



Abstract Volume

11th Swiss Geoscience Meeting

Lausanne, 15th – 16th November 2013

24. Sustainable Water Management – Scientific Findings from recent research

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Swiss Academy of Sciences
Akademie der Naturwissenschaften
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24. Sustainable Water Management – Scientific Findings from recent research

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Swiss Society for Hydrology and Limnology SGHL,
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Steering Committee NRP 61*

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24.1

Runoff generation mechanisms in a Swiss pre alpine catchment by spatial intercomparison

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Mountainous headwaters are dynamic, complex and heterogeneous hydrological systems of different landscape elements in terms of topography, geology, wetlands, land use and land cover which are spatially arranged and connected. Only few catchments have been studied and long-term detailed data are sparse. This makes it difficult to identify runoff generation processes in space and time and understand the event dynamics of a region. Here we present results from a data set collected in the Zwäckentobel a 4.3 km² Swiss pre-alpine catchment with high annual precipitation input, steep and flashy character of streams and dominant wet conditions. Characteristic for mountainous catchments, the contribution and response of the Zwäckentobel to storm flow in space and time is largely unknown. This study tried to address this issue by comparing several sub-catchments. The aim was to learn from differences, similarities and to put each catchment into perspective at different scales. The basic question was whether there is a difference in response to rainfall and if so are the runoff contribution processes different? Can this be linked to catchment characteristics? For the ungauged Zwäckentobel and six sub-catchment, rainfall, runoff and isotope concentrations of the snow free season 2010 and 2011 were measured and compared with a sub-catchment with long-term observations as reference. Here we present results of this study, which show the difference in rainfall runoff response and stable isotopes. From both hydrometric and stable isotope we could identify for all streams their dominant runoff generating mechanisms. Antecedent conditions and storm size have influence on the stream response; all streams are fast responding where big rainfall events tend to have larger event water contribution while smaller events have larger pre-event contribution to stream flow. Small catchment are generally expected to react similar to storm flow, while from this study it emerges that mountainous headwaters have spatial and temporal difference in input as well as in the response of the different streams streams. The mixture of hydrometric short and the indispensable long-term observations in combination with stable isotope were valuable to increase our knowledge of hydrological processes of pre alpine headwater catchments with high precipitation input and a dynamic character. This can serve as base for a better water management in these hydrological complex regions.

24.2

Multiscale Methods: Tools to Balance Accuracy and Efficiency

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Groundwater is the most important drinking water reserve worldwide. Multiple natural and anthropogenic pollution sources can affect the groundwater quality and threaten a sustainable use of this important resource. To assess risks of contamination and avoid environmental and public-health hazards, reliable predictions of flow and transport processes in the aquifer are needed.

Groundwater aquifer systems can extend horizontally over tens of kilometers with a vertical depth of more than hundred meters, but flow and transport properties vary at much smaller scale. The resolution necessary to explicitly describe this heterogeneity structure would yield to prohibitive computational costs. To overcome this limitation, approximate solutions based on upscaling procedures have been widely employed to efficiently solve large-scale field models.

In this context multiscale models gained popularity over the last decade because they allow combining upscaled with local solutions that are used to interpolate the coarse solution to the scale of interest. The major strength of these methods is the high level of flexibility towards adaptive formulations, which permit different resolution in different regions and at different times.

With the new advances recently achieved, adaptive multiscale techniques offer a general framework to balance accuracy and efficiency of the solution. However, an optimal balance depends on the specific application and on the corresponding quantities of interest. We demonstrate the potential of these methods (and in particular of the Multiscale Finite Volume (MsFV) method (Jenny et al., 2003)) by considering density-driven problems.

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24.3

Geometric and hydrological characterization of karst-system combining KARSYS approach and simulation tools - Application to Beuchire/Creugenat and Bonnefontaine/Voyeboeuf karst systems (JU, Switzerland)

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In the frame of the Swisskarst project (part of the NRP61) and thanks to additional subsidies from the Jura Canton; karst flood hazards have been assessed in the region of Porrentruy. The well-known Beuchire/Creugenat karst system which display a discharge rate of 20 m³/s during usual flood event may represent a flood risk for the city as evidenced by strong inundation events in the past (1804, 1910, etc.).

The hydrological functioning of the system (nearly 100 km²) is quite complex as it is controlled by the activation of underground thresholds and emerging overflows which depend on the evolution of the hydraulic gradient in the conduits system (Vouillamoz et al. 2013). Hydraulic gradient rises in the upstream part of the system up to 30-40 m which significantly enlarges the underground catchment. Divergence mechanisms do occur and lead to an interconnection of adjacent karst systems. This may significantly enhance the flood risk.

The communication relates the application of the KARSYS approach (Jeannin et al. 2013) to characterize the systems of Beuchire/Creugenat and Voyeboeuf/Bonnefontaine and to implement a combined-hydrogeological simulation according to the hydraulic parameters resulting of the approach (position and geometry of the drainage axes, geometry of the catchment and sub-catchments). The simulation aims to assess the respective recharge and hydraulic functioning of the systems in order to:

- Reproduce the outlets discharge rates (permanent base springs);
- Explain the evolution of the hydraulic gradient and the activation of the overflow springs (i.e. Creugenat);
- Confirm and quantify the modalities of the diffluent mechanism between these two regional systems according to flow conditions.

The workflow includes a geometric 3d modeling of the karst aquifers and the hydraulic gradients (KARSYS approach) and a combination of two simulation tools to reproduce (i) the hydrological and (ii) the hydraulic behavior of the systems. The recharge simulation of the systems is performed using a semi-distributed routing system model RS.3.0 (e-dric 2012). This type of model focuses on refining recharge and runoff processes on the ground of the catchment -subdivided in sub-catchments. This type of model reveals particularly adapted in karst media and numerous simulation have been succeed (Weber et al. 2011, Weber et al. 2012).

In the second work-step - as the recharge, catchment and sub-catchments have been validated - a hydraulic SWMM model is established to conceive the probable geometry of the karst conduits-network based on the parameters inferred from the KARSYS approach and existing speleological surveys (conduits diameter, connection, storage, thresholds...). Thanks to valuable head measurements (borehole, pit, etc.) the consistency of the model could be checked on various location of the karst-network.

The respective discharges of the permanent springs, the activation and the discharge rate of the overflow springs as well as the oscillation of the boreholes water table have been relevantly reproduced. Exchange thresholds have been identified as well as the respective exchanged flows.

