss transboundary water problems. The first step of the commission will be the definition of an expert group to prepare a road map for implementation of “First Italian Slovenian Isonzo-Soča Common Management Plan”.

Surface water, groundwater and precipitations of the Isonzo plain were monitored thanks to a monitoring network realized in collaboration with the Italian and Slovenian partners in the framework of GEP and ASTIS projects, according to the different realities existing over the territories. The aim of this monitoring network has been the one to monitor the surface and groundwaters from a quantitative and qualitative point of view. This means that were analyzed the water levels within the water level devices and qualitative through geochemical and isotopical analysis. In Italy were used and joined the network of the Servizio Idrografico Regionale, the one of the ARPA FVG and some other points. In Slovenia were used some points of the Slovenian Geological Survey and some made available by ARSO. An important issue is the **monitoring network maintenance** in order to verify, in the foreseen years, the changes in quantity and quality of the exploited waters.

The Permanent Italian Slovenian Commission for Hydro-economy has recognized the need to set up a wide monitoring network in order to define the quality and quantity of water bodies in accordance with the Water Framework Directive. In this framework, a transboundary monitoring network will be planned and it should be immediately operating.

The recent monitoring programmes for water quality are prepared according to a new monitoring approach . They are based on pressure analyses - i.e., data on emissions, land use, surpluses of nitrogen and the amounts of pesticides used etc. According to the analysis of these data, the monitoring program is problem oriented and involves predominantly problematic water bodies. Other water bodies are less frequently included in the program. All the specific activities foreseen have been defined on the Technical Standards proposed in the Piano di Tutela delle Acque actually in approval phase (Regione Autonoma FVG, 2014).

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Estimation of Climate Change land use changes and the impact on water quality – 30/5/2015

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Cross Border Cooperation 2007-2013

The project is co-funded by the European Union,
Instrument for Pre-Accession Assistance

Estimation of CC induced land use changes and the impact on water quality

Impact of land use changes on water quality on ATO 3 Test Area, Italy

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Date last release	07/09/2015
State of document	Final

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1 Introduction

This report concerns the estimation of climate change induced land use changes and their consequent impact on water quality, referring to ATO 3 Test Area, Marche Region, Italy, within DRINKADRIA project.

A common methodology for the estimation of climate change induced land use changes has been identified in the DPSIR approach (Driving forces – Pressures – State – Impact – Responses), proposed by the European Environmental Agency (EEA, 1990) and adopted by many national and European institutions.

The DPSIR framework was originally developped for environmental reporting purposes, allowing the description of evironmental problems by formalising the relationships between various sectors of human activity and the environment as casual chains of links. The environmental management process may thus be described as a feedback loop controlling a cycle consisting of five stages (Fig. 1).

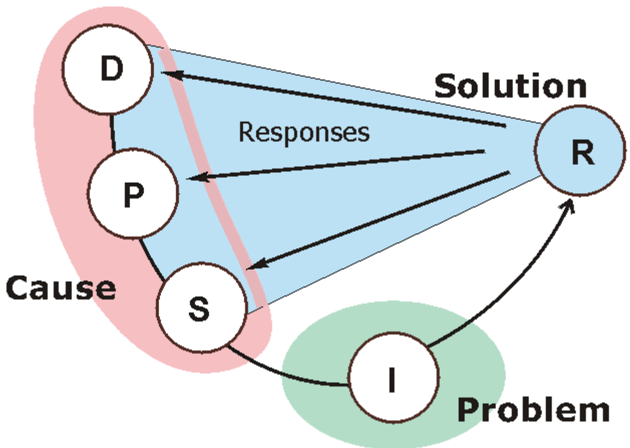

Fig. 1 – The DPSIR framework

Driving forces are the underlying causes, which lead to environmental pressures. Examples are the human demands for agricultural land, water, energy, industry, transport and housing. These driving forces lead to *Pressures* on the environment, for example the exploitation of resources (land, water, minerals, fuels, etc.) and the emission of pollution. The pressures in turn affect the *State* of the environment. This refers to the quality of the various environmental media (air, soil, water, etc.) and their consequent ability to support the demands placed on them (for example, supporting human and non-human life, supplying resources, etc.). Changes in the state may have an *Impact* on human health, ecosystems, biodiversity, amenity value, financial value, etc. Impact may be expressed in terms of the level of environmental harm. The *Responses* demonstrate the efforts by society (e.g. politicians, decision makers) to solve the problems identified by the assessed impacts, e.g. policy measures, and planning actions.

In the specific context of the estimation of CC induced land use changes and evaluation of their impact on water quality on DRINKADRIA Test Areas the potential of the DPSIR approach is evident. It hopefully will result in a sound support for decision making in the field of Water Resources management in the Adriatic area.

2 Analysis of the actual land use on test areas

ATO 3 Test Area territorial extent is around 2,520 km^2. It is located in the central part of Marche Region, Italy, stretching from the Apennines to the Adriatic coast. The most important Water Resources are located within two different physiographic "Macro-Regions" corresponding to as many hydrogeological domains (Fig.2):

1) WR1 – Calcareous ridges

2) WR2 – Hills and alluvial plains.

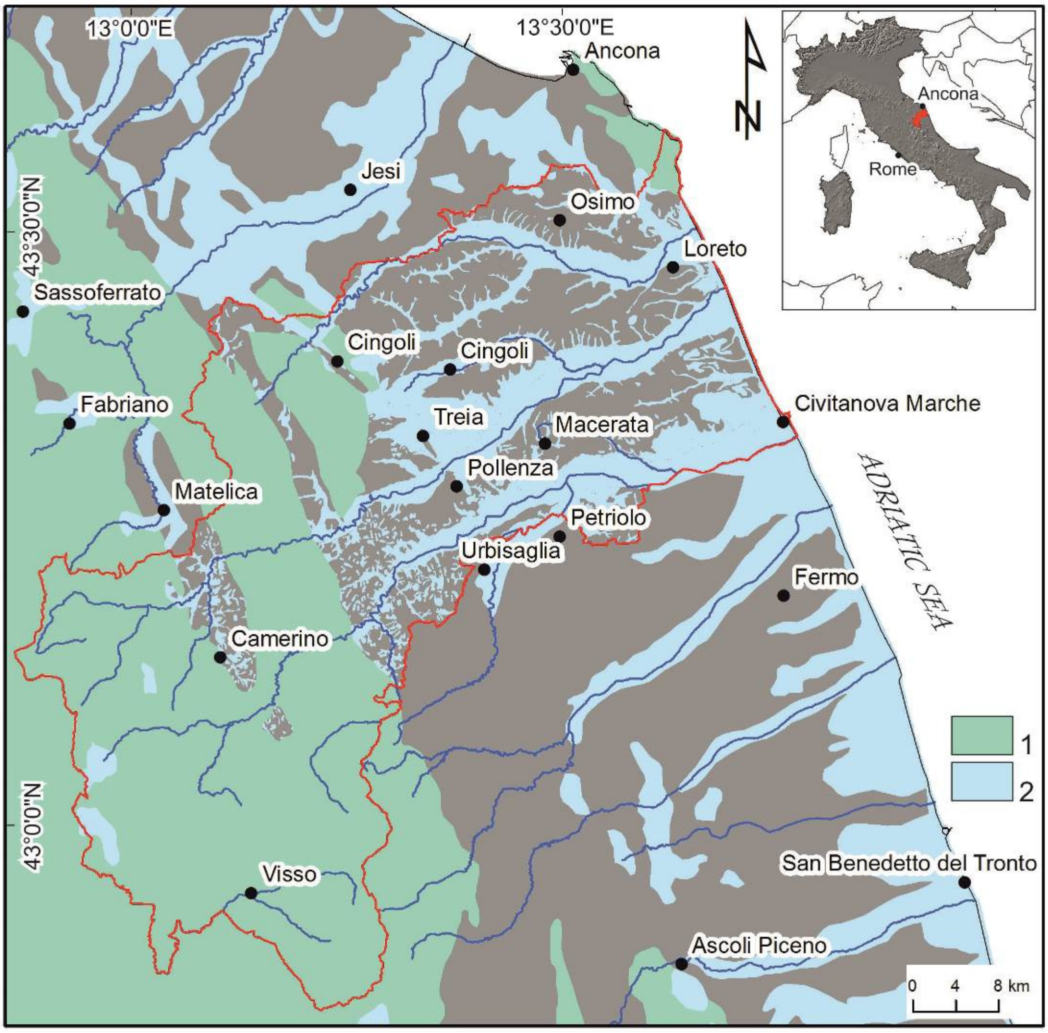

Fig.2 – ATO3 Test Area (marked with the red line): 1) "Calcareous ridges" hydrogeological domain; 2) "Hills and alluvial plains" hydrogeological domain.

The test area can be divided in four main land use classes, according to the Corine Land Cover, 2012 as shown in Fig. 3. Two classes are dominant: agricultural areas, which characterize the low-hilly and flat zones and natural areas and forest which dominate the mountain areas.

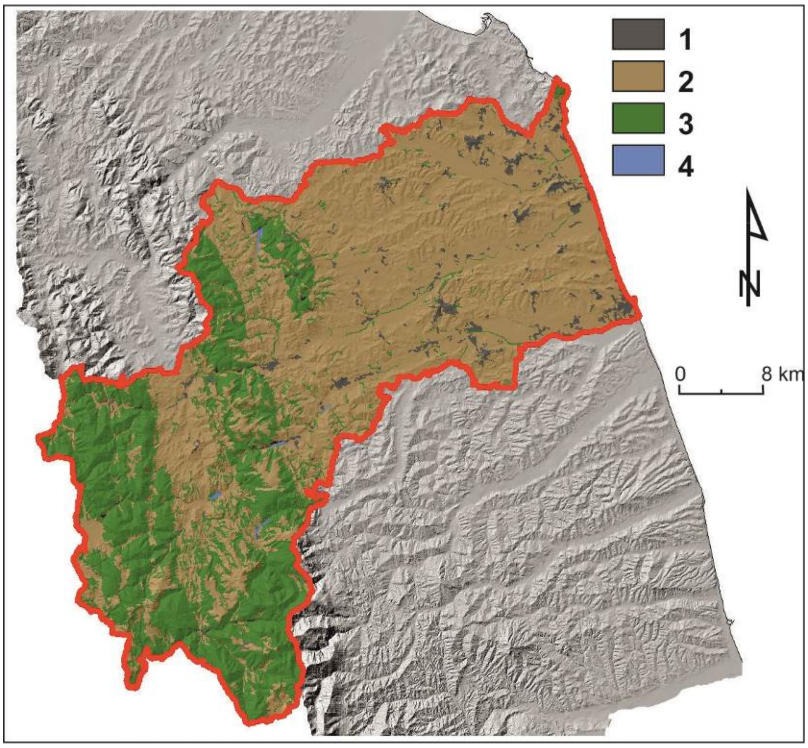

Fig.3 –Land use classes (based on the Corine Land Cover, 2006): 1. artificial surfaces; 2. agricultural areas; 3. forest and semi-natural areas; 4. water bodies.

The agricultural practices in particular, are widely spread throughout the region, while "artificial" surfaces (urbanized areas and/or zones characterized by the presence of important infrastructure) and "uncultivated" surfaces (unused and/or unusable land) are rare and mainly located in the southwest portion of the test area and along the coast respectively.

The geographical distribution does not suggest a particular correlation between the physical characteristics of the territory and the cultivated land but it is clear that only in a few municipalities, agricultural areas remain below the 30%. Among them, the municipalities as Camerino and San Severino Marche, where the significant presence of woodlands and forests tends to lower the average value; likewise, in some coastal municipalities as Civitanova Marche and Porto Recanati, urbanized surfaces tend to limit the weight of the agriculture ones.

Concerning the cultivation methods, in the hilly areas the soil is generally ploughed along the maximum slope (the so called “rittochino”). However, this practice is combined with water regime management that consists of a systematic introduction of ditches. Priority is given to this type of management as the risk of landslides in this area is high due to a very clay-rich soil and increases exponentially with the often recommended contour tillage approach. The farmers have developed this form of tillage management paying attention to most aspects of cultivation and soil conservation. The ditches allow management of surface water flows and should avoid erosive phenomena, while ensuring adequate soil moisture.

As far as concerns the type of cultivation, the arable, which constitutes between 80 and 90% of the total, appears predominant. Such a production decision is linked to a series of combined factors, including the European Common Agricultural Policy (CAP) subsidies which have certainly played a key role. These kind of aid in fact, moving the threshold of affordability for certain crops, especially wheat and sunflower, have oriented in a decisive way the choices of local entrepreneurs. In contrast, fruit production, viticulture and crops such as olive tree, although relevant in the typical business system of local context, characterize just few circumscribed areas of the territory. The distribution pasture lands is limited to mountain areas and strictly dependent on the altitude.

3 Impact of land use on water quality – DPSIR approach for present/past state

3.1 Land use variations and impact factors

Changes in land use can cause, as already well known, also considerable impacts on the qualitative and quantitative characteristics of the water resources exploited for drinking purposes. These changes are determined by different factors, mainly related to human activities or climatic variations on the short to medium term. These changes can be summarized as follows:

- *Changes related to land use:* As much of the Italian territory, ATO 3 Test Area has undergone a significant land use change, related to urbanization and infrastructure construction, resulting in the permanent loss of agricultural land and green belts. It is moreover to be considered that, for the particular geomorphological structure of the area, the building areas are mainly located along the valley floors that come from the Apennines up to the sea. In addition tourism development in recent years has given impetus to a strong building activity along the coast. Although without carrying out any specific activity on this topic, estimates can be made based on the data made available and collected in the database "Change" developed by the project “Image & CORINE Land Cover 2000” which shows the changes of land use in the decade 1990-2000. According to CLC2000 data, the average percentage in terms of surface of impermeable soil (Class 1 of the first level in the CLC2000 classification) is of 4%. Particularly interesting is that the “Change” DB shows that the extent of the artificially impermeable areas (as a consequence of urbanization) in the ATO 3 area of competence is equivalent to that of the areas corresponding to the Class 2 of the first level of classification in CLC. This means that most of the sealed soil has been subtracted from the agricultural sector.

- *Changes related to surface erosion:* Looking at the official map of the risk of water erosion of soils in Marche region, it can be seen that the in ATO 3 area of competence the phenomenon is not so pronounced in terms of magnitude, although it is quite widespread. The major problems are found in the hills, where land use is mostly agricultural (Fig.3a). Furthermore, mountain areas present a risk of erosion, which in some specific situations become higher, if there is a lack of forest cover.

- *Changes related to the loss of organic substance:* Preliminary assessments on the organic matter content of soils can be found in the soil map available at 1: 250,000 scale for the whole Marche region and at 1: 50,000 scale for mostly agricultural areas. Mapping activity has confirmed an already known trend: in the areas with prevalence of agricultural activities a low organic matter content is detected, while in wooded areas the level of organic matter content can be considered high. The mere

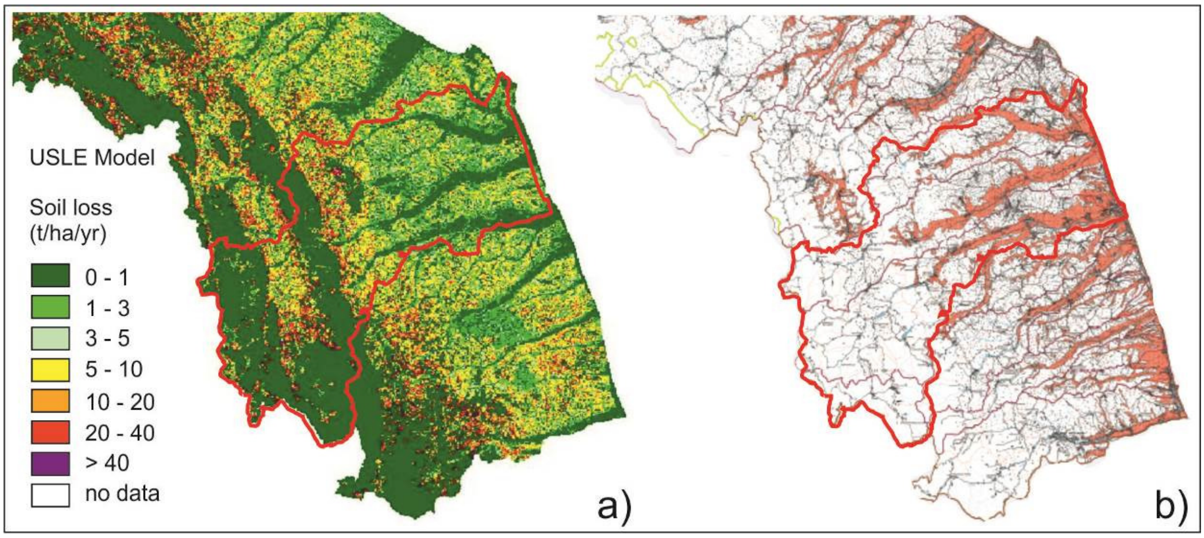

Fig.4 – a) Soil erosion risk map of of the ATO 3 territory (modified from the “Actual risk map of soil erosion of the Marche region”; b) High vulnerability areas (in red) for the presence of NItrates (modified from the Nitrates vulnerability map of the Marche Region)

identification of the organic matter content of regional soils seemed to be too limiting for the implications that this characteristic of the soil plays. The Agency of Agricultural and Food Services of Marche region (ASSAM) has been implementing for several years, in close collaboration with the Italian Joint Research Centre (Ispra) and the European Commission further studies, in specific sites, aimed not only to define the current level of organic substance in the soil, but also to the detection of changes of such content in the time. Suche activity seems to be strategic and in line with the suggestions already given in the Kyoto Protocol, 2008-2012, according to which the soil can and must play a key role as a carbon sink.

- *Changes related to soil contamination:* Chemical contamination is mainly due to the presence of nitrates, whose distribution is primarily connected to the intensive agriculture practices. Monitoring of these substances seems to be a crucial aspect also because it is required by the EU Water Framework Directive. Based on acquired knowledge of soils, Marche Region has therefore implemented a Map of Nitrate Vulnerable Areas (Fig.3b), so allowing a more detailed zoning of the areas where the issue is more evident. Concerning other parameters, just in rare cases they exceed the concentration limits and don’t meet law requirements, mostly because of chemicals (magnesium sulfate, iron..) having a natural origin.

3.2 The DPSIR approach in the ATO3 territory

Tables 1 and 2, show the results of the application of the DPSIR approach on the ATO 3 Test Area.

ID	Water Resource	type	x-coord	y-coord	Drivers: level of influence			
					Population	Industry	Agriculture	Livestock
1	Via Pausola	W	4791669	2397328	**	**	***	*
2	Ponte Cannaro	S	4782462	2357291	*	**	*	*
3	San Giovanni	S	4777691	2353448	*	*	*	**
4	Acquasanta	S	4760287	2373488	*	*	*	*
5	Salette	S	4760116	2361079	*	*	*	*
6	Le Vene	S	4760735	2354664	*	*	*	*
7	Rotacupa	W	4796760	2390853	**	**	***	*
8	Acquevive	W	4791553	2395435	**	**	***	*
9	Centrale Nuova Campomaggio	W	4791130	2405338	**	**	***	*
10	Centrale Via Lelli	W	4794024	2415503	***	***	***	*
11	Crevalcore	S	4805339	2371807	*	*	*	*
12	Madonna dell'Ospedale	S	4800051	2377574	*	*	*	*
13	Sirolo 1	W	4820331	2407178	**	**	***	*
14	Valcimarra Trevase	S	4777704	2372035	*	*	*	*
15	Chiarino	W	4805622	2408251	**	**	***	*
16	Vallememoria	W	4803684	2405936	**	**	***	*
17	Marolino	W	4803552	2406728	**	**	***	*
18	Niccolini	S	4782392	2371180	*	*	*	*
19	Invaso Castreccioni	SW	4805028	2371136	*	*	**	**
20	S. Chiodo sul Nera	S	4750562	2369860	*	*	*	*

Type of Water body: S = spring; W = well field; SW = surface water

Level of influence: * low ** medium *** high

Tab. 1 - Main Driving forces (Drivers) and related level of influence acting in the ATO 3 territory, for each Water Resource.

Referring to springs, mostly located in the mountain area, chemical contamination can be presently considered as non-existent, with Nitrate concentration below 5 mg/l NO_3, which would make this water suitable to be bottled. Bacteriological contamination, on the other hand, is frequent in small springs where intake works are obsolete and not well maintained. Available data indicate that the waters of the mountain area are generally safe. The risk of chemical pollution is particularly low, as these water resources are located in an area characterized by just few small human settlements, with scarce presence of industrial plants and limited agricultural activities.

ID	Water Resource	type	x-coord	y-coord	Water Pollution (fertilizers)	Water pollution (chemicals, hydrocarbons)	Water pollution (metals)	Water pollution (bacteria)	Soil pollution (metals)	Soil pollution (oil-PCD)	Soil pollution (amiantus)	Nutrients	Water abstraction	Urban discharges	Global pressure	Impact assessment
					Pressures level: W, without; M, moderate; H, high;							**Global pressure:** L, low; NS, not significant; M, medium; S, significant				
1	Via Pausola	W	4791669	2397328	M	W	W	W	M	M	M	W	W	M	M-S	Verified
2	Ponte Cannaro	S	4782462	2357291	W	M	W	W	W	W	W	W	W	W	L-NS	Not apparent
3	San Giovanni	S	4777691	2353448	W	W	W	M	W	W	W	W	W	W	L-NS	Not apparent
4	Acquasanta	S	4760287	2373488	W	W	W	W	W	W	W	W	W	W	L-NS	Not apparent
5	Salette	S	4760116	2361079	W	W	W	W	W	W	W	W	W	W	L-NS	Not apparent
6	Le Vene	S	4760735	2354664	W	W	W	W	W	W	W	W	W	W	L-NS	Not apparent
7	Rotacupa	W	4796760	2390853	M	W	W	W	M	M	M	W	M	M	M-S	Verified
8	Acquevive	W	4791553	2395435	M	W	W	W	M	M	M	W	M	M	M-S	Verified
9	Centrale Nuova Campomaggio	W	4791130	2405338	M	H	W	W	M	M	M	W	M	M	S	Verified
10	Centrale Via Lelli	W	4794024	2415503	M	H	W	W	M	M	M	W	M	M	S	Verified
11	Crevalcore	S	4805339	2371807	W	W	W	W	W	W	W	W	M	W	L-NS	Not apparent
12	Madonna dell'Ospedale	S	4800051	2377574	W	W	W	W	W	W	W	W	W	W	L-NS	Not apparent
13	Sirolo 1	W	4820331	2407178	M	W	W	W	M	M	M	W	M	M	M-S	Probable
14	Valcimarra Trevase	S	4777704	2372035	W	W	W	M	W	W	W	W	W	W	L-NS	Not apparent
15	Chiarino	W	4805622	2408251	M	W	W	W	M	M	M	W	M	M	M-S	Probable
16	Vallememoria	W	4803684	2405936	M	W	W	W	M	M	M	W	M	M	M-S	Probable
17	Marolino	W	4803552	2406728	M	W	W	W	M	M	M	W	M	M	M-S	Probable
18	Niccolini	S	4782392	2371180	W	W	W	M	W	W	M	W	W	W	L-NS	Not apparent
19	Castreccioni	SW	4805028	2371136	W	W	W	M	W	W	W	H	M	W	M-S	Verified
20	S. Chiodo sul Nera	S	4750562	2369860	W	W	W	W	W	W	W	W	M	W	L-NS	Not apparent

Type of water body: S = spring; W = well field; SW = surface water

Table 2 - Assessment of the pressure level, in terms of relevant pressures on water bodies, global pressure and impact assessment for each Water Resource.

In the central, medium-low hill area, most of the wate central, medium-low hill area, most of the water supplied for drinking purposes comes from pumping well plants. Nitrates concentration is between 5 and 40 mg/l NO_3 and chemical contamination is mostly referable to and caused by greater agricultural activity, sometimes even resulting in exceeding the limit of 50 mg/l NO_3 required for drinking water. Bacteriological situation is similar to that of mountain springs.

Moving from the mountain area to the valleys (medium-high hilly area and flat-coastal zone), a progressive worsening of water quality features can be detected, also due to the slow underground movement and of the lithological nature of soils (presence of sand with gravel, mainly limestone elements). The significant increase in the concentration of the nitrates is a result of the use and abuse of fertilizers in agriculture. A relevant number of wells are used for irrigation, for industrial water supply and for drinking water supply to the largest urban centers and private country houses in this area, so determining a significant pressure on the natural resource.

Water withdrawn from pumping wells dug in the alluvial deposits near the coastal area shows chemical characteristics similar to the one abstracted in the valleys. In some cases, intense exploitation of wells located close to the sea and their overuse has produced saline ingression phenomena. High Nitrate concentrations and bacterial contamination are less frequent, but a progressive deterioration of groundwater quality has been registered since 1980’s because of contamination caused by industrial activity (Tetrachloroethylene, Trichloroethane).

This deterioration of groundwater quality and the increased drinking water demand have led, since the early 1980’s, to abandon the poorest sources of supply, to be replaced by the use of treated surface water or, whenever possible, by new mountain water resources.

4 The impact of CC and planned development (spatial plans) on the future land use

Quite uncertain are the information about the ongoing climate change in the test area, even though local climatic models indicate, for the next future, an increase of periods with prolonged absence of precipitation followed, on the other hand, by even more frequent extreme rainfall events.

Partial data (to be validated) indicate a shortening in the recurrence of dry seasons: if during the period 1950-2000 a dry season occurred every 10-15 years (Amici and Spina, 2002), after 2000 it seems to occur with a frequency of 5-10 years. More specifically, in the last fifteen years, there has been a peremptory alternating of dry periods especially in early autumn and late winter, followed by periods of intense and prolonged rainfall (even of 48-72 hours), with a total of 250-300 mm (equal to 20-30% of the annual value). The meteoric characteristics above described tend to favor and/or reinforce gravitational and flood phenomena already widespread in the test area and, consequently, to limit infiltration and groundwater recharge (Fazzini, 2002).

Less evident, on the other hand, is the increasing trend in the mean temperature (monthly and annual), even though the available data indicate positive variations mostly in the summer months.

The future, possible, consequences of such climate changes on land use, in the ATO3 territory would therefore be mainly related to:

- evapotranspiration increase and reduction of water content of the soils, especially in summer seasons, resulting in loss of productivity;
- higher incidence and development possibilities of forest fires, especially in the mountain areas, related higher temperatures as well as drier soils and vegetation;
- increased soil erosion phenomena (simple leaching or surface mass movements), as a result of the increased frequency and intensity of storm events and increased degree of dryness of the soils themselves, making them more prone to surface erosion;
- loss of soil rich in nutrients, resulting in less vegetation biodiversity, and growth of species which tend to be fire resistant (Erica, Maritime Pine, D'Aleppo Pine, etc ...), suitable for soils poor in nutrients and highly flammable;
- loss of productivity and pollution of the soils in agricultural areas close to riverbeds, in consequence of overflows: during the phases of higher raising of the water level,

exchange phenomena can in fact be activated, leading to a transfer of polluting substances from the river to the groundwater.

5 Impact of land use on water quality – DPSIR approach for the future state

Looking at the next future, changes in land use caused by climate change, as described in Chapter 4, will produce their greatest effects especially in areas with strong rural traditions as well as in flood plain and coastal areas, where most of the groundwater abstraction works (wells, well fields) are located.

Future regional policies, which look at the development and transformation of the agricultural entrepreneurship as a vehicle of growth for the whole Marche Region will also play a fundamental role. Regional Rural Development Programmes (RDPs) highlight that the areas with greater propensity for growth in the agricultural sector are concentrated in a particular way precisely in the hilly and coastal territory of ATO3, where, however, there is already a considerable density of farms (Fig.5).

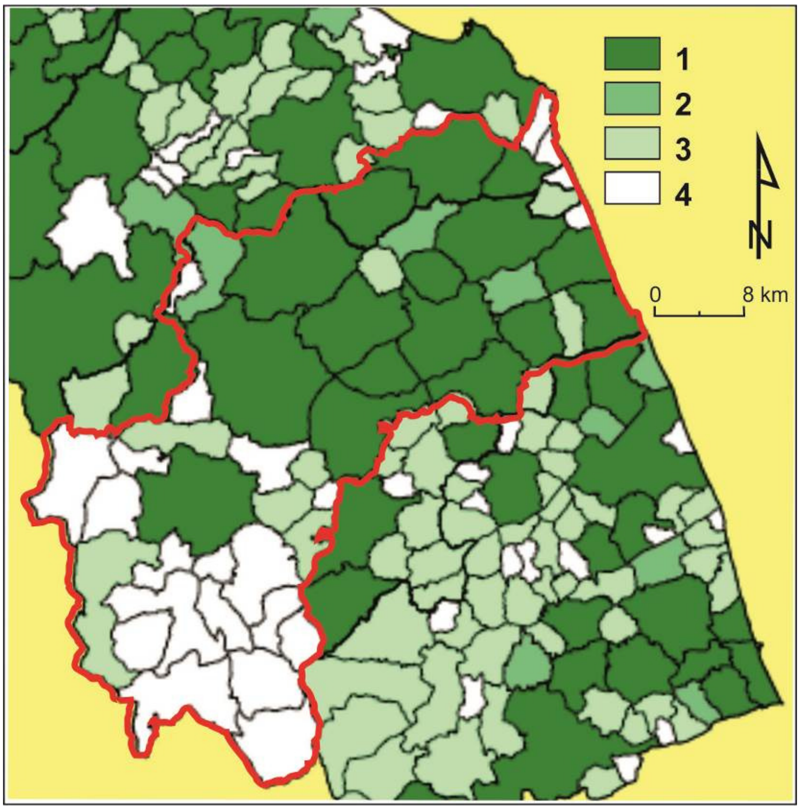

Fig.5 – Map of the suitable areas for agricultural development (modified from Assam, 2010): 1. high; 2. good; 3. moderate; 4. low.

The effects on the state of local water resources, as a consequence, will probably be relevant.

Tables 3, shows the results of the application of the DPSIR approach on the ATO 3 Test Area for the future state and, in particular, concerning the variation in the level of influence of the Drivers .

ID	Water Resource	type	x-coord	y-coord	Drivers: level of influence			
					Population	Industry	Agriculture	Livestock
1	Via Pausola	W	4791669	2397328	***	**	***	*
2	Ponte Cannaro	S	4782462	2357291	*	**	*	*
3	San Giovanni	S	4777691	2353448	**	*	*	**
4	Acquasanta	S	4760287	2373488	*	*	*	*
5	Salette	S	4760116	2361079	*	*	*	*
6	Le Vene	S	4760735	2354664	*	*	*	*
7	Rotacupa	W	4796760	2390853	***	***	***	*
8	Acquevive	W	4791553	2395435	***	***	***	*
9	Centrale Nuova Campomaggio	W	4791130	2405338	***	***	***	*
10	Centrale Via Lelli	W	4794024	2415503	***	***	***	*
11	Crevalcore	S	4805339	2371807	**	*	*	*
12	Madonna dell'Ospedale	S	4800051	2377574	*	*	*	*
13	Sirolo 1	W	4820331	2407178	***	***	***	*
14	Valcimarra Trevase	S	4777704	2372035	**	*	*	*
15	Chiarino	W	4805622	2408251	***	***	***	*
16	Vallememoria	W	4803684	2405936	***	***	***	*
17	Marolino	W	4803552	2406728	***	***	***	*
18	Niccolini	S	4782392	2371180	**	*	*	*
19	Invaso Castreccioni	SW	4805028	2371136	**	*	***	**
20	S. Chiodo sul Nera	S	4750562	2369860	**	*	*	*

Type of Water body: S = spring; W = well field; SW = surface water

Level of influence: * low ** medium *** high

Tab. 3 - Main Driving forces and related level of influence acting in the ATO 3 territory, for the future state and for each Water Resource: red stars indicate sites with substantial variation with respect to the present state.

As it can be noted the level of influence would remain high, or would tend to increase, for all the well fields and for the Castreccioni abstraction facility (from surface waters), located right in the hilly or coastal areas: this is not only due to an increased influence of the driver "Agriculture" but also to the "Population", because of the growth (although quite light, according to recent demographic studies) of the resident population. Concerning the other Drivers, on the opposite, no significant changes are expected.

The “less suitable” areas of the region, according to these intervention policies and plans, would be those of the mountain zone, where the transformations and changes will certainly be less relevant (Fig.5). Nevertheless, an increase in the level of influence of the driver "Population" could be assumed, indirectly, even for the mountain springs: this because of the increased demand arising from the deterioration in the quality of groundwater abstraction in the hilly areas and coastal zones and population living in the same areas. As well known, mountain aquifers feed almost all the waterworks supplying drinking water in the major municipalities in ATO3.

With regard to the "Pressure level" (Table 4) the most sensitive changes would consequently occur only in those indicators closely linked to the activities described above: an increase, although probably minor, in the use of fertilizers and in the quantities of water abstracted from the most important facilities will cause, as a result, an overall increase of the "Global Pressure" for many of the considered Water Resources.

Pressures level: W, without; **M**, moderate; **H**, high; **Global pressure**: L, low; NS, not significant; **M**, medium; **S**, significant

ID	Water Resource	type	x-coord	y-coord	Water Pollution (fertilizers)	Water pollution (chemicals, hydrocarbons)	Water pollution (metals)	Water pollution (bacteria)	Soil pollution (metals)	Soil pollution (oil-PCD)	Soil pollution (amiantus)	Nutrients	Water abstraction	Urban discharges	Global pressure	Impact assessment
1	Via Pausola	W	4791669	2397328	H +	W	W	W	M	M	M	W	M +	M	S +	Probable
2	Ponte Cannaro	S	4782462	2357291	W	M	W	W	W	W	W	W	W	W	L-NS	Probable
3	San Giovanni	S	4777691	2353448	W	W	W	M	W	W	W	W	M +	W	L-NS	Probable
4	Acquasanta	S	4760287	2373488	W	W	W	W	W	W	W	W	M +	W	L-NS	Probable
5	Salette	S	4760116	2361079	W	W	W	W	W	W	W	W	W	W	L-NS	Probable
6	Le Vene	S	4760735	2354664	W	W	W	W	W	W	W	W	W	W	L-NS	Probable
7	Rotacupa	W	4796760	2390853	H +	W	W	W	M	M	M	W	M	M	S +	Probable
8	Acquevive	W	4791553	2395435	H +	W	W	W	M	M	M	W	M	M	S +	Probable
9	Centrale Nuova Campomaggio	W	4791130	2405338	H +	H	W	W	M	M	M	W	M	M	S	Probable
10	Centrale Via Lelli	W	4794024	2415503	H +	H	W	W	M	M	M	W	M	M	S	Probable
11	Crevalcore	S	4805339	2371807	W	W	W	W	W	W	W	W	H +	W	M +	Probable
12	Madonna dell'Ospedale	S	4800051	2377574	W	W	W	W	W	W	W	W	W	W	L-NS	Probable
13	Sirolo 1	W	4820331	2407178	H +	W	W	W	M	M	M	W	M	M	S +	Probable
14	Valcimarra Trevase	S	4777704	2372035	W	W	W	M	W	W	W	W	M +	W	M +	Probable
15	Chiarino	W	4805622	2408251	H +	W	W	W	M	M	M	W	M	M	S +	Probable
16	Vallememoria	W	4803684	2405936	H +	W	W	W	M	M	M	W	M	M	S +	Probable
17	Marolino	W	4803552	2406728	H +	W	W	W	M	M	M	W	M	M	S +	Probable
18	Niccolini	S	4782392	2371180	W	W	W	M	W	W	M	W	M +	W	M +	Probable
19	Castreccioni	SW	4805028	2371136	M +	W	W	M	W	W	W	H	H +	W	S +	Probable
20	S. Chiodo sul Nera	S	4750562	2369860	W	W	W	W	W	W	W	W	H +	W	M +	Probable

Type of water body: S = spring; W = well field; SW = surface water

+/- = increase/decrease with respect the present-day situation

Table 4 - Assessment of the pressure level for the future state, in terms of relevant pressures on water bodies, global pressure and impact assessment for each Water Resource.

6 Measures to improve the quality of drinking water

The analysis described in Chapter 5 makes it clear that, for many of the Water Resources in use in ATO3 Test Area, scenarios of medium-high criticality can be expected in the next future, both concerning the use of the soil (as a consequence of prospective CC and connected anthropogenic actions) and the possible use and the quality of the water resources.

In the hilly areas and coastal zones, however, part of these impacts could be mitigated by the same intervention measures and policies provided by the RDPs (Rural Development Programmes) of the Marche Region, whose overall objective is the continuation of farming but in a framework of ecological and sustainable development (with special reference to the extensive livestock activities). As recommended in these Plans, given that the most widely spread crops and cropping systems are identifiable as high-risk in terms of soil degradation, they should be avoided and other kind of crops, rotations and modern practices introduced.

However, considering that farmers are often attached to current crops and practices, because of profitability, tradition and social norms, long-term investment in machinery, limited skills, pressures from processors and retailers, and other factors, it may be difficult to abandon damaging practices in the short term. Therefore incremental change and more limited technical adjustments may be more realistic goals in the immediate future.

In mountain areas, where the risk of overexploitation and decrease in water resource quality appears not existing or very limited in the short-term, measures should be addressed to the maintenance and modernization of the abstraction facilities, in order to reduce the risk of losses and optimize the management of water intakes, also in view of a general increase in future demand.

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CC induced land use changes – Macerata 07.09.2015

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DRINK ADRIA

The project is co-funded by the European Union, Instrument for Pre-Accession Assistance

WP4.3. Report:

Present and future water safety and risk for drinking supply at Ostuni test area (Apulia, Italy)

FB3 CNR-IRSA

Bari, April 2015

Lead Author/s	Costantino Masciopinto
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Date last release	April 2015
State of document	Final

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DRINK ADRIA

Adriatic IPA Cross Border Cooperation 2007-2013

The project is co-funded by the European Union, Instrument for Pre-Accession Assistance

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1. INTRODUCTION

The Apulia region with more than 4 million inhabitants has been exposed to a sequence of prolonged droughts in the past decades, which caused a general decrease in water supply and an increase of demand for irrigation. Moreover, in the past decade the region has been recognized as being among those at the highest risk of desertification in Europe, due to the observed climatic trends and intensified agricultural practices.

The Pilot Area is 1991 km^2, with a maximum length of 53 km, maximum width of 50 km. The area covers 24 municipalities of the Apulia region, which are in 3 provinces: Brindisi, Taranto and Lecce.

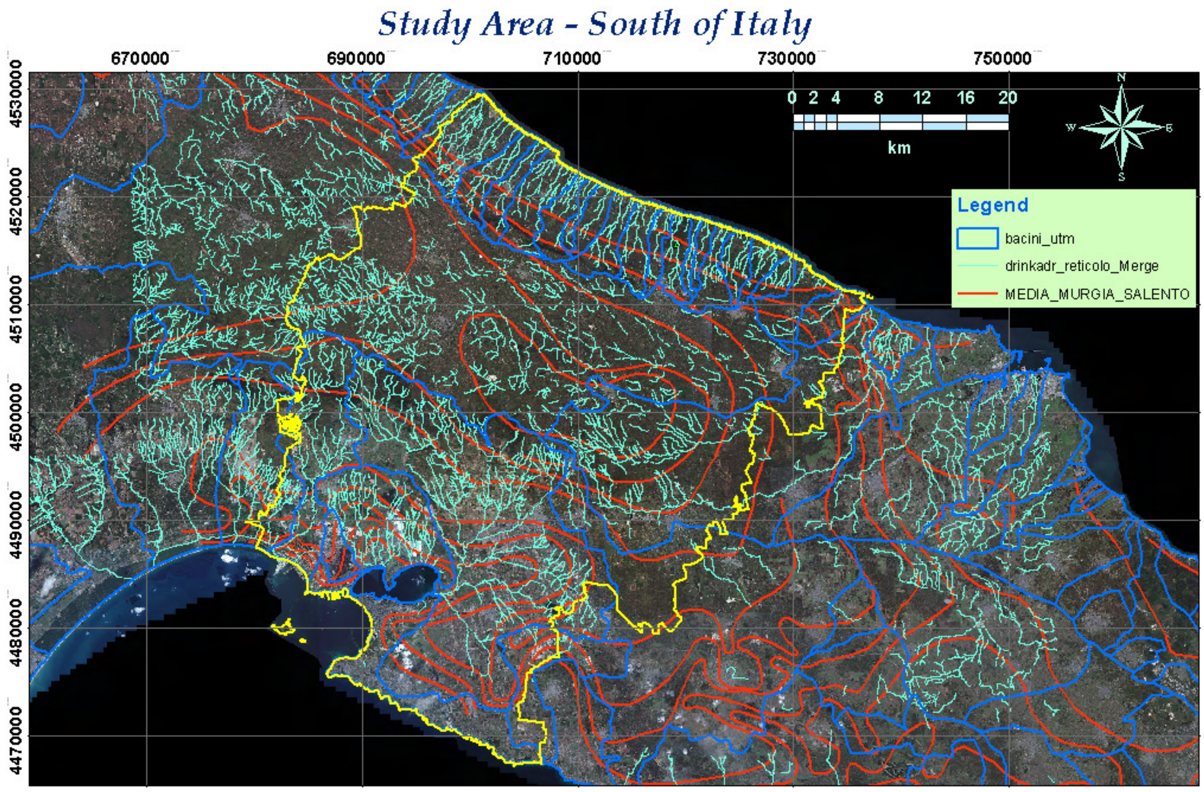


Figure 4.3.1. Ostuni pilot area and stream basins of the Salento peninsula (Apulia region, Southern Italy).

The climate is markedly Mediterranean, with mild wet winters and hot dry summers (the coldest month is January and the warmest is July). Climate variables and rainfall in particular, exhibit a marked inter-annual variability which makes water availability a permanent threat to the economic development and ecosystem conservation of the region. In addition, rainfall has also experienced a declining trend, on average, over the past four decades.

Due to the dominant carbonate nature of rocks (high substrate permeability and infiltration of rainwater), the region has almost no rivers, except in its northern part, where the presence of alluvial materials is favorable to shallow groundwater and permanent (or seasonal) rivers. Instead, in the karst area some basins related to a fossil hydrographical network, present a superficial flow only during intense events.

The region is mainly dominated by agriculture that is a vital economic resource for the region, with more than 70% of the total area occupied by cropped land.

1.1. Actual drinking water deficit

The water balance of drinking water resources has been estimated on the basis of the specific standards for water requirement of different types of drinking consumers (see Table 3).

Table 4.3.1. Comparison of water requirement standards proposed by different Master Plans in Italy.

Total polulation (P) of munipality	Drinking water STANDARD (L/inhab/d)		
	PRGA (1967)	PS14 (1981)	Update PRGA (1998)
Single huose	80	150	170
P < 5,000	120	150÷170	170
5,000 < P < 10,000	150	160÷235	170
10,000 < P < 50,000	200	170÷340	250
50,000 < P < 100,000	250	270÷340	300
100,000 < P	300	340	340
Province	350	375÷445	375
Principal town (Bari)	350	480	420
Tourists in hotels	100	350÷500	500
Tourists not in hotels	100	100	200
Workers in industries	---	150	100
Extra (nonresident) daily population	100	150	100

The total water requirement is then defined when the future trend of population, industry and tourists. The difference between the water demand and the actual water resource availability defines the water deficit in drinking water. The actual estimated value of the deficit of the region is 53 Mm^3, including water losses of 15%, which will be covered by including new artificial lakes.

