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Characterization of amphibian's breeding sites in a karst environment, NE of Italy.

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Introduction

At the First World Congress of Herpetology, held in 1989, experts from all over the world pooled their experiences of amphibians' local decline (Wright et al., 2001) so that for the first time a clear and shared worldwide picture came out showing an amphibian populations' crisis.

Among the causes for this decline several factors concern the human environmental impact such as habitat destruction, degradation and fragmentation as well as introduction of exotic organisms, environmental pollutants and increased ultraviolet radiation. These causes are thought to be the ways by which environmental impact negatively affects amphibian populations (Blaunstein et al., 1994; Wright et al., 2001; Pounds and Masters, 2009).

Habitat fragmentation means additional difficulties and stress due to hindered movements between small habitat patches, possibly separated by roads which can be extreme barriers for ground dwelling species (Vos, 1998). Biological conservation measures for fragmented landscapes are often based on spatial applied metapopulation dynamic models. These are used for habitat characterization (e.g. Cirovic et al., 2008), to predict the long-term permanence of species by means of extinction-colonization processes (Gu et al., 2002; Hanski, 1998), as well as the effectiveness of dispersal corridors (Vermeulen and Opdam, 1995). On the side of natural causes the spread of an extremely striking fungal infection (the chytrid *Batrachochytrium dendrobatidis)* is by some authors identified as the main reason of the amphibians decline (Pennisi, 2009) but falls out of the context of this paper.

The two types of causes are often seen as complementary in determining the critical conditions that lead to local extinction (Pounds and Masters 2009), therefore stressing that amphibians need optimal environmental conditions, especially if infected by diseases, such as chytridiomycosis (Wright et al., 2001).

The main objective of the present study is to provide useful information to support conservation measures for 4 endangered amphibian species in the Montello area (North East of Italy): *Triturus carnifex, Lissotriton vulgaris, Bombina variegata* and *Rana latastei*. This will be primarily done by means of a characterization of the aquatic habitats. Secondarily, considerations about dispersal abilities and use of terrestrial environment will be provided to better frame the required aquatic sites in a landscape perspective.

Problem definition

The "Montello" is a hill of 60 km^2 in the Treviso province, Veneto Region, North-East of Italy. Because of its high biodiversity it is considered among the most important natural areas of the region (Province of Treviso, 2006) and a large part of it is protected as a Natura 2000 site (Romanazzi and Bonato, in press). This area is indeed characterized by the diffused presence of wetlands which host a large diversity of amphibian species (see **Table 1**), some of which are endangered or vulnerable at the local level or present in the Annex II of the Habitat directive 92/43/CEE. These wetlands are often of crucial importance as a stopover and for feeding of birds, mammals and many other groups of wild animals (Romanazzi and Modesto, 2008).

Due to the karst geology (where the carbonate substrate undergoes irregular dissolution processes, leaving a topography with very heterogeneous permeability conditions), a surface hydrographic network is almost absent on the hill. Historically, the local populations used to take care of at least one water site per urban settlement, which was maintained in good conditions, to constantly assure availability of water supply during the year. However, after the installation of the public aqueduct in the 60's, which reaches the settlements present on the hill, the periodical maintenance of the water sites was not needed anymore and so interrupted. As a result a large part of the water sites, which were commonly used by wild fauna and humans over the centuries, is undergoing a process of deterioration. This happens by natural processes of filling up, such as growing vegetation or accumulation of organic debris, or sometimes by humans which voluntarily use them as dump or fill them with soil (Romanazzi and Modesto, 2008).

The karst ponds are habitats for a broad number of species and their disappearance poses a threat especially to those species who are already locally endangered. To prevent some of these particularly valuable spots from being lost, zoologist Enrico Romanazzi and geographer Marta Modesto started a project, subsequently funded by the Province of Treviso, for the recovery of selected wetlands within the area.

The project "Le zone umide del Montello" (The wetlands of Montello) presented on 12th of January 2007 at the Environmental Commission of the Province of Treviso has, as its main objective, the conservation of freshwater in the area of Montello through a census and a successive recovery of sites valuable from a naturalistic and cultural point of view.

The naturalistic focus of the project is centered on "Amphibians, the vertebrate animal class with the highest risk of extinction at the global level", for this reason "considered important index of environmental quality" (Romanazzi and Modesto, 2008, pp.1). The inquiry they carried out aims at understanding what is the actual status of amphibians in Montello, and which are the areas that are more important to protect, and especially to have an increased awareness of the positioning of reproductive sites (Romanazzi and Modesto, 2008).

The recovery aims at re-establishing the conditions under which the wetlands were maintained for centuries in the past, by focusing on their naturalistic, historical and landscape qualities. Indeed, to "minimize the disturbance of fauna and substrate" most of the cleaning operations necessary to restore the sites "have been done manually using shovels, rakes and wheelbarrows" (Romanazzi and Modesto, 2008, pp.1).

Maintaining in good conditions more habitat patches within Montello can help in increasing the size of the local populations of amphibians. However taking care of the local populations could be insufficient if these are relatively small and isolated. When connectivity among patches of suitable habitat is limited, the population dynamics can lead to local extinction if not replaced by other colonists (Hanski, 1992, Hanski, 1994). Geographical isolation can even bring genetic problems such as inbreeding, dangerously leading to inbreeding depression (Allentoft and O'Brien, 2010).

Montello hill is settled in a highly fragmented environment, the Po valley. This is the most industrialized area of Italy and is characterized by a high density of agricultural fields, roads networks and human settlements (Ficetola and De Bernardi, 2004). The geographical framework presents the closest semi-natural area in the pre-alps, starting about 4 km far from the edge of the hill in North-East direction. The connection between these two areas, more suitable for ground dwelling populations, is hindered by the habitat fragmentation of the in-between areas, where the road traffic causes high amphibian mortality during the migration periods (De Stefano, 2010, Menin et al., 2003). To make conservation efforts more effective in sustaining the vulnerable amphibian species, the characterization and conservation of suitable habitat patches on Montello hill alone is insufficient. The connectivity between Montello and other suitable areas should also be considered.

Eleven amphibian species are present in the area of Montello. Although human induced and natural factors of disturbance are likely to threaten all amphibian species present in the area, this study will focus on the most vulnerable species (see **Table 1**): *Triturus carnifex, Lissotriton vulgaris, Bombina variegata* and *Rana latastei.*

Research Questions

Following the conservation project "Le zone umide del Montello" the key issue of this study will be:

- How can the recovery of water sites in the area of Montello be performed so that it can obtain the most effective amphibian conservation?

Subsequently the following more specific sub-questions will be addressed:

- Which environmental variables of the habitat are relevant for the populations' distribution of the four most vulnerable species (*Triturus carnifex, Lissotriton vulgaris, Bombina variegata* and *Rana latastei*)?
- What water points could hold the best characteristics to host the amphibian populations of each of the studied species in this specific geographical framework?
- What features should an ecological corridor have to be effective in preventing the isolation effect of the studied area?

Study area

The "Montello" is a hill of $60km^2$ with an altitudinal range comprised between 70m and 370m, located in the Treviso province (Veneto region, North-East of Italy).

Its landscape is characterized by the diffuse presence of agricultural fields associated with little groups of houses, cleared grasslands used for feeding stocks (together about 20-30% of the land cover) and woody areas (about 70% of the land cover) with prevalence of deciduous forest (*Robinia pseudoacacia, Quercus petraea, Carpinus butulus, Castanea sativa*) (Romanazzi and Bonato, in press).

The karst topography determines fast drainage of surface water, part of which tends to be collected in sinkholes (namely depressions or holes in a karst environment), where the accumulation of clay diminishes the infiltration in the underground.

A very diffuse type of sinkhole is the karst pond (**Figure 1**). Here most of the contribution in water content is due to rain water, the percolation of which is lowered by the accumulation of marlstone (a calcium carbonate lime-rich mud), making the bottom of the pond low permeable. Such karst ponds occasionally can be supplied by underground tributaries, increasing their chances to have a perennial hydro period.

Other form of water sites present on Montello are the wells, which deliver ground water to the surface, supplying creeks and small rivers, or disappear into karst fensters (these are features presenting a spring abruptly disappearing into a sinkhole).

***Figure 1**: Karst pond with snow*

These geological and soil distinctive characteristics make the Montello an area with a diffused presence of wetlands (over 150 water-sites of different sizes) giving hospitality to a variety of amphibian species, including some considered vulnerable at the regional level (Romanazzi and Bonato, in press) (see **Table 1**).

Table 1: Amphibian species and their vulnerability in the area of Montello, province of Treviso, Italy (according to Council Directive 92/43/EEC, Annex 2 and the Regional Red List (Bonato et al., 2007).

Species	**Common name (italian)**	**Common name (english)**	**Community Importance in "Habitat" Directive 92/43/EEC, Annex 2**	**Regional Red List**
Salamandridae				
Salamandra salamandra	Salamandra pezzata	Fire Salamander	No	Near threatened
Mesotriton alpestris	Tritone alpestre	Alpine Newt	No	Least concerned
Triturus carnifex	Tritone crestato italiano	Italian Crested Newt	Yes	Endangered
Lissotriton vulgaris	Tritone punteggiato	Smooth Newt	No	Endangered
Discoglossidae				
Bombina variegata	Ululone dal ventre giallo	Yellow-Bellied Toad	Yes	Vulnerable
Bufonidae				
Bufo bufo	Rospo comune	Common toad	No	Least concerned
Bufo viridis	Rospo smeraldino	European green toad	No	Least concerned
Hylidae				
Hyla intermedia	Raganella italiana	Italian Tree Frog	No	Near threatened
Ranidae				
Pelophylax synklepton *esculentus*	Rana verde	Edible Frog	No	Near threatened
Rana dalmatina	Rana dalmatina	Agile Frog	No	Near threatened
Rana latastei	Rana di Lataste	Italian Agile Frog	Yes	Vulnerable

All the species but *Pseudepidalea viridis* show reproductive populations. *Triturus carnifex, Bombina variegata* and *Rana latastei* are considered of Community Importance and present in the attachment of the "Habitat" directive 92/43/CEE for which the realization of Special Conservation Zones (Council Directive 92/43/EEC, Annex 2) is scheduled. Moreover *Triturus carnifex* and *Lissotriton vulgaris* are considered "endangered" while *Bombina variegata* and *Rana latastei* *"vulnerable"* on the regional Red List (Bonato *et al*., 2007; Romanazzi and Modesto, 2007).

Species' description

Hereafter a brief description of the considered species and their geographical distributions, based on the Atlas of Italian Amphibians and Reptiles, the Atlas of Amphibians and Reptiles in Vicenza Province and The IUCN Red List of Threatened Species is given (Sindaco et al., 2006, Group for Naturalistic Studies Nisoria, 2000, IUCN).

Triturus carnifex

T. carnifex is the biggest Italian newt (up to 14-18cm, including tail).

This species is generally found not over 400-600m altitude, in small lakes, ponds, channels, wells with rich aquatic vegetation. Its terrestrial environment is characterized by meadows and woodlands located not very far from its breeding site. It spends the winter under stones or underground. The males reach the pools from the end of February to April and remain there and until August. After fecundation, the female binds up to 400 eggs to the vegetation or to the bottom of the pool. The hatch happens after 2 weeks form deposition, whilst larval development lasts about 3 months. The lifetime can last up to 18 years. The diet composition for the larvae includes aquatic invertebrates, while for adults includes insects, mollusk, annelids and other young newts. Among its larvae's predators there are aquatic insects and salmonidae (Sindaco et al., 2006).

The geographic range of this species includes the Italian peninsula, Austria, Montenegro and all the countries surrounding the Adriatic Sea. Although it is considered least concerned on IUCN Red List, its population trend is still indicated as decreasing (IUCN) (see also **Table 1**).

Lissotriton vulgaris

L. vulgaris is a relatively little newt reaching up to 10cm length (Group for Naturalistic Studies Nisoria, 2000).

This species is found in eutrophic water bodies, with high vegetation density, with stagnant deep water in sunny spots.

Its terrestrial environment is characterized by woodlands and heterogeneous substrates, which offer room for shelters, where it spends the hibernation period in winter. The males reach the pools in January-February. The females wrap 60-300 eggs into the leaves of aquatic plants. The hatch happens after 8-20 days depending on the water temperature. The larval stage lasts between 6 and 10

weeks. The lifetime lasts up to 12 years. The diet composition is based on crustaceous, for the larvae, and includes also insects and small vertebrates for the adults. These are reported to predate the eggs of *Rana dalmatina* and *Rana latastei* (Sindaco et al., 2006, Group for Naturalistic Studies Nisoria, 2000).
The geographic range of this species includes most European countries, Ireland, Great Britain and southern Scandinavia and goes on until the steppes of Ukraine and Russia. It's missing in Spain and Portugal and on the bigger Mediterranean islands (IUCN). This species is listed as least concern on IUCN Red List and its population indicated as stable; however it is considered endangered according to the Regional Red List *(Bonato et al., 2007)* (see **Table 1**)*.*

Bombina variegata

B. variegata is a newt with a size of up to 5cm. This species is more common in hilly areas, only locally on plains, with altitudinal range never over 1500m. It frequents different aquatic environments as creeks, streams with a weak current, small pools and lakes with shallow water. It reaches the reproductive site between March and April and remains until September/October. The female binds 40-100 eggs to the submerged vegetation. The hatch happens 1 week after deposition, whilst the larval development lasts 2 to 3 months. The larvae are omnivores whilst the adults predate mainly arthropods. Its larvae are predated by fishes and other amphibians, especially newts (Sindaco et al., 2006).
The geographic range of this species includes much of central Europe (France, Germany, Austria and North East of Italy), the Balkan region and the Carpathian Mountains. It is considered least concern on IUCN Red List, however local extinctions are recorded in the western part of its range and the population trend is thought to be decreasing (IUCN) (see also **Table 1**).

Rana latastei

R. latastei is a frog with a size of up to 7,5cm. This species typical lives in plain or hilly woody areas, with dense brushwood and up to 400m altitude. Its breeding sites are small pools, rarely creeks with weak current, where it goes only for reproduction, from February to April. On the contrary most of its life is spent in the terrestrial environment. The female lays 90-900 eggs in a clutch. The eggs hatch after 10-15days, whilst the larval development lasts 3 to 4 months. The larvae are omnivores whilst the adults predate a large variety of invertebrates, especially insects. Its larvae are predated by aquatic insects, whilst the adults by aquatic and rapacious birds and water snakes (Sindaco et al., 2006).

The geographic range of this species is very limited (less than 2000 Km^2) and fragmented. It includes the lowlands of the Po plain in the North East of Italy and reaches the western parts of Slovenia and Croatia. Additionally, the reduced quality and extent of its habitat and its negative population trend make IUCN considering this species as vulnerable (IUCN) (see also **Table 1**).