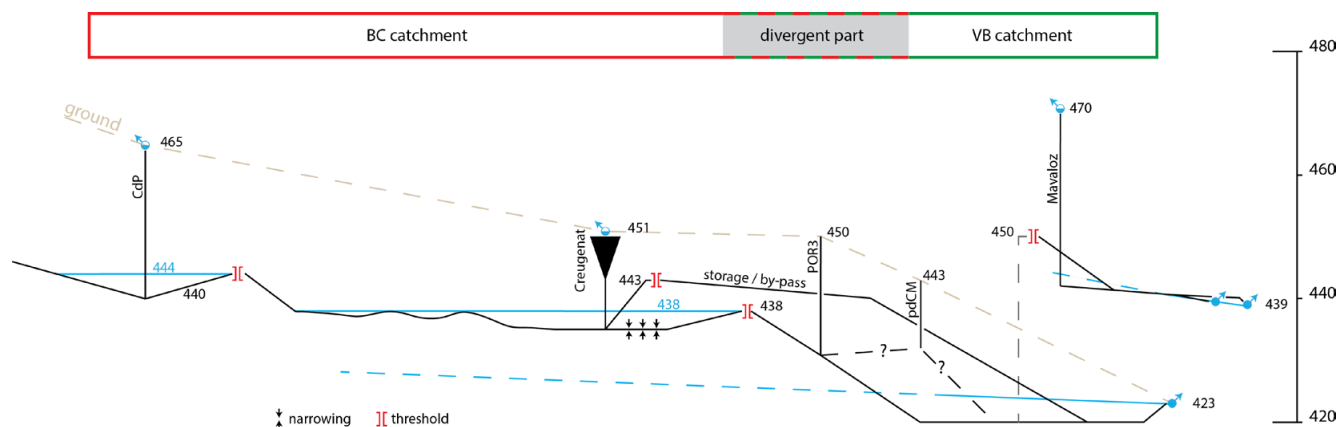


Figure 1. Construction of a probable karst conduits-network of the Beuchire/Creugenat and Voyeboeuf/Bonnefontaine karst system as inferred from the KARSYS approach, observations and measurements. These results prove the efficiency of the combination of the KARSYS approach with an appropriate simulation tools to characterize the geometry of karst systems (i.e. the conduits network), their respective functioning as well as their interaction according to hydrological conditions.

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24.4

Assessing the impacts of climate change and human activities on water allocation in the Ebro catchment (Spain)

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The Mediterranean basin has been identified as one of the world's most vulnerable regions to climatic and anthropogenic changes and constitutes a water crisis' hot spot. By the 2050 horizon, climate change will most likely contribute to the depletion of freshwater resources in already arid to semi-arid catchments. Furthermore, if domestic and agricultural water demands follow past trends, 80% of the Mediterranean basin would have to deal with severe water stress (Milano et al., 2013). The Ebro catchment, third largest Mediterranean basin, is very representative of this context. Since the late 1970s, a negative trend in river discharge has been observed at the outlet of the Ebro catchment and at several gauging stations. This can be attributed to a decrease in mean precipitation, a rise in temperature and a water consumption increase (Milano et al., 2013). Indeed, the Ebro catchment is a key element in the Spanish agricultural production with respectively 30% and 60% of the meat and fruit production of the country. Moreover, population has increased by 20% over the catchment since 1970. Finally, more than 250 storage dams have been built over the Ebro River for hydropower production and irrigation water supply purposes, hence regulating river discharge. If global changes follow past trends, the question arises whether future water needs will still be satisfied in the Ebro catchment. In order to better understand the respective influence of climatic and anthropogenic pressures on the Ebro hydrological regime, an integrated water resources modeling framework was developed. This approach confronts water supplies, generated by a conceptual rainfall-runoff model and by a storage dam module, and water demands and environmental flow requirements. Water demands were evaluated for the most water-demanding sector, i.e. irrigated agriculture (5 670 Hm³/year), and the domestic sector (252 Hm³/year), often defined as being of prior importance for water supply. The capacity of water resources to meet water demands is assessed through a water allocation index. This index depends on site priorities and supply preferences. This modeling framework was applied to 9 sub-catchments to which 11 water demand sites were attributed, in order to take into account the different hydro-climatic regimes. Results define the current pressures applied to water resources and show growing competition among users by 2050. Environmental and domestic water demands should be fully met but agricultural water demands could have to face severe water shortages during the summer season. This study identifies sub-catchments most vulnerable to climate change and anthropogenic pressures as well as those where water use tensions could occur. It also highlights the interest of integrated modeling to better sustain water management policies and to support the co-construction of scenarios between users, policy-makers and scientists.

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24.5

Climate change and socio-economic scenarios, land use modelling and water resources in an inner alpine area, Switzerland

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The MontanAqua project aims to study the water resources management in the region Sierre-Montana (Valais, Switzerland). Land use is known to have an influence on the water resources (soil moisture dynamic, soil sealing, surface runoff and deep percolation). Thus land use modelling is of importance for the water resources management.

Some land use type are more important than other regarding the water resource management, irrigated or not irrigated grassland does not exist as GIS data. Thus an actual land use map was produced using infrared imagery (Niklaus 2012, Fig.1). Land use changes are known to be mainly driven by socio-economic factors as well as climatic factors (Dolman et al. 2003). Potential future Land uses was predicted according to 1-. socio-economic and 2-. climatic/abiotic drivers :

- 4 socio-economic scenarios were developed with stakeholders (Schneider et al. 2013) between 2010 and 2012. We modeled those socio-economic scenarios into a GIS application using Python programming (ModelBuilder in ArcGIS 10) to get a cartographic transcription of the wishes of the stakeholders for their region in 2050.
- Uncorrelated climatic and abiotic drivers were used in a BIOMOD2 (Georges et al. 2013) framework. 4 models were used: Maximum Entropy (MAXENT), Multiple Adaptive Regression Splines (MARS), Classification Tree Analysis (CTA) and the Flexible Discriminant Analysis (FDA) to predict the actual grassland in our study region. Climatic scenarios were then introduced into the models to predict potential land use in 2050 driven only by climatic and abiotic factors

Future work will be to cross the different land use maps obtained by the two models and to use them to implement soil moisture and evaporation data for the near-future in the region Sierre-Montana.