The drinking water supply information at the 24 municipalities of the Ostuni pilot area has been reported in the following table 4.3.2.

COMUNE	PROV	node	Flow rate supplied L/s	Population 01/01/2013 (ISTAT)	Non Resident	Tourists in hotel	Tourist not in hotel	Workers in industries	Actual drinking demand	Actual deficit	Demand (L/s) for Tourist
SAN MICHELE SALENTINO	BR	131	16.3	6359	138	0	1096	492	23	7	2
FRANCAVILLA FONTANA	BR	134	137.7	36908	2372	42	11056	2126	199	61	14
CAROSINO	TA	354	14.0	6963	135	0	138	193	24	10	1
ROCCAFORZATA	TA	6111	5.3	1797	24	18	123	88	6	1	0
MONTEPARANO	TA	6111	5.3	2410	25	0	83	145	8	3	0
PULSANO	TA	6111	61.3	11221	468	405	15975	460	69	7	12
FASANO	BR	128	183.3	39431	2578	1603	29270	2736	227	44	30
OSTUNI	BR	130	178.6	31709	2068	2148	40259	4365	197	19	39
LOCOROTONDO	BA	129	50.2	14258	581	44	5120	2057	78	28	7
CISTERNINO	BR	129	44.9	11678	499	124	4078	936	63	18	5
MARTINA FRANCA	TA	129	205.5	48958	2970	350	33280	3874	277	72	32
CAROVIGNO	BR	130	66.0	16187	670	98	13844	1183	93	27	12
SAN VITO DEI NORMANNI	BR	131	77.6	19494	1349	121	5358	1322	105	28	8
CEGLIE MESSAPICO	BR	131	81.1	20089	1343	22	8285	1254	110	29	10
LATIANO	BR	358	57.2	14919	17504	0	700	3031	113	56	39
CRISPIANO	TA	347-348	45.5	13646	585	0	861	831	71	25	3
VILLA CASTELLI	BR	132	21.0	8965	181	0	1594	384	32	11	2
GROTTAGLIE	TA	133	116.7	32544	2062	14	1162	1547	169	52	7
MONTEMESOLA	TA	350	8.8	4037	50	0	111	235	14	5	0
TARANTO	TA	349	1093.8	198728	22178	2269	0	44301	1763	669	96
MONTEIASI	TA	352	12.3	5530	123	0	65	129	19	7	0
SAN GIORGIO JONICO	TA	6111	51.9	15480	681	32	181	880	80	28	2
FAGGIANO	TA	6111	8.8	3558	42	0	84	114	12	4	0
LEPORANO	TA	6111	27.4	7873	141	210	12899	704	37	9	10
TOTAL			2570.5	572742	58767	7500	185622	73387	3789	1219 (47%)	330 (9%)

The estimation of the drinking water demand was based on the drinking water standards (Table 4) by considering the seasonality of 60 days for tourists and a worker presence of 200 days per year.

Thus we have

Average water demand= ∑ (Water standard x Population x seasonality/365)/86400 x Water losses coefficient (=1.15)

and

Maximum (or actual) water demand = Average water demand x Coefficient of water demand fluctuation (=1.5)

Table 4.3.2. Water requirement for tourists (330 L/s), which is approximately 9% of the total drinking requirement. This means that 9% of the actual drinking water, i.e. 224 L/s is provided from actual water resources, whereas the actual deficit for tourists is about 106 L/s. A fraction of this flow rate, i.e. 76 L/s may be provided by groundwater, along the Ostuni coast. The remaining deficit of 30 L/s may be easily supplied by replenishments and successive pumping from the Ionian coastal groundwater, by using effluent of nearby municipal wastewater plants of (Taranto, Monteiasi, San Giorgio Ionico, Faggiano, Leporano, Carosino, Roccaforzata, Pulsano and Monteparano) after appropriate water treatments).

1.2. Recovery of water losses

The recovery of water by reducing losses from pipelines should be considered a very priority from drinking water communalities. Technology can assist (see for instance geo-radars) operators in the ducting break and pipe failures or leakages from joints. An experimental study carried out from Apulia communality [1] for water supply on a sample of 25 municipalities of region has shown a percentage of water losses ranging from 10%-15% in large city to 30-35% in small towns. This because there are important water losses that are probably localized on the main pipelines that supply the distribution network. These produce the majority of water leakage and, subsequently the water loss volume is reduced in percentage, when the total volume provided for supply is higher. The mean water losses of the Apulian municipalities were estimated to be 16.08% of the total volume supplied.

2. ANALYSIS OF ACTUAL LEND USE ON TEST AREA

Actual land use on test area (Ostuni, Southern Italy) has been depicted in the following Figure 4.3.2.

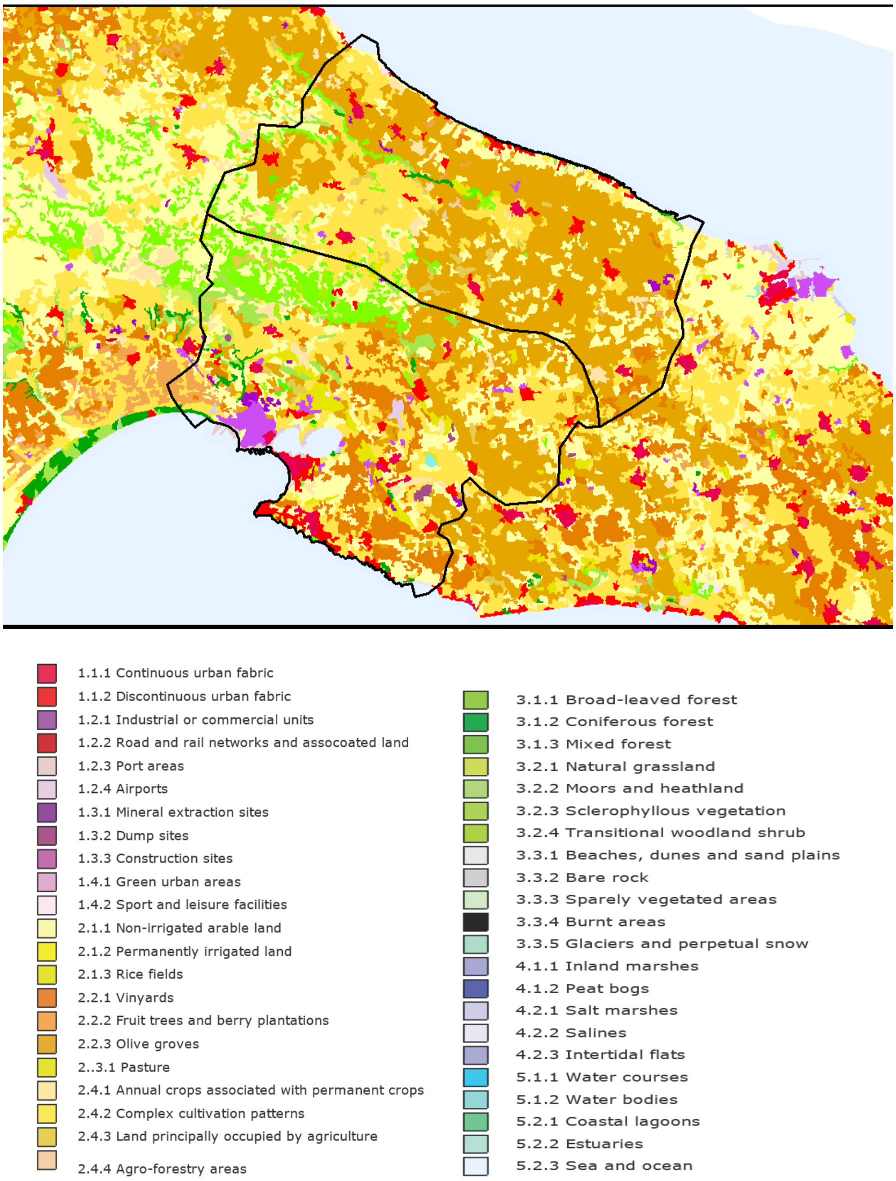


Figure 4.3.2. Actual land use at the Ostuni test area (Southern Italy), (Corinne, 2012; http://www.eea.europa.eu/data-and-maps/indicators/ecosystem-coverage-1/assessment-1).

Irrigation areas are supplied by ARNEO communality and by private wells.

The ARNEO communality area takes in municipalities in the provinces of Lecce, Brindisi and Taranto and covers 249 thousand hectares. Within the area as a whole it is possible to identify – on the basis of the crops grown there – three distinct homogeneous zones:

- A northern, Adriatic coastal zone, which takes in the north-western part of the communality area and some municipalities in the Province of Brindisi, where about 40% of usable land is given over to seed crops;
- A central zone, which comprises the middle part of the communality area straddling the three provinces, where about three quarters of the cultivable land is devoted to growing olives and vines;
- A southern, Ionian coastal zone, which includes the municipalities of Lecce that overlook the Ionian Sea (Porto Cesario, Nardò, Galatone, Sannicola), where 50% of crops are arboreal (olives and vines) and herbaceous.

The table below shows the figures for the irrigated areas within the communality's ambit.

Facility management	Area (ha)	Equipped area (ha)		Irrigated area (ha)	
		Total	In operation	Total	Irrigated/ in operation (%)
Managed by the Communality		15.3	3.7	553	15
Managed by the Region		4.4	4.4	574	17
TOTAL	**249.4**	18.7	7.1	1,127	16

Table 4.3.3. Irrigated areas surfaces by ARNEO communality

The main source of water withdrawal is the groundwater, which is derived from wells. Table 4.3.2 shows the amount of water taken from the sources and the type of use made of it.

Type of water supply	Overall available volume at the source (Mm^3)	Withdrawal volumes (Mm^3)		
		Total	Drinking water	Irrigation
Spring waters	**0.3**	**0.1**	**--**	**0.1**
Apani spring	0.3	0.1	--	0.1
Surface waters	**704**	**50**	**50**	**--**
Pertusillo dam	250	25	25	--
Monte Cotugno dam	450	25	25	--
Cillarese dam	4	--	--	--
Groundwater	**27.5**	23.3	21	2.2
Communality wells	4	0.9	--	0.9
Puglia Region wells	2,5	1.3	--	1.3
AQP wells	21	21	21	--
Overall communality resources	**731.8**	**73.4**	**71**	**2.3**
Private wells (irrigation use)		86	--	86

Table 4.3.4. Water resources supplied per year by ARNEO communality

It is not possible to provide reliable amount of the overall volume of water supplied from groundwater due to numerous private wells, often illegals. In the following there is an estimation of private wells supply.

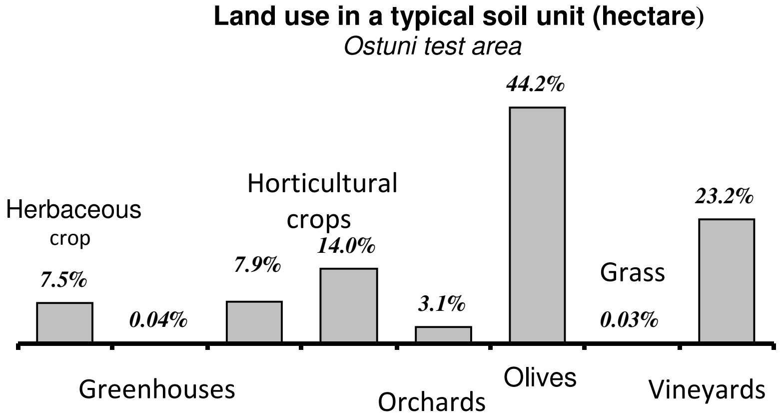
Type of water supply	Volume for irrigation (Mm^3)		
	Availability	Abstraction	Actual use
Spring waters	**0.3**	**0.1**	0.1
Apani spring	0.3	0.1	0.1
Groundwater	**6.5**	**2.2**	**1.5**
Communality wells	4	0.9	0.9
Puglia Region wells	2.5	1.3	0.6
Overall communality resources	**6.8**	**2.3**	**1.6**
Private wells		86	86

Table 4.3.5. Water groundwater supply per year in the communality area.

The main types of crops and the relative annual water requirements are shown in the tables below.

ARNEO COMMUNALITY

Crop type	***Irrigated area*** [ha]	***%***	***Annual net irrigation demand*** [m^3/ha]
Herbaceous crops in open fields with spring-summer cycle	*5798.5*	*7.5%*	*2,200*
Greenhouse crops	*28*	*0.04%*	*5,000*
Vegetables crops with summer-autumn and spring cycle	*6098.9*	*7.9%*	*2,800*
Vegetables crops with spring-summer cycle	*10866.8*	*14.0%*	*4,800*
Orchards	*2439.1*	*3.1%*	*3,250*
Irrigated olive groves	*34334.4*	*44.2%*	*1,400*
Permanent meadows	*23.0*	*0.03%*	*3,000*
Irrigated vineyards	*18051.2*	*23.2%*	*2,750*
TOTAL	***77640.2***	***100.0%***	



Irrigated surface /in operation surface	***26.5%***	
Annual net irrigation demand per average irrigated hectare	***2,419***	*m^3/ha*
Annual net irrigation demand for the communality	***49.8***	*Mm^3*
Efficiency of transport and distribution of water	***90%***	
Efficiency of the irrigation systems	***75%***	
Annual gross irrigation demand per average hectare	***3,584***	*m^3/ha*
Annual gross irrigation demand for the communality	***73.7***	*Mm^3*

3. IMPACT OF LAND USE ON WATER QUALITY

During DRINKADRIA activity the partner FB3 has carried out several water sampling in order to monitor groundwater and surface water the OSTUNI test area.
In particular were selected three sampling locations into a channel and three wells for groundwater monitoring.

Figure 4.3.2a. Monitoring: Sampling locations at the Ostuni test area.

At each sampling site we have collected two liters of water in a sterile container to detect *Salmonella* spp., one liter to detect the indicators of faecal contamination and a third sample of twenty liters to detect somatic coliphage viruses. The coliphages will be determined after concentration to 50-100 mL of water sample by tangential ultrafiltration (VIVAFLOW 200 with 10,000 MWCO PES, *Sartorius*).

Furthermore the IRSA has defined sampling procedure in order to collect water samples from the OSTUNI wells and standard and bimolecular methods that must be used for microbiological analyses during DRINK ADRIA project at the Ostuni pilot area. In particular sampled water will be analyzed for total bacterial count (TBC) at 22° and 37°, coliforms, *Escherichia coli*, spores of sulphate-reducing clostridia, somatic coliphages, and *Salmonella* spp., and physico-chemical constituents, such as ammonia, nitrates, chemical oxygen demand (COD). The presence and abundance of antibiotic resistance genes (ARGs) will be also determined by q-PCR and large volumes of 5-120 L and 200-250 L will be sampled for the protozoa and virus analyses, respectively. For Enteroviruses determination, the groundwater will be filtered on electropositive cartridges (Virasorb CUNO MK/Cuno, Sanford, FL). Cartridges will be eluted with a meat extract solution (elution buffer 0.05 M glycine in 0.3% meat extract pH9.5) and viruses will be further concentrated by precipitation with PEG6000 and centrifugation. Finally viral particles will be quantified by cultivations on cellular systems or by bimolecular methods. Cysts and oocysts will be concentrated by filtration in IDEXX foam filters, purified by means of immune-magnetic separation (*Dynabeads*® Crypto-Combo) and stained with fluorescently labelled monoclonal antibodies (*MERIFLUOR® Crypto & Giardia* kit, Meridian Bioscience, Europe). *Giardia* and *Cryptosporidium* cysts and oocysts will be finally enumerated by epifluorescence microscopy (Olympus BX-51) and phase contrast observation.
Microbial and chemical constituent results during the first sampling period of the DRINK ADRIA project, have been reported in the following Table 4.3.6, whereas the *Salmonella* was below detection limit of the proposed microbiological method (q-PCR).

Water constituents	D'Antelmi Mouth 19/11/2014	D'Antelmi Mouth 13/01/2015	D'Antelmi Mouth 17/02/2015	Channel 1 19/11/2014	Channel 1 13/01/2015	Channel 1 17/02/2015
pH	7.2	6.9	7.5	7	7.2	7.4
Electrical conductance (μS/cm)	1808	1721	1872	1288	1773	1817
COD (mg/L)	64	35	28	41	38	29.6
$N\text{-}NH_4$ (mg/L)	<0.4	8.86	4.5	<0.4	11	5.68
$N\text{-}NO_3$ (mg/L)	7.2	8	3.8	7.2	6.7	4.33
$N\text{-}NO_2$ (mg/L)	0.01	3	1	0.026	2.3	1.2
Microbiological indicators						
E. Coli (MPN/100mL)	2240	31	135	6490	240	137
Total Coliforms (MPN/100 mL)	32550	3450	4160	48800	9210	9606
Spores of C.Perfrigens (CFU/100 mL)	3000	3000	2000	2000	3200	1800
Somatic Coliphages (PFU/100 mL)	300	2400	1300	1000	2800	2000
Enterococci (MPN/100 mL)		218	185		2420	161
HPC 37℃ (CFU/mL)		3550	4200		6900	6500
HPC 22℃ (CFU/mL)	390	850	680	795	980	840

Channel 2			Well	Well 1		Well 2	Well 3	Well 4	Well 5
19/11/2014	13/01/2015	17/02/2015	13/01/2015	19/11/2014	17/02/2015	13/01/2015	17/02/2015	17/02/2015	17/02/2015
7.5	7.7	7.3	6.9	7.2	7.4	7	6.9	7.2	7
1845	1696	1888	9180	1977	3850	687	8500	2700	4000
48.6	44.4	30	21.2	56	8.8	4	20.6	7	8.5
<0.4	8.66	4.2	0.56	<0.4	0.5	0.12	1.3	0.5	<0.4
7.3	5.6	3.29	3.2	2.5	2.24	1.9	1.3	5.5	1.2
0.016	1.5	0.6	0.22	0.04	0.013	0.01	0.01	0.014	0.004
2183	41	47	<1	67	<1	<1	2	<1	<1
14000	3076	3088	260	30800	2419	50	345	387	1
1000	4500	2430	800	200	400	200	0	1500	0
500	1900	1200	0	0	0	0	0	0	0
	866	44	100		10	2	48	8	0
	4500	2900	800		324	100	311	248	260
475	520	600	350	85	155	450	300	185	110

Table 4.3.6. Surface water and groundwater quality sampled at Ostuni test area.

Parameter	ITALIA D. Lgs 31/01 Limit Value
pH	6-9.5
Electrical conductance (μS/cm)	2500
Oxidability (mg/L O_2)	5
N-NO_3 (mg/L)	11.3
N-NO_2 (mg/L)	0.15
N-NH_4 (mg/L)	0.4
E. Coli (number/100 mL)	0
Total Coliforms (number/100 mL)	0
Enterococci (number/100 mL)	0
Spores of C.Perfrigens (number/100 mL)	0
HPC 22℃ (number/mL)	Without abnormal changes
HPC 37℃ (number/mL)	Not expected

LEGEND	
Prudentino	Well
Narducci	Well 1
Guarniero	Well 2
Soleti	Well 3
D'Amico	Well 4
Lobbene	Well 5
Ex-Caseificio	Channel 1
Ponte Fontanelle	Channel 2

3.1. Climate change impact on groundwater discharge: local sea-level rise effect on test area

Considerable work has been published about the impact of climate change on local sea-level rise (LSLR). However, the estimation of its impact on human health and hydrological stress in coastal regions has, surprisingly, not been sufficiently investigated. Focus has been mostly concentrated on direct impacts of sea level related disasters. The impact of LSLR on human health [2] and on groundwater volume reduction has not yet been fully investigated [3], especially in fractured aquifers. Even if there are many challenges relating to predicting and projecting future LSLR, a small increase in sea-level may have a severe impact on many coastal environments. There are many effects potentially caused by LSLR that can affect human health and water availability in various ways. Sea storms amplified by LSLR would also lead to severe impacts on wastewater treatment plants. Furthermore, the reduction of groundwater outflow increases the intrusion length by producing a serious reduction of groundwater volume. This may be very significant in coastal regions, where groundwater is the main source for irrigation and drinking. The sea intrusion problem is truly global in proportion. In Spain, the most severely affected areas by seawater intrusion are the Mediterranean and South-Atlantic coastlines and seawater intrusion is currently one of the main causes of groundwater pollution of about 60% of coastal aquifers. In the world, the most affected areas include Mexico's Pacific and Atlantic coastlines [4], Chile, Peru and Australia. The situation is particularly acute in the Mediterranean, the Yucatan peninsula in Mexico, the Middle East, the SE and SW United States as well as on many islands with arid to semi-arid climates, such as Cyprus.

The aim of our investigation is an experimental evaluation of the LSLR impact during the 21st and 22nd centuries on the Salento peninsula (Southern Italy). Here, the fractured aquifer supplies 80% of the total population's drinking requirements (of about 1 million inhabitants) with 126 million m^3/y of water.

The evaluation has been carried out by generalizing the annual rate of LSLR from the best-fit of ultrasonic tide-gauge sea level measurements recorded at three tide-gauge stations on the Salento coast. Then, the Ghyben-Herzberg formula for fractured aquifers has been inverted to determine the progressive reduction of Salento's groundwater volume during the 21st and 22nd centuries. The new proposed formula highlights the reduction of annual groundwater discharge, which corresponds to the sea inland advancement due to LSLR and can be applied in any coastal fractured groundwater (at a regional scale) in order to evaluate the impact of climate change on local water resources.

3.1.1. The OSTUNI study area

The Salento peninsula was selected among the Mediterranean regions because it is one of the driest areas, with an average rainfall of less than 600 mm/y. Here, similarly to other Mediterranean regions (Greece, Cyprus, Lebanon, Egypt, Tunisian, Spain, etc.) the economy largely depends on farming, leading to mainly agricultural land use with a large share of irrigated crops due to low precipitations. The total water consumption in Apulia is estimated to be about 2400 Mm^3/y, where 58% (1400 Mm^3/y) [5] is consumed by agriculture, 18% (430 Mm^3/y) by industry and 24% for drinking use (580 Mm^3/y). Furthermore, according to other studies [6], the Mediterranean region is expected to undergo particularly negative climate change consequences over the next decades. These effects, combined with the anthropogenic stress of natural resources, make the Salento one of the most vulnerable areas in Europe. The anticipated negative impacts are mainly related to possible extraordinary heat events (especially in summer), increased frequency of extreme storms and reduction of total annual precipitation.

As the Salento peninsula does not have any relevant surface water sources, groundwater has traditionally been the main source of water supply in the region. Moreover, natural recharge does not refill the aquifers sufficiently, and overexploitation, with consequent seawater intrusion into groundwater, is a critical problem at many locations. The number of private wells (often illegally drilled) is around 140,000. The main problem at the Salento peninsula is related to the increase of groundwater salinization due to groundwater over-abstraction and subsequent seawater intrusion.

Here, data (specific conductivities) were collected from 120 wells during the winter of 2009 at a depth ranging from 5 to 10 m below the water table, and were fitted by Surfer (v. 11, Golden Software Inc., Colorado, USA). At several places along Salento's coast, groundwater salinity already exceeds 7 g/l.
In Salento's subsoil, groundwater flows under low pressure inside karstic fissures of carbonate (limestone) aquifers at a depth ranging from 5 to 100 m from the soil. The natural recharge of rocky aquifers occurs via both existing vertical karst fractures and by sinkholes replenished by small ditches (i.e., *lame*) with runoff and, sometimes, [7] with treated effluents derived from municipal plants.
The protection of water resources from seawater intrusion may include several measures to preserve global groundwater balance, considering not only limitations of water supplies and dynamic barriers, but also potential new sources (i.e. reclaimed water) for groundwater replenishment by artificial recharge [8].

3.1.2. Method: Tide-gauge measurements

Many intensive studies have been recently published about global and local sea level forecasting during the 21st and 22nd centuries. Among them, the global rate of sea level rise during the 20th century is generally agreed to be 1–2.5 mm/y, and many authors concur that sea level data series available for the Mediterranean show a sea level rise of a similar rate. However, other authors [9] noted that, from 1990 onward, the sea level recorded in most Mediterranean tide-gauges indicates a rise in sea level at a rate 5–10 times higher than the 20th century mean rate. In addition, Milne et al. [10] have noted a tenfold increase in the sea level rise rate that can be attributed to climate change through glacier melting and ocean water thermal expansion.
Sea-level rise may significantly differ locally and globally due to variations in the ocean circulation as part of variable climate patterns, the isostatic adjustment of the Earth's crust, past and ongoing changes in polar ice masses and continental water storage [11].
In particular, the LSLR spatial variability may also arise for heat content and salinity changes in seawater [12], for vertical geological layer displacement due to tectonics, groundwater reservoir (and hydrocarbon deposit) exploitations, natural sediment consolidation [13] and subsidence. According to Stammer et al. [14], currently, regional sea level changes seem to be primarily caused by natural climate variability.
In the present study, ultrasonic measurements of three tide-gauge stations on the Salento peninsula, from 2000 to 2014, have been fitted using Microsoft Excel [15]. The data are available on the ISPRA website [16].

Measurements are available at intervals of 10 min and were resampled in order to have one measurement per hour. All measurements refer to sea level on January 1, 2000. When, due to device malfunctioning, measurements were missing, no values were considered for replacements, i.e. series have been plotted with missing values. This is because missing data had no influence on the evaluation of the rate during the long period of 14 years, with 129,039 measurements per station (Figure 4.3.3). The straight-line trends of the Bari and Taranto stations have the same rate, i.e. the increasing LSLR is 10^{-4} cm/h (or 8.76 mm/y), while the rate is 0.5×10^{-4} cm/h or 4.38 mm/y (i.e., half) at the Otranto station. Bari and Taranto trends perfectly agree with global sea level (GLS) rise projection as defined by Kopp et al. [17] (see Figure 4.3.3d). They consider 90% (very likely) of probability under representative concentration pathway 8.5 [18], i.e. corresponding to scenarios with usual industrial emissions until the end of the simulation, under maximum radiative forcing (i.e., > 8.5 W/m^2 by 2100) [19]; IPCC AR5 WG1 [20]) and without greenhouse gas mitigation.

It should be considered that this GLS rise accounts for the melting of both Greenland (about 20%) and Antarctica's (10%) ice sheets, thermal expansion (40%), melting of glaciers and ice caps (25%) and the reduction of land water storage (5%). The Bari and Taranto LSLR trends match with the global rise forecast, as defined during the 2100 by IPCC in the fifth assessment report (AR5 WG1 2013) [20] under representative concentration pathway 8.5 and with estimations carried out by Klein and Lichter [9] in the Mediterranean area for decades after 1990.

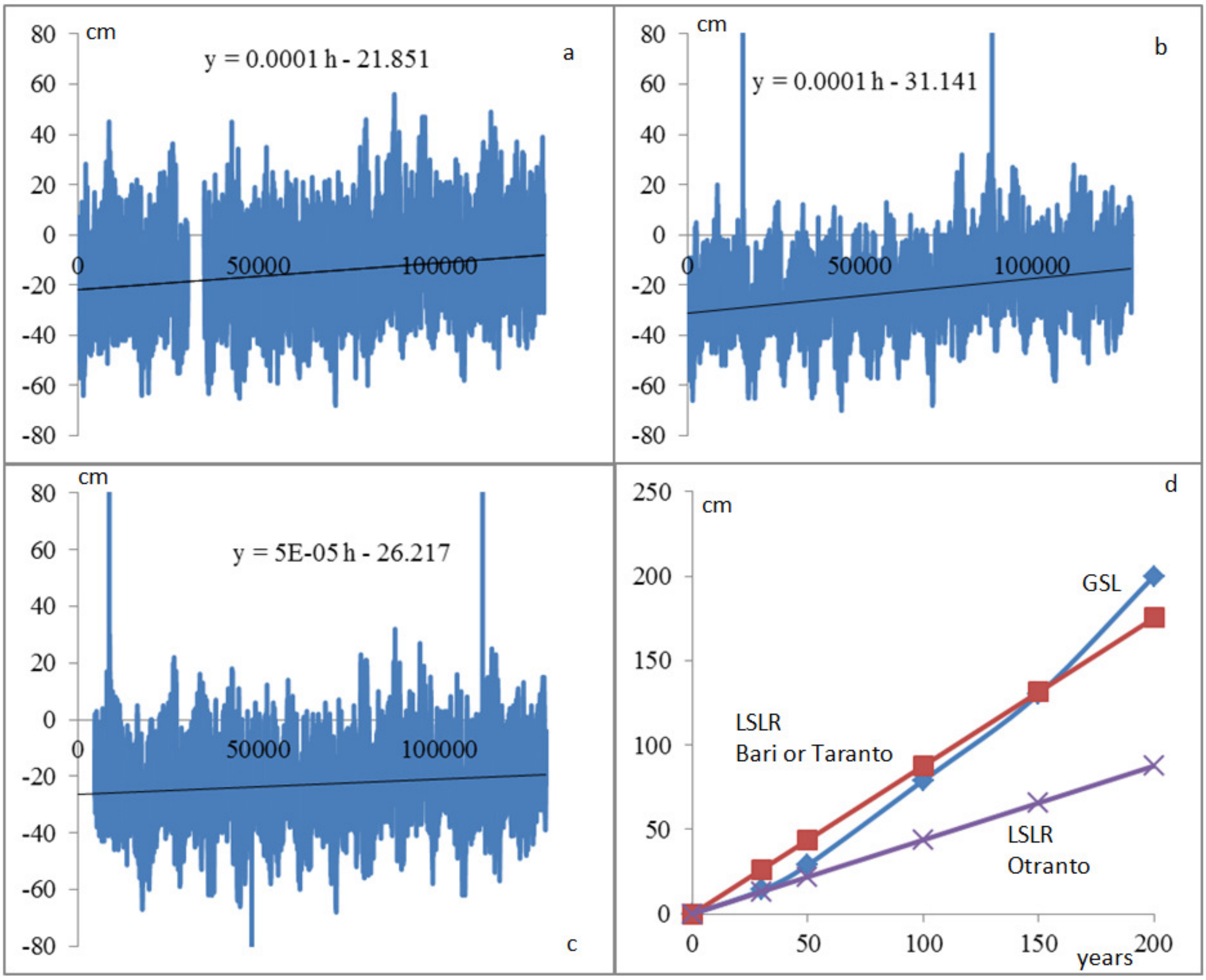


Figure 4.3.3. Tide-gauge measurement trends in (a) Bari, (b) Taranto and (c) Otranto stations from 2000 to 2014, and (d) LSLR trends compared to global level rise projections given by Kopp et al. [17] under representative concentration pathway 8.5 (i.e., 90% very likely).

3.1.3. The coastal salinity map

The sea-level rise may produce inland sea advancements, which depend on the coast morphology. Considering a maximum increase of 2 m until 2200, the Salento sea advancement extension due to this LSLR is below 220 m, on average. This distance was estimated to be in a range from 43±30 m to 781±400 m along the Salento peninsula coastline, according to elaborations made by ArcGIS (http://www.esri.com/software/arcgis) of the coast digital elevation model (http://www.sit.puglia.it) at 8 m of grid size. This average sea advancement is lower than the value of 700–1200 m determined along the same Ionic coast by other authors Romanazzi et al. [21]. Figure 4.3.4 shows the advancements (contour lines) of the sea line determined during the 21st (yellow) and 22nd (blue) centuries compared to the coastline during 2000 (red) along the Lecce's coast (Italy) using ArcGIS. In the same figure is shown in a separate window the groundwater salinity progression in an apparent (i.e. fictitious) borehole placed 1 km from the actual coastline. For this purpose, a second interpolation using TableCurve2D (http://www.sigmaplot.com) has provided the best fit (correlation coefficient of 0.92) between groundwater salt concentrations measured in coastal wells and the modeled distance *(d)* of each borehole from the freshwater/saltwater Ghyben-Herzberg sharp interface,

$$C_{salt} = C_{s0} + A_s\left[\exp\left(-\frac{d}{D_s}\right)\right] \qquad (1)$$

which is a function of the best-fit constants: C_{s0}=1.54 g/L, A_s=12.02 g/L and D_s=592.65 m. For this interpolation, the observed salt concentrations at 1–1.5 m of water depth in 25 wells have been fitted versus the corresponding distances (*d*). Applying equation (1) to the Salento aquifer, we determined into the wells close to the new sharp interface position, a water salinity increase due to LSLR ranging from 7 to 14 g/L. Salinity maps, reconstructed in an apparent well under different LSLR scenarios, corresponding to the years 2000, 2100 and 2200 (Figure 4.3.4), have been determined using *d* = 1000 m, 850 m and 700 m, respectively.

The overall LSLR impact is very far from the catastrophic hypothesis suggested by Andrew Thaler (http://www.weather.com/news/science/environment/drownyourtown-sea-level-rise-your-city-20131219?pageno=4), showing how the Vatican and St. Peter's Square in Rome (Italy) will look with LSLR of 20, 30 and 45 m.

The resulting LSLR of 4.4–8.8 mm/y in the present study and consequent average sea advancement (~220 m) are not negligible when compared with anthropogenic effects, such as over-pumping [22], and surely cannot be neglected in future groundwater volume balances and water management actions. In a previous study at the Ostuni area [23], we showed how stopping the artificial injection of 62 L/s of reclaimed water, it was caused during 1998 a seawater intrusion of about 200 m along 3 km of the coast. This led to a water salinity increase from 2 to 6 times into the wells within 1.5 km from the coastline

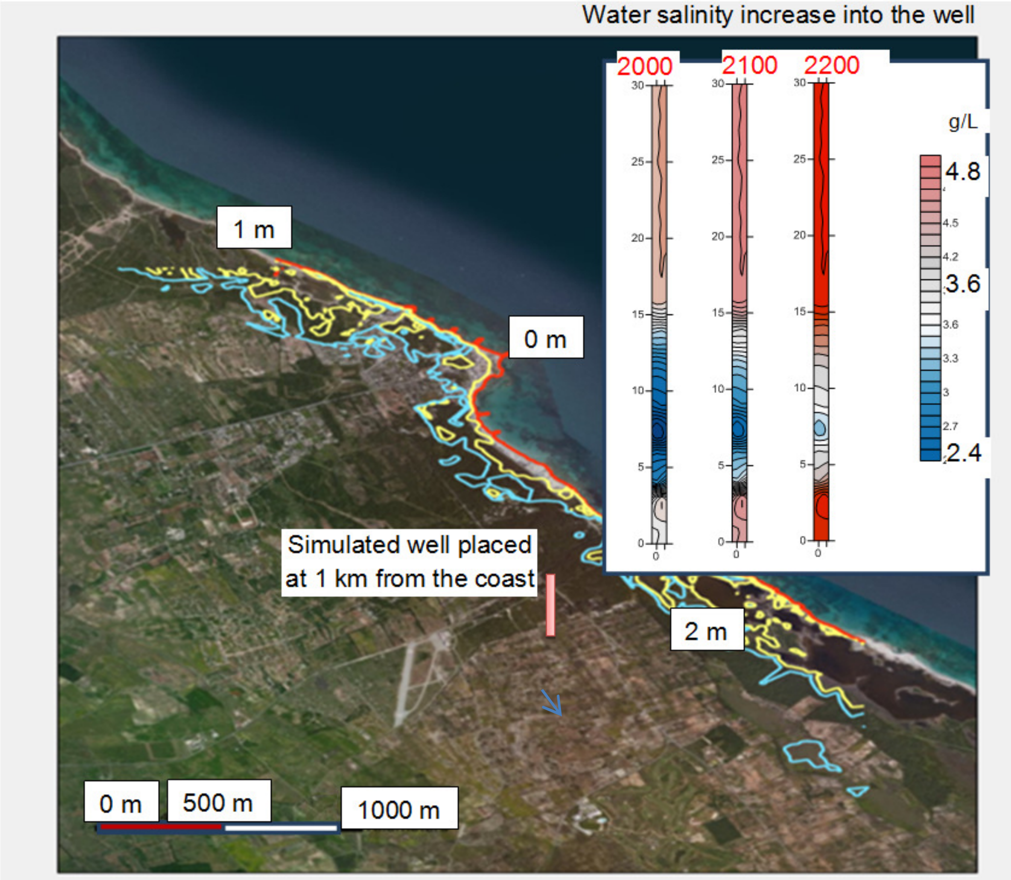


Figure 4.3.4. Sea line advancement (contour line) during the 21st (yellow) and 22nd century (blue) compared to the coastline location in 2000 (red) along Lecce's coast on the Salento peninsula (Italy), using ArcGIS and groundwater salinity progression, in a borehole placed at 1 km from the current coastline.

By defining groundwater outflow at Q_0 when sea water intrusion is absent (i.e. L_d =L), is

$$Q_0 = K \frac{B^2 - H_s^2}{2\delta_\gamma L_d} \tag{2}$$

Moreover by defining Q [L^2/t] as the groundwater discharge when the seawater intrusion is present (i.e. L_d < L), is

$$L - L_d = K \frac{B^2 - H_s^2}{2\delta_\gamma Q} - L_d > 0 \rightarrow Q = K \frac{B^2 - H_s^2}{2\delta_\gamma \left[(L - L_d) + L_d \right]} \tag{3}$$

and it can be defined the groundwater discharge reduction (per unit of the coast length)

$$\Delta Q = Q_0 - Q = Q_0 - K \frac{B^2 - H_s^2}{2\delta_\gamma \left[(L - L_d) + L_d \right]} \tag{4}$$

which is due to a sea advancement equal to L-L_d. Furthermore, in a fractured aquifer, by replacing the aquifer conductivity given by Equation (2) we obtain

$$\Delta Q = Q_0 - n \frac{b_i^2}{3} \frac{\gamma_f}{\mu_f} \frac{B^2 - H_s^2}{2\delta_\gamma \left[(L - L_d) + L_d \right]} \tag{5}$$

It should be noted that, in equation (4) or (5) when the intrusion length is zero, ΔQ must be set zero, i.e. Q=Q_0. Conversely, by increasing the intrusion length, Q will approach zero, and ΔQ will be close to Q_0.

Equation (4), for *K* (0.0037 m/s or 320 m/d), *B* (15 m), L_d (1400) and ϕ_0= 1 m, provides ΔQ= 9.89×10^{-7} m^3/s/m, for Bari groundwater in Bari along the coast, by imposing L-L_d = 157 m. Evaluating a coastline length of about 80 km, the substantial groundwater availability reduction due to the LSLR will be 2.5 Mm^3/y until 2200, i.e. 9.7% (or 79 L/s) of Murgia's current groundwater withdrawal (813 L/s) for drinking purposes (Figure 4.3.5).
The same estimation was performed along Brindisi's coast, where K= 0.0037 m/s (or 320 m/d), B=15 m, L_d =1250 m and L-L_d = 125 m, estimating a groundwater reduction of 2.5 Mm^3/y, i.e. 3.2% (or 77 L/s) of current withdrawal (2500 L/s) for drinking, measuring a coast length of 77 km. On Lecce coast, we have K= 0.008 m/s (or 691 m/d), B=15 m, L_d =2800 m and L-L_d = 480 m, and we obtained a total reduction of 9.25 Mm^3/y, i.e. 11.9% (or 293 L/s) of current withdrawal for drinking, measuring a coast length of 189 km. Along the same coast, if we consider the rate of 4.8 mm/y until 2200, L-L_d is close to 220 m and we will have a total groundwater volume reduction of 4.6 Mm^3/y, i.e. 5.9% of actual withdrawal for drinking.

Finally, along Taranto's coast (about 116 km), we have K= 0.0008 m/s (or 69 m/d), B=15 m, L_d =2500 m and L-L_d = 190 m, estimating a groundwater source reduction of 0.3 Mm^3/y, i.e. 1.2% of Murgia's current groundwater withdrawal for drinking purposes.
These estimations can be carried out with equation (5), even on a local scale, considering effective local piezometric heads along the coast and effective fracture apertures, such as those derived from well pumping tests. In this way, a more appropriate evaluation of groundwater discharge reduction due to the LSLR can be determined, also considering local coast morphology.

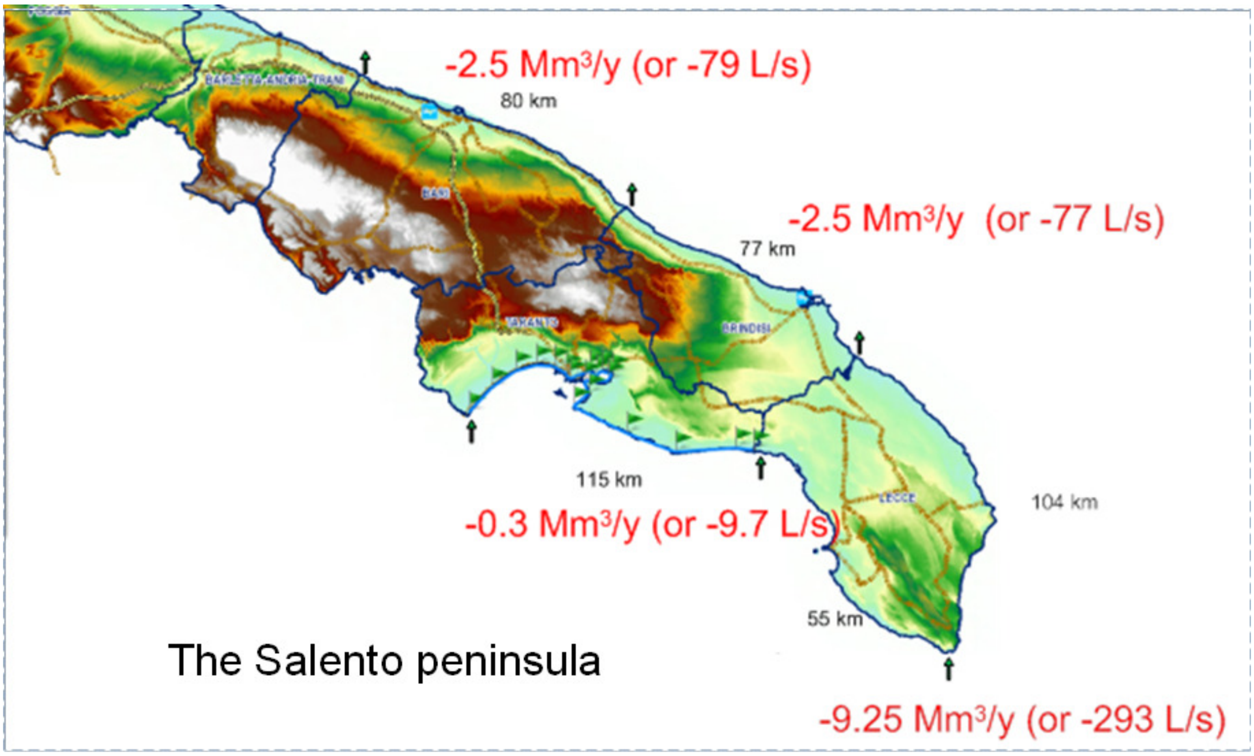


Figure 4.3.5. Groundwater discharge reduction during the 22nd century due to LSLR (over exploitations have not been included) at the test area (Southern Italy).