Materials and Methods

This study focuses primarily on the determination of the habitat preferences of the selected amphibian species in Montello area. For this purpose information about a variety of environmental descriptors was collected (see **Table: 2**). Aerial photos, field sampling, regional thematic maps and information from former studies were elaborated, supported by a Geographical Information System (GIS) software, and eventually statistically analyzed.

Data collection

Hereafter a description of the data collection is provided respectively for the categories:

- regional cartography;
- aerial photos;
- first extensive fieldwork of the reproductive sites for amphibian species conducted in the period 2006-2009;
- second, short lasting, field work occurred during the days 17, 19 and 20 of May 2010.

Features of the regional cartography

The cartography used is the CTR (Carta Tecnica Regionale or Technical Regional Map) on a scale 1:5000. This was drawn up by the Italian Geodetic Commission in 1973 and updated (except for the South-West area of Montello, elements: 105011, 105012, 105013, 105014) in the years 2003-2004. The Cartography is drawn in the representation Gauss-Boaga with coordinates referring to the Italian national system Gauss-Boaga West. It is available on line for download on the website of the Veneto region (http://cartografico.regione.veneto.it).

Features of the aerial photos

The software Google Earth 5.2.1.1547 and its aerial photos of the area of Montello hill, updated on 2nd September 2004, were examined. Two rectangular areas of 100 and 200 meters side, in the four directions (N/E/S/W), with the centre the water site, were highlighted, using the tool called *legend,* and observed. The proportion of land use around the water sites was estimated, according to the same four categories adopted during the first fieldwork (human settlements, wood, grassland and agriculture) (see also Ficetola and De Bernardi, 2004, Pellitteri-Rosa et al., 2008).

Features of the first fieldwork

During the period 2006-2009 Zoologist Enrico Romanazzi recorded 155 water sites potentially suitable for amphibians in the area of Montello, (excluding the escarpment in the northern side and along the Piave river) according to the following set of criteria. A water site was considered suitable for amphibians if it showed (Romanazzi and Bonato, in press):

- presence of water for at least part of the year;
- presence of accessible surface water (not if in closed wells or artifacts);
- borders not completely raised with vertical slopes in respect to the soil.

A sample of 52 sites, visited for at least 5 times, over the 117 showing some evidences of use as reproductive sites by amphibians, was selected. During the visits among years 2006-2009 (of which at least one before the end of April and at one after the beginning of June) the presence of amphibians was recorded. A water site was considered a reproductive one when complying with at least one of the following criteria (data from Romanazzi and Bonato, in press):

- observations of eggs and grubs;
- vocalizations (for Common toad, Italian Agile Frog and Agile Frog);
- at least 5 interacting adults in a potentially reproductive period (for Yellow-Bellied Toad, Common toad and Agile Frog);
- intercourse among couples.

For newt species:

- at least 3 adults in reproductive coat in spring;
- courting activity;
- 1 pregnant female in water.

Statistical analysis showed that the number of species observed and the number of visits performed were not significantly correlated (Spearman R = 0.23, t = 1.686, p = 0.0979) (Romanazzi and Bonato, in press).

During this extensive fieldwork other features of the water sites and their surroundings were observed. The sizes of the water sites were measured (with 1 m precision for width and length and 0.10 m for the depth) (Romanazzi and Bonato, in press) (see also Tockner et al., 2006, Vos and Chardon, 1998, Ficetola and De Bernardi, 2004, Warren and Buttner, 2008, Laan and Verboom, 1990, Pellitteri-Rosa et al., 2008). The coordinates and altitude (see also Espregueira Themudo and Arntzen, 2007, Cirovic et al., 2008) were recorded with a Global Positioning System (GPS). A series of environmental conditions of the water sites were observed: hydro conditions (perennial or temporary water), water quality (in terms of eutrophized or good: depending on the presence of algae, lack of transparency, smells potentially related to organic matter degradation), water supply (rainwater or groundwater), water flow conditions (stagnant, weakly current and current), substrate (soil, rock, concrete or plastic), water vegetation: floating, emerged and submerged (as vegetation cover in percentage), presence/absence of vegetal and mineral debris (see also Tockner et al., 2006, Sebasti and Carpeneto, 2004, Ficetola and De Bernardi, 2004, Laan and Verboom, 1990, Pellitteri-Rosa et al., 2008). The land use in the surroundings of the water sites was recorded (Romanazzi, 2009) (see also Vos and Chardon, 1998, Ficetola and De Bernardi, 2004, Pellitteri-Rosa et al., 2008) according to the categories: human settlements, agriculture, grasslands and wood (in percentage of soil cover). Furthermore other information not used in this study was collected.

Features of the second field work

All the water sites selected as a reproductive one (according to the criteria mentioned in the paragraph *Features of first fieldwork*) were visited one time during the days 17, 19 and 20 of May 2010 by Enrico Romanazzi and Francesco Reyes to execute additional sampling.

Water temperature, air temperature, electrical conductivity, pH and dissolved oxygen saturation in water were sampled (see also Tockner et al. 2006, Vos and Stumpel, 1995, Vos and Chardon, 1998, Sebasti and Carpeneto, 2004, Laan and Verboom, 1990) from 2 to 5 times at each water site, proportionally to its size, in order to account for environmental variability. Canopy cover (in percentage), turbidity (increasing from 0 to 3) and organic matter (low, medium, high) in the water sites (see also Vos and Stumpel, 1995, Ficetola and De Bernardi, 2004, Laan and Verboom, 1990) were visually estimated.

***Table 2**: Variables collected and their sources (C: census, F: fieldwork, G: geographical information system, A: aerial photos)*

Water site	**Code**	**Source**
Coordinates (decimal degrees)	Coordinates	C
Total number of species	Totspec	C
Altitude (m)	Altitude	C
Catchment type	Catchtype	C
Water quality (1=Eutrophic, 0=Good)	Quality	F
Supply (rainwater, groundwater)	Supply	C
Max depth (m)	Maxdepth	C
Sun intensity (in arbitrary scale from 0 to 3)	Sunny	C
Substrate (soil, rock, plastic, concrete)	Substrate	C
Canopy cover (%)	Vegcover	F
Floating vegetation (%)	FloatVeg	C
Submerged vegetation (%)	SubVeg	C
Emerged vegetation (%)	EmergVeg	C
Presence of Vegetable debris (yes = 1, no = 0)	VegDebris	C
Presence of Mineral debris (yes = 1, no = 0)	MinDebris	C
Organic matter (low, medium, high)	Organicmatter	F
Turbidity (in arbitrary scale from 0 to 3)	Turbidity	F
Conductivity (µS)	Conductivity	F
pH	PH	F
Oxygen saturation (%)	OxygenPerc	F
Water temperature (°C)	Watertemp	F
Water flow conditions (Stagnant, Weakly current, Current)	Water	C
Hydro conditions (Perennial, Temporary)	Hydrocond	C
Aspect (from 0 degrees (North) to 359, clockwise)	Aspect	G
Horizontal sizes of the water site (m)	Length	C
Surroundings		
Distance from primary and secondary roads (m)	DistRoads	G
Distance from primary roads (m)	DistRoad	G
Potential accumulation of water (m^2)	FlowAcc	G
Potential accumulation of water flowing through agricultural fields using gridsize 10 (m^2)	AgrCel10	G
Potential accumulation of water flowing through agricultural fields using gridsize 52 (m^2)	AgrCel52	G
Grasslands in the nearest 100m (%)	Gras50	A/C
Woodlands in the nearest 100m (%)	Wood50	A/C
Agricultural fiedls in the nearest 100m (%)	Agri50	A/C
Human settlements in the nearest 100m (%)	Build50	A/C
Grasslands in the nearest 200m (%)	Gras100	A/C
Woodlands in the nearest 200m (%)	Wood100	A/C
Agricultural fiedls in the nearest 200m (%)	Agri100	A/C
Human settlements in the nearest 200m (%)	Build100	A/C

Data elaboration

The data available from the regional cartography have been processed in a GIS environment (see also Cirovic et al., 2008, Pellitteri-Rosa et al., 2008), with the software ArcGIS 9.3.1, in order to obtain numerical information regarding the water sites. Aspect (Cirovic et al., 2008), distance to roads (Vos and Chardon, 1998), area of the catchment contributing in delivering rain water (thus influencing hydroperiod and water conductivity) and the area of this catchment covered by agricultural fields (possibly delivering fertilizers and pesticides (Baird and Cann, 1995) which could in turn affect the biodiversity (Geiger et al., 2010), for each water-site were derived from the regional cartography by mean of a GIS model.

This information, together with the data from the aerial photos, the census and the field work was then statistically analyzed to infer the habitat preferences of the four amphibian species.

Pretreatment of the geographical information

The 30 cartographic elements, representing 3200x2800 meters each of Montello hill and its close surroundings, were downloaded from the website http://cartografico.regione.veneto.it.

The layers containing viability, altitudinal and agricultural information were merged together and underwent filtering and cleaning as follows. Information about elevation points and contour lines were cleaned from obvious mistakes, as points with elevation values higher than the highest known surface in the area, and from not useful/misleading information as measurements of the altitude at the gutter lines. The layers containing agricultural information were cleaned from the information referred to agricultural uses for which the use of chemicals it’s assumed as absent or limited. Doing so, the information regarding the following agricultural types were maintained: orchard, grape-vine, olives, vegetable garden, greenhouses, cultivations, nurseries. On the layers containing information about viability only primary and secondary roads were kept.

GIS model development

The positioning of each water-site, measured by mean of a Global Positioning System (GPS) during the census, were imported in the GIS environment and reprojected in the same coordinate system of all the other layers (Gauss-Boaga West) (see **Appendix: GIS model**).

A Digital Elevation Model (DEM) was developed joining altitudinal points and contour lines, *enforcing* for the presence of sinks at the locations of the water-sites (function "*Topo to Raster*" enforcing for sinks). This allowed the creation of an altitudinal map where the processes of interpolation, needed to cover the relative lack of resolution, could take into account the presence of sinks in the map, avoiding flatting them as if they were errors in the morphological representation.

The layers containing agricultural information as well as those including the positioning of the water-sites were converted to raster format (functions "*Feature to Raster*" and "*Point to Raster*") and their values reclassified (function "*Reclassify*") to unique values in order to make them suitable for successive procedures.

The aspects (orientation of the main slope in the surroundings of a specified point) of the DEM were derived (function "*Aspect*") and associated with the respective water-sites (functions "*Times*" and "*Extract values to Point*").

The distances of the water-sites from "Primary" and "Primary and Secondary" roads were extracted (function "*Euclidean Distance*") and associated with the positions of the water-sites (functions "*Times*" and "*Extract values to Point*").

The relative amount of rainwater potentially flowing to each water-site was calculated accounting only for the surface of the catchment involved in providing water to each single sink (functions "*Flow Direction*" and "*Flow Accumulation*" applied to the DEM). In this sense uniform precipitations over the entire hill were assumed. The outcomes were associated with their respective water-sites (functions "*Times*" and "*Extract values to Point*").

The contribution of the rainfall flowing through agricultural areas until the water-sites was calculated by mean of the DEM, a raster layer obtained merging the raster layers containing agricultural information (function "*Single Output Map Algebra*") and the position of the water-sites (functions "*Flow Direction*", "*Watershed*" and "*Times*").

Eventually all the values resulting from the elaboration were collected in a joint table (iteration of the function "Join Field").

The computation was run using a grid size of 10 m (10 m is the linear measure of a cell), this being half of the smallest distance between different contour lines, as well as half of the shortest linear distance represented in the cartography of origin. In this way the information present in the cartography of origin were used without loss of details.

Aerial photos

The aerial images available on Google Earth were compared with the data concerning land use, gathered during the extensive fieldwork, and the layers of the regional cartography containing agricultural information, to check their coherence. This information sometimes mismatched, especially for the classification of patches of agriculture or grassland. Grasslands and agricultural field are difficult to distinguish from an aerial photo and their attribution to one of the two categories resulted difficult. To determine a univocal attribution of the land use it was necessary to identify some specific criteria **(Figure 2)**. The distinction and successive attribution of coverage between the groups woodland, human settlement and "grassland-agriculture" were straightforward. To distinguish between grasslands and agriculture the field observations, conducted during the census by the expert of the area Enrico Romanazzi, were considered the most reliable source. However field observations miss the overview provided by satellite images. So, where from the aerial photos it was possible to estimate a higher agricultural coverage (due to the clear presence of rows of plants) than in the field observation, this was considered the most reliable estimate and recorded.

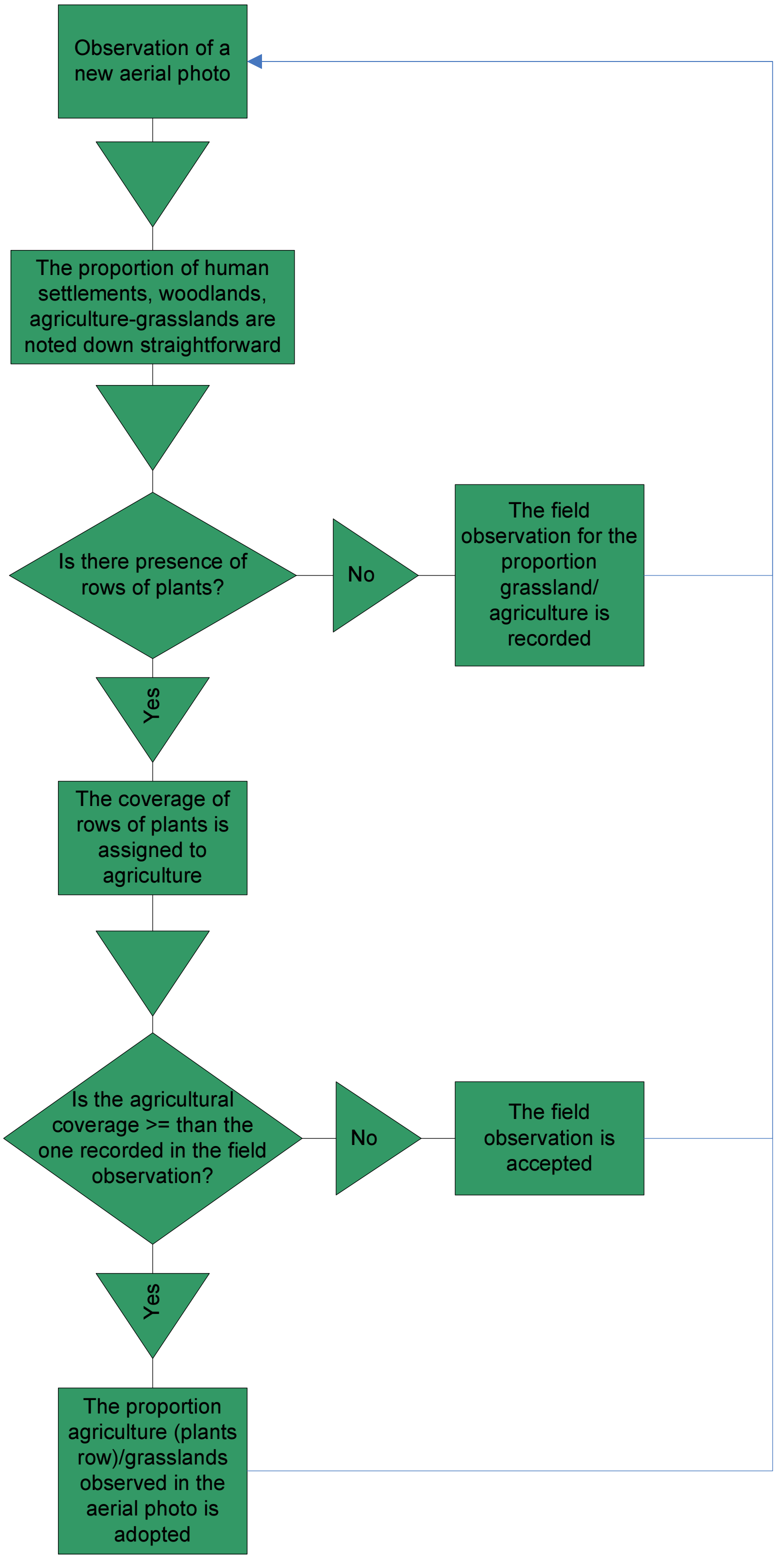

Figure 2*: Scheme for the attribution of the landuse*

Validation of the geographical information

The GIS layers containing information about the part of the catchment of each water-site under agricultural use (variables *AgrCel10* and *AgrCel52*) was compared with the satellite images from Google Earth and the field observations. Three errors in the GIS map were discovered: in the surroundings of three of the water-sites (id 13, 15, 47) the map described presence of agriculture whilst the other two sources revealed its absence. This means that all the surface water flowing into these three water-sites doesn't pass by lands under agricultural use. Therefore the values of *AgrCel10* and *AgrCel52* in these three points, that from the geographical computation in GIS resulted to be positive, were equalized to zero.