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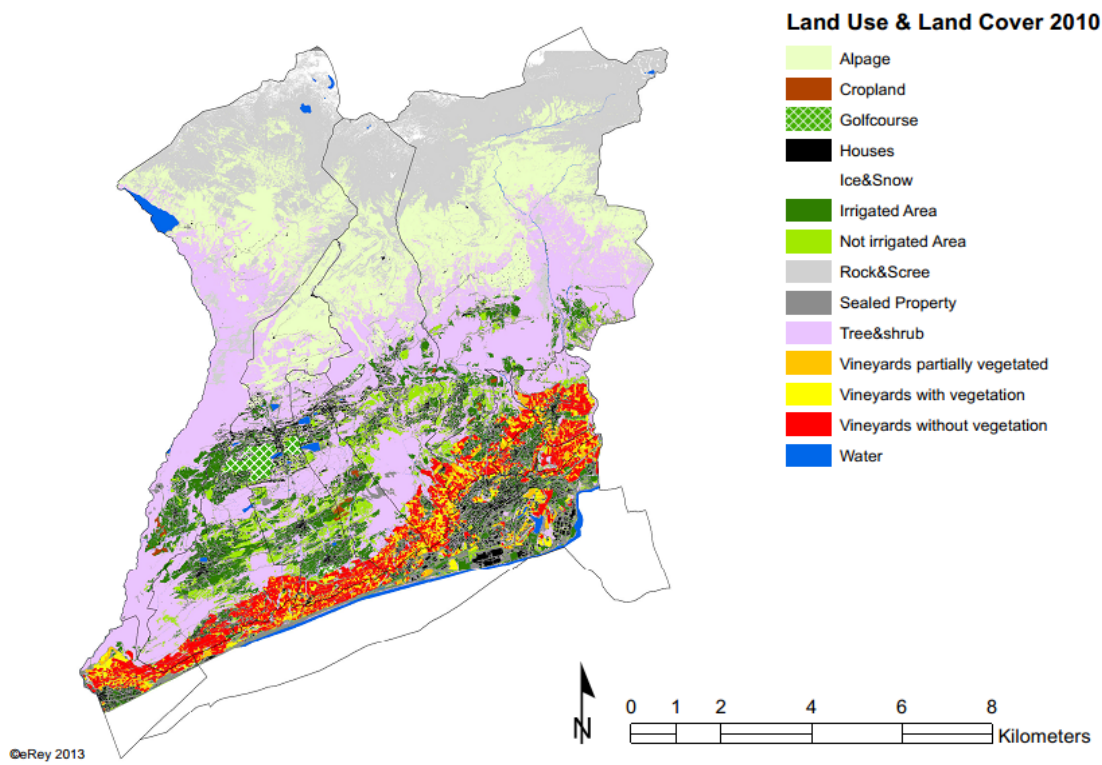


Figure 1: Actual land use in the Siere-Crans-Montana region (Niklaus 2012)

24.6

Mashhad Plain Groundwater Quality Assessment for Drinking and Irrigation Suitability, Iran

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Mashhad plain which belongs to the Kashafrud catchment with area more than 16500 Km², located between Binaloud and Hezarmasjed mountains (Fig. 1). In order to investigation of groundwater quality characteristics in Mashhad plain, 42 data from water of well belong to 2012 selected to processing and interpretation. All data were processed for determination of groundwater quality such as magnesium adsorption rate (MAR), solution sodium percent (SSP), residual sodium bicarbonate (RSBC), permeability index (PI), Kelly ratio (KR) and sodium adsorption ratio (SAR) after editing of data. According to Piper diagram the groundwater type of the study area is currently Na+Cl-SO₄²⁻ (Piper, 1994). Assessment of the suitability for drinking and domestic consumption was evaluated using Schoeller diagram as well as comparing the hydrogeochemical parameters of groundwater in the study area with the prescribed specification of World Health Organization (WHO, 2004). On the basis of Schoeller diagram, the water is unsuitable for drinking and domestic uses (Schoeller, 1955). According to the electric conductivity (EC) and SAR calculation the most dominant classes (C4-S4, C4-S2, C4-S3 and C3-S2) were found. The salinity hazard for water samples in Mashhad Plain is classified as high (50%) and very high (50%). Sodium content in above 85% of water samples collected is regarded as high and is not suitable for irrigation purposes. Thus, high salinity, SAR and Na% in most water samples have restricted the water quality for irrigation uses. Investigation and interpretation of hydrogeochemistry data indicated that SAR and total dissolved solid (TDS) amounts from northwest to southeast of the plain increase because of huge amount of marl and evaporate sediments in the north-eastern part of the study area (Fig. 2). On the other hand, topography map and curves of water table changes indicate that the plain recharge from NW and discharge to SE.

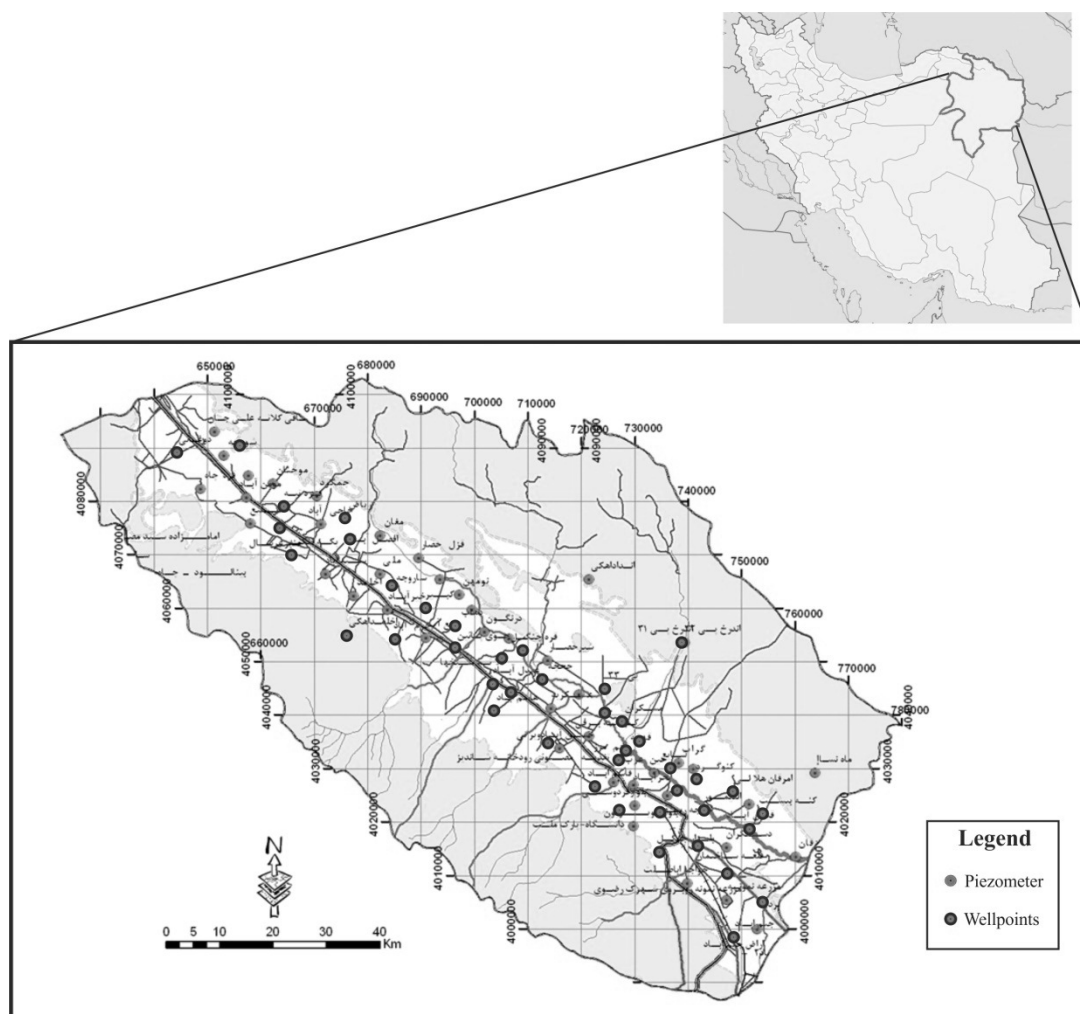


Figure 1. Location of Mashhad Plain (Geological Survey of Iran, 2006).