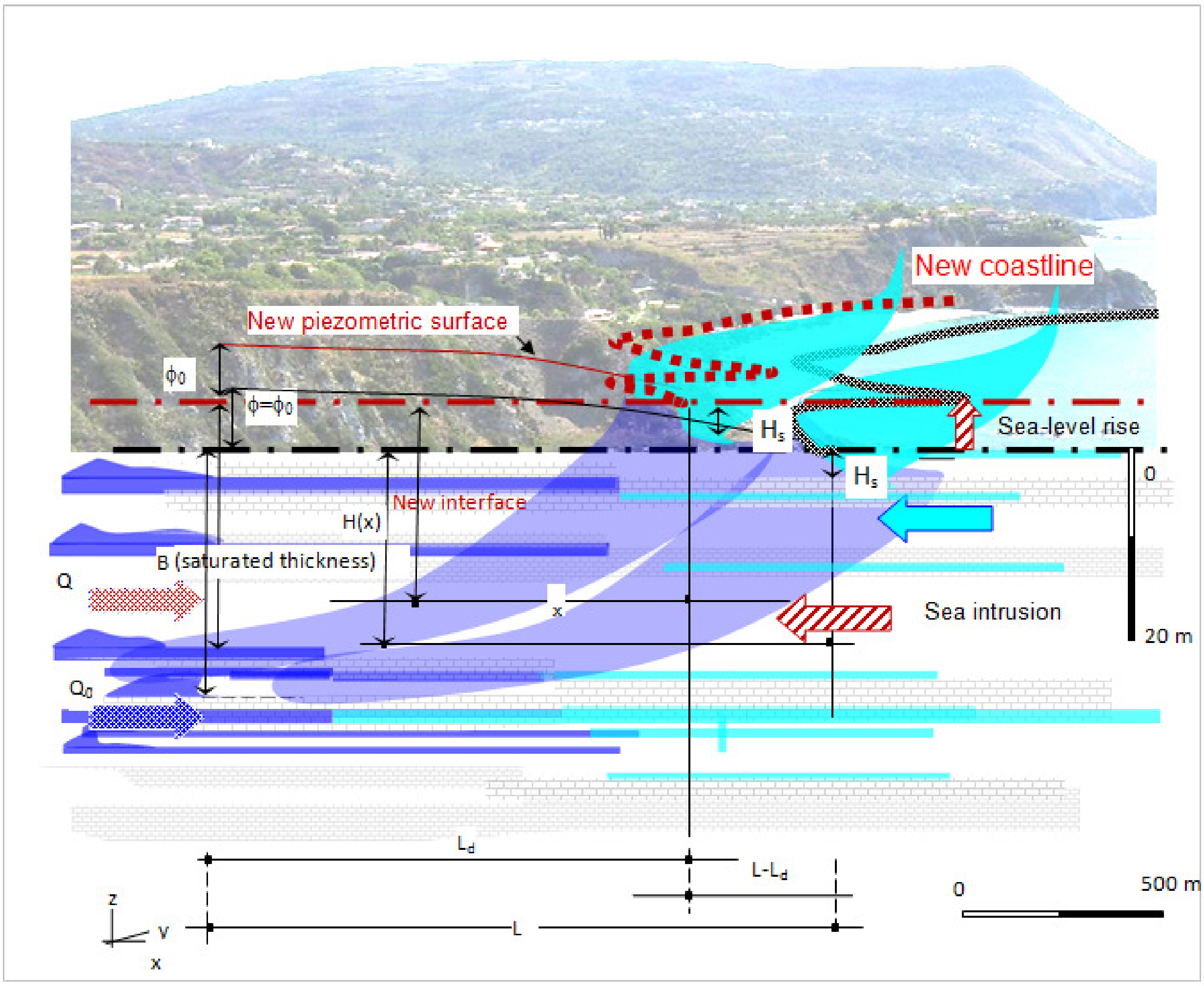


Figure 4.3.6. Sea-level rise and corresponding coastline displacement (red line) can significantly alter the freshwater/saltwater interface leading to a groundwater salinity increase in a very wide zone (shaded area).

3.2. Sea water intrusion problem: theory

Following some authors [24] the variation of groundwater discharge after a LSLR highly depend on the inland boundary conditions. Theoretical studies carried out by same authors suggests two conceptual models to study the impact of sea-level rise in coastal aquifers, i.e.: (1) flux-controlled systems, in which ground water discharge to the sea is persistent despite changes in sea level, and (2) head-controlled systems, whereby groundwater abstractions or surface features maintain the head condition in the aquifer despite sea-level changes (Figure 4.3.6). Other authors [25] suggest a third approach by relating the groundwater discharge to the head at the inland boundary of domain. In this work, as suggested by Carretero et al. [26], due to high rock hydraulic conductivity (ranging from 60 to 700 m/d), low coast elevation, general inability of the water table to migrate vertically, and low LSLR with respect to the aquifer thickness, it is likely that the conceptual model approaches a *head-controlled system*. This means that there is a distance, generally higher than 1 km from the Salento seacoast, at which the piezometric head ϕ_0 [L] and depth of seawater/freshwater interface edge B [L] will remain unchanged even when the sea-level rises of 2 m. Moreover, under the *head-controlled system* in this work, we assume that the LSLR will induce a reduction in the seaward groundwater flux, because the cross-section of outflow per unit of coast length (i.e. $H(x) \times 1$) will be reduced (see Figure 4.3.6).

At Salento, the fractured aquifer was idealized in a layered (i.e. confined) model [27; p. 272] made by several horizontal fractures bounded by impermeable rocks (see Figure 4.3.6). This idealization was confirmed by tracer (Rhodamine-Wt and Iodine) tests carried out in the same aquifer, under pumping and natural pressure gradient [7]. Each fracture is characterized by variable apertures which can be derived from the aquifer transmissivity values estimated in wells of the study area, by mean of stochastic methods [28]. In each fracture, we can define the stationary interface position by considering the hydrostatic equilibrium of freshwater/saltwater pressures, based on the Ghyben-Herzberg equation (see Figure 4.3.6). In addition, using the Dupuit assumption, we assume that inside the fractures freshwater flows in a horizontal direction [29; p. 196-206]; [30; p. 395]. In the proposed conceptual scheme all fractures were assumed to have hydraulic connections between them and to have the same mean aperture $2b_i$ [L], whereas the sharp interface approximates the 50% salt concentration contour line in the water. The analytical solution of the stationary (i.e. steady flow) interface position can be derived from integration of the Laplace (i.e., the continuity) equation in the vertical plane, where the total freshwater out flows into the sea.

The groundwater discharge per unit of seacoast length Q_0 [L^3/t/L] was derived from the flow solution of the Navier-Stokes' equations in a single fracture bounded by two parallel plates

$$Q(x) = -\frac{b_i^{\,2}}{3}\frac{\gamma_f}{\mu_f} nH(x)\frac{\partial \phi(x)}{\partial x} = const = Q_0 \tag{6}$$

where x [L] is coordinate along the fracture length towards the sea direction; γ_f/μ_f (=10^7 $m^{-1}s^{-1}$ at 20 °C) is freshwater density/viscosity ratio; $\phi(x)$ [L] is the piezometric head of freshwater in x direction; H(x) [L] is the depth of the sharp interface below the sea (i.e., freshwater thickness); and n [-] is effective aquifer porosity.

Based on the analogy of Equation (1) with the Darcy's formula we can state the hydraulic conductivity K [L/t] of the aquifer

$$K = \frac{b_i^{\,2}}{3}\frac{\gamma_f}{\mu_f} n \tag{7}$$

As known, n defines the uniform ratio of the void-space per unit volume of aquifer and at the section where is $x=0$ it will be

$$n = \frac{\sum_{i=1}^{N_f} 2b_i}{B} \tag{8}$$

where Σb_i (m) is the sum of all the horizontal apertures in the vertical aquifer column with unitary horizontal area ($1x1$ m^2) and thickness B [L], while N_f is the total number of the fractures of the parallel set. In addition, as all fractures have been assumed to have the same mean aperture $2b_m$ [L], it follows that, on average:

$$Q_0 = N_f Q_i = \frac{\sum_{i=1}^{N_f} b_i}{b_m} Q_i \tag{9}$$

where Q_i [L^3/t/L] is the flowrate of the single fracture of the parallel set per unit of coast length. Following the Ghyben-Herzberg formula, in every cross-section at distance x, for $0 \le x \le L$, where L is the distance of coastline from the Ghyben-Herzberg interface toe position (see Figure 4.3.6), we can write the freshwater piezometric head H as:

$$H(x) = \phi \frac{\gamma_f}{\gamma_s - \gamma_f} = \delta_\gamma \phi \tag{10}$$

where $\delta_\gamma = \gamma_f / (\gamma_s - \gamma_f)$ [-] (=33-35, in Mediterranean sea) and, Equation (6) can be rewritten as

$$Q_0 \times \partial x = -K \frac{H(x)}{\delta_\gamma} \partial H(x) \tag{11}$$

Equation (11) is a first order differential equation in *x* and *H*, which can easily be integrated between the sections: i) *x=0* at *H=B*, and ii) the generic vertical cross-section *x* at *H=H(x)*

$$Q_0 \times x = K \frac{(B^2 - H(x)^2)}{2\delta_\gamma} \tag{12}$$

(as it is $\partial H < 0$, for $\partial x > 0$). At the outflow section, i.e., at *x=L*, we may set $H(L)=H_s$ and

$$Q_0 \times L = K \frac{B^2 - H_s^2}{2\delta_\gamma} = n \frac{b_i^2}{3} \frac{\gamma_f}{\mu_f} \frac{(\delta_\gamma \phi_0)^2 - H_s^2}{2\delta_\gamma} \tag{13}$$

where *L* [L] is minimum extent from coastline required to avoid seawater intrusion and H_s [L] is the depth (below the sea surface) of the sharp interface at the outflow section. The reader should note that the origin (*x=0)* of *L* measurement is defined at the position where is $\phi=\phi_0$ (or *H(x) =B*) and not at coastline.

In the present work the distance from origin of the estimated position where the freshwater outflow should take place, L_d [L], is defined by groundwater flow model by means of position of ϕ_0 from the coastline. The depth H_s may be usually set equal to zero leading to the well-known equation [30; p. 395] of stationary interface toe position in confined aquifers. Really the Ghyben-Herzberg interface is an approximate theory which considers that at outflow section is *H(L)*=0. This is of course not possible and in the real situation (see Bear and Verruijt [29; p. 204]) the interface always terminates at depth H_s on the sea bottom at some distance from the coastline. Then, $\phi(L)$ =0, defines the position with respect to the coastline where the groundwater outflow takes place: i.e., 1) inland, for L_d < L (i.e., there is seawater intrusion); 2) at coastline, L_d =L (no intrusion), or 3) offshore, L_d >L, below the sea surface (i.e., there is a submarine spring). Equation (13) allows the sharp seawater/freshwater interface to be drawn in a three-dimensional domain of a fractured aquifer.

Under this conceptual framework we may assume that the extent of seawater advancement caused by LSLR can be similar to the effect caused by an over-pumping. This means that due to LSLR the distance from the new coastline of the aquifer vertical cross-section where is $\phi = \phi_0$, that is L_d (see Figure 4.3.6), is less than minimum distance L required by Equation (13) to avoid seawater intrusion. This causes the seawater intrusion extent of L-L_d due to LSLR. Moreover, by inverting Equation (13), we may also evaluate the groundwater discharge reduction per unit of coast length, ΔQ [L^3/t/L], which is due to the sea advancement of L-L_d.

3.3. Measures to improve the groundwater quality and quantity

The measure to improve the groundwater quality by contrasting seawater intrusion in coastal aquifers is the Management of Aquifer Recharge (MAR).

The principal benefits of the concept of MAR are twofold:

- It allows storage of large quantities of surface water (including surface runoff, storm water, reclaimed water, and also freshwater from desalination) at those periods of the hydrological year when availability exceeds demand and to restore them when demand exceeds availability.
- The underground passage (unsaturated and saturated zone) can constitute a complementary treatment step, due to physical, chemical and biological processes that will affect water quality.

The major challenge to meet is thus a potential conflict of the MAR system with other uses, mainly in terms of water quality (risk of degradation of chemical or biological background quality for one or more parameters due to infiltration or infiltration-induced chemical processes in the storage medium). In order to address those benefits and risks, the designer or operator of any MAR system will need to address the following key questions:
(1) How efficient is my system in terms of recovery of the recharged water?
(2) How long will the water and solutes reside in the system and be in contact with reactive minerals and biofilms?
(3) In which way will the recharge-recovery cycles affect the quality of the recovered water and the background water, on short term and long term?
These questions will be asked from the very beginning of the planning phase and over the whole lifetime of the MAR project and groundwater models provide the unique possibility to preview the feasibility of the MAR system in the regional context, to optimize the choice of the site, the configuration of an appropriate recharge-recovery system, to optimize operating conditions in a way to meet fixed quantity and quality targets. Those targets are most frequently quantified through the key parameters recovery efficiency, residence time, and recovered water quality compared to target quality. Recovery efficiency [31] as a measure of success of a MAR system, is defined either by the percentage of injected water that can be recovered or by the percentage of usable water (meeting a defined target quality, e.g. drinking or irrigation water standards) compared to the injected volume per cycle of injection.

Residence time or transfer time (in the case of Aquifer Storage, Transfer and Recovery, ASTR) will be the average duration of water and solutes in the reservoir determining the time available for water-rock interactions and bio-geochemical reactions. Residence time will largely influence the potential for degradation of pollutants and thus the efficiency of Soil Aquifer Treatment (SAT) systems and to estimate this parameter may therefore be legally compulsory. A typical example is the Californian draft regulations applying to new recharge projects [32].

They define the minimum retention time to allow identification of treatment failures and implement remediation actions and to guarantee the overall treatment efficiency. Target quality for the groundwater quality is generally defined by law and water reuse guidelines. Potential use of recovered water is also defined in these guidelines. The quality of the recovered water has to be constantly compared to this target quality and is determined by the quality of recharged water, the attenuation potential of the unsaturated and saturated aquifer and the background water, frequently but not necessarily of lower quality than the recharged water (e.g. freshwater injection into saline aquifers). The underlying processes controlling water quality are (1) mixing by advection and hydrodynamic dispersion (2) density dependent stratification (3) ambient groundwater displacement and (4) reactions within the aqueous phase induced by mixing and reactions with aquifer material and subsurface microbial communities.

Those key parameters are determined by intrinsic, physical factors (aquifer properties like permeability, effective porosity, dispersivity, preferential flow zones and the natural hydraulic gradients, aquifer mineralogy and background water quality) and by operational variables (e.g. storage period, volumes recharged, and recharge/recovery rates). The intrinsic properties are generally constant but may evolve over the lifetime of a MAR system (e.g. through clogging [33]; [34]). Intrinsic factors will depend on the selection and design of the system, operational variables on the strategy for MAR operation. Groundwater models can help for both purposes.

Currently available groundwater models allow quantifying recovery efficiency, residence time and quality of recovered water. However, a complete response to the questions listed above may need the use of state of the art models (reactive transport models) or go beyond the current capacities of the state of the art (bio-geochemical reaction modelling). Even simple models (analytical models) can provide sufficient information at least for preliminary design or evaluation of MAR systems but, most frequently, numerical models will be used. Standard numerical models will nowadays be able to simulate up to full 3D advective (e.g. through particle tracking) and dispersive flow and transport of water and solutes.

Supplementary features may be needed as, in the order of increasing complexity:
• Density driven flow (in the context of highly saline waters, like in coastal aquifers)
• Sorption and (bio-) degradation of solutes (e.g. through sorption isotherms, degradation factors)
• Variable saturation flow (in the case of a significant thickness of the unsaturated zone, in particular if the latter plays an important role for water quality improvements in SAT systems)
• Geochemical reactions through the combined use of flow-transport models and thermodynamic equilibrium models or thermo-kinetic models taking into account the reaction kinetics
• Biologically mediated geochemical reactions (specific models available)
• Aquifer ecosystem simulation accounting for changing microbial communities and their assimilation of nutrients, competencies for metabolism of organic contaminants, enzymatic attack on pathogens and their influences directly and through microbial products (such as polysaccharides) on aquifer porosity and hydraulic conductivity.

The IRSA outlines the use of groundwater models suitable for MAR focusing on the strategic phases of a MAR system (site selection, MAR design, MAR operation), on the data needs to build and run such models.

Applications of models within the OSTUNI pilot area of DRINK ADRIA will be carried out in the Work Package 6.

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Present and future water safety and risk for drinking supply at Ostuni test area –April 2015.

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Climate change and land use change impact on water quality – Slovenian test aera

Faculty of Natural Sciences and Engineering
University of Ljubljana
(FB5)

Ljubljana, 2015

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Date last release	7.8.2015
State of document	FINAL

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1 Introduction

This report presents general estimation of climate change and land use change and its possible impact on water quality on test areas of Slovenian project partner (FB5) within the DRINKADRIA project. Slovenia test area is located in NW Slovenia and cover three potential aquifers; Kobariški Stol, Mia and Matajur aquifer (Figure 1). The source of data for this estimation is the national monitoring of meteorological data and Corine Land Cover (CLC) data for land use on this area.

Figure 1: Slovenian test area: Kobariški Stol, Mia and Matajur aquifer

2 Climate and climate change

The climate in Slovenia is highly variable in small area as a consequence of numerous factors such as geographic location, relief diversity, orientation of mountain ridges and proximity to the sea. There are three main types of climate occur from east to west: the east Slovenia has a temperate continental climate, central Slovenia subalpine or alpine climate, and the west Slovenia sub-Mediterranean climate. The Slovenian test area presents Kobariški stol, Mia and Matajur aquifers, which are positioned in NW Slovenia.

This area has influences of sub-mediterranean climate from SW Slovenia and alpine climate of NW Slovenia.

Detailed descriptions of climate and climate change on national as well as local level (test area) were described in two reports that were prepared within DRINKADRIA project (Žvab Rožič & Čenčur Curk, 2014; Zupančič et al., 2014). According national monitoring data from two main meteorological stations (Bilje and Portorož) and three local stations (Kobarid, Livek and Žaga) there were no significant changes noted in temperature and precipitation that could have a significant impact on land use.

3 Land use (CLC)

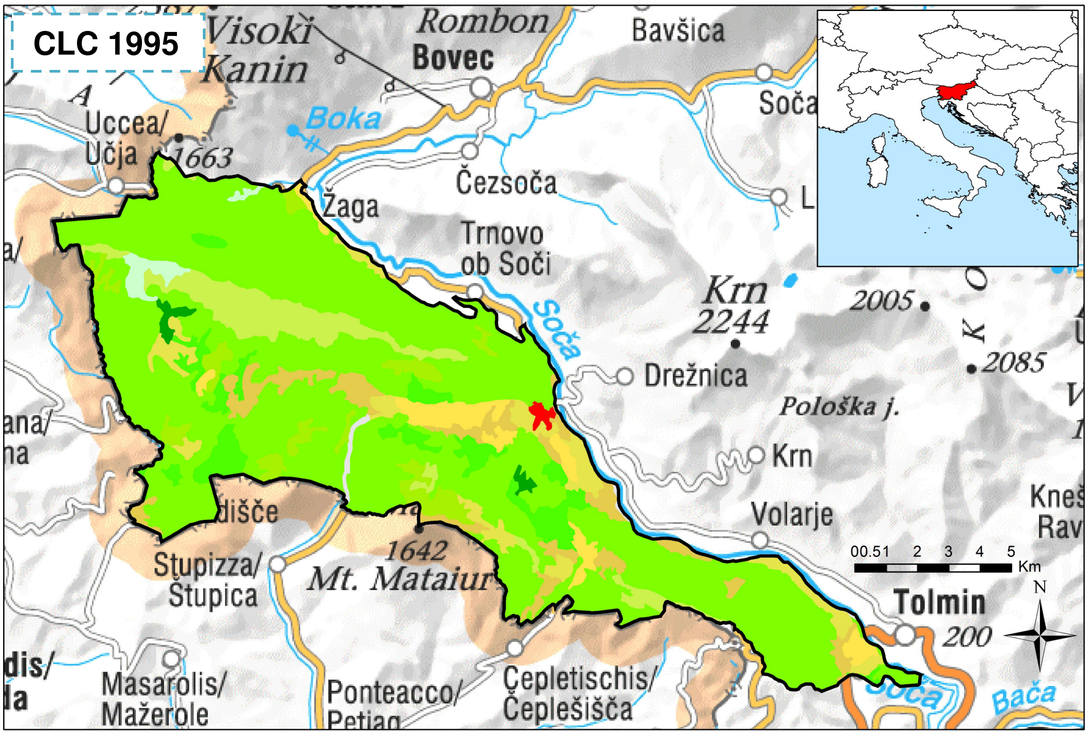
The sources of land use data are free available CLC databases that (http://www.eea.europa.eu/, http://www.arso.gov.si/en). Four CLC situations (Figure 2) in different years (1995, 2000, 2006, 2012) and changes in land use from 1995 to 2012 are presented and described in this report.

The land use in the test area presents mostly forests and grassland (light and dark green). According CLC these areas belong to category "*Forest and semi natural areas*" (85.17 to 85.29%). The possible anthropogenic impact present category "*Agricultural areas*" (14.45 to 14.56%) covers the land principally occupied by agriculture with significant areas of natural vegetation, pastures and other complex cultivation patterns. Generally test area covers less populated foothill area, where "*Artificial surfaces*" (aver. 0.26% of test area) occur only as isolated settlements, such as Kobarid at the eastern part of the map.
Distribution of CLC categories in year 2012 for test area is presented on Figure 3. While the percentage of the potential impact of land use on water quality is very low, serious problems with water pollution on the test area are not expected. There may be only slightly elevated levels of nitrogen compounds and microbes, as a result of cattle grazing.

Comparison between land use maps shows that in the last 20 years no significant changes in land use occur (Table 1). Minor changes are visible only within separate land cover group, such as different kinds of grassland or forest. Regarding this data and the information about spatial plans changes in this area, also in the future significant changes in land use are not expected.

Table 1: Percentage of land cover categories for test area for different CLC 1995, 2000, 2006 and 2012

CLC category	*CLC 1995*	*CLC 2000*	*CLC 2006*	*CLC 2012*
Artificial surfaces	0.26%	0.26%	0.26%	0.28%
Agricultural areas	14.45%	14.51%	14.51%	14.56%
Forest and semi-natural areas	85.29%	85.23%	85.23%	85.17%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Učja
1663
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Čezsoča
Žaga
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ob Soči
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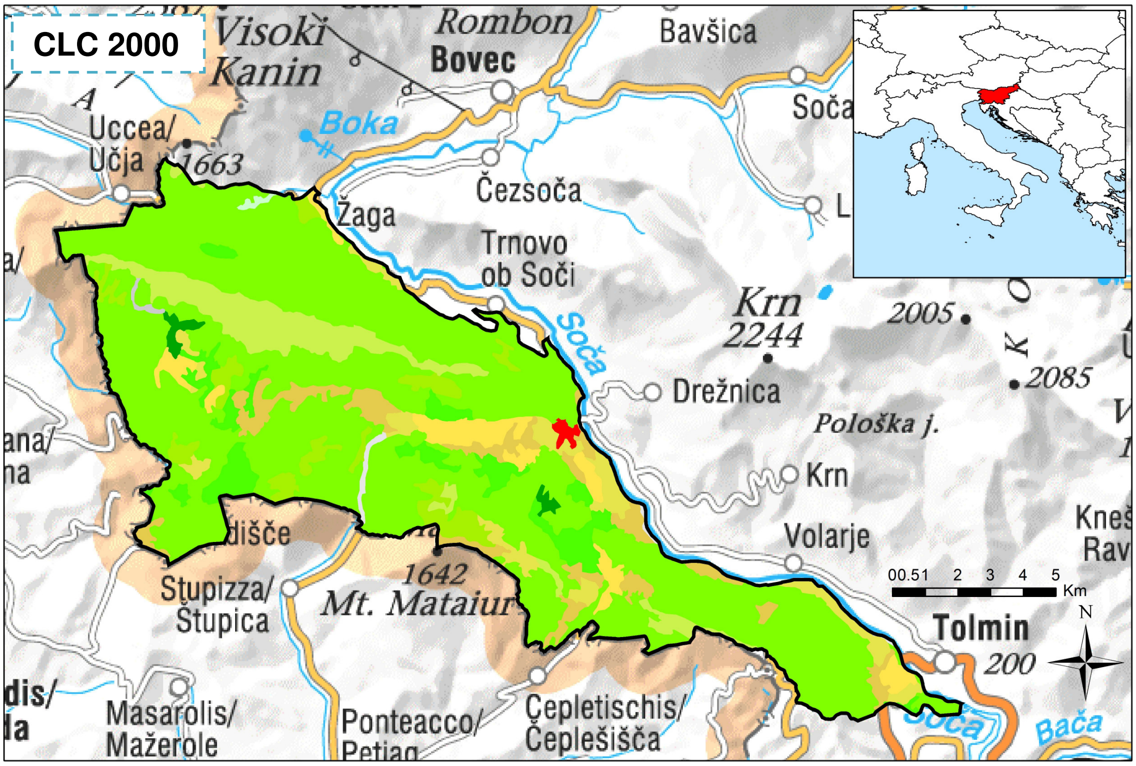
CLC 2000
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Drežnica
Pološka j.
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Stupizza/
Stupica
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Mt. Mataiur
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DRINK ADRIA


CLC 2006
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CLC 2012
Visoki Kanin
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Bovec
Bavšica
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Legend

CLC

CODE

- Discontinuous urban fabric
- Pastures
- Complex cultivation patterns
- Land principally occupied by agriculture, with significant areas of natural vegetation
- Broad-leaved forest
- Coniferous forest
- Mixed forest
- Natural grasslands
- Transitional woodland-shrub
- Beaches, dunes, sands
- Bare rocks
- Sparsely vegetated areas
- Burnt areas

Figure 1: Maps with land use and legend of categories within the test area (CLC 1995, 2000, 2006 and 2012)

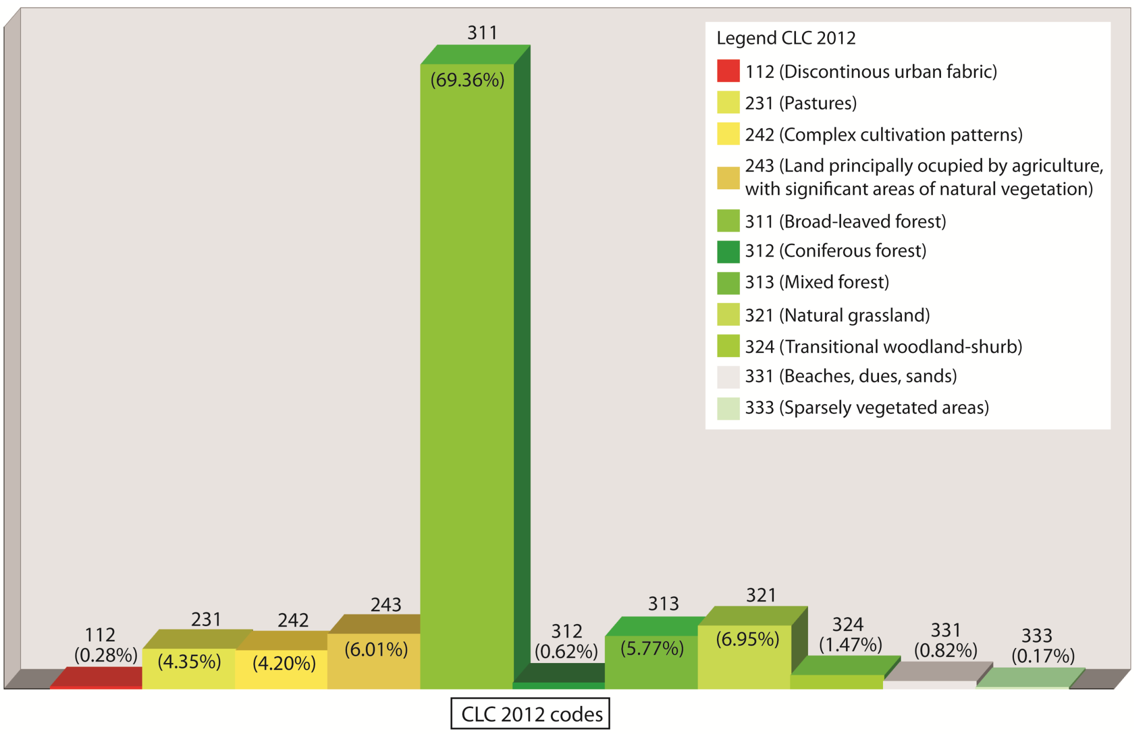

Figure 2: Percentage of CLC categories in the test area (CLC 2012)

4 Measures

Regarding analyses of climate and climate change on national and local level (Žvab Rožič & Čenčur Curk, 2014; Zupančič et al., 2014) no significant changes are noted in temperature and precipitation that could have a significant impact on land use. Comparisons between land use in the last 20 years show no significant changes in land use. Besides, surface and groundwater quality in test area (Žvab Rožič et al., 2014b) show good quality status of water. According to these facts and the results obtained, it can be said that measures to improve the quality of potential resources of drinking water in the area of Kobariški stol, Mia and Matajur are not necessary.

5 Conclusions

In the report [5] about surface and groundwater quality in test area (Kobariški stol, Mia and Matajur aquifers) good quality status of water was described. Analyses of climate and climate changes and land use changes in the last decades show no significant changes as well as trends for the future are not observed. Therefore, we can conclude that the climate changes and potential changes in land use within the test area will not affect the water quality of potential cross-border aquifers.

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Climate change and land use change impact on water quality – Slovenian test area - Ljubljana, August 2015

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Impact of land use changes on water quality on test areas in Northern Istria (springs: Gradole, Bulaž and Sv. Ivan)

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Date last release	18/05/2015
State of document	FINAL

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1. INTRODUCTION

Present, past and future land use changes analyses on test areas in Northern Istria (springs Sv. Ivan, Bulaž and Gradole) and the impact on water quality is given in this report.
The impact of land use changes on water quality is shown according to the **DPSIR** methodology [1].
Using Corine Land Cover (CLC) and other relevant data, *pressures* such as BOD_5 and nutrients; nitrogen and phosphorous are calculated here. The pressures are then linked with water quality on test areas, which represents the *state* of the system.
Water quality on test area is presented in the report "Water quality analysis and trends on test areas in Nothern Istria - Croatia" [2]. Then the *impacts* which impact the given *state* are determined, and in the end the *responses* are given, i.e. measures to be taken to improve the *state* of the system i.e. drinking water sources, if necessary.

2. DESCRIPTION OF TEST AREAS

2.1. Spring Sv. Ivan

Spring Sv.Ivan (Figure 1) is located in the bottom of the river Mirna Valley, about 1 km southeast of Buzet, and about 200 m from the Mirna riverbed, at an altitude of 47 m.a.s.l. Water from carbonate base goes through flysch deposits towards the surface. Spring abundance ranges from 200 l/s to 2.000 l/s, while extreme minimum is about 90 l/s. The main recharge area of spring Sv.Ivan is the west part of Ćićarija which is relatively richer in precipitation then the rest of Istria. Inflow area of the spring was recently determined for the first time (in the 1990s), as a part of efforts to determine the water protection areas of the spring. On that occasion, as criteria for determining the inflow area, data on certainly established relationships between swallow-holes and springs by tracing are taken into account, and also the hydrogeological characteristics of the rocks and structural relationships, and hydrological analysis (within them especially the correlation between the amount of water outflow and precipitation amount) [3]. This area is about 70 km^2 (karst area 46 km^2, flysch 24 km^2) [4].

Figure 1: Spring Sv. Ivan [4]

2.2. Spring Bulaž

Spring Bulaž (Figure 2) is located at the beginning of the wide valley of Mirna middle flow near thermal water source Istarske toplice. It is a typical upward type karst spring which occurs on the valley edge, on the contact of Cretaceous limestones and quaternary formations. It has the form of a lake on the surface, with diameter of about 50 m. According to the conducted bathymetric recordings, the maximum spring depth is about 25 m and considering the overflow altitude is about 17 m.a.s.l, it means that its bottom is below sea level. Although its abundance is very variable, the spring never dries out. High spring abundances occur as a result of intense precipitation and they characterize fast draining. In dry period the impact of precipitation is poorly expressed. Mean annual abundances are somewhat larger than 2 m^3/s, while minimum recorded abundance is 42 l/s and maximum about 38 m^3/s [4]. Catchment area of spring Bulaž is made of carbonate rocks - mainly limestones, flysch - marl and sandstone. Determination and interpretation of the catchment is also based on the data outside the catchment area. Catchment boundaries are determined according to the hydrogeological parameters and the control is also performed using hydrological values by analysis of spring abundance as a function of the catchment area, precipitation height and evaporation [5]. The size of spring inflow area is about 105 km^2 (karst area about 43 km^2, flysch 62 km^2). On the areas within the flysch terrain which belong to the basins of certain watercourses it is possible to make accumulations to slow down the runoff [4].

Figure 2: Spring Bulaž [4]

2.3. Spring Gradole

Spring Gradole (Figure 3) is located on the left bank of river Mirna valley, about 9,5 km upstream of its confluence. The spring emerges from the karst cavern below limestone rock of Cretaceous age. In the natural state the spring had the form of an oval lake 8x16 m. The water emerged from a cavern on the bottom. Today the intake is located inside the building with overflow at an altitude of 8 m n.m. The spring was included in water supply in 1969, using temporary pumping aggregate. In 1973 the entire water supply system was completed. Maximum spring abundance is 10.000 l/s (in winter and spring) and minimum abundance is 1.000 l/s, while extreme minimum is below 400 l/s [4]. Determination of the area and boundaries of spring Gradole catchment was conducted in the 90s, and it was based on the geological data, tectonics, morphology, photo geological interpretation of the terrain, hydrogeological characteristics of the rocks, karst morphological features and on the groundwater tracing data. Using the above factors the hydrogeological catchment is defined, whose area is about 104 km^2 (carbonate rocks about 85 km^2, flysh deposits about 19 km^2) [4,6]. Control of the catchment area is made using the existing hydrological values and thus the resulting spring catchment area is about 113 km^2 [4].

Figure 3: Spring Gradole [4]

3. DPSIR METHODOLOGY

The European Environmental Agency (EEA) assesses the State (**S**) of the environment using the **DPSIR** methodology. Namely, the State (**S**) is the result of specific Drivers (**D**) and Pressures (**P**), positive or negative, which Impact (**I**) the environment. The Responses (**R**) represent the solutions (e.g. policies, investments) that should then be done to improve or maintain that state. The EEA report also looks at Outlooks (**O**) for the state of the environment-namely, what will happen to that state over time based on various scenarios [1].

The DPSIR framework is in some way a conceptual model (see Figure 4) representing direct interactions through a loop in the way that human being interacts with the environment [1].

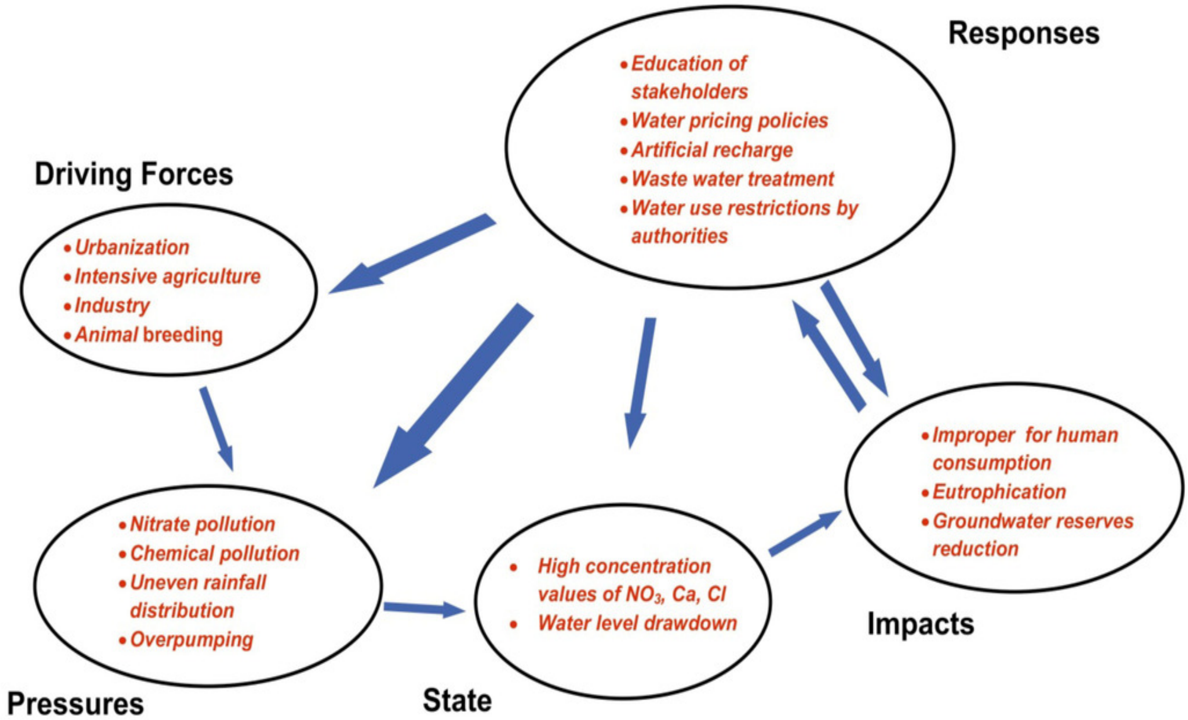

Figure 4: DPSIR methodology [1]

4. ANALYSIS OF THE ACTUAL LAND USE ON TEST AREAS

In this chapter analysis of present/actual land use presented as CLC on test areas in Northern Istria (springs Sv.Ivan, Bulaž and Gradole) is shown.
Corine land cover (CLC) which here presents land use is a digital database on types of land cover/use [7]. On *Figure 5* CLC in year 2012 (given as present state) for test areas Sv. Ivan, Bulaž and Gradole in Northern Istria is presented. Description of each color/class of CLC is given in *Appendix 1*. Distribution of CLC in year 2012 for the test area is given on *Figure 6*. It can be seen on the *Figure 6* that on the area of spring Sv.Ivan broad leaved forest covers about 53 % of the area. On spring Bulaž area 36 % is covered by broad leaved forest and 22 % by land principally occupied by agriculture. On spring Gradole area 36 % is covered by land principally occupied by agriculture, and 26 % by broad leaved forest. It can be seen that most of the test area is covered by broad leaved forest and land principally occupied by agriculture.

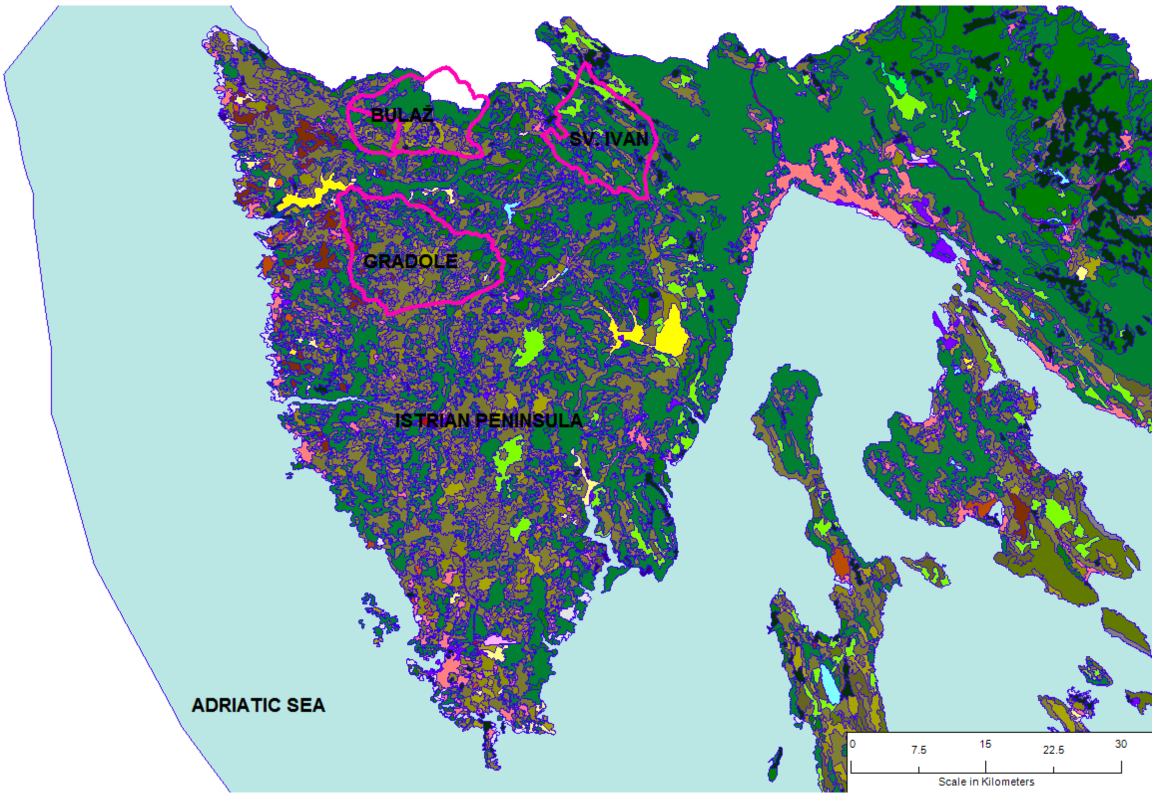

Figure 5: Corine land cover for year 2012 (Istria) with marked dominant watershed areas for springs Sv.Ivan, Bulaž and Gradole, [7]

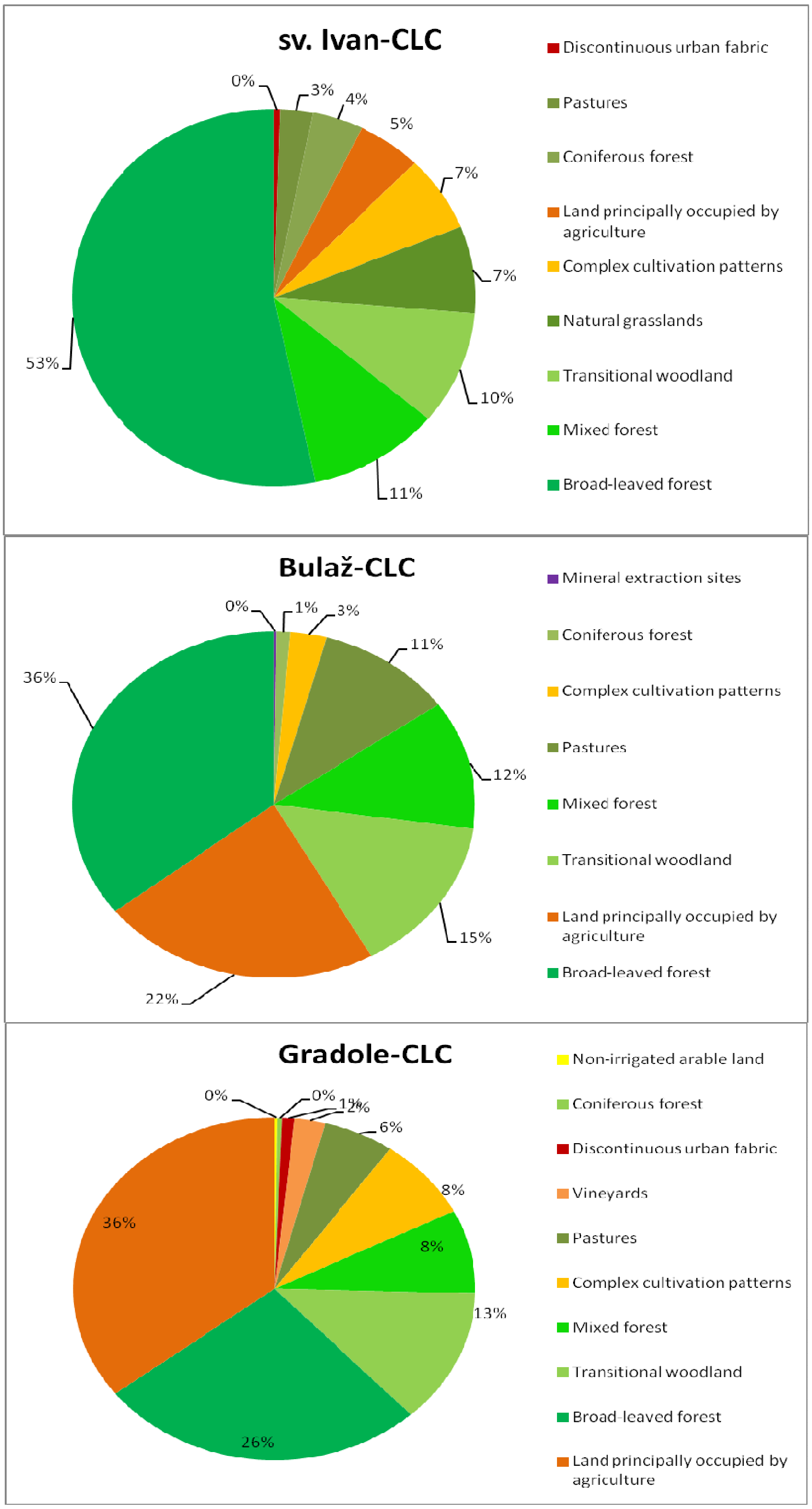

Figure 6: CLC in % for springs Sv.Ivan, Bulaž and Gradole in 2012.