A proxy for the water-site surface was created multiplying length and width of the water-sites (e.g. Warren and Buttner, 2008).

Dataset assemblage and statistical analysis

Pretreatment of data

The dataset in use contained 26 variables, each one measured in 49 samples: some variables presented missing values. In phase of validation of the dataset a general criterion was adopted for their treatment. If less than 5 samples per variable were missing, they were substituted with the average value of the same variable, calculated on the remaining values. When, on the contrary, this number was higher than 5, the variable was excluded from the analysis.

The variables presenting missing values, the relative number of missing values, the identification code of the correspondent water-site (ID), and their mean, mode and standard deviation are shown in **Table 3**.

Table 3: *Substitution of missing values*

Variables	**Number of missing values**	**ID**	**Mean/Mode**	**Standard deviation**
Hydro conditions	3	1, 41, 42	-/Perennial	-
Canopy cover	1	12	71/90	28
Organic matter	9	6, 12, 18, 19, 26, 33, 36, 38, 49	70/100	36
Turbidity	3	3, 27, 47	2/2	1

The variable *organic matter* was often impossible to measure because of presence of high turbidity or of dense aquatic vegetation. Therefore it presented a high number of missing values and was excluded from the analysis.

The substitution of the missing values for the variable *hydro condition* was performed differently than with the over mentioned criterion in an attempt to cope with its low variance. Since the vast majority of the analyzed water-sites presented perennial water, the substitution of missing values with the same class would necessarily lead to no relations in regression analysis. On the contrary their attribution to the less numerous class would give the chance to a relationship to emerge, without increasing very much the error. Therefore, not knowing the true nature of these pools, and in order to increase the variance of the variable, the missing values were assumed to be temporary water-sites. However, the single regression was run also keeping the values as missing, which didn't lead to significantly different results.

Normalization of the dataset

Frequency diagrams were plotted for all the variables. All the variables showing high skewness were reclassified. Frequency classes were regrouped in order to increase the size of the smaller ones and/or the logarithm was taken according to the formula: *ln(variable + 1)* to reduce the skewness, while avoiding negative results. All the treated variables were thus re-plotted (see **Appendix**: **Frequency plots**). The logarithm was recalculated for the variables measuring conductivity, dissolved oxygen, potential accumulation of water, potential accumulation of water flowing through agricultural fields and the water-site surface (respectively called *LogCond*, *LogOxyperc*, *LogFloAc*, *LogAgr* and *LogSurface*).

The variable for *substrate* contained a majority of samples with soil (36), whilst limited were those with rocky (1), or anthropogenic (1 plastic, 5 concrete) materials. According to the over mentioned criteria the materials were reclassified as: natural (rock and soil) and anthropogenic (concrete and plastic) into the variable *Substrate2*.

The water flow conditions (*stagnant*, *weak current* and *current* water) presented only a few samples with *current* or *weak current* water (respectively 2 and 3 water-sites). To reduce the skewness, the classes *current* and *weak current* were grouped as *current*.

Aquatic vegetation was absent in most water-sites. Thus the frequency class for null cover presented relatively many cases, providing a very much skewed frequency distributions. Its reclassification was made as present/absent, reducing the disproportion of the cases belonging to the different classes. The variables for floating vegetation (*floatVeg*), submerged vegetation (*subVeg*) and emerged vegetation (*emergVeg*) were respectively re-named: *RcFloatV*, *RcSubmeV* and *RcEmergV*.

The variables *AgrCel52* and *AgrCel10* reported the agricultural surfaces included in the catchments of the water-site. These were calculated according to an elaboration performed with the software ArcGIS respectively on the default setting, which results in using a cell size of 52, and on a customized setting, with cell size of 10 (half of the minimum distance between two contour lines). According to the maps used, most water-sites were located far from agricultural lands, thus the agricultural surfaces included in their catchments were in most cases null. Therefore the frequency distributions of variables *AgrCel52* and *AgrCel10* were extremely skewed towards the value zero. To reduce the skewness of these variables their values were reclassified in three groups representing: no agriculture, modest agricultural use and high agricultural use (see **Table 4**).

Table 4: *Reclassification of the variables AgrCel*

	AgrCel10		**AgrCel52**	
	Original values	Reclassified values	Original values	Reclassified values
No agriculture	0	0	0	0
Modest agricultural use	1-5	4	1-10	4
High agricultural use	6-25	11	11-120	40

The variable *aspect* (orientation of the slope in the near surrounding of a water-site), as calculated in the ArcGIS environment, is expressed in positive degrees from 0 to 359.9, measured clockwise from the north.

The distribution of *Triturus vulgaris* was found almost significantly related with this variable in a single logistic regression analysis (see chapter **Results**). Presence of *Triturus vulgaris* and aspects of the water sites were thus plotted together to look for specific distributional patterns. The species was observed as present on not East oriented pools (see **Figure 3**). The East-West direction was also observed as the most common direction of the local winds (see **Figure 4**). According to this observation (see also chapter **Discussion**) the variable *aspect* was reclassified in two classes with the values: 1 for the interval 0-180 degrees and 0 for the interval 181-359.

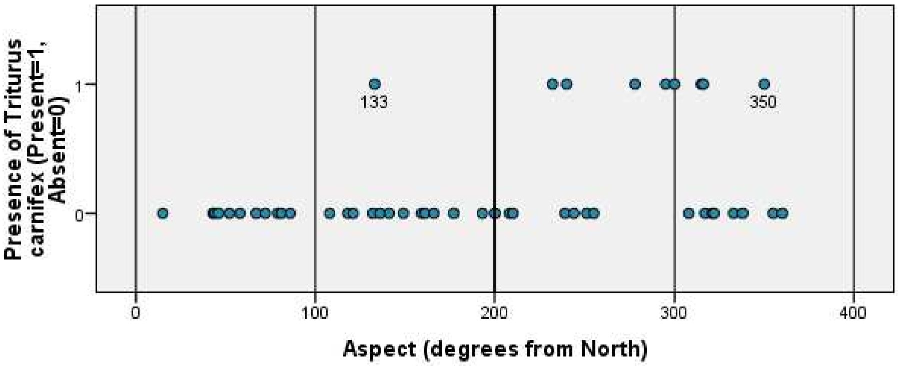

Figure 3: *Distribution of Triturus carnifex (present=1, absent=0) vs Aspect (from 0=North to 359 clockwise).*

Simplifying the dataset: lack of accuracy and autocorrelation

Some of the variables measured or calculated initially were excluded from the analysis at different stages. These were taken out because they missed accuracy in representing the environment or were highly correlated with other variables in the dataset, thus bringing little additional information.

The variables *water* and *air temperature* did not carry enough information to be a reliable representation of the temperature conditions. Both water and air temperatures are presumably highly variable between days and seasons. Moreover catchments of different sizes and with different water sources (rain or groundwater) go to thermal equilibrium with the rest of the environment at different speed. Thus single measurements, performed at different hours during the day for different water-sites, were considered as not bringing enough meaningful information. Even some data elaboration by means of moderate modeling efforts would hardly contribute to solving the lack of information in the data, especially when considering the high variability of this karst environment.

A cross tabulation (see **Appendix: Correlation table**) was run for all the variables still present in the dataset, in order to identify and exclude significantly highly correlated ones (P > 0.7) (Ficetola and De Bernardi, 2004).

Autocorrelation can also be used to discern which highly correlated variables of a dataset better represent the environment. Ecosystems are systems where the different components often deeply interact with each other. The results of these interactions could be seen in the co-variation of some environmental characteristics. In this way, higher or lower correlations among measurements of different environmental features could reveal the degree of interaction between these parts. The correlations between analogous variables and the rest of the dataset could show which one of them was more highly related to the environment.

In this study different measurements were performed for similar environmental descriptors: at different spatial scales (e.g. land use) or with similar but not identical methods (e.g. *sun intensity* and *canopy cover*). Some of the analogous variables showed a larger number of significant correlations with the other environmental descriptors, thus were thought to be more linked with the rest of the environment. Thus the variables showing the highest number of significant correlations with the rest of the dataset were maintained, whilst the less correlated analogous one discarded.

The variables *LogAgr10* and *LogAgl52* were highly correlated (P= 0.885, Sig.=0.000) and brought the same kind of information, as well as the variables *Gras50* (P= 0.852, Sig.=0.000), *Wood50* (P= 0.915, Sig.=0.000), *Agri50* (P= 0.938, Sig.=0.000) and *Build50* (P= 0.658, Sig.=0.000), respectively with *Gras100*, *Wood100*, *Agri100* and *Build100* and the variables *DistRoads* and *DistRoad* (P= 0.676, Sig.=0.000). In both cases different measurements were performed, not much to gather different types of information, but to check what grid size (for the first variable), road types (for the second) and surface area around the water-sites (for the third group) was more meaningful to analyze.

The variable *Sun intensity* was highly significantly correlated with *Canopy cover* (P= -0.624, Sig.=0.000).

Eventually the variable indicating the *Catchment type* was significantly highly correlated with *Flow condition* (P= -0.624, Sig.=0.000). This is due to the fact that the water coming from a fountain is naturally current, while the one present in a pond tends to be stagnant.

The variables *LogAgr10*, *Gras100*, *Wood100*, *Agri100*, *Build100*, *DistRoads, Sun intensity, Total number of species* and *Catchment type* were less correlated with the rest of the dataset than their analogous and thus excluded from the dataset.

Furthermore the variable *Total number of species* was excluded since obviously auto-correlated with the presence/absence of each single species.

Regressions

A logistic regression was run between each single variable left in the dataset (see **Table 5**) and the distribution of the selected species: *Triturus carnifex, Lissotriton vulgaris, Bombina variegata* and *Rana latastei*.

A multiple logistic regression analysis was run on all the 26 variables at the same time, following a stepwise forward procedure and using the likelihood ratio as the criterion to lower the probability of the model to fit (see also Laan and Verboom, 1990, Ficetola & De Berardi, 2004, Hartel et al., 2010). This method was considered the most suitable since it allows one to compute a large amount of variables, keeping out of the model all the one that show little importance from the beginning. At the same time it includes the predictors according to the contribution they individually bring to the model and avoids the inclusion of covariates (Field, 2005).

Table 5: *Variables used in the logistic regression (L: log transformed variables)*

Water-site	**Code**	**Source**
Altitude (m)	Altitude	C
Water quality (1=Eutrophic, 0=Good)	Quality2	F
Maxdepth (m)	Maxdepth	C
Substrate (Natural (soil, rock) = 1, Artificial (plastic, concrete) = 0)	Substrat2	C
Canopy cover (%)	Canopy	F
Presence of vegetable debris (yes = 1, no = 0)	VegDebris	C
Presence of mineral debris (yes = 1, no = 0)	MinDebris	C
Turbidity (from 0 = null, to 3)	Turbidity	F
Conductivity ^{L} (µS)	LogCond	F
pH	PH	F
Oxygen saturation ^{L} (%)	LogOxperc	F
Water flow conditions (Stagnant water = 1, Current = 0)	Stagnant	C
Hydro conditions (Perennial water = 1, Temporary = 0)	Perennial	C
Water-site surface ^{L} (m^2)	Logsurface	C
Floating vegetation (0 = absent, 1 = present)	RcFloatV	C
Submerged vegetation (0 = absent, 1 = present)	RcSubVeg	C
Emerged vegetation (0 = absent, 1 = present)	RcEmergV	C
Aspect (reclassified as 0 = 0-180, 1 = 181-359)	AspectEW	G
Surroundings		
Distance from primary roads (m)	DistRoad	G
Potential accumulation of water ^{L} (m^2)	LogFloAc	G
Potential accumulation of water flowing through agricultural fields ^{L} (m^2)	LogAgr52	G
Grasslands in the nearest 100m (%)	Gras50	A/C
Woodlands in the nearest 100m (%)	Wood50	A/C
Agriculture in the nearest 100m (%)	Agri50	A/C
Human settlements in the nearest 100m (%)	Build50	A/C

Results

49 are the water-sites sampled in the study area. These are distributed from 98 to 349m AMSL, without a preferential geographical orientation (*aspect*). The max depth varies between 0.2m and 3.0m (average 0.8m) and the proxy for surface from 1 to 2500m^2 (average 30m^2).

82% of the water-sites are perennial and mostly (90%) with stagnant water. Conductivity range is from 31 to 597μS (micro Siemens) (average 126μS), pH from 5,4 to 8,9 (average 6,9), oxygen saturation from anoxic conditions (4%) to oversaturation (155%) (average 36%).

Although some water-sites are located on open areas, most are surrounded by woodlands (average woodlands cover in the nearest 100m from the water-sites 74%, median 90%), present a high degree of canopy cover (average 70%, median 80%) and often a conspicuous load of vegetable debris. The degree of turbidity is variable over the water-sites and the presence of floating, submerged and emerged vegetation limited respectively to 30%, 10% and 20% of the sites.

The hill is located in a fragmented landscape. However, at a closer view, 37% (18) of the water-sites do not present any sign of human land use in their close surroundings (nearest 100 meters). Indeed although the houses and associated agricultural fields and clearings for feedstock are widespread around the hill, these are relatively rare when compared to a highly exploited area, with intensive agriculture, as the surrounding Po valley.