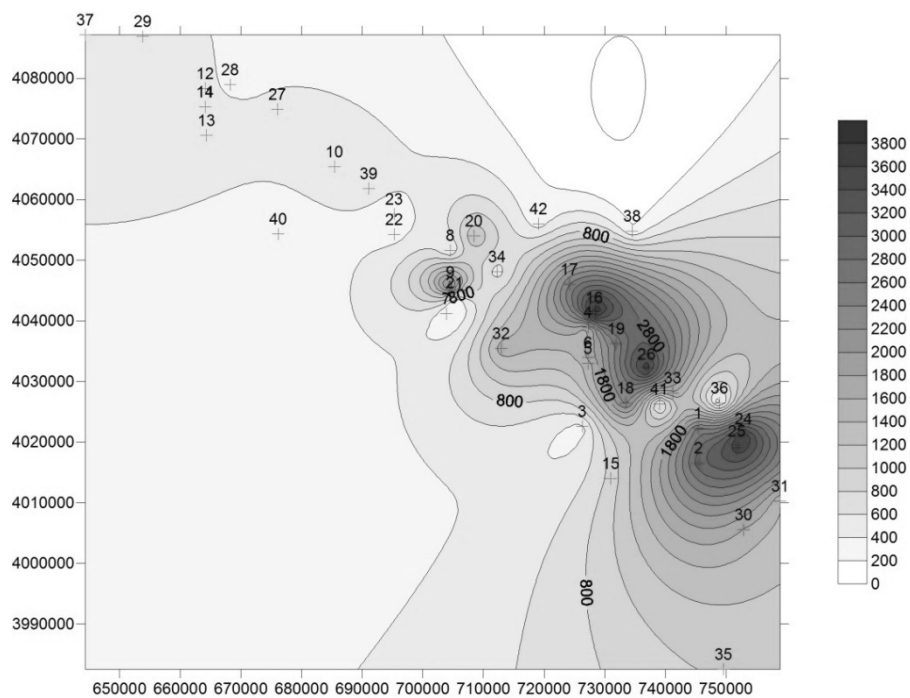


Figure 2. Distribution map of TDS parameter in the study area.

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24.7

HydroServ – Vulnerability of Hydrological Ecosystem Services: linking land use, hydrology and ecosystem services for sustainable water management

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Sustainable water management implies addressing both human needs for natural resources delivery and the state of the natural system. In order to support decision-making, a thorough understanding on how to link the human and the natural spheres is required. The NRP 61 project 'HydroServ' deals with the vulnerability of hydrological ecosystem services (HES) resulting from societal changes to the natural system. The interdisciplinary project links land use, hydrology and ecosystem service valuation for fostering the understanding of the value chain of HES under uncertain changes of climate and land use, using flood protection HES as an example.

We present an integrative framework that links results from a land use model, a hydrological model and of HES valuation in a Bayesian Network (BN). The key root nodes include precipitation and land use changes. These states of the natural system are transformed into monetary values by adding a cost factor and stated preferences. The BN is developed in two directions to model (1) potential flood damage costs and (2) willingness to pay for flood protection HES.

The resulting monetary values are compared to see whether land management can serve as a partial substitution to technical flood protection measures. The results allow for (1) a comparison of the monetary values of flood damage costs and willingness to pay for flood protection HES, and (2) a comparison of the uncertainties inherent in the modeling of damage costs and the willingness to pay.

Finally, we reflect trade-offs between technical measures and land use management in terms of monetary efficacy in order to reduce flood hazards. The same integrative approach can be applied to quantify other HES and may therefore support sustainable water management.

24.8

Cooperative irrigation governance in Valais: a model of sustainable water resource management?

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As in other mountain regions, meadows in dry Alpine valleys have been irrigated from time immemorial. The Swiss canton of Valais, characterised by spectacular and century-old water channels (FR: *bisses* / DE: *Suonen*), makes no exception. Showing long trajectories of historical continuity, these *bisses* constitute what the literature often refers to as *common-pool resources* (CPR, Ostrom 1990). Far from representing the relics of a bygone agro-pastoral age, they still provide a wide range of services that are crucial not only to the mountain communities, but also to the people living downhill: water provision for the irrigation of agricultural land (meadows, vineyards, orchards), biodiversity support and landscape formation (ecoservices), regulation of floods, socio-cultural and touristic services. Constructed, maintained, and regulated by local communities or users' groups (*consortages* / *Geteiltschaften*), *bisses* have been traditionally characterised by cooperative governance structures the robust, enduring and sustainable nature of which has been highlighted many times (e.g., Ostrom 1990, Crook 1997). Long before concepts such as "participation" and "integration" became matters of concern and begun being advocated for in the literature (e.g., Ansell & Gash 2008, Bäckstrand et al. 2010), the Valaisan irrigation systems thus offered examples of cooperative and participative water management. Hence, they provide rare empirical settings to study such forms of governance on the long-term, in a context that has experienced major changes during the last century, (diversification of water and land uses, arrival of new actors in previously enclosed arenas, etc.).

Against this background, the NRP 61 project *Water channels – a model for sustainable management* aimed at offering a holistic appraisal of these cooperative models of governance, with specific *foci* on the analysis of the alterations they have experienced in the last decades, their capacity to integrate new actors, and their impacts in terms of sustainability. Relying on a qualitative (participant observations, semi-structured interviews) and interdisciplinary (at the crossroad of political sciences, human geography, and institutional resource economics) approach, the project applied a resource-based and actor-centred perspective to five in-depth case studies (*bisse Vieux* in Nendaz, *bisse de Tsa Crêta* in Mont-Noble, *Torrent-Neuf* in Savièse, *Grossa* in Birgisch, *Niwärch* in Ausserberg).

The goal of this contribution is to present the main results of this three-year research project (to be published in a collective book, Schweizer et al. *in press*). Characterized by a diachronic approach (comparison of two periods throughout the 20th century), the five case studies proved to be rich in theoretical and empirical findings. Our results highlighted, first, the changing nature of the traditional cooperative models of governance. Today's *bisses* are not managed as they were yesterday, and politico-administrative as well as touristic actors appeared to play a critical role in their evolution and survival. Second, our analysis showed that the sustainable character of the cooperative models of governance does not go without saying. Those models had strengths as well as weaknesses, notably on a social level. *Bisses* and *consortages* were, in particular, characterized by a strong exclusivity of access that tends to reproduce rather than reduce social inequalities within the community, and to bring them closer to *clubs* rather than to *common-pool resources*. All in all, these results challenge the rosy picture generally associated with cooperative models of governance in the literature, and demonstrate that the path towards sustainability is a complex one, in which a multitude of actors, interests, and strategies interact.