5. IMPACT OF LAND USE ON WATER QUALITY – PRESENT/PAST STATE

In this chapter is given analysis of past land use and their changes presented as CLC on test areas in Northern Istria (springs Sv.Ivan, Bulaž and Gradole). Also, the impact of present and past land use changes on water quality is given.

5.1. Land use changes on test areas

For the analysis of land use changes in the past CLC 2000 (*Figure 7*), CLC 2006 (*Figure 8*) and CLC 2012 (*Figure 5*) were used. Changes in land use using CLC are shown for periods between the years 2000-2006 (Figure 9) and 2006-2012 (Figure 10), [7]. On Figure 9 for changes between 2000-2006 it can be seen that on the area of spring Bulaž (mark 1) the cover was changed from transitional woodland-shrub (324) into broad leaved forest (311), area of about 38 ha. On the area of spring Gradole two changes were occurred; broad leaved forest (311) into complex cultivation patterns (242, mark 2) area of about 5.5 ha, and pastures (231) into complex cultivation patterns (242, mark 3) area of about 21.4 ha. On the area of spring Sv.Ivan there haven't been any changes in land use.
On Figure 10, which shows changes in period 2006-2012, it can be seen that on the area of spring Sv.Ivan the land cover changed from pastures (231) into transitional woodland shrub (324, mark 1) area of about 63.4 ha. On the area of spring Gradole there was a change from broad leaved forest (311) into vineyards (221), and land principally occupied by agriculture (243) into vineyards (221, mark 2) with total area of about 19.6 ha. On the area of spring Bulaž there haven't been any changes.
It can be concluded that in the period 2000-2012 there were no significant changes of land use on the test area.

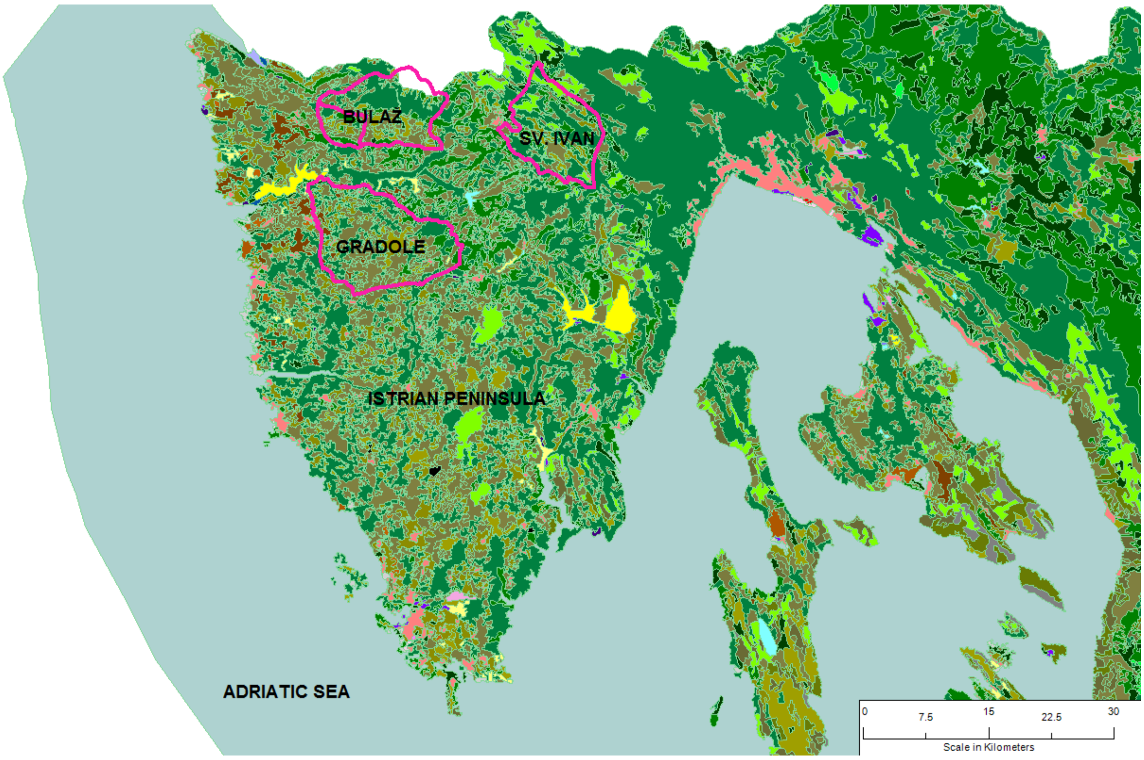

Figure 7: Corine land cover for year 2000 (Istria) with marked dominant watershed areas for springs Sv.Ivan, Bulaž and Gradole, [7]

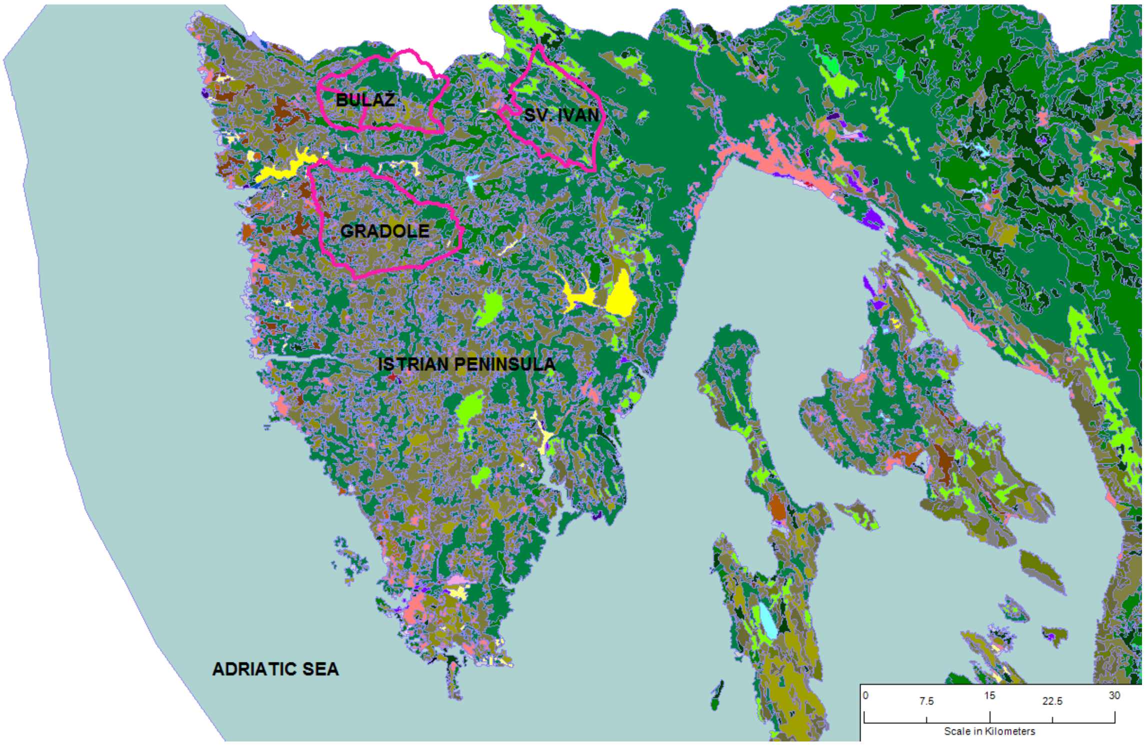

Figure 8: Corine land cover for year 2006 (Istria) with marked dominant watershed areas for springs Sv.Ivan, Bulaž and Gradole, [7]

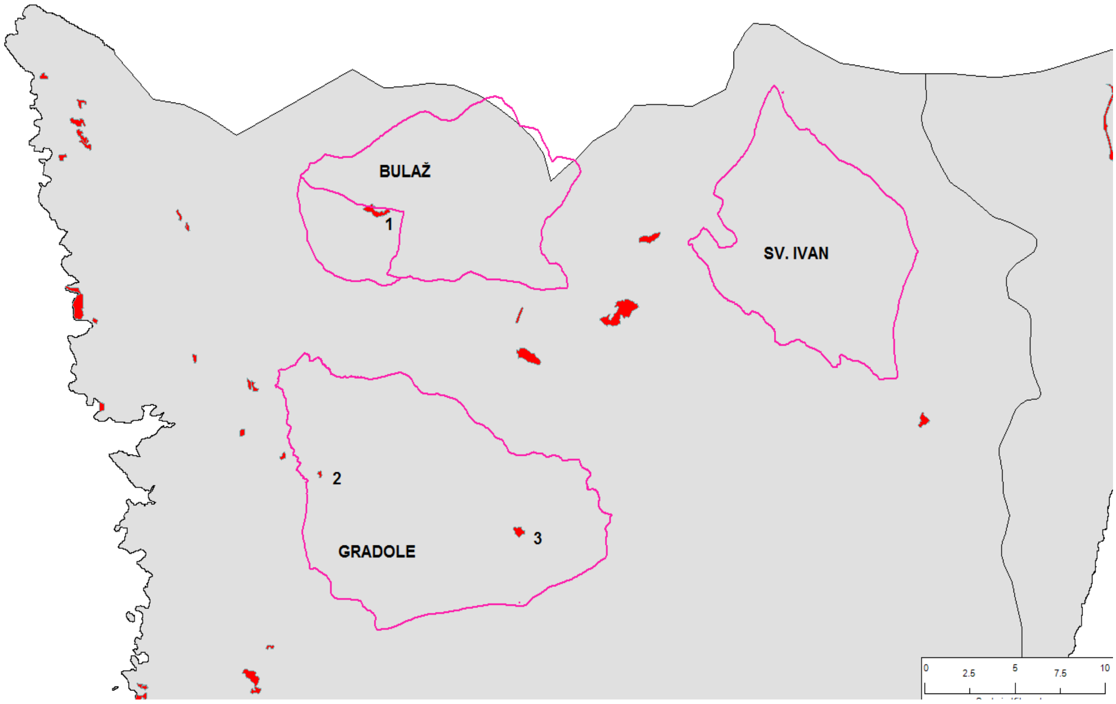

Figure 9: CLC changes in period 2000-2006 for Sv.Ivan, Bulaž and Gradole [7]
Note: State borders are not representative.

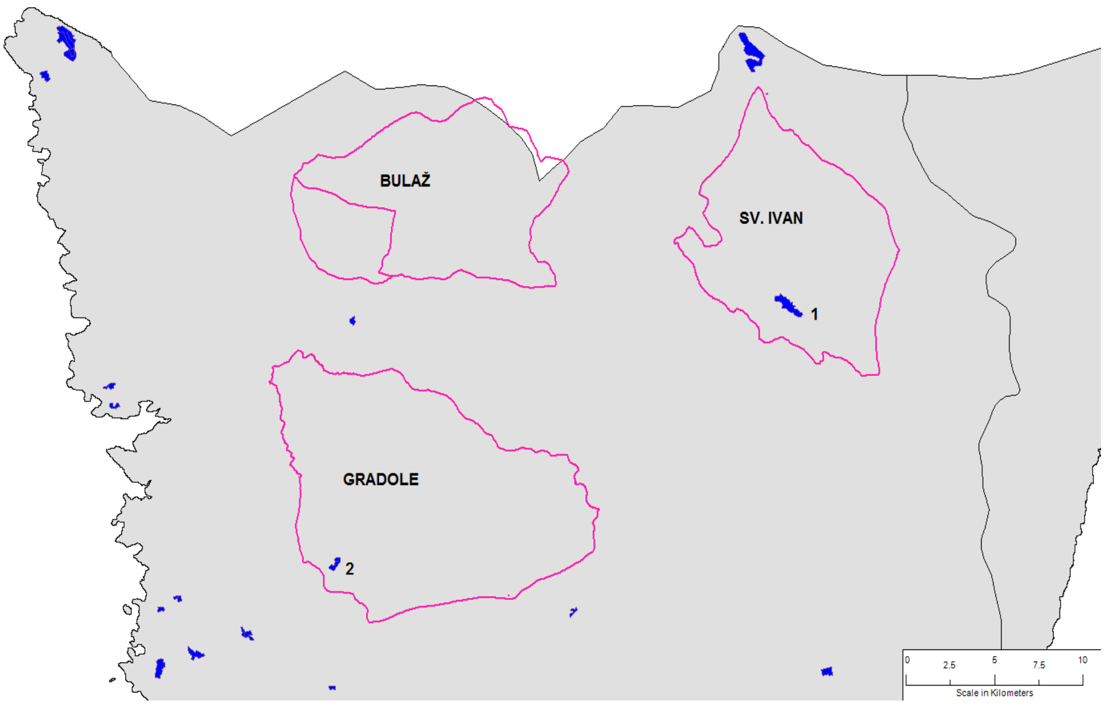

Figure 10: CLC changes in period 2006-2012 for Sv.Ivan, Bulaž and Gradole [7]
Note: State borders are not representative.

5.2. Estimation of pollutant loads in test areas for year 2012

Results of pollutant loads in the watersheds are obtained using simple pollutant load model - STEPL [11]. Results of model are presented in Table 1 and 2 for each land use category (urban land, agricultural land, pastures, forests, natural grasslands, septic systems or direct discharge of wastewater in underground and wastewater treatment plants - WWTP).

Larger watershed areas usually have greater pollution load. But, this does not mean that smaller watershed areas cannot produce more pollution load of the larger watersheds. In fact, smaller watersheds can have a bigger population, more developed agricultural production and more intensive livestock farming. For this reason it is important to determine the specific loads or loads per km^2 of watershed area.

In the case of drinking water sources Sv. Ivan, Bulaž and Gradole greater watershed area also means greater pollution load, so the greatest pollution load is obtained from Gradole watershed, then from Bulaž and finally from Sv. Ivan. After dividing the total pollution load with watershed area specific pollution loads were obtained. Obtained results for specific loads also give the largest pollution load per km^2 of watershed area for Gradole watershed (according to all indicators of pollution), then for Bulaž and finally, the smallest load for Sv. Ivan. Total and specific loads by watershed are given in Table 1.

Table 1: Total and specific loads by watershed

Watershed	Sv. Ivan	Bulaž	Gradole
Area [km^2]	103,00	108,22	163,38
Total Load by Watershed [t/yr]			
BOD_5 Load	40,48	55,01	200,34
N Load	11,41	18,85	57,08
P Load	3,39	6,18	16,98
Sediment Load	4126,99	9021,62	20619,61
Specific Load by Watershed [t/km^2/yr]			
BOD_5 Load	0,39	0,51	1,23
N Load	0,11	0,17	0,35
P Load	0,03	0,06	0,10
Sediment Load	40,07	83,36	126,21

Results for different categories of pollution sources (population, agriculture and livestock farming) are shown in Table 2. Urban land and forests are not taken into account, so these categories are not shown in the table. The first part of the table shows the load that is produced by population (i.e. septic systems or direct discharge of wastewater in the underground and the pollution load generated at the WWTPs, if they exist), and the second part shows the results for pollution load from agriculture and livestock farming (agricultural land, pastures and natural grasslands). Agriculture and livestock farming are presented as one category because STEPL does not calculate separately loads from livestock; the load is equally distributed to areas with livestock farming.

Table 2: Total load from population, agriculture and livestock farming by watersheds

Watershed	Sv. Ivan	Bulaž	Gradole
Total Load from Population [t/yr]			
BOD_5 Load	27,60	26,97	136,44
N Load	5,02	4,90	25,15
P Load	1,00	0,98	5,07
Total Load from Agriculture and Livestock Farming [t/yr]			
BOD_5 Load	12,38	27,67	63,23
N Load	6,18	13,78	31,68
P Load	2,31	5,14	11,83
Sediment Load	4034,09	8941,81	20534,03

Also, it is important to point out that phosphorus largely depends on erosion by flood events, while nitrogen directly on the discharged water volume due to its higher solubility.

5.3. Water quality on test areas

Conclusions from the report on water quality on test areas (Water quality analysis and trends on test area in Northern Istria - Croatia, 2013; [12]) are presented below.
All springs are well saturated with oxygen, owing to the well-developed underground relief. The content of the substance that can be oxidized and decomposed by microorganisms (expressed as a five-day biochemical oxygen demand-BOD_5) or by using a strong oxidant (expressed as a chemical oxygen demand-COD permanganante index), is very low.
Nutrient content is shown through the content of nitrates and total phosphorus. For all springs maximum values of these indicators have decreasing trend. The values of total nitrogen are several times below the MAC (Maximum Allowable Concentration) for drinking water (for nitrate content is 50 mg/l (NO_3^-) or 11.3 mgN/l). The largest contribution to the total nitrogen is from inorganic content of nitrogen due to the nitrate content. Generally the content of the inorganic nitrogen is almost all composed of the nitrates, which means that the content of ammonium and nitrite, as indicators of present fresh contamination is very low and very rarely appears in detectable concentrations. Nitrate content on springs that drain water from Ćićarija Mountain and the northern part of Istrian peninsula (Sv. Ivan and Bulaž) is low. Due to the more developed agricultural activities in the catchment of spring Gradole which drains water from the interior of Istrian peninsula content of nitrate is higher. But on all springs in last years we have a decreasing trend, although up to year 2007 we have increasing trend for total N and nitrates. All values are bellow MAC for drinking water. For all springs phosphates and total phosphorus are very low. Phosphorus content on all test areas is generally below the MAC for drinking water for dissolved phosphates.
Microbiological contamination is present on all springs which is associated to the hydrological conditions in the watersheds. High values are associated with the occurrence of torrential waters and increased amounts of silt which is entering in the aquifers. Due to

turbulent flow of water, move of the internal sediment occurs and then results with the appearance of turbidity.
Higher concentrations of total number of microorganisms and microorganisms of fecal origin were observed also on all springs (at least occasionally). The source of these organisms can be wild animals or livestock which moves in the watershed areas of springs, but mostly the main sources are untreated urban waste waters from settlements in the observed watersheds.
Due to occurrence of extreme turbidity increased concentrations, above the MAC for drinking water, of iron and manganese occur.
From observed mean annual values of BOD_5, COD, total suspended solids, nitrates, total phosphorus, iron and manganese it can be concluded that: on spring Sv. Ivan all tested parameters have declining trend only TSS have slightly increasing trend, on the spring Bulaž there are slightly increasing values of BOD_5 and TSS, and at spring Gradole increasing trend is only for TSS. However, the content of TSS depends primarily on hydrological conditions in the basin, on the amount and intensity of rainfall, so this should not be considered as an indicator of pollution.
From the analysis of the water quality for springs Sv. Ivan, Bulaž and Gradole can be concluded that the values of nearly all indicators are decreasing, respectively as the quality of the water on springs improves.

5.4. Impact of present land use on water quality in test areas

From the report "Water quality analysis and trends on test areas in Nothern Istria – Croatia" [12] in Table 3 are presented mean annual concentration of nutrients, average annual flow and the average nutrient load for the springs of Sv. Ivan, Bulaž and Gradole in 2012. In the absence of detailed information regarding water quality and hydrological conditions, average nutrient loads were calculated as a multiple of mean annual concentrations of nutrients and average annual flows. As such they are not relevant, but they could be taken for comparison with the estimated pollutant loads.
Comparing the values in Table 3 with estimated values (Table 1) it can be observed that the values in Table 3 for total nitrogen are almost twice higher than those estimated with STEPL. The values for total phosphorus are however much less. Therefore for further analysis estimated values with STEPL will be used because this is a standard approach in estimation of pollution load in watersheds when there is insufficient measured data.

Table 3: Mean annual concentration of nutrients, average annual flow and average nutrient loads on springs Sv. Ivan, Bulaž i Gradole in 2012.

Indicator / Spring	Sv. Ivan	Bulaž	Gradole
Total N (mgN/l)	1,071	1,3706	3,5823
Total P (mgP/l)	0,0278	0,0329	0,0218
$Q_{ave.yr}$ (m^3/s)	0,684	0,986*	0,866
Total N (t/god)	23,1	42,63	97,86
Total P (t/god)	0,6	1,02	0,6

Note: some data are missing

From Table 1, pollution load at the spring Sv. Ivan is ranging from 11,41 t/year for total nitrogen and 3.39 t/year for total phosphorus, for Bulaž the values are 18.85 t/year and 6.18 t/year and for Gradole 57.08 t/year and 16.98 t/year, respectively. Specific load at spring Sv. Ivan is 0.11 t/km^2/year for total nitrogen and for total phosphorus 0.03 t/km^2/year. Spring Bulaž has 0.17 t/km^2/year for total nitrogen and 0.06 t/km^2/year for total phosphorus while spring Gradole has 0.35 t/km^2/year and 0.10 t/km^2/year, respectively. According to this data spring Gradole has the biggest nutrient load. The same results are written in report “Water quality analysis and trends on the test areas in Nothern Istria - Croatia“ [12] and in “Report on water quality on springs in the Istria County for 2012“ [2].
In these reports measured concentrations are bellow the MAC and that for now don’t have a negative impact on water resources.

5.5. Impact of land use changes in the past on water quality on test areas

Summarizing all the reports on water quality on springs in the Istria County (see also “Water quality analysis and trends on the test area in Nothern Istria – Croatia”) [12, 2] it can be concluded that the concentrations of total nitrogen and total phosphorus had an increasing trend to year 2007, while after 2007 the trend is decreasing.
In Section 4.2, can be seen that in the period 2000-2012 there were no significant changes in land use, and that this changes did not have a significant impact on the nutrient trends. Most likely the decreasing trend of nutrients after 2007 is related to more rational usage of fertilisers in agriculture which have become more expensive. Also farmers are more educated in application of fertilisers so they can be better incorporated into the plant biomass and not needlessly washout into groundwater.

6. THE IMPACT OF CLIMATE CHANGE AND PLANNED DEVELOPMENT ON THE LAND USE IN THE FUTURE

Future land use changes induced by climate change on analyzed test areas currently cannot be exactly defined due to lack of data. In the report “Analysis of simulated climate for the Mirna River and Prud wellspring catchments” [8] it can be concluded that on the Mirna area (station Pazin) temperature and precipitation have an increasing trend. This trend for mean annual air temperature, for the station located in central Istria in the period 1951-2050, for all the three models (see [8]) is from 0.17 °C/10yr for model RegCM to 0.31 °C/10yr for model Promes [8]. For the annual precipitation amount in the period 1951-2050 all three bias-corrected models simulate increasing trend. However, in all the models, these trends are not statistically significant. For the period 1961-2012, when DHMZ observations at the Pazin station show statistically significant decreasing trend in annual precipitation amount, only RegCM3 simulates the same sign of the trend as observed, but with greatly reduced amplitude and no statistical significance. Even for seasonal precipitation, trends are rarely statistically significant and are model dependent in terms of both the amplitude and sign. This implies that, according to the CC-WaterS [9] bias corrected RCMcorr simulations presented in Report [8], no robust estimates of significant precipitation change could be made for the first part of the 21st century.

Future land use is shown in the Spatial Plan of the Istria County (see Appendix 2, [10]), where part of the area is intended for agriculture and development of settlements, and other part belongs to forest, protected and unprotected areas. From Appendix 3 [10] it can be seen that quite a large part within the spring’s catchments belongs to protected areas, or protected areas by some other protection criteria, so it can be concluded that in the future no significant changes of land use on the test areas will happen.

If possible climate changes are observed, not only in spatial domain of test areas but on the wider area of the Istrian peninsula another important impact can be expected; increased salinization of groundwater in coastal karst aquifers. The reason for this is the increasing number of boreholes for water abstraction which are used for irrigation, and increasing demand for the development of irrigation systems. Because of that, it is expected that use of agricultural land will increase, and with this also pressures on groundwater resources. According to the Plan for irrigation of Istria County-Revisions [15] for the period until 2040 it is planned intensive development of irrigation on the whole area of the Istrian County with total water demand over 50 million cubic meters which is more than double of the current water use for water supply and irrigation. It is expected that for expressed needs for water, not only planned water reservoirs but also groundwater supplies will be used in greater extent. This can in insufficiently controlled conditions and in hydrological unfavourable years cause overexploitation and deeper incursions of sea water in coastal karst aquifer.

7. IMPACT OF LAND USE ON WATER QUALITY - FUTURE STATE

According to the Spatial Plan of Istria County [10] in the future there are planned no significant changes in land use. Almost every change that is predicted should have a positive impact on quality of drinking water sources. Also, the Spatial Plan should enable organic farming, which means production without the use of fertilisers, pesticides, hormones and similar products. Such concept of agricultural production is more complex and its essence is not only in omitting agrochemicals, but also in everyday management which allows us to achieve all this. In the Spatial Plan can also be seen that most of drinking water sources areas are under protected areas (see Appendix 3).

Article 45 of Spatial Plan of Istria County [10] says:

"*In the use of agricultural land development of conventional agriculture should gradually be rejected, while development of organic farming should be anticipated and promoted.*

Organic farming (also ecological or biological) is agricultural production without the use of fertilisers, pesticides, hormones and similar product.

Conventional agriculture is agricultural production which with help of machinery, agrochemicals, newly varieties and breeds, and with large amounts of energy manages to achieve very high yields.

Spatial Plans for cities and municipalities must separately evaluate areas designated exclusively for organic farming, but after verification of studies from Point 1 of Article 149 of the provisions of the Plan."

On the area of Istria County until 2008, there were only seven family farms with organic production, which on the one hand shows that food production in the Istria County is present, but also shows that it is necessary to develop it more intensively. The efforts and resources invested in programs of ecological production of agricultural and food products (co-financed by the Administrative Department of Agriculture, Forestry, Hunting, Fishery and Water Management of Istria County) have a solid base for the development, which is consistent with the strategic goals and interest for sustainable development of Istria County [14].

Although Istria County has very favourable conditions for the development of ecological agriculture, agricultural entities have started only sporadically to be interested in the possibilities of mass production. However, organic food production has still not received its proper place.

Among the first Croatian regions, Istria County has recognized the importance of organic food production as one of the strategic commitments in the sector. The development of organic farming supports the establishment and operation of associations by offering financial support through the budget of the Istria County.

Istria County in many ways was the initiator of changes in the current development programs of organic farming and also through related projects.

The pioneer advantage of Istria County was slowed down by the impossibility of active participation in more international development projects due to lack of financial resources. However, a lack of skilled personnel, the resistance of the business of the agricultural sector, advertising of industry chemicals for fertilization and protection, abuse of ecological product names, identification of traditional agriculture with conventional, the lack of large quantities of products for installation in tourist companies are more than clear limitations for overall development.

The basis for development beside registered organic producers represents also a critical mass of registered family farms which are ready for certification i.e. entry into the system of organic production.
Ongoing implementation of the program for production of bio-food (stimulation of interest associations, promotion of typical and organic products, development of programs for the protection of originality, geographical origin and genetic material, incentive programs for traditional and cultural heritage of the organization of fairs and exhibitions) showed that the implemented activities yielded good results. The prohibition of the use of genetically modified seeds and foods, and installation of organic farming in the Spatial Plans are a starting point for systematic planning and development of organic farming.
Also, with implementation of Istria water protection system Ltd. (Croatian: Istarski vodozaštitni sustav d.o.o.) [13] plan "Sewerage and wastewater treatment for small settlements in drinking water sanitary protection zones of Istria County" the problem of wastewaters drainage with corresponding WWTP will be solved. The primary purpose of the Plan is to protect drinking water sources from pollution, but the positive side effect is also the protection of the environment in the broad sense, including the protection of the sea.
The Decision on sanitary protection zones of the Istria County requires that residential buildings in the zone III and IV must have a septic tank or biological treatment device, while in zone II for springs and also in the zone II and III for reservoirs and lakes must have watertight collecting tank with controlled discharge done by authorized institutions [13].
The real situation is that tanks are not watertight and untreated wastewater is drained into the underground, there is no control on discharging tanks and the removal of their content to adequate treatment, and also Istria County does not even have enough equipped devices for the reception of content from all septic and collecting tanks. The consequences of such conditions pose a threat to the safety of the water supply because of:

- more demanding treatment in the process of obtaining drinking water,
- need for more chemicals used in water purification
- greater insecurity of water supply system regarding health safety of drinking water.

Significant are also negative consequences for the environment because it increases the concentration of micro-organisms (many of which may be pathogenic) in surface and groundwater and the concentration of nitrogen and phosphorus in the reservoirs and coastal sea, causing an overgrowth of algae and other undesirable organisms which ultimately leads to the degradation of water and sea quality.
With the construction of watertight sewage systems and WWTP with tertiary treatment it can be prevented:

- contamination of surface and groundwater flows with pathogens,
- pollution of reservoirs and coastal waters with nitrogen and phosphorus and their degradation,
- aesthetic impact on the environment.

Also, this will open the possibility to re-use the treated water for irrigation or other needs, which is particularly important for Istria County which has limited water resources in the summer [13].

This treated waste water could be also used in form of artificial recharge of coastal karst aquifers to reduce the impact of expected climate changes (reduced natural flows and increased water extraction for irrigation) on coastal aquifers [16].
Therefore, goals and challenges of Istria water protection system Ltd. are: construction and management of water protection systems of Istria County, construction of sewage systems and wastewater treatment plants for small settlements to the highest standards, and maintenance of the system with providing high customer service [13].

8. ANALYSIS AND SYNTHESIS OF BOTH THE ACTUAL AND THE EXPECTED FUTURE SCENARIOS IN THE FRAMEWORK OF THE DPSIR APPROACH

As mentioned in the Introduction, this report is made according to DPSIR methodology [1].
Analysis of current scenario is given in Chapter 4.1 and refers to 2012. Development of future scenarios is possible based on analysis of Spatial Plan of Istria County [10] and project documentation of the Istria water protection system Ltd. [13] that has, for the final goal, the improvement of water quality on all water sources used for drinking purpose.
In Table 4 the most significant *Driving forces*, *Pressures*, *States*, *Impacts* and *Responses* on test areas in Northern Istria associated with urban and agriculture areas are given.

Table 4: Most significant Driving forces, Pressures, States, Impacts and Responses on test areas in Northern Istria.

URBAN AREAS				
Driving forces	**Pressures**	**State**	**Impacts**	**Responses**
Areas without sewage system Runoff from paved structures Collection and storage of wastewater Health service Waste disposal	Emission of microbiological pollutants, pathogens, nutrient N&P compounds, chemicals, heavy metals	Groundwater state Health	Deterioration of underground water quality, impact on human health	Implementation of appropriate measures, i.e. construction of sewer systems and WWTP
AGRICULTURE				
Driving forces	**Pressures**	**State**	**Impacts**	**Responses**
Use of fertilisers (N and P consumption)	Diffuse N contribution (runoff and percolation)	Groundwater state Biodiversity landscape Health	Deterioration of underground water quality, impact on human health	Implementation of appropriate measures, i.e. organic farming: National Directive 91/676/EEC (the so-called Nitrates Directive)
FARMS				
Driving forces	**Pressures**	**State**	**Impacts**	**Responses**
Farms	High concentration of pathogenic animal waste	Groundwater state Health	Deterioration of underground water quality, impact on human health	Implementation of appropriate measures, i.e. appropriate WWTP and waste disposal

9. MEASURES TO IMPROVE THE QUALITY OF DRINKING WATER

The Spatial Plan of Istria County gives advantage to organic farming which means production without mineral fertilisers, pesticides, hormones and similar products. Such concept of agricultural production is more complex and its essence is not only in omitting agrochemicals but also in everyday management which allow us to achieve all this.

In the Istrian County Spatial Plan it can also be seen that most of drinking water sources areas are under protected areas (see Appendix 3).

Also, with implementation of Istria water protection system Ltd. [13] plan "Sewerage and wastewater treatment for small settlements in drinking water sanitary protection zones of Istria County" the problem of wastewaters drainage with corresponding WWTP will be solved.

It is also expected that the application of other structural (arrangement of road runoff through protected areas with the treatment of storm waters) and non-structural measures (restrictions and stimulations in agriculture and livestock farming) will achieve reduction of negative pressures on water resources.

All above listed measures are given to improve the quality of drinking water sources in test areas in Northern Istria.

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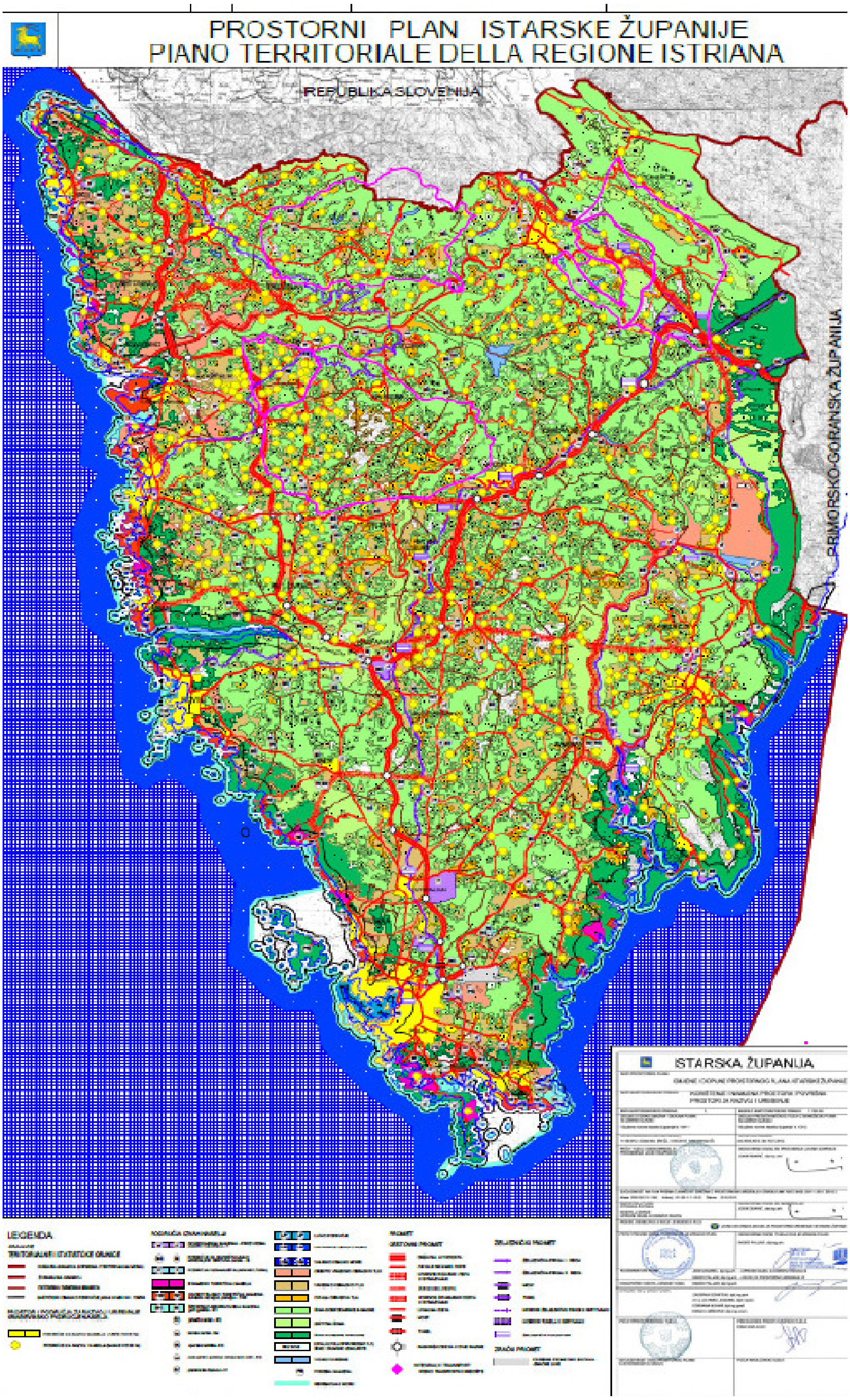
11. APPENDIXES

Appendix 1: CLC nomenclature (in Croatian), [7]

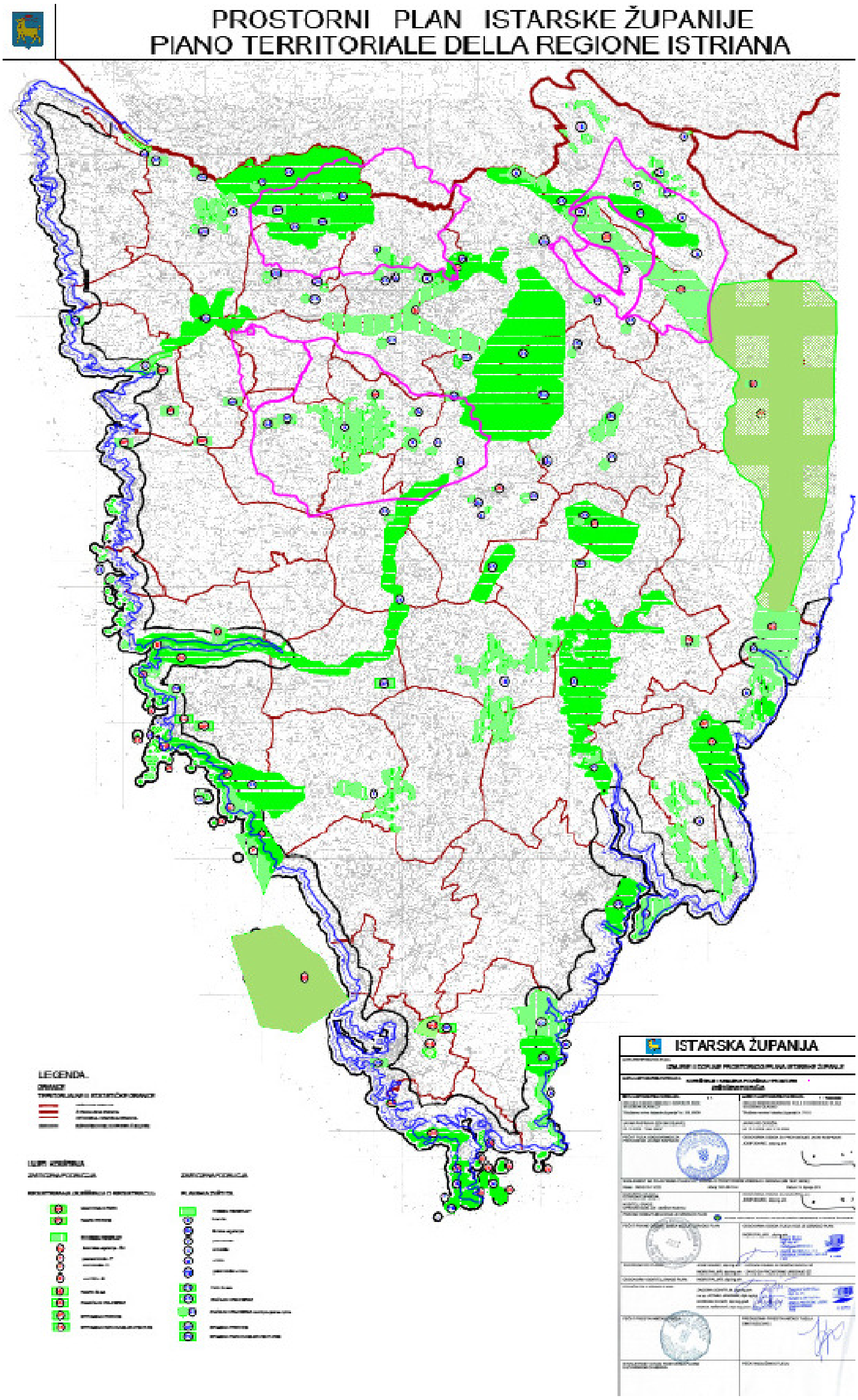
CORINE Land Cover klase
CORINE Land Cover classes

1. razina	2. razina	3. razina	Boja	Naziv klase
1. Umjetne površine	1.1. Gradsko područje	111		Cjelovita gradska područja
		112		Nepovezana gradska područja
	1.2. Industrijske, komercijalne i transportne jedinice	121		Industrijske ili komercijalne jedinice
		122		Cestovna i željeznička mreža i pripadajuće zemljište
		123		Lučke površine
		124		Zračne luke
	1.3. Rudokop, odlagalište otpada i gradilište	131		Mjesta eksploatacije mineralnih sirovina
		132		Odlagališta otpada
		133		Gradilišta
	1.4. Umjetni, nepoljodjelski, biljni pokrov	141		Zelene gradske površine
		142		Sportsko rekreacijske površine
2. Poljodjelska područja	2.1. Obradivo zemljište	211		Nenavodnjavane oranice
		212		Navodnjavane oranice
		213		Rižišta *
	2.2. Trajne kulture	221		Vinogradi
		222		Voćnjaci
		223		Maslinici
	2.3. Pašnjaci	231		Pašnjaci
	2.4. Raznorodna poljodjelska područja	241		Jednogodišnji usjevi u zajednici s višegodišnjim
		242		Složeni uzorak uzgojnih parcela
		243		Pretežno poljoprivredno zemljište, s značajnim udjelom prirodnog biljnog pokrova
		244		Područja poljoprivrednog šumarstva
3. Šume i poluprirodna područja	3.1. Šume	311		Bjelogorična šuma
		312		Crnogorična šuma
		313		Miješana šuma
	3.2. Grmlje i/ili travnati biljni pokrov	321		Prirodni travnjaci
		322		Močvare i vrištine
		323		Makija i garig
		324		Prijelazna šumska područja
	3.3. Područja s neznatnim ili bez biljnog pokrova	331		Plaže, dine i pijesci
		332		Gole stijene
		333		Područja s oskudnim biljnim pokrovom
		334		Opožarena područja
		335		Ledenjaci i vječni snijeg
4. Vlažna područja	4.1. Kopnena vlažna područja	411		Kopnene močvare
		412		Tresetišta
	4.2. Priobalna vlažna područja	421		Slane močvare
		422		Solane
		423		Područja plimnog utjecaja
5. Vodene površine	5.1. Kopnene vode	511		Vodotoci
		512		Vodna tijela
	5.2. Morske vode	521		Obalne lagune
		522		Estuariji
		523		More

Appendix 2: Spatial Plan of Istria County: Land use and purpose [10]



Appendix 3: Spatial Plan of Istria County: Land use and purpose: protected areas [10]



Impact of land use changes on water quality on test areas in Northern Istria (springs: Gradole, Bulaž and Sv. Ivan) – 18.05.2015.