All the variables present in the dataset showed some significant autocorrelation (see **Appendix: Correlation table**) meaning that they were a good representation of the environment.

The presence of the four species is relatively rare even among those sites considered potentially suitable for reproduction. *B.variegata* and *L. vulgaris* are recorded only in 12% of the ponds each (6 times), *T. carnifex* on 20% (10) while *R. Latastei* on 35% (17).

Triturus carnifex

T. carnifex is recorded in relatively deep (average 1,3m) and large (average 242m^2, min 25m^2) sites. These are characterized by canopy cover lower than the average (47,5%), high water turbidity (in 9 over 10 cases between medium and high, 1 case with low) and presence of floating vegetation (60% of the times) higher than the average over the area. This species was found only in perennial water-sites.

The water-sites' surroundings are generally rich in low vegetation (grasslands or agricultural areas) and relatively poor in woodlands (52% in the nearest 100m).

T. carnifex was found only in ponds orientated from 133 to 350 degrees (clockwise from North), namely on non E/N-E oriented slopes (see **Figure 3**).

Logistic regression analysis (see **Table 6**) showed the presence of *T. carnifex* as positively correlated with water depth, East-West orientation of the slope, proxy for surface, presence of floating vegetation, turbidity and presence of agriculture. Negative correlation is showed for canopy cover and presence of woodlands in the nearest 100 meters.

Table 6: *Results of the single regression for Triturus carnifex.*
Relationships indicated as: "▲"positive and "▼"negative.

	Signif.	*Triturus carnifex*	Exp(B)	%Correct
Maxdepth	0,008	▲	19,49	79,6
Canopy	0,010	▼	0,97	81,6
AspectEW	0,041	▲	5,75	79,6
LogSurface	0,009	▲	1,92	79,6
RcFloatV	0,048	▲	4,35	79,6
Turbidity	0,014	▲	5,06	83,7
Wood50	0,011	▼	0,97	83,7
Agri50	0,034	▲	1,05	83,7

Lissotriton vulgaris

Presence of *L. vulgaris* is recorded in 6 relatively deep, large water-sites with average *max depth* and *surface* of 1,7m and 915m^2, between 121 and 325m altitude. This species was found only in perennial water-sites. It was found particularly often in sites with presence of emerged vegetation (70% of the times).

The nearest 100 meters from the water-sites presented relatively high low vegetation coverage (grasslands) (28%), whilst the woodlands were particularly limited (43%).

The orientation of the water-sites ranges from 232 to 322 degrees clockwise from North (with the exception of site number 9, aspect equal 46 degrees).

Table 7: *Results of the single regressions for Lissotriton vulgaris.*
Relationships indicated as: "▲"positive and "▼"negative.

	Signif.	*Lissotronis vulgaris*	Exp(B)	%Correct
Maxdepth	0,008	▲	370,34	91,8
LogSurface	0,002	▲	3,71	91,8
RcEmergV	0,015	▲	10,29	87,8
Gras50	0,046	▲	1,05	89,8
Wood50	0,014	▼	0,96	85,7

Logistic regression analysis (see **Table 7**) shows *L. vulgaris* as positively correlated with water depth, proxy for surface, presence of emerged vegetation and presence of grasslands in the nearest 100 meters form the water-sites. Negative correlation is shown for presence of woodlands in the nearest 100 meters around the water-site.

Bombina variegata

B. variegata was recorded in 6 shallow, small ponds with average max depth and surface of 0,6m and 11m^2, between 98 and 210m altitude, in spots with relatively high water conductivity (average 265µS). These are generally far from main roads (average 648m), human settlements (0% in the surroundings) and agricultural activities (2%). They are located in woody areas with vegetation cover around 60-70% and almost absence (3%) of grasslands.

Table 8: *Results of the single regressions for Bombina variegata. Relationships indicated as: "▲"positive and "▼"negative.*

	Signif.	*Bombina variegata*	Exp(B)	%Correct
Altitude	0,056	▼	0,98	87,8
LogSurface	0,043	▼	0,41	87,8
DistRoad	0,013	▲	1,00	85,7

Logistic regression analysis (see **Table 8**) shows presence of *B. variegata* as positively correlated with distance to main roads. Negative correlations are showed for surface and altitude of the water-sites.

Rana latastei

R. latastei is, among the considered species, the most diffused on Montello, being present in 17 water-sites between 98m and 344m altitude. Its distribution ranges over all the environments present in the area and doesn't result associated with any of the selected descriptors. Only the eutrophic degree of its water-sites seemed to play a role. The species was found 70% of the times in sites with *good* water quality (in respect to eutrophized conditions) and also logistic regression (see **Table 9**) revealed a weak negative relationship with the eutrophic water conditions.

Table 9: *Results of the single regressions for Rana latastei.*

Relationships indicated as: "▲"positive and "▼"negative.

	Signif.	*Rana latastei*	Exp(B)	%Correct
Quality2	0,051	▼	0,29	65,3

The multiple logistic regressions (see **Table 10**) for *R. latastei* didn't provide any result. One to two significant predictors were found for all the other species. These results are coherent with the ones showed for the single logistic regression.

Table 10: *Results of the multiple regressions.*

Relationships indicated as: "▲"positive and "▼"negative.

Forward Logistic Regression	Present	Absent	Explained by the average	Predictors	Significance	Exp(B)	Direction	Explained by the Model
Triturus carnifex	10	39	79,6	Maxdepth	0,038	14,52	▲	
				Turbidity	0,059	4,07	▲	87,8
Lissotriton vulgaris	6	43	87,8	Maxdepth	0,008	370,34	▲	91,8
Bombina variegata	6	43	87,8	Substrat2	0,040	0,05	▼	87,8
				DistRoad	0,009	1,01	▲	
Rana latastei	17	32	65,3					

Discussion

Characterization of breeding sites

In this study multiple logistic regression analysis was performed to identify the environmental features of the breeding sites preferentially chosen by 4 amphibian species. This tool is better suited for the identification of habitat preferences when compared to single logistic regression or correlation. However due to the low number of samples (N=49), the large number of predictors and the limited presence for some of the species, the multiple logistic regression analysis resulted in limited results (0 to 2 significant predictors per species). To draw more information about habitat characterization, the results provided by the single regressions analysis will be also considered.

Single logistic regression showed several environmental descriptors as significantly related with the species' distributions. Most of the results are largely supported by former studies. However some of the findings seem to bring relatively new contribution to what is known in literature.

The breeding sites of the two newt species shared similar features and scored the highest number of significant predictors. Conversely, different and in much lower number were the environmental descriptors related to the toad *B. variegata* and the frog *R. latastei*.

Newt species: Triturus carnifex and Lissotriton vulgaris

T. carnifex and *T. vulgaris* were often found together (as in Sebasti and Carpeneto, 2004) and always in water-sites with a high number of amphibian species (syntrophy analysis based on Sorensen index by in Romanazzi and Bonato, in press).

The positive correlation of these species with the depth of the pools is reported in Ficetola and De Bernardi, 2004 and Warren and Buttner, 2008. However in the Montello area also the surface size seem to play a role. This finding is in agreement with the fact that larger water volumes (due to large surface and depth) host a higher number of species (Laan and Verboom, 1990) *(Romanazzi and Bonato,* in press***)*.**

Presence of aquatic vegetation showed to positively influence the newt species' presence (as in Ficetola and De Bernardi, 2004, Cirovic et al., 2008). This is especially true for submerged vegetation, of which the leaves are used to wrap eggs for protection by *L. vulgaris* (Warren and Buttner, 2008). *T. carnifex* was found associated with emerged vegetation (as in Hartel et al., 2007*),* and is reported in literature as positively related to species richness, for which it is even proposed as index (Gustafson et al., 2006).

The water-sites occupied by *T. carnifex* presented generally high turbidity. This could be partially explained by the high correlation between this variable and *maxdepth* (P= 0.510, sign.=0.000). The correlation with *maxdepth* could be explained by the fact that its measurement was performed without use of specific instruments, but just visually. In this way the deepest pools were likely to seem less transparent, namely more turbid, than the shallow ones, providing biased results.

The two newts species were found only in perennial ponds as suggested by other authors (see Sebasti and Carpeneto, 2004, Cirovic et al., 2008). However, because of the large prevalence of water-sites with prolonged hydro period (40 over 49 water-sites), the logistic regression didn't point out any relationship between hydroperiod and species' distributions.

The vegetation surrounding the water-site showed to be particularly important in determining the newts' species distribution. Low canopy covers (often resulting in high sun exposure) as well as presence of open woodlands and clearings were positively related with the species' presence (see also Sebasti and Carpeneto, 2004).

T. carnifex was associated with pools not oriented eastward. The part of the Veneto region including Montello is subjected to almost constant wind throughout the year, blowing in the East-West direction (see **Figure 4**). This wind comes from the inland and from higher altitudes (Alps and pre-Alps), thus it is presumably dry. It was found that exactly the ponds oriented towards the direction where the wind comes from are avoided by *T. carnifex*. Furthermore two other predictors (*Canopy cover* and *woodland in the nearest 100 m from the water-site)* showed high negative relationships (Sign. 0.01, exp(B) 0.968) and (Sign. 0.011, exp(B) 0.967)) with the ponds inhabited by this species, supporting this hypothesis. This would mean that *T. carnifex* chooses breeding sites with relatively low canopy cover and woodland in the surroundings, namely areas that would be highly exposed to wind flow if eastward oriented. A possible explanation of the relationship wind-species' distribution could lie on the sensitiveness of amphibians' pattern of movement on humidity gradients (Hartel, 2008) and more specifically on soil moisture (Hartel et al., 2008, Hazzel et al., 2003) which could be decreased in particularly windy areas.

Clarifying the possible relationship between wind patterns and species' distribution seems worthwhile. Further investigations about wind intensity in the proximity of ponds inhabited by *Triturus carnifex* as well as a look for other possible mechanisms lying between wind pattern and newt distribution (e.g. preys availability in windy spots) could help to clarify the mechanism underlying this relationship.

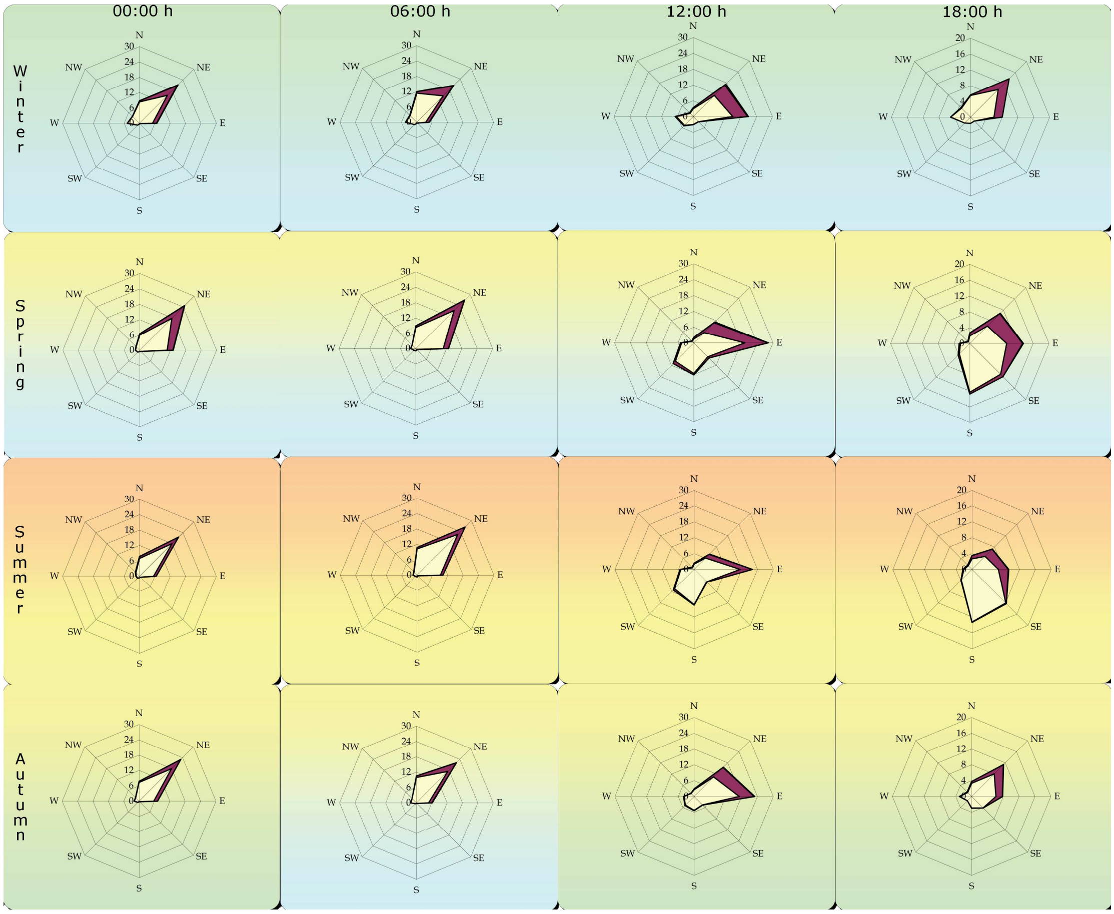

***Figure 4**: Anemometric diagrams. Treviso Istriana meteo station, 42m a.s.l. years 1971-2000 (Meteorological Service of the Minister for Defense of the Italian Republic, 2010).*

Other studies found the two newt species restricted to intermediate values of conductivity and pH (Cirovic et al., 2008), however the ranges of these parameters in the study area were already narrow (pH: Min=5,4; Max=8,9; Average=6,9; SD=0,7. Conductivity: Min=30μS, Max=596μS, Average=170μS, SD=142μS) making the large majority of the water-sites not limiting the species presence (see **pH** and **Logarithm of conductivity** in **Appendix: Frequency plots)**.

Bombina variegata

B. variegata is known to be a toad with preferences for small ((Babik and Rafinski, 2001) in (Warren and Buttner, 2008)), newly created or associated with a high degree of disturbance (Warren and Buttner, 2008), temporary ponds (Hartel et al. 2010, ((Babik and Rafinski, 2001) in (Warren and Buttner, 2008))). Ponds with a permanent hydroperiod are generally avoided ((Babik and Rafinski,

2001) in (Warren and Buttner, 2008)), however they may be used depending on the existence of temporary pools in the surroundings (Hartel et al., 2010).

B. variegata is found to prefer clayey, calcareous soils ((Babik and Rafinski, 2001) in (Warren and Buttner, 2008)) and karst topography ((Gollmann et al., 1988) in (Warren and Buttner, 2008)) where it is found preferentially in exposed mineral soils ((Babik and Rafinski, 2001) in (Warren and Buttner, 2008)). These findings could explain some peculiarities of the recorded local distribution. The species was found especially related to artificial substrates (it is present 4 times on soil and 2 times on concrete substrates, over the 7 sites made of artificial material). The material of the two artificial sites is concrete, a material with high mineral composition. These structures are made and settled by hunters to attract ungulates during the game season. These animals in turn could produce a periodic and substantial disturbance.