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24.9

Hydrochemical exploration of Ennedi, Northern Chad

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The Ennedi is a vast region of northern Chad, at the southern edge of the northern middle of the Sahara desert. A remarkable hydrological and hydrogeological regime characterizes the area, despite the aridity that prevails in most of the region: the Ounianga lakes (Ounianga Kébir and Ounianga Seghir), and the Archéï and Bachiquélé springs are some examples of groundwater occurrence indicating that significant resources may be present underground.

The Nubian Sandstone Aquifer System (NSAS) is believed to represent a thousand meter aquifer, with water having last being recharged during the Holocene. Referring to the current coupe geologic profile for the area (Mahamoud, 1986), mesozoic rocks are laying onto the palaeozoic sedimentary rocks that outcrop in the Ennedi region and in the area of Faya Largeau, south of Erdis plateau and Tibesti massif. Although NSAS is commonly considered to be composed only by Mesozoic formations, an increasing consensus (REF) consider that it should also comprise the Palaeozoic formations. In the cited regions, springs and artesian phenomena occur frequently.

The Ennedi Plateau is a thousand meters sedimentary pile of Palaeozoic sedimentary rocks, mainly sandstones (Boeuf et al., 1971, Mahamoud, 1986). At its southern edge, coarse sandstones of Cambrian age are in discordance onto the granitic Precambrian basement. They are locally overlain by Ordovician periglacial sediments. The series continues with fine-grained and argillaceous (Devonian) sandstone. North of the Ennedi massif, the E-W trending Mourdi depression, composed of marine Carboniferous sediments (Klitzsch et al., 1993), separates the range from the Erdis Bassin, composed of various Mesozoic sandstone. The Ennedi massif is an important hydrological divide: a complex network of ouadis conveys runoff water from the Ennedi to the Mortcha depression, to the West, to the Nile basin to the East and to the Mourdi depression, to the North.

In the framework of the RésEau I-Chad project, a scientific mission has been held early 2013 in the Ennedi, coupling geological works and a hydrochemical investigation. A total of 31 water points, mainly wells and springs were sampled for chemical (major and traces elements), stable (¹⁸O, ²H) and radiogenic (³H) isotopes.

Plateau is a thousand meters sedimentary pile of Palaeozoic sedimentary rocks, mainly sandstones (Mahamoud, 1986). Its coarse sandstones of Cambrian age are granitic. There are locally overlain by Ordovician periglacial sediments. The series continues with fine-grained Devonian sandstones and argillaceous sandstones, in particular in the Fada region and on the top of the Plateau. To the north, the E-W trending depression is composed of Carboniferous sediments. The northern side of the depression is the so-called Erdis Bassin and is composed of various Mesozoic sandstone units., mainly

Preliminary results indicate that the Ennedi water supply is currently relying entirely on juvenile water, the fossil water being deeper or eventually absent; water conductivity suggests that to some extent modern recharge in the area may be present. A hydrochemical divide is observable, with water having a pH of 6-7 and conductivity values of 300-500 µS/cm on the southern part of the range, and pH of 8-9 and conductivity values of 800-900 µS/cm on the northern part of the range.

A differential GPS survey was carried out near Fada to dress a piezometric map and to propose a simple hydrogeological model. The measured water table shows that groundwater flow is to NW, with a hydraulic gradient of 3 ‰. Electrical conductivity of water along flowpath indicates that some modern recharge is present near discharge areas probably due to the position of the phreatic layer close to ground surface.

Acknowledgments

This research work has been performed in the frame of the "RésEau Tchad" project. The project was born as a result of a request by the Ministry of Rural and Urban Hydraulics MHRU) in Chad to the Swiss Development and Cooperation (SDC). The United Nations Institute for Training and Research (UNITAR) and in particular its operational satellite applications programme, UNOSAT, has been mandated from SDC to implement the project together with Chadian government. The project's aims are to increase the knowledge of water resources in Chad, reinforce national capacities, and diffuse a Geographical Information System on Water Resources as well as survey hydrogeological maps. Chemical and isotopic measurements have been possible thanks to KFH funding.

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24.10

Could electrical conductivity replace water depth in rating curves for alpine streams?

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Note: adapted from (Weijs et al. 2013).

Time series of streamflow are an important source of information for inference and understanding of the hydrological processes in alpine watersheds. Streamflow is expensive to continuously measure directly, hence it is usually derived from measured water levels, using a rating curve that models the stage-discharge relationship. In alpine streams, this practice is complicated by the fact that the streambed constantly changes due to erosion and sedimentation by the turbulent mountain streams, which never lie quietly in their beds. This makes the stage-discharge relationship dynamic, requiring frequent discharge gaugings to have reliable streamflow estimates. The remaining uncertainty, which is considerable, needs to be accounted for in model calibration, for example by using information-theoretical measures for model-data comparisons (Weijs et al 2011).

During an ongoing field study in the Val Ferret watershed in the Swiss Alps, 93 streamflow values were measured in the period 2009–2011 using salt dilution gauging with the gulp injection method. The natural background electrical conductivity in the stream, which was measured as by-product of these gaugings, was shown to be a strong predictor for the streamflow, which even marginally outperformed water level over the 3 year period. Simultaneous analysis of the residuals of both predictive relations revealed errors in the gauged streamflows. These could be corrected by filtering disinformation from erroneous calibration coefficients. In total, by extracting information from the auxiliary data, we were able to reduce the uncertainty in the rating curve, as measured by the root-mean-square error in log-transformed streamflow relative to that of the original stage-discharge relationship, by 43.7% (Weijs et al 2013).

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P 24.1

Impact Of River Restoration On Alluvial Soils

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Floodplains provide environmental functions (flood protection, recreation areas, biodiversity reservoir, nutrients cycling). These ecosystems have been intensively altered, but are now being restored. Our aim is to assess the post-restoration changes in alluvial soils and the success of river restoration.

A successful river restoration re-creates a panel of i) habitats (soil types), ii) pedological functions (carbon storage) and iii) faunal biodiversity (earthworm communities) similar to those of near-natural floodplains.

We make a comparison of pre-restored stretches, restored stretches and near-natural stretches using complementary criteria: soil type, earthworm communities, carbon storage. Soil diversity increases from embanked to near-natural stretches, but varies according to floodplain characteristics (fig 1). Earthworm diversity is higher in the restored stretch than in the embanked one with presence of colonizer species (*Lombriacus. rubellus*, *Aporectodea ripicola*) (fig 2). Carbon storage is different in near-natural and in restored stretches and varies according to soil type within each stretch (fig 3).

River restoration has increased i) soil type and earthworm diversity and ii) the variability of carbon storage within floodplain. As earthworms rapidly colonize habitats created by river restoration, they can thus be used as bioindicators of early stages of river restoration. The restored stretches remain different from the near-natural ones could be interpreted as a partial success of river restoration projects.