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Cross Border Cooperation 2007-2013

The project is co-funded by the European Union,
Instrument for Pre-Accession Assistance

Impact of land use changes on water quality on test area Southern Dalmatia-Croatia

Croatian Geological Survey

(FB9)

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Date last release	28/7/2015.
State of document	Final

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The project is co-funded by the European Union, Instrument for Pre-Accession Assistance

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1. INTRODUCTION

This report presents the impact of land use on water quality using the DPSIR methodology. For presenting land use map on test areas in Southern Dalmatia – Blatsko polje and spring Prud catchment area - Corine Land Cover was used. As the spring Prud catchment area partially belongs to Croatia, and partially to Bosnia and Herzegovina (BiH) different sources for land use data was used. For Croatian part of catchments the data were obtained from Croatian environment agency (Corine Land Cover Croatia 2000, 2006 and 2012) [1] and for Bosnian part of catchment from European environment agency (Corine Land Cover 2000 and 2006, while Corine Land Cover for 2012 still not available) [2]. Land use has important role in protection of the aquifer because it warns on major possible negative effects and thus allows better management of water resources.

1.1. DESCRIPTION OF TEST AREAS

1.1.1. Spring Prud catchment area

Prud spring is the most important spring in the lower course of the Neretva river (Figure 1). It represents the basis of water supply in the regional aspect. This spring could supply nearly half a million inhabitants, but so far is used only 10% of its capacity. In comparison to other karst springs, fluctuations of minimum and maximum discharge is relatively small: Q_{min}: Q_{max} = 2,5 : 20 m^3/s. The size of spring catchment area is approximately 1200 km^2 (about 200 km^2 in Croatia and 1000 km^2 in Bosnia and Herzegovina). Karst geomorphology of the right bank of the Neretva river, to which spring Prud catchment area belongs, is marked by the great complexities and intertwinement of hydrogeological relations. Despite numerous investigations and tracing experiments in this system there are still a great number of uncertainties and doubts. The underground connection, surface streams that sink and appearing on the surface again, karst springs, estavelles or swallow holes, and present a big challenge for hydrogeological investigations.

Figure 1 *Spring Prud*

1.1.2. Blatsko polje catchment area

The western part of the island Korčula with the settlements of Blato and Vela Luka has a water supply from the island's karst aquifer in the area of the Blatsko karst polje (Figure 2). The Blatsko polje is a typical karst polje with a few temporary springs, mostly in the southern and western side, and the estavelle of Mali Studenac in the east. Groundwater used for public water supply is pumped from four pit wells (Studenac, Prbako, Franulović-Prcalo and Gugić), and the maximal pumping rate is about 60 l/s [3]. After extensive hydrogeological researches Blatsko polje catchment covers about 28 km^2. The wells are constructed in the field but they extract water from the karstified limestones bellow the polje's deposits. These deposits are thick up to 7 m. When hydrological conditions are extremely unfavourable, there is a significant salinity increase of the pumped water. The sea water intrusion happens only when the pumping rates are close to maximal and a dry season (much below average) has lasted for at least one hydrological year.

Figure 2 *Blatsko polje and its wells*

2. LAND USE AND ITS CHANGES IN TEST AREAS

In this chapter land cover (CLC) and its changes on test area in Sounthern Dalmatia (Prud and Blatsko polje) is shown.

2.1. ACTUAL LAND USE IN TEST AREAS

Corine land cover (CLC) which here presents land use is a digital database on types of land cover/use [1]. Actual land use is presented for the year 2006 for both test area. Prud spring catchment area is a transboundary aquifer. Although spring Prud is located in Croatia, most of its catchment belongs to Bosnia and Herzegovina. CLC 2012 for Croatia is already done and available on the web site of the Croatian environmental agency, while for BiH CLC 2012 is still not available. Thus, as majority part of the catchment area belongs to BiH it is decided to present for both test areas CLC maps for 2006 (Figure 3,4,5). Pie graphs (Figure 6,7,8) represents the percentage shares of individual categories of land use for the latest available version.

Blatsko polje catchment area is about 28 km^2, and spring Prud catchment area cover about 1750 km^2 (of which 180 km^2 belongs to Croatian part and 1579 km^2 on BiH part).

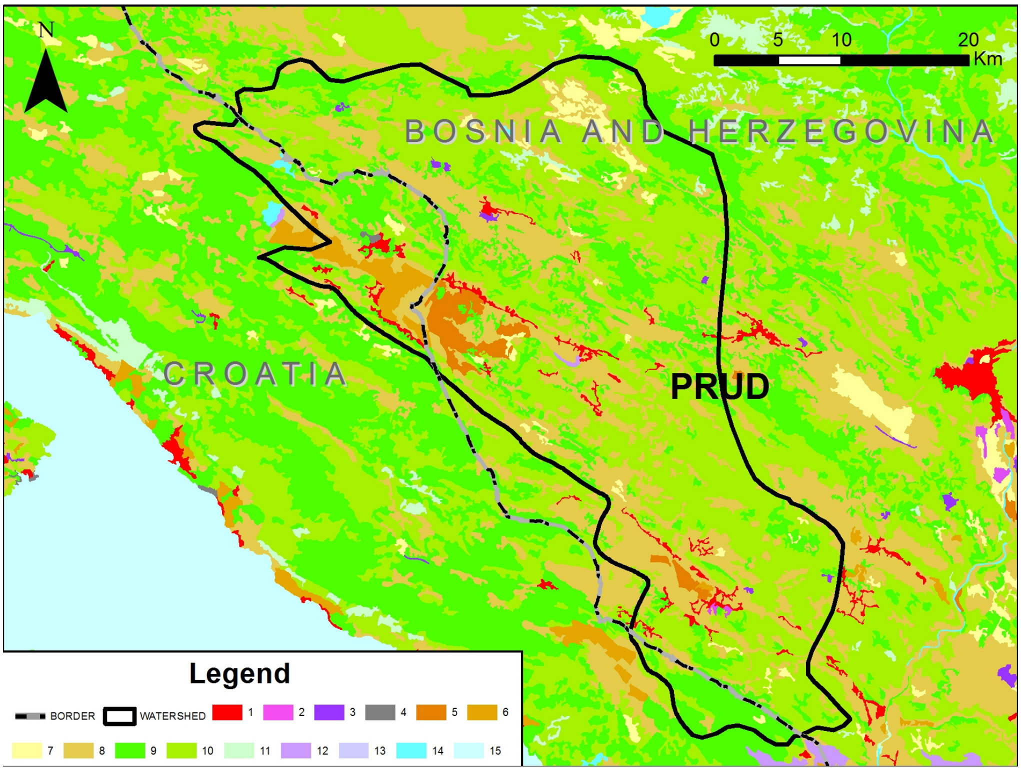

***Figure 3** Corine land cover for the spring Prud catchment area for year 2006 [1]*

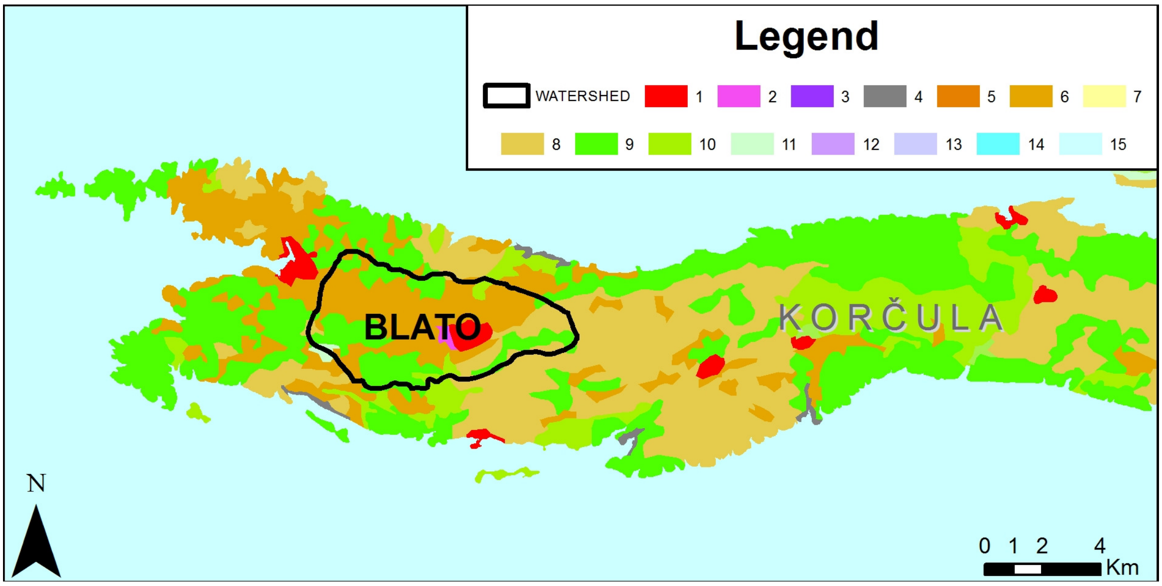

***Figure 4** Corine land cover for Blatsko polje for year 2006 [2]*

1	Urban fabric
2	Industrial, commercial and transport units
3	Mine, dump and construction sites
4	Artificial, non-agricultural vegetated areas
5	Arable land
6	Permanent crops
7	Pastures
8	Heterogeneous agricultural areas
9	Forests
10	Scrub and/or herbaceous vegetation associations
11	Open spaces with little or no vegetation
12	Inland wetlands
13	Maritime wetlands
14	Inland waters
15	Marine waters

***Figure 5** Corine land cover legend*

Pie diagrams show land cover categories expressed as a percentage. While cartographic presentations representing spatial distribution of certain land-use categories, pie charts display percentage of total area occupy by individual land use category. It can be noticed that the largest percentage of agricultural land are in Blatsko polje area (Figure 8) which occupy more than half of its catchment. In the catchment area of spring Prud is a somewhat higher percentage of agricultural land on the Croatian side of the catchment, but considering that the Bosnian part of the catchment is far greater, expressed as surface area, part of the agricultural land in Bosnia and Herzegovina belonging to the Prud's catchment is several times greater than the surface of whole Prud's catchment on Croatian side.

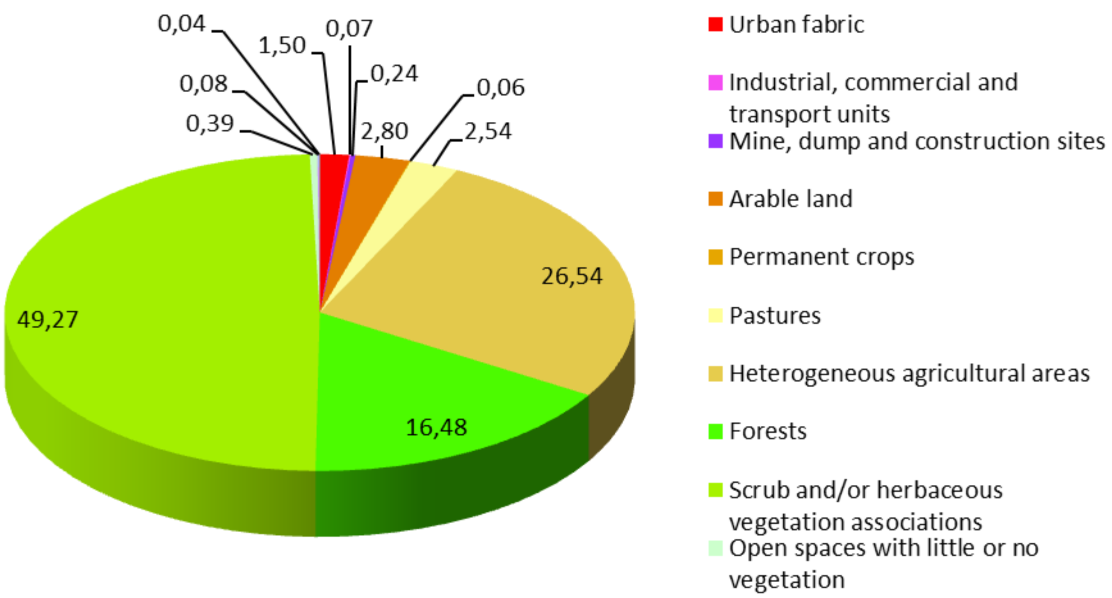

Figure 6 *CLC 2006 in % for BiH part of the catchment area of spring Prud [1]*

DRINK ADRIA

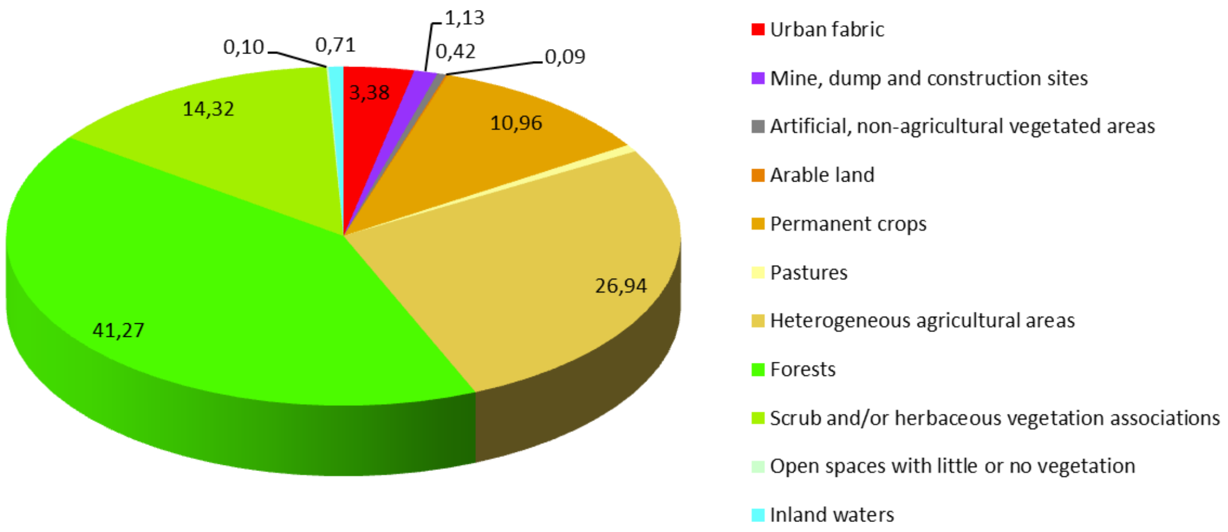

Figure 7 *CLC 2012 in % for Croatian part of the catchment area of spring Prud[2]*

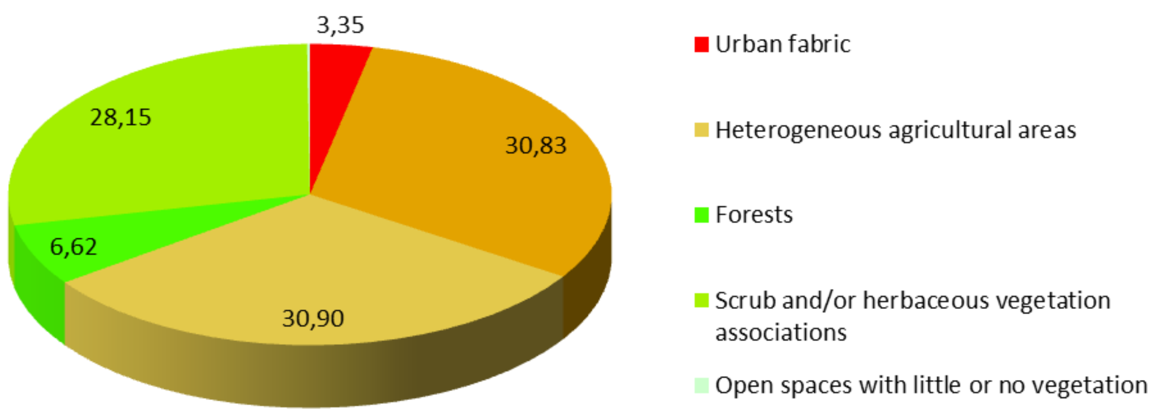

Figure 8 *CLC 2012 in % for Blatsko polje [2]*

2.2. LAND USE CHANGES IN TEST AREAS

Table 1 *Comparison in land use categories for different years of CLC for the Prud catchment test area on Bosnian-Herzegovinian side [2]*

Prud BiH CLC	2006	2000
Landuse categories	Area (%)	Area (%)
Urban fabric	1,50	1,50
Industrial, commercial and transport units	0,07	0,07
Mine, dump and construction sites	0,24	0,24
Arable land	2,80	2,80
Permanent crops	0,06	0,06
Pastures	2,54	2,54
Heterogeneous agricultural areas	26,54	26,54
Forests	16,48	16,48
Scrub and/or herbaceous vegetation associations	49,27	49,27
Open spaces with little or no vegetation	0,39	0,39
Inland wetlands	0,08	0,08
Inland waters	0,04	0,04

Table 2 *Comparison in land use categories for different years of CLC for the Prud catchment test area on Croatian side [1,2]*

Prud Croatia CLC	2012	2006	2000
Landuse categories	Area (%)	Area (%)	Area (%)
Urban fabric	3,38	3,38	3,25
Mine, dump and construction sites	1,13	1,13	0,00
Artificial, non-agricultural vegetated areas	0,42	0,42	0,42
Arable land	0,09	0,09	0,00
Permanent crops	10,96	10,96	10,87
Pastures	0,69	0,69	1,07
Heterogeneous agricultural areas	26,94	26,94	22,77
Forests	41,27	41,27	40,39
Scrub and/or herbaceous vegetation associations	14,32	14,32	20,52
Open spaces with little or no vegetation	0,10	0,10	0,00
Inland waters	0,71	0,71	0,71

Table 3 *Comparison in land use categories for different years of CLC for the Blatsko polje test area [1,2]*

Blatsko polje CLC	2012	2006	2000
Landuse categories	Area (%)	Area (%)	Area (%)
Urban fabric	3,35	4,06	4,06
Permanent crops	30,83	50,12	50,12
Heterogeneous agricultural areas	30,90	11,59	11,59
Forests	6,62	29,76	29,76
Scrub and/or herbaceous vegetation associations	28,15	2,92	2,92
Open spaces with little or no vegetation	0,16	0,50	0,50

3. IMPACT OF LAND USE ON WATER QUALITY - DPSIR APPROACH FOR THE PRESENT/PAST STATE

3.1. DPSIR METHODOLOGY

The DPSIR framework is in some way a conceptual model (Figure 9) representing direct interactions through a loop in the way that human being interacts with the environment [2,7]. The characterization relies on system understanding, in particular on the knowledge of drivers (D), pressures (P), status (S), impacts (I) and responses. It involves analyzing the pressures and impacts of human activity on the quality of groundwater. Detailed description of the method is given in the report "Determination of hazard and risk for water pollution with DPSIR method" [5].

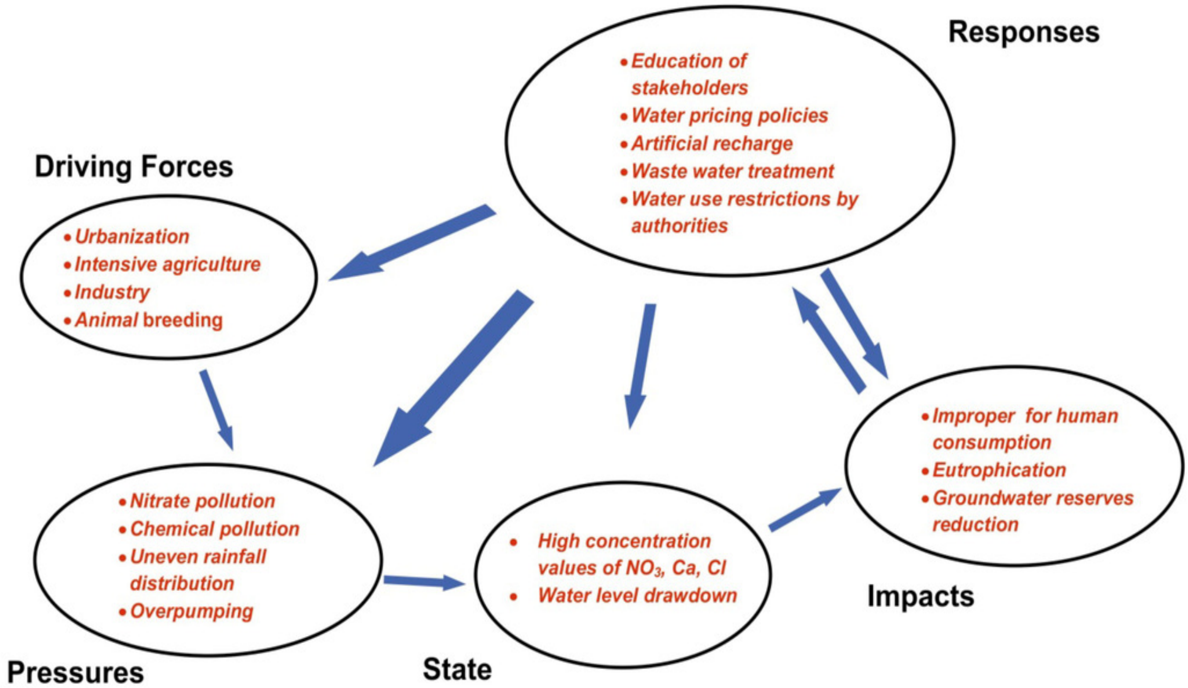

Figure 9 *DPSIR methodology [4,5]*

3.2. DPSIR APPROACH FOR THE PRESENT/PAST STATE

The first step is to apply DPSIR approach to the actual state. Drivers and Pressures are estimated by analysis of CORINE land use maps for 2000, 2006 and, where possible, 2012 and from Municipal/Regional Spatial plans. State for present is known and is determined from the water quality monitoring (see Water quality report - [6]). DRINKADRIA is focusing on drinking water resources, therefore impacts are effects to human health (e.g. microbiological pollution may cause digestion problems). Responses are measures to improve the quality of drinking water.

Analysis of the current condition is given in section 2.1 of this report. The most widespread land use on test areas in Southern Dalmatia is agriculture and urban areas, therefore, in Table 4. are given the most important Drivers, *Pressures, States, Impacts and Responses for those land use categories.*

Table 4 *The most important Drivers, Pressures, States, Impacts, Responses in test areas of Southern Dalmatia*

URBAN AREAS				
Driving forces	**Pressures**	**State**	**Impacts**	**Responses**
Areas without sewage system	Emission of microbiological pollutants, nutrient N&P compounds	Groundwater state [6]	Deterioration of groundwater quality, impact on human health	Implementation of appropriate measures, for example, the construction of the sewage system and devices for wastewater treatment
AGRICULTURE				
Driving forces	**Pressures**	**State**	**Impacts**	**Responses**
Use of fertilisers (N consumption)	Diffuse N contribution (runoff and percolation)	Groundwater state[6]	Deterioration of groundwater quality, impact on human health	Implementation of appropriate measures, for example, ecological agriculture

4. THE IMPACT OF CLIMATE CHANGE AND PLANNED DEVELOPMENT (SPATIAL PLANS) ON THE LAND USE IN FUTURE ON TEST AREAS

Unfavourable predictions of climate changes in the test areas, what is presented in the report of water resources [7], lead to decrease of possible pumping quantities already in the period 2021-2050. The total annual recharges will decrease as well as the minimum mean monthly discharges. Future spatial plans for Dubrovačko-Neretvanska County do not provide significant changes in the land use on test areas in Croatia in the near future [10].

5. IMPACT OF LAND USE ON WATER QUALITY - DPSIR APPROACH FOR THE FUTURE STATE

An important driver determining water quality is land use. Impacts on drinking water quality may change in the future due change in land use, which can be caused by climate change, politics (spatial plans), etc. Land use change in the future can be estimated on the basis of trends in land use changes in the past with comparing CORINE land cover maps from different years. On the other hand, also future spatial plans of the area have to be considered, where information about activities in the area are defined [10].

Comparing CLC for different years in order to evaluate trends in land use, it was observed following:

- Part of Prud spring catchment area in Bosnia and Herzegovina
  - there is no any changes in land use comparing CLC 2000 and 2006 (Table 1)
- Part of Prud spring catchment area in Croatia
  - there is just minor changes in land use - areas of Pastures and Scrub and/or herbaceous vegetation associations are reduced while, Mine, dump and construction sites and Heterogeneous agricultural areas are slightly increased (Table 2)
- Blatsko polje catchment has significant changes, but in a way that there has been a change in use of agricultural areas – areas of Permanent crops are reduced approximately as much as Heterogeneous agricultural areas are increased, but there is not significant changes between agricultural and natural areas (Table 3)

Evaluated trends of changes in Corine land cover shows that there is no significant changes in land use categories over the years that could have negative impact on water quality. Moreover, as mentioned in the previous section, after county spatial plans, it is not expected significant changes in land use in the future at Croatian part of Prud catchment and Blatsko polje. On the other side, there are a number of measures which are in County strategic plan which should have positive impact on groundwater quality. These are:

- development of energy which would promote clean technologies,
- renewable energy, entrepreneurial development
- environmental protection
- reduced using of fertilizer
- building of sewer systems in areas where they don't exist and making devices for wastewater treatment
- restoration of existing and construction of regional waste disposal sites
- making of sanitary protection zones for the spring Prud" which should enable better protection of groundwater from agricultural areas located in the Prud catchment

Still, as Croatian part of spring Prud catchment is just a smaller part and majority of catchment is in BiH, in the report on land use from BiH partner will be mentioned its future plans in land use and its impacts on water quality.

Despite above analyses did not determine significant impact on groundwater quality, the impact of climate change could have significant negative impact. Climatological models have indicated [7] that the amount of runoff could significantly reduce during the modeled period of 2021-2050. Problems associated with the predicted climate change [7] will caused that pumping at present rates at Blatsko polje wells will lead to more expressed and more usual saline intrusions of this karst aquifer. The situation will, in the periods after that, only get worst. Predicted climate change would certainly have a negative impact on both, water quality and quantity on spring Prud also, however, there is not sufficient data to predict the extent on which these changes will impact on Prud spring water in the future.

6. PROBLEMS OF SEA WATER INTRUSION

There are no problems associated with seawater intrusion at the spring Prud for now, but recent activity in Bosnia and Herzegovina has shown that this is a very sensitive area. Because of the large construction project of six hydropower plants upstream from this area, spring downstream from spring Prud has been salinized. Water from this spring is used for the water supply of the city Metković, and as a result, the Metkovic was compelled to connect on spring Prud water supply system. In addition to this, Neretva valley, which is intensively used for agriculture, was also salinized as well as water used to irrigate agricultural land, therefore this situation is a major threat to this valuable agricultural area.

Blatsko polje test area has occasional sea water intrusion problems. Maximum rates from pumping wells in Blatsko polje are always extracted in the summer seasons when the need for water is increased as a result of tourism and agricultural production, while the recharge in this period of the year is usually minimal or none. When hydrological conditions are extremely unfavourable, there is a significant salinity increase of the pumped water. The sea water intrusion happens only when the pumping rates are close to maximal and a dry season (much below average) has lasted for at least one hydrological year. In such years surface flow does not occur at all, so there is no surface water to retain before the tunnel entrance. In the seasons when surface flow occurs, the underground will usually be saturated enough not to allow any sea water intrusions during the summer season.

7. MEASURES TO IMPROVE THE QUALITY OF DRINKING WATER ON TEST AREAS

Despite a number of measures to improve water quality, directly and indirectly, that are provided by county strategic plan, it is necessary continuous and regular monitoring of water quality trends. As the two test areas have intensive agricultural production, and by the fact that they are characterized by karst nature which is very sensitive to pollution, it would be highly preferable to increase organic agriculture in the future that will ensure the best preservation of underground water. It is important not only for people, but for the entire ecosystem. Therefore, it is necessary to organize educational workshops to raise human awareness of the need of preserving the quality and quantity of water and the ways in which this can be achieved, which creates a basis for good health and quality of life.

The sea water intrusion problems on the Blatsko polje test area can be solved by decreasing pumping rate, because this leads to groundwater levels recover and its pressure improves the underground dynamic relation of fresh and seawater, partially according to the Ghyben-Herzberg law. Since such events are quite rare the problem is not too extent, but according to predicted climate changes and their influence on water balance, such event will occur more often and with higher extent. That will probably cause the necessity of decreasing the pumping rates, especially during the summer dry periods, when water demand is on its yearly peak because of tourism and agriculture. This water, on the other hand, does not influence any protected water dependent ecosystem [9].

Due to the negative predictions of climate change on test areas [7], it is necessary to establish continuous monitoring of the karst system behaviour – by the monitoring of groundwater levels, their quantity (especially chloride ion concentrations and – to make the monitoring efficient, fast and cheap – electrical conductivity). Also, there is a need for further exploration of the karst aquifer by pumping tests with further assessments of the present state and future risk.

8. REFERENCES

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[7] Report on "Water resources availability on test areas in Southern Dalmatia – catchment areas of spring Prud and Blatsko polje" Croatian Geological Survey (FB9), Zagreb, 2015, DRINK-ADRIA.

[8] Izmjene i dopune prostornog plana Dubrovačko-Neretvanske županije: http://www.edubrovnik.org/pp_2013/03a_izvornik_IDPPDNZ_obrazlozenje_prociscen i__09_13.pdf

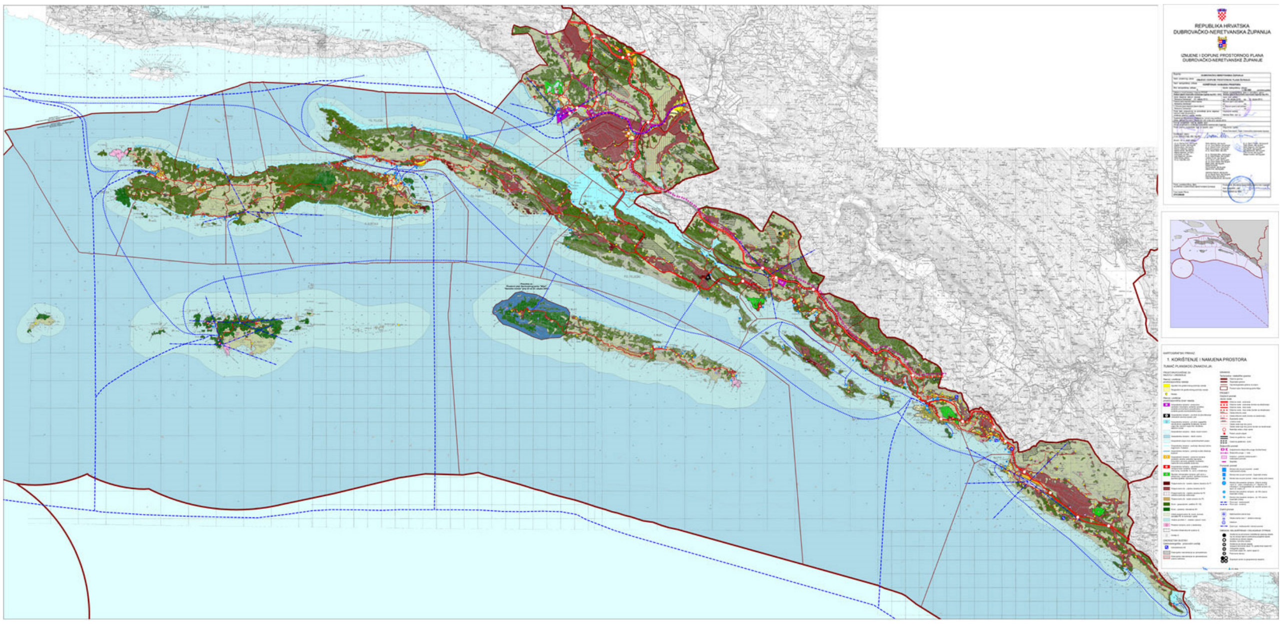
[9] Rubinić, J., Terzić, J., Marković, T., Horvat, B. (2011) Blatsko polje test area report (under the CC WaterS project http://www.ccwaters.eu/)

[10] Dubrovačko-neretvanska county regional plan: land use and allocation *http://www.edubrovnik.org/kartografski_prikaz_1.php#*

[11] *Legend for Dubrovačko-neretvanska county regional plan http://www.edubrovnik.org/pplan2010/kartografski_prikazi/karta_1/k1_p_leg.jpg*

9. APPENDIX

Appendix 1 *Dubrovačko-neretvanska county regional plan: land use and allocation [10]*



Appendix 2 *Legend for Dubrovačko-neretvanska County regional plan [11]*

DRINK ADRIA

Impact of land use changes on water quality on test area Southern Dalmatia – 28/7/2015.

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DRINK ADRIA

Adriatic IPA
Cross Border Cooperation 2007-2013

The project is co-funded by the European Union,
Instrument for Pre-Accession Assistance

Estimation of climate change induced land use changes and the impact on water quality

On test area

Nikšić, Montenegro

Institute for water resources development

Jaroslav Černi (FB 10)

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Date last release	19/11/2015
State of document	Final

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1. INTRODUCTION

Pilot Area Nikšić is located in Central - Western part of Montenegro as depicted in Figure 1. More precisely, drinking water sources (karst springs) are located in Nikšićko Polje, karst field with significant water yield and partly within the Upper Zeta river basin.

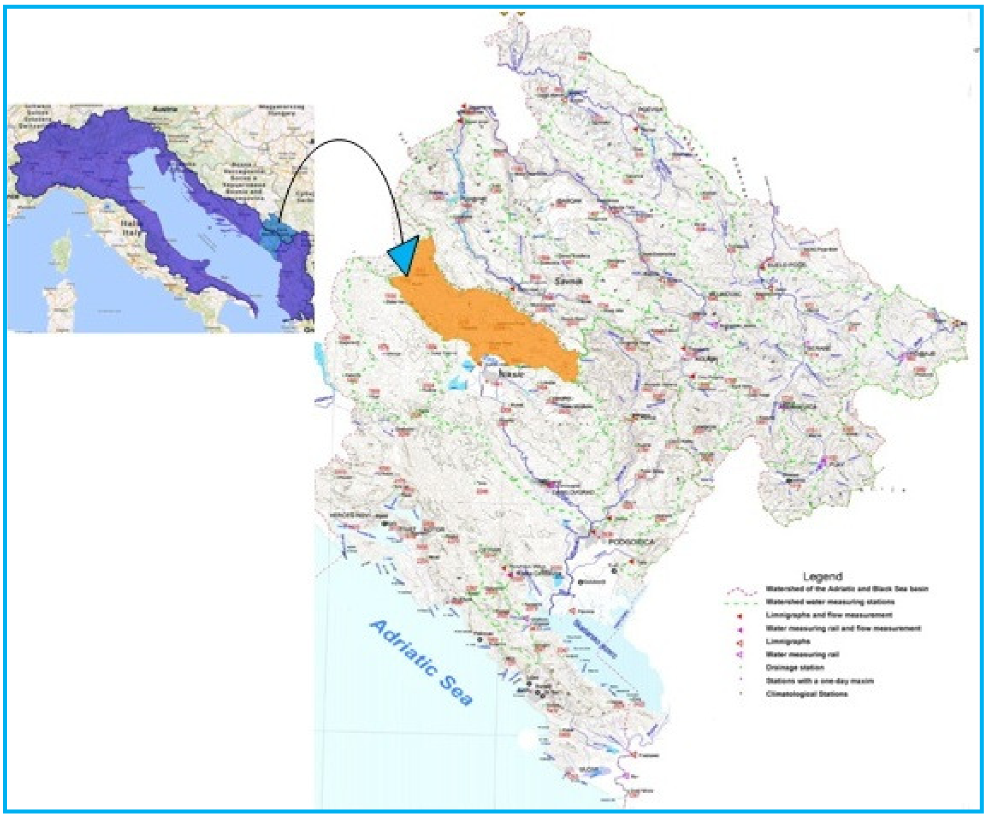

Figure 1: Position of Upper Zeta catchment

Drainage area of Upper Zeta catchments is 327 km2 while area that covers Drinking Water Protection Zones (***inner -I, middle - II and outer -III***) for 3 sources used for water supply is approximately 310 km^2 based on Report on Drinking Water Protection Zones (DWPZ) for Poklonci source. Two other springs Gornji and Donji Vidrovan are located within this area as well. Different geological groups of rocks create study area. Terrains are predominantly comprised of rocks from a group of hydrogeological collectors with fracture and cavernous porosity that are Mesozoic carbonate sediments characterized by limestone.

Besides to this there are Mesozoic dolomites and hydrogeological isolators represented by Younger Paleozoic, clay-marl layers, volcanic rock of volcanic rocks of Triassic age, Jurassic layers of marl, and clay-marl-sandy and calcareous layers of Upper Cretaceous and Cretaceous-Paleogene flysch. Given the hydrogeological properties of study area groundwater water divide at Pilot area is not precisely delineated and very likely drainage area that contributes to recharge extends outer DWPZ, i.e., 310 km2. The same applies to Nikšićko polje and Upper Zeta. Location of Upper Zeta and outer DWPZ for Pilot Area water sources are presented on Nikšićko polje hydrogeological map in Figure 2.

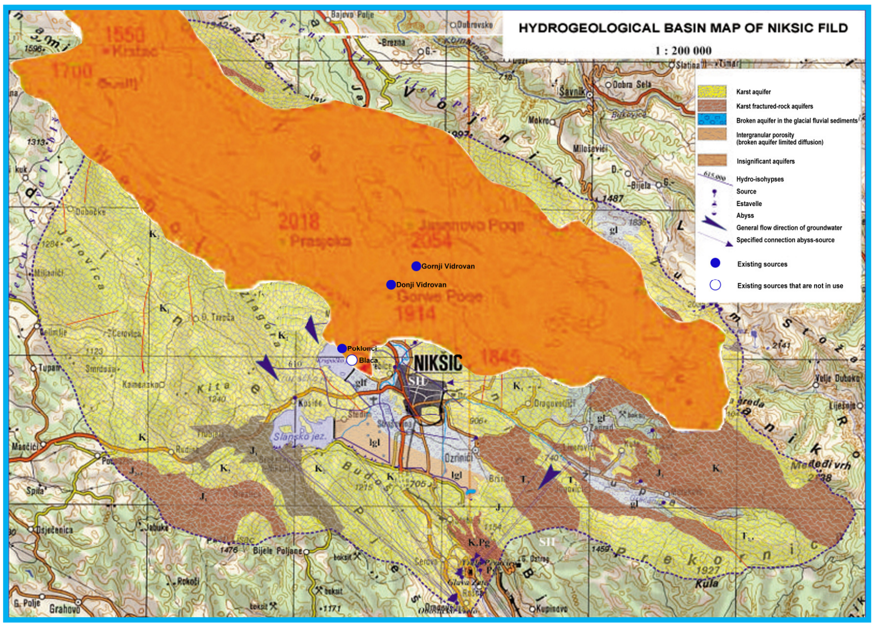

Figure 2: Location of Upper Zeta and DWPZs on the Nikšićko Polje hydrogeological map

Based on the literature review yearly precipitation average varies from 1986 up to 2200 mm per year, very likely due to different time frame analyzed. Rainfall distribution during the year is characterized by maximum at the end of fall and beginning of winter and minimum quantity during the summer season in July. Data for temperature are more uniformly reported in different reports and studies with annual average value of 10.7 °C, and minimum and maximum - 4.3 °C and 24.2 °C in January and July, in a given order. Given the scope of this report high percolation rate should be underlined with respect to groundwater recharge drainage area hydrogeological characteristics. The water supply system of the city of Nikšić consists of springs, wells and pumping facilities, chlorine stations, reservoirs, booster units and primary and secondary network. The town and its suburban areas are water supplied from the sources Gornji Vidrovan, Donji Vidrovan and Poklonci (Figure 2). The sources are closed, physically and technically protected and has identified and marked water protection zones.

2. WATER QUALITY TRENDS FOR NIKŠIĆ TEST AREA

The water supply sources in Nikšić municipality (Figure 3), i.e., Gornji Vidrovan, Donji Vidrovan and Poklonci are karst springs very sensitive to changes in the hydrological regime. The water quality parameters are defined by Regulation on hygienic drinking water quality.

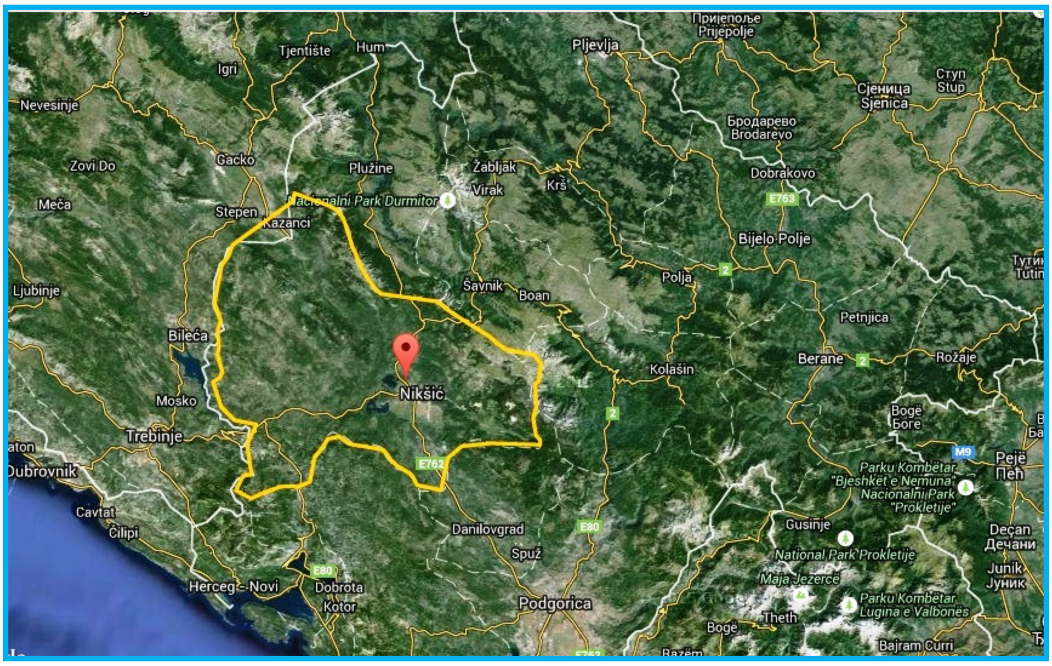

Figure 3 Nikšić municipality

Physical-chemical parameters are monitored at a local lab on a daily basis, while the Institute of Public Health in Podgorica is responsible for complete water microbiological and physical-chemical analysis. Excerpts from DRINKADRIA Report on Water quality analysis and trends on pilot areas in Nikšić (Public Utility Vodovod i kanalizacija – Nikšić, 2015) are presented in Figures 4 and 5 for physical – chemical and Microbiological parameters for 11 years period (2003 - 2013).