The pools where *B. variegata* was found are shallow, aquatic vegetation free sites, with limited presence of other species, especially T. carnifex and L. vulgaris (syntrophy analysis based on Sorensen index by Romanazzi and Bonato, in press).

The most relevant result concerning the human environmental impact was found on *B. variegata.* This toad was found negatively related with presence of main roads. The amphibian class is constituted by small ground dwelling animals which can encounter high mortality in crossing barriers such as roads (Vermeulen and Opdam, 1995). A negative effect on the occupation probability of ponds was already found in other species by Vos and Chardon (Vos and Chardon, 1998). *B. variegata* is a small toad, thus with a relatively high movement metabolic cost (Schabetsberger, 2004) and is recorded as one of the European amphibian species with the most limited migration distances (Kovar et al., 2009). It is thus reasonable to think that its limited movement capacities makes this species more affected by the presence of road networks than other amphibian species, even in low densely populated areas such as Montello, where there is relatively low traffic.

Eventually *B. variegata* had a weak negative relationship with the altitudinal gradient (Sign. 0.056, exp(B) 0.98). This could be partly explained by the decreased availability of shallow and temporary ponds with altitude (Maxdepth and Hydro conditions are significantly correlated with Altitude, respectively (P= 0.296, sign.=0.039) and (P= 0.374, sign.=0.008)) which are reported in literature as preferred. Similarly, altitude is negatively correlated with distance between water-sites and main roads (P= -0.306, sign.=0.032), which in turn was found to affect the presence of breeding site, thus contributes in explaining the preference for low altitudes.

Rana latastei

R. latastei is a frog, the egg mass density of which is reported to be positively influenced by pond size (Tockner et al., 2006) or depth (Ficetola and De Bernardi, 2004, ((Ficetola and De Bernardi, 2005b) in Pellitteri-Rosa et al. 2008))) and presence of riparian forest (Tockner et al., 2006).

The species was found distributed over ponds with an average 63% canopy cover and 68% of woodlands on the nearest 100 m from its breeding sites. The depth of the pools was not significantly higher than the average in the study area and the sites surface was only in one case less than about 9 m^2. So the former findings available in literature are not contradicted.

The only relationship found between this species and the environmental descriptors was the one with *water quality*. *R. latastei* was found almost significantly (sign.= 0.051) related with eutrophized water. However the method used to measure this variable was highly inaccurate (only based on one visual observation) and such a relation is too loose to lead to any conclusion.

Limitations of this study

Montello area presents a much larger number of water-sites than those included into the present analysis. Although an extensive survey of the amphibians' distributions was available, the intensity of its observations was not as high as desirable to provide complete information on the local amphibians' distributions. The large size of the area and the fact that most work was performed as voluntarism made the description of the environment necessarily limited. Only about 30% of the sites (51 over 155) were visited for a sufficient number of times to reliably describe the amphibian's presence. This partial survey of the environment implied, as a result, that an environmental descriptor that could greatly increase the correctness of the model's predictions, such as the distance between pools inhabited by the same species (e.g. Vos and Chardon, 1998, Ficetola and De Bernardi, 2004), was not included in the model.

Furthermore other variables were sampled without support of proper instruments (*turbidity*, *water quality*), determining presumably high incorrectness in the environmental description.

Eventually the measurements of all variables were replicated in very limited numbers and time extent thus relatively poorly accounting for time variability.

Broad assumptions concerning the use of chemicals in agricultural areas and the land uses attributions itself were made to look for possible influences of land use on the water-site’s populations. The classification of land patches into different categories was assisted by a set reasonable criteria (see **Figure 2**), which most likely improved the correspondence between dataset and reality. However this was still made on the base of rough/inaccurate data, as revealed during validation of the dataset.

Therefore, although it was possible to highlight several relationships between environmental characteristics and presence of breeding sites, the results of the model are still relatively limited in explaining the local amphibian’s distribution.

Conclusions

Besides strengthening former findings, this study enlightened the contribution of two factors determining amphibian species distributions. Road networks, even in relatively low traffic areas, revealed as negatively affecting the presence of the endangered pioneer species *B. variegata*, which presents limited movement capacities.

Furthermore wind patterns were found to probably influence the distribution of the newt’ species *T. vulgaris*.

This paper confirmed that a number of different environmental factors influence the distribution of vulnerable amphibian species and should thus be considered when drawing protection measures (Pellitteri-Rosa et al., 2008).

However higher investments in terms of time and equipment could lead the research to broader and more reliable results.

Further research about the actual land use and use of chemicals into the agricultural patches in the study area could bring more light on the influences chemicals on amphibians.

In further works on the study area an environmental descriptor accounting for distances between habitat patches should be included.

Recommendation

Although the aquatic environment is central for amphibian populations, since it hosts reproduction, it is only part of the habitat they need. Up to now terrestrial habitats received relatively little attention by the scientific community (Schabetsberger, 2004). However some consideration based on literature can be formulated, to frame the findings presented in this study in a landscape perspective including a network of ponds. In this way habitat fragmentation could be accounted, so that second and third research questions (see chapter **Research questions**) will find answers.

Information about migration distances, use of terrestrial habitat and ecological corridors will be reported to provide suggestions for conservation measures.

Montello is separated from other semi-natural environments by areas relatively unsuitable to wildlife (Ficetola and De Bernardi, 2004) and road networks causing high mortality during migrations (De Stefano, 2010, Menin et al., 2003). Ecological corridors could increase connectivity and limit road mortality (Hartel et al., 2010) and should be implemented at least between the largest habitat patches. During their creation, terrestrial and aquatic habitats characteristics should be attuned to the ecological preferences and movement capabilities of the different amphibian species.

Woodlands are landscape elements known to increase connectivity between water-sites (Laan and Verboom, 1990). They would be more suitable for a variegated community if surrounded by low vegetation (e.g. meadows) (Kovar et al., 2009). These areas could not just allow transit, but provide shelters used during the terrestrial life stage. In this sense the larger the area of the corridor, the lower will be the competition for preys and available shelters (Schabetsberger, 2004).

Studies on amphibians' migrations indicate that amphibians' species tend to stop in pools at different distances from the place where their movements started. The frequency of water-sites along the corridor should account for these species' specific features. For this purpose **Table 11** shows some results obtained from former studies on migration patterns of amphibians.

***Table 11**: Distance of movement from the water site of origin. a: estimation for 95% of the adults (Kovar et al. 2009); b: most frequent recapture (Hartel, 2008); c: movement around the native sites (Lanza, 1983, Bernini et al., 2000) in (Pellitteri-Rosa et al., 2008).*

	T. carnifex	*L. vulgaris*	*B. variegata*	*R. latastei*
Distance (m)	161-866[a]	174-303 [a]	170 [a], 200 [b]	100-150 [c] m

Therefore a series of water-sites should be present in the described ecological corridor at distances not higher than those showed in **Table 11**.

Especially the species with strong pioneer behaviors (e.g. *B. variegata*) would probably encounter high road mortality when exploring areas outside the corridor. To reduce the magnitude of this problem, fences could be settled on the corridor perimeter to reduce crossing.

A heterogeneous disturbance regime should be maintained to stimulate colonization by *B. variegate,* of which the presence is reported as positively correlated with recent ground disturbance. Indeed pools less than 1 year old are preferred, whilst negative correlation is found with the ones older than 2 years (Warren and Buttner, 2008).

Eventually the pools size should be considered. Although large and deep pools are generally found to host the richest communities (Laan and Verboom, 1990), some species need small water-sites (on this study area *Romanazzi and Bonato,* in press). To host variegated amphibians' species, pools of different dimensions should be available.

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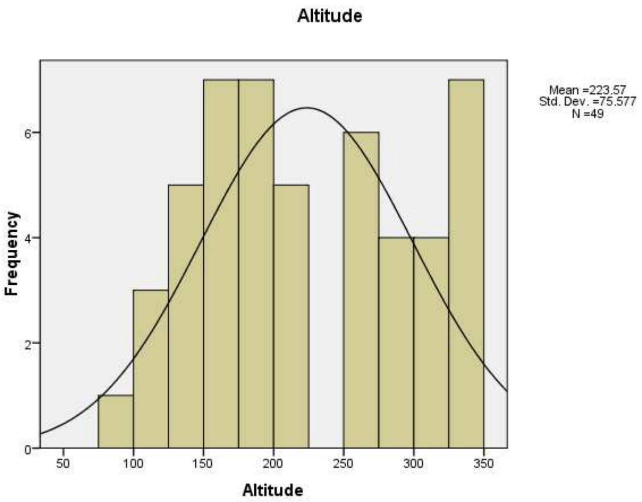
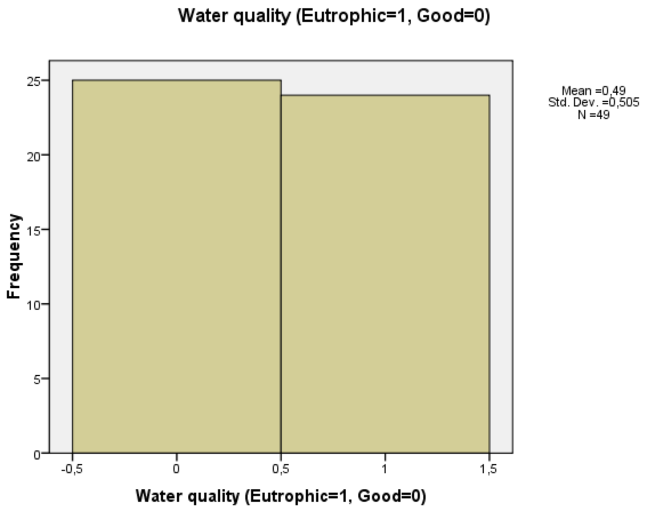
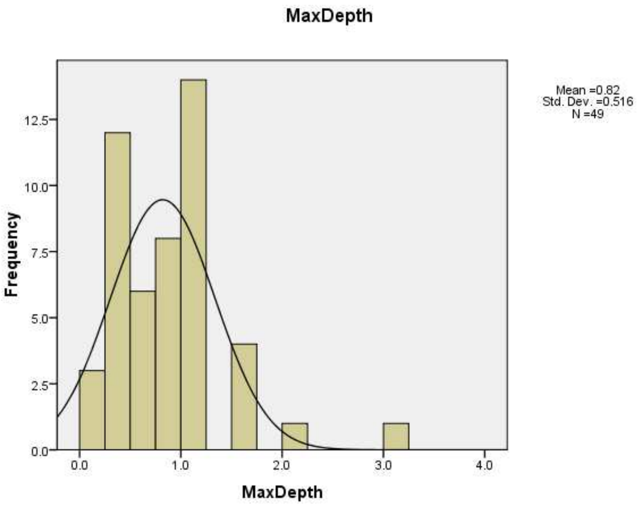
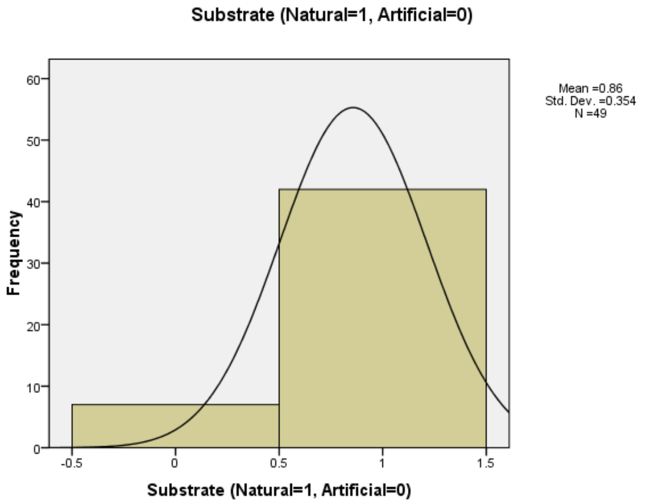
Appendix