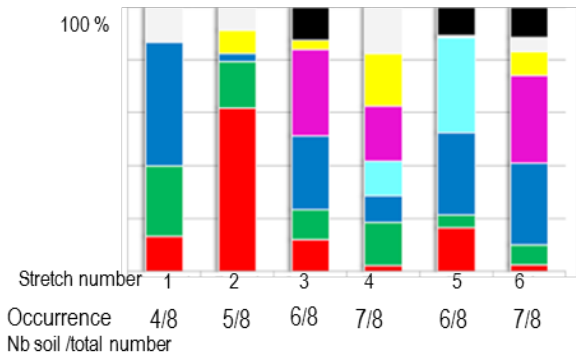


Figure 1. Frequency and occurrence of soil types in six river stretches. Emme River: embanked stretch (1) and restored stretch (3). Thur River : embanked stretch (2) and restored stretch (4). Rhine River : near-natural stretch (5). Sense River : near-natural stretch (6) (from P. Aelvoet, Master thesis)

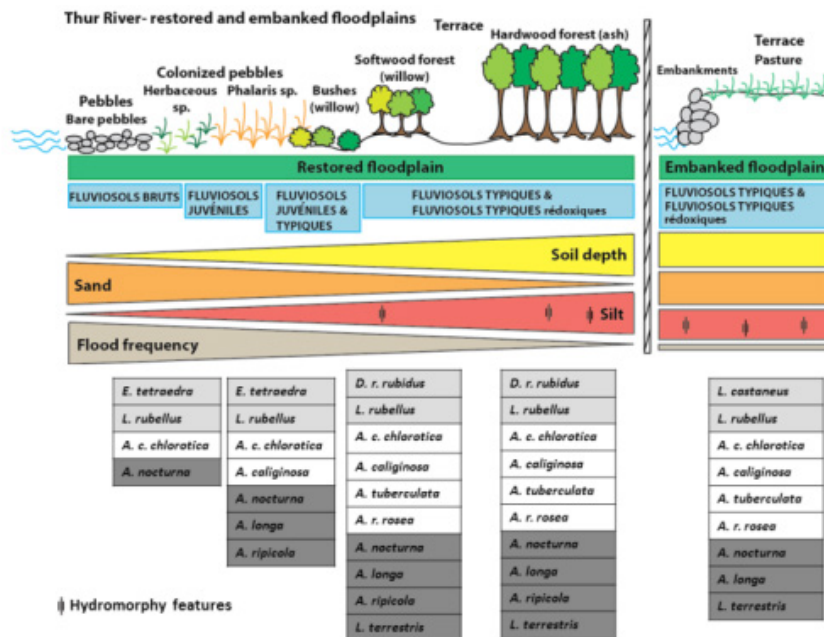


Figure 2: Vegetation, soil, floods and earthworm communities at Thur floodplain. Earthworm species and ecological categories: epigeic, (white), endogeic (grey) and anecic (black) (from Le Bayon et al , 2013, in press).

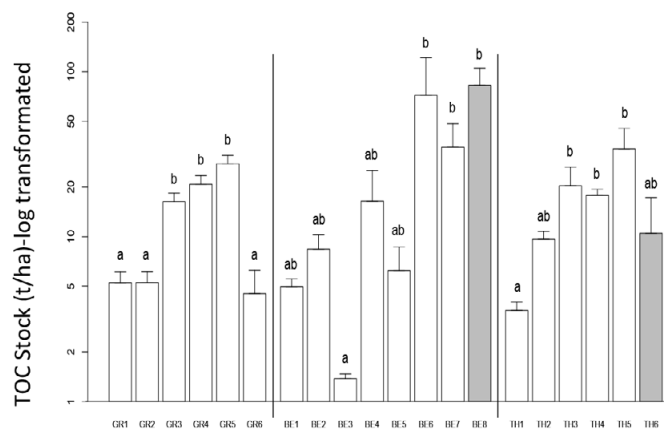


Figure 3: Total Organic Carbon stock in the different topsoils

Grey bars correspond to embanked topsoil groups (from Bullinger et al, in revision)

REFERENCE:

Le Bayon R-C. & Bullinger-Weber G. & Gobat J-M. & Guenat C. 2013 : Earthworm communities

P 24.2

WeSenseIt – a citizen-based observatory of water

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For detailed understanding and forecast of water resources and components of the water cycle spatially and temporally resolved observations of numerous water-related variables are required. Such observations are typically obtained from wireless networks of automated weather stations. The WeSenseIt project develops a citizen- and community-based observatory of water to improve the water and risk management at the catchment scale and support decision-making of stakeholders. Each citizen becomes a potential observer and transmits intentionally or not water-related variables. Recent technologies (wireless communication, internet, smartphone) enable to use smartphones or create innovative low cost sensors that may be less accurate but accessible to a large community; these sensors will be combined with traditional sensing techniques. The goal is to increase the spatial and temporal coverage of observations, which results in the acquisition of large amounts of data. In three specific case studies citizen observatories are being implemented addressing questions related to flood, drought, water resource management, and water quality and pollution. Acquired data ranges from quantitative physical data to qualitative 'social' data extracted from data streams and social media/networks. This study presents the most recent progress and developments of the project related to the measurement of water conditions and fluxes.

P 24.3

The dark side of the blueprint. A reflexive analysis of watershed management in Switzerland

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This poster summarizes the scope and first results of a new research project conducted within the Institute of Geography and Sustainability that aims at questioning present Swiss water policies that globally target the implementation of integrated water resources management (IWRM) in the catchment area, i.e. at the watershed level. More precisely, this research questions the common idea that the watershed, as a supposedly “neutral” scale, should be seen as the panacea to solve coordination problems.

This reflexive analysis is based on two corpora. On the one hand, we focus on recent research that empirically reveals that many attempts to implement IWRM since two decades have not been as successful as expected (Biswas 2008); and theoretically shows that considering the watershed as the sole relevant scale is, at least, biased, or even instrumented (Graefe 2013). On the other hand, blueprint documents produced by the Federal Office for the Environment (FOEN), which pertain to the goal of “shaping evidence”, are analysed.

The notion of IWRM appeared in the middle of the twentieth century and then fell into disuse until the Conference in Mar del Plata in 1977. From 1992 on, it has become the flagship concept of effective and sustainable water policy particularly via the Agenda 21 (or Action 21) adopted at the Earth Summit in Rio de Janeiro and via the Dublin Conference whose first principle states that: “effective management links land and water uses across the whole of a catchment area or groundwater aquifer”.