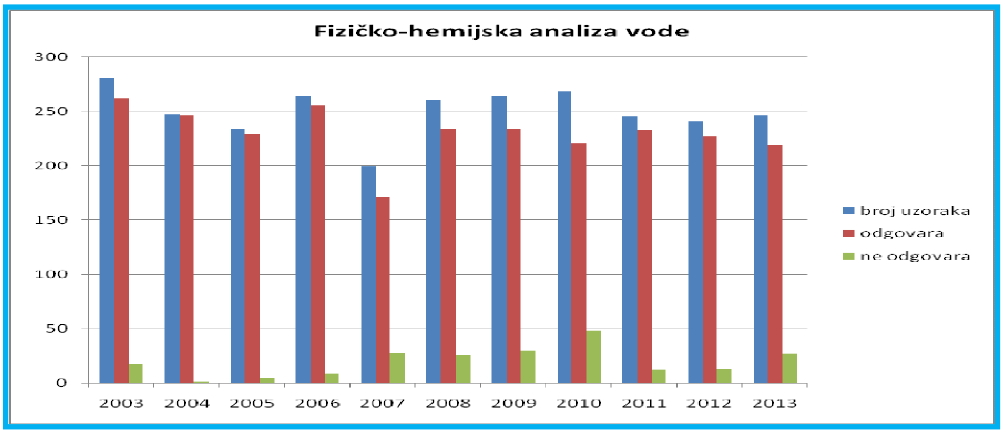

Figure 4: Physical – chemical parameter analyses for NikšićTest Area

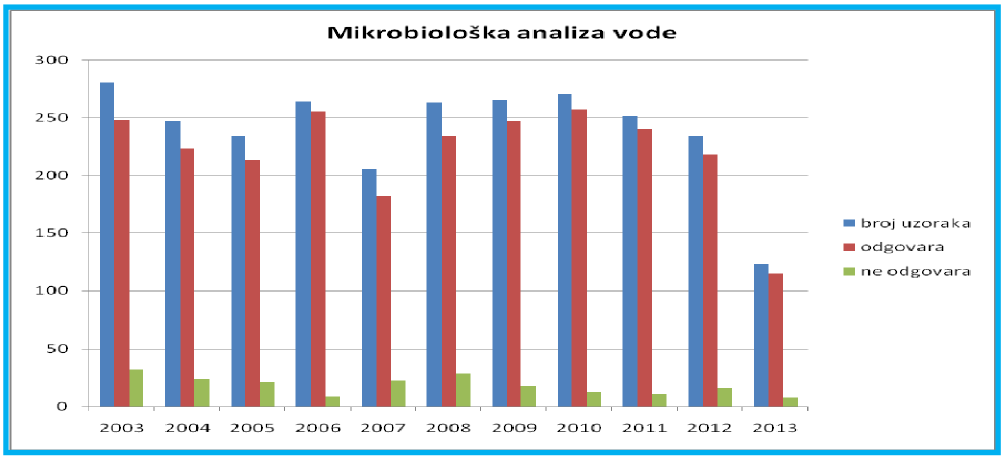

Figure 5: Physical – chemical parameter analyses for NikšićTest Area

As presented above, the majority of samples are lower than Maximum Allowable Concentration (MAC) values, with higher concentration of less than 10 % on average. It should be notated that those concentrations occur mainly during the heavy rainfall events.

The full list of monitored parameters are available in original sources of water quality data. Based on analysis, water used for water supply in the pilot area in Nikšić has a good quality. Deviations of quality parameters (turbidity and mild microbiological contamination) from MAC occur only during heavy rainfall events. The only treatment that is applied is the chlorination at springs.

3. CLIMATE CHANGE DATA

Data for climate change influence in Temperature and Precipitation time series are based on outputs from Report – Climate and Climate Change data for Pilot Area Nikšić (Institute for Water Resources Development Jaroslav Černi, 2014). In summary, outputs from 3 climatological models (Aladin, Promes and RegCM3) for two periods and trend assessment in observed data are compared for temperature and precipitation at Nikšić and Lukovo station. For precipitation huge discrepancy is identified in models outputs for referent period (1961 - 1991). Based on trend assessment in observed data series, results for temperature are more uniform, and are in line with other studies at regional and global level. Observed temperature trends for Meteorological Station Niksic are in the range 0.5 – 1.0 ℃ / 100 years with seasonal increasing trends in winter, spring and particularly summer, while decreasing trend is observed for autumn. Seasonal increasing trends have been observed in winter, spring and particularly summer, while decreasing trend is observed for autumn.

Modeled values for precipitation appears to be significantly underestimated for referent period in comparison with observed data for Nikšić station, namely over 3 times lover than observed values on yearly average amounts. Table 1 summarizes outputs and correction factors for precipitation. Correction factor is derived from correlation between observed and modelled data. It is evident that future projection for selected variables should be assessed and evaluated given the contradiction with observed data.

Table 1: Precipitation Nikšić summary data for period 1961 – 1991

	RCMs from CCWaterS				Corrected values for RCMs		
Month	Aladin	Promes	RegCM3	Observed	Aladin	Promes	RegCM3
JAN	**76**	68	**83**	208	**2.75**	**3.06**	**2.52**
FEB	71	**74**	**63**	194	**2.72**	**2.62**	**3.07**
MAR	**74**	**69**	73	186	**2.52**	**2.68**	**2.55**
APR	65	**67**	**74**	170	**2.61**	**2.55**	**2.29**
MAY	**69**	**69**	66	108	**1.56**	**1.56**	**1.64**
JUN	**61**	**58**	55	93	**1.53**	**1.59**	**1.70**
JUL	42	**43**	**43**	63	**1.51**	**1.48**	**1.48**
AUG	43	**47**	**53**	86	**2.02**	**1.84**	**1.64**
SEP	66	**83**	**70**	138	**2.10**	**1.66**	**1.96**
OCT	**92**	80	**88**	202	**2.19**	**2.51**	**2.29**
NOV	108	**111**	**112**	298	**2.76**	**2.69**	**2.67**
DEC	97	**99**	97	239	**2.46**	**2.42**	**2.46**
Year	863	869	877	1986			

4. LAND USE FOR NIKŠIĆ TEST AREA

According to Study for Poklonci karst spring water protection zones delineation, outer protection zone is approximately 310 km^2 and includes other two springs (Donji and Gornji Vidrovdan) that are water sources for Nikšić Drinking Water Supply System. Based on Spatial plan of Montenegro [6], approximately 65 % of land within the drainage area is forests, followed by agricultural land (29%), artificial surfaces (5 %), and less than.2 % of surface waters. Land use within the area is depicted graphically in Figure 6. As mentioned in previous section, the most significant trigger for water quality within the test area are heavy rainfall. Secondly, un proper waste water treatment and lack of sanitary network should be considered seriously as a threat to water quality. The number of wild landfields [5, 6] within the drainage area should not been neglected. Given the size of area and type of water source, namely, karst aquifer more detailed assessment with respect to these and other polluters, e.g., agriculture is required.

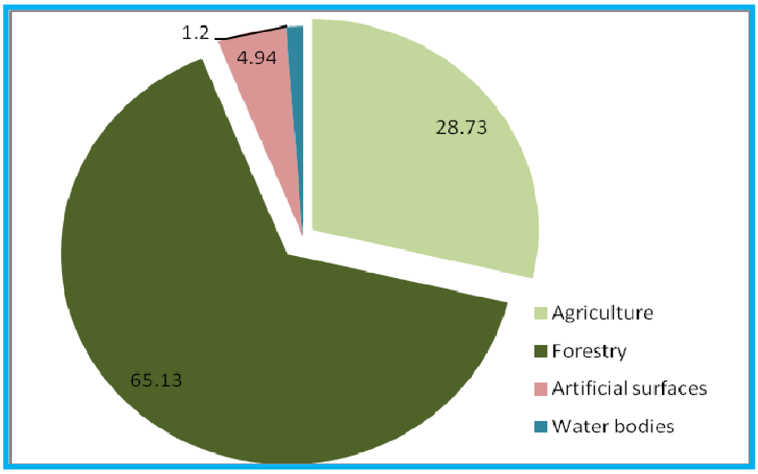

Figure 6: Percentiles of land use practices for NikšićTest Area

According to 2 CORINE land use for two referent years there is no significant changes in land use practices between 2006 (Figure 7) and 2012 (Figure 8). However, occurrence of burnt areas in Figure 8 should not be neglected. Very likely it is due to decrease in precipitation and increase in temperature during the summer season.

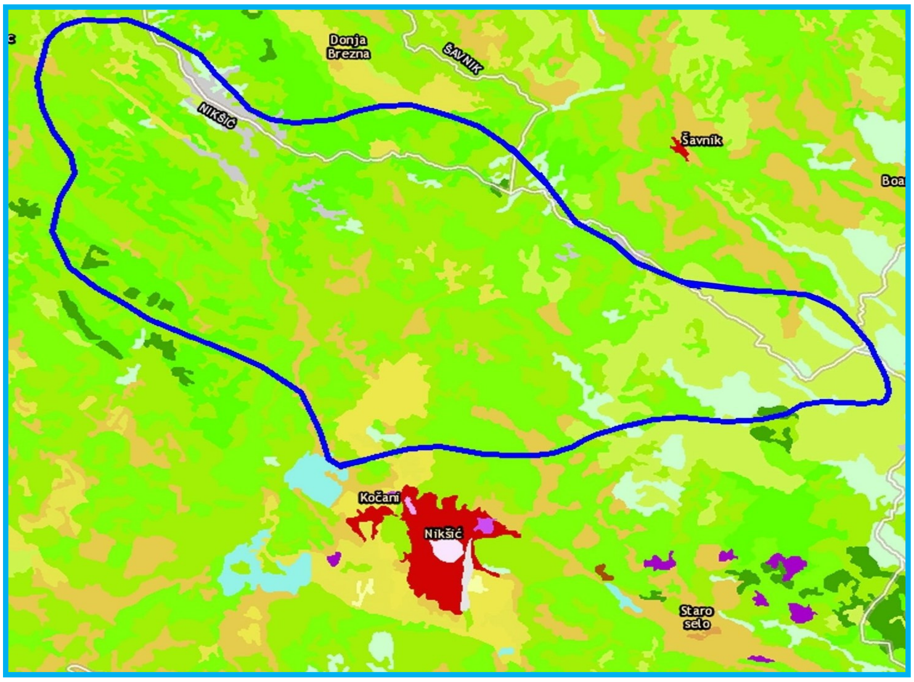

Figure 7:CORINE land cover (2006) for NikšićTest Area

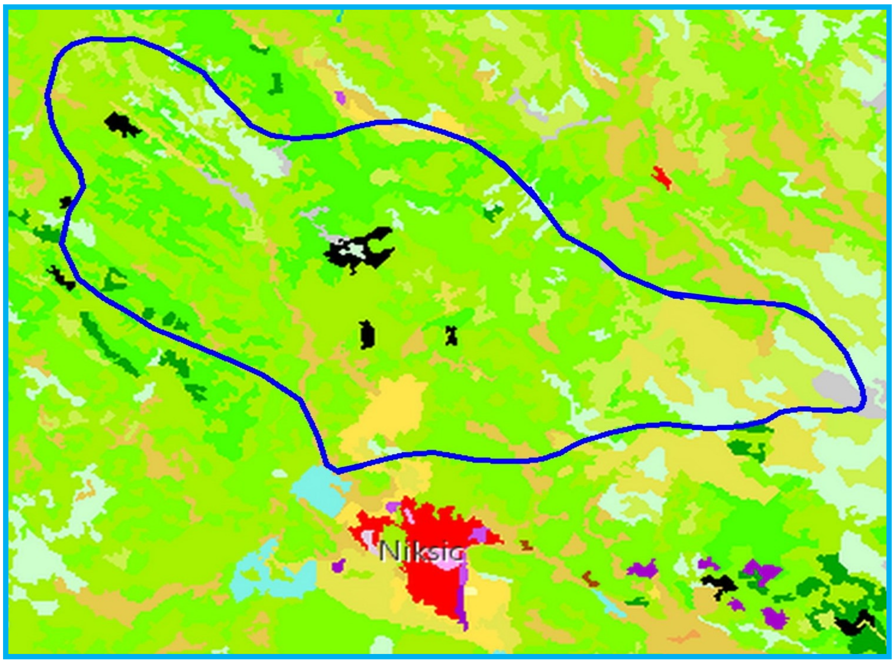

Figure 8:CORINE land cover (2012) for NikšićTest Area

Figure 9:CORINE land cover classes

For great number of households that are not connected to sewer network septic tanks are not design properly. According to [5] following have adverse effects on water quality:

- House holds waste waters from Gornje polje (Vidrovan, Miločani, Rastovac, Zavrh etc.);
- Uncontrolled waste dumping within the drainage area;
- Agricultural measures to intensity productivity (pesticides, herbicides)
- Manure wild landfills;
- Waste substances along the abandon railway Nikšić – Bileća;
- etc.

All this triggers can decrease water quality, especially during the heavy rainfall events. Based on Spatial plan for Montenegro [6] additional development and spatial-ecological problems exists within the Central region of Montenegro, where the Nikšić test area is located:

- Seasonal floods;
- Prolonged disappearing of the forests in Nikšić Plain;
- The lack of good quality soil in Karst area;
- Forest ecosystems are not managed in an integrated manner;
- The danger of possible uncontrolled spilling of the transforming oils remains;
- Etc.

Also, changes in land use practices from agriculturaral and forest land cover to urban land use should not be neglected as the risk for water quality. It is of particular interest for area with increased population, like Nikšić municipality. Since the increase in population is projected and possible increase in agricultural activities according to Spatial plan of Montenegro, possible adverse effects on water quality should be evaluated prior to changes in land use practices.

5. MEASURES

Some of the measures (Response) that would decrease water quality vulnerability are technical but there are number of them that are non technical but would contribute to protection of water sources within the Test area. In summary, all measures should decrease adverse effects from the different triggers. Generally speaking following practices are of interest for Nikšić Test Area:

- Households waste waters from Gornje polje (Vidrovan, Miločani, Rastovac, Zavrh etc.) are properly managed;
- Uncontrolled waste dumping within the drainage area are managed in the way that there is no negative impacts on water quality at the present and in the future;
- Agricultural measures to intensity productivity (pesticides, herbicides) should be applied in a way and by application of BAT in line with Common Agricultural Policy and other policies that consider inter sectoral cooperation that would generate protection of drinking water sources;
- Manure wild landfills should be managed in a way to decrease water sources pollution during the heavy rainfall events;
- Re – cultivation of areas with waste substances along the abandon railway Nikšić – Bileća to decrease risks for water sources pollution;
- Proper storm water management to decrease adverse effects of seasonal floods;
- Forest management that would decrease deforestation within the Nikšić Plain;
- Management of the forest ecosystems in an integrated manner;
- Re-mediation of the areas with transforming oils remains to prevent uncontrolled spilling;
- Other.

Given the high water quality within the test area any future development has to follow integrated approach and improved sectoral cooperation. Thus, in addition to before mentioned measures, that are technical some of non-technical measures should be considered to prevent water quality in the future. Following institutional and other measures [6] that contribute to sustainable development with respect to water quality, land use changes and climate change are:

- Land management policy of Montenegro;

- Strategy for food production and development of rural areas;
- Long-term program for development of forestry;
- Integrated environmental protection in Montenegro with elaboration of cadaster of environmental polluters (air, water and land);
- Protection and use of waters with elaboration of cadaster of sanitary zones for protection of water springs;
- Elaboration of the management program for urban cores protected by national legislation;
- Program of vitally developed towns and settlements in Montenegro;
- Spatial and urban norms and standards for equipment of settlements in Montenegro;
- Project for reform of system for construction land use;
- Harmonization of legislation in the field of spatial and urban planning, environmental Protection and construction of facilities in accordance with the EU regulations;
- Study of urban agglomerations, as a base for settlement determinations, where the waste water treatment facilities should be built,
- Research of spatial factors of Montenegro and research of measures for planning direction of development of special areas (borders, hills, mountains, etc.);
- Research of water supply in pasture areas (karst);
- Elaboration of methodology for monitoring and evaluation of realization of the Spatial Plan of Montenegro;
- Evaluation of environmental capacities and spatial sensitivity of Montenegro, with elaboration of the map of ecological potential of Montenegro with elements of ecological limitations and conflicts and the map of ecological risks with elements of ecological endurance in the existing and future (projected) conditions;
- Research for the needs of use and management of water resources;
- Research of basic geological, hydro-geological, engineering-geological, geomorphologic, conditions and development of maps.

6. CONCLUSIONS

Based on results presented here and studies and reports used in water quality assessment for Test Area Nikšić water has good quality, in generally. However, some triggers should not be neglected. With respect to water quality within the test area there are impacts that should be addressed given the land use. At the present, the drinking water sources have high quality with less than 10 % of monitored data above MAC during the heavy rainfall events. Thus need for more comprehensive study with respect to extreme rainfall events exist.

According to CORIN Land use maps for 2006 and 2012 there is no significant changes in land use practices. However, there is evidence that percentage of burned areas increase after 2006 very likely due to temperature increase and precipitation decrease during the summer season. Thus, future land use planning should seriously consider projected changes in average values for temperature and precipitation within the test area.

Management of diverse waste should be in a proper way to protect high quality of drinking water. Moreover, integrated approach and integration of responding measures with respect to land use changes, spatial planning, forest management, water resources management etc., would sustain water quality at the present level in the future.

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Estimation of CC induced land use changes and the impact on water quality on test area Nikšić, Montenegro – 19/11/2015

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DRINK ADRIA

Adriatic IPA Cross Border Cooperation 2007-2013

The project is co-funded by the European Union, Instrument for Pre-Accession Assistance

Estimation of climate change induced land use changes and the impact on water quality on test areas (Drini Basin)

Water Supply and Sewerage Association of Albania (SHUKALB)

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Date last release	24/6/2015
State of document	Final

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1. INTRODUCTION

Post-socialist transitions in Eastern Europe have focused on the establishment of private property rights as the cornerstone of a market economy, often to the exclusion of other aspects of rural livelihoods. Upon the demise of socialism in 1991 Albania implanted a radical land reform, redistributing formerly collective land on an equal per capita basis, leading to drastic change s in land use. The Albanian case is illustrative, due to the nature of land reform, and the preponderance of rural poverty. After the collapse of socialism, Albania instigated a radical and unique land reform in July 1991 by redistributing virtually all agricultural plots on an equal per capita basis to former farm workers in the collective system. Each family received an allotment of land proportional to their household size, including the elderly and small children. Before the transition, Albania was primarily an agricultural country; one third of gross domestic product (GDP) came from agricultural production during the nineties (World Bank 2006), and 55 percent of the population was employed in agriculture (FAO 2006).

The immediate consequence of the transition was a sharp economic recession in 1991 followed by a slow recovery. The main objective of the proposed report is to identify the relationship between land reforms, land tenure in the dynamics of land-use and land-cover change in Albania in the framework of the environmental consequences and policy response. The report provides a conceptual framework for understanding the relationship between land tenure, land use and land reform in the environmental consequences in Albania during the post socialist period. A systems approach is used to describe land use changes in Albania, addressing the complex and dynamic nature of the relationships among the subject matter areas. Analysis of property relationships therefore includes attention to various kinds of social actors recognized to take part in property relationships; material and cultural goods considered as valuable; and, different types of relationships, often expressed in terms of rights and obligations.

2. ANALYSIS OF THE ACTUAL LAND USE ON TEST AREAS (USING CORINE LAND COVER-CLC, SPATIAL PLAN OR/AND OTHER)

For each piece of land, individuals choose a type of use from which they expect to derive the most benefits in the context of their knowledge, the individual's household, the community, the bio-physical environment and the political structure to which the individual may be subject. These choices vary in space and time resulting in a spatial pattern of land uses.

In Albania, the smallest spatially explicit land unit that one can define and subject to a particular use coincides with the land parcel unit of the multi-purpose cadaster. This legal unit, at which digital data is available, has been adopted as the basic unit for the data modelling and the land-use change analysis.

The use of cadastral information for urban planning is an established practice, whereas the use of the cadaster for rural land-use planning is less common. The analysis at the spatially explicit detailed level may show the variability at the level of each cadastral zone while the aggregated level of commune may show patterns that remain invisible at the detailed scale, and vice versa. The aggregated level of the commune is important in the land-use policy and planning process while the cadastral parcel unit is a level that corresponds with the decisions made by the individual landowner or land user. It should be clear though, that such decisions may be L.J.M. Jansen, G. Carrai and M. Petri, 2005. Land-use change dynamics at cadastral parcel level in Albania 3/34

2.1 The geo-database, data model of land-use change

The geo-database constructed uses CASE Visio and ArcInfo UML diagrams in order to organise the objects and feature classes of the Information System comprising data sets structured according to the European Environmental Agency's INSPIRE (Infrastructure for Spatial Information in Europe) initiative that coordinates and develops agreed rules and standards to facilitate data harmonisation processes and to ease the access to environmental spatial information (Figures 1 and 2).

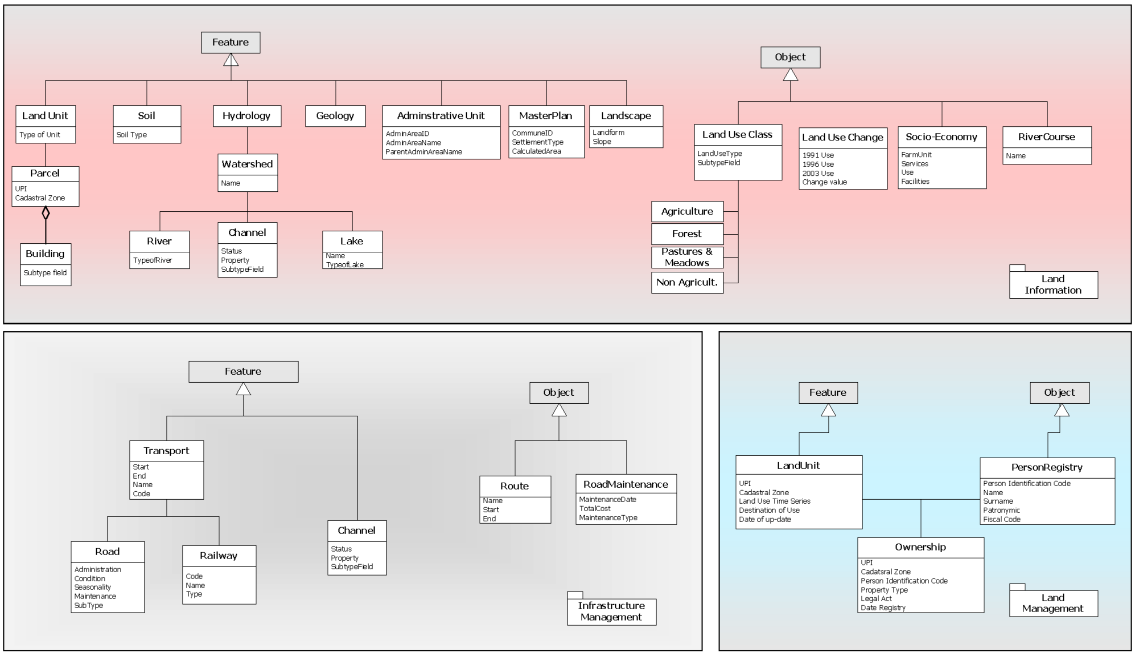

Figure 1. *Data model for the Land Use Policy II project geo-database [1]*

An object-oriented approach has been followed in the developed land-use change application that puts each cadastral parcel unit of 2003 in relation to its parent cadastral parcel unit in 1991 and 1996 of which the land uses are known using the relation.

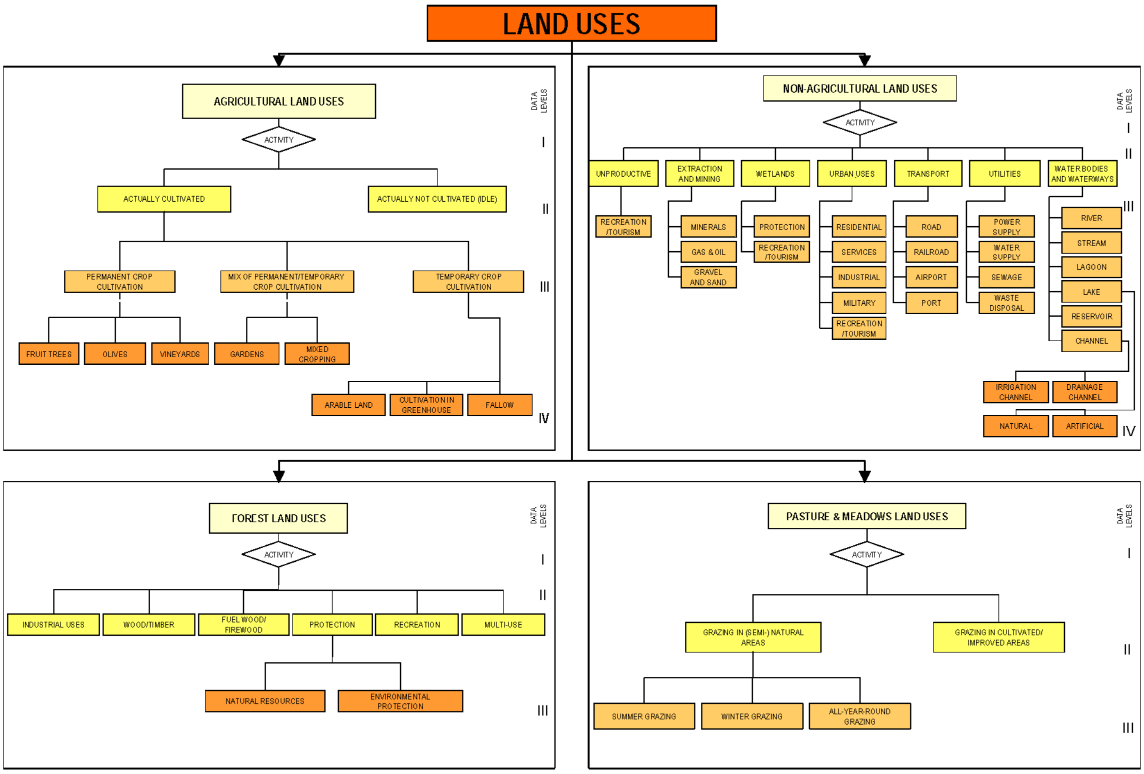

Figure 2. *Overview of the LUISA legend with the four main categories “Agricultural”, “Forests”, “Pasture and Meadows” and “Non-agricultural” land uses [1]*

The object-oriented approach in information systems is defined as the “*collection of cooperative objects, treating individual objects as instances of a class within a hierarchy of classes*” . The parent-child relationships created facilitate the analysis of the spatio-temporal dimensions, i.e. area and perimeter over time, because with the usual GIS overlay method one will have dispersion of a class into other classes with no information in the database about the relationships related to this dispersion. The data model considers also the fact that sometimes a cadastral parcel changes land use as a consequence of the construction of a building (e.g., an area with vegetables and fruit tree cultivation in which a residential house has been built) in which case two types of information are stored (e.g., the “garden” representing a kind of peri-urban agriculture and the residential building), related to the group and its size the individual belongs to. Individuals interact to form groups and organise collective action (e.g., farmer associations).

In general, land registration and the cadastre should be seen as part of the process of natural resources planning and management. They deal with two of the world's major resources, i.e. land and information. Land information is necessary in many central and communal government activities. The registers may be used for land taxation, the rights over public utilities over private land or along public roads for facilities such as electricity and water may need to be protected, infrastructures need to be maintained and/or improved, restrictions may be necessary where misuses occur, etc. The multi-purpose cadastre should therefore be seen as an integral part of the land management system. It is therefore important to establish linkages with a wider range of land-related data, especially those on the environment. In this manner managing land and land information meet . Land cover shows a very dynamic behaviour in the different areas in Albania between 1990 and 2007. In the (Figure 3), the land use structure in Albania today is shown.

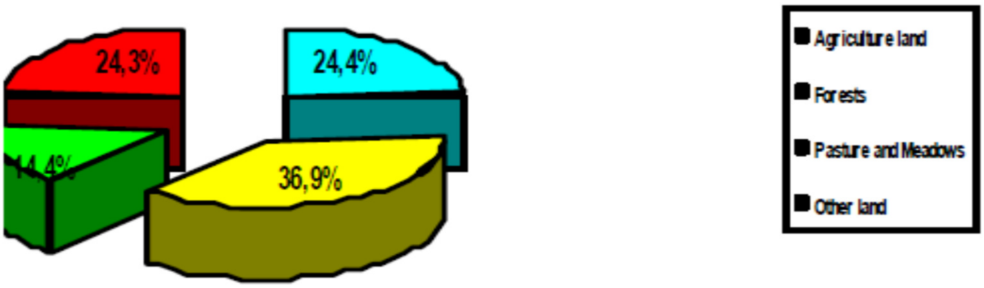

Figure 3. *Land use in Albania*

The main changes in land cover are forest regeneration, deforestation, and cropland abandonment which lead to a substantial reorganization of the landscape. Land change is highly heterogeneous across the four districts and across villages. A large share of the heterogeneity, particularly in shrub and grassland cover, cannot be explained by the variables hypothesized to influence land use. Nationwide land use in Albania changed little since the distribution of agricultural land to farm households in 1991. According to the MoAF (2007) the broad categories of arable land (24%), forests (36%), pastures and meadows (15%) and of other land (25%) remained stable between 1991 and 2006. According to preliminary results of the Albanian National Forest Inventory (ANFI), the first nationwide analysis of remote sensing data for the years 1991 and 2006, broad land-cover categories indeed changed relatively little. ANFI results for 2006 show cultivated area at 21% and forests cover at 32% (Figure 4).

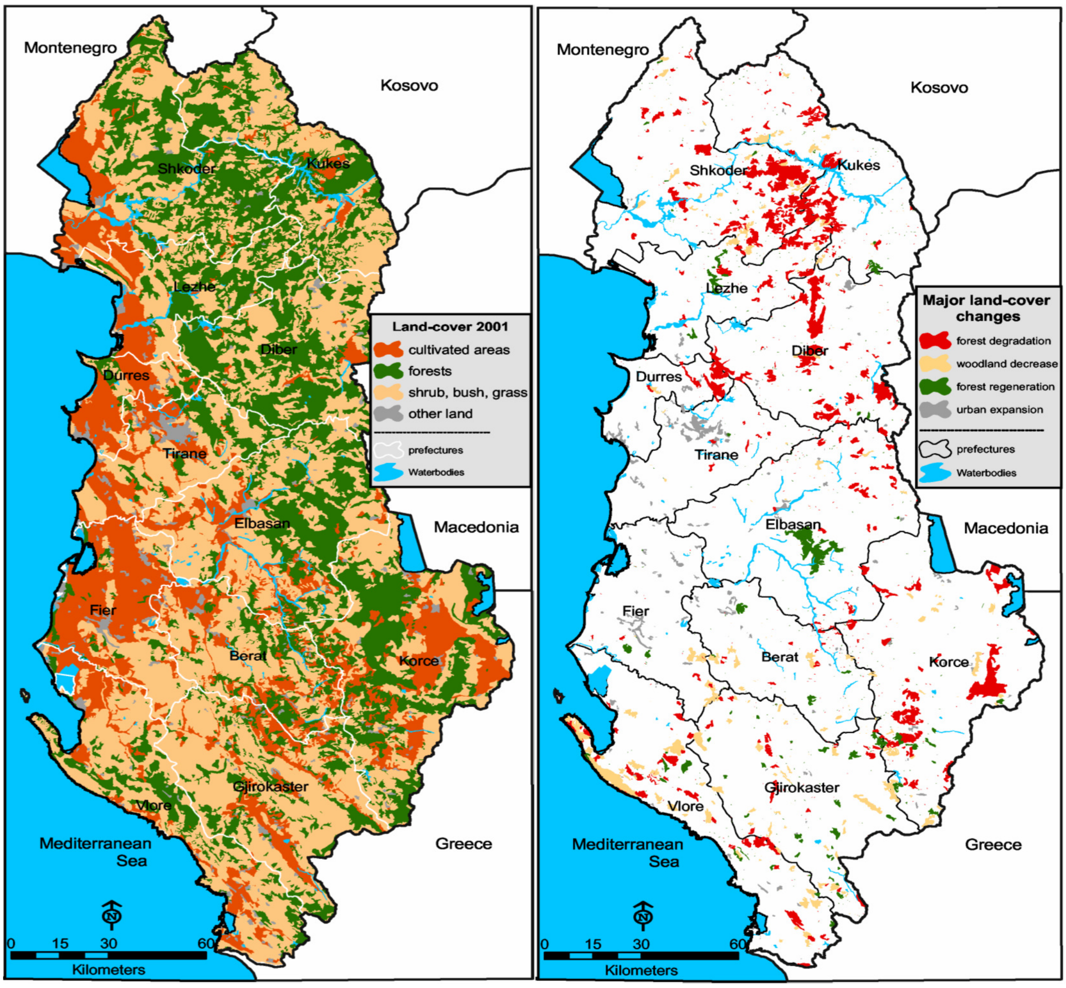

Figure 4. *Major land-cover modification, 1991, 2001, 2006*

3. IMPACT OF LAND USE ON WATER QUALITY FOR THE PRESENT/PAST STATE/FUTURE

Soil loss studies using watershed sediment assessment methods indicate that the river network transports in a year about 60 million tons of fine and coarse sediment, 1.2 million tons of organic materials and 170 thousand tons of N, P, and K salts. The environmental consequences of cropland abandonment are largely unknown. Nevertheless, research from other parts of Europe suggests that land abandonment can lower soil fertility, decrease biodiversity levels, degrade water ecosystems, and lead to a loss of cultural landscapes. An initial increase in landscape heterogeneity may be followed by later homogenization due to the decease of the aging population. Such a homogenization affects both the biological and scenic diversity of the land.

The statistical data shows that agricultural abandonment in Albania is strongly mediated by both the biogeophysical environment and transportation infrastructure. District level effects provide some evidence that abandonment is more likely in some regions than others, but were most likely in relatively remote areas, or in the presence of other economic opportunities, such as tourism. Interestingly, the importance of remittance income was not a significant correlate of cropland abandonment, perhaps because a low share of remittance income is channelled into agricultural investments. Forest-cover loss was highly sensitive to the time period. Forest clearing tended to shift from subsistence orientation in the first years after the collapse of socialism to more commercial extraction in later stages. Effects on biodiversity are of global significance as the research area is located within the Mediterranean Basin, which is recognized as a global biodiversity hotspot in terms of endemic flora and fauna species. On the other hand, land abandonment may also lead to increases in biomass, e.g., through an expansion of woodland and a regeneration of forest land, with positive effects on global carbon cycles and local hydrological cycles.

4. THE IMPACT OF CLIMATE CHANGE AND PLANNED DEVELOPMENT (SPATIAL PLANS) ON THE LAND USE IN FUTURE ON TEST AREAS

In general, predictions of climate change will lead to warmer and more variable weather in the DMRD area. Studies have aimed to elucidate how warmer temperatures, decrease in annual precipitation, increase of atmospheric concentrations of CO2, likely changes in sea level, and increase in extreme weather events, (including spells of very high temperatures, torrential rains and flooding, and droughts) may affect a) crop yields, and b) the economic costs of agricultural production. The following conclusions can be reached:

- Expected temperature increases are likely to hasten the maturation of annual crop plants, thereby reducing their total yield potential, with extremely high temperatures causing more severe losses;
- Climate change projections include an increased likelihood of both floods and droughts. Variability of precipitation - in time, space, and intensity - will make the agriculture in the area increasingly unstable and make it more difficult for farmers to plan what crops to plant and when;
- Higher temperatures and lower precipitation are likely to result in the spread of plant pests and diseases. Higher temperatures reduce insect winterkill, and lead to increased rates of development and shorter times between generations. Wet vegetation promotes the germination of spores and the proliferation of bacteria, fungi, and nematodes. Prolonged droughts can encourage other pests and diseases; -especially those carried by insects;
- Increased crop pests may necessitate intensified use of agricultural chemicals that carry long-term health, environmental, and economic risks.

Falls in crop yields will be exacerbated by an increase in prolonged periods of droughts, a lack of water availability and a drop in precipitation incidence, which will in turn be much more intense. More frequent occurrences of extremes, such as dry spells and heat waves, will contribute as well. Thus, as elsewhere in the Mediterranean countries, there is a need to invest in better irrigation systems, more balanced crop-rotation methods and crops better adapted to water and heat stress, and to maintain levels of soil organic matter. The expected impact of climate change on agriculture (Figure 5), will have an indirect impact on other sectors of the economy in the area that have some degree of dependency on agricultural production (e.g. tourism). The expected impact of climate change on agriculture will definitely have an indirect impact on other sectors of the economy in the area and tourism will be most probably one of highly affected. The region has become a popular tourist destination as a result of some unique environmental features, for example, the Patok lagoon. Since most of the food for the tourist facilities comes from the region and is based on organic farming, a change in the structure of the crops, yield and the phenological stages will affect the tourism industry.

Figure 5. *Agriculture areas that risks from flooding*

5. PROBLEMS OF SALT WATER INTRUSION

Freshwater inland resources can be contaminated due to the intrusion of saline water, both underground and on surface, increasing drought problems (e.g. experienced in 2003 in the southern region of the Venice lagoon), both for human use and agriculture production. Along the Adriatic and the Mediterranean, storm surge and saltwater intrusion into aquifers threaten parts of the Croatian, Albanian, and Turkish coasts. Problems of saline intrusion would be further exacerbated by reductions in runoff and by increased withdrawals in response to higher demand. Excessive demand already contributes to saline intrusion problems in many coastal areas of Italy, Spain, Greece and North Africa. The coasts have started to erode along almost the entire Adriatic coastline in Albania due to sea level rise. In some places the sea has advanced more than 50 m inland, destroying the coastal forests and vegetation, and increasing the salinity in the lagoons and fields near the coast. Sea level rise has wreaked havoc on the beautiful Mediterranean Pine forests that cover the Adriatic coast in Albania. Most of the trees that are found on the coastal margins are dying from increasing salinity. In other places, especially in villages near the coast, the salinity in the soil and in the water wells has increased significantly, damaging the small rural economies along the coast (4). Salt water intrusion due to sea-level rise is mostly a very slow process that may take several centuries to reach equilibrium. Even small rates of groundwater pumping from coastal aquifers are expected to lead to stronger salinization of the groundwater than sea-level rise during the 21st century.

Salt Water intrusion occurs in freshwater coastal aquifers where the density difference between fresh water and saline water causes the sea water to intrude in the freshwater aquifer. Saline intrusion can be detected by monitoring the amount of Cl-, K+, Na+, water conductivity and TDS in the coastal aquifer. According to EPA, to asses the presence of saline intrusion the electrical conductivity should be more than 0.8mS/cm and the Cl- concentration should be more than 24 mg/l. These two values indicate a possible salt water intrusion.. The saline investigation for this case study was determined by evaluated the distribution maps of Cl, Na+K and TDS (Figure 1, 2 and 3). These maps clearly illustrate that the concentration of these parameters increases towards the coast line of Durres. The highest value for Clconcentration is registered in Durres city (400mg/l in the period 1982-2001). Further analyzes of two time series data (Cl distribution map for the period 1982-2001 and 2010) shows that the amount of Cl- ions has increased toward the centre of the region. The main source of this intrusion is the urbanization of the area and the high demand of freshwater. The groundwater is the primarly in Durres City for drinking, domestical and irrigation purpose. The fresh water is withdrawn at a faster rate than it can be replenished. 0 2 4 6 8 10 12 1 NH4 concentration (mg/l) Stations Fig. NH4 Concentration Ibe Ndroq Sallmone Brari Ishmi Gjola Lana Rinasi Papër Labinot Rrogozhinë.

Another reason of saline intrusion is the poor management of the river sediments that are discharged in Durres city. Erzeni and Ishmi River's sediment are highly exploited for construction materials. Through past ten years, due to this situation, the sea line has progressed towards the land, and most possibly intruded to the ground water resources. Immediate measurements should be taken to control and improve the current situation. A recommended solution is to build injection wells. These injection wells should be placed strategically such that the injected freshwater can produce barriers to prevent further intrusion of the salt water.

6. MEASURES TO IMPROVE THE QUALITY OF DRINKING WATER ON TEST AREAS

Benefits of improved drinking water will accrue (i) to households that have a new connection to water supply, and (ii) to households that already have water supply, but are guaranteed better quality water. The actual connection rate in the year 2005 is 72% instead of the 82.5%, which was set as an objective for the year 2004. Given the rather optimistic objective, it was preferred to apply an experts' estimate of 5% increase to calculate future connection percentages. Adding the 5% estimate of new connections to the current connection rate of 72% yields a total share of 77% which can be assumed to benefit from quality improvements of drinking water. The coastal area and the inland lakes have a big potential for tourism in Albania. The water quality of the lakes and of most of the coastal area is good, except for Durres area (Golem, Shkembi I Kavajes, Durres, Currila). This is caused by discharge of urban waster water without treatment in this area. Based on the Water Supply and Sanitation Strategy, approved in 2003 by Council of Ministers, the aim is to treat 25% of the urban wastewater in 2012. According to the local experts, the improvement of the river water quality will result in increase of the number of local tourists. The total population was assumed to benefit from the bathing water quality improvement of inland waters, through a reduction of the nitrates and phosphates load discharged. The population of the coastal counties and the tourists visiting seaside resorts were assumed to benefit from the coastal bathing water quality improvement. 60% of the rivers in Albania belong to quality class III and 30% of the rivers belong to quality class IV to V. As it was not possible to assess what the precise effect of the implementation of the various water directives (mainly Urban Waste Water Directive, the Nitrate Directive and the Dangerous Substances Directive) would be on river quality, it has been assumed that the full implementation of the various directives will have the effect that the real water quality in all watercourses will be such that the designated Water Quality Objective class I or II will be met. This seems a reasonable assumption, as the main cause of not meeting the WQO is the discharge of various substances by sewage and industrial discharges and these discharges will be dealt with by the directives. The total benefits of clean drinking water are estimated to amount to around 44.1 million EUR/year upon full compliance.