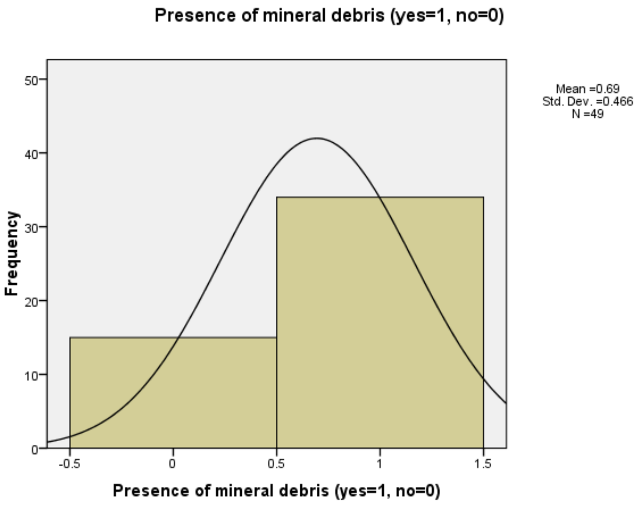
Frequency plots

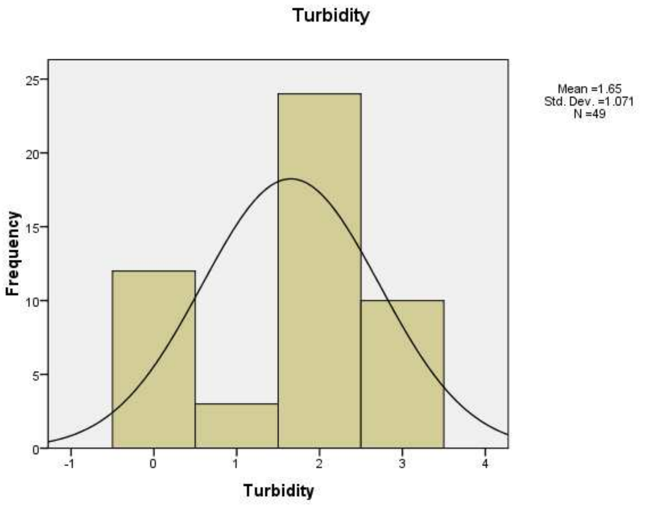


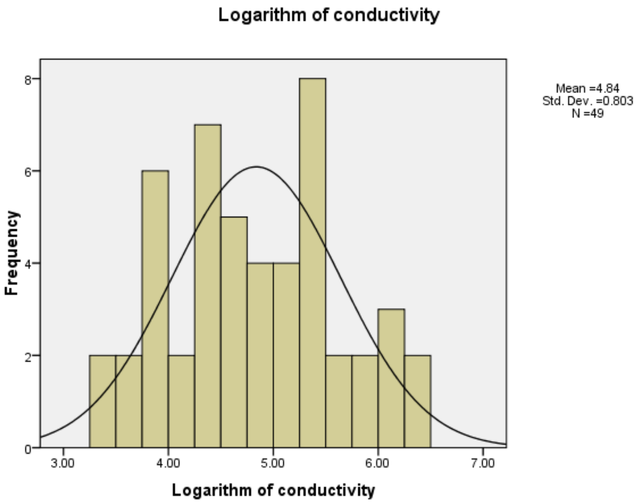


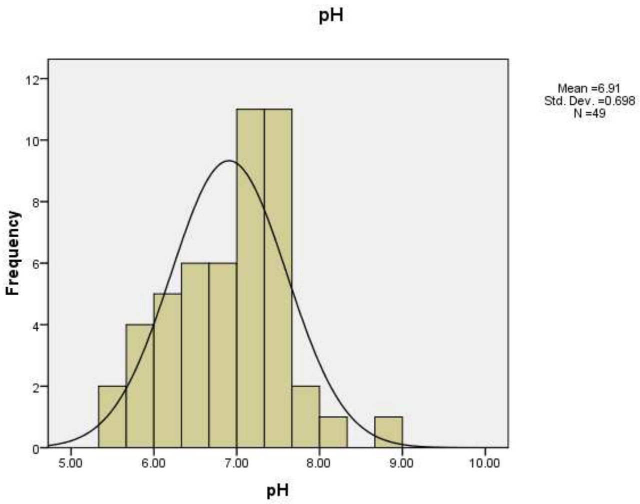









Logarithm of conductivity
Mean =4.84
Std. Dev. =0.803
N =49
Frequency
0
2
4
6
8
3.00
4.00
5.00
6.00
7.00
Logarithm of conductivity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Std. Dev. =0.698
N =49
Frequency
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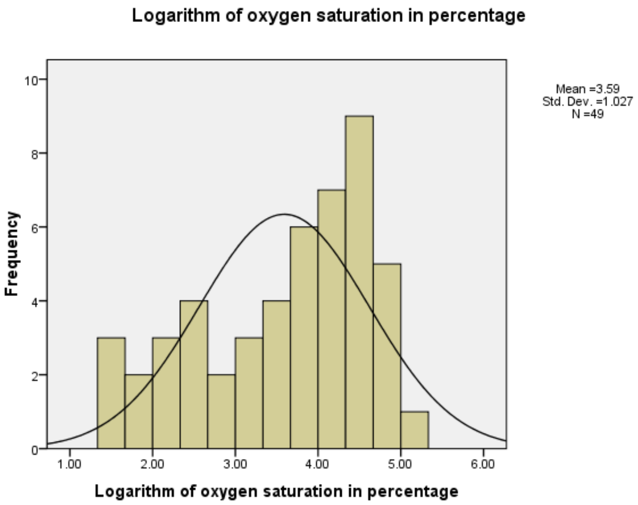
6
8
10
12
5.00
6.00
7.00
8.00
9.00
10.00
pH


Logarithm of oxygen saturation in percentage
Mean =3.59
Std. Dev. =1.027
N =49
Frequency
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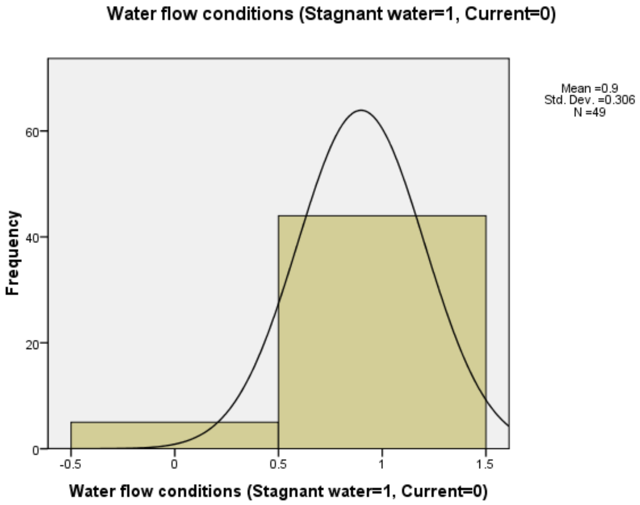
2
4
6
8
10
1.00
2.00
3.00
4.00
5.00
6.00
Logarithm of oxygen saturation in percentage


Water flow conditions (Stagnant water=1, Current=0)
Mean =0.9
Std. Dev. =0.306
N =49
Frequency
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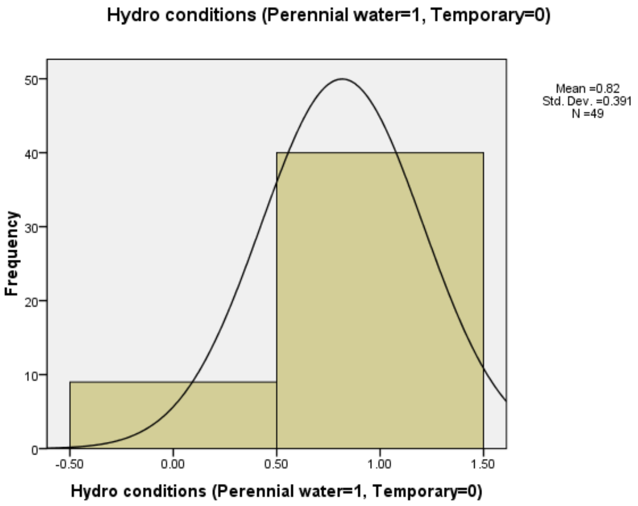
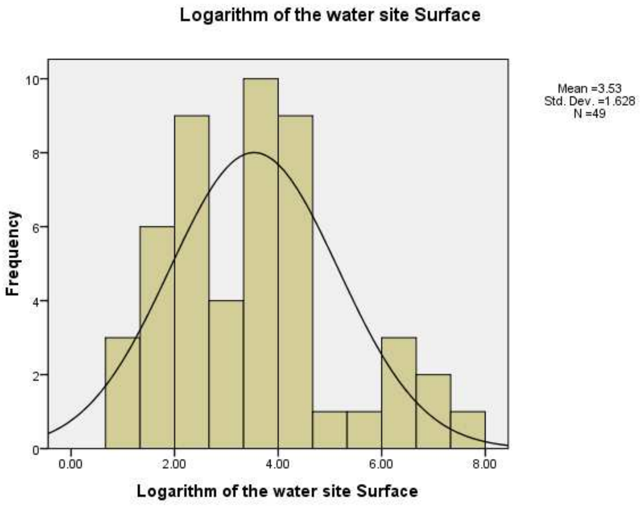
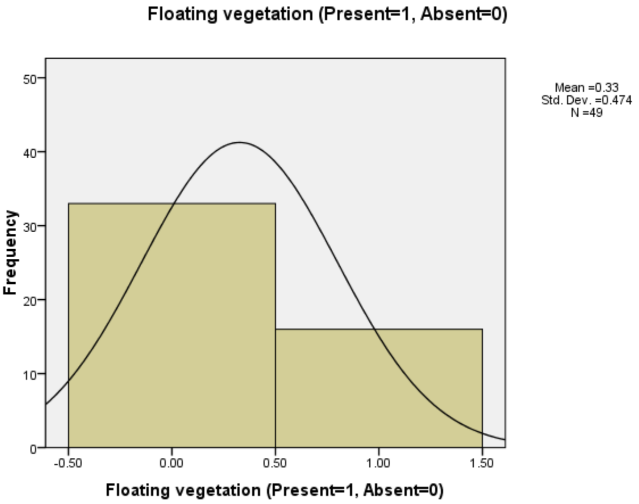
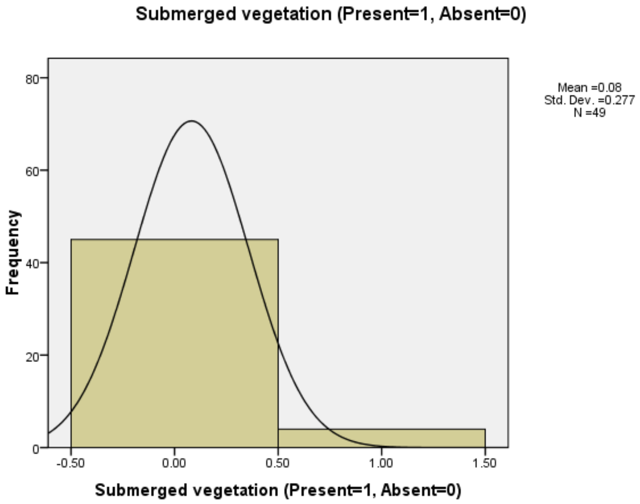
20
40
60
-0.5
0
0.5
1
1.5
Water flow conditions (Stagnant water=1, Current=0)


Hydro conditions (Perennial water=1, Temporary=0)
Mean =0.82
Std. Dev. =0.391
N =49
Frequency
0
10
20
30
40
50
-0.50
0.00
0.50
1.00
1.50
Hydro conditions (Perennial water=1, Temporary=0)


Logarithm of the water site Surface
Mean =3.53
Std. Dev. =1.628
N =49
Frequency
0
2
4
6
8
10
0.00
2.00
4.00
6.00
8.00
Logarithm of the water site Surface


Floating vegetation (Present=1, Absent=0)
Mean =0.33
Std. Dev. =0.474
N =49
Frequency
0
10
20
30
40
50
-0.50
0.00
0.50
1.00
1.50
Floating vegetation (Present=1, Absent=0)


Submerged vegetation (Present=1, Absent=0)
Mean =0.08
Std. Dev. =0.277
N =49
Frequency
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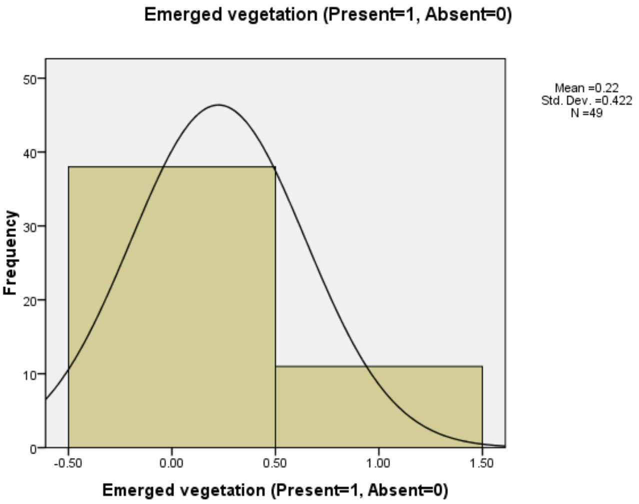
20
40
60
80
-0.50
0.00
0.50
1.00
1.50
Submerged vegetation (Present=1, Absent=0)


Emerged vegetation (Present=1, Absent=0)
Mean =0.22
Std. Dev. =0.422
N =49
Frequency
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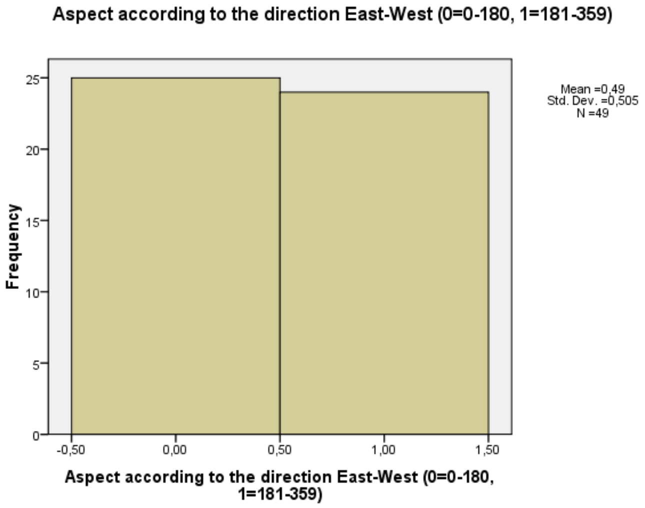
10
20
30
40
50
-0.50
0.00
0.50
1.00
1.50
Emerged vegetation (Present=1, Absent=0)


Aspect according to the direction East-West (0=0-180, 1=181-359)
Mean =0,49
Std. Dev. =0,505
N =49
Frequency
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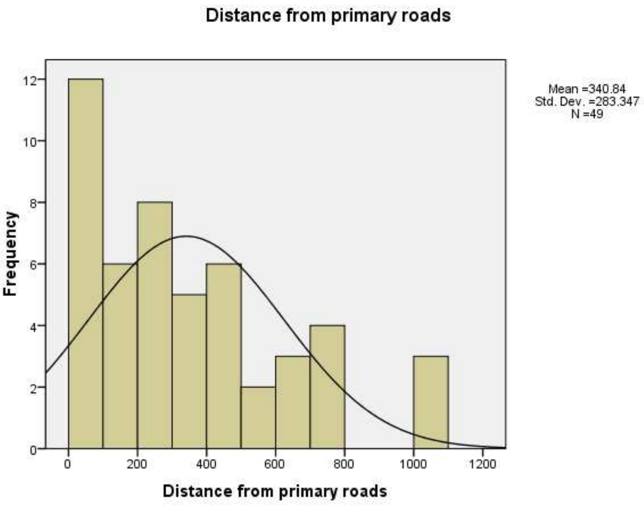
5
10
15
20
25
-0,50
0,00
0,50
1,00
1,50
Aspect according to the direction East-West (0=0-180, 1=181-359)