In Switzerland, the notion explicitly appeared in policy documents in 2003 (during the International year of freshwater) as an “imperative” (FOWG 2003), and the attention paid to the notion has intensified since 2007, when the FOEN mandated several reports on this topic and when the Federal Council mandated the Swiss National Fund to launch the “Sustainable Water Management” National Research Programme (NRP 61). Since then, the Swiss water policy has truly been oriented toward watershed management. FOEN states that “with the watershed as reference area, the integrated management of water is primarily based on the natural system. The area in which the interactions occur and the decision-making scope coincide. The problems are solved where they are caused” (2011: 14). Thanks to IWRM at the watershed level, water management is supposed to be “efficient”, “customised”, “future oriented” and “durable”.

If several attempts to implement integrated water management in Switzerland can be mentioned (Fribourg, Neuchâtel, Geneva, etc.), to consider the watershed as the most relevant “functional regulatory space” (Varone et al.: 2013) does not seem so obvious. More fundamentally, the reference to the basin should also be discussed from the perspective of its supposed “axiomatic neutrality”. For example, for Graefe (2013: 15): “the river basin fetishism, the domination of the IWRM and governance concepts are symptoms of the depoliticisation of water management. They should be seen as being part of a process creating new instances of environmental management dominated by scientific and technocratic expertise void of political interests, political representations and politics overall”.

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P 24.4

Rainfall driven cholera outbreak modelling

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Epidemiological models can provide crucial understanding about the dynamics of infectious diseases. Possible applications range from real-time forecasting and allocation of health care resources to testing alternative intervention mechanisms such as vaccines, antibiotics or the improvement of sanitary conditions. We apply a spatially explicit model to the cholera epidemic that struck Haiti in October 2010 and is still ongoing. The dynamics of susceptibles, infectives and recovered are modelled at the scale of local human communities. Dissemination of *Vibrio cholerae* through hydrological transport and human mobility along the road network is explicitly taken into account, as well as the effect of rainfall as a driver of increasing disease incidence. Rainfall data was obtained from remotely sensed satellite measurements. The model is calibrated using a dataset of reported cholera cases. The model allows us to draw predictions on longer-term epidemic cholera in Haiti from multiseason Monte Carlo runs, using rainfall fields forecasts.

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P 24.5

Bedload transport dynamics in mountain rivers – Development and application of the model *sedFlow*

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In alpine environments the hazard potential of a stream, its ecologic relevance and the sustainability of civil engineering measures is influenced by bedload transport dynamics. In numerous contexts this entails the need for the numeric simulation of the bedload transport process. Within the framework of the NRP 61, the model *sedFlow* has been developed, which accounts for the different requirements of such simulations.

Bedload transport in steep mountain channels shows different characteristics compared to flatter channel gradients and thus requires modified calculation procedures (e.g. Rickenmann 2001; Rickenmann & Recking 2011; Nitsche et al. 2011). Feedbacks between hydraulics and sediment dynamics accounting for the evolution of channel gradient and grain size distribution are considered in the *sedFlow* model as well.

Despite more detailed results and process interactions, *sedFlow* facilitates simulations, which are two to three orders of magnitude faster as with the comparable modelling software. For data input, xml and other special formats have been largely renounced in favour of intuitive spread sheet representations. Thus, a quick and easy pre-processing of input data with regular spread sheet software such as Excel™ is possible.

As an example, observations concerning bedload transport and morphodynamics of the Brenno river in southern Switzerland have been reproduced with *sedFlow* simulations using a reasonable parameter set-up. The Brenno sediment transport system is found to be more sensitive to variations of discharge and grain size distributions compared to variations of the threshold for initiation of transport and of channel width. Simulations with variable sediment input by tributaries show that the downstream effect is more pronounced regarding transported bedload volumes whereas variable sediment inputs have a spatially much more limited impact on the morphodynamics.

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P 24.6

Customization of a hydrological model for the estimation of water resources in an alpine karstified catchment with sparse data

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The main objective of the MontanAqua transdisciplinary project is to develop strategies moving towards a more sustainable water resources management in the Crans-Montana-Sierre region (Valais) in view of global change. Therefore a detailed assessment of the available water resources in the study area today and in the future is needed.

The study region is situated in the inner alpine zone, with strong altitudinal precipitation gradients: from the precipitation rich alpine ridge down to the dry Rhône plain. A typical plateau glacier at the top of it is partly drained through the karstic underground formations and linked to various springs. The main anthropogenic influences on the system are reservoirs and diversions to the irrigation channels. Thus the study area does not cover a classical hydrological basin as the water flows frequently across natural hydrographic boundaries. This is a big challenge from a hydrological point of view, as we cannot easily achieve a closed, measured water balance.

A representative climatological measurement network covering altitudinal belts as well as the main land cover types has been recently installed, but the calibration and validation of a hydrological model require longer time series. The general lack of comprehensive historical data in the catchment reduces the degree of process conceptualization possible, as well as prohibits usual parameter estimation procedures.

Besides the need for a physically based hydrological model, a flexible discretization is essential. It minimizes the resolution of spatial discretization (fewest number of elements to preserve the essential physics) while still capturing the local heterogeneities in parameters and process dynamics.

The Penn State Integrated Hydrologic Model (PIHM) (Kumar, 2009) has been selected to estimate the available natural water resource for the whole study area. It is a semi-discrete, physically-based model which includes: channel routing, overland flow, subsurface saturated and unsaturated flow, rainfall interception, snow melting and evapotranspiration. Its unstructured mesh decomposition offers a flexible domain decomposition strategy for efficient and accurate integration of the physiographic, climatic and hydrographic watershed.

The model was modified in order to be more suitable for a karstified mountainous catchment: it now includes the possibility to punctually add external sources, and the temperature-index approach for estimating melt was adjusted to include the influence of solar radiation.

Parameters are estimated with values obtained from the literature, catchment boundaries were determined basing on tracer experiments, as well as the relationship between precipitation, spring- and river-discharge.

Historical data such as river discharge, infiltration experiments and snow measurements were used to validate simulations, and are here presented in case studies.

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P 24.7

Geochemical characterization of Chiasso aquifer

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The aim of this work is to determine the geochemical characterization of Chiasso aquifer (Switzerland), and to investigate the behavior of dissolved nitrogen related compounds (NO_2^- , NO_3^- , NH_4^+).

A monitoring survey including groundwater and surface water sampling, and piezometric measurements was carried out in 2012 and 2013. (figure 1) Sampling was completed in collaboration with SPAAS and the Environmental monitoring office, which performed the chemical analysis.