There are about 500 monitoring points at the distribution water supply system in Albania in the urban area. For the studied period (2000- 2005), the average of bacterial pollution is about 4.015 % of water samples analyzed. Between May 2004 and May 2005, the IPH has reported testing of 3,801 samples, out of which only 15.8 percent do not comply with national standards. The percentage of the population supplied with safe drinking water is estimated to be 96.72% (data of 2005). Some years ago the Institute of Public Health has organized a programme for the monitoring of nitrates in drinking water, controlling the water sources which are used for water supply. The water samples has been analysed in a laboratories of the Institute of Public Health. In 1998, the IPH controlled the ground water quality in some areas where intensive agricultural activity was assumed. After the analyses the level of nitrates was under the standard, negligible. There were no nitrates in spring water, because of the lack of agriculture activity in those areas. The level of pesticides in spring water was below detection limit.

7. CONCLUSIONS

The commitment by the Albanians to abandon five decades of state ownership and control and the steady progress made in completing substantive and procedural privatization laws are laudable. In this report, we analyzed the impacts of heterogeneous landuse incentives on land cover which allow us to examine evolving land-cover transitions following the large-scale policy shifts immediately following the transition and the subsequent realignment of land-use incentives due to land reform. The agricultural abandonment in Albania is strongly mediated by both the biogeophysical environment and transportation infrastructure. District level effects provide some evidence that abandonment is more likely in some regions than others, but were most likely in relatively remote areas, or in the presence of other economic opportunities, such as tourism. Forest-cover loss was highly sensitive to the time period. Forest clearing tended to shift from subsistence orientation in the first years after the collapse of socialism to more commercial extraction in later stages. The abandonment of large areas of cropland partly reflects the adjustment of the rural sector to the evolving market conditions and leads to a concentration of cultivation on more productive areas. In Albania, further abandonment of cropland may continue as returns from internal and international migration will become the most important livelihood strategy for the younger generation and as many of the remaining elderly farmers decease. Future abandonment in Albania may be aggravated by the projected reductions in crop productivity caused by high temperatures and drought in a region already vulnerable to climate variability. The impact of the successional vegetation on biodiversity, soil conditions, or the carbon sequestration potential depends on the prevailing natural conditions and will therefore vary across regions. Rural landscapes will continue to evolve and change. Land reforms, particularly the establishment of private property rights, are based on the logic that efficiency gains in agricultural production will occur as a result.

Nevertheless, impediments to a fully functioning land market remain. Issues such as restitution and compensation, illegal occupation of land and other land disputes continue to cloud legal title. Rural condition throughout the region in Albania, have deteriorated during the transition period. There is growing inequality between rural and urban areas, with most of the poor now living in rural areas. These areas are characterized by declining populations that are increasingly represented by women and the elderly. Rural infrastructure has often deteriorated considerably and many rural roads, irrigation systems and erosion control measures are in poor condition. An effective incentive to production and conservation of land and water resources in Albania is the right to secure tenure to land and other natural resources. Security of tenure is a major concern of the land user in deciding whether or not to invest in measures to promote conservation or sustainable production on a long-term basis. Land rights must be robust, allowing the user effective control over the resource, and the right to exclude others who might adversely affect its management. An important part of Albanian government policy should be to reduce disparities between urban and rural areas by improving the rural situation.

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Estimation of climate change induced land use changes and the impact on water quality on test areas (Drini Basin) – 24/6/2015.

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The project is co-funded by the European Union,
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WP4.3 Report:

Estimation of Climate Change Induced Land Use Changes - Impact of land use changes on water quality on test areas: Corfu, Greece

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Volos, 2015

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Date last release	17/6/2015
State of document	FINAL

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1 INTRODUCTION

Corfu Island is situated in the north part of the Ionian Sea and the whole Corfu prefecture (including Paxi and Othoni islands) has an area of 641 Km^2 while the island of Corfu only has an area of 591 Km^2. The population of the whole prefecture is 111,975 people (2001 census) [1] and 104,371 (2011 census). The island is characterized by mountainous terrain especially in its northern part. The cultivated area is dominant in the island covering 83% of the area. The main crops are trees (olive groves). The total cultivated area of the whole Corfu prefecture (including the neighborhood islands) is 241,884 acres. The coastal areas' length is 217 Km. During the decade 1991-2001 the population increased by 4% only while in the next decade it decreased by 6.8%. The island's population decreased by 5.4% during 2001-2011. The island's economy is based on the tertiary production sector mainly due to the touristic development.

2 ANALYSIS OF THE ACTUAL LAND USE ON TEST AREAS (USING CORINE LAND COVER-CLC, SPATIAL PLAN OR/AND OTHER)

2.1 Analysis of actual land use on Corfu using Corine Land Cover

Corine Land Cover programme provides data regarding the land use cover in Corfu island in 2000 [2] (Tables 1;2 & Figures 1&2). The dominant land use is agricultural areas (84.04%) followed by forests and semi-natural areas (9.52%), artificial surfaces (5.24%) and surfaces under water (1.2%). The main part of agricultural areas is covered by permanent crops. Urban areas cover 4.84% of the total area of the island.

Table 1: Land uses in Corfu island in thousand acres and % of total area [2]

	Total area	Area under cultivation and fallow land	Pastures	Forests	Area under water	Areas occupied by the locality (buildings, roads, etc)	Other areas
%		78,95	5,08	9,01	1,20	5,22	0,52
TOTAL (thousand acres)	591,5	467,0	30,1	53,3	7,1	30,9	3,1
Ag. Georgios	38,4	34,5	0,0	2,4	0,0	1,4	0,1
Achilia	47,6	40,7	0,0	3,5	0,7	2,7	0,0
Esperia	54,4	51,5	0,0	0,2	0,0	2,7	0,0
Thinaliou	78,2	47,2	12,4	14,8	0,9	2,6	0,3
Kerkyra	41,3	30,8	0,0	0,1	0,2	9,6	0,6
Korission	27,2	26,2	0,0	0,0	0,0	1,0	0,0
Lefkimmi	50,8	45,6	0,0	1,9	1,2	1,6	0,5
Meliteion	67,5	54,7	0,4	3,9	4,1	2,8	1,6
Palaiokastritsa	48,3	39,8	1,3	6,5	0,0	0,7	0,0
Parelion	48,6	44,9	0,0	2,0	0,0	1,7	0,0
Feakon	54,9	34,7	4,2	13,3	0,0	2,7	0,0
Kassopeon	34,3	16,4	11,8	4,7	0,0	1,4	0,0

Table 2: Land uses in Corfu Prefecture and Corfu Island in thousand acres and % of total area [2]

Geografic Regions and departments	Number of Municipalities / Communes	All areas	AGRICULTURAL AREAS						FORESTS AND SEMI - NATURAL AREAS				SURFACES UNDER WATER			ARTIFICIAL SURFACES				
			Arable land	Permanent crops	Pastures - transitional wood land / shrumb	Pastures - shrumb and / or herbaceous vegetation associations	Rastures - Open spaces with little or no vegetation	Heterogenous agricultural areas	Forests	Transitional wood land / shrumb	Shrumb and / or herbaceous vegetation associations	Open spaces with little or no vegetation	Inland waters	Inland wetlands	Coastal wetlands	Urban fabric	Industrial and commercial units	Transport units	Mine , dump and construction sites	Artificial, non agricultural vegetated areas sport and cultural activity sites
CORFU PERFECTURE (Thousand acres)	16	639.9	28.8	332.4	0.0	29.7	0.4	106.1	3.2	6.8	55.3	38.9	4.1	0.2	2.8	28.8	0.8	0.8	0.1	0.7
CORFU ISLAND (Thousand acres)		591.5	28.8	332.4	0.0	29.7	0.4	105.8	0.7	4.0	48.6	3.0	4.1	0.2	2.8	28.6	0.8	0.8	0.1	0.7
CORFU ISLAND (%)			4.87	56.2	0	5.02	0..7	17.89	0.12	0.68	8.22	0.51	0.69	0.03	0.47	4.84	0.14	0.14	0.02	0.12

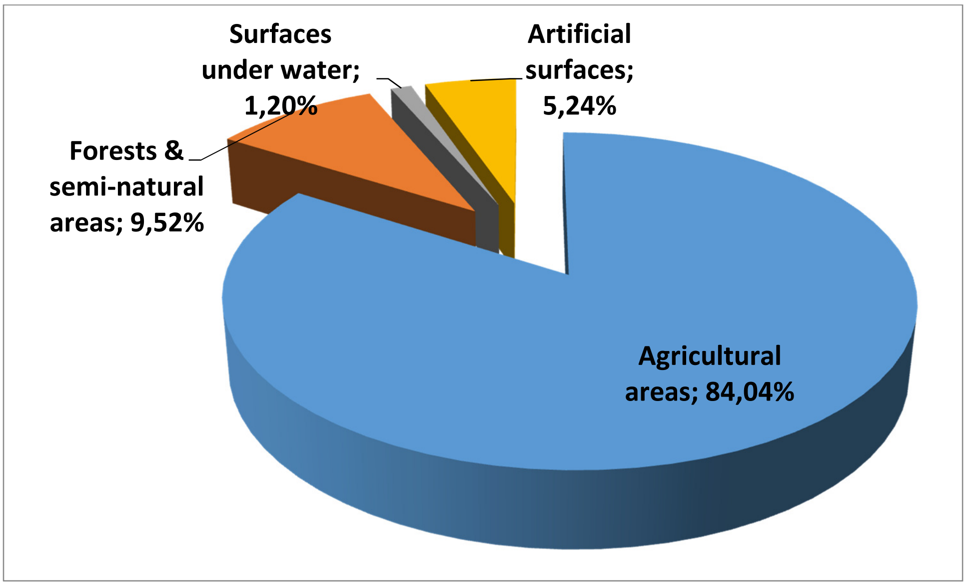

Figure 1: Land uses in Corfu Island as % of total area [2]

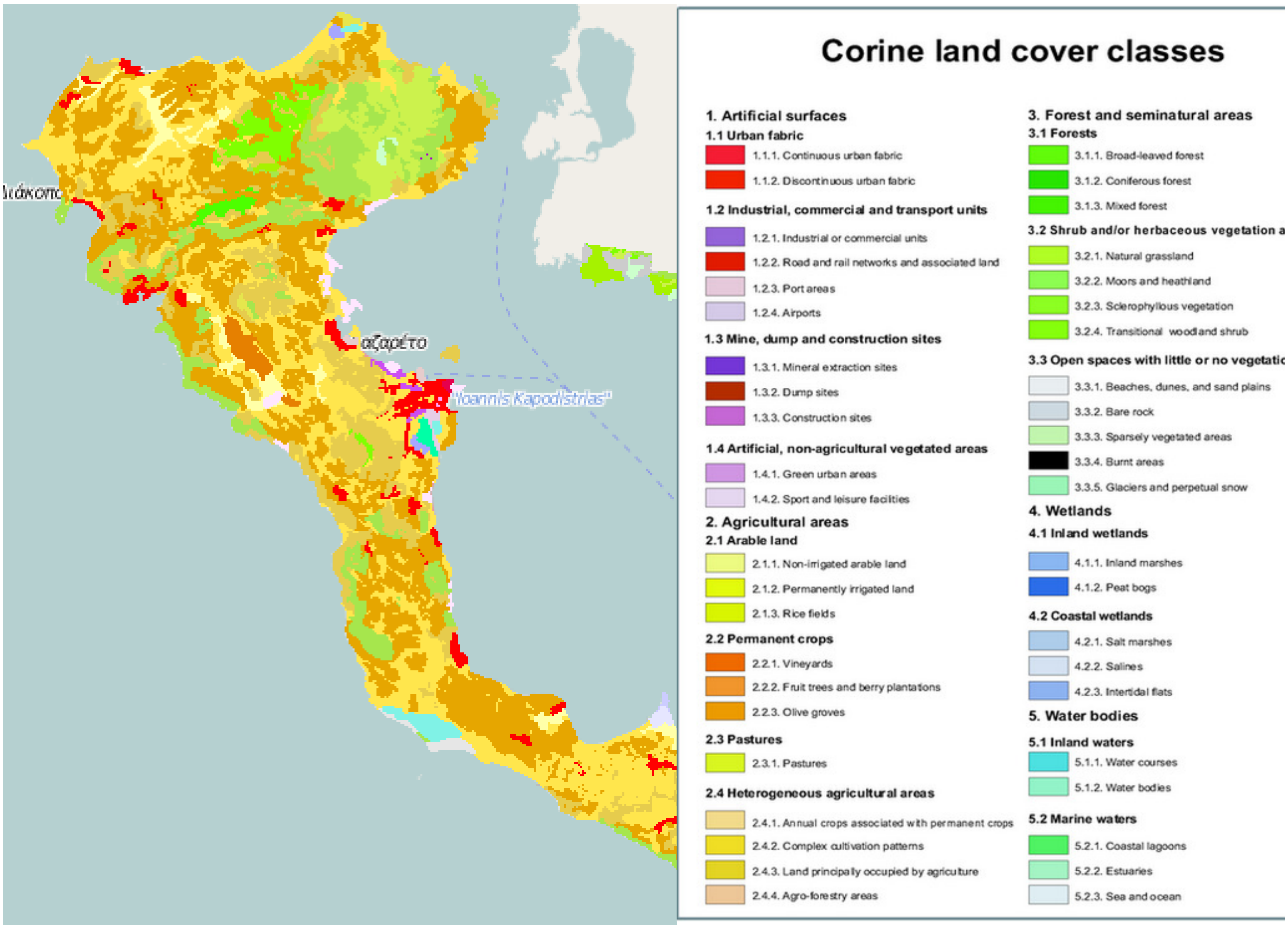

Figure 2: Land uses in Corfu Island from Corine Land Cover [2]

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2.2 Analysis of actual land use on Corfu using the River Basin Management Plan

Based on the River Basin Management Plan of Epirus the detailed analysis of land uses in each aquifer is presented [3].

2.2.1 Limestone system of Corfu Island GR0500010

A part of the water body is agricultural land while the rest of it is forest area scattered with settlements. There are no specific problems of diffuse or point pollution sources on the surface of the water body. This body is used for water abstraction used for human consumption and it is part of the protected areas registry [3].

The chemical status of the aquifer is assessed and found to be good (coloured in green in Figure 3) [3]. There is only point pollution diagnosed. The absence of significant point pollution sources, the limited area of the agricultural activities and the mountainous terrain are factors contributing to the good status of the groundwater. The increased values of chlorides, conductivity and sulfates are connected in most of the cases with values of the natural background. The water abstractions increase the chlorides concentrations [3].

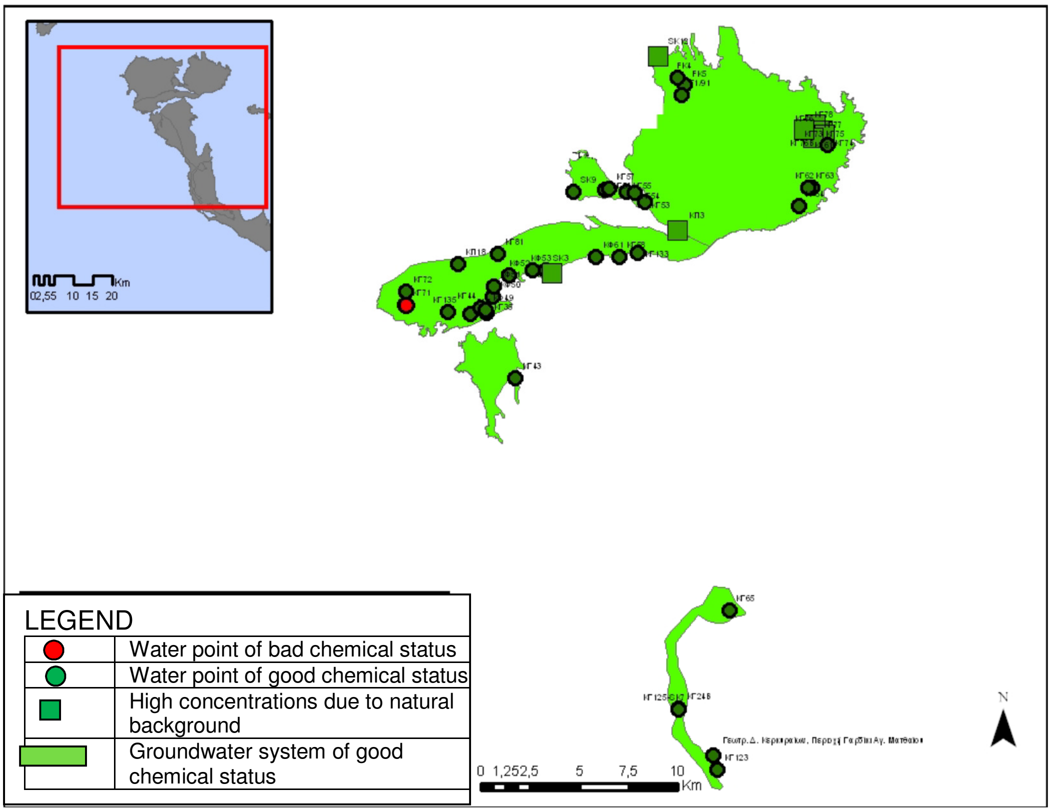

Figure 3: Chemical status of the GR0500010 system [3]

2.2.2 Ternary breccia system of Corfu Island GR0500020

Part of the water body is covered by agricultural land, while the rest is forests land with intense urbanization. The water body is used for water abstraction for drinking purposes [3].

The chemical status of the water body is assessed and found to be in a good status (coloured in green in Figure 4) [3]. Only point pollution has been identified. Although the extensive residential development, the absence of point sources of pollution and the limited area of agricultural activities, are the main factors contributing to the good chemical status of the groundwater of the system. The increased values of chlorides, conductivity and sulphates is connected to the values of the natural background [3].

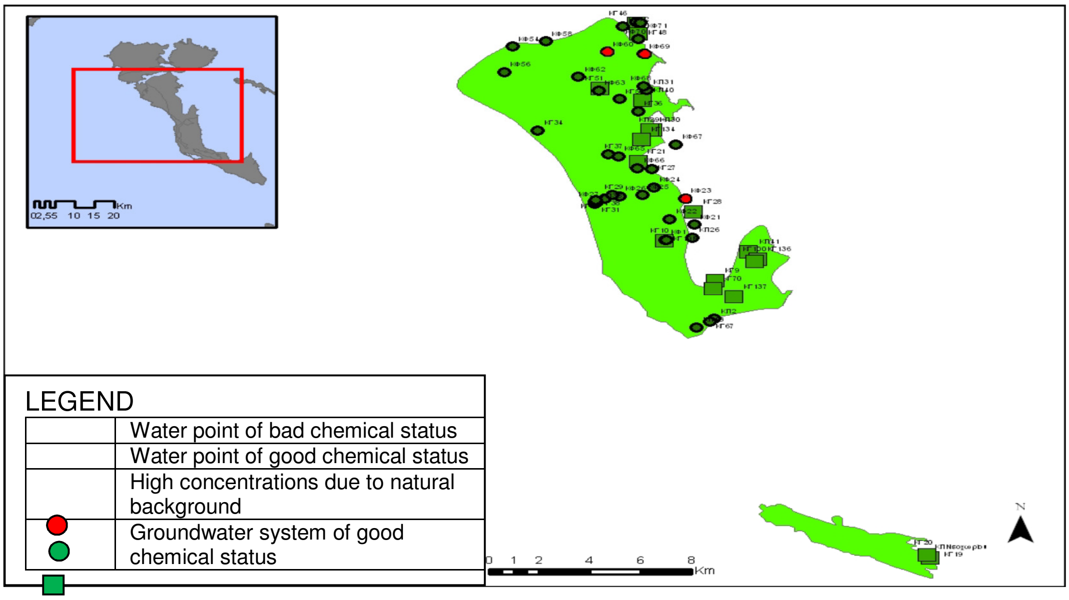

Figure 4: Chemical status of the GR0500020 system [3]

2.2.3 Granular aquifers system of Corfu Island GR0500030

A significant part of the water body is agricultural land. The water body receives diffuse and point pressures including not only the cultivated crops but also oil mills etc. The water body is used for water abstraction for human consumption.

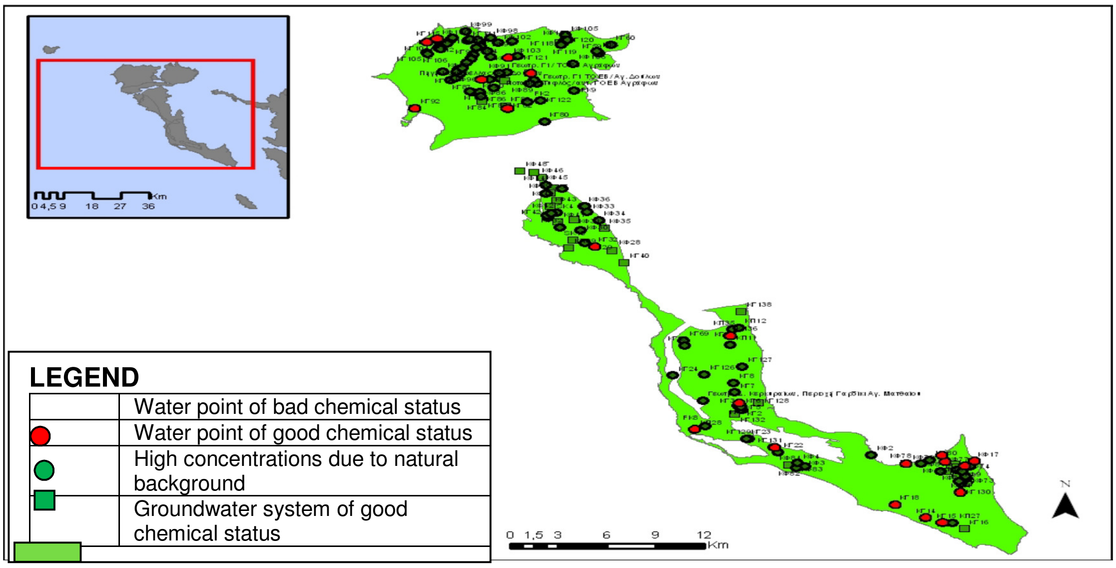

Figure 5: Chemical status of the GR0500030 system [3]

The assessment showed that the water body is in good chemical quality status (coloured in green in Figure 5) [3]. Pollution of anthropogenic origin is diagnosed in the groundwater body. Although there are point and diffuse pollution sources, there is not related pollution charges in the groundwater. Only locally increased values of sulphates of natural origin are met. Locally there are increased concentrations of nitrates, chlorides and conductivity because of anthropogenic activities and overexploitation. The monitoring points with increased concentrations due to anthropogenic pressures does not exceed 13% of the total sampling points [3].

3 IMPACT OF LAND USE ON WATER QUALITY - DPSIR APPROACH FOR THE PRESENT/PAST STATE

The identified pressures on the water bodies of the test area include point pollution sources (wastewater treatment plants, industries, landfills and unmonitored waste disposal sites) and diffuse pollution sources (agriculture, livestock farming, urban waste) and other pollution sources (fish farming).

3.1 Point Pollution Sources

3.1.1 Wastewater Treatment Plants

There are 7 wastewater treatment plants in Corfu island discharging in the sea (6 of them) and in a river (1 of them) (Table 3 & Figure 6) [4]. The most important pressure is caused by the wastewater treatment plant (WWTP) serving equivalent population of more than 10,000 people (WWTP of Corfu town). Table 4 shows the aggregate status of the town served with WWTPs and the pollutant loads [4]. The River Basin Management Plan also provided data for settlements not connected to WWTP. In Corfu island there are no such settlements.

Figure 6: WWTPs in Corfu island [4]

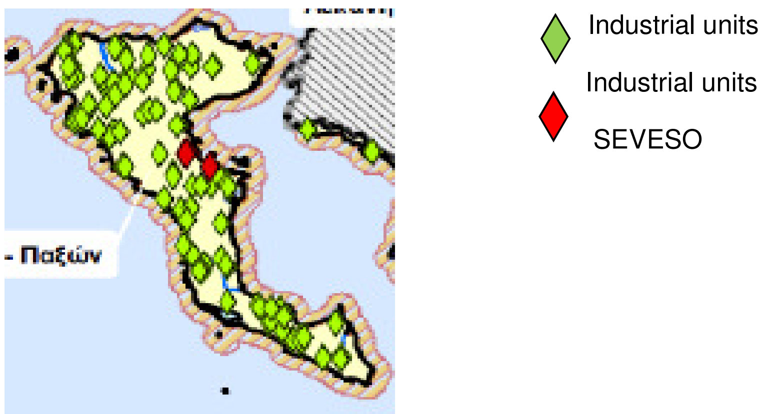

Figure 7: Industries in Corfu island [4]

Table 3: WWTP characteristics in Corfu Island [4]

WWTP	Population served (ep)	Current operating conditions (ep)	Type of treatment	BOD load (tn/year)	SS load (tn/year)	N load (tn/year)	P load (tn/year)	Receiving water body
Benitses	13,500	1,200	2	3.5	4.7	4.2	0.9	Sea
Kinopiaston	5,500	2,600	2	3.8	4.9	9.1	1.9	River
Melitieon	10,000	8,000	2NP	17.5	21.9	7.0	1.5	Sea
Agios Stefanos		120	2	0.3	0.3	0.4	0.1	Sea
Paleokastriton	1,500	1,500	2NP+Distillation	1.6	0.4	0.6	0.1	Sea
Corfu	69,674	47,000	2N	102.9	128.7	41.2	34.3	Sea
Agios Markos		8,600	2N	18.8	23.5	7.5	6.3	Sea

2: secondary treatment
2N: secondary treatment with Nitrogen (N) removal
2NP: sedondary treatment with Nitrogen (N) and Phosphorus (P) removal
+ Distillation: further treatment for the removal of suspended soils (SS)

Table 4: Operating WWTP and pollutant loads in Corfu Island [4]

	WWTP	**Without WWTP**				
	Types of Settlements		**Types of Settlements**			
	A B	C	A	B	C	
	>15,000 permanent population (pp) in sensitive receiveing body	>10,000 permanent population in normal receiveing body	10,000>pp>2,000 in normal and 15,000>pp>2,000 in sensitive receiveing body	>15,000 permanent population in sensitive receiveing body	>10,000 permanent population in normal receiveing body	10,000>pp>2,000 in normal and 15,000>pp>2,000 in sensitive receiveing body
Corfu – Paxi GR34 Basin	0	1	2	0	1	0

	WWTP	**Current Operating Conditions (ep)**	**Pollutant Loads (tn/year)**			
			BOD	**TSS**	**TN**	**TP**
Corfu – Paxi GR34 Basin	7	69,020	148.5	184.4	70.1	45.0

3.1.2 Industries

In Corfu prefecture there are 121 industrial units recorded in the River Basin Management Plan [4]. 82% of them are oil mills (Figure 7). Table 5 provides the data for the industrial activity in the basin of Corfu – Paxi [4].

Table 5: Industrial units pollutant loads in Corfu –Paxi Basin [4]

	Total Units	**SEVESO units**								
Corfu – Paxi GR34 Basin	121	3								
	Total Units	**Units drained in WWTP**	**Pollutant Loads (tn/year)**							
			BOD	**TSS**	**TN**	**TP**	**Fats, oils**	**Phenols**	**Sulphides**	**Cr**
Corfu – Paxi GR34 Basin	121	2	2172.5	9576.4	2.0	0.4	3.4	0	0	0

3.1.3 Livestock farms

There are no livestock farms recorded in the Corfu-Paxi basin [4].

3.1.4 Mining – Quarries

There are no mining or quarries activities recorded in the Corfu-Paxi basin [4].

3.1.5 Sanitary Landfill

The sanitary landfill of Central Corfu serves the central and northern part of the island (Table 6 & Figure 8) [4] . A second sanitary landfill is expected to operate in the Southern Corfu (its construction is concluded).

Table 6: Landfills characteristics in Corfu Island [4]

Name	**Municipality**	**Operating condition**	**Area (m^2)**	**Equivalent population served in 2010**	**Annual quantity of waste (tn/year)**	**Treatment type of leachate**	**Annual production of leachate (m^3/year)**	**Receiving water body**
Landfill of Central Corfu	Corfu	Operating	100,000	166,874	67,000	Tertiary	130,435	Irrigation & recirculation
Landfill of Southern Corfu	Leykimmeon	To be operable soon	16,840	38,854	15,600	Secondary	16,840	Irrigation & recirculation

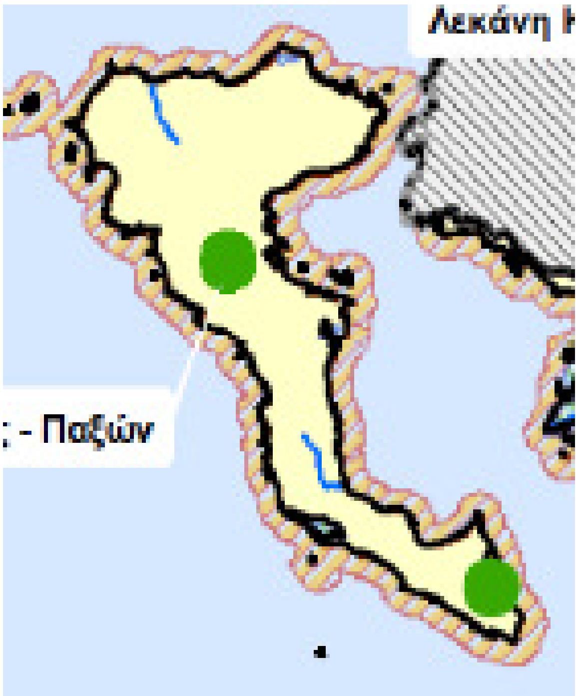

Figure 8: Landfills in Corfu island [4]

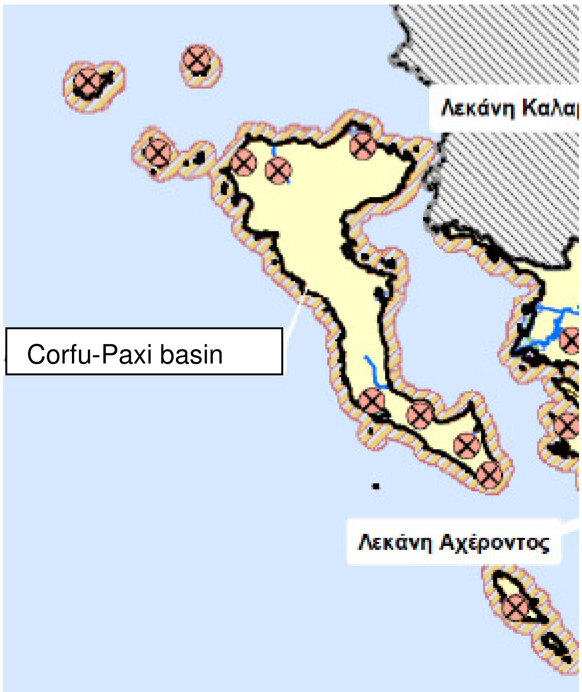

Figure 9: Uncontrolled waste disposal sites in Corfu Perfecture [4]

3.1.6 Uncontrolled Waste Disposal Sites

The River Basin Management Plan recorded 11 uncontrolled waste disposal sites in Corfu Perfecture (including the islands of Paxi and Othoni) [4] (Figure 9). 4 of them are active (in the 4 islands namely Paxi, Othoni, Erikouses and Manthraki) while the rest are closed but not restored [4].

3.2 Diffuse Pollution Sources

3.2.1 Agriculture

The land uses per river basin in Corfu island is identified in the River Basin Management Plan based on Corine 2000 [4] (Figure 10).

Agriculture is identified as a diffuse pollution source. In Corfu – Paxi basin the annual nitrogen load drained in surface towards the water bodies is estimated to be 24 tn with special annual charge per sub-basin from 1.7 to 2.2 kgN/ha [4] (Table 7 & Figure 11). Respectively the annual phosphorus load is estimated to be 8.5 tn with special charge per sub-basin of 0.55 to 0.74 knP/ha [4] (Table 7).

Table 7: Special Nitrogen and Phosphorus loads per river basin in Corfu island [4]

	Special Nitrogen load (kg/ha/year)	**Special Phosphorus load (kg/ha/year)**
Potami basin	1.7	0.55
Messagis basin	2.2	0.74
Fonissa basin	1.9	0.72

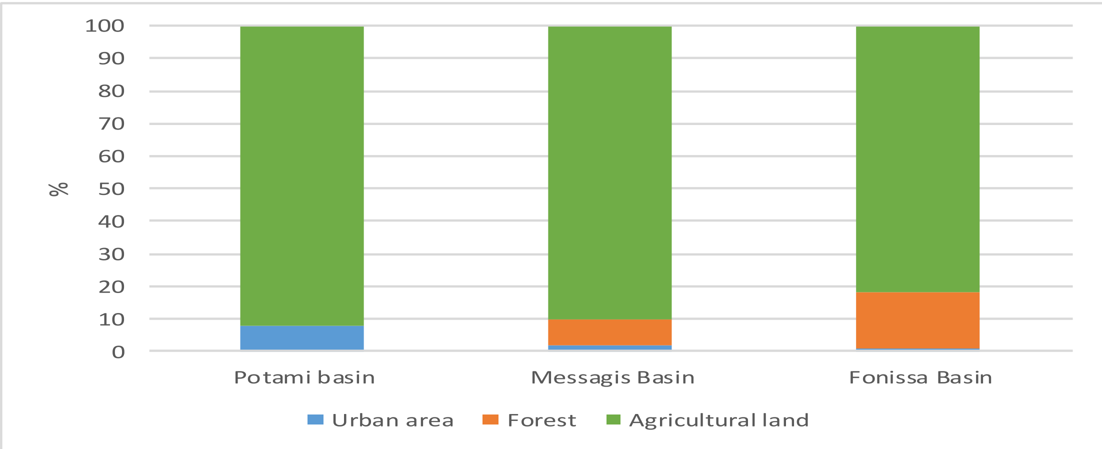

Figure 10: Land uses per surface water body in Corfu island [4]

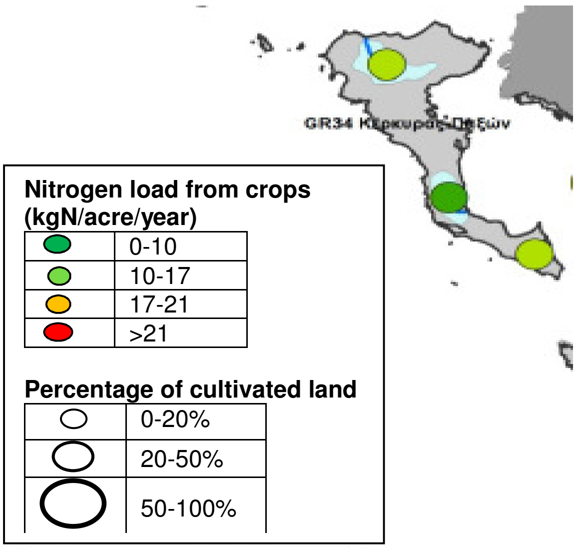

Figure 11: Nitrogen load from agriculture in river basins in Corfu island [4]

3.2.2 Livestock farming

Another diffuse pollution source is the livestock farming. The breeding animals include sheep and goats, poultry, cattles and pigs. Each kind of animals produces pollutant loads. The loads drained in surface bodies are estimated for the Corfu-Paxi basin in the River Basin Management Plan (Table 8; Figure 15) [4].

Table 8: Pollutant loads from livestock farming drained in surface bodies in Corfu island [4]

	BOD (tn/year)	**N (tn/year)**	**P (tn/year)**
Sheep and goats	10	5.1	0.24
Poultry	8	2.2	0.12
Cattles	3	0.8	0.01
Pigs	0	0.1	0.00
OTAL	**22**	**8.2**	**0.38**

The more intense livestock activity is identified in the sub-basins of Mesaggis and Fonissa rivers where most of the pollutant loads end up [4] (Figures 12-14).

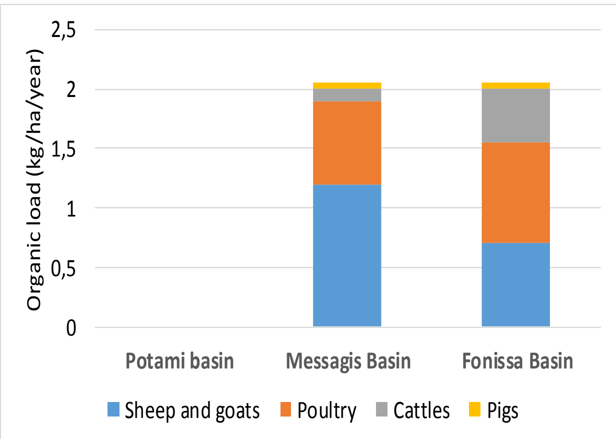

Figure 12: Organic load in Corfu sub-basins [4]

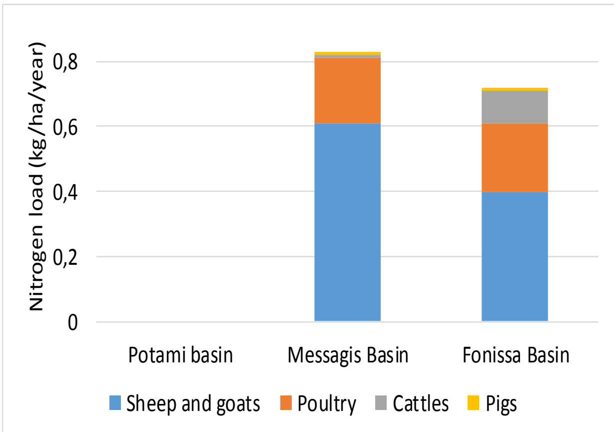

Figure 13: Nitrogen loads in Corfu sub-basins [4]

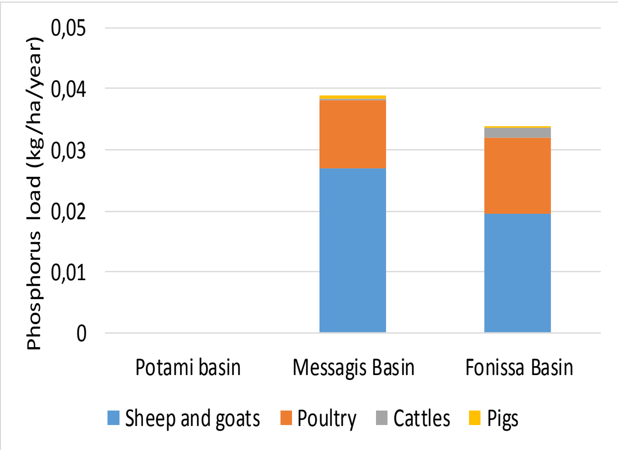

Figure 14: Phosphorus load in Corfu sub-basins [4]

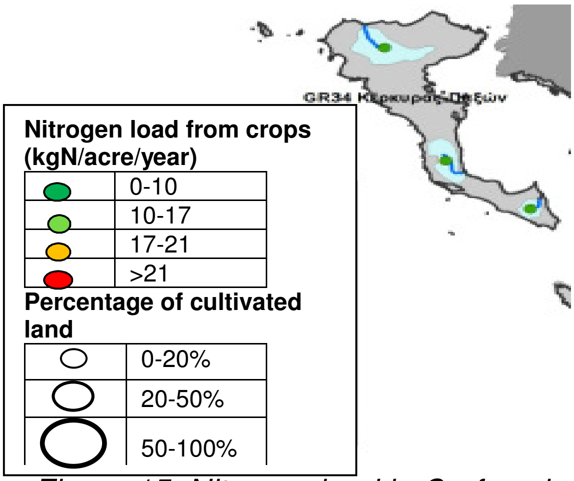

Figure 15: Nitrogen load in Corfu sub-basins [4]

3.2.3 Urban Waste

In the Corfu-Paxi basin there are 50 settlements with a total permanent population of 35,362 people (as estimated in the RBMP) while the population categorization based on the settlement's size is provided in Table 9 [4]. According to the Framework Directive 91/271/EEC all settlements with permanent population above 2,000 people are obliged to have sewerage networks and wastewater treatment plants. In the area there are no settlements with population above 2,000 people not served from a WWTP [4]. The contribution of the urban waste to the diffuse pollution is connected with the predominant practice in settlements not served by WWTPs. The equivalent population not served by WWTPs is 27,024 people. The pollutant loads ending up to the surface bodies are estimated in the RBMP (Table 10) [4].

Table 9: Types of settlements in Corfu-Paxi basin [4]

Settlements types	Settlements' number		Equivalent population	
	Without WWTP	With WWTP	Without WWTP	With WWTP
Below 2,000 ep	48	1	27,024	637
2,000 to 10,000 ep		1		7,701
10,000 to 15,000 ep				
Above 15,000 ep				
TOTAL	48	2	27,024	8,338

Table 10: Pollutant diffuse loads due to the urban population drained in sub-basins Corfu-Paxi basin [4]

Water Body		**BOD (kg/year)**	**N (kg/year)**	**P (kg/year)**
GR0534R000501082N	Fonissa	39,898.81	11,399.66	393,07
GR0534R000301081N	Messagis	30,201.62	8,629.04	272,22
GR0534R000101080N	Potami	8,327.93	2,379.41	74,49

3.2.4 Pressures evaluation of the diffuse pollution sources

The aggregate pressures are evaluated regarding diffuse pollution in Corfu – Paxi basin in the RBMP [4]. The results showed that the surface runoff from agriculture and urban waste contribute significantly to the diffuse pollution. Specifically for the Corfu-Paxi basin (GR34) the total pollution loads are given in Table 11 [4]. Analytically they are presented in Figure 16 [4].

Table 11: Total pollution loads Corfu-Paxi basin [4]

		Corfu – Paxi basin
BOD (kg/year)	Urban	78,428
	Livestock	21,646
N (kg/year)	Urban	22,408
	Livestock	8,192
	Agriculture	23,928
P (kg/year)	Urban	740
	Livestock	380
	Agriculture	8,527

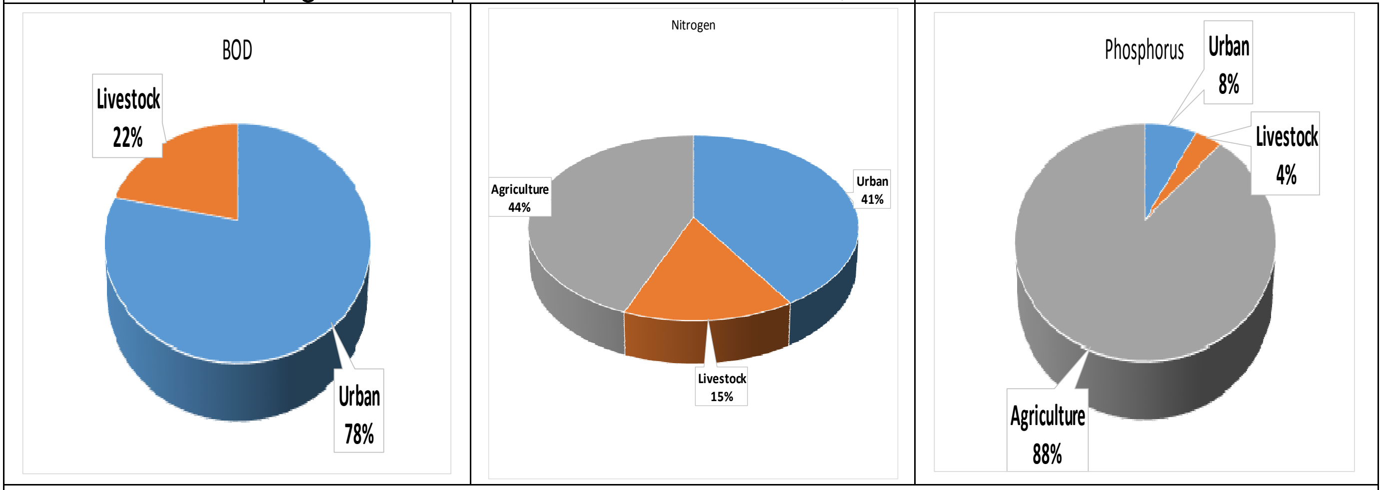

Figure 16: Contribution of urban waste, agriculture and livestock to (a) BOD; (b) N; & (c) P loads [4]

In all the sub-basins of the Corfu-Paxi basin the produced pollutant loads concentrations are lower from the existing limits and it is concluded that there is not a significant pressure on the surface water bodies due to the diffuse pollution sources in this basin.