Distance from primary roads
Mean =340.84
Std. Dev. =283.347
N =49
Frequency
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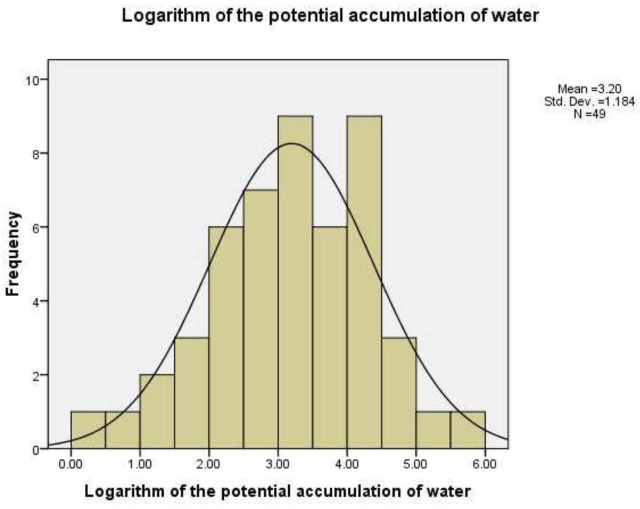
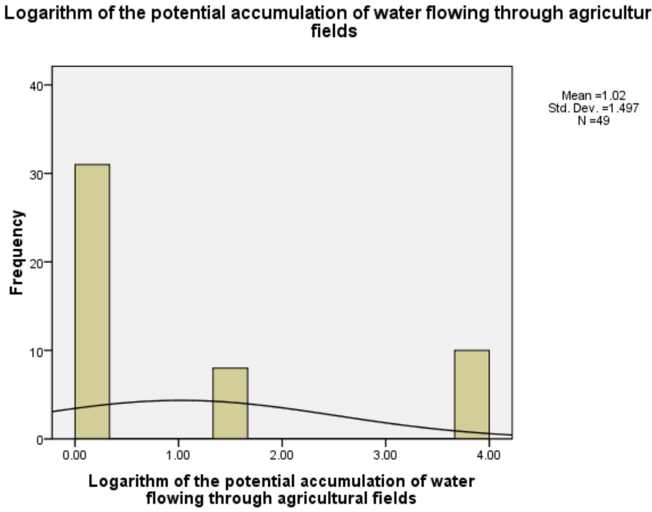
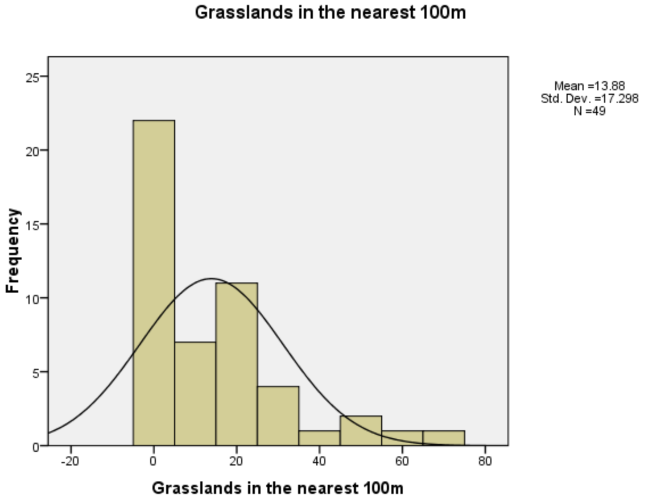
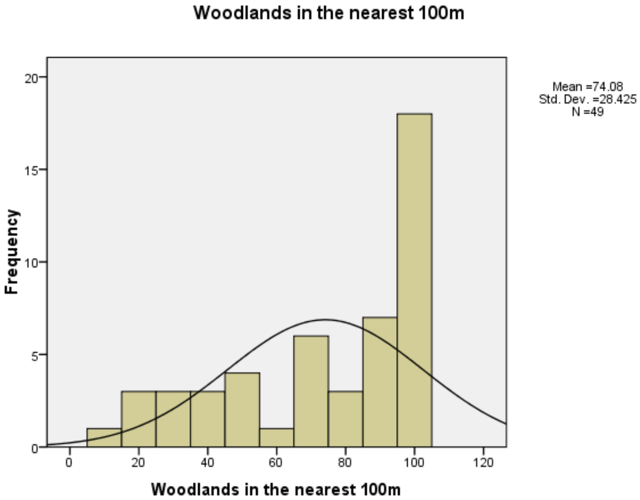
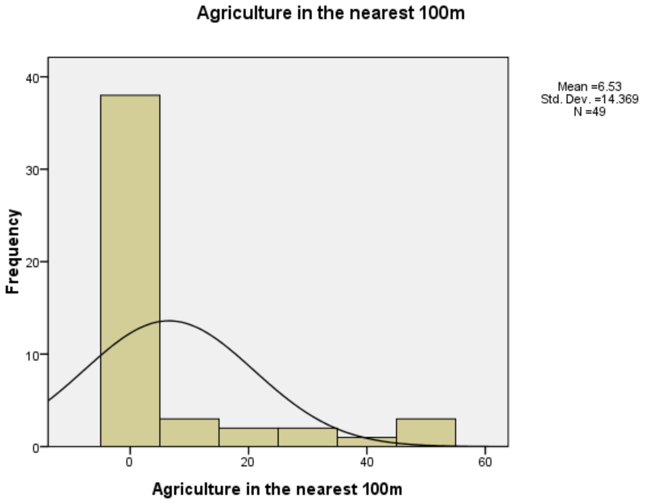
4
6
8
10
12
0
200
400
600
800
1000
1200
Distance from primary roads

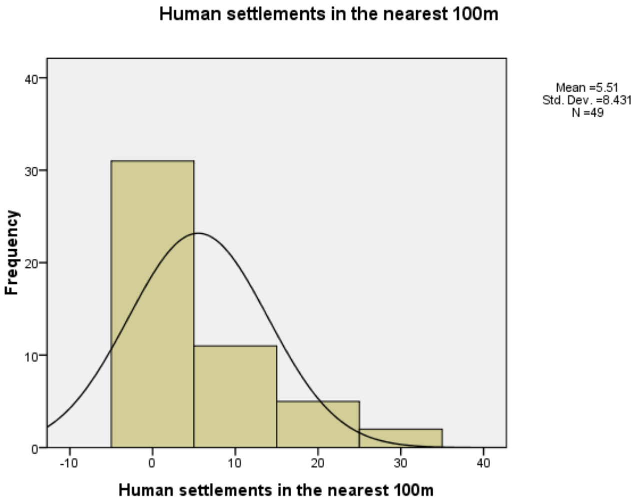

Logarithm of the potential accumulation of water
Mean =3.20
Std. Dev. =1.184
N =49
Frequency
0
2
4
6
8
10
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Logarithm of the potential accumulation of water


Logarithm of the potential accumulation of water flowing through agricultural fields


Grasslands in the nearest 100m


Woodlands in the nearest 100m


Agriculture in the nearest 100m


Human settlements in the nearest 100m

Correlation Table

		Altitude	Quality (1=Eutrophic, 0=Good)	Maxdepth	Substrat2 (Natural=1, Artificial=0)	Canopy	VegDebris (yes=1, no=0)
Altitude	Pearson Correlation	1,000	,080	.296*	-,056	-,275	-,181
	Sig. (2-tailed)		,583	,039	,702	,056	,213
Quality (1=Eutrophic, 0=Good)	Pearson Correlation	,080	1,000	,145	.283*	-,087	,212
	Sig. (2-tailed)	,583		,322	,049	,551	,144
Maxdepth	Pearson Correlation	.296*	,145	1,000	.324*	-.418**	,061
	Sig. (2-tailed)	,039	,322		,023	,003	,678
Substrat2 (Natural=1, Artificial=0)	Pearson Correlation	-,056	.283*	.324*	1,000	,128	.451**
	Sig. (2-tailed)	,702	,049	,023		,381	,001
Canopy	Pearson Correlation	-,275	-,087	-.418**	,128	1,000	.348*
	Sig. (2-tailed)	,056	,551	,003	,381		,014
VegDebris (yes=1, no=0)	Pearson Correlation	-,181	,212	,061	.451**	.348*	1,000
	Sig. (2-tailed)	,213	,144	,678	,001	,014	
MinDebris (yes=1, no=0)	Pearson Correlation	-,019	.385**	,079	.362*	,131	.425**
	Sig. (2-tailed)	,896	,006	,592	,011	,368	,002
Turbidity	Pearson Correlation	,201	.282*	.510**	,251	-.338*	,064
	Sig. (2-tailed)	,166	,050	,000	,081	,018	,663
LogCond	Pearson Correlation	-.390**	-.414**	-,097	-.291*	,147	-,007
	Sig. (2-tailed)	,006	,003	,508	,042	,312	,960
pH	Pearson Correlation	-.381**	-,124	,025	-.356*	-,240	-.413**
	Sig. (2-tailed)	,007	,394	,866	,012	,097	,003
LogOxperc	Pearson Correlation	,190	-,106	,122	-,275	-.356*	-.350*
	Sig. (2-tailed)	,192	,467	,402	,055	,012	,014

The number of samples is always N=49.One star(*) stands for significative, two stars(**) for highly significative.

		Altitude	Quality (1=Eutrophic , 0=Good)	Maxdepth	Substrat2 (Natural=1, Artificial=0)	Canopy	VegDebris (yes=1, no=0)
Stagnant (Stagnant=1, Current=0)	Pearson Correlation	,259	,195	,119	,248	-,226	-,149
	Sig. (2-tailed)	,072	,178	,415	,086	,118	,307
Perennial (Perennial=1, Temporary=0)	Pearson Correlation	.374**	-,273	,163	-,194	-,015	-,067
	Sig. (2-tailed)	,008	,057	,262	,182	,917	,648
LogSurface	Pearson Correlation	,070	.301*	.586**	.296*	-,138	,034
	Sig. (2-tailed)	,632	,036	,000	,039	,345	,818
RcFloatV (0=absent, 1=present)	Pearson Correlation	,232	,275	.423**	,160	-,199	,072
	Sig. (2-tailed)	,109	,055	,002	,272	,170	,623
RcSubVeg (0=absent, 1=present)	Pearson Correlation	,111	-,143	,251	,122	-,095	-,070
	Sig. (2-tailed)	,446	,327	,082	,405	,515	,633
RcEmergV (0=absent, 1=present)	Pearson Correlation	-,094	,158	.361*	,220	-,013	,105
	Sig. (2-tailed)	,522	,279	,011	,129	,931	,471
AspectEW (0=0-180, 1=18-359)	Pearson Correlation	,104	-,062	.360*	,050	-,168	,101
	Sig. (2-tailed)	,478	,674	,011	,733	,250	,488
DistRoad	Pearson Correlation	-.306*	-,048	-,024	,134	,113	,055
	Sig. (2-tailed)	,032	,745	,871	,358	,439	,708
LogFloAc	Pearson Correlation	-,172	-,044	-,064	-.308*	-,014	-,072
	Sig. (2-tailed)	,238	,764	,660	,031	,925	,624
LogAgr52	Pearson Correlation	,131	,014	,271	-,157	-,225	-,092
	Sig. (2-tailed)	,369	,924	,060	,280	,120	,528
Gras50	Pearson Correlation	,157	,207	,140	-,112	-.464**	-,061
	Sig. (2-tailed)	,281	,153	,337	,444	,001	,676

The number of samples is always N=49.One star(*) stands for significative, two stars(**) for highly significative.

		Altitude	Quality (1=Eutrophic, 0=Good)	Maxdepth	Substrat2 (Natural=1, Artificial=0)	Canopy	VegDebris (yes=1, no=0)
Wood50	Pearson Correlation	-,223	-,142	-.368**	,059	.588**	,241
	Sig. (2-tailed)	,123	,330	,009	,686	,000	,096
Agri50	Pearson Correlation	,170	-,077	.428**	,023	-.408**	-.341*
	Sig. (2-tailed)	,241	,600	,002	,873	,004	,017
Build50	Pearson Correlation	,139	,185	,222	-,010	-.337*	-,105
	Sig. (2-tailed)	,339	,204	,124	,946	,018	,471

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		MinDebris (yes=1, no=0)	Turbidity	LogCond	pH	LogOxperc	Stagnant (Stagnant=1, Current=0)
Altitude	Pearson Correlation	-,019	,201	-.390**	-.381**	,190	,259
	Sig. (2-tailed)	,896	,166	,006	,007	,192	,072
Quality (1=Eutrophic, 0=Good)	Pearson Correlation	.385**	.282*	-.414**	-,124	-,106	,195
	Sig. (2-tailed)	,006	,050	,003	,394	,467	,178
Maxdepth	Pearson Correlation	,079	.510**	-,097	,025	,122	,119
	Sig. (2-tailed)	,592	,000	,508	,866	,402	,415
Substrat2 (Natural=1, Artificial=0)	Pearson Correlation	.362*	,251	-.291*	-.356*	-,275	,248
	Sig. (2-tailed)	,011	,081	,042	,012	,055	,086
Canopy	Pearson Correlation	,131	-.338*	,147	-,240	-.356*	-,226
	Sig. (2-tailed)	,368	,018	,312	,097	,012	,118
VegDebris (yes=1, no=0)	Pearson Correlation	.425**	,064	-,007	-.413**	-.350*	-,149
	Sig. (2-tailed)	,002	,663	,960	,003	,014	,307
MinDebris (yes=1, no=0)	Pearson Correlation	1,000	,159	-,131	-.327*	-,252	,215
	Sig. (2-tailed)		,277	,370	,022	,080	,138
Turbidity	Pearson Correlation	,159	1,000	-,209	,214	-,065	.398**
	Sig. (2-tailed)	,277		,149	,140	,655	,005
LogCond	Pearson Correlation	-,131	-,209	1,000	.445**	-,006	-.534**
	Sig. (2-tailed)	,370	,149		,001	,967	,000
pH	Pearson Correlation	-.327*	,214	.445**	1,000	.308*	-,152
	Sig. (2-tailed)	,022	,140	,001		,032	,296
LogOxperc	Pearson Correlation	-,252	-,065	-,006	.308*	1,000	-,250
	Sig. (2-tailed)	,080	,655	,967	,032		,083

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		MinDebris (yes=1, no=0)	Turbidity	LogCond	pH	LogOxperc	Stagnant (Stagnant=1, Current=0)
Stagnant (Stagnant=1, Current=0)	Pearson Correlation	,215	.398**	-.534**	-,152	-,250	1,000
	Sig. (2-tailed)	,138	,005	,000	,296	,083	
Perennial (Perennial=1, Temporary=0)	Pearson Correlation	-,201	,143	,214	,281	.284*	-,160
	Sig. (2-tailed)	,167	,327	,141	,051	,048	,272
LogSurface	Pearson Correlation	-,135	.357*	-,157	,160	,271	-,213
	Sig. (2-tailed)	,355	,012	,282	,273	,059	,142
RcFloatV (0=absent, 1=present)	Pearson Correlation	,179	,269	-,158	,026	,232	,091
	Sig. (2-tailed)	,218	,062	,280	,857	,109	,534
RcSubVeg (0=absent, 1=present)	Pearson Correlation	,198	,098	,104	-,060	,059	,101
	Sig. (2-tailed)	,173	,505	,476	,684	,687	,492
RcEmergV (0=absent, 1=present)	Pearson Correlation	,145	,222	-,101	,032	-,087	,020
	Sig. (2-tailed)	,320	,125	,491	,829	,551	,893
AspectEW (0=0-180, 1=18-359)	Pearson Correlation	,031	,090	,147	,076	,058	-,209
	Sig. (2-tailed)	,834	,541	,314	,605	,694	,149
DistRoad	Pearson Correlation	,257	,185	,125	,067	-.331*	,128
	Sig. (2-tailed)	,074	,202	,393	,646	,020	,381
LogFloAc	Pearson Correlation	-,262	-,013	,198	,130	,111	-.372**
	Sig. (2-tailed)	,069	,930	,173	,375	,449	,008
LogAgr52	Pearson Correlation	-,145	,114	,101	,151	,147	-,275
	Sig. (2-tailed)	,319	,434	,491	,301	,314	,056
Gras50	Pearson Correlation	-,134	,198	-,001	,116	,262	-,160
	Sig. (2-tailed)	,358	,173	,996	,428	,069	,272