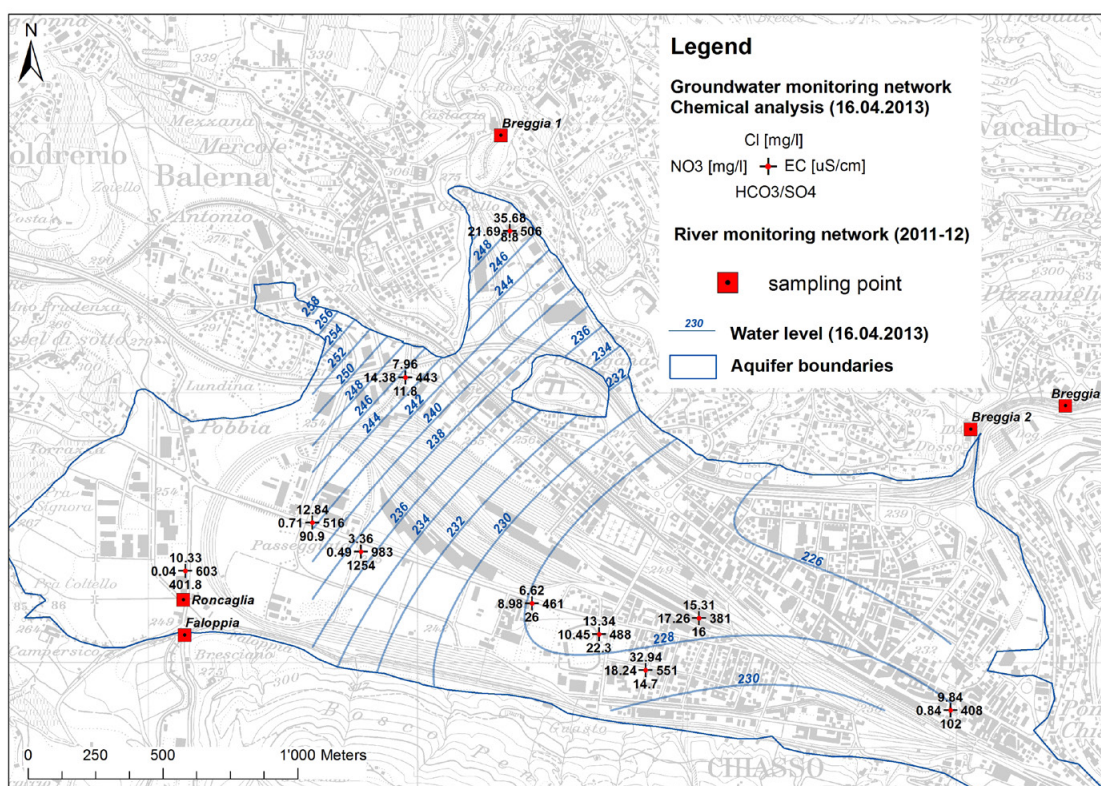


Figure 1 sampling network, piezometric map and selected results

The results from chemical analysis were treated with Statistica 6 software to analyze correlation among elements and the presence of clusters. Based on the results and the observed spatial geochemical variation, two different models were tested with PHREEQC to investigate processes that control geochemical evolution of water within the aquifer. According with the results waters are classified as alkaline-earth bicarbonate in Ludwig-Langelier diagram being bicarbonate the main anion. Along the flowpath HCO_3^- ratios to the other main anions generally tends to decrease (figure 1), especially downstream urban areas where the amount of chlorides and sulphates augments. The bicarbonate remains the predominant species due to atmospheric CO_2 dissolution and water interaction with the aquifer's matrix which is partially derived from limestone. Temporal variations of conductivity and bicarbonates follow the same pattern reflecting recharge effects during fall and late spring diluting the salts concentrations, and therefore lowering water conductivity. Most nitrate and potassium have natural origin, from interaction of water with the organic matter in the aquifer matrix (Istituto Geologico Cantonale, 1990). However, spatial distribution of N related compounds also suggests that other sources, like wastewaters treatment facilities, overflow sewage discharge, fertilizers may be also present. The statistical analysis emphasizes that the calcium represents the dominants cation and it is closely related with bicarbonate as both have the same origin. Chlorides and sulphates seem to have different sources, one geologic probably enrichment from gypsum present in limestone of the area, and the other from evaporites dissolution from the aquifer's matrix, as the area was originally a swamp.

Principal Component Analysis applied to major anions, cations and nitrogen compounds highlighted that the origin of nitrogen, chlorine, probably due to the weathering of organic matter contained in the aquifer matrix. Results from Phreeqc modeling shows that Na – K exchange and calcite precipitation occur along flow- path. Geochemical evolution of water proceeds controlled by increasing CO_2 and NO_3^- derived from organic matter oxidation, and water - rock interaction within the aquifer.

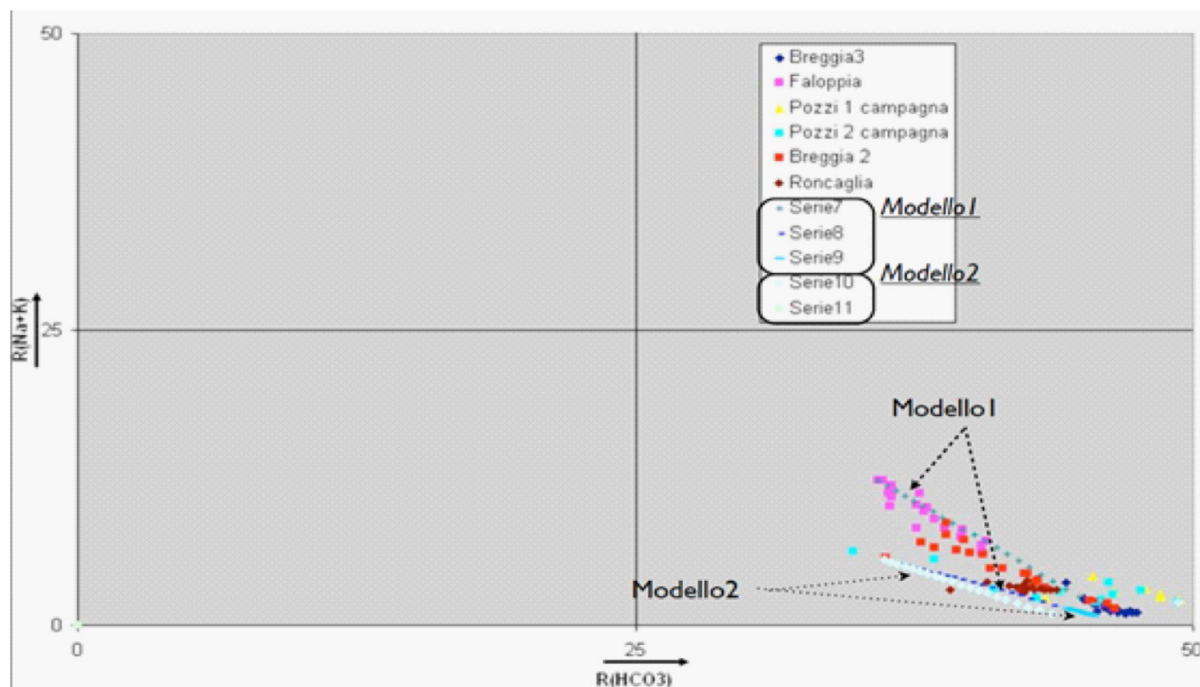


Figure 2 Langelier Ludwig diagram with tested Phreeqc models

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