Table 12 presents the estimated pollutant loads in the surface runnoffs of the sub-bsins on Corfu-Paxi basin. The total pollution pressure intensity from diffuse point sources is presented in Figure 17.

Table 12: Total pollution loads in surface water bodies in Corfu-Paxi basin [4]

Water body code	Water body name	BOD mg/l	N mg/l	P mg/l
GR0534R000301081N	Messagis	7.88	5.01	0.96
GR0534R000501082N	Fonissa	6.63	4.28	0.92
GR0534R000101080N	Potami	4.38	3.25	0.68

Pressure intensity in the basin	
	Low
	Medium
	Significant
	Very significant

Figure 17: Diffuse point sources pressure intensity in Corfu [4]

3.3 Other Pollution Sources

3.3.1 Fish Farming

Fish farming is another pollution source. Fish farming units in Corfu are situated in sea water in Lorida Sagiadas, belonging in the coastal water body of “North part of the Eastern coast of Corfu sea”. The data and pollution loads of fish farming are given in Table 13.

Table 13: Total pollution loads from fish farming in sea water in Corfu-Paxi basin [4]

Basin		Units	Pollutant Loads (tn/year)		
			BOD	TN	TP
GR 34	Corfu-Paxi	1	199.4	36.4	8.3

3.4 Impacts

The pollutants are both conventional and unconventional.

Conventional pollutants: When the organic mater, the ammonium, nitrate and phosphate salts' concentrations are low in receiving waters, they are not considered as pollution. Their concentrations are increased due to anthopogenic activities causing pollution problems to the aquatic ecosystem. Such substances are met in point pollution sources such as urban wastewater, livestock waste, industrial waste and non point pollution sources such as surface runnoff from agricultural land.

Nonconventional pollutants: This category includes mainly toxic substances such as lead, mercury, cadmium, fluorinated and radioactive material that can be found in the water. Nickel, chromium, arsenic, selenium, sulfuric acids, cyanide acids have also toxic effects when their concentration in water exceeds the limits. Tables 14 and 15 show the basic conventional and nonconventional pollutants and their related pollution problems.

Table 14: Effects of conventional pollutants to aquatic ecosystems [4]

Conventional pollutants	Effect to aquatic ecosystems
Organic mater increase	Deoxygenation of the receiving water
Nutrient N, P increase	Eutrophication
NH3 concentration increase	Toxicity in aquatic organism
NO3-N concentration increase	Toxicity
Suspended soils concentration increase	Sediment creation, turbidity increase in receiving water, reduction of the aesthetic value of the receiving water

Table 15: Effects of non-conventional pollutants [4]

Non-conventional pollutants	Effects
Heavy metals Cd, Zn, Cr, Hg, Ni, Cu, etc.	Toxic effect in the short and long term in human and aquatic organisms. Some of them (e.g. Cd) are suspicious for cancer. The organic compounds are responsible for bioaccumulation
Synthetic organic compunds, chlorinated hydrocarbons, organophosphorus compounds, trihalogenated methanes	Mainly long term toxic effects to the health. Low biodegradability ⟶ bioaccumulation and growth. Some of them are suspicious carcinogenic
Nox, SO2	Acid rain. Nitrogen increase in receiving waters
Petroleum	Toxic immediate effect. Carcinogenic compounds. Deoxygenation.

Table 16: Impacts Assessment in sub-basins of Corfu for surface and coastal waters [4]

Water body code	Water body name	Pressure intensity in the sub-basin	Settlements with WWTP	IPPC units	Industrial units related to the dumping of priority substances	Industrial units related to the dumping of other substances	Livestock farms	Farm fishing units	Number of quarries	SEVESO units number	Land use of urban region	Land use of cultivated land	Settlements without WWTP	Organic mater and nutrients concentration in surface runnoff, mg/l	BOD concentraiton in surface runnoff, mg/l	Nitrogen concentration in surface runnoff, mg/l	Phosphorus concentration on surface runnoff, mg/l
GR0534R000101074N	Potami	H	L	L	L	H	L	L	L	L	L	H	L	L	L	L	L
GR0534R000301075N	Messagis	H	L	L	L	H	L	L	L	L	L	H	L	L	L	L	L
GR0534R000501076N	Fonissa	H	L	L	L	H	L	L	L	L	L	H	L	L	L	L	L

River Basin District	Pressure intensity in the sub-basin	Livestock farms	Industrial units related to the dumping of priority substances	Industrial units related to the dumping of other substances	SEVESO units number	IPPC units	Farm fishing units
Corfu	H	L	L	H	H	L	L

Other effects are thermal pollution and contamination.

According to the River Basin Management Plan of Epirus, the impacts assessment in the water bodies took place taking into consideration the pressures' analysis and their intensity based on criteria. The pollution pressure is estimated for each sub-basin for surface and coastal waters.

In Corfu the pollution pressures are estimated as high because of the industrial units, the cultivated land and the number of SEVESO units (Table 16).

3.5 Impacts in the groundwater bodies

All five groundwater bodies identified in Corfu-Paxi basin are assessed to be in good chemical status (Table 17) [4]. Locally increased concentrations of SO_4 are met due to the geological background (gypsum presence). Only locally some increased concentrations of nitrates and ammonium are found because of the diffuse and point pollution sources. Also locally in the coastal zones increased consentrations of chlorides are found because of the sea water intrusion from excessive pumping and natural causes [4].

Table 17: Main quality problems of groundwater bodies of Corfu sub-basin [4]

Groundwater body code	Groundwater body name	Type of aquifer	Quality problems	Pollution trend	Chemical status
GR0500010	Limestone system	Karstic	Locally increased values of NO3 due to agricultural activities	Yes	Good
GR0500020	Ternary breccia system	Karstic	Naturally increased values of SO4 due to gypsum. Locally increased values of NO3 due to agricultural activities	No	Good
GR0500030	Granular aquifer system	Granular	Locally increased values of NO3 due to agricultural activities. Naturally increased values of SO4 due to gypsum.	Yes	Good

As already indicated in the report "Water quality and trends on Corfu test area in Greece" by FB16, University of Thessaly, the groundwaters' quality is assessed as follows [9]:

Limestone system: In detail, the increased concentrations of conductivity, chlorides and sulfates are due to the natural background. The increased values of the chlorides are connected to the exploitation of the aquifer (sea water intrusion) but they are also due to natural causes. The increased values of sulfates are due to the natural geological background met in the central part of the water basin district. Increased values of nitrates are met locally and they are due to anthropogenic activities.

Ternary breccia system: the increased presence of sulfates and conductivity is connected to the high values of the natural geological background. Locally increased concentrations of nitrates and ammonium are met due to anthropogenic activities as part of the water system's land use is agricultural land while the remaining one is woodland with increased urbanization.

Granular aquifer system: Concentrations of conductivity, chlorides and sulfates exceed the Maximum Allowable Concentrations in some monitoring points. The increased presence of sulfates is connected to the increased value of the natural background due to the geological status of the area. Increased concentration of nitrates and ammonium are due to human activities. A big part of the water system is agricultural land. The local increased concentrations of nitrates, chlorides and conductivity are due to human activities and exploitation.

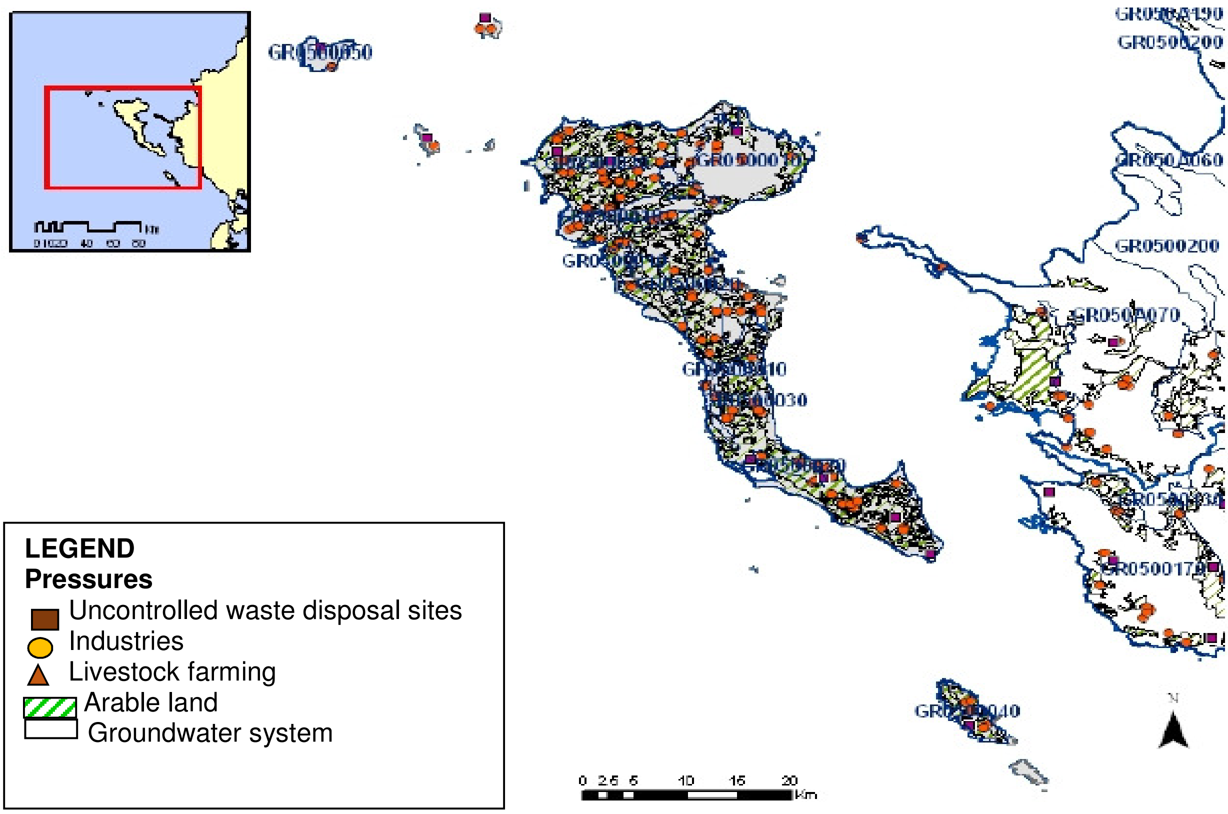

Figure 18: Land use and pollution causes in Corfu [4]

The impacts of human activities in the two (out of three) groundwater bodies of Corfu island requiring further classification are given in Table 18.

Table 18: Human activities' impacts in groundwater bodies of Corfu [4]

Groundwater body code	Groundwater body name	Current overexploitation conditions	Diffuse pollution sources	Point pollution sources	Sea water intrusion	Human causes for water quality degradation
GR0500010	Limestone system	No	Crops	Animal farms, oil mills, cheese dairy	Yes. Local in the north	Crops, oil mills, livestock farming
GR0500030	Granular aquifer system	No	Crops	Animal farms, oil mills	Yes. In the coastal areas	Crops, oil mills, hotel units

3.6 The DPSIR approach – impact of the land use on water quality (present state)

The DPSIR approach is followed to assess the impact of land use on water quality in the present state.

Based on the land uses described in section 2 of this report the predominant land use in Corfu island is agriculture, followed by forestry and urban settlements. The DPSIR approach for agricultural activities, forestry, urban settlements, climate change and tourism is given in Table 19 below.

Tourism is the main activity of the inhabitants (Figure 19) and according to the spatial plan [1] there is a conflict of land used for agriculture and tourism in the island. Thus, tourism is considered as an important pressure.

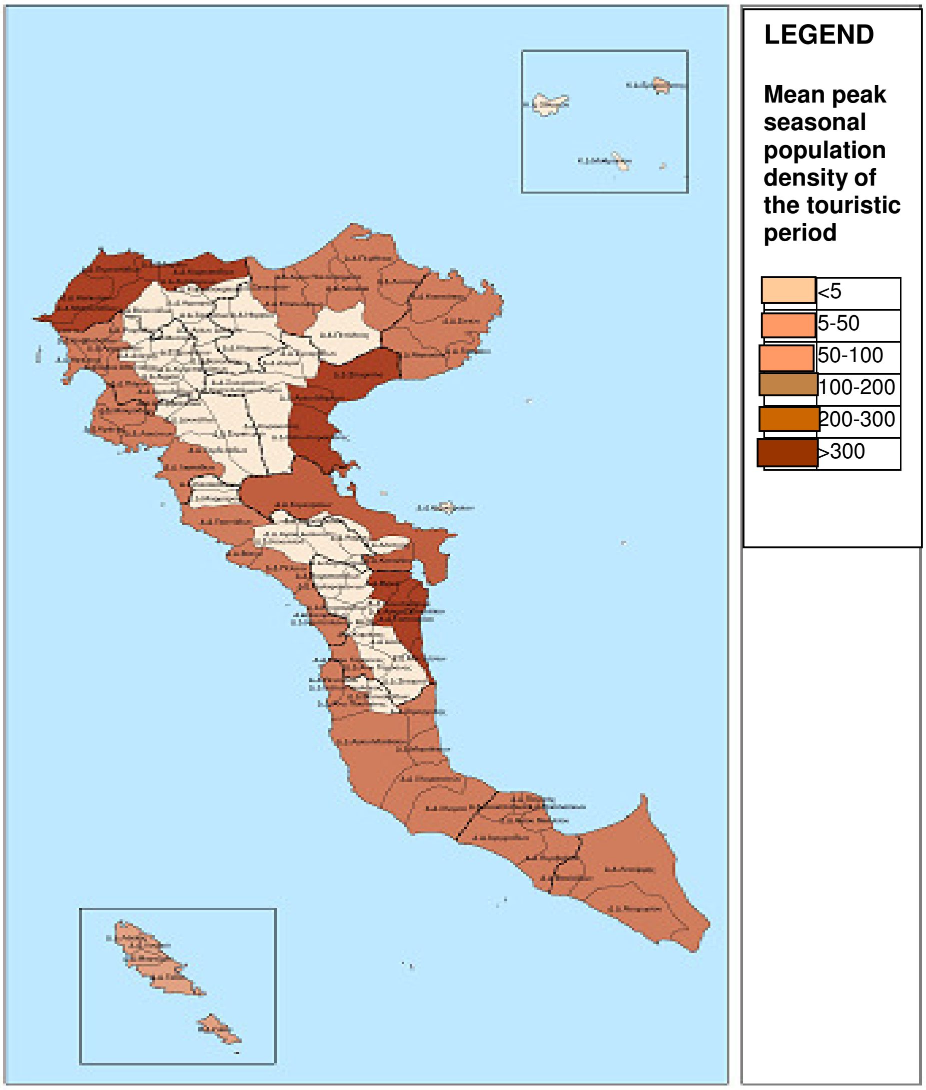

Figure 20: Mean peak seasonal population density of the touristic period in Corfu regional unit [1]

Table 19: The DPSIR approach for land uses in Corfu – present state

DRIVING FORCES	PRESSURES	STATE	IMPACT
Agriculture: use of fertilizers and pesticides	• Diffuse nitrogen contribution (runoff) • Nitrogen and phosphorus towards the aquatic environment	Groundwater and surface water quality deterioration	• Eutrophication • Contamination risks
Agricutlure: irrigation	Water abstraction	Water quantity	Water shortage / drought
Urban areas: Sewage and wastewater	• Microbiological pollution • Pharmaceuticals • Heavy metals to groundwater	Groundwater and surface water quality deterioration	• Contamination risks • Public health risks
Urban areas: transportation	Heavy metals and oil spills	Groundwater and surface water quality deterioration	• Contamination risks • Public health risks
Industry: oil mills	Pollutants in groundwater & surfac water	Groundwater and surface water quality deterioration	• Contamination risks • Public health risks
Forestry: loss of trees due to urbanization & temperature increase	• Climate change conditions • Higher temperatures • Drought periods • Forest fires	Deforestation	Loss of forest cover; erosion process (may affect water quality)
Climate Change	Land uses	Increased temperature; decreased precipitation	Drought conditions Water unavailability
Tourism	• Land uses • Construction • Wastewater and solid waste	Limited cultivated land Pollutants in groundwater and surface water	• Contamination risks • Public health risks • Climate change

RESPONSE

European Legislation: WFD 2000/60/EC; Drinking Water Directive 98/83/EEC; GW directive 2006/118/EC; Urban Wastewater Treatment Directive 91/271/EEC; Nitrates Directive 91/676/EEC; Environmental Impact Assessment 85/337/EEC; Special Protection Zones Directives 92/43 & 2009/147/EC

Greek Legislation: Law 3199/2003; JMD Y2/2600/2001; PD51/2007; JMD 146896/2014; Law 4117/2003; JMD 146896/2014; MD 39626/2208/E130/2009; River Basin Management Plans; MD 85178/820/2000; JMD 161690/1335/1997; JMD 5673/400/1997; JMD 191002/2013; JMD 145116/2011; MD 33318/3028/1998; 37338/1807/E.103

Measures: Water Safety Plans; Drinking Water Masterplans; Drinking Water Protection Zones

4 THE IMPACT OF CLIMATE CHANGE AND PLANNED DEVELOPMENT (SPATIAL PLANS) ON THE LAND USE IN FUTURE ON TEST AREAS

Land use cover from Corine project is available only for 1990 and 2000 for Greece. Greece is not included in the CLC of 2006 and 2012. Figure 20 shows the CLC 1990 and Figure 21 shows the CLC 2000. The % change is shown in Figure 22. From Figure 22 it is evident that the land use changes are not very significant from 1990 to 2000.

Since there are no data available from the Corine Land Cover project, other sources are used to assess the land use changes in Corfu island. A comparative study done in 2002 showed that agricultural land is increased by 4.9%, pastures increased by 1.4% and forests decreased by 10.62% from 1830 to 2000 (170 years) [10] (Table 20).

Table 20: Land uses in Corfu in 1830 and 2000 [10]

	1830			**2000**				
%	**Agriculture**	**Pastures**	**Forests**	**Agriculture**	**Pastures**	**Forests**	**Artificial surfaces**	**Other surfaces**
Total	79.53	8.10	12.37	84.39	9.50	1.75	3.74	0.63

The spatial plan of 2008 for the island of Corfu [1] identified that the island's economy is based on the tertiary production factor mainly due to the touristic development. According to data from 2001 census, 51.7% of the island's working population are occupied in services and tourism. The regional unit of Corfu accepts annually about 983,000 foreign tourists (data from 2007). However, officially only 430,000 foreign and 126,000 domestic tourists are recorded (Table 21) [1].

Table 21: Number of overnight stays and arrivals in hotel type settlements except campings in Corfu regional unit [1]

	Overnight stays				
	2003	**2004**	**2005**	**2006**	**2007**
Corfu Regional Unit	3,372,053	1,754,043	4,340,803	4,339,576	4,158,743
	Arrivals				
	2003	**2004**	**2005**	**2006**	**2007**
Corfu Regional Unit	439,801	245,879	563,321	564,636	555,539

<u>Land uses conflicts</u>

A large number of rural settlements are located in the island (some of them with population of less than 100 people). Their extended boundaries increased the residential space against the agricultural land. Two are the main problems in the island: the demand for buildings due to tourism and the institutional framework allowing the settlements to develop against the natural resources. Zones of land uses conflicts exist in the whole area of the island mainly in the coastal zones. The conflict of the industrial use with residential of agricultural use is based on the oil mills operation within the limits of the rural settlements [1].

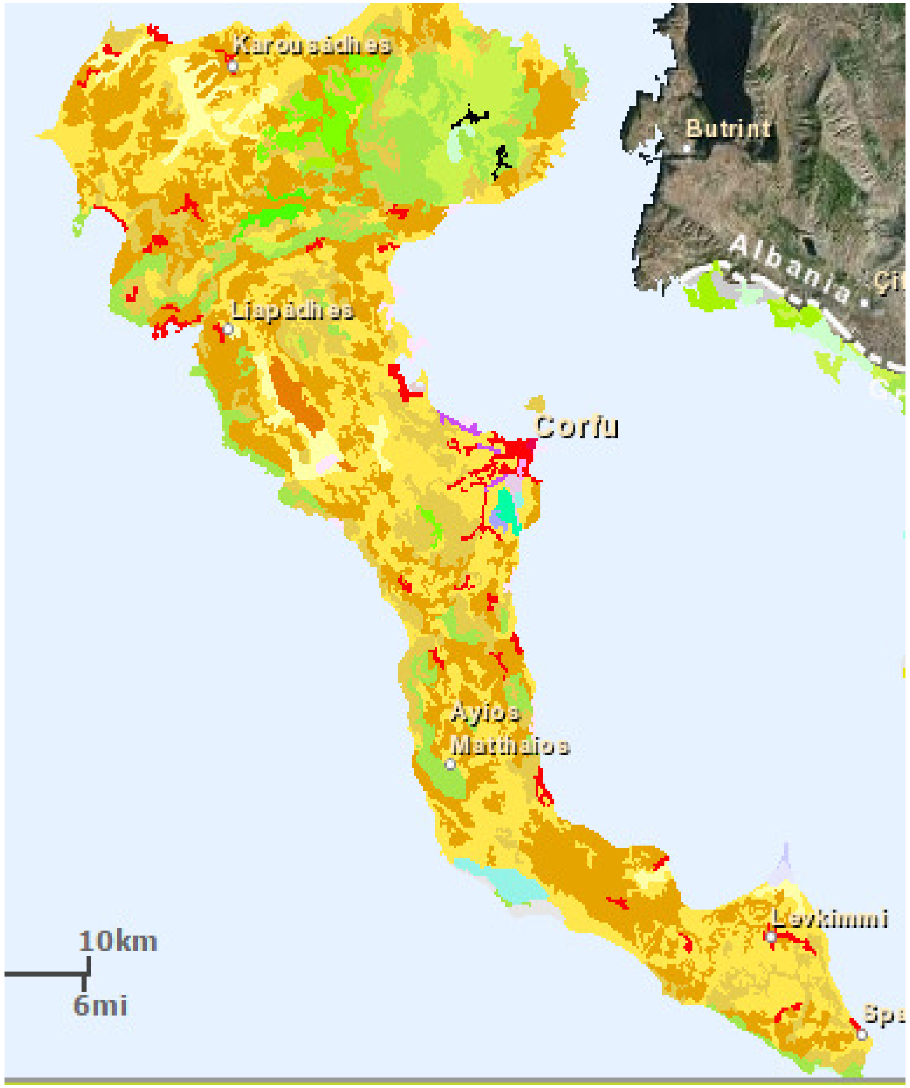

Figure 20: Land use in Corfu, 1990 [6]

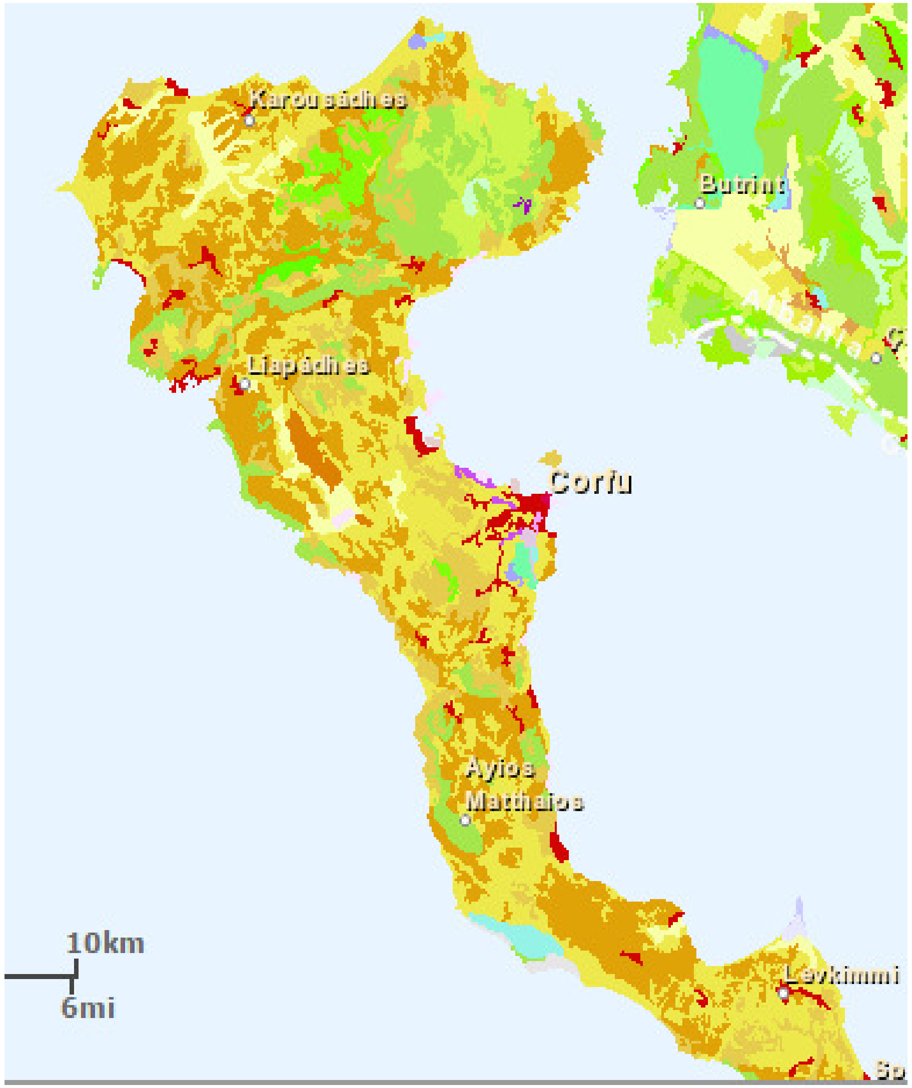

Figure 21: Land use in Corfu, 2000 [7]

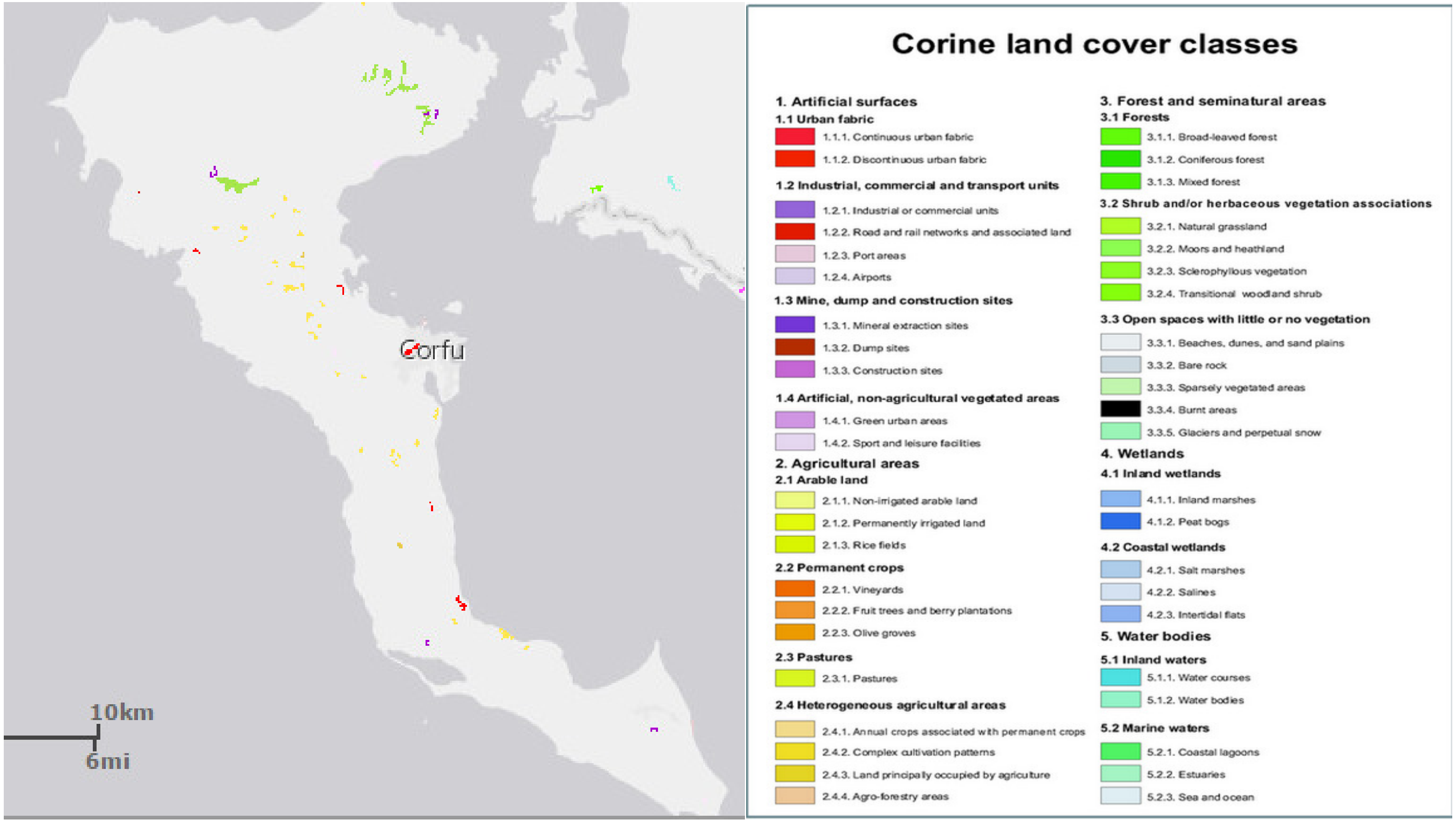

Figure 22: Differences in land use in Corfu, 1990-2000 [8]

In conclusion the land uses in the future are not expected to vary greatly. Due to the touristic development of the island it is expected that the agricultural use will be decreased. However there are measures applied to protect the natural environment.

5 IMPACT OF LAND USE ON WATER QUALITY - DPSIR APPROACH FOR THE FUTURE STATE

The DPSIR approach is also used for the assessment of the impact of land use changes on water quality. The climate change prediction for the future (2021-2050) in Corfu test area showed that the average annual mean temperature is expected to increase from 1.23^{o}C to 4.27^{o}C (Table 22). The total precipitation is expected to decrease especially in the summer months [11]. In the winter months two out of four models predict a slight increase in total precipitation values. Total annual precipitation values are expected to decrease from 3.93% to 25.4% depending on the model (Table 22) [11]. Climate change is expected to have an impact in the water quality. Land uses are expected to change but their variations are not expected to be big. Tourism is expected to turn agricultural land to urban settlements. The DPSIR approach is given in Table 23.

6 PROBLEMS OF SALT WATER INTRUSION (FOR PILOT AREAS WITH THIS PROBLEM)

The groundwater bodies in the basin of Corfu-Paxi are surrounded by the sea. Each groundwater body is examined separately based on the River Basin Management Plan of Epirus [4].

6.1 Limestone system of Corfu (GR0500010)

Increased concentrations of chlorides are met in the northern part of the system. The main causes are natural (open carstic system to the sea) and excessive abstractions locally. The chlorides values exceed 2,000mg/l with average values of 800-900mg/l [4].

6.2 Granular aquifers system of Corfu (GR0500010)

Local salinization is met due to excessive abstractions in the coastal area in the north western part of the system (south part of Lefkimi). The chlorides values are 1,900 mg/l [4].

Totally the results are presented in Figure 23 and Table 24.

Table 22: Temperature and precipitation variations predicted for the future in Corfu [11]

	Ensemble (A1B)					**Prudence (A2)**					**Prudence (B2)**					**REGCM (A1B)**				
Change in	Winter	Spring	Summer	Autumn	Year	Winter	Spring	Summer	Autumn	Year	Winter	Spring	Summer	Autumn	Year	Winter	Spring	Summer	Autumn	Year
minimum air temperature (ºC)	1,04	0,89	1,52	1,51	1,24	3,58	3,29	5,55	4,26	4,17	2,46	2,39	4,43	3,12	3,1	1,14	0,77	1,52	1,36	1,19
maximum air temperature (ºC)	0,98	0,93	1,5	1,51	1,23	3,81	3,77	6,19	4,68	4,61	2,43	2,48	4,78	3,4	3,27	1,15	0,9	1,53	1,47	1,26
average air temperature (ºC)	1,01	0,91	1,51	1,49	1,23	3,58	3,44	5,76	4,32	4,27	2,37	2,42	4,51	3,2	3,12	1,15	0,87	1,53	1,15	1,25
total precipitation (%)	2,29	-13,9	-11,13	-5,31	-3,9	-1,47	-15,1	-60,01	-24,88	-25,4	5,94	-1,19	-44,54	-3,15	-10,7	-16,56	-6,3	-44,01	-9,19	-7,9

Table 23: The DPSIR approach in Corfu – future state

DRIVERS	**PRESSURES**	**STATE**	**IMPACT**	**RESPONSE**
Climate Change	Land uses	Increased temperature; decreased precipitation	Drought conditions Water unavailability	• National Programme of Measures Off.Gaz. 58/5.3.2003 • River Basin Management Plans
Tourism	• Land uses • Construction • Wastewater and solid waste • Increased demand for water	Limited cultivated land Pollutants in groundwater and surface water Water unavailability	• Contamination risks • Public health risks • Climate change • Water unavailability	• Measures for protection areas • Drinking water masterplan • Natura 2000 sites • Water Safety Plans • Drinking water protection zones

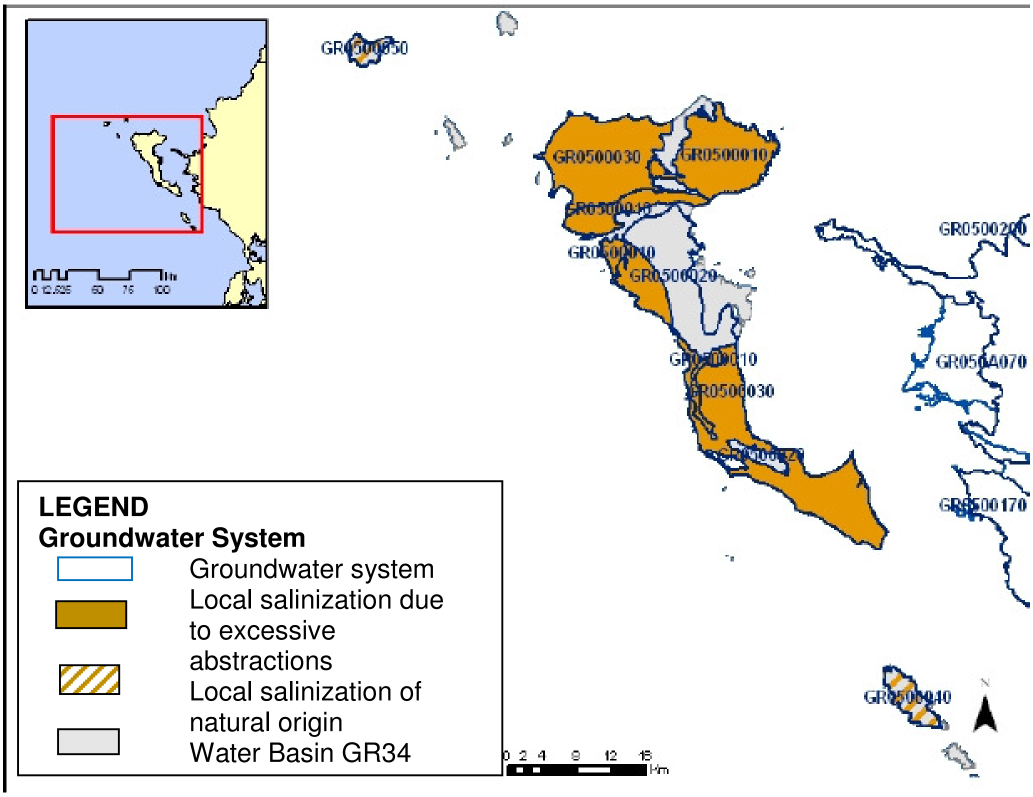

Figure 23: Salinization map of Corfu-Paxi bain [4]

Table 24: Sea water intrusion in groundwater bodies of Corfu [4]

Groundwater body code	Groundwater body name	Sea water intrusion
GR0500010	Limestone system	Yes. Local in the north
GR0500020	Granular aquifers system	Yes. In the coastal areas

7 MEASURES TO IMPROVE THE QUALITY OF DRINKING WATER ON TEST AREAS

According to the River Basin Management Plan of the Water District of Epirus [12] the following measures are proposed (Table 25).

Table 25: The proposed measures according to the River Basin Management Plan of the Water District f Epirus [12]

Measures		Measure category
WD05B010	Promotion - Integration of the introduction procedure of the River Basin Management plans for the protected areas of species and habitats with special reference to water management issues	Natura sites (Directives 92/43/EEC - 2009/47/EC)
WD05B050	Promotion and implementation of management and safe disposal of sludge projects	Sludge disposal (Dir.86/227/EEC); Point disposal sources; Diffuse disposal sources; Confrontation of impacts in the water status
WD05B060	Integration of the necessary projects for the urban wastewater and sewage networks to comply with the Directive 91/271/EEC	Urban Wastewater treatment (Dir. 91/271/EC); Diffuse disposal sources; Confrontation of impacts in the water status; Measures to avoid pollutants disposal directly to groundwater systems
WD05B070	Completion of the vulnerable areas list and upgrade of the existing wastewater treatment plants	Urban Wastewater treatment (Dir. 91/271/EC); Point disposal sources; Confrontation of impacts in the water status
WD05B080	The whole island of Corfu will be included in the vulnerable zones from nitrates from agricultural activities, including all three aquifers	Nitrates Pollution Protection (Dir. 91/676/EEC); Diffuse disposal sources; Confrontation of impacts in the water status
WD05B120	Actions to update the operation of drinking water distribution networks in combination with actions to reduce Non-Revenue Water	Drinking Water (WFD article 7)
WD05B140	Projects for the restoration of the existing drinking water distribution network	Drinking Water (WFD article 7)
WD05B150	Recording of water quantities from the abstraction points of surface and/or groundwater for drinking, irrigation from the organized networks and the big consumers	Control of surface and groundwater intake
WD05B200	Prohibition of new drillings in: - Water systems at bad quantitative status - 200m zone from the coast line - Within the zones of collective irrigation networks - In the protection zones (I and II) of the springs and the drinking water boreholes, except of special cases (drinking water) to be examined from the Water Directorates with the submission of hydrogeological report	Drinking Water (WFD article 7); Control of surface and groundwater intake; Confrontation of impacts in the water status
WD05B210	Set in principle protection zones for abstraction point of groundwater for drinking purposes	Drinking Water (WFD article 7)
WD05B220	Update the General Masterplans from the water utilities	Drinking Water (WFD article 7)
WD05B230	Ammendment / update of the regulatory decisions of prohibitive, restrictive and other regulatory measures	Drinking Water (WFD article 7)

	aiming at the protection and management of the water potential based on the RBMP program of measures	
WD05B240	Determination of registry for areas of disposal of treated wastewater either through irrigation or artificial recharge (Off.Gaz.354/B/08.03.2011)	Confrontation of impacts in the water status; Measures to avoid pollutants disposal directly to groundwater systems
WD05B250	Immediate integration of the program to close and restore all uncontrolled waste disposal sites	Point disposal sources; Confrontation of impacts in the water status; Measures to avoid pollutants disposal directly to groundwater systems
WD05B260	Review of the existing permits for reuse of wastewater according to the requirements of the articles 9&11 of the JMD 145116/2011	Point disposal sources
WD05B270	Reinforcement of the environmental controls and inspections	Point disposal sources; Confrontation of impacts in the water status; Measures to avoid pollutants disposal directly to groundwater systems
WD05B280	Application of control and measures for the zones of fish farming in internal water systems	Point disposal sources; Confrontation of impacts in the water status
WD05B290	Determination of the pollutants emmissions limits from the Regional Water Directirates at the river basin level	Point disposal sources
WD05B310	Establishment of a registry for pollution sources (emmissions, disposals and leakages) from priority substances and special pollutants and undate of the related permits	Point disposal sources; Measures to avoid pollutants disposal directly to groundwater systems
WD05B320	Integration of the infrastructure of sewage and wastewater treatment in the industrial areas	Point disposal sources; Confrontation of impacts in the water status
WD05B330	Promotion of the replacement of absorbent cesspools with water proof ones	Point disposal sources; Diffuse disposal sources; Confrontation of impacts in the water status
WD05B340	Ammendment of the Decisions of Approval of Environmental Conditions of existing establishments without a permanent permit for disposal, so that the modified decision will be a definite permit for siposal according the article 12 of the Law 4014/2011	Point disposal sources
WD05B350	Examination of integration of additional measures to the action program of vulnerable areas in nitrates pollution	Diffuse disposal sources; Confrontation of impacts in the water status
WD05B360	Gradual, selective conversion of conventional cultivations to biological ones	Diffuse disposal sources; Confrontation of impacts in the water status
WD05B370	Prohibition of establishment of small hydropower plants in the areas characterized as internal waters recreation areas in the Protected Areas Registry	Confrontation of impacts in the water status

WD05B380	Ensuring controls to comply with the predictions of the environmental permits of the industries according article 13 of the Directive 91/271/EEC	Confrontation of impacts in the water status
WD05B390	Reinforcement of control actions for the more efficient operation of the existing projects for wastwater and sewage treatment	Confrontation of impacts in the water status
WD05B400	Reinforcement of actions for the hydromorphological restoration of coastal zones	Confrontation of impacts in the water status
WD05B410	Reinforcement of the synergy of spatial and urban planning with the river basin management planes of each water district	Confrontation of impacts in the water status
WD05B420	Assure the good operation level of the existing wastewater treatment plants	Confrontation of impacts in the water status
WD05B430	In principle determination of the seashore in protected areas of species and habitats	Confrontation of impacts in the water status
WD05B440	In principle preparation of the cadaster in protected areas of species and habitats	Confrontation of impacts in the water status
WD05B060	Integration of all necessary projects for wastewater	Measures to avoid pollutants disposal directly to groundwater systems

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