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		MinDebris (yes=1, no=0)	Turbidity	LogCond	pH	LogOxperc	Stagnant (Stagnant=1, Current=0)
Wood50	Pearson Correlation	,254	-.336*	,068	-,270	-.370**	,025
	Sig. (2-tailed)	,079	,018	,644	,060	,009	,865
Agri50	Pearson Correlation	-,224	.313*	-,132	.304*	.315*	,155
	Sig. (2-tailed)	,121	,029	,367	,034	,027	,288
Build50	Pearson Correlation	-,198	,193	-,002	,156	,174	-,020
	Sig. (2-tailed)	,172	,184	,987	,285	,231	,893

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		Perennial (Perennial=1, Temporary=0)	Log Surface	RcFloatV (0=absent, 1=present)	RcSubVeg (0=absent, 1=present)	RcEmergV (0=absent, 1=present)	AspectEW (0=0-180, 1=18-359)
Altitude	Pearson Correlation	.374**	,070	,232	,111	-,094	,104
	Sig. (2-tailed)	,008	,632	,109	,446	,522	,478
Quality (1=Eutrophic, 0=Good)	Pearson Correlation	-,273	.301*	,275	-,143	,158	-,062
	Sig. (2-tailed)	,057	,036	,055	,327	,279	,674
Maxdepth	Pearson Correlation	,163	.586**	.423**	,251	.361*	.360*
	Sig. (2-tailed)	,262	,000	,002	,082	,011	,011
Substrat2 (Natural=1, Artificial=0)	Pearson Correlation	-,194	.296*	,160	,122	,220	,050
	Sig. (2-tailed)	,182	,039	,272	,405	,129	,733
Canopy	Pearson Correlation	-,015	-,138	-,199	-,095	-,013	-,168
	Sig. (2-tailed)	,917	,345	,170	,515	,931	,250
VegDebris (yes=1, no=0)	Pearson Correlation	-,067	,034	,072	-,070	,105	,101
	Sig. (2-tailed)	,648	,818	,623	,633	,471	,488
MinDebris (yes=1, no=0)	Pearson Correlation	-,201	-,135	,179	,198	,145	,031
	Sig. (2-tailed)	,167	,355	,218	,173	,320	,834
Turbidity	Pearson Correlation	,143	.357*	,269	,098	,222	,090
	Sig. (2-tailed)	,327	,012	,062	,505	,125	,541
LogCond	Pearson Correlation	,214	-,157	-,158	,104	-,101	,147
	Sig. (2-tailed)	,141	,282	,280	,476	,491	,314
pH	Pearson Correlation	,281	,160	,026	-,060	,032	,076
	Sig. (2-tailed)	,051	,273	,857	,684	,829	,605
LogOxperc	Pearson Correlation	.284*	,271	,232	,059	-,087	,058
	Sig. (2-tailed)	,048	,059	,109	,687	,551	,694

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		Perennial (Perennial=1, Temporary=0)	Log Surface	RcFloatV (0=absent, 1=present)	RcSubVeg (0=absent, 1=present)	RcEmergV (0=absent, 1=present)	AspectEW (0=0-180, 1=18-359)
Stagnant (Stagnant=1, Current=0)	Pearson Correlation	-,160	-,213	,091	,101	,020	-,209
	Sig. (2-tailed)	,272	,142	,534	,492	,893	,149
Perennial (Perennial=1, Temporary=0)	Pearson Correlation	1,000	,188	,106	,141	-,124	,254
	Sig. (2-tailed)		,196	,471	,332	,397	,078
LogSurface	Pearson Correlation	,188	1,000	,277	,065	.355*	,188
	Sig. (2-tailed)	,196		,054	,658	,012	,196
RcFloatV (0=absent, 1=present)	Pearson Correlation	,106	,277	1,000	,110	.355*	,188
	Sig. (2-tailed)	,471	,054		,451	,012	,195
RcSubVeg (0=absent, 1=present)	Pearson Correlation	,141	,065	,110	1,000	,197	,155
	Sig. (2-tailed)	,332	,658	,451		,175	,287
RcEmergV (0=absent, 1=present)	Pearson Correlation	-,124	.355*	.355*	,197	1,000	,158
	Sig. (2-tailed)	,397	,012	,012	,175		,279
AspectEW (0=0-180, 1=18-359)	Pearson Correlation	,254	,188	,188	,155	,158	1,000
	Sig. (2-tailed)	,078	,196	,195	,287	,279	
DistRoad	Pearson Correlation	-,052	-,073	-,091	,020	,156	-,171
	Sig. (2-tailed)	,725	,618	,532	,894	,286	,241
LogFloAc	Pearson Correlation	-,030	,182	-,144	-.465**	-,098	-,029
	Sig. (2-tailed)	,837	,211	,324	,001	,502	,842
LogAgr52	Pearson Correlation	,137	.349*	-,025	-,043	,034	.307*
	Sig. (2-tailed)	,347	,014	,864	,767	,817	,032
Gras50	Pearson Correlation	,046	.303*	,096	-,111	,135	.327*
	Sig. (2-tailed)	,754	,034	,510	,447	,354	,022

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		Perennial (Perennial=1, Temporary=0)	Log Surface	RcFloatV (0=absent, 1=present)	RcSubVeg (0=absent, 1=present)	RcEmergV (0=absent, 1=present)	AspectEW (0=0-180, 1=18-359)
Wood50	Pearson Correlation	-,137	-.454**	-,256	-,176	-,269	-.360*
	Sig. (2-tailed)	,347	,001	,076	,227	,061	,011
Agri50	Pearson Correlation	,107	.337*	,262	.387**	,166	,153
	Sig. (2-tailed)	,466	,018	,069	,006	,255	,294
Build50	Pearson Correlation	,187	.335*	,218	,160	.348*	.283*
	Sig. (2-tailed)	,198	,019	,132	,271	,014	,049

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		DistRoad	Log FloAc	Log Agr52	Gras50	Wood50	Agri50	Build50
Altitude	Pearson Correlation	-.306*	-,172	,131	,157	-,223	,170	,139
	Sig. (2-tailed)	,032	,238	,369	,281	,123	,241	,339
Quality (1=Eutrophic, 0=Good)	Pearson Correlation	-,048	-,044	,014	,207	-,142	-,077	,185
	Sig. (2-tailed)	,745	,764	,924	,153	,330	,600	,204
Maxdepth	Pearson Correlation	-,024	-,064	,271	,140	-.368**	.428**	,222
	Sig. (2-tailed)	,871	,660	,060	,337	,009	,002	,124
Substrat2 (Natural=1, Artificial=0)	Pearson Correlation	,134	-.308*	-,157	-,112	,059	,023	-,010
	Sig. (2-tailed)	,358	,031	,280	,444	,686	,873	,946
Canopy	Pearson Correlation	,113	-,014	-,225	-.464**	.588**	-.408**	-.337*
	Sig. (2-tailed)	,439	,925	,120	,001	,000	,004	,018
VegDebris (yes=1, no=0)	Pearson Correlation	,055	-,072	-,092	-,061	,241	-.341*	-,105
	Sig. (2-tailed)	,708	,624	,528	,676	,096	,017	,471
MinDebris (yes=1, no=0)	Pearson Correlation	,257	-,262	-,145	-,134	,254	-,224	-,198
	Sig. (2-tailed)	,074	,069	,319	,358	,079	,121	,172
Turbidity	Pearson Correlation	,185	-,013	,114	,198	-.336*	.313*	,193
	Sig. (2-tailed)	,202	,930	,434	,173	,018	,029	,184
LogCond	Pearson Correlation	,125	,198	,101	-,001	,068	-,132	-,002
	Sig. (2-tailed)	,393	,173	,491	,996	,644	,367	,987
pH	Pearson Correlation	,067	,130	,151	,116	-,270	.304*	,156
	Sig. (2-tailed)	,646	,375	,301	,428	,060	,034	,285
LogOxperc	Pearson Correlation	-.331*	,111	,147	,262	-.370**	.315*	,174
	Sig. (2-tailed)	,020	,449	,314	,069	,009	,027	,231

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		DistRoad	Log FloAc	Log Agr52	Gras50	Wood50	Agri50	Build50
Stagnant (Stagnant=1, Current=0)	Pearson Correlation	,128	-.372**	-,275	-,160	,025	,155	-,020
	Sig. (2-tailed)	,381	,008	,056	,272	,865	,288	,893
Perennial (Perennial=1, Temporary=0)	Pearson Correlation	-,052	-,030	,137	,046	-,137	,107	,187
	Sig. (2-tailed)	,725	,837	,347	,754	,347	,466	,198
LogSurface	Pearson Correlation	-,073	,182	.349*	.303*	-.454**	.337*	.335*
	Sig. (2-tailed)	,618	,211	,014	,034	,001	,018	,019
RcFloatV (0=absent, 1=present)	Pearson Correlation	-,091	-,144	-,025	,096	-,256	,262	,218
	Sig. (2-tailed)	,532	,324	,864	,510	,076	,069	,132
RcSubVeg (0=absent, 1=present)	Pearson Correlation	,020	-.465**	-,043	-,111	-,176	.387**	,160
	Sig. (2-tailed)	,894	,001	,767	,447	,227	,006	,271
RcEmergV (0=absent, 1=present)	Pearson Correlation	,156	-,098	,034	,135	-,269	,166	.348*
	Sig. (2-tailed)	,286	,502	,817	,354	,061	,255	,014
AspectEW (0=0-180, 1=18-359)	Pearson Correlation	-,171	-,029	.307*	.327*	-.360*	,153	.283*
	Sig. (2-tailed)	,241	,842	,032	,022	,011	,294	,049
DistRoad	Pearson Correlation	1,000	,027	-.357*	-.329*	.378**	-,171	-.310*
	Sig. (2-tailed)		,855	,012	,021	,007	,241	,030
LogFloAc	Pearson Correlation	,027	1,000	.354*	.296*	-,045	-.326*	,100
	Sig. (2-tailed)	,855		,013	,039	,760	,022	,496
LogAgr52	Pearson Correlation	-.357*	.354*	1,000	.584**	-.594**	,204	.458**
	Sig. (2-tailed)	,012	,013		,000	,000	,160	,001
Gras50	Pearson Correlation	-.329*	.296*	.584**	1,000	-.808**	,013	.650**
	Sig. (2-tailed)	,021	,039	,000		,000	,928	,000

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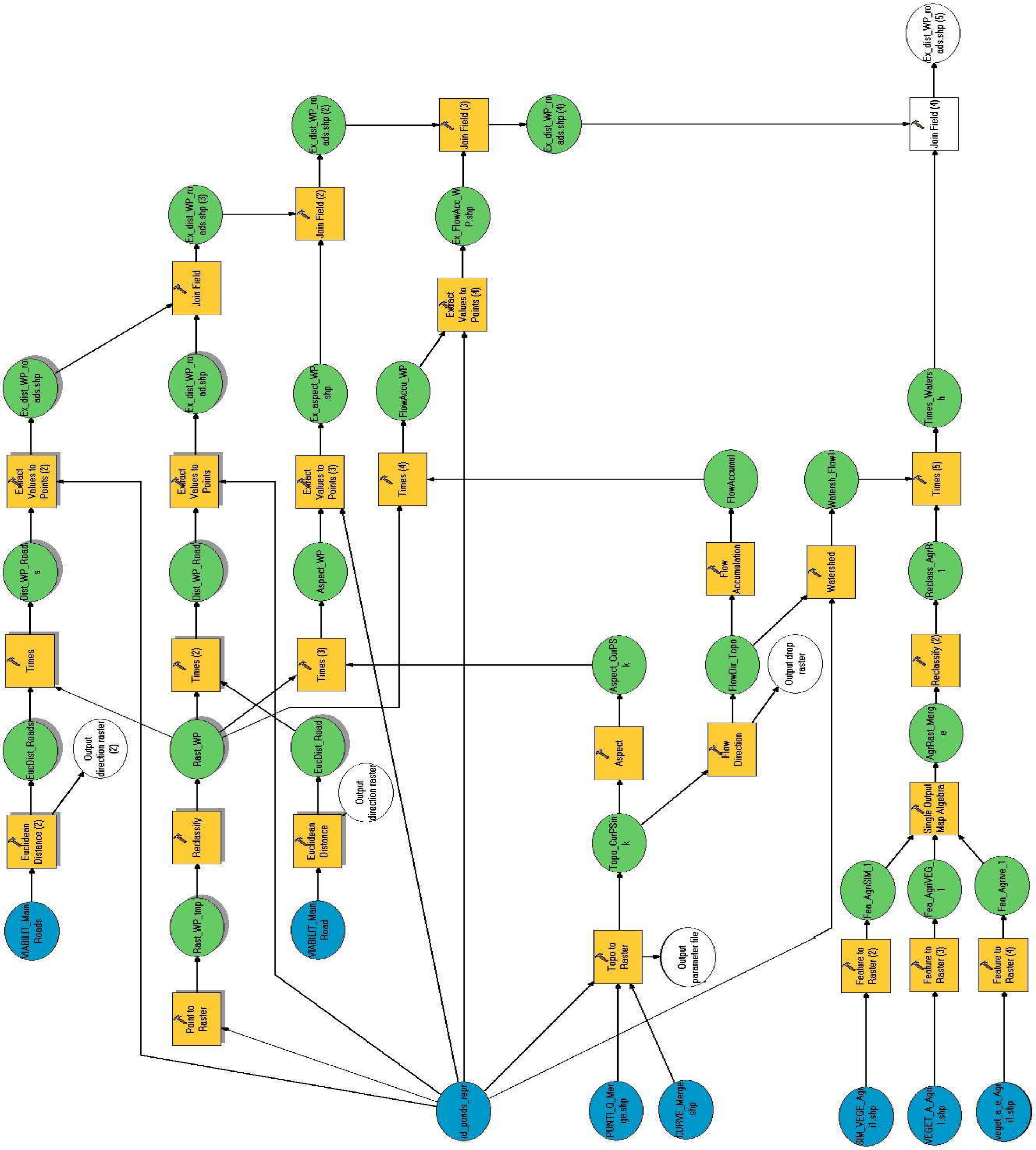
		DistRoad	Log FloAc	Log Agr52	Gras50	Wood50	Agri50	Build50
Wood50	Pearson Correlation	.378**	-,045	-.594**	-.808**	1,000	-.556**	-.765**
	Sig. (2-tailed)	,007	,760	,000	,000		,000	,000
Agri50	Pearson Correlation	-,171	-.326*	,204	,013	-.556**	1,000	,144
	Sig. (2-tailed)	,241	,022	,160	,928	,000		,324
Build50	Pearson Correlation	-.310*	,100	.458**	.650**	-.765**	,144	1,000
	Sig. (2-tailed)	,030	,496	,001	,000	,000	,324	

The number of samples is always N=49.One star(*) stands for significative, two stars(**) for highly significative.

GIS model



Description of the names of the initials layers:

Positions of the water-sites: id_ponds_repr. Viability layers: Viabilit_Main_Roads, Viabilit_Main_Road. Altitudinal points: Punti_Q_Merge. Contour lines: Curve_Merge. Agricultural layers: Sim_Vege_Agri1, Veget_A_Agri1, Veget_a_e_Agri1.